Technical information

MAN industrial Diesel engines
Installation instructions

General information

This installation instruction is to provide aid and advice for installing MAN industrial engines.

The objective of this publication is to create conditions for faultless operation of the entire system and to prevent installation related malfunctions and possible consequential damage to the engine.

Area of application

This installation instruction applies to the installation of stationary industrial diesel engines as well as to the installation of diesel engines in non-road vehicles and machinery. It neither applies to the installation of vehicle engines in trucks and buses/coaches nor is it type-related.

General regulations

The installation and operation of MAN diesel engines must satisfy all legislation and regulations valid at the place of use and for the type of operation.

Applicability

This installation instruction is applicable to MAN D 08 and D 28 installation engines from the Nuremberg production, superseding all previous installation instructions for MAN industrial diesel engines.

MAN reserves the right to make technical modifications in the course of further development.

Warranty

Warranty claims against MAN will be accepted only if this installation instruction has been complied with.

On request, MAN will perform installation inspections against payment. Final acceptance tests of prototypes for series production installations will be valid only if no subsequent modifications are made.

If any modification to an engine installation accepted by MAN is planned, MAN is to be informed in writing, as a new acceptance test may become necessary.

We reserve the right to make technical modifications in the course of product development.

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General information

This brief overview summarises important instructions to be heeded when an engine system is installed and commissioned in order to impart the knowledge necessary to prevent accidents involving injury to persons, damage to the vessel and harm to the environment. Observe the additional notes in the operator’s manual.

Important:
If despite all safety precautions an accident occurs as a result of contact with caustic acids, penetration of fuel into the skin, scalding with hot oil, anti-freeze splashes into the eyes etc, ***consult a doctor immediately!***

1. Instructions for preventing accidents with injury to persons

During installation of the engine and before its commissioning

- Persons must not stand under an engine suspended from a crane hook. Keep lifting gear in good order.

- Read the Operator’s Manual carefully before commissioning the engine.

- On ships for passenger transport a sign reading ”No entry for unauthorised persons” must be conspicuously attached at the entry to the engine room.

- The engine must be operated by authorised personnel only. When carrying out work in the engine room, ensure that the engine cannot be started from the bridge by unauthorised persons.
- Surround rotating engine parts such as cardan-shafts, flanges with suitable protection against accidental contact. When the engine is running do not get too close to revolving components. Wear tight-fitting working clothes.

- Work only with tools that are in good condition.

- Do not touch hot engine with bare hands: risk of burning yourself. Fit exhaust gas pipes with protection against accidental contact. Any insulation must be made of fireproof, fuel- and lubricating-oil-resistant material.

- Exhaust pipes must be gas-tight, of suitable material and stable.
- Keep engine vicinity, ladder and steps free of oil and grease. Accidents resulting from slipping may have serious consequences.

- Open coolant circuit only after the engine has cooled down. If opening the coolant circuit while the engine is hot is unavoidable, observe the instructions in the chapter ”Maintenance and care” in the Operator’s Manual.
- Neither retighten nor open pressurised pipelines and hoses (lubricating-oil circuit, coolant circuit and hydraulic oil circuit if fitted): risk of injuries resulting from emerging fluids.

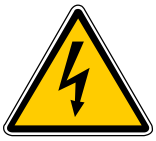
- Fuel is inflammable. Neither smoke nor handle open fire in their vicinity. Refill with fuel only while the engine is switched off. Fit a shutoff valve in the fuel lines.

- Wear protective goggles if compressed air is used.

- Store operating materials (antifreeze agents) only in containers that cannot be mistaken for beverage containers.

- Observe the manufacturer’s instructions for handling batteries.
  Caution:
  Battery acid is poisonous and corroding. Battery gases are explosive.

- When working on the electrical system, unplug negative cable from battery (terminal 31) first and reconnect it last to avoid short-circuits.



- When carrying out welding work, observe the ”Information sheets for welders”.

In addition, the following is to be heeded for commissioning engines:

- Only authorised specialist personnel must inspect the installation and commission the engine.

- Never operate the engine while it is dry, i.e. without lubricant or coolant.

- Do not use any additional starting aids (e.g. start pilot) for starting the engine.

- Only use operating materials (engine oil, antifreeze and anti-corrosion agents) approved by MAN. Ensure cleanliness. Diesel fuel must be free of water; see chapter ”Maintenance and care” in the Operator’s Manual.

- Do not immediately switch off hot engine but let it idle for about 5 minutes without load so that a temperature equalisation can be brought about.

- Never fill overheated engine with cold coolant; see chapter ”Maintenance and care” in the Operator’s Manual.

- ***Do not fill up with engine oil above the max. notch on the dipstick. Do not exceed the engine’s maximum permissible operating inclination.***
  Non-compliance with these instructions may cause severe engine damage.

- Always ensure that control and monitoring devices (charging control, oil pressure, coolant temperature) work faultlessly.

- Observe the instructions for operating the alternator; see chapter ”Commissioning and operation” in the Operator’s Manual.

- Never operate the raw water pump while it is dry. In danger of frost empty raw water pump when the engine is shut down.

2. Instructions for preventing environmental damage

Engine oil and filter cartridges and elements, fuel/fuel filters

- Take old oil to an old oil disposal point only.

- Ensure without fail that oil and Diesel fuel will not get into the sea or rivers and canals or the ground.

- Treat filter elements and cartridges as special waste.

Coolant

- Treat undiluted anti-corrosion and/or antifreeze agents as special waste.

- The regulations of the relevant local authorities are to be observed for the disposal of spent coolants.

3. Instructions for handling used engine oil *

Prolonged or repeated contact of any kind of engine oil with the skin causes the skin to degrease, which may result in dryness, irritation or inflammation. Old engine oil also contains hazardous substances that may cause skin cancer. Handling old engine oil does not pose any health hazard if the basic safety- and hygiene-related regulations are observed.

Health and safety regulations:

- Avoid prolonged, repeated contact of old engine oil with the skin.
- Use a suitable skin protection agent or wear protective gloves.
- Clean the skin that has been in contact with engine oil.
    - Wash yourself thoroughly with soap and water. A nailbrush is an effective aid.
    - Special hand cleaning agents facilitate cleaning soiled hands.
    - Do not use petrol, diesel fuel, gas oil, fluxes or solvents as cleaning agents.
- After washing apply moisturising handcream to your skin.
- Change oil-soaked clothes and shoes.
- Do not put any oil-soaked cloths into pockets.

Pay meticulous attention to the proper disposal of old engine oil.
- Old oil is a water hazard -

Therefore, do not pour any old oil into the ground, the drains or the sewerage system. Any violation of this rule is punishable.

Collect and dispose of old engine oil properly. For information concerning collection points, contact seller, supplier or the local authorities.

* Based on the ”Merkblatt für den Umgang mit gebrauchtem Motorenöl”
(Notes on how to handle old engine oil).

The engine vicinity is gaining increasing importance for assessing the installation situations for modern diesel engines.

The following reasons are decisive for this development:

- The engines used nowadays are almost without exception turbocharged engines with intercoolers of high power density as these achieve low fuel consumption and low exhaust emissions.

  In these engines, the slightest installation faults may lead to operating faults or damage, particularly if the engines are used continually in heavy-duty operation.

  Along with the power density, the necessary mass flows for combustion air, coolant, cooling air and exhaust gases to be supplied to and conducted away from the engine have increased too.

- Emission-curbing regulations which cannot be satisfied with internal engine measures necessitate the use of soot filters and catalytic converters.

  Incorrect design or faults in exhaust-gas cleaning devices cause operating faults or damage to the engine.

- For stationary engines for driving generators, authorities are increasingly granting permits for the operation with subsidised fuel only if the primary energy used is being exploited to a high degree.

  This stipulation leads to the utilisation of thermal energy in coolant and exhaust gases. Using heat exchangers entails additional risks for the engine’s operational reliability if improper design causes faulty cooling and combustion.

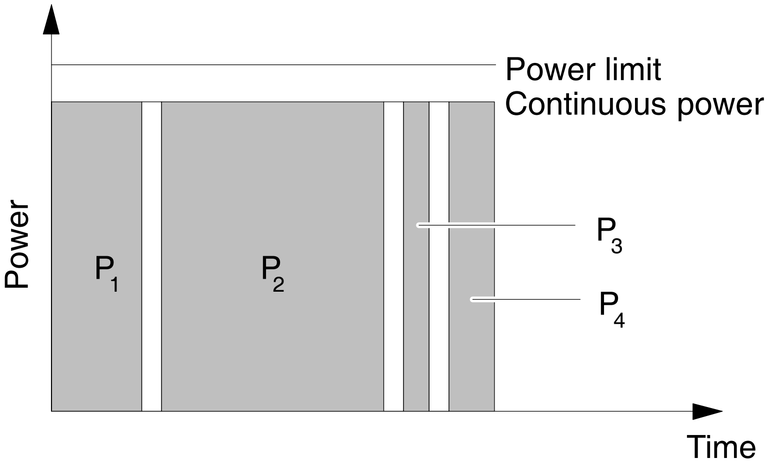
Therefore, when analysing operating faults, check the influence of all components in the vicinity of the engine to see whether they have any bearing on the engine’s operating conditions.

Definitions of rated output for genset engines

The performance definitions for genset engines are laid down in the ISO 8528 standard. There, the following definitions can be found (excerpt from ISO 8528):

Genset continuous power (COP = Continuous power)

Genset continuous power is defined as the power which a genset can generate during an unlimited operating period per year assuming compliance with set maintenance intervals and given environmental conditions, maintenance work having to be carried out in accordance with the manufacturer's regulations. The load spectrum is 100 %.



Variable prime power (PRP)

Variable prime power is defined as the maximum power available during a variable power sequence during an unlimited operating period per year assuming compliance with set maintenance intervals and given environmental conditions, maintenance work having to be carried out in accordance with the manufacturer's regulations. The permissible mean power output P_{pp} (see Fig. 2) during 24 h must not exceed a certain percentage of variable genset prime power specified by the manufacturer of the reciprocating internal combustion engine.

For calculations of the actual mean power output P_{pp}, outputs of less than 30 % of variable genset prime power are to be included in the respective calculation as 30 % outputs.

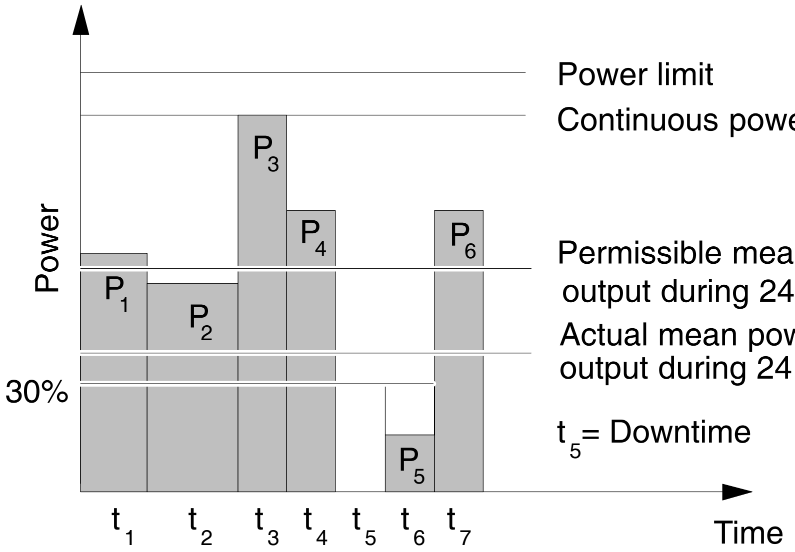
Downtimes are not to be included in the calculation.

The actual mean output is calculated as follows:

$$P_{pa} = \frac{P_1 \times t_1 + P_2 \times t_2 + P_3 \times t_3 + ... + P_n \times t_n}{t_1 + t_2 + t_3 + ... + t_n}$$

P_1, P_2, P_3 ... stand for power per period of time t_1, t_2, t_3 ... .

In practice, this mostly results in use of 70% of continuous power on average (empirical value). It is important that the power output be intermittent.



Remarks:

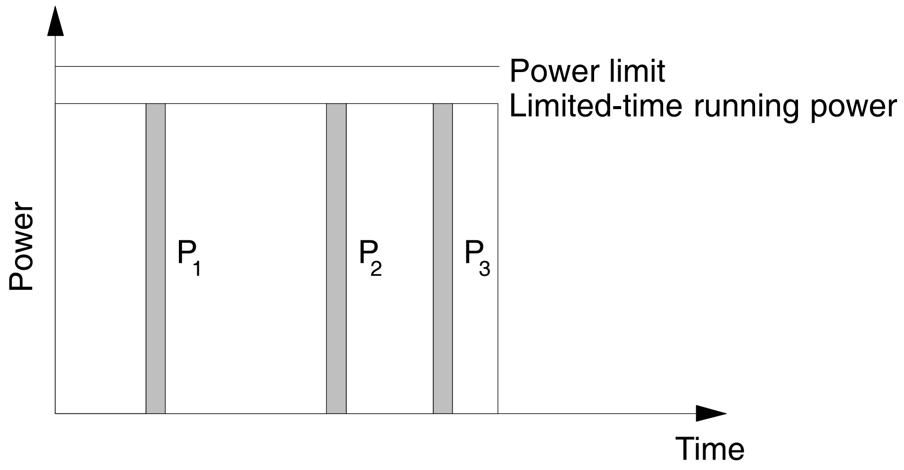
- Non-compliance with the preconditions specified will limit the service life of the reciprocating internal combustion engine.
- Downtimes are not to be included in the calculation.
- The period of operation at variable prime power ought to be long enough for the generator to reach a stable thermal condition.

Limited-time running power (LTP)

A genset can generate limited-time running power for 500 hours per year under the respective environmental conditions. The genset may be up and running for a period of 300 consecutive hours.

Maintenance work is to be carried out in accordance with the engine manufacturer's regulations.

Please note that operation at rated output may affect the service life of the genset.



The period of operation at limited-time running power ought to be long enough for the generator to reach a stable thermal condition.

Estimating the power output of a genset engine

For estimates of the output of a vehicle or rail engine it is usually not known what output will be required at the respective operating point.

In-situ comparisons of auxiliary quantities, eg charge air or exhaust-gas temperature on the respective unit, with test-bed values are too imprecise, since set-up and operating conditions vary in most cases.

In genset engines, however, the respective engine load application is fairly easy to determine provided that the following quantities are known:

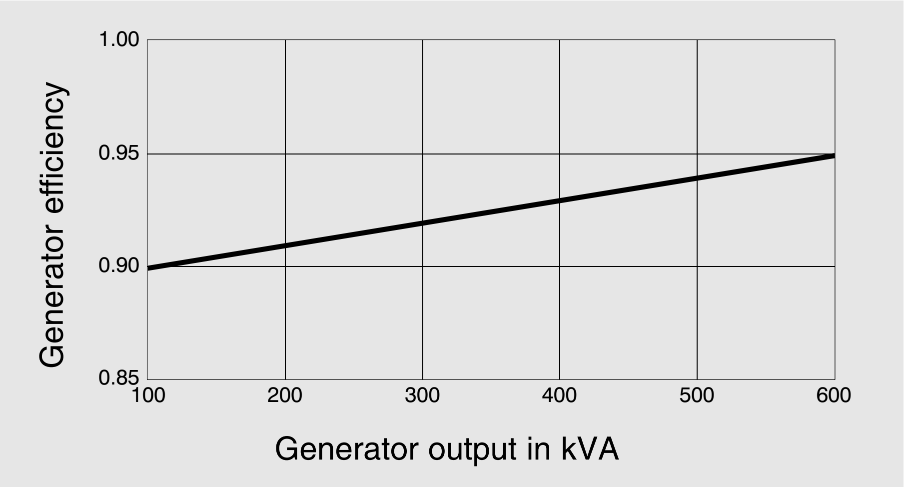
- Engine speed (in Europe it is mostly 1500 rpm, equivalent to a power frequency of 50 Hz).
- The generator current I of each phase in ampere.
- The generator voltage U in volt (mostly 400 V)
- The efficiency η of the generator
- Reactive power factor cos φ measured by the varmeter in the switch cabinet. If such a device is not available, it can be assumed that in the event of ”mixed consumers” a cos φ factor of 0.8 will yield useful calculation results. In consumers with a high ohmic load share (heaters, light sources, no electric motors), the cos φ value may increase to up to 1.0. In operation in parallel with the power system, a cos φ value of 1.0 is always to be assumed.

From these known quantities the following relationships can be derived:

Apart from the generator, the engine usually has to drive the radiator fan as well, ie the entire engine output is the result of the sum of the flywheel output and the fan output.

$$P_{\text{mech.}} = P_{\text{Flywheel}} + P_{\text{Fan}}$$

The generator does not work without losses. In the output range from 600 to 100 kVA, approximately 5 to 10 % of the mechanical energy supplied is given off into the vicinity in the form of heat.



In the output range from 400 to 500 kVA, the generator efficiency ranges from 0.93 to 0.94.

$$P_{Flywheel} = \frac{P_{elektr.}}{\eta_{Generator}}$$

The electrical output which the generator supplies to the consumers is calculated as follows:

$$P_{elektr.} = U \times I \times \sqrt{3} \times \cos\varphi$$

Value $\sqrt{3}$ is the so-called link factor which must be taken into consideration for three-phase generators.

Combining these two formulae furnishes the following relationship:

$$P_{mech.} = P_{Fan} + \frac{U \times I \times \sqrt{3} \times \cos\varphi}{\eta_{Generator} \times 1000}$$

In this formula the following values can be taken as constant for a rough calculation:

$U = 400$ Volt
$\cos\varphi = 0.8$
$\eta_{Generator} = 0.93$

Consequently, only the generator current remains as a variable, which results in a surprisingly simple calculation:

$$\boxed{P_{mech.} = P_{Fan} + 0.6 \times I \text{ [kW]}}$$

The fan output depends on the engine model and lies between 6 kW (D 2866 TE) and 24 kW (D 2842 LE 201).

With this formula it is easy to make fairly precise in-situ calculations of the engine output for gensets.

Load acceptance

Fundamental relationships:

The speed behaviour of a genset when load is being added depends on the quality of the speed governor, the design of the diesel engine as well as on the genset's entire mass moment of inertia.

In naturally aspirated engines, 100 % of continuous power may be added in one go, the control precision as stipulated in DIN 6280 / ISO 3046 being satisfied.

In turbocharged engines, the turbocharger and, consequently, the engine's power output react to additional load with a delay, because some time is required before charge-air pressure has built up. As the degree to which the engine is turbocharged increases, this effect will become all the more conspicuous.

It is therefore necessary that load be added step by step in turbocharged engines.

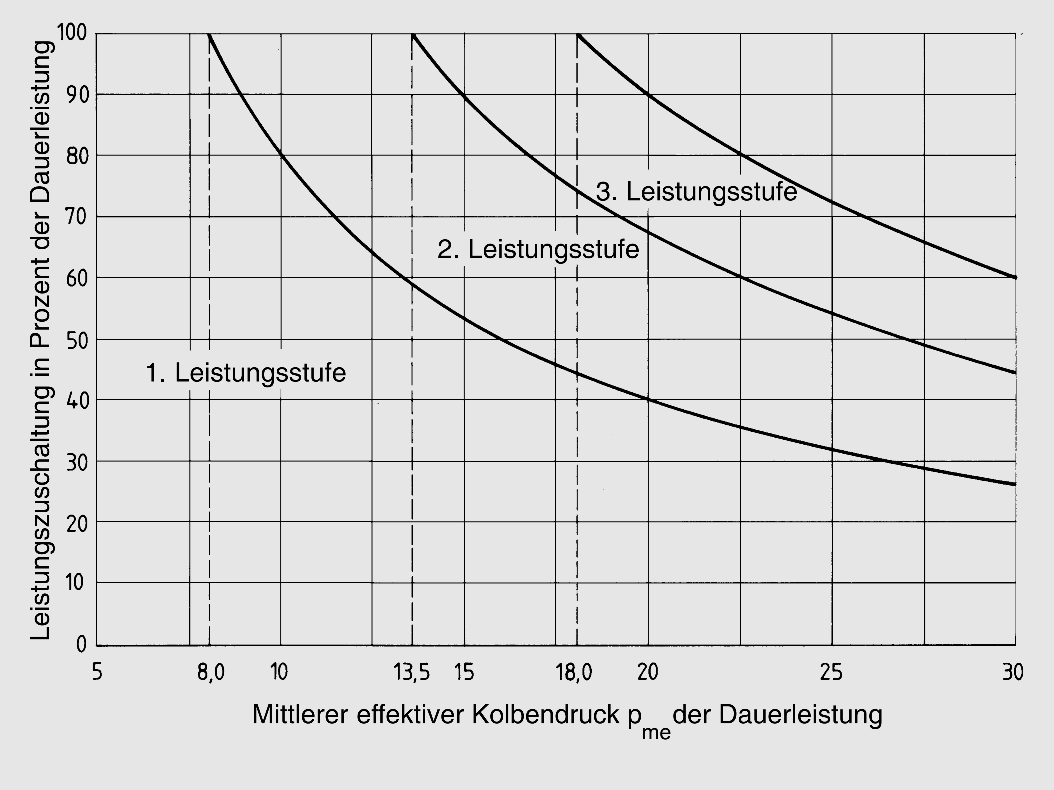
The following factors have an influence on the behaviour of the engine when load is being added:

- Subsequent modification to the charge-air system (installation of the charge-air cooler at a remote position, changes to the routing of pipes) has an unpredictable detrimental effect on the genset's behaviour when load is added.
- If a larger generator is fitted, the high mass moment of inertia will improve the speed behaviour when load is being added. Minimum values for the mass moments of inertia of generators are indicated on page 14.
- Low intake air temperatures and cooler fuel have a positive effect on the speed behaviour when load is being added.

Load application as per DIN 6280

The diagram below is taken from DIN 6280 / ISO 3046 and shows the guideline values for maximum load application in % of continuous power as a function of the effective piston pressure. These values guarantee compliance with the permissible dynamic engine speed deviation.

The limit values for the dynamic speed deviation are indicated in the table ”Control conditions for genset diesel engines and gensets” in the Appendix to this publication.



The effective piston pressure is calculated as follows:

$$p_{me} = \frac{P \times 1200}{V_h \times n}$$

Key to the formula:

p_{me} = Effective piston pressure in bar

V_h = Overall piston displacement in litre

n = Speed in rpm

Control conditions

1. Engines with mechanical speed governor

   The engine-related control conditions comply with the ISO standard power:
   - DIN 6280, part 3.4, class 2
   - ISO 3046, part 4, class A1
   - ISO 8528, part 5.16, quality G2.

2. Engines with electronic speed governor

   Control conditions as under point 1. The P-degree, however, is adjustable between 0 % and 6 %. In addition, synchronisation of and load distribution between several engines running in parallel operation is made considerably easier.

The control conditions are indicated in the table ”Control conditions for genset diesel engines and gensets” in the Appendix to this publication.

Mass moment of inertia of generators

To comply with the aforementioned control requirements, the generators and machinery to be attached must have the following mass moments of inertia.

Engine model	Mass moment of inertia of the generator in kgm^2
D 0826 LE20	1,5
D 0826 LE201	1,67
D 2866 E	1,4
D 2866 TE	2,1
D 2866 LE	3,1
D 2866 LXE	4,4
D 2848 LE	6,4
D 2840 LE20/21	5,75
D 2840 LE201	6,8
D 2842 LE20/21	8,0
D 2842 LE201	9,77

For smaller mass moments of inertia no guarantee can be given for compliance with control requirements.

Access to the engine in the engine room

When installing the engine ensure that there will be sufficient space for regular maintenance work as per Operator's Manual and possible overhauls after long periods of operation. It must be possible to carry out the following jobs on engine and gearbox without obstruction:

- Checking oil and coolant levels,
- Filling up with fuel, oil and coolant,
- Changing fuel, oil and air filters,
- Draining fuel, oil and coolant,
- Setting valves, retightening cylinder head bolts,
- Checking and adjusting delivery start of injection pump,
- Retightening and exchanging V-belts,
- Exchanging starter, alternator and water pump,
- Maintenance and exchange of battery,
- Actuating hand pump at the fuel delivery pump and bleeding fuel system,
- Exchanging injection nozzles,
- Visual checks and retightening of nuts and bolts and hose connections,

As the engine has elastic mounts, it will move in operation. Sufficient space must therefore be provided to ensure that the engine does not come into contact with parts in its vicinity.

Engine operation causes component surfaces to become hot, dissipating radiant heat which must be conducted away by means of an effective ventilation system.

Engine room temperature

Even under the most adverse conditions an engine room temperature of 70°C must never be exceeded (critical components: vibration damper, starter, alternator). If possible, it should be below 50°C. In systems with pressure fan, a maximum of 45°C is feasible.

The following value is to be taken as a yardstick:

Intake-air temperature at the air filter $\leq$ ambient air temperature + 15°C

Hot intake air and hot fuel mean lower output. In the event of charge-air temperatures (downstream of intercooler) of more than 50°C, engine output is to be reduced (see chapter ”Intercooling”).

Radiation heat to be dissipated

Depending on the engine model, the radiation heat amounts to about 5 % of the thermal output supplied with the fuel.

If silencers or long exhaust-gas pipes are fitted in the engine room, the heat dissipation of these components is to be taken into consideration as well. To keep the amount of radiation heat to be conducted away within limits, these components ought to be provided with fireproof insulation.

a) Engines with attached fan

In engines with attached fan and radiator cooling, the heat radiated by the engine is conducted away by the flow of air generated by the fan. In engines with pressure fan, this means that air will enter the radiator at a higher temperature which must be reflected in the design of the cooling system.

b) Engines with remote cooling equipment

Here, a forced ventilation system is recommended for conducting away the radiation heat generated in the engine room. Ventilation can be achieved via both fresh air and suction ventilators.

Fresh-air ventilators supply cool air from the outside to the engine room. Hot waste air flows outwards through outlet orifices. Waste-air orifices ought to be located at as high a point as possible, as hot air always rises.

Suction fans remove hot air from the engine room. Fresh cool air enters through inlet orifices. Not only the removal of waste air, but also an unimpeded supply of fresh air must be ensured. The fresh air inlet must be located as far away from the waste air outlet as possible in order to prevent any air short circuit.

The air requirement for conducting away radiation heat is calculated as follows:

$$\dot{V} = \frac{\dot{Q} \times 3600}{c_p \times \Delta t \times \varrho}$$

Key to this formula:

$\dot{Q}$ = Total amount of radiation heat in kW to be conducted away

$\dot{V}$ = Air volume flow [m^3 / h]

c_p = Specific heat capacity of air [1.005 kJ / kg K]

Δt = Permissible temperature difference between engine room and vicinity [°C]

ϱ = Density of air [kg / m^3]

The density of air is temperature and pressure dependent. To aid comprehension, the following table lists some values for air density as a function of the temperature at an air pressure of 1,000 mbar.

Density of air as a function of the temperature at an air pressure of 1,000 mbar.

Temperature in °C	Density in kg/m^3
0	1.28
10	1.23
20	1.19
30	1.15
40	1.11
50	1.08

In the aforementioned calculating method, the engine room is considered to be a heat-tight system, ie to simplify matters, it is assumed that no heat energy will be dissipated through the walls to the ambient air.

Total amount of air required

The total amount of air required is calculated from the sum of the air required for conducting away radiation heat and from the engine's combustion-air requirement.

The amount of air required for conducting away radiation heat is calculated by means of the aforementioned formula.

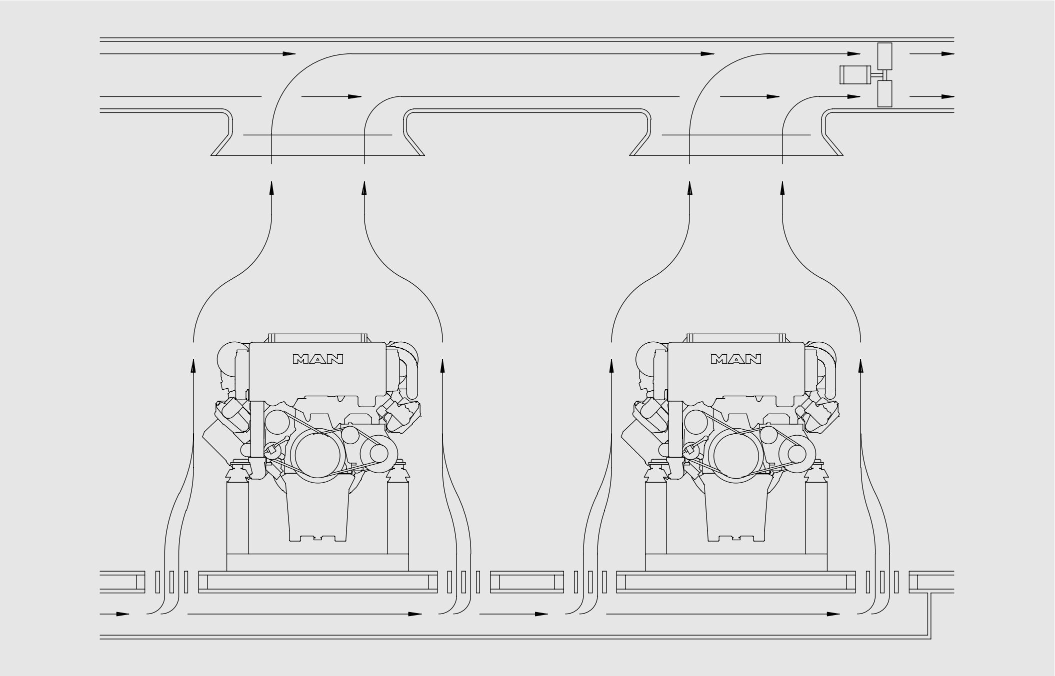
The technical data sheet provides information on the engine's combustion-air requirement.

Information on the amount of cooling air required by the generator can be obtained from the manufacturer. Generally speaking, a heat dissipation value of 3 m^3/min per kW power loss can be taken as a yardstick.

Air ducting in the engine room

In many cases the engine room also serves as the workroom for the operating staff. For this reason excessively high air speed is to be avoided, as this is found at least tiresome for humans.

An upper limit value of 0.25 m/s can be assumed.



If air is ducted as shown in the picture, fresh air constantly flows past the engines, safely conducting away radiation heat, while in the rest of the engine room unnecessary air turbulence is prevented.

Elastic mounts

General information

Elastic mounts for limiting dynamic loads channelled into the foundation are to be preferred to rigid mounts. They are recommendable for engines with free speed-dependent mass forces or mass moments. The following engines fall under this category:

Engine	Type of load
4-cylinder in-line engine	Mass force of the 2nd order
5-cylinder in-line engine	Mass moment of the 2nd order
10-cylinder V-type engine	Mass moment of the 2nd order

Even the alternating torques inherent in every reciprocating piston engine can be virtually kept away from the engine foundation by means of suitably adjusted elastic mounts, so that the foundation has to absorb only the useful moment.

The basis for designing elastic mounts is the data for the respective engine. These data are available from MAN on request.

They provide information on:

- Engine weight, centre-of-gravity co-ordinates and mass moment of inertia
- Free mass forces and moments
- Free alternating torques

Degree of insulation

When dimensioning elastic mount elements, ensure that the basic frame will be as resistant to bending as possible, ie it must have a high stiffness.

Desirable as a high degree of insulation for the mounts is, it also holds risks for the engine and machines connected with it.

With rubber-metal rails which are being increasingly used, maximum spring compression ought to be $\leq$ 3 mm.

On no account must mount elements be compressed beyond the permissible weight loads indicated by the respective manufacturer.

Elastic mount elements are to be dimensioned so that the same load will be applied to all mount points, ie that spring compression will be identical.

In accordance with VDI directive 2063 and DIN 6280, the maximum vibration frequencies occurring must not exceed the following values:

Engine: 45 mm/s
Generator: 28 mm/s

If these values are exceeded in permanent operation, damage is bound to occur particularly to auxiliary units (alternator) and in the form of leakages (injection pump, exhaust manifold).

Supercritical adjustment

a) Engines with variable speed

If elastic mounts are used, supercritical adjustment

$$\frac{n_{min}}{n_{crit}} > 1$$

is required for preventing resonance vibrations during engine operation (the engine passes through the resonance range only when it is being switched on and off).

Adjustment is defined as the ratio of exciter frequency to natural frequency. For easy relation to the engine speed, the number of vibrations per minute is measured.

The critical engine speed n_{crit},

$$n_{crit} = \frac{n_e}{i}$$

is defined as the speed n_e at which resonance occurs, taking into account the lowest exciter order i.

The lowest exciter order i to be taken into consideration is that of the alternating torque. In four-stroke engines it is half the number of cylinders, eg in a 6-cylinder in-line engine $i = 3$.

Insulation (ie reduction of foundation forces in relation to exciter forces) is achieved only with an adjustment of $n/n_{crit} > \sqrt{2}$. In practice, elastic mounts for engine systems with variable speed are therefore adjusted to idle speed.

$$\frac{n_{min}}{n_{crit}} > \sqrt{2}$$

If no sufficient insulation can be achieved via the elasticity of the mounts for engines of small exciter order, eg 4/5-cylinder in-line and 10-cylinder V-ype engines, it can only be accomplished by raising the idle speed.

b) Engines with fixed engine speed

For units which have a fixed speed and are to be installed in buildings, an adjustment of

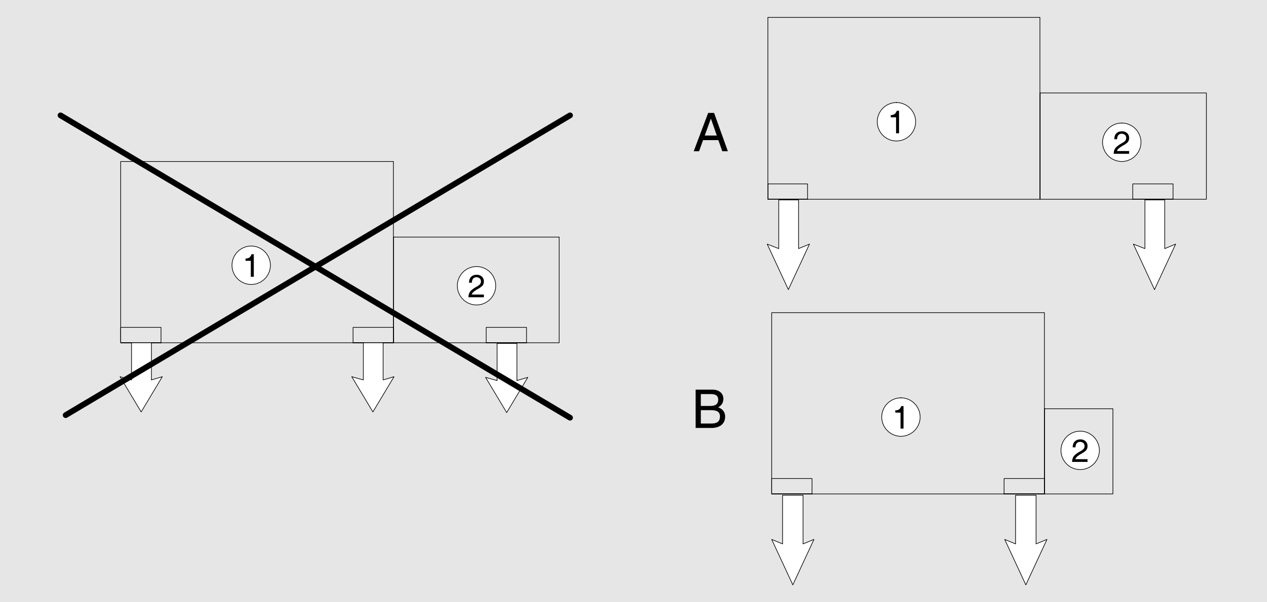
$$\frac{n}{n_{crit}} > 3$$

is necessary for achieving sufficient sound suppression and preventing inadmissible stress on the ceiling.

Connection lines

To cancel out vibration amplitudes in systems with elastic mounts, all pipes leading away from the engine must be uncoupled elastically, as rigid connections to the foundation, frame or walls cause add-on parts to break and/or reduce at least the insulating efficiency.

Engines with flanged-on unit



① Engine

② Flange-mounted unit (eg generator, gearbox)

If a unit is flanged on the engine, the following mount arrangements for the entire system are possible:

A: Engine mounts at non-flywheel end and mounts for the flange-on unit

B: Engine mounts at non-flywheel end and at flywheel end

Combining A and B is not permissible.

For permissible bending moment on the flywheel housing see page 28 (D 08 engines) and page 31 (D 28 engines).

Failure of one mount in an engine with flanged-on unit

In firmly flanged systems, failure of one mount at the engine side or at the flange-mounted unit results in extra load on the remaining mounts.

Torsional load that may occur here will be absorbed by the flywheel housing. In the event of damage to the elastic mounts, the system must be stopped immediately.

Rigid mounts

Suitability of engines

Only engines with no free mass forces or free mass moments are suitable for rigid mounts. The following engines are suitable:

Engine	Type of load	Rigid mounts
6-cylinder in-line engine	none	possible
8-cylinder V-type engine	none	possible
10-cylinder V-type engine	mass moment of the 2nd order, weak	restrictedly possible
12-cylinder V-type engine	none	possible

It is always to be examined whether insulating mats or rubber feet under the engine frame should be provided to improve comfort, eg to damp or deaden structure-borne noise and/or vibrations.

Rigid frame / rigid foundation

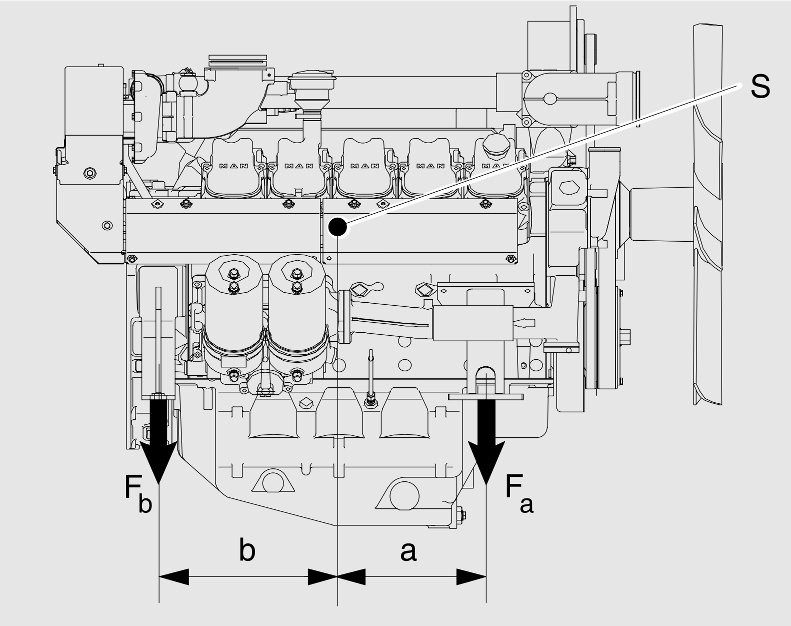
Rigid mounts must be designed so rigid that the vibration system of engine and foundation is subcritically adjusted.

With four-point mounts fully bending- and torsion-resistant frames are to be used to prevent damage to the engine.

Exact, plane-parallel alignment of the rigid mount points on the foundation or on the frame is therefore necessary.

Calculating the supporting forces

The entire weight G of the engine (including oil and coolant) acts at the centre of gravity S. Data on the centre of gravity co-ordinates is provided in the data for the respective engine.

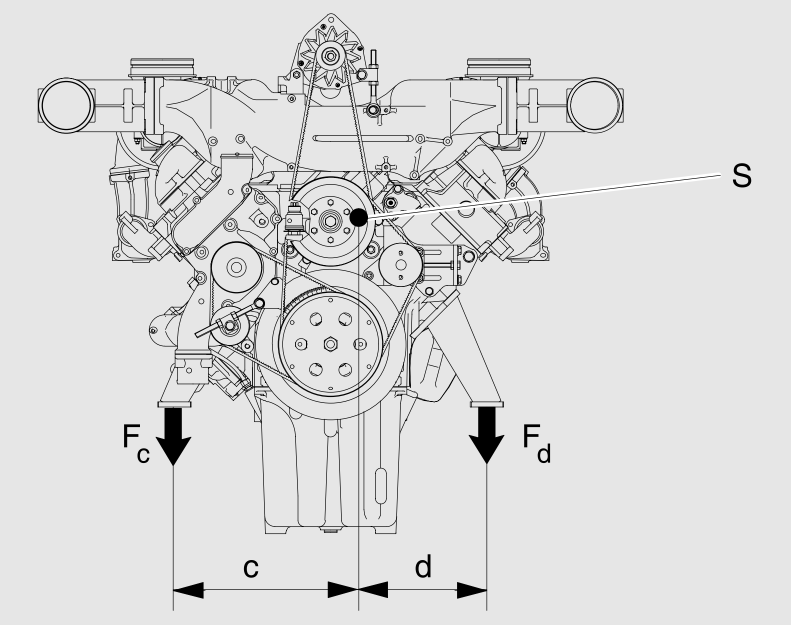


$$F_a = \frac{G \times b}{(a+b)}$$

$$F_b = G - F_a$$

If the centre of gravity lies in the crankshaft plane, the forces F_a and F_b are to be halved to obtain the supporting force per mount.

If the centre of gravity does not lie in the crankshaft plane (asymmetric set-up), the front (non-flywheel-end) supporting forces are to be calculated as follows:



$$F_d = \frac{F_a \times c}{(c+d)}$$

$$F_c = F_a - F_d$$

The rear supporting forces are to be calculated analogously.

This publication deals with power output related questions which may arise in the context of the following applications:

- Rail engines
- Engines for automotive machines such as construction machines, machines for agricultural, forestry and municipal work
- Engines for stationary drive systems such as pumps, drilling machines, generators

Danger:
For reasons of safety, rotating parts (V-belts, shafts, flanges) on stationary engines are to be fitted with suitable protection devices preventing any contact with these parts. Observe accident prevention regulations.

Possible arrangements for taking off power

These depend on the engine model and the equipment fitted.

Generally speaking, power can be taken off at the following points:

- at the flywheel end
- at the non-flywheel end
- at gear-driven power take-offs
- at the air-compressor output

The basis for a detailed examination of possible arrangements for taking off power is the installation drawing with the associated data.
These documents are engine model dependent and can be obtained from MAN. They include:

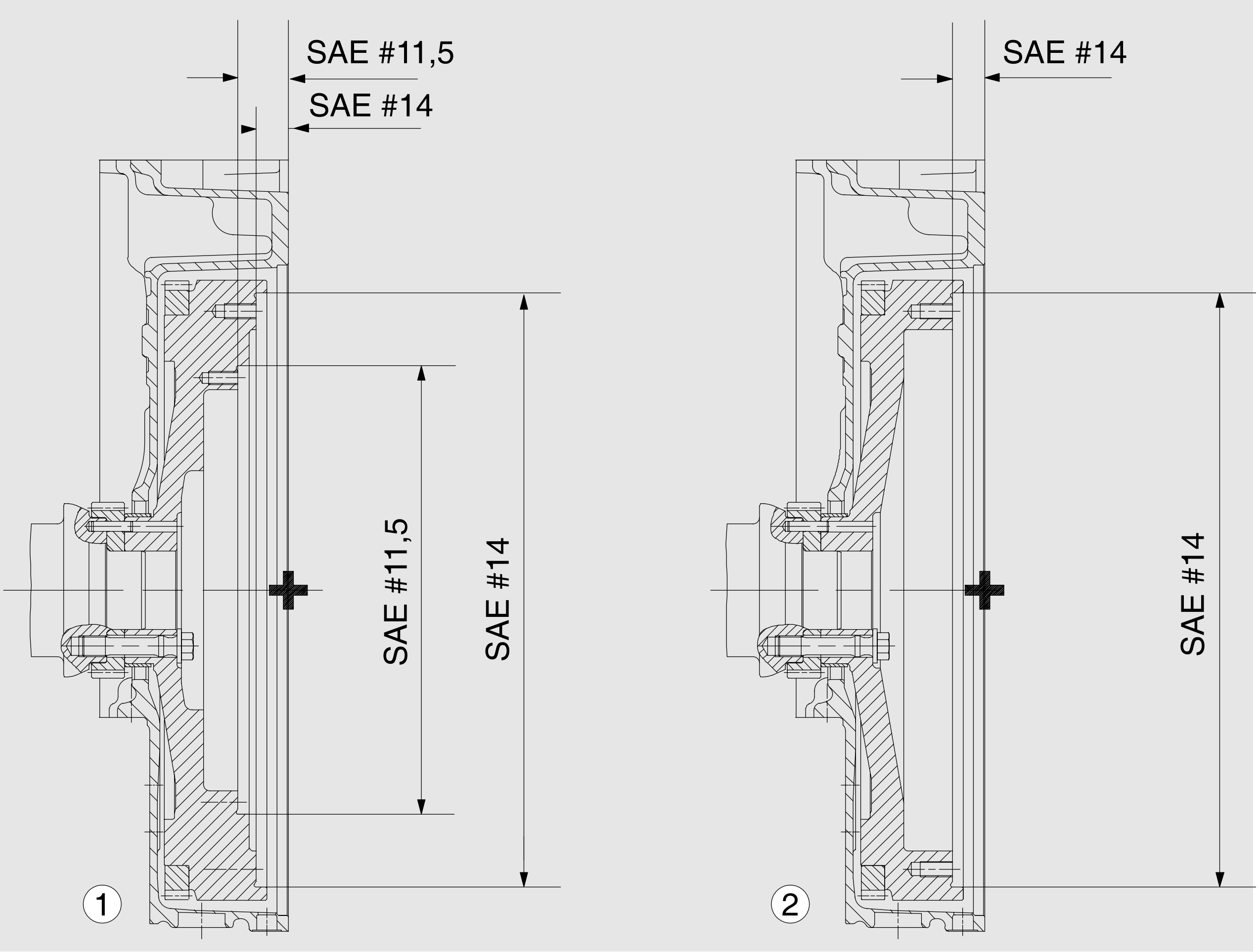
- Connection dimensions for flywheel, flywheel housing and power take-off
- Performance and torque diagrams
- Data on engine mounts
- Engine weight, centre of gravity co-ordinates and mass moments of inertia
- Free mass forces and moments
- Free alternating torques

The flywheel

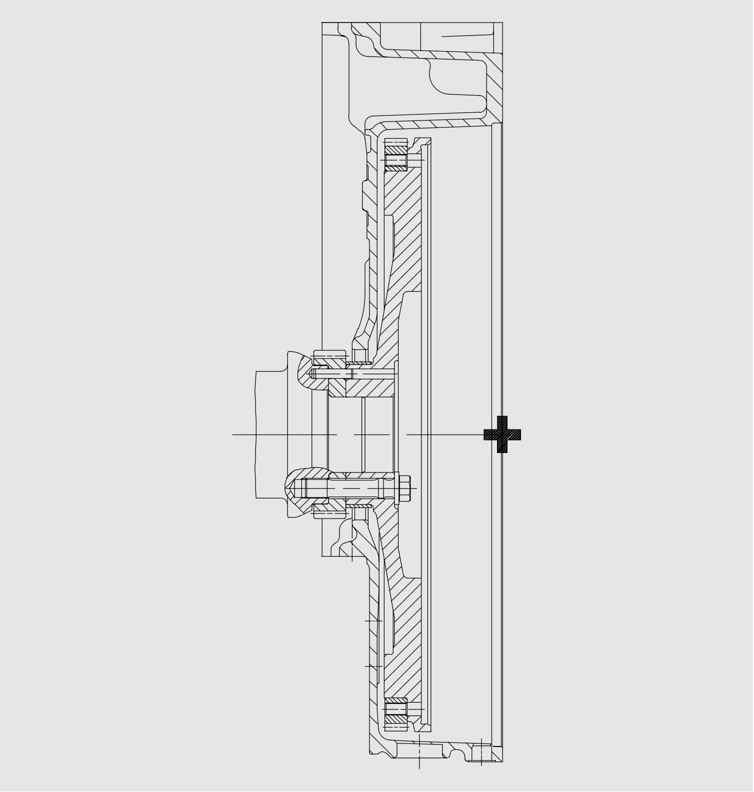
Depending on the kind of engine operation, MAN offers several flywheel variants. Criteria for selecting a flywheel are:

- Unevenness
- Regulating behaviour
- Accelerating behaviour
- Possibility of attaching a clutch
- Possibility of flanging a device (gearbox, clutch) on to the flywheel housing
- Weight

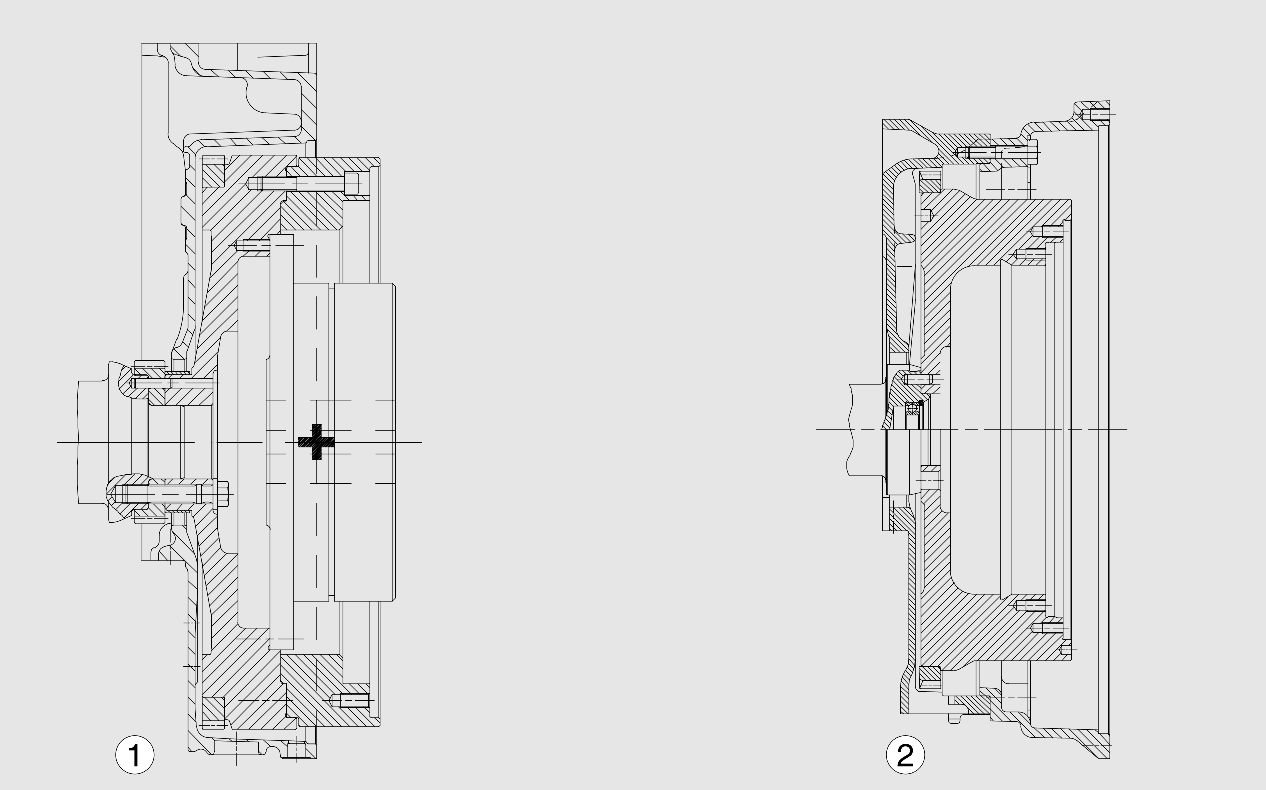
Below you will find some examples of flywheel variants for various applications. For vehicle and tractor engines further versions can be supplied. For an exact installation examination, please ask for an installation drawing with detailed dimensions of the flywheel and flywheel housing.
All flywheel housings depicted here have an SAE1 connection.



Flywheels for industrial engines from the D 28 model range
① Flywheel with I = 2.412 kgm^2.
② Flywheel with I = 2.003 kgm^2



Flywheel with I = 1.10 kgm^2 for attaching a propshaft coupling for D 28 engines



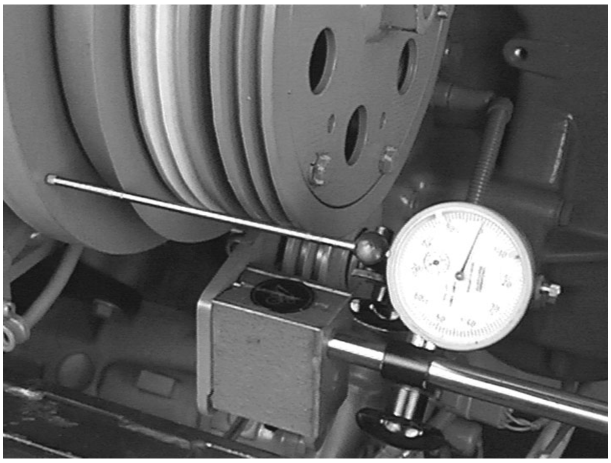
Flywheel with additional mass for improving the regulating behaviour of genset engines

① Flywheel for D 28 engines with I = 4.212 kgm^2.
② Flywheel for D 08 engines with I = 1.73 kgm^2.

Axial play of crankshaft

On no account must the engine's designed crankshaft axial play be reduced as a result of flanging on clutches or other components.

It is therefore essential that **before** and **after** the flanging on of add-on components the axial play of the crankshaft is measured by means of a dial gauge held in a magnetic holder. If the results of the two measurements are not identical, or if the crankshaft springs back after being shifted, the attachment is to be examined.



Torsional vibration calculation

The gas and mass forces of the engine may cause the entire driveline to vibrate. To detect the position and strength of resonance points and to prevent overstressing, a torsional vibration calculation is to be carried out.

The engine data for carrying out a torsional vibration calculation, eg exciter factors and torsional substitute vibrators, can be obtained from MAN.

Power take-off at flywheel without flanged-on unit

1. Permissible forces on the crankshaft in D 08 engines

   The forces permissible on the crankshaft during operation are listed in the table below. The crankshaft must not be subjected to axial pre-load as a result of the attachment of add-on components to the engine (see page 27)

Time-related application of force	Axial force input in N	Radial force input in N
For short periods of time	3600	--
For prolonged periods of time	2200	5000

2. Permissible bending moments in Nm on the crankshaft as a result of radial force input in D 08 engines

Direction of power output	Engine speed in rpm			
	1500	1800	2100	2400
In the direction of the cylinder head	500	500	500	500
90° relative to cylinder head	620	590	570	540
Opposite direction to cylinder head	870	820	760	690

3. Calculating the bending moment on the crankshaft

$$M_d = (A + L) \times \frac{F_R}{1000}$$

M_d = Bending moment in Nm on the crankshaft $\leq$ permissible bending moment as per table (see section 2)

F_R = Radial force in N

A = Distance from centre of additional V-belt pulley package to flange-on face on flywheel housing in mm

L = Distance from flange-on face on flywheel housing to centre of rear crank web. This dimension is determined by design and is obtained from the following table.

Dimension L in mm for D 08 engines			
	Flywheel housing SAE 1	Flywheel housing SAE 2	Flywheel housing SAE 3
Vehicle engine	153.5	104.5	104.5
Industrial engine	205.3	205.3	145.3

Power take-off at flywheel via flanged-on unit

1. Permissible forces on the crankshaft in D 08 engines

   The forces permissible on the crankshaft during operation are listed in the table below. The crankshaft must not be subjected to axial pre-load as a result of the attachment of add-on components to the engine (see page 27).

Time-related application of force	Axial force input in N	Radial force input in N
For short periods of time	3600	--
For prolonged periods of time	2200	5000

2. Permissible bending moments in Nm on the flywheel housing as a result of radial force input in D 08 engines

Flywheel housing	Vehicle engine $M_{B\ perm.}$ in Nm			Industrial engine $M_{B\ perm.}$ in Nm		
	SAE 1	SAE 2	SAE 3	SAE 1	SAE 2	SAE 3
made of aluminium	6000	4500	3200	4500	3200	3200
made of grey cast iron	9000	7700	4800	7700	4800	4800

In borderline cases a check is to be carried out to see whether

a) the static initial tension in the housing

b) the dynamic load (statically superimposed)

does not exceed the permissible values.

For aluminium, the following applies: a) 60 N/mm^2 and b) 40 N/mm^2. For grey cast iron consultation with MAN will be necessary.

If the aforementioned values are exceeded, it is to be checked whether a different arrangement of the mounts can lower the load.

If this proves impossible, the flanged-on unit must be arranged free-standing.

3. Calculating the bending moment

$$(1) \qquad d = \frac{m_1 \times x + m_2 \times y}{m_1 + m_2} + a - x$$

$$(2) \qquad F_A = (m_1 + m_2) \times \left(1 - \frac{d}{a + b}\right) \times 9{,}81$$

$$(3) \qquad M_{B1} = F_A \times \frac{(a + L - x)}{1000} - m_2 \times \frac{(y + L)}{1000} \times 9{,}81$$

$$(4) \qquad M_{B2} = F_R \times \frac{(z + L)}{1000}$$

$$(5) \qquad M_{BG} = \sqrt{M_{B1}^2 + M_{B2}^2 + 2\, M_{B1} \times M_{B2} \times \cos \alpha}$$

Caution: Put in M_{B1} with the correct preceding sign, as in equation (3)

a in mm	Distance from centre of mount on flywheel housing or on flange-on unit to engine's centre of gravity
b in mm	Distance from centre of mount at non-flywheel end to the engine's centre of gravity
x in mm	Distance from bell housing flange face to engine's centre of gravity
y in mm	Distance from bell housing flange face to centre of gravity of flange-on unit
z in mm	Distance from bell housing flange face to point of radial force input, eg centre of V-belt pulleys
d in mm	Intermediate value for further calculation
m_1 in kg	Mass of engine
m_2 in kg	Mass of flanged-on unit
F_A in N	Supporting force
F_R in N	Radial force, eg pull of belt
M_{B1} in Nm	Bending moment from supporting force F_A and as a result of weight of flanged-on unit
M_{B2} in Nm	Bending moment resulting from radial force F_R
M_{BG} in Nm	Total bending moment resulting from M_{B1} and M_{B2}
α	Direction of radial power take-off, eg pull of belt
L	Distance from mounting flange face on flywheel housing to centre of rear crank web

Dimension L in mm for D 08 engines			
	SAE 1	SAE 2	SAE 3
Vehicle engine	153.5	104.5	104.5
Industrial engine	205.3	205.3	145.3

Power take-off at flywheel without flanged-on unit

1. Permissible forces on the crankshaft in D 28 engines

   The permissible forces acting on the crankshaft during operation are listed in the table below. The crankshaft must not be subjected to axial pre-load as a result of the attachment of add-on components to the engine (see page 27)

Time-related application of force	Axial force input in N	Radial force input in N
For short periods of time	4600	--
For prolonged periods of time	3000	10000

2. Permissible bending moments in Nm on the crankshaft as a result of radial force input in D 28 engines

Direction of power output	Engine speed in rpm		
	1500	1800	2200
In the direction of the cylinder head	420	420	420
90° relative to cylinder head	840	790	710
Opposite direction to cylinder head	1680	1550	1350

3. Calculating of the bending moment on the crankshaft

$$M_d = (A + L) \times \frac{F_R}{1000}$$

M_d = Bending moment in Nm on the crankshaft $\leqq$ permissible bending moment as per table (see section 2)

F_R = Radial force in Nm

A = Distance from centre of additional V-belt pulley package to mounting flange face on flywheel housing in mm

L = Distance from mounting flange face on flywheel housing to centre of rear crank web. This dimension is determined by design and is 199.5 mm.

Power take-off at flywheel via flanged-on unit

1. Permissible forces on the crankshaft in D 28 engines

   The forces permissible on the crankshaft during operation are listed in the table below. The crankshaft must not be subjected to axial pre-load as a result of the attachment of add-on components to the engine (see page 27).

Time-related application of force	Axial force input in N	Radial force input in N
For short periods of time	4600	--
For prolonged periods of time	3000	10000

2. Permissible bending moments in Nm on the flywheel housing as a result of radial force input in D 28 engines

Flywheel housing	Permissible bending moment $M_{B\,perm.}$ in Nm
made of aluminium	6000
made of grey cast iron	9000

In borderline cases a check is to be carried out to see whether

a) the static initial tension on the housing

b) the dynamic load (statically superimposed)

does not exceed the permissible values.

For aluminium, the following applies: a) 60 N/mm^2 and b) 40 N/mm^2. For nodular cast iron consultation with MAN will be necessary.

If the aforementioned values are exceeded, it is to be checked whether a different arrangement of the mounts can lower the load.

If this proves impossible, the flanged-on unit must be arranged free-standing.

3. Calculating the bending moment

$$(1)\qquad d = \frac{m_1 \times x + m_2 \times y}{m_1 + m_2} + a - x$$

$$(2)\qquad F_A = (m_1 + m_2) \times \left(1 - \frac{d}{a + b}\right) \times 9{,}81$$

$$(3)\qquad M_{B1} = F_A \times \frac{(a + 148{,}0 - x)}{1000} - m_2 \times \frac{(y + 148{,}0)}{1000} \times 9{,}81$$

$$(4)\qquad M_{B2} = F_R \times \frac{(z + 148{,}0)}{1000}$$

$$(5)\qquad M_{BG} = \sqrt{M_{B1}^2 + M_{B2}^2 + 2\, M_{B1} \times M_{B2} \times \cos \alpha}$$

Caution: Put in M_{B1} with the correct preceding sign, as in equation (3)

a in mm	Distance from centre of mount on flywheel housing or on flanged-on unit to engine's centre of gravity
b in mm	Distance from centre of mount at non-flywheel end to engine's centre of gravity
x in mm	Distance from bell housing flange face to engine's centre of gravity
y in mm	Distance from bell housing flange face to centre of gravity of flange-on unit
z in mm	Distance from the bell housing flange face to point of radial force input, eg centre of V-belt pulley
d in mm	Intermediate value for further calculation
m_1 in kg	Mass of engine
m_2 in kg	Mass of flanged-on unit
F_A in N	Supporting force
F_R in N	Radial force, eg pull of belt
M_{B1} in Nm	Bending moment from supporting force F_A and from weight of flanged-on unit
M_{B2} in Nm	Bending moment resulting from radial force F_R
M_{BG} in Nm	Total bending moment resulting from M_{B1} and M_{B2}
α	Direction of radial power take-off, eg pull of belt

Single-bearing generators

In single-bearing generators the bearing at the engine side of the rotor is replaced by the crankshaft bearing at the flywheel end of the diesel engine.

In D 28 engines, single-bearing generators may be used for rotor weights of up to 630 kg and for a mass moment of inertia of up to 11 kgm^2.

In the event of larger rotor weights and mass moments of inertia, consultation with MAN is absolutely necessary.

Fundamental guidelines to installing propshafts

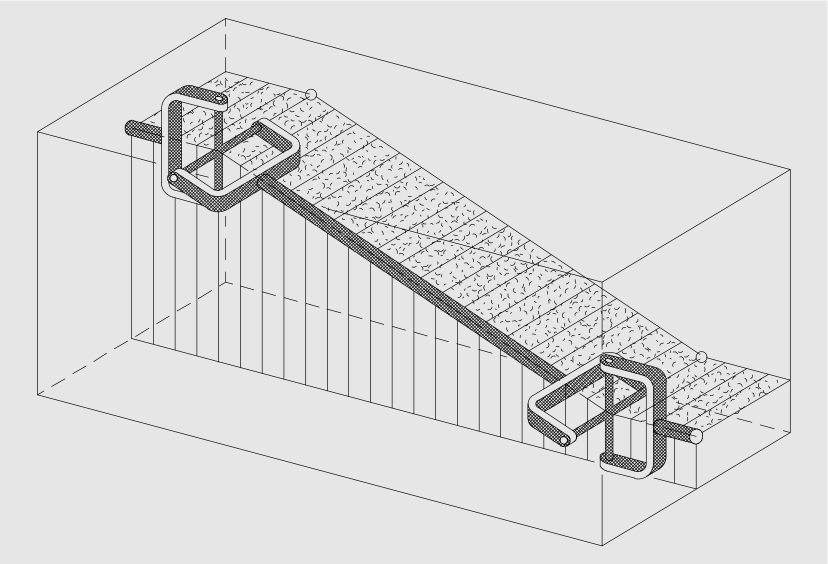
The guidelines given in this chapter are taken from the documents of some propshaft manufacturers. When installing propshafts, also heed the regulations from the respective manufacturer.

If a single universal or ball-and-socket joint in deflected condition is turned evenly, an uneven motion will occur at the output end.

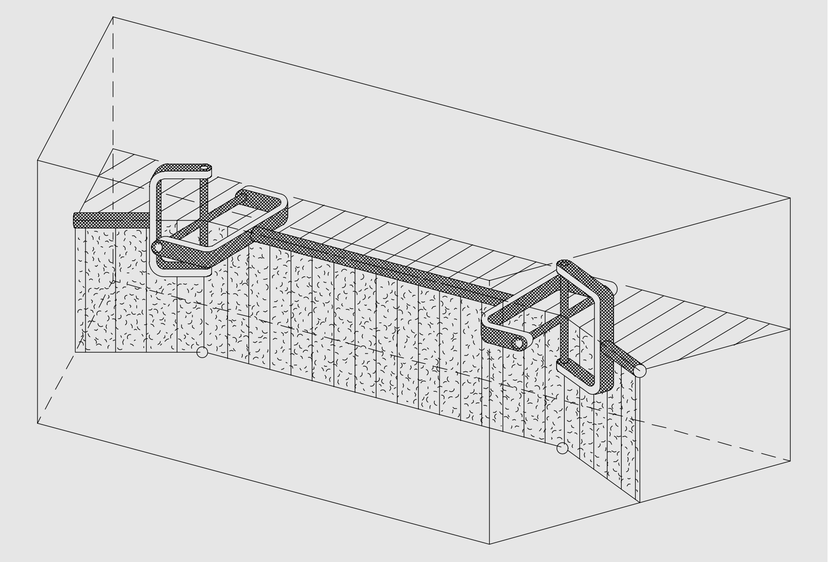
This unevenness can be cancelled out if two single joints are combined into a propshaft. To cancel out uneven motion completely, the following conditions are to be met:

- Identical deflection angles at both joints ($ß_1=ß_2$)
- The two inner joint forks must be in the same plane
- Input and output shafts must be in the same plane too

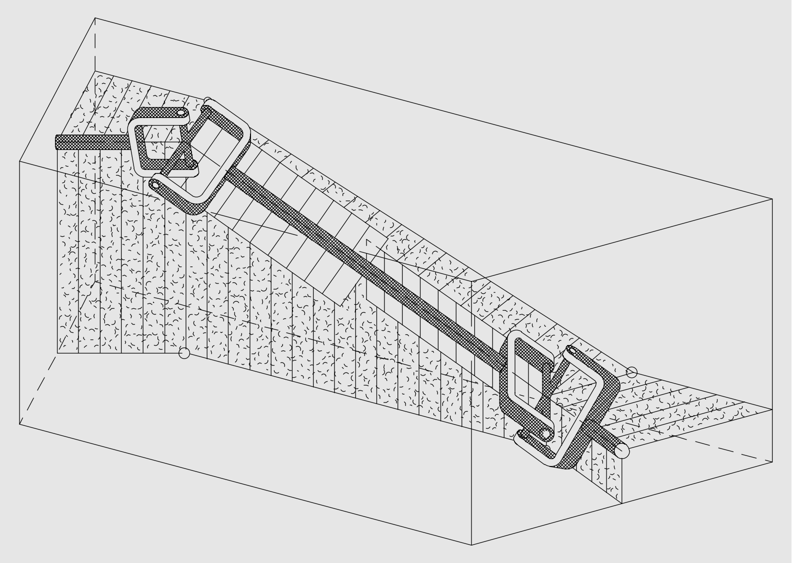
Propshaft arrangement in Z shape



Propshaft arrangement in W shape

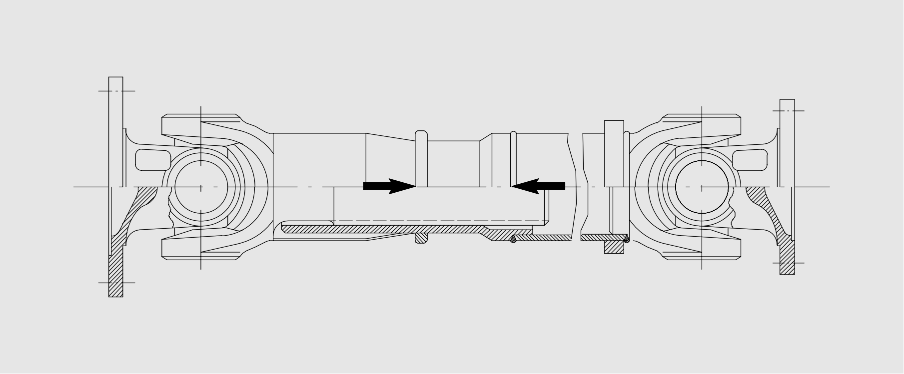


Exception:
In propshafts which are deflected in several planes, the input and output shafts are not in the same plane. To achieve an even output motion, it is necessary in this case to twist the inner joint forks against each other until they are in the same deflection plane as their respective joint. In addition, the multi-plane deflection angles must be equally large.



Assembly of propshafts

When assembling the propshaft halves, ensure that the markings (arrows) on the splined shaft and the spline bore hub face each other.



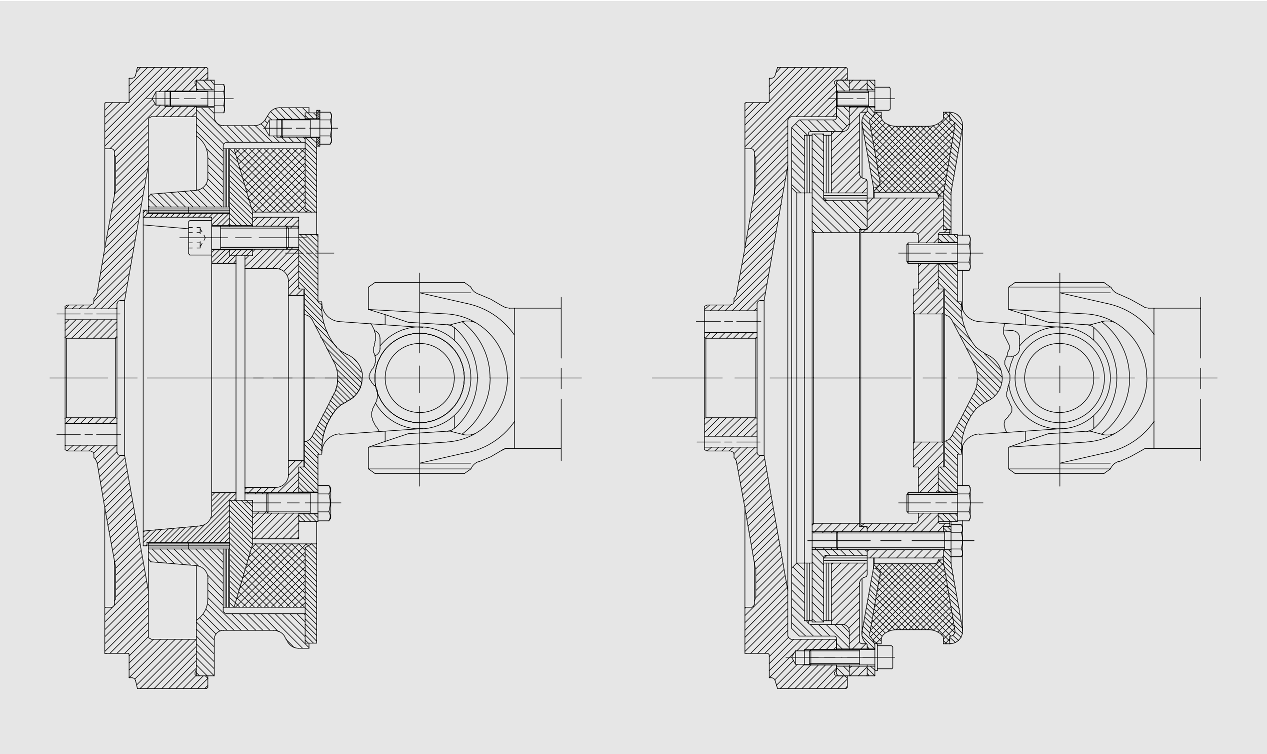
Caution:
Incorrect assembly of propshafts will not cancel out but increase uneven output motion, causing vibrations in the driveline. Furthermore, pivoting bearings and spline sections may be destroyed.

Torsionally elastic coupling for propshaft drive and max. permissible deflection angle

The maximum permissible deflection angles $ß_1$, $ß_2$ depend on:

- Model, design and weight of the elastic coupling
- Propshaft version

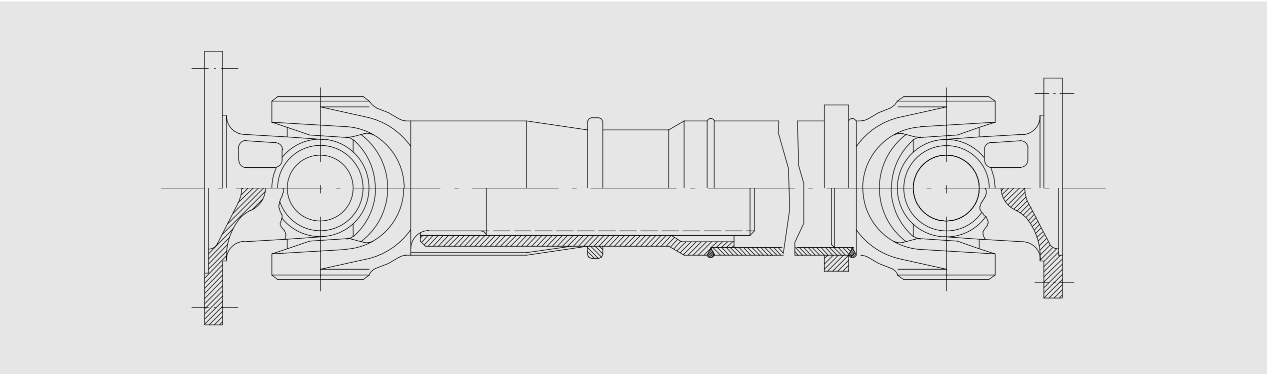
The pictures below show two examples of propshaft couplings.
Relative to the engine, the **maximum permissible deflection angle** per joint is **5**°.



Weights:

Flywheel: 53 kg

Coupling:	53 kg	Coupling	64 kg
together:	106 kg	together:	117 kg



Weight-optimised propshaft for L_z from 700 to 1700 mm and 2 different flange versions; weight $L_{z\,1700}$ = 66 kg.

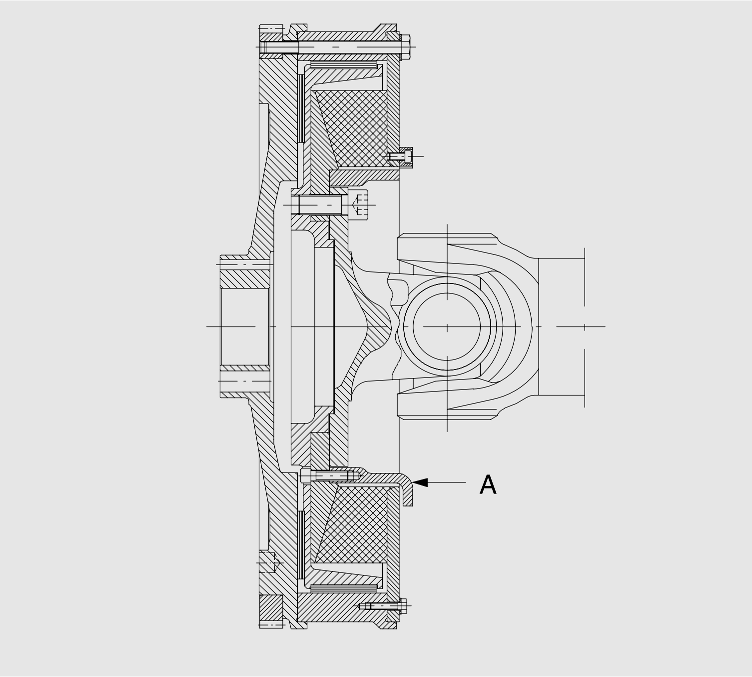
Coupling for large deflection angles

The use of *integrated couplings* reduces vibration stress on engine and driveline.

These couplings offer the following advantages:

- Universal joint approx. 100 mm closer to the nearest crankshaft bearing
- More solid axial and radial coupling bearings
- Improved smooth running (imbalance) of the universal joint owing to the reduced overhang.

With this coupling the **max. permissible deflection angle per joint is 8°.**



A: Monitoring / Anti-barring device

Weights:	
Flywheel:	33 kg
Coupling:	48 kg
together:	81 kg

Note:
The deflection angles β_1, β_2 indicated above are permissible values for the engine. For the permissible gearbox values, please consult the gearbox manufacturer. For the installation angles β_1, β_2, the smaller value is always to be selected:eg: perm. β_1, β_2 relative to engine: 5°, relative to gearbox 7°. Installation angle set: $\beta_1 = \beta_2 =$ max. 5°.

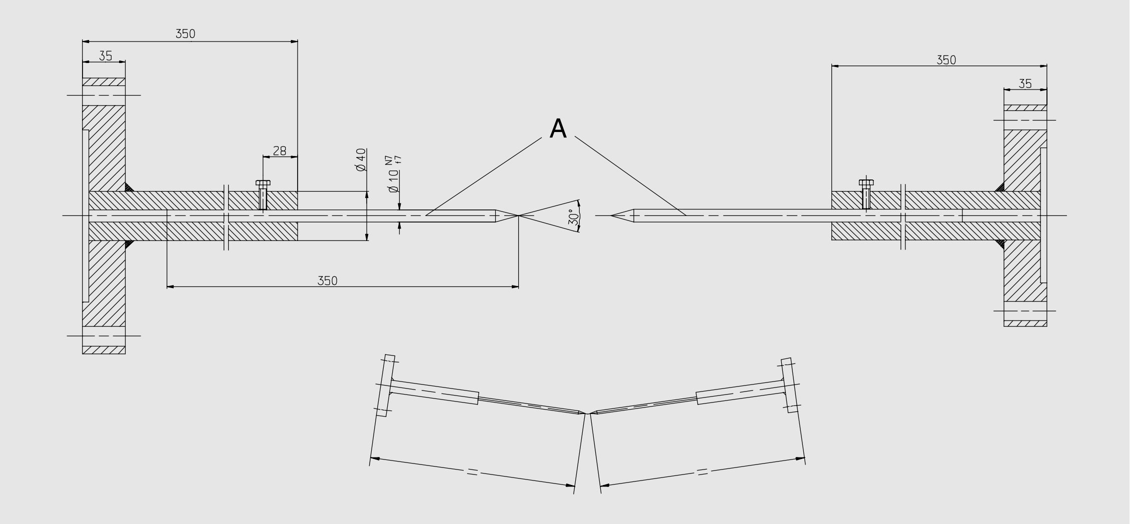
Aligning engine and drive system

	Type of alignment	Permissible tolerances
1	Max. angle per joint	see page 36
2	Input and output angles β_1, β_2 (= deflection angle) must be equal.	Difference $|\beta_1 - \beta_2| \leq 0{,}5^\circ$
3	Engine, propshaft and gearbox must form a line when looked from above.	<1 per mil, ie 0.5 mm over a measuring length of 500 mm
4	The inner yoke heads must be the same.	<1 °
5	Static offset from engine to gearbox longitudinal axis (when looked at from above)	<1 mm

To achieve identical deflection angles for V-type arrangements, an accessory device consisting of two aligner rods may be used.

Such a device is depicted below.

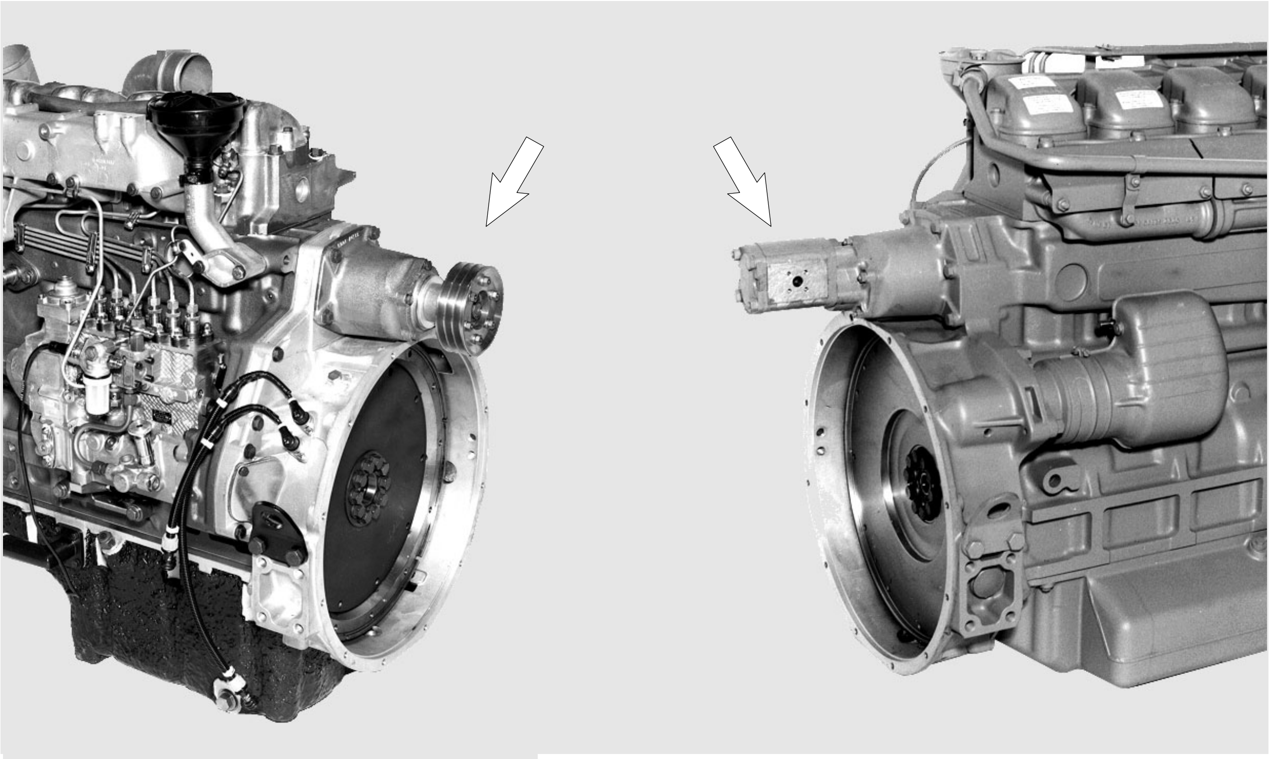
With regard to the dimensions indicated, this device may be employed for propshafts with lengths from L_Z = 700 to 1,300 mm. Shorter and longer propshafts necessitate correspondingly shorter or longer rods A.



How to proceed: Fit aligner rods instead of propshafts. Both parts must be equally long. Align engine and gearbox in such a way that the points of the aligner rods will be in contact. Afterwards, remove the accessory device and fit the propshafts.

Power from gear-driven power take-off in D 28 engines

Six-cylinder in-line and V-type D 28 engines can be equipped with a gear-driven power take-off at the flywheel end. The picture shows this power take-off on an in-line engine with attached belt pulley (at left) and with attached hydraulic pump (at right).



Owing to engine-specific loads, the attachment of a power take-off to 5-cylinder engines is usually not possible.

However, under certain conditions and if the operating conditions are known, power output via the power take-off at the flywheel end can be made possible here too.

Assembly drawings for the power take-off can be obtained from MAN.

For taking off power via directly driven units (eg hydraulic pumps), special designs have been created. Relevant installation documents can be obtained from MAN on request.

Transmission ratio:

In D 28 in-line and V-type engines, the speed of the power take-off is:

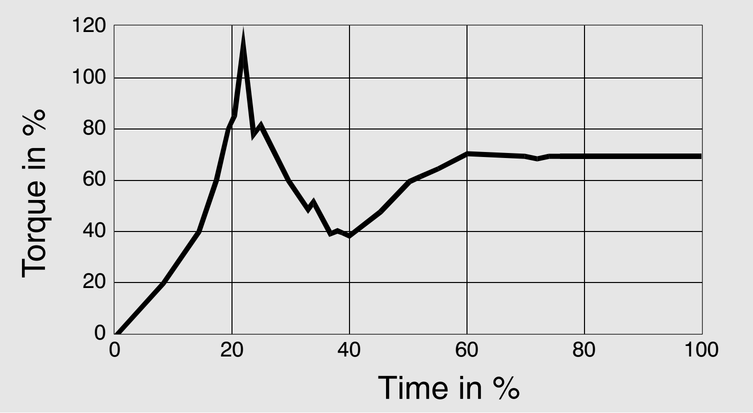
n = 1.075 x engine speed (i = 0.9302)

Axial power take-off:

The usable nominal torque is:

M_{nom} = 450 Nm

Switching on or momentary increases in load may cause brief dynamic peaks (see diagram).



As a result of brief dynamic peaks, the usable peak torque is:

M_{max} = 560 Nm

Higher peak torques require approval by MAN.

Radial power take-off:

Apart from the axial power take-off, radial output via V-belts is also possible. In this case power take-off will be limited by the bending moment channelled into the power-take-off shaft via the pull of the belt.

Permissible bending moment:

$$\boxed{M_{B\ perm.} = 250\ \text{Nm}}$$

Permissible radial force:

$$\boxed{F_R = 2500\ \text{N}}$$

Power take-off from air compressor

With vehicle engines a hydraulic pump for the power steering is driven via the air compressor shaft. If the power steering is deleted, a hydraulic pump may as an alternative be connected up for other purposes.

Axial transmission is established via a drive plate connecting the claws.

The transmission ratio $i = \dfrac{n_{engine}}{n_{air\ comp.}}$ can be calculated with the aid of the following table:

	1-cylinder air compressor	2-cylinder V-type air compressor	2-cylinder in-line air compressor
In-line engine	0.8163	0.8163	1.0204
V-type engine	0.7907	0.7907	---

Transferable torque (for permanent operation):

$$\boxed{M = 50\ \text{Nm}}$$

Output formula:

$$P = \frac{M \times n_{engine}}{i \times 9549.3}$$

Combustion air requirement

The engine requires a sufficient amount of fresh air (as indicated in the data sheets) for fully combusting the fuel and achieving full output.

Air filter

The size of the air filter is to be determined together with the manufacturer so that, taking into account the amount of dust which is expected to occur the following conditions will be satisfied:

- The maximum permissible intake vacuum is to be complied with.
- The filter must be cleared by MAN with regard to the air flow rate and degree of separation.

The air intake point upstream of the filter is to be located in a low dust area well protected against rain and splashwater and be arranged so that hot air from the engine room cannot be sucked in.

Of the well-known filter designs, the dry-air filter is always to be used.

Caution:
Unfiltered or insufficiently filtered intake air leads to rapid engine wear.

Depending on the installation situation the air filter is delivered either attached to the engine or loose.

Partial vacuum downstream of air filter

The intake vacuum is measured approx. 300 mm before the inlet into the engine or into the turbine at maximum air intake capacity.
Maximum air intake capacity is achieved:

- Naturally aspirated engine: at max. speed (cut-off speed)
- Supercharged engines: at rated engine speed and full load (max. delivery output of turbocharger)

The maximum permissible intake vacuum is:

- Filter in ”as new” condition: 30 hPa (30 mbar, 300 mm head of water)
- Filter in contaminated condition: 60 hPa (60 mbar, 600 mm head of water)

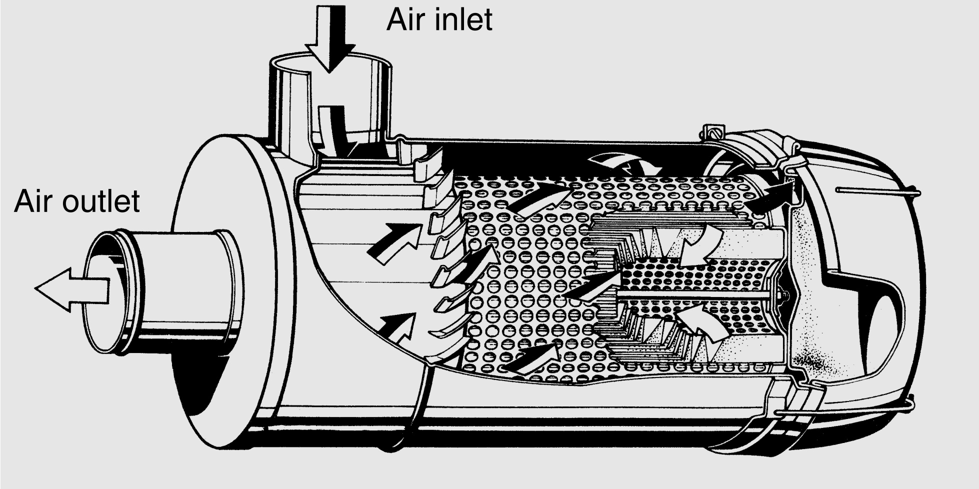
If the intake vacuum is too high, this will lead to incomplete combustion, to formation of black smoke and to a drop in output.

Dry air filter for continuous operation

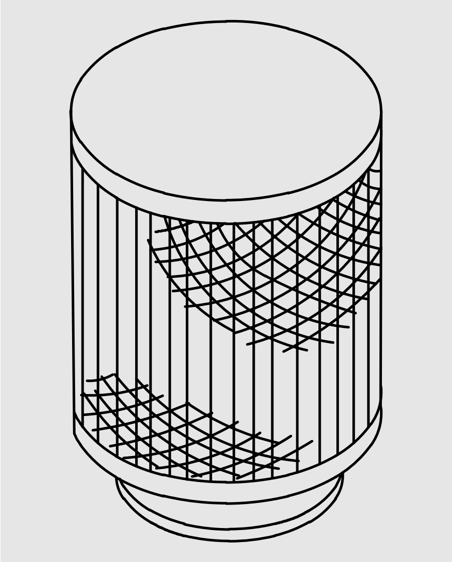
Characteristics of the dry-air filter with exchangeable paper element are high separation efficiency in all operating ranges and an increase in resistance as the element becomes dirty.

In many cases cyclone separators are integrated in the dry air filter housing. The cyclone separator causes air to rotate, which prompts part of the dust to be separated before reaching the downstream air filter.

For dry air filters the installation position recommended by the manufacturer is to be observed.



Dry air filter for limited-time operation (standby power systems)



A dry air filter (paper air filter ”Duratite”) with limited service life is available for standby power units. With regard to the separation degree this air filter is comparable with the dry air filter for continuous operation.
However, its service life is markedly shorter.

Designing the air intake pipe

The air pipe from the filter to the engine must satisfy the following requirements:

- Absolute tightness
- Short routing with favourable flow characteristics and with as few interfaces as possible
- Inside faces must be scale-free and protected against corrosion
- Compensation of relative movements between engine and filter by means of elastic connections (hoses)
- For hose connections, provide pipes with beads. Use suitable hose connections only (also see Appendix to this brochure)
- Before assembling, clean all pipe and hose connections on the inside
- Water is the only permissible lubricant for fitting hoses
- Air intake lines must not be laid near hot components.
- Clear cross-section A of the air intake line:

Naturally aspirated engines: 40 - 50 mm^2 / kW
Supercharged engines: 50 - 65 mm^2 / kW

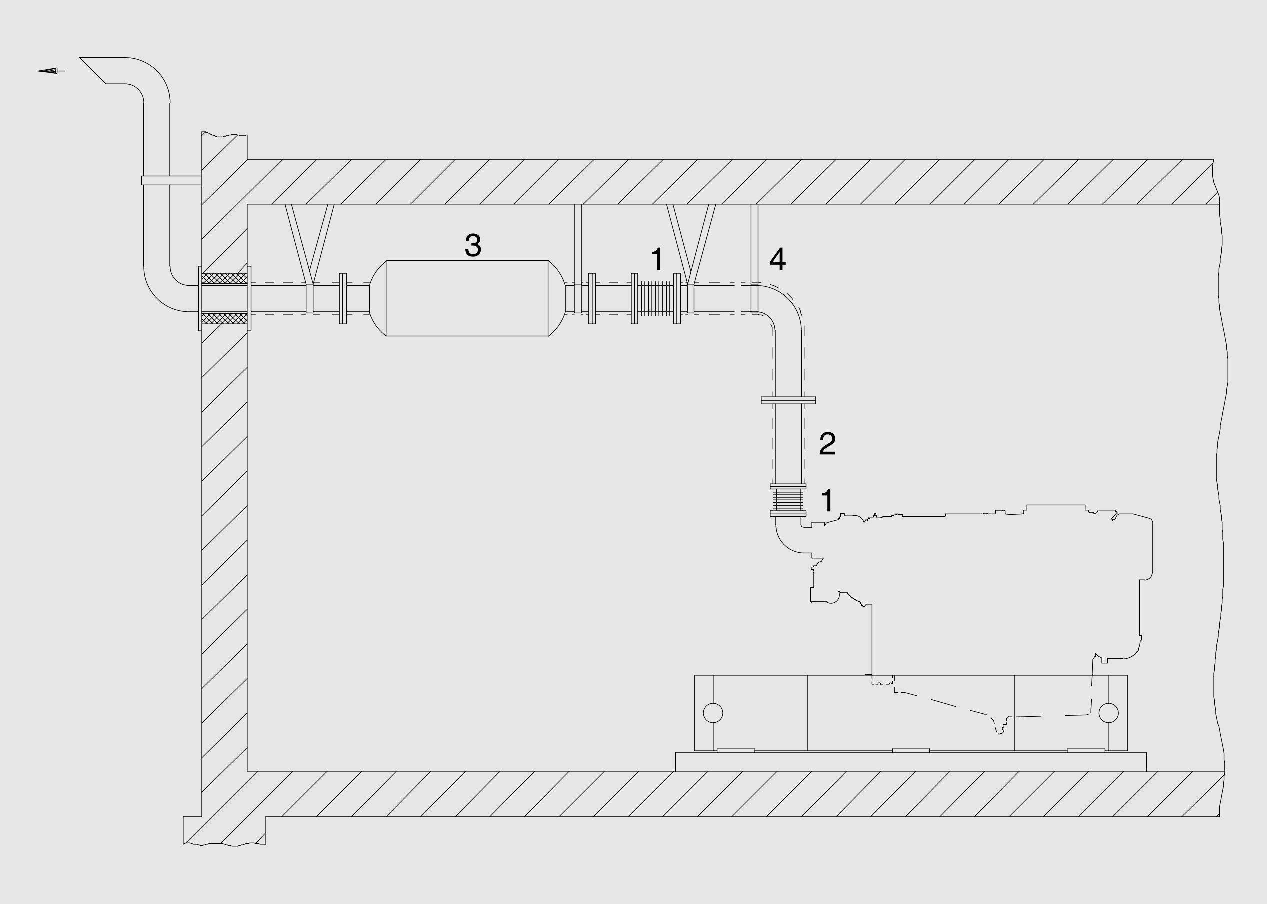
Designing the exhaust system

Exhaust lines are to be attached and supported so that no forces can act on the turbochargers.

One or several elastic intermediate pieces (compensators) are to be installed between engine and exhaust system. The manufacturer’s installation regulations are to be complied with.

This will prevent vibrations from being transferred from the engine to the exhaust system and will compensate the exhaust pipes’ longitudinal extension due to the high temperatures.

Acid-resistant steel is to be preferably used as material for the exhaust system.



① Compensators
② Y-pipe
③ Silencer
④ Locate the fastening a close as possible to the pipe elbow.

The following is a guideline value for the elongation of steel pipes as a function of temperature:

1 mm per meter and 100°C

It is inadmissible to channel the exhaust gases from several engines into one system. In multi-engine systems separate exhaust-gas piping is required for each and every engine so that when one engine is running exhaust gases cannot penetrate into another engine.

Caution:
Exhaust-gas systems must be absolutely gas-tight to preclude any poisoning.

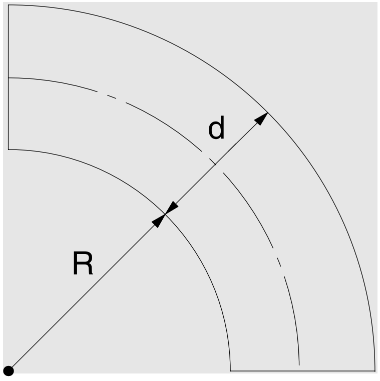
Owing to the high temperature of exhaust gases (several hundred degrees Celsius), exhaust pipes heat up considerably. For reasons of safety exhaust pipes are to be fitted with suitable anti-heat protection devices.

To prevent the engine room from heating up too much, fire-resistant, fuel and lube-oil repellent insulation is to be recommended. The engine's exhaust manifold and the turbocharger are to be fitted with an anti-contact protection device. Any insulation of these components requires approval.

To minimise the exhaust back pressure, sharp bends and manifolds are to be avoided. Pipe bends must have large radii ($R / d \geqq 1.5$). When installing silencers, soot filters, catalytic converters etc, ensure that the maximum permissible exhaust back pressure is not exceeded.

Condensation may form in the exhaust system and must under no circumstances be allowed to flow into the engine. For this reason a condensation trap with drain valve is to be provided near engines with very long, ascending exhaust pipes.

On no account must rain water penetrate into the exhaust system.



Permissible exhaust back pressure

At rated engine power, immediately downstream of the exhaust turbine or the flange of the collector pipe, this is

in turbocharged engines:	60	hPa (60 mbar, 600 mm head of water)
in naturally aspirated engines:	110	hPa (110 mbar, 1100 mm head of water)

Exceeding these values leads to inadmissible exhaust-gas temperature, thermal stress and an increase in the formation of smoke.

For this reason it is indispensable that during the commissioning of an engine the exhaust back pressure be measured and the exhaust-gas system redimensioned if necessary.

Caution:
For engines in continuous operation with downstream exhaust emission control systems or with exhaust-gas heat exchangers permanent monitoring of the exhaust back pressure is mandatory.

Calculating the back pressure of the exhaust system

We recommend that, if possible, the maximum permissible back pressure value (= pressure drop) is not fully exploited when the exhaust system is designed. The exhaust pipe diameter, the number of bends, the silencers and the pipe routing are to be selected so that when the engine is new 75% of the maximum value is not exceeded.

The total back pressure (total pressure drop) Δp in the exhaust system is calculated as follows:

$$\Delta p = \Delta p_R \times L + \Delta p_K \times n_K + \Delta p_S$$

Explanation of the formula:

Δp_R = Back pressure (pressure drop) per 1 m of pipe

L = Length of pipe in m

Δp_K = Back pressure (pressure drop) per 90°bend

n_K = Number of bends

Δp_S = Back pressure (pressure drop) in silencer

If apart from the silencer further components, eg soot filter, catalytic converters or heat exchangers, are installed, their resistance is also to be taken into consideration.

Since the exhaust back pressure of these components rises during operation, continuous exhaust back-pressure monitoring is to be provided.

Examples of calculations for exhaust systems

Example:

An exhaust system with a pipe length of 4 m, two 90° bends and a silencer is planned. The clear diameter is to be 120 mm.

Is this system adequately designed for a turbocharged diesel engine with an exhaust gas mass flow of 1,300 kg/h?

The following values can be found in the tables:

Back pressure per 1 m of pipe = 3.4 hPa

Back pressure per 90° bend = 5.7 hPa

For back pressure data in silencer, contact manufacturer.
A value of 5 hPa is assumed here.

The total back pressure Δp is calculated as follows:

$$\Delta p = \Delta p_R \times L + \Delta p_K \times n_K + \Delta p_S$$

$$\Delta p = 3.4 \text{ hPa} \times 4 + 5.7 \text{ hPa} \times 2 + 5 \text{ hPa} = 30 \text{ hPa}$$

The calculated value is within the permissible range.

Average back pressure (pressure drop) in hPa per 1 m of exhaust pipe, depending on the exhaust gas mass flow in kg/h and the clear diameter in mm (1 hPa = 1 mbar)

Exhaust gas mass flow *	Diameter in mm						
kg/h	80	100	120	140	160	180	200
200	0.7	0.2	0.1	---	---	---	---
300	1.6	0.5	0.2	0.1	---	---	---
400	2.8	0.9	0.3	0.1	0.1	---	---
500	4.4	1.3	0.5	0.2	0.1	0.1	---
600	6.3	1.9	0.7	0.3	0.1	0.1	0.1
700	8.6	2.6	1.0	0.4	0.2	0.1	0.1
800	11.2	3.4	1.3	0.6	0.3	0.2	0.1
900	14.2	4.3	1.6	0.7	0.4	0.2	0.1
1000	17.5	5.3	2.0	0.9	0.4	0.2	0.1
1100	21.2	6.5	2.5	1.1	0.5	0.3	0.2
1200	25.3	7.7	2.9	1.3	0.6	0.3	0.2
1300	---	9.0	3.4	1.5	0.7	0.4	0.2
1400	---	10.5	4.0	1.8	0.9	0.5	0.3
1500	---	12.5	4.6	2.0	1.0	0.5	0.3
1600	---	13.7	5.2	2.3	1.1	0.6	0.3
1700	---	15.5	5.9	2.6	1.3	0.7	0.4
1800	---	17.3	6.6	2.9	1.4	0.8	0.4
1900	---	19.3	7.3	3.2	1.6	0.8	0.5
2000	---	21.4	8.1	3.6	1.8	0.9	0.5
2100	---	23.6	9.0	3.9	1.9	1.0	0.6
2200	---	25.9	9.8	4.3	2.1	1.1	0.7
2300	---	---	10.7	4.7	2.3	1.2	0.7
2400	---	---	11.7	5.2	2.5	1.4	0.8
2500	---	---	12.7	5.6	2.8	1.5	0.8
2600	---	---	13.7	6.0	3.0	1.6	0.9

* For engine values, see technical data sheets

Average back pressure (pressure drop) in hPa per 1 m of exhaust pipe, depending on the exhaust gas mass flow in kg/h and the clear diameter in mm (1 hPa = 1 mbar)

Exhaust gas mass flow *	Diameter in mm						
kg/h	80	100	120	140	160	180	200
2700	---	---	14.8	6.5	3.2	1.7	1.0
2800	---	---	15.9	7.0	3.5	1.8	1.1
2900	---	---	17.0	7.5	3.7	2.0	1.1
3000	---	---	18.3	8.0	4.0	2.1	1.2
3100	---	---	19.5	8.6	4.2	2.3	1.3
3200	---	---	20.8	9.2	4.5	2.4	1.4
3300	---	---	22.1	9.7	4.8	2.6	1.5
3400	---	---	---	10.3	5.1	2.7	1.6
3500	---	---	---	11.0	5.4	2.9	1.6

* For engine values, see technical data sheets

Average back pressure (pressure drop) in hPa per 90° bend (R/d = 1.5), depending on the exhaust gas mass flow in kg/h and the clear diameter in mm (1 hPa = 1 mbar)

Exhaust gas mass flow *	Diameter mm						
kg/h	80	100	120	140	160	180	200
200	0.7	0.3	0.1	0.1	---	---	---
300	1.5	0.6	0.3	0.2	0.1	---	---
400	2.7	1.1	0.5	0.3	0.2	0.1	---
500	4.3	1.8	0.8	0.5	0.3	0.2	0.1
600	6.2	2.5	1.2	0.7	0.4	0.2	0.2
700	8.4	3.5	1.7	0.9	0.5	0.3	0.2
800	11.0	4.5	2.2	1.2	0.7	0.4	0.3
900	13.9	5.7	2.8	1.5	0.9	0.5	0.4
1000	17.2	7.0	3.4	1.8	1.1	0.7	0.4
1100	20.8	8.5	4.1	2.2	1.3	0.8	0.5
1200	24.8	10.1	4.9	2.6	1.5	1.0	0.6
1300	---	11.9	5.7	3.1	1.8	1.1	0.7
1400	---	13.8	6.6	3.6	2.1	1.3	0.9
1500	---	15.9	7.6	4.1	2.4	1.5	1.0
1600	---	18.0	8.7	4.7	2.7	1.7	1.1
1700	---	20.4	9.8	5.3	3.1	1.9	1.3
1800	---	22.8	11.0	5.9	3.4	2.2	1.4
1900	---	---	12.3	6.6	3.9	2.4	1.6
2000	---	---	13.6	7.3	4.3	2.7	1.8
2100	---	---	15.0	8.1	4.7	3.0	1.9
2200	---	---	16.4	8.9	5.2	3.2	2.1
2300	---	---	18.0	9.7	5.7	3.6	2.3
2400	---	---	19.6	10.7	6.1	3.9	2.5
2500	---	---	21.2	11.5	6.7	4.1	2.8
2600	---	---	23.0	12.4	7.3	4.6	3.0

* For engine values, see technical data sheets

Average back pressure (pressure drop) in hPa per 90° bend (R/d = 1.5), depending on the exhaust gas mass flow in kg/h and the clear diameter in mm (1 hPa = 1 mbar)

Exhaust gas mass flow *	Diameter mm						
kg/h	80	100	120	140	160	180	200
2700	---	---	---	13.4	7.8	4.9	3.2
2800	---	---	---	14.4	8.4	5.3	3.5
2900	---	---	---	15.4	9.0	5.6	3.7
3000	---	---	---	16.5	9.7	6.0	4.0
3100	---	---	---	17.6	10.3	6.4	4.2
3200	---	---	---	18.8	11.0	6.9	4.5
3300	---	---	---	20.0	11.7	7.3	4.8
3400	---	---	---	21.2	12.4	7.8	5.1
3500	---	---	---	22.5	13.2	8.2	5.4

* For engine values, see technical data sheets

Measuring the pressure drop

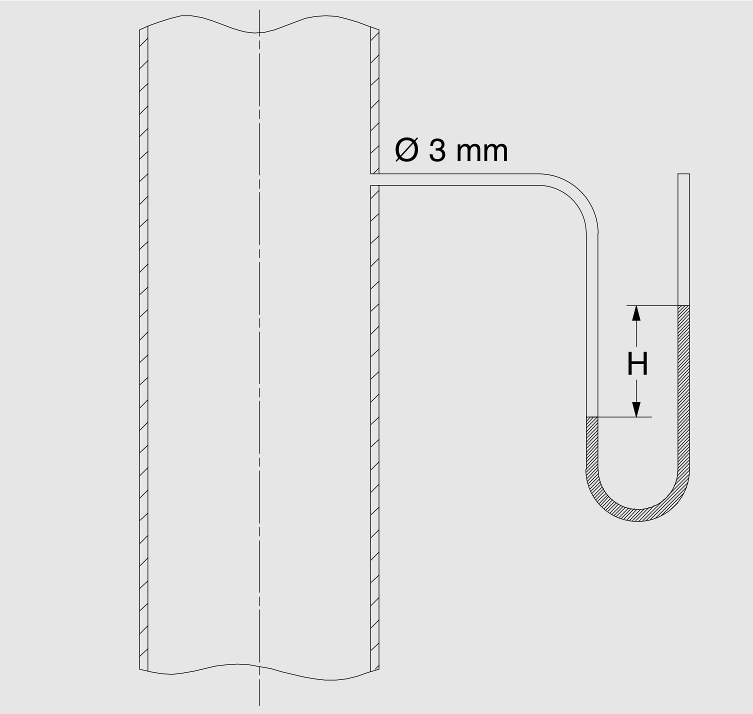
Unit of measurement: 1 hPa = 1 mbar = 10 mm head of water

Measuring instrument: The simplest measuring instrument is a U-pipe manometer filled with water. If the U-pipe manometer is filled with mercury, the reading of the liquid's difference in height given in mm is to be multiplied by 13.6 to obtain the result in mm head of water.

1 mm Hg = 13.6 mm head of water = 1.33 mbar

Measuring arrangement: The quantity to be measured is the static pressure, ie the measuring connection must fit flush with the inside of the pipe wall.

Select a straight part of the pipe for the measurement.

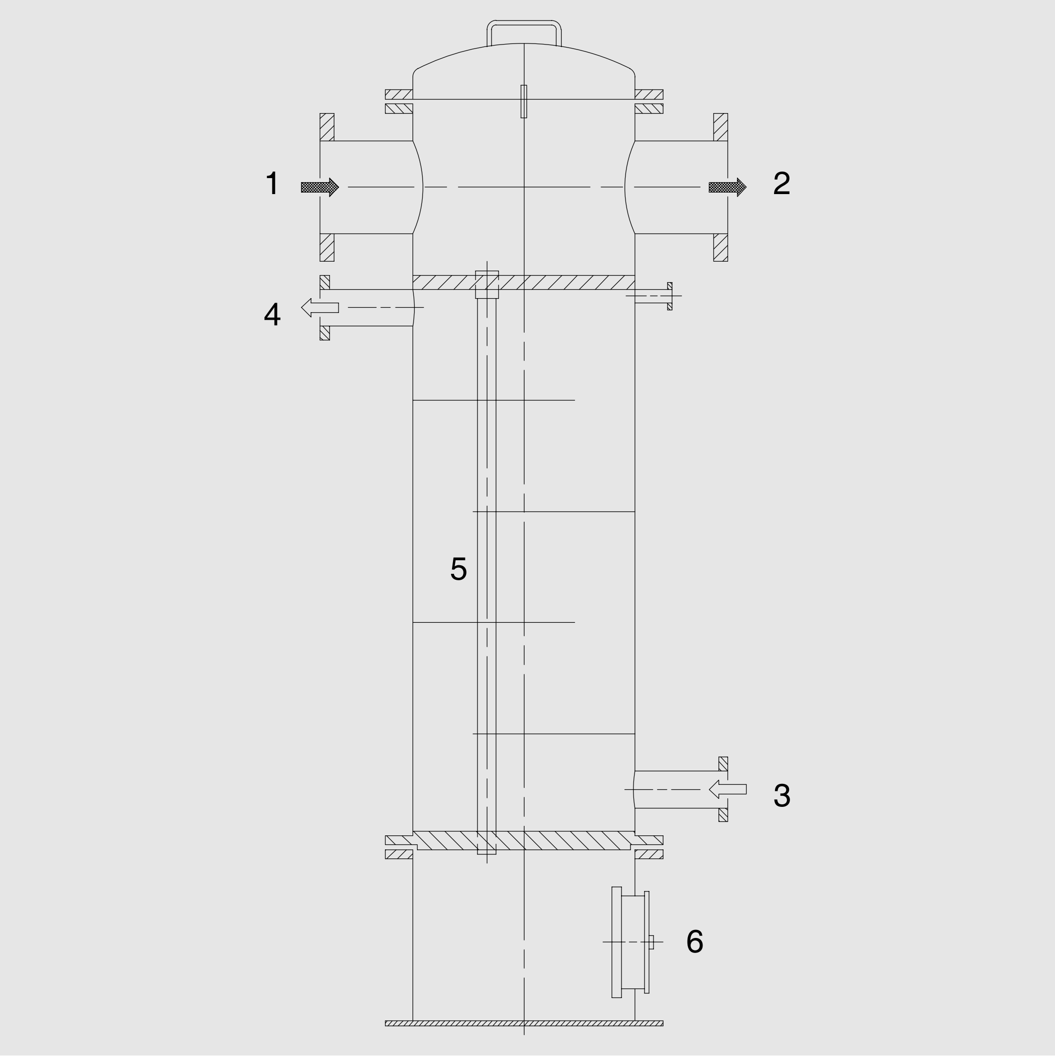


If the overall pressure drop of the exhaust system is to be measured, a point approx. 300 mm downstream of the engine's or turbocharger's exhaust gas collecting pipe is to be selected for the measurement.

During the measuring operation the engine must run at maximum power and rated speed.

Exhaust gas heat utilisation in stationary systems

In stationary diesel engines for cogeneration, exhaust gas heat exchangers are frequently employed in connection with heat exchangers for recovering heat losses in coolant. Exhaust gas water preheaters are frequently used as heat exchangers. For this reason the properties of these units are described in the following.
The picture shows as an example the basic design of an exhaust gas water preheater designed as a smoke tube boiler.



① Exhaust gas inlet
② Exhaust gas outlet
③ Water inlet
④ Water outlet
⑤ Smoke tubes
⑥ Detachable flange caps

Operating principle:

Hot gases, in this case the exhaust gases from the engine, enter the preheater at the top left (1), flow downwards through a system of tubes and then flow upwards to leave the preheater on the right-hand side (2).
Water enters the preheater at the bottom right (3) and is channelled upwards - opposite to the direction of the gases -, whereby it warms up and then leaves the preheater again at the top left (4).

Properties of exhaust gas water preheaters

Exhaust gas water preheaters are frequently subject to considerable wear resulting from corrosion on the exhaust gas side.

The cause of this is that they are charged with aggressive, acidic exhaust condensation at low wall temperatures in partial load operation.

This wear can be countered by the use of suitable materials, but the use of special steel means high costs.

Consideration is therefore to be given to whether it is worth making such investments to extend the service life of the respective unit or whether it is more economical to exchange the pipe cluster at certain intervals.

For cleaning and exchanging the pipe cluster, the heat exchanger must be fitted with detachable flange caps.

The smoke tube internal diameter must not be smaller than 22 mm to prevent the tube from prematurely clogging up and, consequently, to prevent considerable increases in the exhaust back pressure.

Wear resulting from corrosion can be limited if precipitation of condensation from the exhaust gases is prevented. This can be achieved if the exhaust gas temperature at the outlet from the exhaust gas system is not less than 180°C.

$$\boxed{\text{Exhaust gas temperature at the exhaust gas outlet} \geq 180^\circ\text{C}}$$

The best results are achieved if the systems always run at high load, ie at high temperatures, and if the preheaters are fully charged.

It must be possible to switch off the exhaust gas water preheater via hot gas slides or butterfly valve. A bypass is then necessary for the exhaust gas ducting. This prevents both the heat exchanger from being charged with exhaust gases at low exhaust gas temperatures (eg when the system is being started) and the formation of condensation.

As contamination increases, so does the exhaust back pressure of exhaust gas heat exchangers. For this reason continuous monitoring of the exhaust back pressure must be carried out without fail.

Ascertaining the usable exhaust gas heat

The amount of usable heat contained in exhaust gases is calculated with the following formula:

$$\dot{Q} = c_p \times \dot{m} \times \Delta t$$

Key:

$\dot{Q}$ = Amount of usable heat in the exhaust gases [kJ/h]

$\dot{m}$ = Exhaust-gas mass flow [kg/h]

c_p = Specific heat capacity of the exhaust gases [kJ/kg K]

Δt = Usable temperature drop in the exhaust gases [°C]

The usable temperature drop in the exhaust gases $\Delta t = (t_1 - t_2)$ is calculated as follows:

t_1 = temperature of the exhaust gases at the engine outlet [degree]

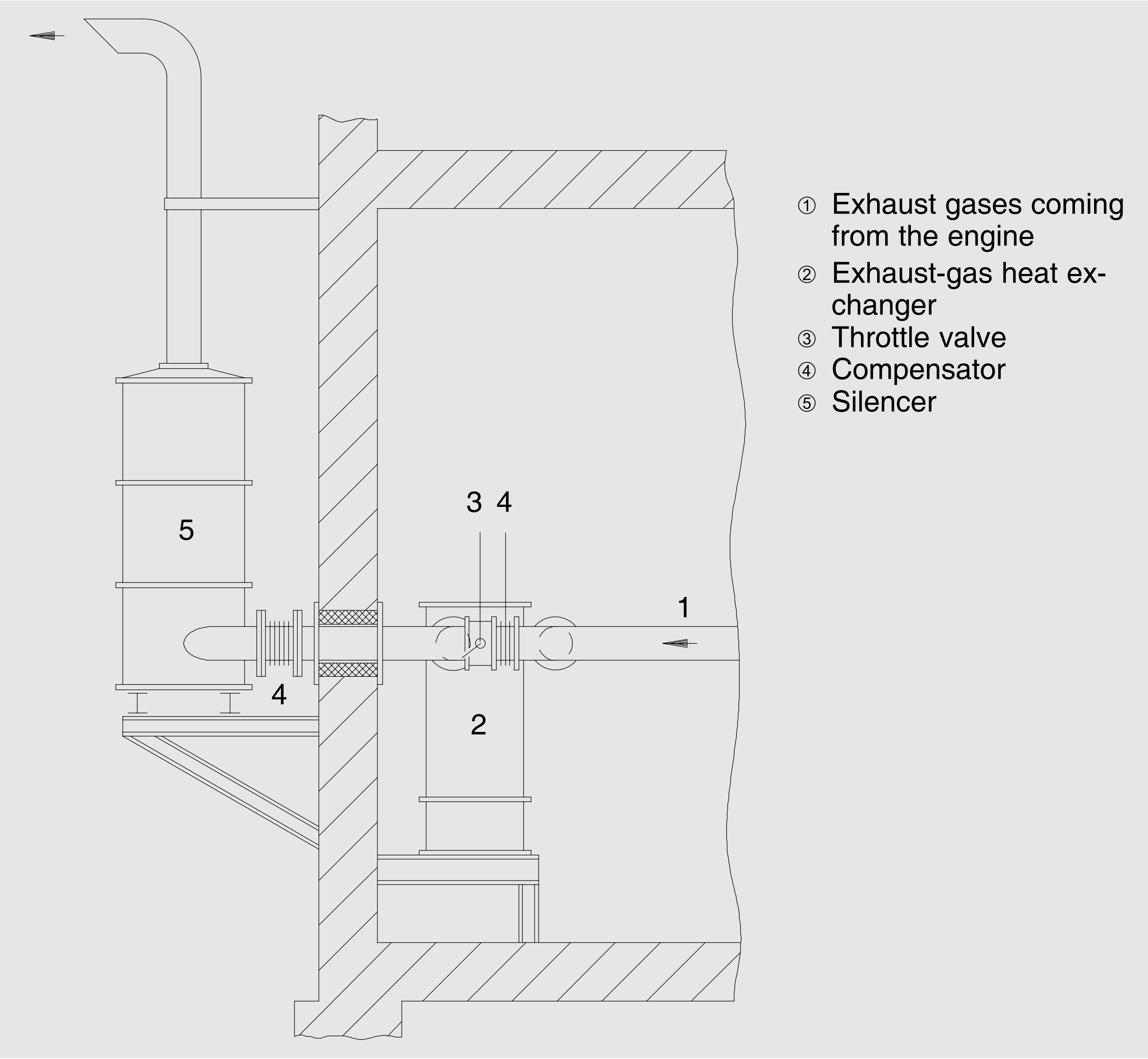
t_2 = temperature of the exhaust gases downstream of the heat exchanger [degree]

The specific heat capacity of the exhaust gases is approx. 1 kJ/kg × K.
The amount of exhaust-gas heat to be conducted away is calculated in kJ/h by means of the aforementioned formula. If this value is divided by 3,600, the unit will be kW.

The values for the exhaust-gas mass flow and the exhaust-gas temperature can be learned from the data sheets or can be obtained from MAN for the respective project.

The exhaust-gas temperature downstream of the heat exchanger must be at least 180°C.

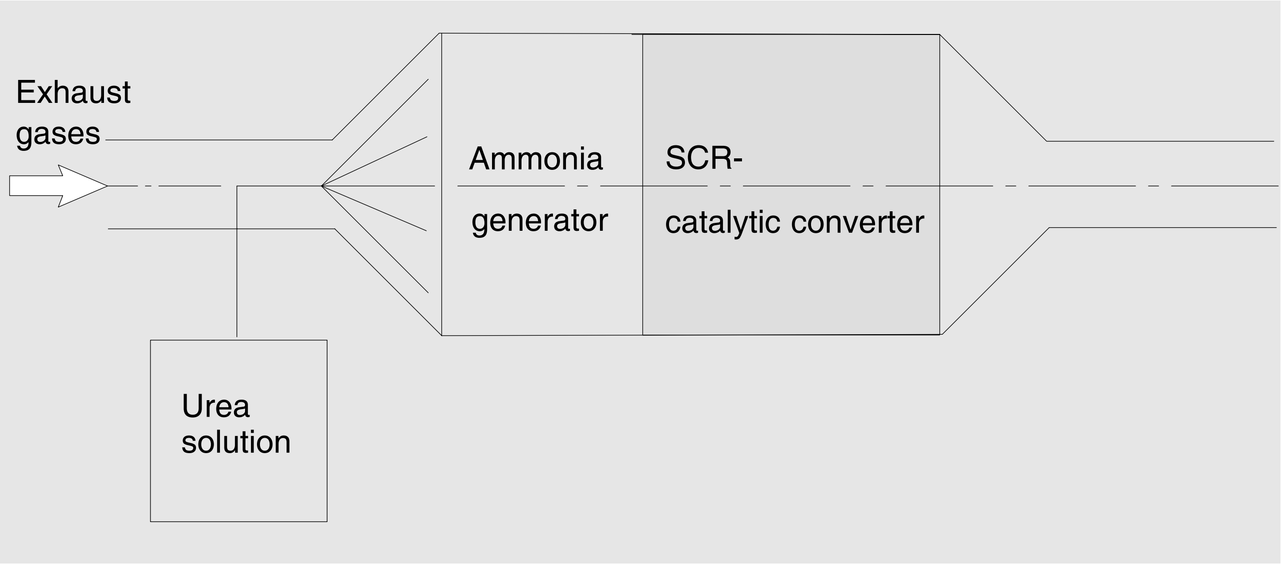
Installing the exhaust-gas heat exchanger in the exhaust-gas system



① Exhaust gases coming from the engine
② Exhaust-gas heat exchanger
③ Throttle valve
④ Compensator
⑤ Silencer

Catalytic converters

The emission of harmful substances can be considerably lowered by means of exhaust-gas cleaning systems.



To reduce NO$_x$ the exhaust gases from the diesel engine are, with addition of a reducing agent, channelled through the catalytic converter integrated in the exhaust gas pipe. Ammonia or a watery urea solution may be used as reducing agent.

Some minutes before the engine is switched off, the supply of the reducing agent is to be stopped so that when the engine is at a standstill no ammonia can flow back into the engine.

Caution:
When the engine is at a standstill, no ammonia gas from the catalytic converter must flow back into the engine.

Basic information on the cooling system

If the cooling system functions properly, the engine will operate with fewer faults and its service life will be prolonged.

Today, almost all MAN diesel engine are fitted with charge-air intercoolers.

Apart from the dissipation of the heat generated in the engine cooling circuit, recooling the charge air is therefore also of particular importance.

For this reason and as a standard solution for stationary engines we recommend purchasing the cooling system (fan radiator with combined air/air intercooler) from MAN. Modifications to the cooling system, eg the installation of additional heat exchangers for waste heat utilisation require approval by MAN.

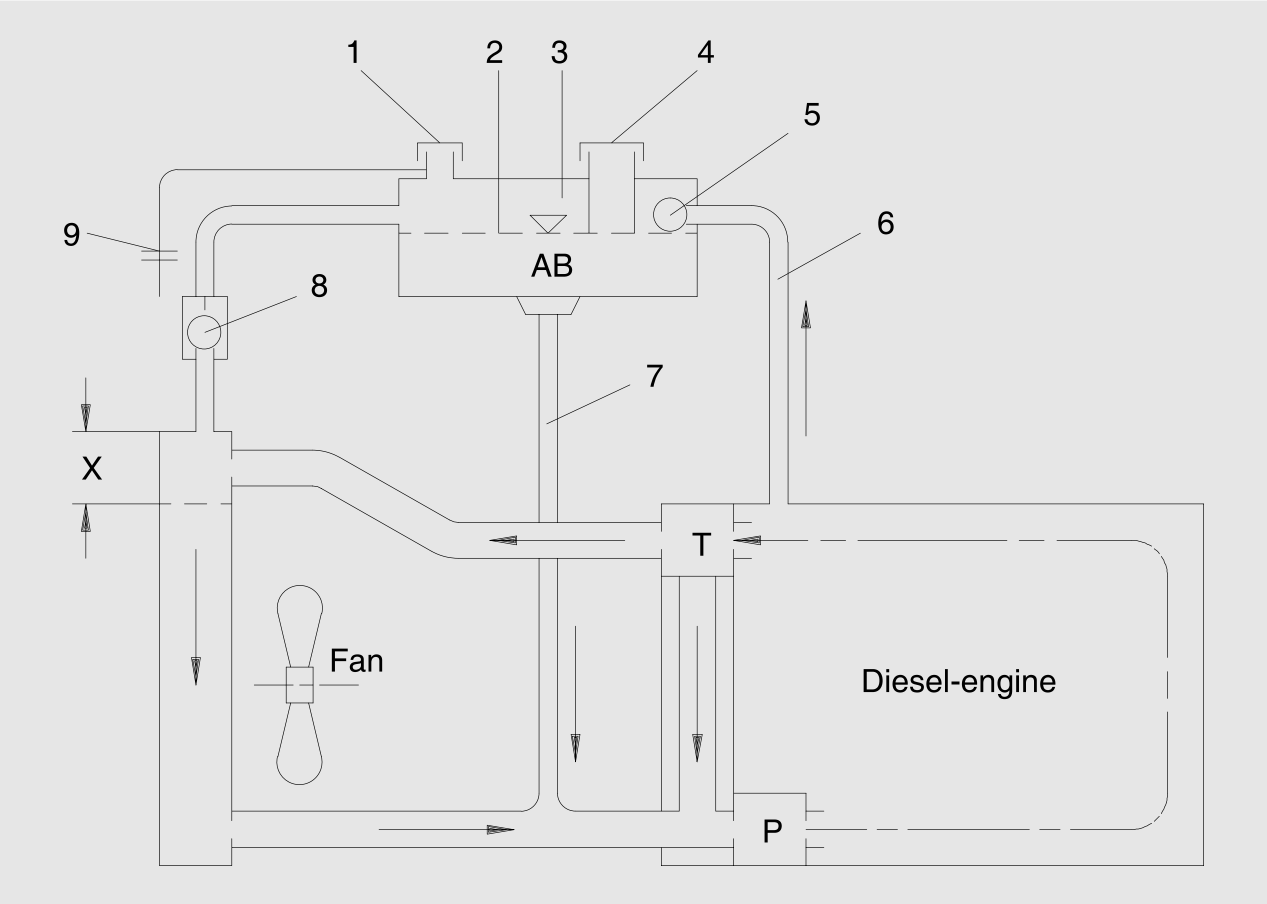
Cooling systems matched to the installation of an engine in a vehicle or in machinery must be checked and cleared by MAN in order to safeguard warranty.

All cooling systems for MAN engines are to be designed as closed, pressurised systems.

They will work properly only if the coolant has been mixed with an MAN-approved antifreeze with anti-corrosion protection agent (see also Appendix to this brochure and publication ”Fuels, Lubricants, Coolants for Industrial and Marine Diesel Engines”).

Radiator cooling

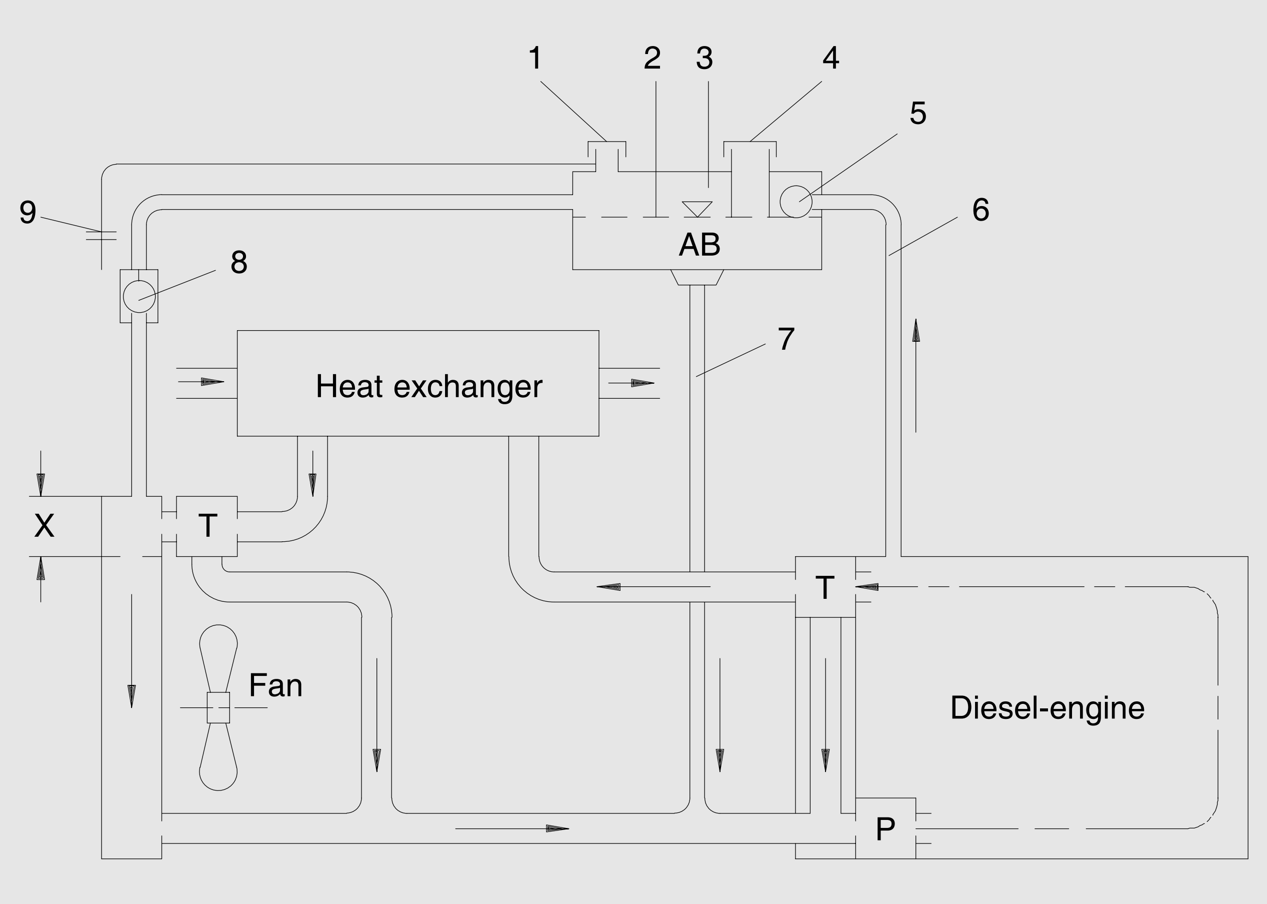
The diagram below shows the basic components of a standard cooling system for the engine coolant. These components are indispensable for the faultless operation of MAN diesel engines. The intercooler is not shown here. It will be dealt with separately.



① Working valve, opens at 0.6 - 0.7 bar overpressure, 0.02 - 0.03 bar partial vacuum
② Coolant level in expansion tank
③ Air expansion volume
④ Filler neck with safety valve, opens at 0.85 - 1.2 bar
⑤ Degasifying system
⑥ Permanent engine breather
⑦ Filler line
⑧ Radiator breather with check valve
⑨ Overflow and bleeding line
X $\geq$ 20 mm above thermostat
T Thermostat
P Water pump
AB Expansion tank

Stationary diesel engine for cogeneration

The diagram shows as additional components a heat exchanger and a second thermostat.



① Working valve, opens at an overpressure of 0.6 - 0.7 bar, and at a partial vacuum of 0.02 - 0.03 bar
② Coolant level in expansion tank
③ Air expansion volume
④ Filler neck with safety valve, opens at 0.85 - 1.2 bar
⑤ Degasifying system
⑥ Permanent engine breather
⑦ Filler line
⑧ Radiator breather with check valve
⑨ Overflow and bleeding line
X $\geq$ 20 mm above thermostat
T Thermostat
P Water pump
AB Expansion tank

Properties of diesel engine for cogeneration

Combined generation of power and heat makes sense only if the system is in continuous operation. The cooling system must therefore be designed with particular care, since in continuous operation even the smallest defects may cause very serious damage.

When installing additional heat exchangers and associated pipes, ensure that the flow resistance in the system is not too high, as this will cause the circulation of coolant to fall below the permissible value. Values for coolant circulation can be found in the engine data sheets.

Additional heat exchangers are to be arranged so that no air pockets will develop.

As already mentioned, cooling systems must be designed as closed overpressure systems. In continuous heavy duty operation the valves installed in the caps (items 1 and 4) may fail after some time without this being noticed. The system will then slowly lose pressure, so that consequential damage to the engine may occur.

Consequently, we recommend running the system with hydrostatic pre-pressure. For this purpose the expansion tank is fitted 6 - 7 m above the engine
(1m head of water is corresponding 0.1 bar).

The expansion tank is to be fitted with a coolant level probe (see page 85) which will actuate the shut-off device if the coolant level drops (burst hose).

Components of the cooling system

Fan

The fan may be driven constantly or via a Visco or electromagnetic coupling and be switched on and off as required.

If it is not possible to drive the fan from the engine, it can also be driven by means of a hydraulic or electric motor.

To save fuel and to keep the noise level low, the fan for cooling the engine coolant ought to be switched on only if the coolant necessitates this.

In combination radiators (radiator for both engine coolant and charge air, also see page 70), the fan must never be completely switched off even if the engine is idling or in low-load operation, because intercooling cannot be guaranteed in the event of a load on the engine.

Thermostat

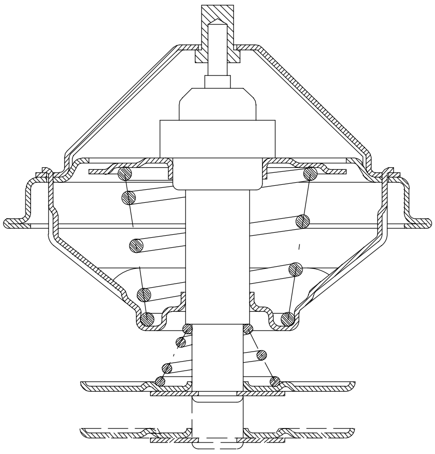
Before the coolant reaches operating temperature, it is conducted around the bypass circuit via a thermostat before the water pump. Once the operating temperature has been reached, the thermostat will gradually open the passage to the radiator.

Thus the operating temperature will be quickly reached and be kept constant during operation.

To prevent the flow of coolant from pulsating, only thermostats cleared by MAN must be installed.

The thermostat may be fitted either directly to the engine or in the line to the radiator.

If pipe thermostats are used outside the engine, short-circuit inserts must be installed in the engine's thermostat housing.



Coolant lines

The clear diameters of the coolant pipes must at least be equivalent to the cross-sections of the engine connections. Restrictions are to be avoided.

The coolant piping is to be routed in such a way that its flow characteristics are as favourable as possible. Route all lines as ascending or descending to prevent the formation of air bubbles.

If the engine rests on elastic mounts and the cooling system is fitted at a separate point, the pipe connections are to be designed flexible. Sectional hoses are to be recommended for non-aligned installation set-ups. The length of these sectional hoses is to be kept as short as possible and dimensionally stable, particularly on the suction side of the water pump.

Detailed requirements for coolant hoses can be found in the Appendix to this brochure.

Expansion tank

The efficiency and the functioning of a cooling system depend to a large degree on whether it is supplied with system pressure and is bubblefree. Both properties are largely influenced by the efficiency of the expansion tank.

For this reason all cooling systems for MAN engines must be fitted with a separate expansion tank that

- holds coolant expanded due to heat,
- builds up and maintains the operating pressure of the cooling system,
- separates the air bubbles from the coolant circuit,
- provides coolant reserves in the event of leakages,
- is readily accessible since coolant is filled in at the expansion tank and coolant level checks are carried out at the expansion tank.

The expansion tank is to have a fluid volume of $\geq$ 15 % and an air volume of approx. 7 - 12 % of the overall filling quantity of cooling system. A riser pipe is to be provided as a protection against overfilling.

From the expansion tank a filler line (∅ = 18 - 25 mm) must be routed so that it enters the pipe between the radiator outlet and the water pump inlet at the lowest possible point in the coolant circuit. Thus air inclusions will be largely avoided when the coolant circuit is being filled.

If, apart from the radiator breather, the coolant circuit has several bleeding lines, these ought to be combined into a collector pipe upstream of the expansion tank.

For bleeding lines an internal pipe diameter of 8 - 10 mm has proved adequate.

To achieve air separation as far as possible, even at reduced coolant levels in the expansion tank, it is necessary to limit the coolant flow rate in the expansion tank to 7 - 10 l/min. For this purpose a throttle (∅ approx. 3.5 mm) is necessary in the bleeding line immediately upstream of the expansion tank inlet.

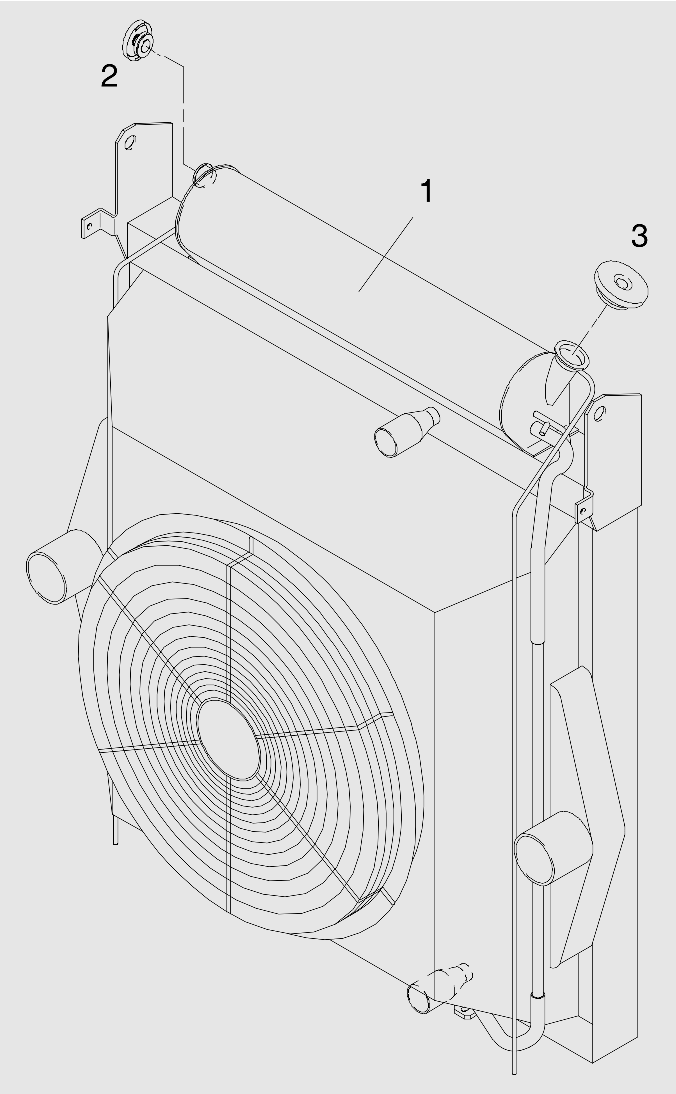
As described above, a separate bleeding line from the radiator to the expansion tank ought to be provided. Apart from a throttle this bleeding line must be fitted with a check valve to prevent any backflow and, consequently, prevent the engine from cooling down.

The expansion tank is always to be positioned in such a way that all bleeding lines can be laid in a continuously ascending manner.

Expansion tanks ought always to have two caps that differ in size. In the smaller of these caps a working valve is to be integrated that keeps the system pressure between 0.6 and 0.7 bar during engine operation. At the same time, however, this working valve must limit the partial vacuum in the cooling system to 0.02 - 0.08 bar if a partial vacuum should occur while the coolant is cooling down. The larger cap for the filler neck is to be fitted with a safety valve that opens between 0.85 and 1.2 bar.

As regards their mechanical strength, the expansion tanks ought to withstand a test pressure of at least 1.5 bar at a temperature of approx 120°C. In many cases their strength can be improved by baffles, which simultaneously smoothes the flow in the expansion tank.

If the engine installer wishes to fit a coolant level probe, it is to be positioned in the expansion tank in such a way that the warning signal appears if 5 - 8 % of the overall filling quantity has escaped while cold. However, air must not yet be sucked into the system.



① Expansion tank

② Valve cap with working valve, opens at 0.6 to 0.7 bar overpressure, 0.02 to 0.08 partial vacuum. Do not open cap unless this is absolutely necessary. Fill system up via filler neck (item 3).

③ Filler neck with safety valve, opens at 0.85 to 1.2 bar overpressure.

Dimensioning and designing the cooling system

If the cooling system is not obtained from MAN, it must be designed by the manufacturer.

The following data must be taken into consideration in the cooling system design:

- The heat quantity to be conducted away into the coolant from the engine and other components if fitted (see technical data sheet for the respective engine).
- Max. permissible coolant temperature at outlet from the engine (see technical data sheet for the respective engine).
- Surrounding conditions at the cooling system’s place of operation including the highest cooling air temperature to be expected.
- The minimum coolant circulation quantity required (see technical data sheet for the respective engine).
- Delivery rate and lift of the water pump (water pump diagrams can be obtained from MAN). Please note that the water pump speed is to be limited to max. 3600 rpm. If this speed is exceeded, shorter service life and increased noise output must be expected.
- If the radiator is fitted above the engine, the max. permissible installation height is 10 m.
- The connection dimensions and the type of fan drive including the drive speed and the direction of rotation can be learned from the installation drawing.
- Pipeline diameter and design as per installation drawing.

Checking the coolant circuit

When checking the coolant circuit the engine installer must ensure that

- the coolant circuit can be swiftly filled (approx 8 l/min),
- the coolant circuit, starts immediately when the engine is started or accelerated and that there is a constant coolant circulation,
- the coolant circuit vents itself automatically and completely,
- no partial vacuum can build up upstream of the water pump,
- a system pressure (guideline value: 0.4 - 0.5 bar) builds up in the coolant circuit and is maintained after the engine has been switched off,
- the coolant circuit ensures the required coolant flow rate at max. permissible coolant temperature and fully opened thermostat,
- the coolant circuit does not eject coolant even if the engine is switched off in the hot condition,
- approx 10 % of the filling quantity can be drained from the expansion tank before air is also sucked into the filling line,
- the coolant circuit including the engine and heat exchanger can be completely emptied,
- air bubbles are separated from the coolant,
- no air inclusions remain in the cooling system,
- hose connections are accessible for maintenance purposes.

Assessing the coolant circuit

In the coolant circuit a certain amount of heat corresponding to the respective engine load must be conducted away. The maximum heat quantities which occur in individual engines are indicated on the data sheet.

Here too the minimum coolant circulation quantities necessary for satisfactory heat dissipation and prevention of vapour pockets and local overheating can be found.

The following relationship can be established between the amount of heat to be conducted away and the mass flow of coolant:

$$\dot{Q} = c \times \dot{m} \times \Delta t$$

Key:

$\dot{Q}$ = Amount of heat to be conducted away from the coolant

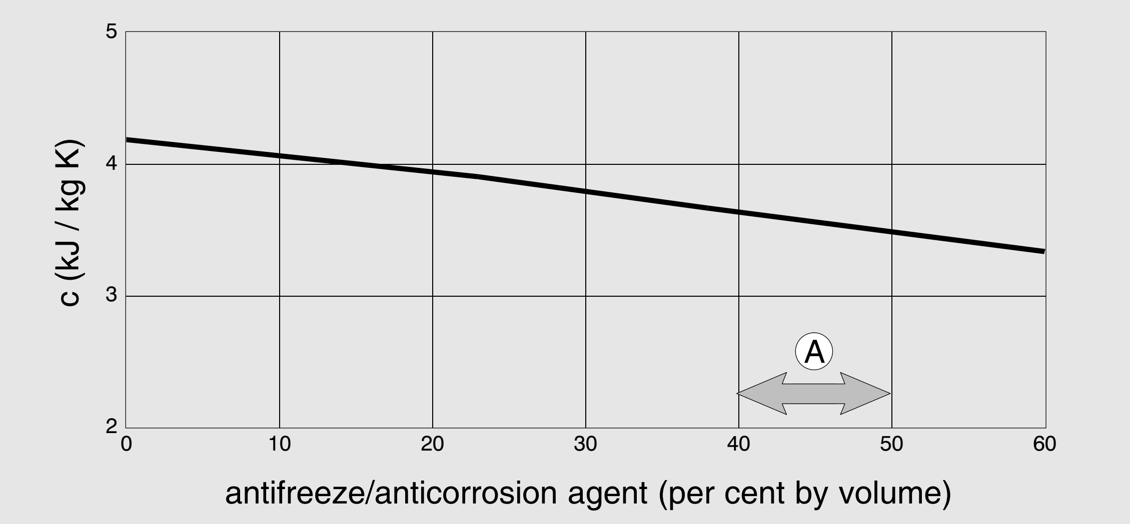
$\dot{m}$ = Coolant mass flow [kg / h]

c = Specific heat capacity [kJ / kg $\times$ K]

Δt = Temperature difference between engine inlet and engine outlet [°C]

The aforementioned formula is used to calculate in kJ/h the amount of heat to be conducted away in the coolant. If this value is divided by 3,600, the result will be in kW.

The specific heat capacity of the coolant depends on the antifreeze/anti-corrosion agent concentration. The higher the concentration of antifreeze/anti-corrosion agent in the coolant, the less heat per kg coolant can be conducted away.



A = Permissible range, ie the concentration of antifreeze/anti-corrosion agent must always be between 40 and 50 per cent by volume.

The minimum coolant circulation quantities are to be large enough to ensure that at maximum (blocked) output there is a temperature difference of 5 to 7°C between engine inlet and engine outlet.

If the engine runs at constant load, an equilibrium will be created after several minutes, ie the amount of heat to be conducted away in the coolant will remain constant.

The specific heat capacity of the coolant is determined by the concentration of antifreeze/anti-corrosion agent in the coolant and also constitutes a constant quantity.

If the flow resistance in the cooling system is increased owing to the installation of additional heat exchangers and/or long pipelines with tapered cross-sections and, consequently, the flow of coolant is throttled down, the temperature difference between the engine inlet and engine outlet is bound to increase.

This relationship becomes obvious in the aforementioned equation.

The coolant temperature difference between engine inlet and engine outlet is measured with the thermostats blocked in open position and at maximum output.

The coolant temperature difference between engine inlet and engine outlet is an important criterion to assess the cooling system.

Caution:
Coolant temperature difference between engine inlet and engine outlet $\leq$ 5 - 7°C

The cooling output of the fan radiator

To assess the cooling output of a cooling system the cooling constant (KK)

$$\boxed{KK = t_{WA} - t_L}$$

has been found reliable.

Key: t_{WA} = Coolant temperature at engine outlet

t_L = Air temperature at radiator inlet

To measure the outlet temperature, the coolant must contain at least 40 % antifreeze by volume, and the engine must be operated at full load.

The thermostat is to be blocked in the maximum opening position.

The air temperature is measured immediately before the radiator inlet area.

The cooling constants can be used to assess the output of a cooling system. It is a yardstick for the max. permissible air inlet temperature t_{Lmax} up to which the cooling system may be operated.

As the cooling constant is usually measured using new cooling systems, a safety margin t_s of approx 5°C must be deducted to allow for contamination.

Example:

The max. permissible coolant outlet temperature in continuous operation is 90°C. A cooling constant of 40°C was ascertained.

Up to what cooling air inlet temperature is the cooling system adequate if a safety margin of 5°C is deducted?

$$t_{Lmax} = t_{WAmax} - KK - t_s$$

$$t_{Lmax} = 90^\circ C - 40^\circ C - 5^\circ C$$

$$t_{Lmax} = 45^\circ C$$

As a result, the cooling system in this example suffices for air temperatures of up to 45°C.

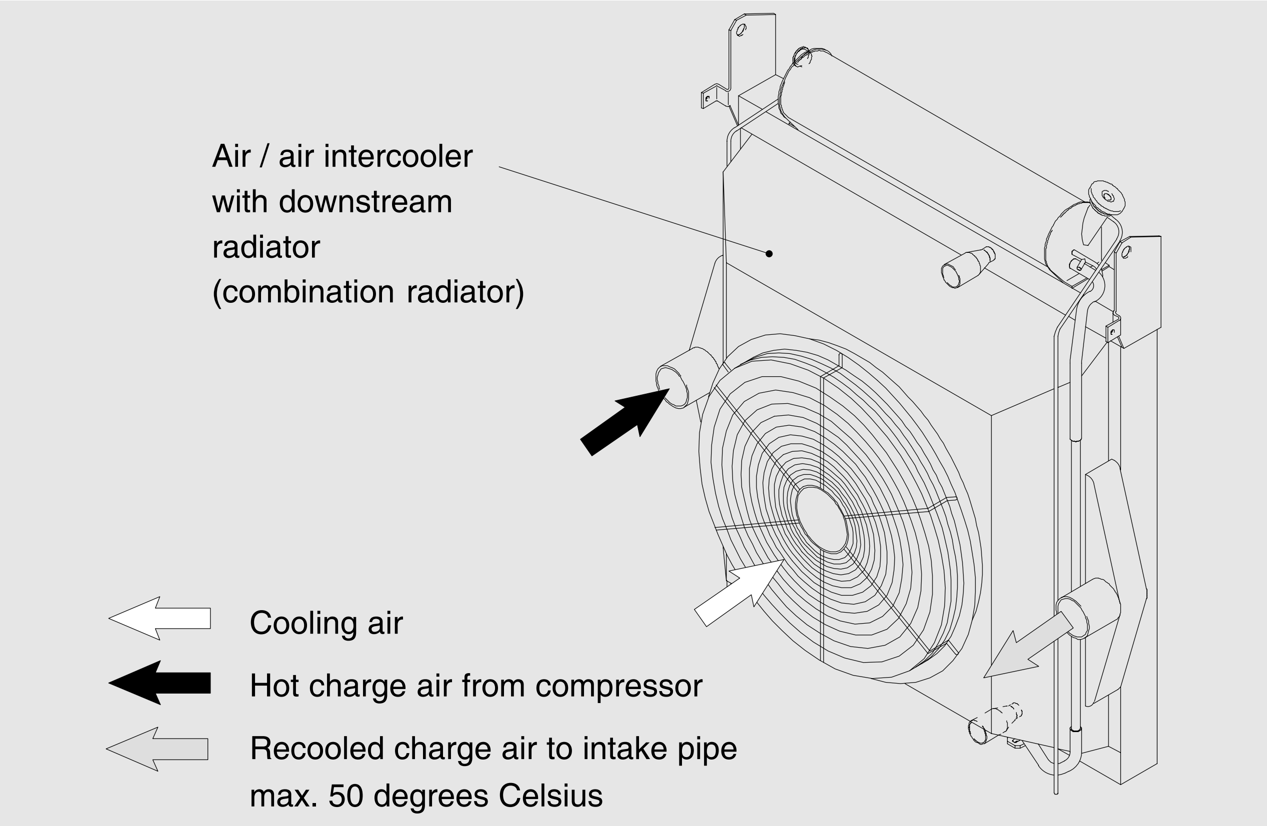
Intercooler

The intercooler has basically the following functions:

- As a result of the increase in combustion air density due to the reduced temperature, it is possible to markedly increase the specific output of the engines.
- The recooled combustion air reduces the thermal stress on the engine.
- The pollutant (NO_X) content of the exhaust gas is reduced.

Intercooling with air/air intercooler

The air/air-intercooler must be installed upstream of the radiator.



The following values are to be complied with in the intercooler design:

- permissible charge-air temperature downstream of radiator: max. 50°C (measured at an ambient air temperature of 25°C). If this requirement cannot be complied with, the engine output is to be reduced.
- permissible pressure loss in the intercooler: max. 120 mbar (including pipeline).

Note:
In remote intercoolers not only is the pressure loss in the pipelines to be taken into consideration, but also the additional air volume in the intercooler system, because this additional air volume may lead to delayed engine response.

In addition, the following data is required:

- heat quantity to be conducted away from the charge air,
- air flow rate,
- charge-air pressure
- pipe connection diameter at the engine

MAN provides this data for individual projects.

The intercooler must be constantly supplied with cooling air independently of the radiator. This applies even if the engine is idling or in low-load operation.

If the fan is not rigidly driven, intercooling is usually ensured via the drag speed of the Visco fan.

Pressure lines downstream of the compressor and their connections are required to comply with the following:

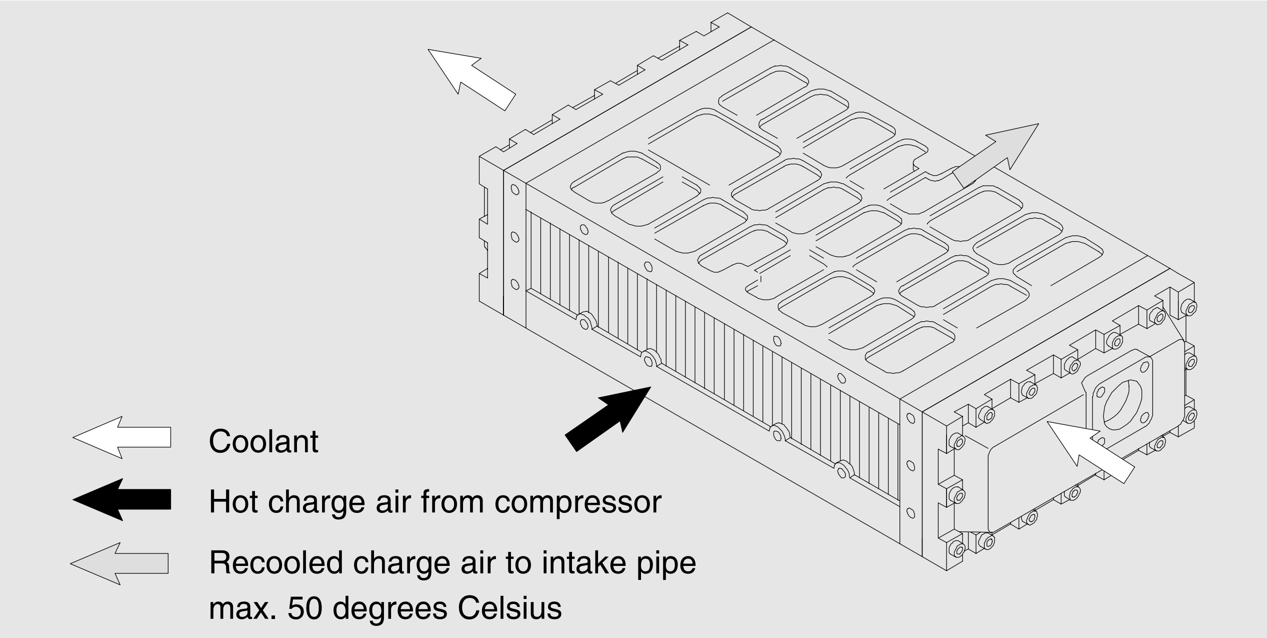
- they must withstand overpressures of up to 2.5 bar and must be absolutely tight
- they must resist temperatures of up to 200°C
- they must be oil-resistant
- the piping must have favourable flow characteristics

The criteria for selecting coolant hoses can be found in the Appendix to this brochure.

Intercooling with air/water intercooler

If engine and cooling system are installed separately or if the charge air is used for other purposes, air/water intercoolers are employed, as this makes it impossible to combine intercooler and fan radiator because of long charge-air pipes.

Intercooling is then effected in an intercooler charged with water or coolant.



In closed systems the coolant for intercoolers consists of water and about 40 to 50 % of antifreeze/anticorrosion agent by volume.

The intercooler cooling circuit is to be designed as a separate circuit and must not be integrated in the engine coolant circuit.

The intercooler coolant is circulated by a pump and recooled in a specially provided radiator.

Depending on the application, an electric circulating pump or one driven by the engine may be used.

In this set-up the intercooler coolant temperature is always above the ambient air temperature. The temperature difference between the intercooler coolant temperature and the ambient air temperature depends on the dimensioning of the recooling equipment.

As in air/air intercooling, here too the following condition for full engine output applies:

Caution:
Charge-air temperature downstream of intercooler $\leq 50^{\circ}$C

Reduced output in intercooled engines

As was mentioned at the beginning of this chapter, the permissible charge-air temperature downstream of the intercooler must not exceed 50°C. If the charge-air temperature is higher the engine's output must be reduced.

For D 2866 LE 2.., D 2848 LE 2.., D 2840 LE 2.. and D 2842 LE 2.. the following applies:

Reduction table for D 28 genset engines		
Charge-air temperature downstream of intercooler in °C	Reduction in output at 1,500 rpm in %	Reduction in output at 1,800 rpm in %
50	0	0
55	3	2
60	5	3
65	8	5
70	10	6
75	13	8

Design and function

To guarantee quick starts and the quick take-up of load (eg in standby power units), the engine coolant is to be preheated during standstill.

This is effected with an electric heater (2 kW) supplied from an alternating mains current.

The coolant temperature can be set on the thermometer of the heater (recommended temperature range: 30°C to 40°C).

Coolant enters the heater via a check valve so that the direction of flow is unequivocally determined.

The coolant is then heated in the heater. The hot coolant with less specific weight rises, enters the engine and gives off its heat. Once cooled down, the coolant has a higher specific weight and therefore sinks downwards, and the circulation starts again (thermo-siphon effect).

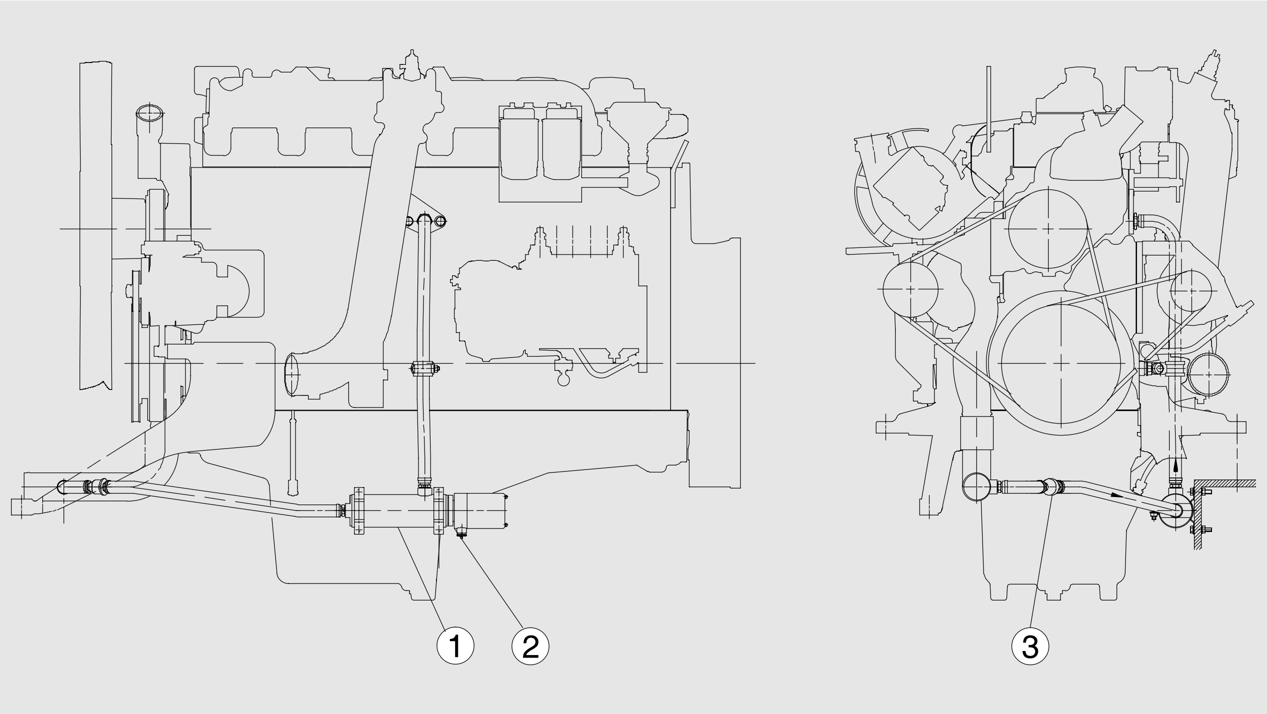
Attachment of the preheater

The coolant preheater is available as loose accessory from MAN.

The heater will be attached horizontally to the genset frame at the lowest possible height. The arrangement of all components can be learned from the drawings relevant at the respective time. These drawings can be obtained from MAN.

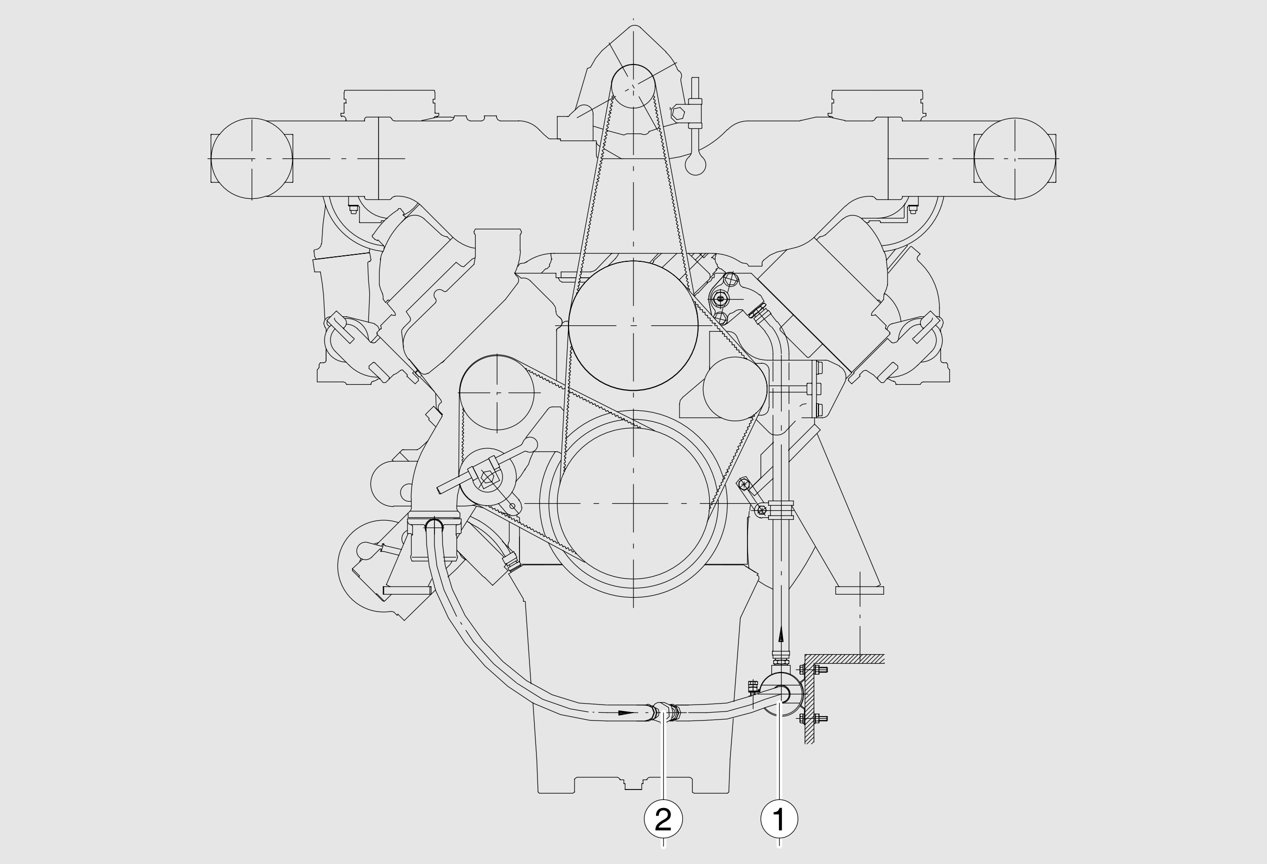
All coolant hoses are to be routed so that they will not chafe and at an adequate distance from movable and hot parts. Fit check valve in horizontal position.

Attachment of coolant preheater in D 28 in-line engines



① Heater
② Electric connection 230 V
③ Check valve

Attachment of the coolant preheater to a D 28 V-type engine



① Heater
② Check valve

Commissioning

After connecting up the coolant preheater, commission the unit as follows:

- Fill up with coolant.
- Start engine and bleed coolant circuit to guarantee proper circulation in the preheating system. Check for leaks, if necessary adding coolant.
- Set the required temperature on the thermostat of the screw-in heater and commission heater, using 230 V alternating current.
- Functional check: The heating outlet must become warm, whilst the heating inlet must remain relatively cool.

Possible causes of faults

- Heater has been mounted at too high a position.
- Heater is not attached in horizontal position.
- Check valve is not fitted in horizontal position and/or with the wrong direction of flow.
- The heating outlet connection on the heater is at the bottom instead of at the top.
- The cooling system is not adequately bled.
- The cooling system is contaminated.
- The hose line from the heater to the engine is not mounted in a continuously ascending manner.

Fuel circuit

Fuel is sucked from the tank by the supply pump and fed to the inlet chamber of the injection pump via the fuel filter.

The fuel supply pump supplies more fuel than is actually needed for combustion. The delivered surplus fuel flows back to the tank via a return line. This circuit conducts away heat and prevents the formation of bubbles in the fuel system.

Schematic diagrams of fuel systems can be found in the Operator's Manual for the engine.

Dimensions for the fuel pipe connections for the supply and return pipes are indicated in the installation drawing.

Tank capacity

The required tank capacity is determined by the engine power, the fuel consumption and the required operating period. The following equation can be used for a rough-and-ready estimate. In addition, a sufficiently large amount of reserve fuel must be taken into consideration too.

$$V = \frac{P \text{ x } b_e \text{ x } t}{830}$$

Key:

V = Tank capacity in litres
P = Engine power in kilowatt at cruising speed
t = Operating period in hours
b_e = Specific fuel consumption at full load in gram per kilowatt and hour.
A guideline value of 220 g/kWh is sufficiently precise for the estimate.

Arrangement of the tank system

The tank should be located at roughly the height of the engine. If this is impossible, the following points must be heeded:

Note:
The inspection criterion for an optimum fuel supply to the injection pump is that the vacuum upstream of the fuel delivery pump is $\leq$ 300 hPa (300 mbar).

- Tank located under the engine

  The max. suction height of the fuel supply pump is approx. 1 m for in-line injection pumps (D 28 / D 08 models) and approx. 0.5 m for engines with distributor injection pumps.

  The suction height is reduced if an additional filter is installed in the suction line or a longer pipe is required for reasons of space.

  If the maximum permissible suction height is exceeded, an additional fuel pump is required or, in stationary engines, a day tank may be installed that can be filled from the main tank by means of a separate fuel pump.

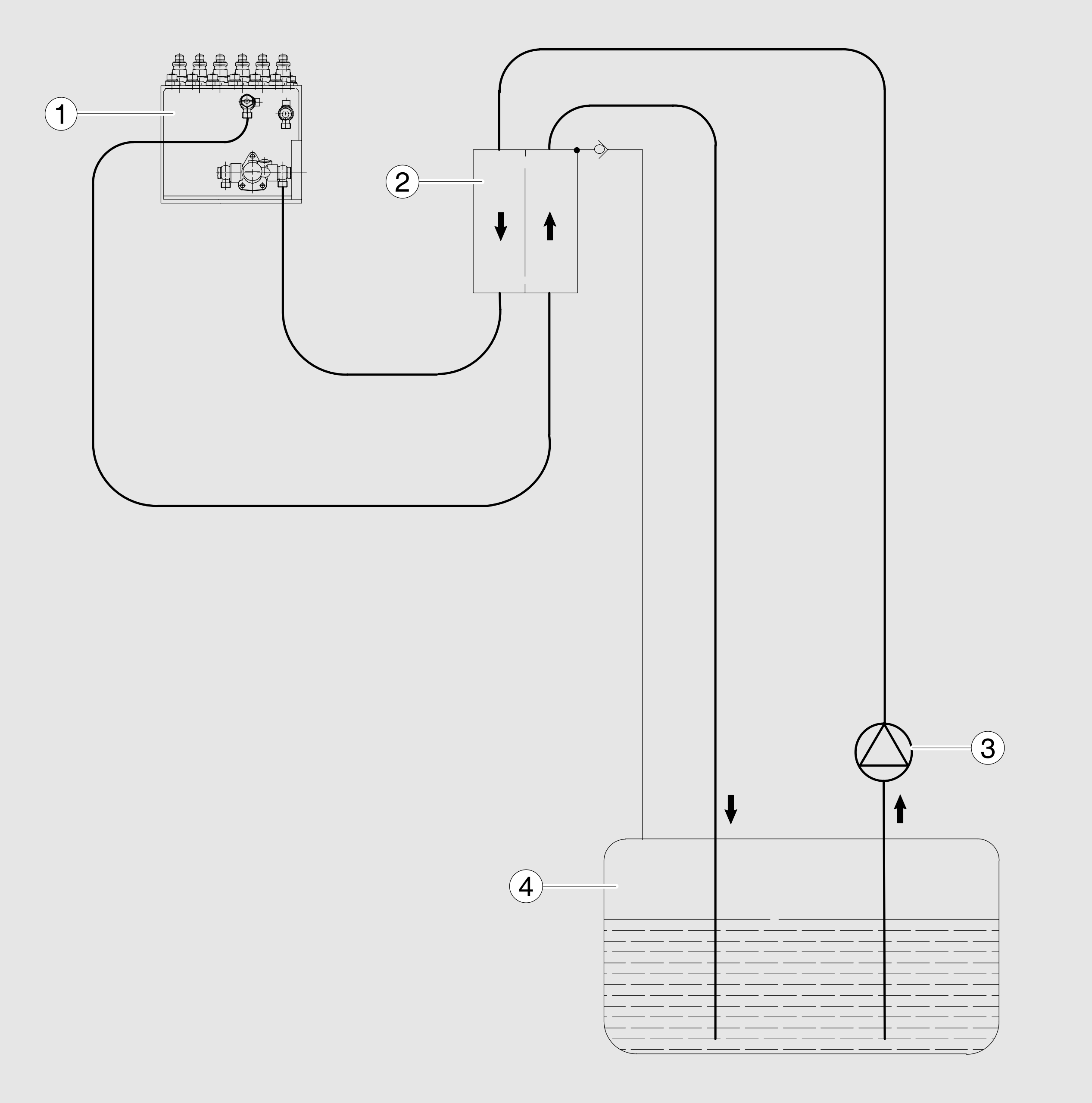
  Here it must be ensured that when the engine is switched off the static vacuum in the suction gallery/chamber of the injection pump does not exceed 100 mbar in order to prevent the system being drained. If necessary an additional fuel tank must be fitted as an intermediate storage unit at the height of the injectin pump.

  This tank must satisfy the following criteria:

  - Capacity approx. 2 litre
  - Bleeder line to tank
  - Fuel supply pipe must be screened off from return pipe to prevent intake of warm return fuel. Complete separation is, however, not permissible. Openings should be provided in the partition wall for pressure equalisation.

  See page 78 for flow diagram.

Fuel flow diagram for a special-purpose vehicle with low-lying tank located below the engine



① njection pump
② Additional tank with bleeder line to main fuel tank
③ Additional electrically driven fuel pump
④ Main fuel tank

- Tank located above the engine

  In this case a shut-off valve may be installed in the fuel supply and return lines to prevent fuel from running out during maintenance work.

> ⚠ **Danger:**
> If the engine is operated by mistake when the fuel return system is closed, a pressure increase caused by the leakage fuel up to the injection pressure of the injector nozzles (approx. 300 bar) can be expected.
> Danger for personnel, as hoses may burst. Risk of fire!

Tank manufacturing

The tank must be made of fuel and corrosion resistant material. We recommend special sheet steel as tank material. Under no circumstances must galvanised sheet metal be used. The tank must be made stable. The tank bottom must have a depression with a drainage device where dirt and condensation water can collect.

Condensation water in the fuel tank provides the basis for the growth of micro-organisms in Diesel fuel. These micro-organisms cause premature filter blockages and corrosion damage, which is why condensation water collected in the tank and in the filter must be drained regularly.

The suction line inlet to the engine should be approx. 50 mm above the tank bottom. We recommend that the fuel return line from the engine to the tank be located as far away from the suction line as possible and extend as far into the tank as the suction line.

The filling line must have an adequate cross section, lead to the tank without sharp turns and close securely.

In addition, the tank must be equipped with a bleeding line.

Having completed the tank assembly, remove all dirt, forging scales and welding beads from the tank and check it for leaks.

Fuel lines

Protect fuel against heating up.
The return line is to be routed back to the tank separately. Direct integration into the supply line leads to an increase in fuel temperature in the suction chamber of the injection pump. Since the pump supplies fuel volumetrically, output drops owing to the reduction in density.

Caution:
The maximum permissible fuel temperature upstream of the delivery pump is 50°C

At fuel temperatures > 50°C the lubricity of fuel deteriorates, which results in increasing element wear.

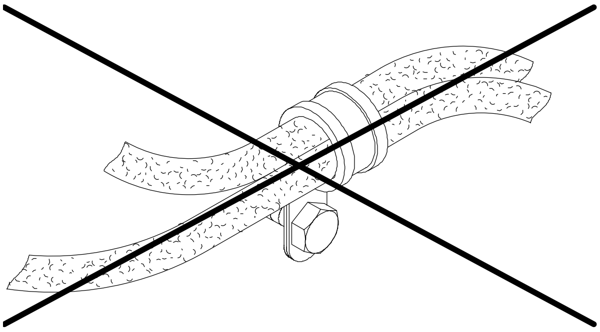
The following applies to the internal pipe diameter:

- up to 400 kW: $Ø_i = 10$ mm
- above 400 kW: $Ø_i = 12$ mm

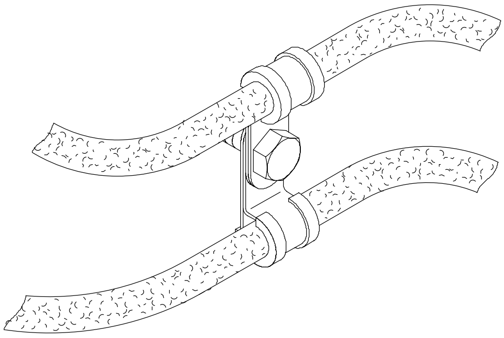
The material for the lines is to be fuel-resistant and inflammable.
Fuel lines are to be routed so that they are free of tension and kinks and do not chafe.

Danger:
Inexpertly routed fuel lines chafe and become leaky or break. Risk of fire as a result of diesel fuel which may emerge.

Fuel lines must never be clamped together with a single piece clamp.



Incorrect



Correct

Parallel fuel lines may be grouped together by cable ties, but not together with injection lines or corrugated pipes. Lines which cross each other must not be grouped together.

Do not route fuel lines over corners, edges, bolt heads etc.

Before the fuel system (tank and pipes) is commissioned, the entire system is to be flushed out with diesel fuel.

Fuel prefilter and water separator

We recommend that a prefilter (mesh width 30μ - 60μ) and a water separator be provided in the fuel supply system.

⚠ **Caution:**
Water in the fuel system causes:

- inadequate combustion
- nozzles to clog up
- damage to injection pumps
- damage to pistons
- destruction of engine

On request MAN engines can be equipped with a flame starter.

The purpose of a flame starter

The flame starter is a starting aid. It reduces the formation of blue and white smoke during the cold phase by means of post-flaming and expedites the engine's smooth running.

Design and function

A flame glow plug screwed into the intake pipe is preglowed at temperatures below 20°C, generating a flame through the combustion of diesel fuel. This flame preheats the intake air during the starting procedure.

The diesel fuel required for this is supplied under pressure into the flame glow plug by the fuel delivery pump as the engine turns over.

Fuel is supplied from the suction chamber of the injection pump, the pre-pressure (ranging from 1.0 to 1.8 bar) thereby being controlled by the overflow valve. In the flame glow plug fuel is metered and supplied into the intake pipe where it is mixed with air and ignites.

The generation of a flame is possible only if the flame glow plug is at operating temperature and the engine is turning over. Only then will a solenoid valve permit the supply of fuel to the glow plug. Post-flaming, ie maintaining the flame after the start, will shorten the warming-up phase and reduce the formation of cold smoke. The post-flaming period is controlled via a temperature transmitter (NTC transmitter) as a function of the engine temperature. All functional processes are carried out automatically via an electronic flame start relay which has diagnostic functions.

Circuit diagram

A circuit diagram, maintenance and inspection notes are supplied together with the flame starter (publication no. 51.99493-8390).

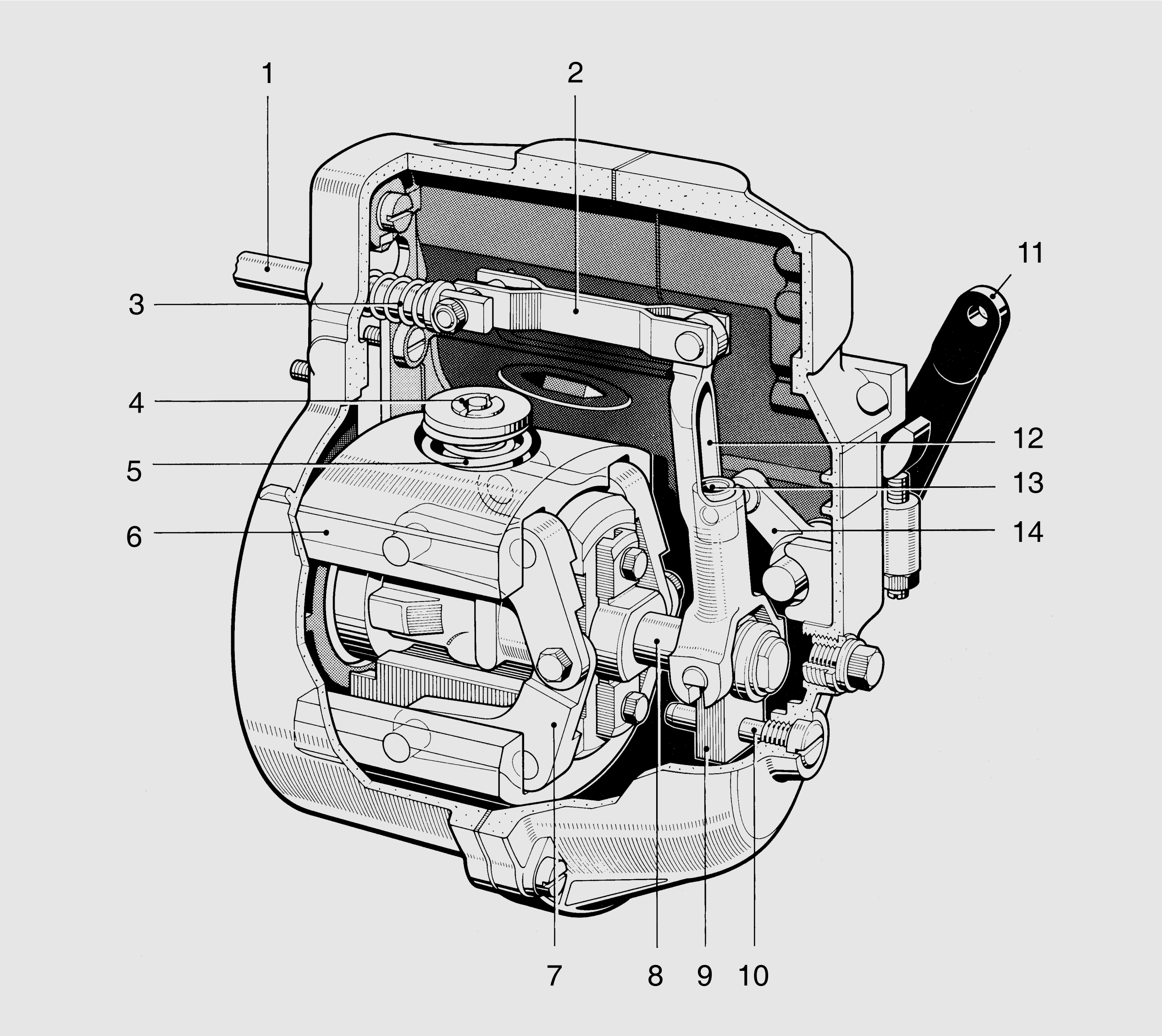
Notes

A few MAN vehicle and industrial engines may still be fitted with Bosch centrifugal governors.

Whilst rail and drive engines for special vehicles are equipped with either an RQ no-load maximum speed governor or an RQV all-speed governor, engines for gensets have an RQ maximum speed governor.

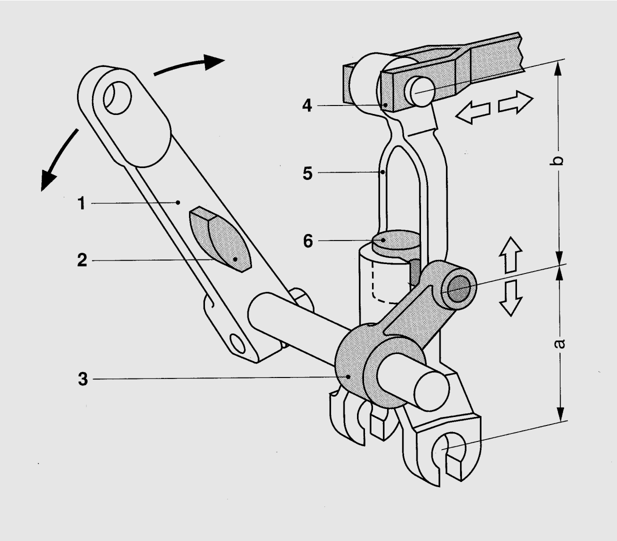
AN RQ governor is used here to explain the general design and some basic functions.

RQ no-load maximum speed governor



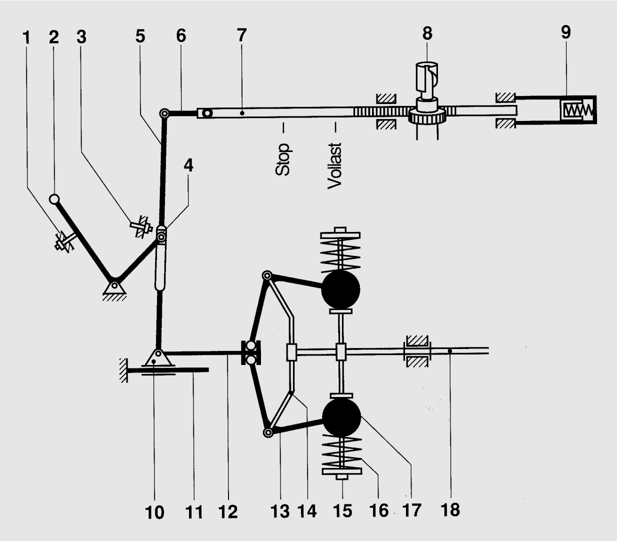
1 Control rod
2 Articulated fork
3 Compensation spring for play
4 Adjusting nut
5 Control spring
6 Centrifugal weight
7 Angle lever
8 Adjusting pin
9 Sliding element
10 Guide pin
11 Adjusting lever
12 Control lever
13 Sliding block
14 Steering lever

Design and function of the RQ no-load maximum speed governor



Changing the transmission ratio a/b at the control lever on the RQ governor

1 Adjusting lever
2 Stop dog
3 Steering lever
4 Articulated fork
5 Control lever
6 Sliding block



RQ governor in stopping position

1 Stop
2 Adjusting lever
3 Full-load stop
4 Sliding block
5 Control lever
6 Articulated fork
7 Control rod
8 Pump plunger
9 Control-rod stop (spring-type)
10 Sliding element
11 Guide pin
12 Adjusting pin
13 Angle lever
14 Governor hub
15 Setting nut
16 Control spring
17 Centrifugal weight
18 Camshaft

The schematic diagram shows the basic components and their interaction:

The governor hub is driven by the camshaft of the injection pump via a vibration damper. The two centrifugal weights with their angle levers are supported in the governor hub.

One set of springs is installed in each centrifugal weight. The radial centrifugal weight movements are converted via the angle lever into axial movements of the adjusting pin which transmits them to the sliding block.

The sliding element is rectilinearly guided by the guide pin; it establishes a connection between the centrifugal weight measuring unit and the control rod via the control lever.

The lower end of the control lever is supported in the sliding element. A guide for the sliding element is located in the control lever.

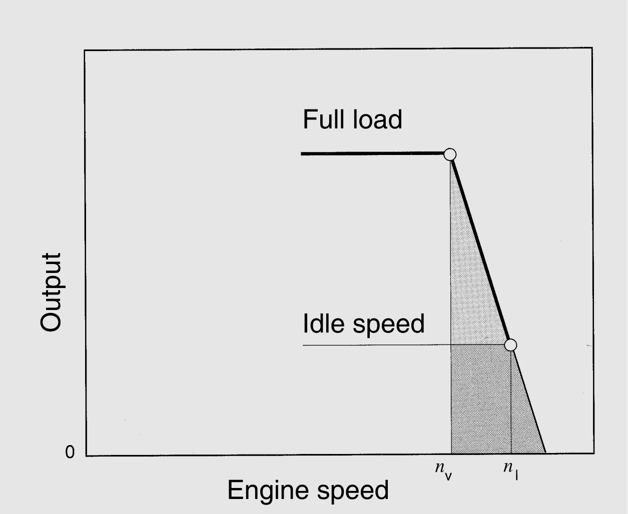
The movable sliding block is radially guided by the steering lever which is connected with the adjusting lever sitting on the same shaft. In genset engines the adjusting lever is actuated via speed precision adjustment.

On actuation of the adjusting lever the sliding block moves, and the control lever inclines about the fulcrum on the sliding block.

When the governor becomes active, the fulcrum for the control lever is on the sliding block. Owing to the sliding block the transmission ratio of the control lever changes.

As a result, a sufficiently large setting force for the control rod will be created even in the idle-speed range, in which the centrifugal forces are small.

The P degree



$$\delta = \frac{n_l - n_v}{n_v} \times 100$$

δ in %	P degree
n_l in rpm	Upper idle speed (engine not under load)
n_v in rpm	Full-load speedδ

If load is taken off the engine and the adjusting lever position does not change, the speed will increase by a factor given by the governor characteristics.

The speed increases in proportion to the load change, ie it increases as the load increases. For this reason the terms *proportional* or *P degree* and *governors with P behaviour* are used.

The governor’s P degree is usually referred to the upper full-load speed (equivalent to rated speed).

Example: Full-load speed (rated speed) = 1,500 rpm; idle speed = 1,575 rpm;

$$\delta = \frac{1{,}575 - 1{,}500}{1{,}500} \times 100$$

$$\delta = 5\ \%$$

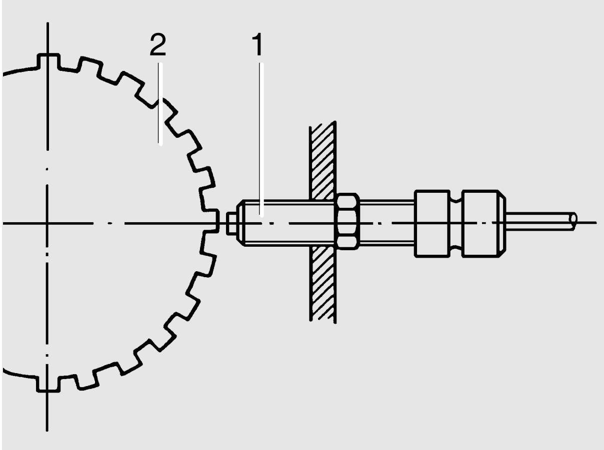
Higher requirements on the quality of control processes (eg P degree = 0) can be satisfied only with electronic speed control systems.

An electronic control system consists of three components:

1. Speed pickup

   In MAN engines the speed pickup, which works according to the induction principle, is located on the flywheel housing. It consists of a permanent magnet surrounded by a coil.

   Depending on whether a tooth of the starter gear ring (2) is before the magnet or not, the magnetic field changes and induces in the coil an alternating voltage which is proportional to the engine speed and serves as input signal for the control unit.



2. Electronic control unit

   The electronic control unit receives the signal (actual value) generated by the pickup and compares it with a preset value (nominal value).

   If the actual and the nominal values are identical, the electronic control unit will generate an output signal with which the final control element will be triggered.

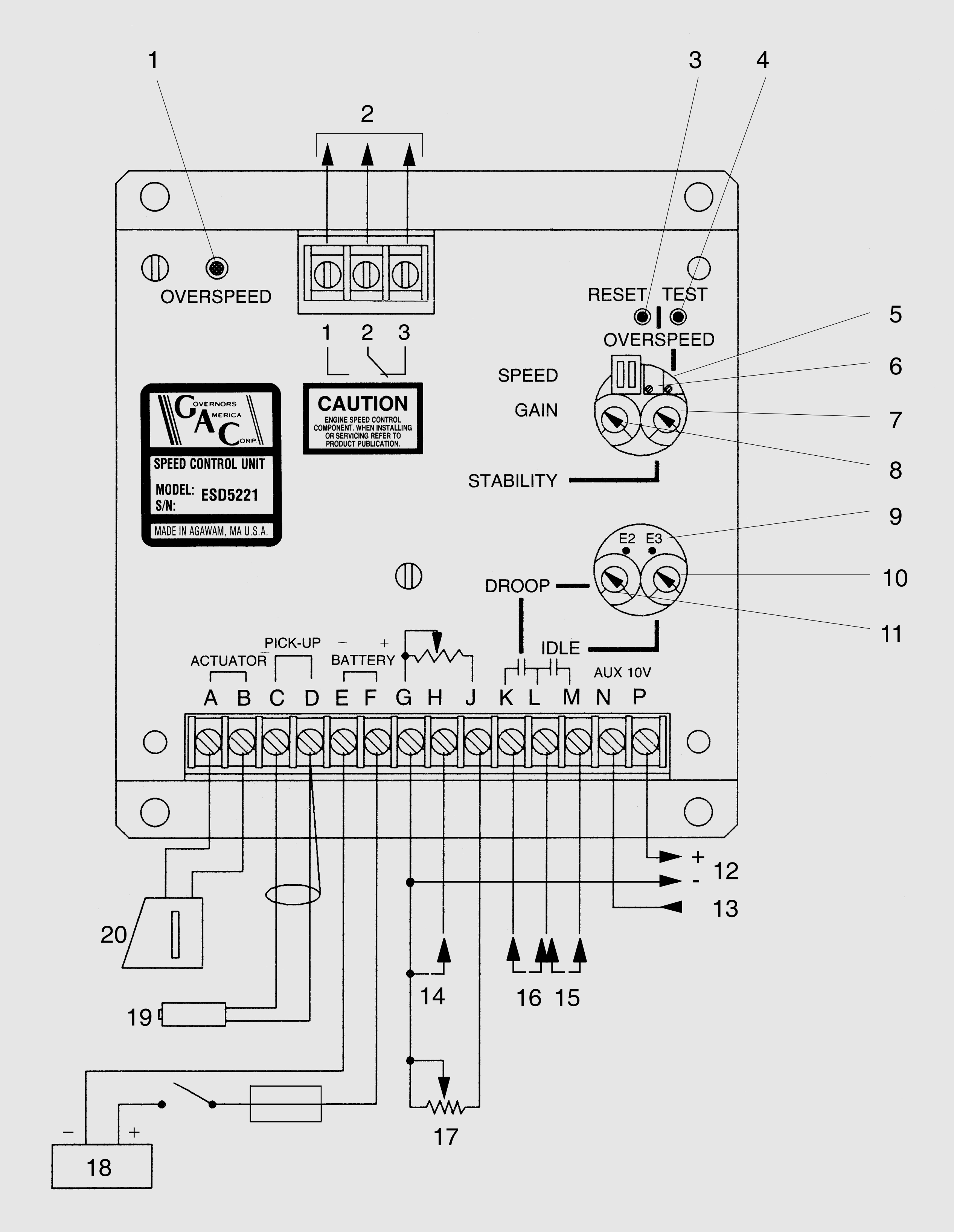
3. Final control element

   In GAC governors, for example, the final control element is a spring-loaded linear solenoid.

   This solenoid is connected to the control rod of the injection pump and changes its position according to the signal from the control unit. As a result, the injection quantity and, consequently, engine speed are controlled.

GAC electronic speed governor

The GAC ESD 5221 electronic speed governor is used as an example here to give a general overview of the possibilities provided by this control system and to show what characteristic data can be set or altered.
When installing and commissioning, please **heed without fail the Operator's Manual for the respective control unit model**.



1 LED display for electronic overspeed control

2 Output contacts ”Overspeed” LED display for overspeed

3 Overspeed reset button: initial position of the relay contacts after overspeed signal has been sent. Resetting can also be effected by briefly interrupting the battery power supply.

4 Overspeed test button, lowers the switching point by approx. 12 %

5 25-step potentiometer: setting of overspeed. Let engine idle, press test button and simultaneously turn it left until engine stops and the display comes on.

6 25-step potentiometer: setting of rated speed.

7 Setting of stability

8 Setting of sensitivity.

9 Additional assistance for stability improvement. In the event of very slow pendulum motion, set 10 + 20 mF condensator from E3 to E2.

10 This makes it possible to set the lower idling speed limit if ”L” and ”M” are connected.

11 Setting the P degree if ”L” and ”K” are connected.

12 Stabilised voltage 10 V for triggering additional modules

13 Input for signals from synchroniser, load divider, smoke limiter etc.

14 Connect ”G” and ”H” only if a high P degree (10 %) is required.

15 Operation at low idling speed if L and M are connected.

16 P degree if ”K” and ”L” are connected.

17 Speed precision setting (only required for remote control)

18 Battery

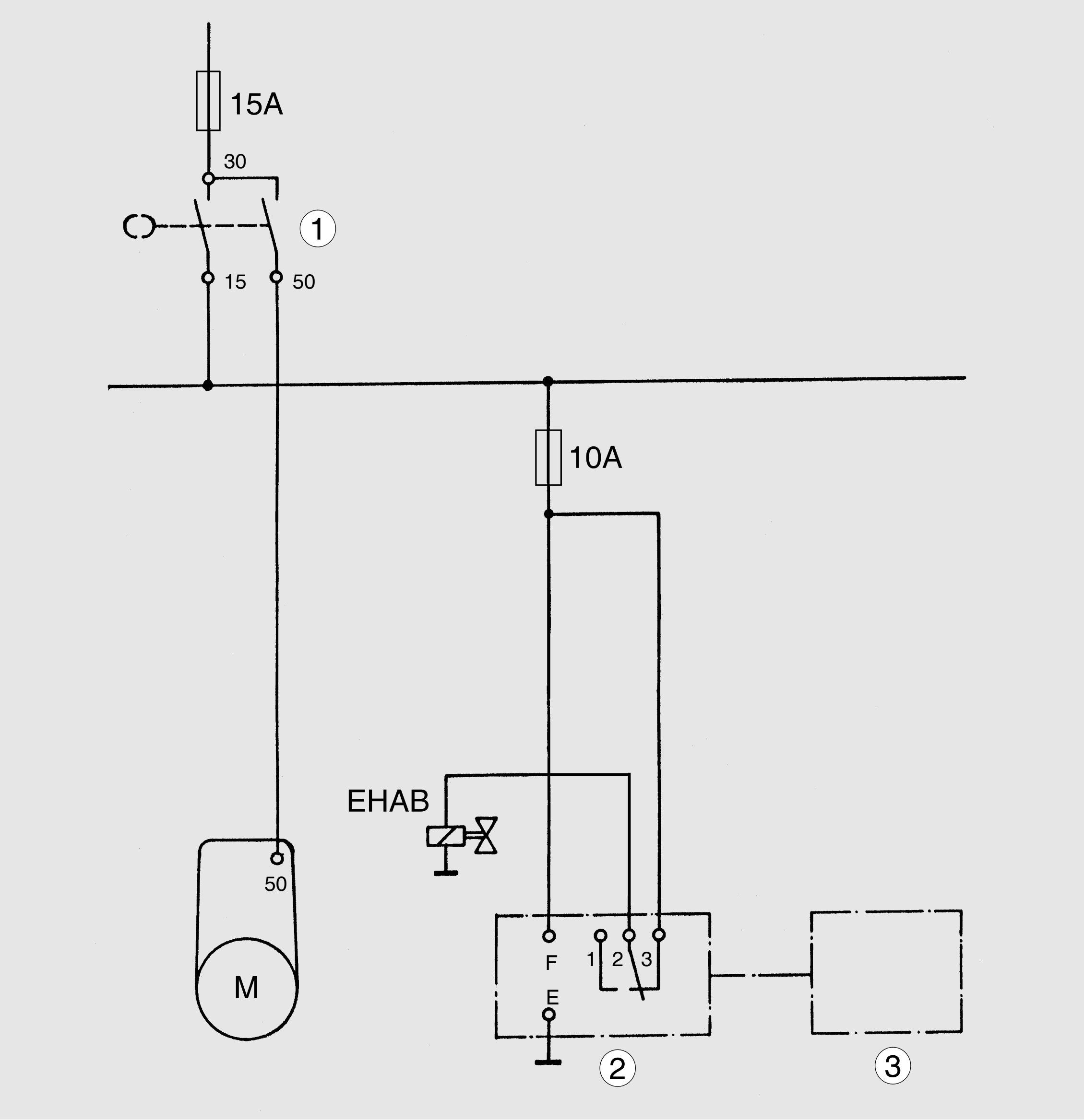
19 Pulse generator

20 Final control element

Overspeed protection

If an electronic speed governor is used, an overspeed protection independent of the governor must be provided. For this purpose an electromagnetic shut-off valve (EHAB) is installed in the fuel supply line to the injection pump. If the governor fails, this valve will shut off the fuel supply, thus preventing the engine from revving up in an uncontrolled manner. The triggering of the shut-off valve is to be installed by the genset manufacturer.

Proposal for the circuitry of an electromagnetic shut-off valve



① Starter lock
② GAC control unit
③ GAC-actuator

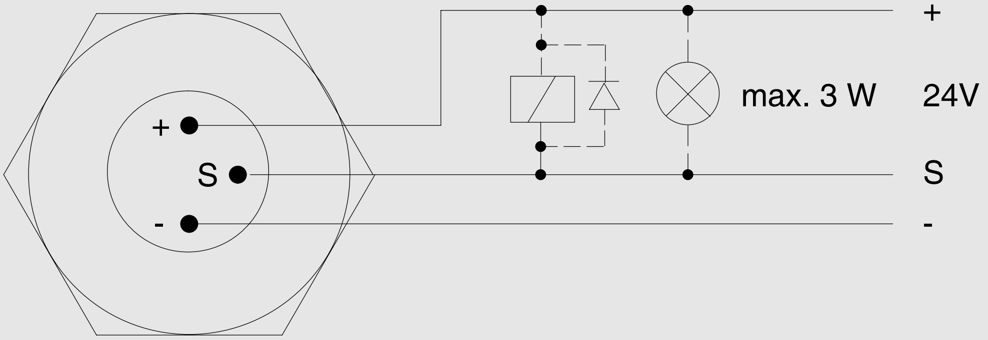
Note:
When bleeding the fuel system switch on the electromagnetic shut-off valve (EHAB) without fail, as otherwise fuel cannot reach the injection pump suction gallery / suction chamber.

Engine control

Monitoring the coolant level

Fluid-monitoring probes may be used for monitoring the coolant level in the coolant expansion tank. The probe available from MAN is a capacitive device. The sensor and the electronic evaluation system form one unit.

If the coolant drops below the level to be monitored, a negative potential will be sent to the signal output ”S”. This can then be used to trigger a signal lamp or a relay. Output ”S” must not be charged with more than 3 watt.



This output ”S” must not be directly connected to the plus terminal as this would destroy the output transistor.

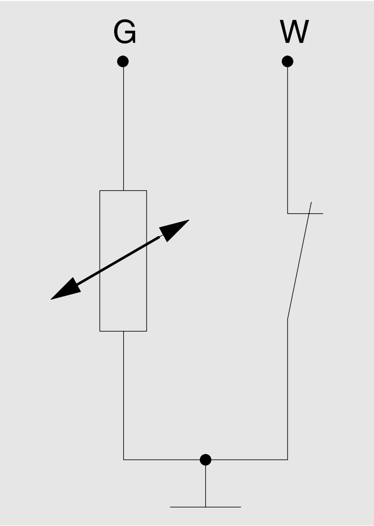
To avoid incorrect messages, the signal will be triggered with a delay of 7 seconds.

Transmitters

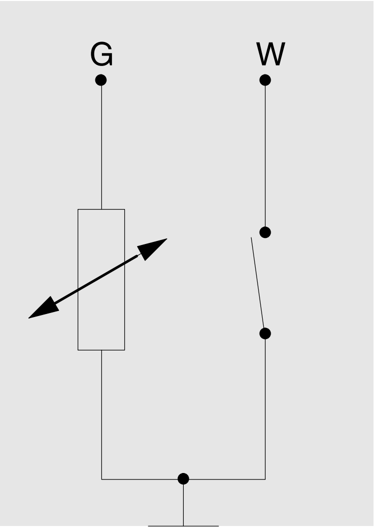
Transmitters record actual conditions of electric display units, eg pressure or temperature values.

The standard extent of delivery contains coolant temperature and lube oil pressure transmitters with switching contact designed as NO contacts with earth connection (for circuit-closing connection). Other versions available on request. The transmitters are suitable for connecting up VDO measuring instruments.

Pressure transmitter



Temperature transmitter



Monitors

The monitoring system can be operated in normally closed or normally open connection mode. The connection arrangement is decisive for the type of monitor.

Normally closed connection means that an alarm will be triggered if no current is flowing, ie the contact will be opened in the event of a fault.

Normally open connection means that an alarm will be triggered if current is flowing, ie the contact will be closed in the event of a fault.

The monitors transmit signals, eg to an engine control unit which then triggers an optical or acoustic message.

The monitoring device can also actuate the shut-off solenoid. A time relay limits the on-time of the shut-off solenoid to approx. 10 to 15 seconds, so that the shut-off solenoid will drop out again once the engine has been switched off.

Shut-off solenoid

Shut-off solenoids are available both for energised to run and energised to stop.

General information

The following instructions are designed to aid the customer in installing and classifying MAN auxiliary marine diesel engines.

During engine installation and operation the valid guidelines and regulations of the classification societies must be observed.

Radiator

Auxiliary marine diesel engines with radiator cooling are equipped with an uncooled exhaust manifold. The engine is cooled by an attached fan radiator. This is available from MAN completely assembled or can be installed by the customer himself. If the customer carries out the installation himself, the guidelines in the installation instruction for MAN industrial diesel engines (chapter on ”Cooling system”) must be heeded without fail. Furthermore, in the event of a classified engine, an auxiliary radiator is to be supplied together with a 3.1c certificate.

Hoses for coolant

Please note that only the temperature and pressure-resistant hose pieces contained in the MAN extent of delivery must be used for the intercooling and fan radiator systems in order to comply with the regulations of both the classification societies and the professional associations.

The hose material must be designed to the MAN 3055 standard to withstand prolonged operation at a minimum temperature of 200°C. To fasten the unit, disc spring clamps to the MAN M 3292 standard (see Figs. 1 and 2) must be used to prevent the hose from slipping during operation. The clamps must be tightened first to 5 Nm and then, after approx. five minutes, to a further 5 Nm.

Bleeding the cooling system

The opening pressure for bleeding the coolant in the expansion tank must be adapted to the operating pressure of the cooling circuit.

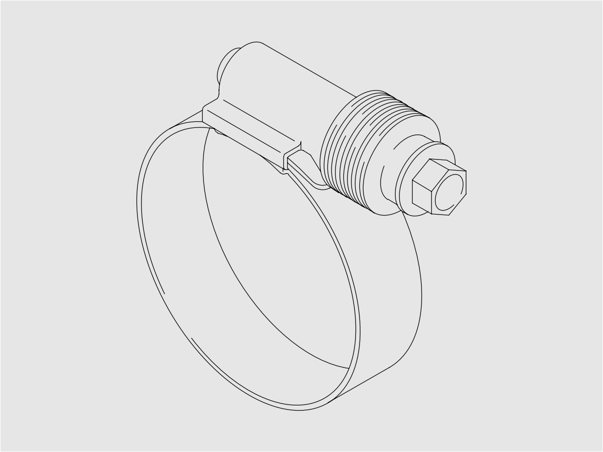


Fig. 1
Disc spring clamps

Fig. 2
Hose connection

Exhaust system

Heat insulation and anti-contact protection

For classification of the engine, the uncooled exhaust manifold and the turbocharger must be insulated with approved non-flammable material (eg heat mats from Fibretech or similar material). The surface temperature must not exceed 220°C (see Fig. 3). It must be ensured that no service products can get under the insulation.

In addition, an anti-contact protection device in the form of a perforated metal sheet (max. surface temp. 80°C) to the accident prevention regulations is to be fitted round the insulation (see Fig. 4). The hot charge-air pipe to the radiator too is to be provided with a perforated metal sheet for protection against contact (see Fig. 4). The sheets are not to be fastened to the turbocharger housing, as thermal stresses may occur.

Exhaust-pipe expansion joints

The exhaust pipe must be attached and supported in such a way that no force acts on the turbocharger. Between engine and exhaust system one or several intermediate pieces (expansion joints) are to be installed. The installation work is to be carried out according to the manufacturer's regulations.

This prevents engine vibrations from being transferred to the exhaust system and offsets the longitudinal expansion of the exhaust pipes, which occurs as a result of the high temperatures. The exhaust pipes ought to be made preferably of acid-resisting steel.

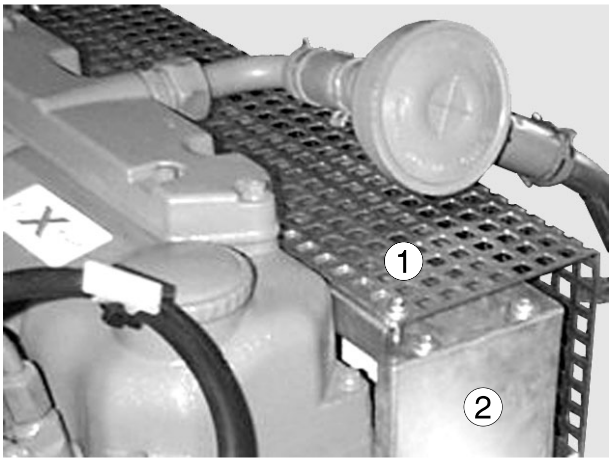


Fig. 3
Anti-contact protection device on exhaust manifold
① Anti-contact protection
② Non-flammable material

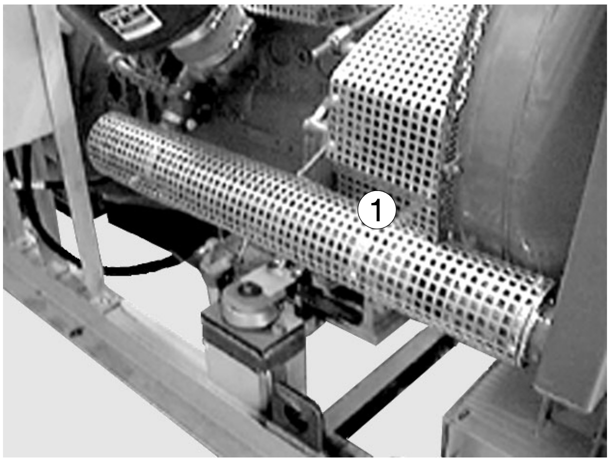


Fig. 4
Anti-contact protection device on charge-air pipe
① Anti-contact protection

Conponents fitted to the engine

V-belt protection

All rotating parts, especially the fan drive, are to be protected on all sides against contact. Unintentional intervention must not be possible (see Fig. 5).

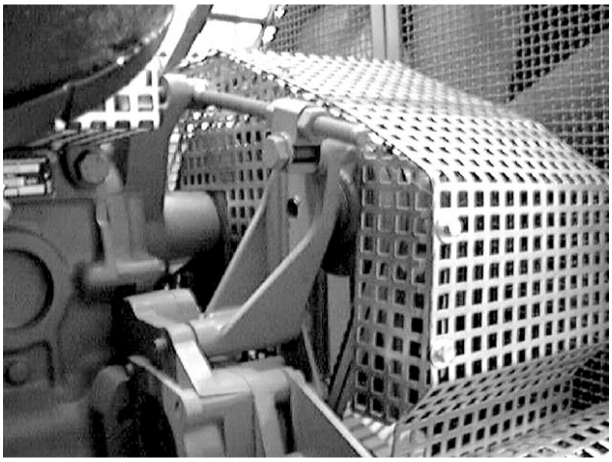


Fig. 5

Engine monitoring

To prevent abnormal operating conditions at the combustion engine from causing consequential damage or complete failure, an electric engine monitoring device for early fault recognition must be fitted. In the event of an alarm, this device either automatically switches off the engine or reduces its output, depending on the model used. The sensors necessary for this must be approved by the classification societies.

At least the following parameters should be monitored:

- Overspeed
- Cooling-water temperature
- Lube-oil pressure
- Leaks in the double-wall injection lines

Lube-oil and fuel filters

To enable changing the fuel and lube-oil filters during engine operation, filters with changeover device are to be fitted.

For design-related reasons the lube-oil filter on the D 0824LE 201 engine can be fitted only in a remote position. An installation package is available from MAN.

For engines that are to be classified there is an MAN installation package, no. 51.05500-6074, that has been cleared by the classification societies. If non-approved filters are used the engine’s warranty will become null and void.

Tightening torque for attaching the radiator to the engine

The fan radiator is to be directly attached to the crankcase with the aid of sectional carriers fitted to the lateral engine support brackets. Owing to the weight force and the dynamic influences during operation, a moment is transmitted via the carrier into the crankcase. To ensure that the moment is fully transmitted by the mounting bolts (4x M12x80-10.9), frictional engagement is indispensable.

The tightening torque specified is 75 Nm.

Contents:

- Antifreeze, anti-corrosion and anti-cavitation protection for cooling systems
- Requirements for coolant hoses
- Directives for battery sizes
- Regulating conditions for power-generating units
- Conversion of physical units

1. General recommendations

Reliability of the cooling system can be guaranteed only if the system works under pre-pressure. For this reason it is imperative that it be kept clean and tight, the heat exchanger closing and working valves function correctly and the required coolant level be maintained.

To prevent corrosion, cavitation and to protect against cold in cooling and heating systems, mix cooling water with antifreeze agent approved as per MAN Works Standard 324.

Tested and cleared antifreeze agents guarantee adequate anti-cold, anti-corrosion and anti-cavitation protection, they neither attack the seals and hoses used by us nor foam. Approved antifreeze agents are listed in the brochure ”Fuels, Lubricants, Coolants for Industrial and Marine Diesel Engines”.

2. Coolant

Correctly prepared coolant is of particular importance for troublefree engine operation. Coolants that are unsuitable or inadequately or wrongly prepared may cause failure of coolant circuit units and components as a result of cavitation and/or corrosion damage.

In addition, heat-insulating deposits may form at heat transferring components such as cylinder liners, cylinder heads, oil coolers and banks of sea water heat exchanger pipes which lead to overheating and, eventually, to engine failure.

As a matter of principle, the coolant must consist of water and an antifreeze agent throughout the year to guarantee reliable operation of MAN engines. In exceptional cases the use of anti-corrosion agents (chemicals) as per MAN Works Standard 248 (see 2.3) is possible.
The use of soluble anti-corrosion oils is not permissible!

Regulations regarding coolant components:

2.1 Water

Potable tap water with the following analysis values is suitable:

Aspect: colourless, clear, free of mechanical impurities

Hardness: max. 20° German total hardness
= 35,6° French hardness
= 25° British hardness
= 358 ppm USA-hardness

Chlorides: max. 100 ppm

Sulphates: max. 150 ppm

pH-values at 20°C: 6,5 to 8,5

Water analyses have to be obtained from the appropriate local authorities.

Where such mains water is not available, the water available must be mixed with condensate or fully desalinated water until the aforementioned analyis values are attained.

Fully desalinated water, distillate and condensate are suitable too.

Sea water, brackish water and waste water are not suitable.

2.2 Antifreeze and anti-corrosion agents as per MAN 324

Only those antifreeze agents are allowed to be used which are approved under the MAN 324 Works Standard. A minimum concentration of 40% by volume must always be kept as no adequate anti-corrosion protection can be guaranteed under 40% by volume.

The cooling system is designed in such a way that a coolant filling with max. 40% anti-corrosion agent by volume (anti-cold protection down to -27°C) can be left in the system even in summer in Central Europe as long as the system is operational.

At the beginning of the cold season the antifreeze content of the coolant must be raised according to the outdoor temperatures to be expected (see table in ”Fuels, Lubricants.. .”). An antifreeze content of over 50% by volume must be avoided and is technically useless.

3 Maintenance, repair

Any coolant loss must be replenished with a mixture of antifreeze and water with the same concentration required for summer and/or winter operation.

Every other year coolant must be replaced. It is essential that during this period of time the antifreeze concentration does not sink below 40% by volume.

Apart from the coolant the working valves and filler caps must also be replaced every other year.

4 Disposal

Waste (drained) coolant must be collected separately from other waste fluids and be disposed of as special waste.

Requirements for coolant lines

Excerpt from the MAN Works Standards

Basis for this summary

This summary is based on the MAN Works Standards nos. 334, 305, 307, 303 and 358. These standards can be obtained from MAN.

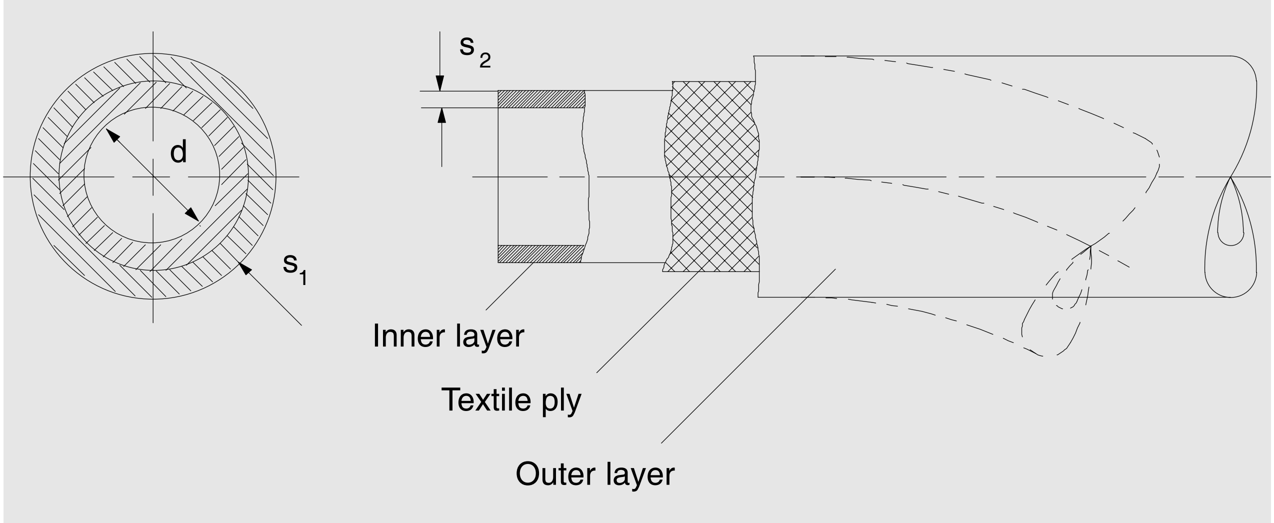
Applicability

These requirements apply to hoses with textile ply for coolant under operating conditions which are usual in motor vehicles.

In the event of deviations from the usual operating conditions, further requirements may have to be taken into account. In addition, respective regulations from supervisory authorities are to be heeded.

The stipulations of this standard apply analogously to machined parts too.

Designation



Dimensions and permissible deviations

Nominal diameter d			Wall thickness s_1		
Nominal dimension mm	Perm. deviation mm		Nominal dimension mm		Perm. deviation mm
All models*	Type 2, 4*	Type 3*	Type 2, 4*	Type 3*	All types*
8	0 - 0.5	+0.4 - -1.2	3.75	5	±0.6
10	0 - 0.5	+0.4 - -1.2	4	5	±0.6
12	0 - 0.5	+0.4 - -1.2	4	5	±0.6
15	0 - 0.6	+0.4 - -1.2	4	5	±0.6
16	0 - 0.6	+0.4 - -1.2	4	5	±0.6
18	0 - 0.6	±0.6	5	5	±0.6
20	-0.1 - -0.7	±0.6	5	5	±0.6
22	-0.1 - -0.7	±0.6	5	5	±0.6
25	-0.1 - -0.7	±0.6	5	5	±0.6
28	-0.1 - -0.9	±0.6	5	5	±0.6
30	-0.1 - -0.9	±0.6	5	5	±0.6
32	-0.1 - -0.9	±0.6	5	5	±0.6
35	-0.2 - -1.0	±0.6	5	5	±0.6
38	-0.2 - -1.1	±0.6	5	5	±0.6
40	-0.2 - -1.1	±0.6	5	5	±0.6
42	-0.2 - -1.2	±0.6	5	5	±0.6
45	-0.3 - -1.3	±0.6	5	5	±0.6
50	-0.3 - -1.3	±0.6	5	5	±0.6
55	-0.3 - -1.4	±0.6	5	5	±0.6
60	-0.3 - -1.4	±0.6	5	5	±0.6
65	-0.3 - -1.4	±0.6	5	5	±0.6
70	-0.4 - -1.6	±0.6	5	5	±0.6
75	-0.4 - -1.6	±0.6	5	5	±0.6
80	-0.4 - -1.6	±0.6	5	5	±0.6

Thickness of inner layer $s_2 = \frac{s_1}{2}$

* The type of hose is defined by the materials selected. See page 105

Bending radius and test pressure

Nominal dimension mm	Smallest perm. bending radius mm	Test pressure bar
8	70	6
10	80	6
12	90	6
15	135	6
16	140	6
18	165	6
20	195	6
22	200	6
25	240	6
28	280	6
30	360	6
32	380	6
35	420	6
38	460	6
40	480	4
42	500	4
45	550	4
50	650	4
55	750	4
60	850	4
65	900	4
70	950	4
75	1050	4
80	1150	4

Requirements concerning material properties

Type of hose (material)	Inner layer	Outer layer	Textile ply	Perm. operating temperature
2	MAN-Standard 305 EPDM 5	MAN-Standard 305 EPDM 5	Textile ply wound in multiple layers (aramide or polyester)	-40°C to +120°C
3	MAN-Standard 307 MVQ 3	MAN-Standard 307 MVQ 3	Textile ply wound in multiple layers (aramide or polyester)	-55°C to +125°C
4	MAN-Standard 305 EPDM 5	MAN-Standard 303 ECO 2 or MAN-Norm 358 CM / CSM 1	Textile ply wound in multiple layers (aramide or polyester)	-40°C to +125°C

Explanation:

EPDM 5	Elastomer on ethylene-propylene-terpolymer base of category 5 as per MAN Standard 305.
MVQ 3	Elastomer on MVQ base (silicone caoutchouc) of category 3 as per MAN Standard 307.
ECO 2	Elastomer on ECO base (epichlorhydrine) of category 2 as per MAN Standard 303.
CM / CSM 1	Elastomers on CM base (chlorinated polyethylene) or base (chlorosulfonated polyethylene) as per MAN Standard 358.

All synthetic materials are resistant to atmospheric conditions such as solar irradiation and to contact with water/antifreeze and anti-corrosion agents.

Notes

Allocation guideline values: starter system, battery value and starter cable

Engine models	**D 02 / D 08**			**D 28 in-line engines**			**D 28- V-type engines**			
Starter model	IF			KB			KB			
Rated voltage (V)	24			24			24			
Rated power (kW)	4			5,4			6,5			
Permissible battery capacity [1)](Ah)	66	88	110	110	143	170	143	170	200	210
Starter short ciruit current (A) at + 20° C with supply line 1mΩ / m	940	1 050	1 100	1 570	1 750	1 800	1 760	1 810	1 830	1 910
Required starter cable cross section (mm^2) (Copper)	Recommended starter cable length (m) (applies to supply and return line, voltage drop: max. 4% in each individual case related to 0,5 x starter short circuit)									
35	4,0	3,6	3,4	--	--	--	--	--	--	--
50	5,7	5,0	4,8	3,4	--	--	--	--	--	--
70	7,9	7,1	6,8	4,8	4,3	4,1	4,2	4,1	4,0	3,9
95	10,8	9,6	9,2	6,5	5,8	5,6	5,8	5,6	5,5	5,3
120	13,6	12,2	11,6	8,2	7,3	7,1	7,3	7,0	7,0	6,7
140 (2 x 70)	15,9	14,2	13,6	9,5	8,5	8,3	8,5	8,2	8,2	7,8
Control line (between starter switch and starter terminal 50										
(mm^2)	Max. permissible line lengths (m)									
2,5	9,8			20						
4,0	15,7			31						
6,0	23,6			47						

---

[1] Batteries as per DIN 72 311. The maximum battery capacity for each and every starter must not be exceeded to avoid damage to starter and gear ring

Control conditions for genset diesel engine and gensets

	DIN 6280				ISO 8528				ISO 3046		
Category	1	2	3	4 1)	G1	G2	G3	G4 1)	A2	A1	A0 1)
Speed adjustment range 2) ± %	2.5	2.5	2.5		2.5	2.5	2.5		2.5	2.5	
P-degree %	8	5	3		8	5	3		8	5	
Variation range %	-	1.5	0.5		2.5	1.5	0.5		1	0.8	
Dynamic speed deviation 3) ± %	15	10	7		18	12	10		15	10	
Settling time s	-	5	3		10	5	3		15	8	

1) By arrangement

2) Upward adjustment range is relative to idle speed (ie nominal speed + P-degree + 2,5%)

3) The dynamic speed deviation applies to load release from full load and to load application as per the diagram on page 13

Conversion of physical units frequently used in this publication

1. Temperature

t (degree Celsius) = T (Kelvin) - 273

T (Kelvin) = t (degree Celsius) + 273

t (degree Fahrenheit) = 1.8 x t (degree Celsius) + 32

2. Pressure

1 kilopascal (kPa) = 10 Millibar (mbar)

1 hektopascal (hPa) = 1 Millibar (mbar)

3. Energy flow

Megajoule/hour (MJ/h) x $\frac{1000}{4.187}$ = Kilocalories/hour (kcal/h)

Megajoule/hour (MJ/h) x $\frac{1}{3.6}$ = Kilowatt (kW)

Declaration

In accordance with Article 4, Paragraph 2, in conjunction with Appendix II, Section B, of Directive 89/392/EEC, Version 93/44/EEC

MAN Nutzfahrzeuge Aktiengesellschaft,

hereby declares that the engine described below is destined for installation in a machine as defined in the EC directive on machines.

Engine model:

Design:

For data see original declaration
Enclosed with delivery note

Engine number:

Rating / speed:

Note:

The manufacturer of the complete ready-to-use machine in which this engine is to be installed must take the further action necessary in the context of indirect safety related engineering and provision of instructions to ensure that the ready-to-use machine complies with the requirements of the EC directive on machines.

The engine must not be put into operation until the complete machine satisfies the conditions laid down in the EC directive on machines 89/392/EEC, most recently amended by 93/44/EEC, or the latest amendment of said directive.

MAN Nutzfahrzeuge Aktiengesellschaft

Vogelweiherstraße 33

D-90441 Nürnberg

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