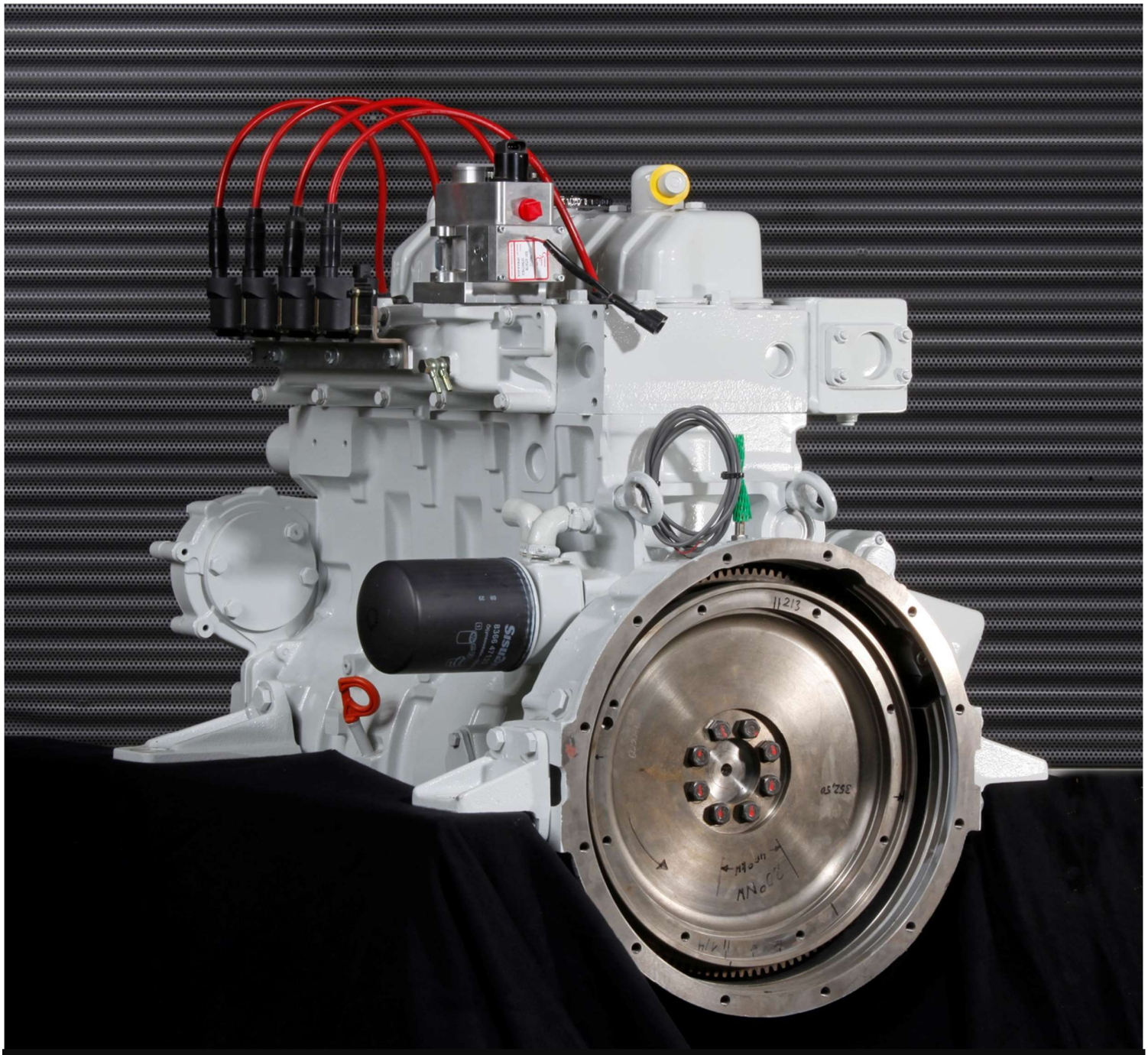
MAMOTEC
ENERGY SOLUTIONS



Installation Guideline

for stationary industrial gas engines of the series MAG/MAH 24.4-84.6

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Content

1 Preface

The aim of this installation guideline is to support you in the installation of the gas engine in your system and to give you assistance.
Please follow the information in this manual to avoid accidents and to maintain the manufacturer's warranty and the functionality of the gas engine.
Nonobservance of this installation guideline can lead to personal injury, as well as malfunctions and engine damage, for which the manufacturer assumes no liability.
The relevant accident prevention regulations as well as other generally recognized safety and occupational health rules must be observed.

1.1 Area of application

These installation instructions are valid for the installation of stationary industrial gas engines of MAMotec GmbH of the series MAG/MAH 24.4 to MAG 84.6. They are not valid for mobile applications, e.g. vehicle engines. This installation guideline is not type-bound. All previous installation guidelines for MAMotec industrial gas engines are hereby replaced.

1.2 General rules

When installing and operating MAMotec industrial gas motors, the valid laws, regulations and rules of the respective location and field of application must be observed.

Dangers due to non-compliance with standards and legal regulations

WARNING

Therefore:

- In addition to the safety instructions given in these installation instructions, the standard DIN EN 60204-1 "Electrical equipment of machines" must be observed.

1.3 Liability for material defects

Warranty claims against MAMotec GmbH exist only if this installation guideline has been observed.

The motors have been built exclusively for the intended use specified in the scope of delivery (intended use). Any other use is considered improper. MAMOTEC GMBH is not liable for any damage resulting from this. The risk for this is borne solely by the user.

Proper use also includes compliance with the operating, maintenance and repair conditions specified by the manufacturer. The motor may only be used, maintained and repaired by persons who are familiar with it and have been informed about the dangers.

MAMotec GmbH accomplishes installation acceptances when desired against payment. Acceptances of prototypes are only valid for series installations if no subsequent changes are made.

The installation of the motor must correspond to the intended use. Only parts approved by the manufacturer for the respective intended use may be used for conversion work.

Unauthorized modifications to the motor exclude the manufacturer's liability for any resulting damage.

If it is intended to change an engine installation accepted by MAMotec GmbH, MAMotec GmbH must be informed in writing, if necessary a new acceptance is needed.

The liability for material defects against MAMotec GmbH concerns the scope of delivery defined in the order confirmation.

2 General safety instructions

This chapter informs about residual risks and dangers when the gas engine is used as intended.

It lists generally valid and essential safety instructions, which provide for an optimal protection of the personnel as well as for the safe and trouble-free operation of the engine.

Specific, action-related or situation-related safety instructions are described below before the corresponding action step or in the described chapter.

Nonobservance of the handling instructions and safety instructions listed in this installation guideline can result in considerable dangers.

2.1 Intended use

The motor is built as a stationary drive of facilities and for coupling heat exchangers within the limits of the technical data. Any use beyond this is considered as not in accordance with the intended purpose. MAMotec GmbH is not liable for any damage resulting from this. The operator bears the risk exclusively.

Proper use also includes compliance with the prescribed operating, maintenance and repair work. The motor may only be used, maintained and repaired by persons who are familiar with it and have been informed about the dangers.

Unauthorized modifications to the motor exclude any liability for resulting damage to property and personal injury.
Manipulations to the control system can also influence the performance and exhaust gas behavior of the engine. Compliance with the statutory environmental protection requirements is therefore no longer guaranteed.

⚠ DANGER

Danger due to improper use

Any use of the motor beyond the intended use and/or any other use of the motor can lead to dangerous situations and the operating license expires.

Therefore:

- Only use the motor for its intended purpose.
- Only use the motor outside hazardous areas.
- Only use the motor with overspeed protection.

2.2 Content of the installation instructions

Every person charged with installing the motor must have read and understood the installation guidelines before starting work. This also applies if the person concerned has already been involved in the installation of a similar motor or has been trained by MAMotec GmbH.

Knowledge of these instructions is therefore binding.

2.3 Changes and conversions to the engine

To avoid dangers and to ensure the optimal performance, neither changes nor attachments and conversions may be made to the engine, which have not been expressly approved by MAMotec GmbH.

If modifications are made without the written consent of the engine manufacturer, any warranty or guarantee obligation for damages and defects resulting from the unauthorized modification expires. Furthermore, the manufacturer does not assume any liability for damages caused by the unauthorized modification.

2.4 Responsibility of the operator

The operator of the engine is subject to the legal obligations for occupational safety.

In addition to the occupational safety instructions in these installation instructions, the safety, accident prevention and environmental protection regulations valid for the area of application of the engine must be observed.

The following applies in particular:

- The operator must inform himself about the applicable occupational health and safety regulations and, in a risk assessment, identify additional hazards arising from the special working conditions at the engine's place of use. He must implement these in the form of operating instructions for the operation of the engine.
- The operator must check during the entire operating time of the engine whether the operating instructions issued by him correspond to the current status of the regulations and adapt them if necessary.
- The operator must clearly regulate and define the responsibilities for installation, operation, maintenance and cleaning.
- The operator must ensure that all employees who handle the engine have read and understood the installation instructions.
- In addition, he must train the personnel at regular intervals and inform them about the dangers.
- The operator must provide the necessary protective equipment for the personnel.
- The operator must arrange for access restrictions to the operating room.
- The operator must ensure that the operating room is ventilated.
- These installation instructions must be kept in the immediate vicinity of the engine and must be accessible at all times to persons working on and with the engine.
- The operator is responsible for ensuring that the motor is always operated in a technically perfect and safe operating condition.

  The following applies in particular:
- Maintenance work, as described in this manual, must be perfomed completely and in specific time periods
- or have them performed by a MAMotec service partner
- The operator must have all safety equipment checked regularly for functionality and completeness.
- The information in the instructions must be followed completely and without restriction!

2.5 Personnel requirements

2.5.1 Qualifications

WARNING

Risk of injury due to insufficient qualification.
Improper handling can lead to considerable personal injury and damage to property.

Therefore:

- Special activities may only be performed by the persons named in the respective chapters of this manual.

The following qualifications for various fields of activity are named in the manual:

- Instructed person
was trained in an instruction about the tasks assigned to her and possible dangers in case of improper behaviour.
- Qualified personnel
is, due to his professional training, knowledge and experience as well as knowledge of the relevant regulations, able to carry out the assigned tasks in a professional manner.
- Qualified electrician
is able to carry out work on electrical installations and to independently recognize and avoid possible dangers due to their technical training, knowledge and experience as well as their knowledge of the relevant standards and regulations.
The qualified electrician has been trained for the specific location in which he/she works and knows the relevant standards and regulations.

Only persons who can be expected to carry out their work reliably are permitted as personnel. Persons whose ability to react is influenced, e.g. by drugs, alcohol or medication, are not permitted.

- When selecting personnel, observe the age- and occupation-specific regulations applicable at the place of use.

2.5.2 Unauthorized

WARNING

Danger for unauthorized persons
Unauthorized persons who do not meet the requirements described here are not aware of the dangers in the working area.

Therefore:
- Keep unauthorized persons away from the work area.
- In case of doubt, contact persons and show them to leave the work area.
- Interrupt the work as long as unauthorized persons are in the work area.

2.5.3 Instruction

The personnel must be instructed regularly. For better follow-up, the execution of the instruction must be recorded.

2.6 Personal protective equipment

Personal protective equipment must be worn during work to minimize health hazards.

Always wear the personal protective equipment necessary for the respective work during the work.

Follow existing signs in the work area regarding personal protective equipment.

Protective clothing

is close-fitting work clothing with low tear resistance, with tight sleeves and without protruding parts. It is mainly used for protection against injuries, climatic influences and dirt. Do not wear rings, chains or other body jewelry when working.

Safety helmet

to protect against falling and flying parts.

Safety shoes

to protect against heavy falling parts and slipping on slippery surfaces.

Safety gloves

to protect hands from friction, abrasion, punctures or deep injuries and from contact with hot or corrosive parts or liquids.

Wear for special work

Special protective equipment is required when carrying out special work.
This will be pointed out separately in the individual chapters of this manual.

Safety glasses

to protect the eyes from flying parts and liquid splashes.

Hearing protection

to protect against hearing damage caused by noise.

2.7 Special hazards

The following section lists residual risks that have been identified.

Observe the safety instructions listed here and the warnings in the other chapters of this manual to reduce health hazards and avoid dangerous situations.

Electric current

⚠ DANGER

Danger to life due to electrical voltage

There is a danger to life if live parts are touched. Damage to the insulation or individual components is life-threatening.

Therefore:

- If the insulation is damaged, switch off power supply immediately and arrange for repair.
- Have work on the electrical system carried out by qualified electricians only.
- Before carrying out any work on the electrical system, disconnect it from the power supply and check that it is voltage-free.
- Before maintenance, cleaning and repair work, switch off power supply and secure it against being restarted.
- Do not bypass or disable any fuses. Maintain the correct amperage when replacing fuses.
- Keep moisture away from live parts. This can lead to short circuits.

Moving parts

WARNING

Risk of injury from moving parts

Rotating and/or linear moving parts cause injuries.

Therefore:

- Do not reach into moving components or handle moving components during operation.
- Do not open covers during operation.
- Carry out inspection and maintenance work only when the motor is at a standstill.
- Observe run-on time: Before opening the covers, make sure that no parts are moving.
- Wear close-fitting protective work clothing in the danger area.

Components flying around in case of sudden engine damage

WARNING

Risk of injury from running motors

In the event of engine damage, components with high energy can fly through the engine room and injure people in the immediate vicinity.

Therefore:

- No stay in the engine room while the engine is running.

Exhaust gases

WARNING

Health hazard due to leaking exhaust system
Exhaust gases cause damage to health.

Therefore:
- Switch off and repair machines with leaking exhaust systems immediately.
- Ensure sufficient ventilation.

Highly flammable substances - gaseous fuels, oils and greases

WARNING

Risk of injury from highly flammable substances
Highly inflammable materials, liquids or gases catch fire.

Therefore:
- Smoking, naked flames and sources of ignition are prohibited in the danger zone and the immediate vicinity.
- Keep fire extinguisher ready.
- Report suspicious substances, liquids or gases immediately to the responsible person.
- Repair leaks.
- In case of fire, stop operation immediately. Leave the danger area until the all-clear signal is given.

Coolants - antifreeze, corrosion inhibitors

WARNING

Risk of injury from coolants that are hazardous to health
Coolant contains substances hazardous to health.

Therefore:
- Observe the safety sheets of the manufacturers.
- Always wear protective clothing, chemical-resistant gloves and safety glasses when handling coolants.
- Avoid spills and fogging.

Hot operating materials

WARNING

Danger of burns from hot operating materials
Operating materials reach high temperatures during operation and cause burns on contact.

Therefore:
- Before handling operating materials, check whether they are hot. If necessary, let them cool down.

Hot surfaces

WARNING

Danger of burns from hot surfaces
Contact with hot components causes burns.

Therefore:
- Always wear protective clothing and protective gloves when working near hot components.
- Before all work, make sure that all components have cooled down to ambient temperature.

Noise

WARNING

Hearing damage due to noise
The noise level occurring in the working area causes serious hearing damage.

Therefore:
- Always wear hearing protection when working.
- Stay in the danger area only if necessary.

Sharp edges and pointed corners

WARNING

Risk of injury at edges and corners
Sharp edges and pointed corners cause abrasions and cuts to the skin.

Therefore:
- Be careful when working near sharp edges and pointed corners.
- In case of doubt, wear protective gloves.

Dirt and lying around objects

WARNING

Risk of tripping due to dirt and objects lying around
Dirt and objects lying around are sources of slipping and tripping and cause serious injuries.

Therefore:
- Always keep the work area clean.
- Remove items no longer needed.
- Highlight tripping points with yellow-black marking tape.

2.8 Safety devices

The operator must retrofit the following safety devices:

Before putting the motor into operation, install an emergency stop device and integrate it into the safety chain of the system.

Connect the emergency stop device in such a way, that dangerous situations for persons and material assets are excluded if the power supply is interrupted or activated after an interruption.

The emergency stop device has to be freely accessible at all times.

Danger to life due to non-functioning safety devices

WARNING

Therefore:

- Before starting work, check that all safety devices are functional and correctly installed.
- Before starting the engine, check that all safety devices are functional and correctly installed.

2.9 Conduct in case of danger and accidents

Preventive measures

- Always be prepared for accidents or fire!
- Keep first aid equipment (first aid kit, blankets, etc.) and fire extinguisher ready to hand.
- Check first-aid equipment and fire extinguishers regularly for completeness and functionality.
- Familiarize persons with accident reporting, first aid and rescue facilities.
- Regularly carry out safety instructions.
- Keep access routes free for rescue vehicles.

In case of an accident: act correctly

- Keep calm.
- Stop the motor immediately by pressing the emergency stop button.
- Initiate first aid measures.
- Alert rescue service and/or fire department.
- Rescue persons from the danger zone.
- Clear access roads for rescue vehicles.
- Inform responsible persons.

Accident despite all precautions

WARNING

If an accident occurs in spite of all precautions, e.g. due to these listed points.

Therefore consult a doctor immediately:

- Contact with corrosive acid.
- Penetration of fuel into the skin.
- Scald by hot oil or coolant.
- Antifreeze splashes in the eyes, etc.

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2.10 Signposting

Risk of injury due to unreadable symbols

WARNING

Over time, stickers and symbols become dirty or otherwise unrecognizable.

Therefore:

- Always keep all safety, warning and operating instructions in a clearly readable condition.
- Clean or replace unreadable safety, warning and operating instructions.
- The following symbols should be placed in the immediate danger area.

No trespassing

Rooms marked in this way are not allowed to be entered.

Electric voltage

Only qualified electricians may work in the work area marked in this way. Unauthorized persons may not enter the rooms marked in this way.

Risk of explosion

Leaks in the gas supply system pose a risk of explosion and have to be repaired immediately.

Hot surfaces

Hot surfaces, such as hot engines and hot liquids are not always noticeable. Do not touch them without protective gloves.

Danger to life from suspended loads

During lifting operations, loads can swing out and fall down. This can cause serious injuries or even death.

Risk of injury

There is a risk of injury if the instructions are not followed.

2.11 Environmental protection

Note

Risk of environmental pollution due to incorrect handling of operating materials
There is considerable damage to the environment.

Therefore:

- Observe safety regulations.
- If environmentally hazardous substances are accidentally released into the environment, take appropriate measures immediately.
- If necessary, inform the competent local authority of the damage.

The following environmentally hazardous substances are used:

Lubricants

Lubricants such as greases and oils contain toxic and environmentally hazardous substances. They are not allowed to get into the environment. They must be disposed of by a waste management company.

Coolant

Cooling liquids can contain toxic and environmentally hazardous substances. They are not allowed to get into the environment. They have to be disposed of by a waste management company.

3 Engine environment

When assessing the installation situation of a modern gas engine, the engine environment is of central importance.

The following reasons are decisive for this development:

- In the case of stationary industrial gas engines, even the smallest of installation errors can lead to malfunctions or damage, especially if they are used in heavy continuous operation.
- Emission protection requirements that cannot be met by internal engine measures require the use of catalyst systems.
- Incorrect configuration or disturbances at exhaust gas purifiers cause operating faults or damage to the engine.
- The use of heat exchangers bears additional risks for the operational safety of the engine, if cooling and combustion are disturbed by improper configuration.

When analyzing malfunctions, the influence of all components in the engine's environment must therefore be checked for their operating conditions.

3.1 Engine limits and conditions to be observed

Oil pressure:	>	3.0bar
Oil temperature	<	110°C
Coolant outlet Warning threshold	≤	90°C (Measuring point cylinder head)
Coolant outlet cut-off limit	≤	93°C
Max. ΔT MKW entrance to exit	≤	6k
Speed of change MKW	≥	2k/min (at the operating point)
Coolant pressure min. MKW inlet	≥	0,8bar
Coolant pressure max. MKW inlet	≤	2,5bar
Exhaust back pressure max.	≤	50mbar
Ambient temperature max.	≤	70°C
Intake air filtration	≤	3 µm particle size

The following sensors must be installed on the gas engine and monitored electronically:

- Coolant temperature sensor
- Oil pressure switch or sensor with stored switch-off threshold
- Speed sensor with limit switch-off
- Intake air temperature sensor

The following monitoring must be provided for the entire system:

- Differential pressure switch or comparable for monitoring the function of the electric coolant pump.
- Coolant pressure monitoring max./min.
- Exhaust gas back pressure monitoring
- Exhaust gas temperature monitoring
- Monitoring of the gas-air mixture
- Gas warning system for the detection of the respective fuel used in the gas engine

3.2 Engine accessibility

To ensure high reliability of the engine, regular inspection and maintenance work must be carried out.

Therefore:

- When installing the motor, make sure that there is sufficient space for regular maintenance work according to the maintenance schedule.

3.2.1 Advantages of good accessibility

- High reliability of the engine due to easy control and maintenance
- Low maintenance costs due to low time expenditure

When installing the motor, it must be ensured that there is sufficient space for regular maintenance work according to the operating instructions and for a possible overhaul of the motor after a longer period of operation.
For movements of the motor, caused by an elastic support, sufficient clearance must be provided to safely avoid contact with adjacent parts.

3.3 Maintenance of the engine

It must be possible to carry out the following maintenance work on the engine without hindrance in the engine compartment:

- Rotate the motor with the rotation device
- Adjusting the valves, tightening the cylinder head screws
- Setting and changing the speed pulse pick-up
- Maintenance and replacement of the battery
- Air filter maintenance
- Visual inspection and retightening of screw, hose and pipe connections
- Simple visual inspection for leaks
- Control and adjustment of the ignition timing
- Check and adjust the actuator motor of the throttle valve
- Maintenance of the components for engine monitoring
- Check the lubricating oil level, refill lubricating oil (description in the operating instructions)
- Changing the oil filters (description in the operating instructions)
- Drain the coolant and fill in the coolant (description in the operating instructions).
- Tighten / retighten the cylinder head screws

We would advise you to allow sufficient space for repairs and engine overhauls already in the planning phase.

4 Engine compartment ventilation

During operation, the motor emits radiant heat due to its surface temperature, which must be dissipated by effective ventilation.

4.1 Engine temperature

Even under the unfavourable conditions, a motor ambient temperature of 70°C may not be exceeded.

The engine compartment temperature should be between 0°C and 45°C for continuous operation. Rapid temperature and pressure fluctuations in the engine room, e.g. opening of doors, are not permitted (max. 0.5mbar).

Ideally, the air flow in the engine room should be from below, diagonally upwards.

Blowing of the air filter should be prevented to avoid pressure fluctuations caused by clocking fans.

4.2 Pressure in the engine compartment

Basically, the ventilation can be configured as "pressing" or "sucking". Both concepts have their areas of application. It is advisable to control the ventilation system and exhaust system with supply air fans and exhaust air fans in such a way that the pressure in the engine room is approximately equal to atmospheric pressure.

4.3 Radiant heat to be removed

Depending on the type of engine, the amount of heat to be dissipated is approx. 5% of the heat output supplied with the fuel.

If there are exhaust silencers or longer exhaust pipes in the engine room, the heat dissipation of these components must also be taken into consideration. In order to keep the radiant heat to be dissipated within limits, these components should have a fireproof insulation.

⚠ GEFAHR

It is imperative to ensure that fireproof insulation does not come into contact with oils of any kind under any circumstances. There is a risk of fire during operation!
If fireproof insulation has come into contact with oil, replace the insulation before restarting the engine!

The air density is dependent on temperature and pressure. For orientation, the following table shows some values for air density as a function of temperature at an air pressure of 1000 mbar.

Air density as a function of temperature at an air pressure of 1000 mbar:

Temperature in ^{o}C	Density q in kg / m^3
0	1,28
10	1,23
20	1,19
30	1,15
40	1,11
50	1,08

In the above calculation method, the engine compartment is considered a heat-tight system, i.e. for the sake of simplicity it is assumed that no heat energy is emitted through the walls to the ambient air.

4.4 Total air demand

The total air requirement is calculated from the sum of the air required to dissipate radiant heat and the combustion air requirement of the engine.

The technical data sheet provides information on the combustion air requirement of the engine. The manufacturer can provide information about the cooling air requirement of the generator. As a guideline, a flat rate of 3 m3/min per kW power loss can be assumed.

4.5 Air exchange in the engine room

The air exchange in the machine room should not be more than 100 times per hour. Exceeding 100 air changes per hour can be uncomfortable for the operating and maintenance personnel.

In the event of a gas leak, the engine room must be ventilated in such a way that an explosive gas-air mixture cannot form under any circumstances. This is particularly important for gas engines of the MAH series!

4.6 Air flow in the engine compartment

If the engine compartment is also to be used as a working area for the operating personnel, high air speeds should be avoided, as these are at least annoying for humans.

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

Select a diagonal flow around the motor from bottom to top to avoid unnecessary air turbulence.

5 Elastic mounting

5.1 General context

An elastic support to limit the dynamic load introduced into the foundation is preferable to a rigid support. It is advisable for motors with free, speed-dependent mass forces or mass moments. This includes, for example:

Even alternating torques present in every reciprocating piston engine can be kept almost away from the engine foundation by means of an elastic mounting with appropriate adjustment, so that the foundation is only loaded with the useful torque.

The following data are the basis for the layout of an elastic support:

- Motor weight, centre of gravity coordinates and mass moments of inertia
- Free mass forces and moments
- Free alternating torques

Some requirements for the design of elastic engine mounts are already specified.

5.2 Degree of Isolation

When dimensioning the elastic bearing elements, care must be taken to ensure that the base frame is designed as rigid as possible, i.e. with a high moment of resistance.

Although a high degree of bearing insulation is desirable, it also poses risks for the motor and the driving machines connected to it.

With the increasing use of rubber-metal rails, the maximum deflection should be 3mm.

Under no circumstances should the bearing elements be pressed beyond the weight loads permitted by the respective manufacturer.

Dimension the elastic bearing elements in such a way that the same specific load, i.e. the same deflection, is present at all bearing points.

Risk of damage to components by exceeding the permissible vibration speeds.

Therefore:

- According to the VDI guideline 3838 and DIN / ISO 10816, the maximum vibration velocities must not exceed the following values:
    - Engine: 45 mm/s
    - Generator: 28 mm/s

If these values are exceeded in continuous operation, damage - especially to attached auxiliary units - is an inevitable consequence.

5.3 Supercritical tuning

5.3.1 Engines with variable speed

If an elastic mounting is used, supercritical tuning is required to avoid resonance vibrations during engine operation (resonance range is only run through quickly when the engine is started and stopped).

MAMotec GmbH understands tuning as the ratio of the excitation frequency to the natural frequency. Due to a simple reference to the motor speed, the number of oscillations per minute is measured.

The critical motor speed nkrit is the speed ne at which resonance i occurs, taking into consideration the lowest order of excitation.

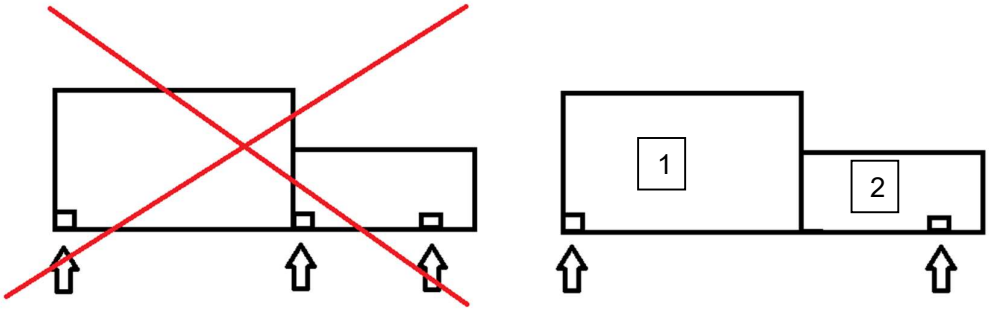
The lowest order of excitation i is the alternating torque. In a four-stroke engine it is half the number of cylinders, e.g. in a 6-cylinder in-line engine i = 3.

Insulation (i.e. reduction of the foundation forces against the excitation forces) is only present when n/nkrit > 2. In practice, elastic mountings of engine systems with variable speed are therefore tuned to idle speed.

5.3.2 Connection lines

In order to compensate the vibration deflections of elastically mounted systems, all pipelines leading away from the motor must be elastically uncoupled. Stiff connections to the foundation, frame or wall can lead to breakage of the attached parts and / or at least reduce the insulation efficiency.

5.3.3 Engines with flanged generator



1 Engine
2 Generator

If a generator is flanged to the motor, only a bearing arrangement according to drawing B is permitted.

5.3.4 Breakdown of a bearing of an engine with flange-mounting unit

In fixed flanged systems, the failure of a bearing on the motor side or on the side of the flanged unit leads to an additional load on the remaining bearings.

The torsional load arising from this is absorbed by the flywheel housing. In case of damage to the elastic bearing, the system must be shut down immediately.

6 Power reduction at flywheel

6.1 Power reduction at flywheel without flange-mounting unit

6.2 Permissible bending moments in Nm on the crankshaft due to radial force transmission for engines of MAG 33.3-84.6

Direction of force application View of the flywheel	Speed in U/min
	1500
12 o´clock Position	520
3/9 o´clock Position	660
6 o´clock Position	910

6.3 Calculation 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 S permissible bending moments according to table

F_R = Radial force in N

A = Distance from centre of auxiliary pulley package to flanged surface Flywheel housing in mm

L= Distance from the flanged surface of the flywheel housing to the centre of the rear crank web. This dimension is determined by the design and is shown in the table below

7 Power take-off at flywheel via flange-mounting unit

7.1 Permissible bending moments in Nm on the flywheel housing due to radial force transmission with MAG 33.3-84.6

Flywheel housing	Industrial gas engines		
	SAE 1	SAE 2	SAE 3
made of cast iron	7700	4800	4800

In limiting cases, measurements must be taken to check that

- the static preload in the housing
- the dynamic load (statically superimposed) does not exceed the permissible values

If the above values are exceeded, check whether the load can be reduced by a different bearing arrangement.
If this is not possible, the flange-mounting unit must be arranged free-standing.

7.2 Generator types

Both 1-bearing and 2-bearing generators are available on the market. MAMotec GmbH only recommends the use of 2-bearing generators. However, a torsional vibration calculation is required in any case.

7.3 The torsional vibration calculation

The gas and mass forces of the engine can excite the entire drive train to vibrate. In order to determine resonance points according to position and strength and to avoid overstressing, a torsional vibration calculation is necessary, which must be carried out by the system manufacturer.

Here are the mass moments of inertia of the MAG series

					6 cyl engines: crank journal dia 90 mm			
Engine type	**MAG 33.3**		**MAG 49.4**		**MAG 74.4**		**MAG 84.6**	
Bore mm	108		108		108		111	
Stroke mm	120		134		134		145	
Cyl number	3		4		6		6	
Con rod length mm	208		208		208		232	
Firing order	1-2-3		1-2-4-3		1-5-3-6-2-4		1-5-3-6-2-4	
Crank pin dia mm	68		68		68		73	
oscillating mass kg	2,68		2,68		2,68		3,23	
	Inertia kgm2	Stiffness Nm/rad	Inertia kgm2	Stiffness Nm/rad	Inertia kgm2	Stiffness Nm/rad	Inertia kgm2	Stiffness Nm/rad
Pulley+damper	0,026	2,757E+05	0,026	3,004E+05	0,103	4,252E+05	0,152	4,292E+05
cyl 1.	0,051	1,438E+06	0,039	1,328E+06	0,051	1,521E+06	0,058	1,631E+06
cyl 2.	0,026	1,438E+06	0,039	1,394E+06	0,040	1,521E+06	0,047	1,631E+06
cyl 3.	0,051	2,261E+06	0,039	1,328E+06	0,059	1,492E+06	0,063	1,598E+06
cyl 4.			0,040	2,345E+06	0,052	1,521E+06	0,063	1,631E+06
cyl 5.					0,040	1,521E+06	0,047	1,631E+06
cyl 6.					0,065	2,562E+06	0,066	2,722E+06
cyl 7.								
Flywheel *)	0,005		0,005		0,005		0,007	
Damper ring inertia					0,084		0,122	

*) Flywheel inertia must be added to given value

Flywheel for 11,5" drive plate with SAE 3 flywheelhousing	Inertia J=0,45 kgm^2	MAG xx.x S3xx
Flywheel for 11,5" drive plate with SAE 2 flywheelhousing	Inertia J=0,88 kgm^2	MAG xx.x S2xx

Specialparts non series

Flywheel for 14" drive plate with SAE 1 flywheelhousing	Inertia J=1,68 kgm^2
Flywheel for 14" drive plate with SAE 1 flywheelhousing	Inertia J=1,70 kgm^2

⚠ DANGER

Risk of accidents due to rotating machine parts

Therefore:

- For safety reasons, rotating machine parts (V-belts, shafts, flanges) of stationary motors must be provided with suitable protection against accidental contact. Observe accident prevention regulations!

8 Intake unit

8.1 Combustion air requirement

The engine needs a sufficient amount of fresh air to ensure complete combustion of the fuel and thus to achieve full performance. This can be found in the technical data sheet of the respective engine.

Hot intake air and heated fuel results in reduced performance!

8.2 Air filter

8.2.1 Air filter selection

In principle, MAG industrial gas engines can only be operated with an air filter. Unfiltered or insufficiently filtered fresh air leads to massive wear on the gas engine.
The size of the air filter must be determined in cooperation with its manufacturer in such a way that the following conditions are met for the expected dust content in the air:

- The maximum permissible suction vacuum must be observed (see technical data sheet).
- The filter must be approved by MAMotec GmbH with regard to air throughput and separation efficiency.
- The air intake point in front of the filter should be located in a low-dust area, protected from the weather and arranged in such a way that ideally between 10-25°C warm air is sucked in.
- For module installations in closed acoustic enclosures, the air must be drawn in from outside the enclosure.
- The insulation and soundproofing materials must be free of silicon fibres, as these are air filterable and can reach the intake tract.

Of the known filter designs, a dry air filter has to be used in principle.

Risk of damage to components due to penetration of foreign bodies.

Therefore:

- No air filters with expanded metal or internal screws or washers.
- All components in the intake section must be free of foreign bodies.

8.2.2 Dry air filter for continuous operation

Characteristic features of the dry air filter with replaceable paper insert are high separation efficiency in all operating areas as well as the resistance increase with rising dust levels. In many dry air filters, cyclone separators are integrated into the housing. The cyclone separator causes the air to rotate, whereby part of the dust is separated before it reaches the downstream air filter.

For dry air filters, the installation position recommended by the manufacturer must be observed.

8.3 Crankcase ventilation

8.3.1 Type

Depending on the type of engine, various designs of crankcase ventilation with oil mist separator can currently still be used. These must be installed by the system manufacturer. Operation without crankcase ventilation with oil mist separator is not advisable for naturally aspirated engines and not permissible for turbo engines.

An active crankcase ventilation system must be provided for MAH series gas engines.

8.4 Layout and design of the air intake pipe

The air pipe from the filter to the gas mixer must meet the following requirements:

- Absolute tightness
- Short, streamlined cable routing with less separation points as possible
- Inner surfaces free of scale and protected against corrosion
- Compensate relative movements between motor and filter by elastic connections (hoses)
- For hose connections, bead the pipes, use only suitable hose connections
- Clean the inside of all pipes and hoses before installation
- Only water is permitted as a lubricant during assembly of the hoses
- Do not lay the air intake line near hot components
- Free cross-section of the air intake pipe: 50-65 mm2 / kW
- The installation instructions of the gas mixer manufacturer must be observed with regard to the minimum specified inflow and outflow distance (min. 3x outer diameter of the air intake pipe)

8.5 Structure of mixture formation

The mixture formation must be designed according to the installation instructions of the gas mixer manufacturer in such a way that a homogeneous gas-air mixture is present at the intake manifold of the gas engine. This mixture must meet the minimum requirements for MAMotec gas engines and be free of condensate.
For turbocharged engines, ensure a straight intake distance of at least 150 mm into the compressor of the exhaust gas turbocharger.

Risk of damage to components due to solids being sucked into the gas supply line.

Therefore:

- Installation of a filter with mesh size S 6 µm in the gas supply line is absolutely necessary.

9 Exhaust system

9.1 Basic construction concept

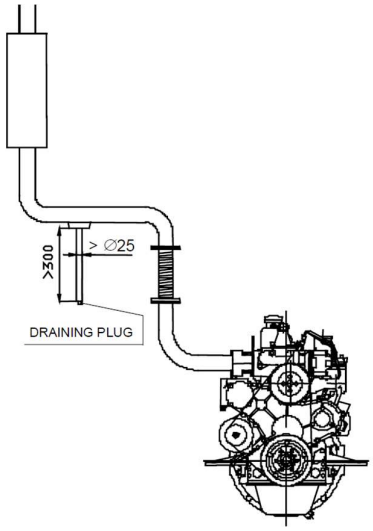
WARNING

Exhaust gases are toxic and hot

Therefore:

- Exhaust system must be completely gastight.
- The exhaust system must be fitted with fireproof insulation.

One or more elastic intermediate pieces (compensators) must be installed between the engine and the exhaust system. The manufacturer's instructions must be observed during installation.



This prevents the transmission of vibrations from the engine to the exhaust system and compensates for the longitudinal expansion of the exhaust pipes due to high temperatures.

9.1.1 Mounting the exhaust system

Component damage due to forces acting on the turbochargers

Therefore:

- Exhaust pipes must be fastened and supported in such a way that no forces act on the turbochargers.

The material used for the exhaust system is preferably acid-resistant steel.

The exhaust pipes heat up considerably due to the high temperature of the exhaust gas of several hundred degrees Celsius.

The standard value for the linear expansion of steel pipes as a function of temperature is

1 mm per meter and 100°C

In order to avoid excessive heating of the engine compartment, fireproof fuel and lubricating oil repellent insulation is recommended. The possibly dry exhaust manifold of turbo engines must be provided with a protection against contact. Insulation of these components requires a permit.

Danger of burns from hot surfaces

WARNING

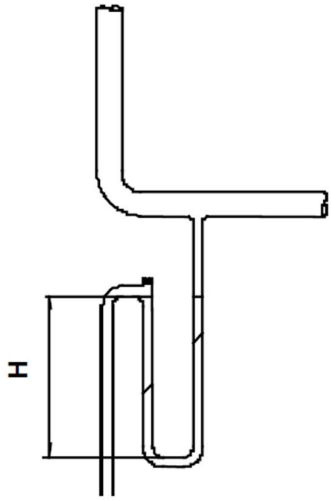
Therefore:

- Insulate exhaust pipes carefully with fireproof material!

It is not permitted to combine the exhaust gas from several engines into one system. In multi-engine systems, separate exhaust gas routing is required for each engine to prevent exhaust gas from one running engine entering the other.

Condensation forms in the exhaust system, which must never flow into the engine.

If the exhaust pipes are very long and laid in a rising position, a condensate trap with a drain device for the condensation water must therefore be provided near the engine. Under no circumstances should rainwater enter the exhaust system.



In order to keep the exhaust back pressure as low as possible, sharp deflections and bends have to be avoided.

Only execute pipe bends with a large radius. When installing silencers, soot filters, catalytic converters, etc. make sure that the maximum permissible exhaust back pressure is not exceeded.

9.1.2 Connecting the exhaust system to the engine

Elastic connecting elements must be installed between the engine and the exhaust system, which allow engine movements due to the elastic engine mount and decouple the engine from the exhaust system on the vibration side.

9.1.3 Installation of the exhaust compensator

Exhaust compensators prevent the transmission of vibrations from the engine to the exhaust system and compensate for the temperature-related longitudinal expansion of the exhaust pipes.

Due to the high gas velocities, the compensators are equipped with guide tubes. The distance between guide tube and corrugated tube of the compensator is relatively small.

It is therefore necessary to install the compensators as vertically as possible or to safely support the continuing exhaust pipe.

If installed at an incline and the continuing exhaust pipe is not suitably supported, the compensator may be damaged. The guide tube and corrugated tube then contact each other.

The exhaust compensator must be installed under tension.

Tensile pretensioning means that before the compensator is screwed on, a distance between the flange of the compensator and the counter flange of the continuing exhaust pipe

is approx. 2-10 mm. Due to the guide tube the direction of flow is prescribed for compensators. This has to be observed during installation.

9.2 Permissible exhaust back pressure

Thermal load as well as insufficient engine power and high gas consumption due to exceeding the permissible exhaust back pressure of 50 mbar and more.

Therefore:

- For engines in continuous operation with downstream exhaust gas purification systems or exhaust gas heat exchangers, continuous monitoring of the exhaust back pressure is mandatory.

For all gas engines, depending on the installation, the range of the max. permissible exhaust back pressure is

in new condition 5-40 mbar.
Marginal conditions: Measurement at nominal power in a straight pipe section.

For this reason it is absolutely necessary to measure the exhaust back pressure when starting up an engine and, if necessary, to re-dimension the exhaust system. The connection point to be provided for measuring the exhaust back pressure in naturally aspirated engines is shown in the picture (A).

9.3 Permissible exhaust gas temperature

The exhaust gas temperature depends not only on the engine type but also on other factors, such as

- Engine Power
- mixture temperature before entering the combustion chambers
- Ignition time
- Air ratio

The maximum permissible exhaust gas temperature is 710°C.

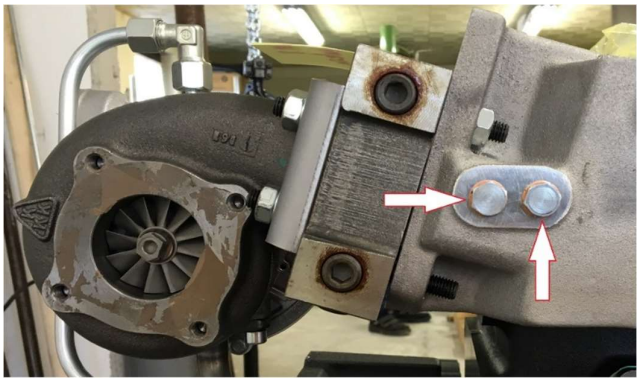
Risk of thermal overload of the engine or its components and ultimately of serious engine damage due to excessively high exhaust gas temperature.

Therefore:

- Continuous monitoring of the exhaust gas temperature is mandatory.

The exhaust gas temperature is monitored as follows:

- A temperature sensor must be provided to monitor the exhaust gas temperature. The installation location must be directly on the exhaust manifold (B see illustration), this applies to engines MAG49.4 - MAG84.6. For the MAG24.4 and 33.3 series, a measuring point must be provided by the system manufacturer directly after the exhaust pipe
- The measuring range of the exhaust gas temperature sensor is at least: 0-800°C



9.4 Design of the exhaust system

The diameter of the exhaust pipe, the number of bends, the silencers and the pipe routing must be selected in such a way that 75% of the maximum exhaust back pressure is not exceeded in new condition.

If other components apart from the silencer are installed, e.g. soot filters, catalytic converters, heat exchangers, their resistance has to be considered additionally.

As the exhaust backpressure of these components increases during operation, continuous exhaust backpressure monitoring must be provided.

9.5 Measuring exhaust back pressure

The exhaust back pressure must be measured during start-up.

Measurements directly behind an exhaust gas turbocharger can distort the result by up to 20 mbar.

The static pressure is measured, i.e. the measuring connection has to be flush with the pipe wall on the inside.

Measurements of dynamic pressure and measurements in pipe bends give incorrect results.

During the measurement the motor has to be operated at full power and nominal speed.

The simplest measuring instrument is a U-tube

Manometer filled with water (1 hPa = 10 mm Ws)

9.6 Use of exhaust gas heat exchangers

Stationary gas engines for combined heat and power generation are often used in conjunction with heat exchangers to recover the lost heat of the exhaust gas.

9.6.1 Special features of exhaust water heaters

Exhaust gas water heaters are often subject to very heavy wear and tear due to heavy soiling and corrosion on the exhaust gas side.

Causes of contamination are mostly combustion errors caused by faulty or worn components such as gas mixers, spark plugs or piston rings. The cause of corrosion is the impact of the aggressive, acidic exhaust gas condensate at low wall temperatures in the partial load range.

Wear due to corrosion can be limited if the separation of condensate from the exhaust gas is avoided. This is achieved if the exhaust gas temperature at the exit from the exhaust system is not lower than 180°C.

The best results are achieved when the systems are always under high load, i.e. at high temperature, and the heat exchanger is fully charged.

The exhaust back pressure of exhaust gas heat exchangers rises with increasing contamination. Therefore, continuous monitoring of the exhaust back pressure is mandatory.

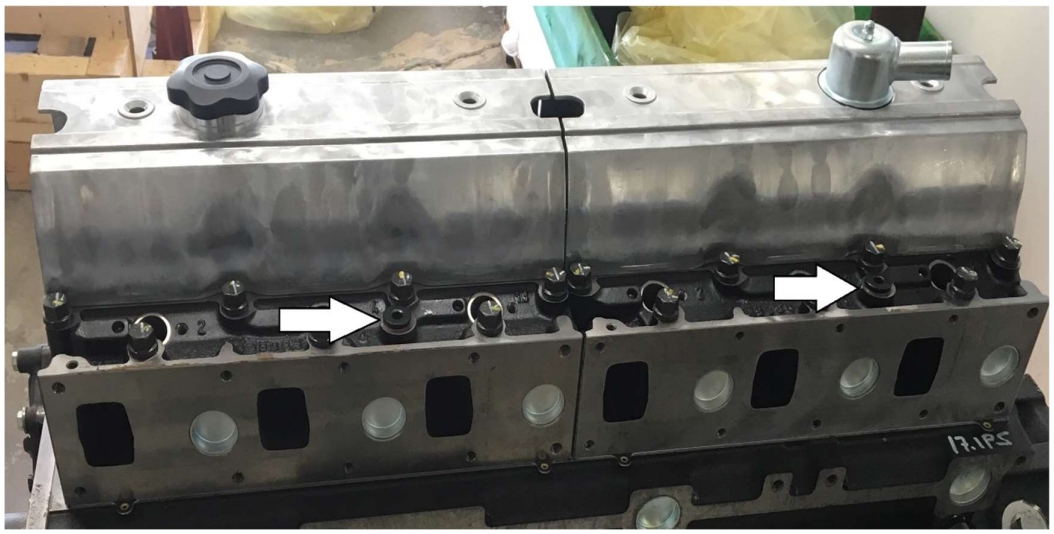
10 Engine cooling system

10.1 Components of the cooling system

Basically, the cooling system of the MAMotec industrial gas engines must be designed as a closed pressure system. The coolant pump has to be installed directly connected to the coolant inlet of the gas engine.
The following components must be provided in the cooling system:

- Coolant pump with flow monitoring (differential pressure switch)
- 3-way mixing valve to control the motor inlet temperature
- Safety pressure valve
- Water shortage protection
- Membrane expansion vessel

  The cylinder head of the engine has to be connected to the highest point of the cooling system with a permanently open venting pipe rising to prevent air bubbles from settling in the cylinder head.



10.2 Coolant lines

The clear widths of the coolant pipes must at least correspond to the cross sections of the engine connections. Throttle points have to be avoided.

The coolant pipe routing should be designed as flow-favourable as possible. All pipes must be laid in a rising or falling manner so that no air bubbles can form.

With elastic mounting of the motor and separate arrangement of the cooling system, the pipe connections directly at the motor connection have to be flexible. For non-aligned installation positions, the use of shaped hoses is recommended. These should be as short and rigid as possible in their length, especially on the suction side of the water pump.

10.3 Cooling system configuration

The following information must be taken into consideration when designing the cooling system:

- Amount of coolant heat to be dissipated from the engine (see technical data sheet of the respective engine) and any other units and system parts present.
- Ambient conditions at the location of the cooling system, including the highest cooling air temperature to be expected.
- The minimum required coolant circulation quantity (see technical data sheet of the respective engine).
- Delivery capacity and delivery head of the coolant pump (not included in the scope of delivery of MAMotec GmbH).
- Pipe connection diameter according to installation drawing.
- Temperature difference between inlet and outlet max. 6 Kelvin in normal operation.
- Coolant inlet temperature at least 75°C at each operating point.
- Setpoint value of the coolant outlet temperature maximum 88°C at each operating point (limit value 92°C).
- Coolant inlet temperature fluctuations T≤ 2 Kelvin/min
    - Coolant outlet temperature monitoring: Warning: 90°C
      Shutdown: 93°C

Risk of engine damage due to overheating as a result of insufficient coolant circulation
In new condition the coolant temperature difference AT is 3 to 5 Kelvin.

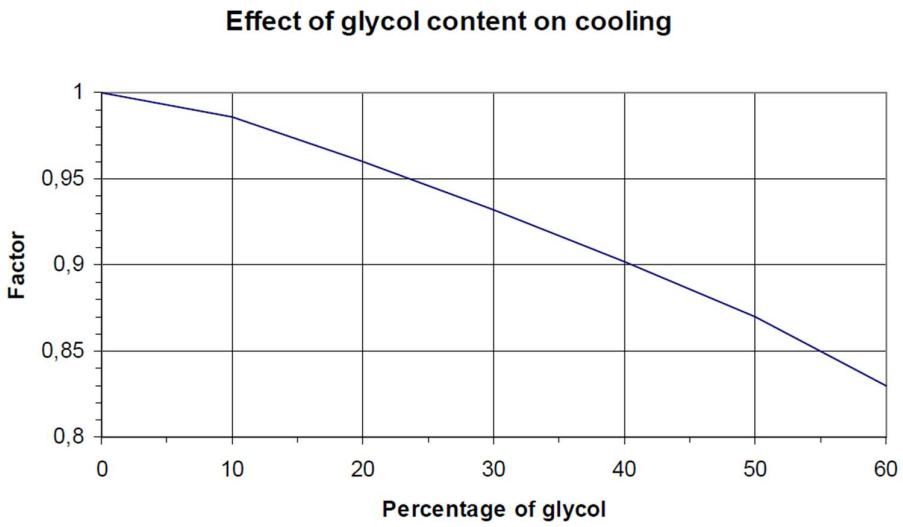
Therefore:

- Observe minimum coolant circulating quantities (see engine data sheet)!
- Flow rate monitoring with flow monitor or differential pressure monitoring.
- Heat exchangers must be configured with safety reserves.
- Pre- and post-run times of the coolant pump must be strictly adhered to.

10.4 Checking the cooling system

When checking the cooling circuit, it must be ensured that

- the cooling circuit can be filled quickly (8 l/min);
- the cooling circuit is completely vented;
- no negative pressure can develop upstream of the coolant pump (cavitation);
- a system pressure (guide value: 0.4-0.5 bar static) builds up in the cooling circuit and is maintained after the engine is switched off;
- the cooling circuit ensures the required coolant flow rate at max. permissible coolant temperature and with the mixing valve fully open;
- no coolant escapes from the cooling circuit even when the engine is switched off when hot;
- the cooling circuit including motor and heat exchanger can be completely emptied;
- air bubbles can be removed from the coolant;
- no air pockets remain in the cooling system;
- hose connections are accessible for maintenance purposes.



The specific heat capacity of the coolant depends on the concentration of frost / corrosion protection agent. The more frost / corrosion protection is contained in the coolant, the less

Heat per kg coolant can be removed (see diagram).

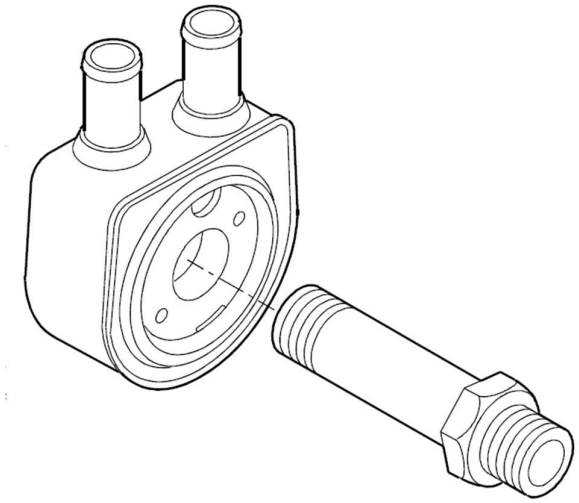
The minimum coolant circulation quantities are dimensioned in such a way that at maximum (blocked) power a temperature difference of 3 to 5 Kelvin - in new condition - is established between the engine inlet and the engine outlet.

When the motor is operated at constant load, the steady state is reached after a few minutes,

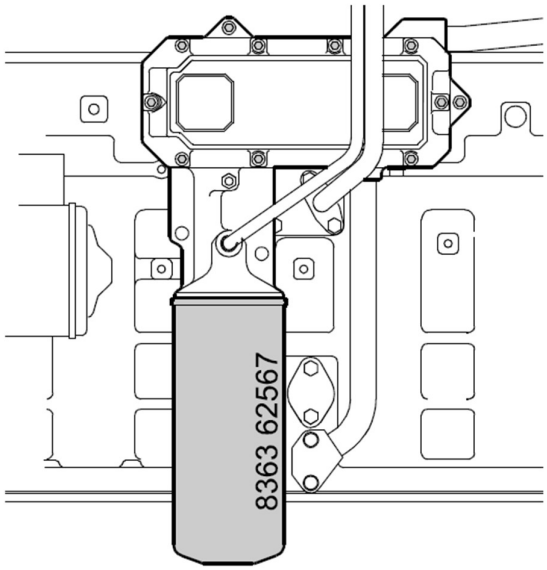
i.e. the amount of heat to be dissipated in the coolant remains constant.

10.5 Integration of the oil cooler into the cooling system

The gas engines of the MAG series are equipped with an oil cooler. There are different types of oil cooler construction.
MAG 24.4-74.6
The oil cooler of these engine series is a plate heat exchanger, which is attached to the oil filter connection of the engine block.

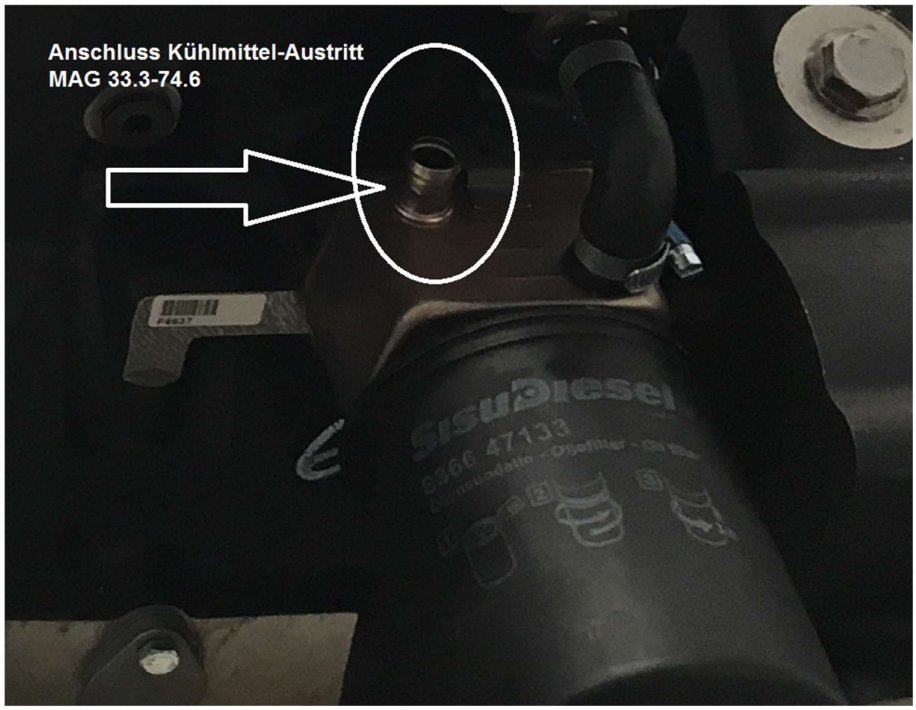


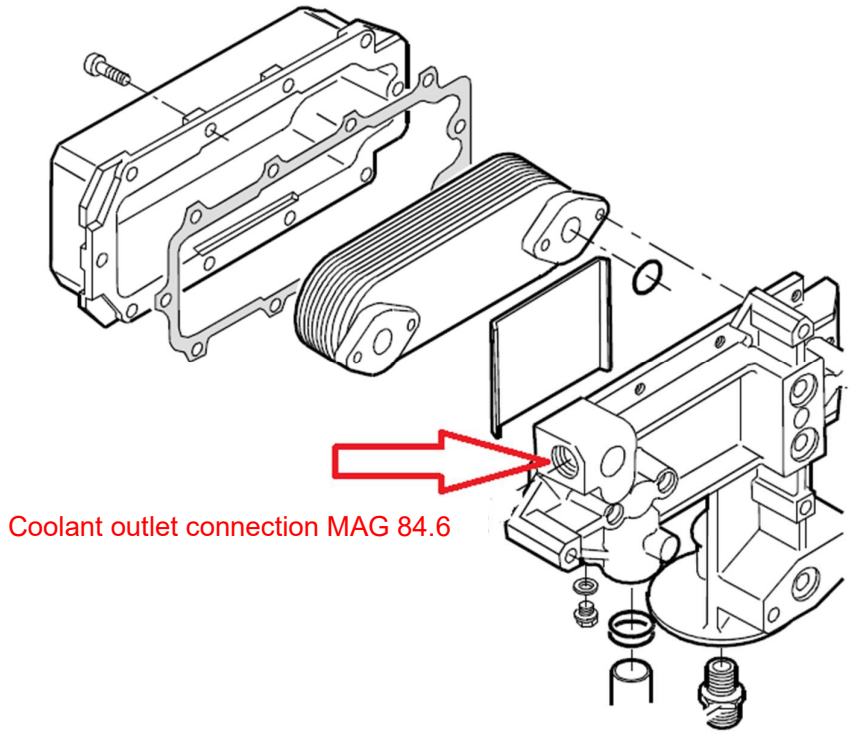
MAG 84.6
The oil cooler of this gas engine is installed as a fixed housing on the engine block.



Both oil cooler systems have their coolant inlet firmly installed on the engine block.

Important:
The coolant outlet of the oil coolers must be installed by the system manufacturer in such a way that no air bubbles can settle in the system and free flow is ensured. This must be connected to the coolant outlet of the engine.





Coolant outlet connection MAG 84.6

11 Electrical system

11.1 Ignition system

For operation and installation please refer to the documentation of the ignition system.

⚠ DANGER

Risk of accidents due to moving and hot engine parts

Therefore:

- Before starting, make sure that nobody is in the immediate area of the engine.

The ignition system must be parameterised before commissioning. Here the gas and engine-specific ignition timing must be observed. Incorrectly set ignition systems can result in engine damage.

⚠ DANGER

Risk of accidents due to defective components

Spark plugs and spark plug connectors must be secured by the system builder against being thrown out during engine operation. No person may stand directly next to or above the engine during engine operation!

DANGER TO LIFE AND LIMB!

For further information we refer to the operating instructions of the ignition system and to the installation guidelines. Only trained personnel should carry out the parameter setting.

Note!

The ignition system is not included in the basic scope of delivery of the MAG series!

11.2 Starting

Switch on the coolant pump before starting.

Switch on the starter and let it rotate with the ignition activated for at least 3 seconds to ensure air purging.

After air purging, the ignition is released and followed by the gas line (usually automated).

After reaching the nominal speed, the system can be put under load. The load is increased from 0 to 100% over a period of 3 minutes. This minimises the thermal load on the motor block.

11.2.1 Permissible duty cycle of the starter

The permissible operating temperature of the starter is permanently exceeded due to unsuitable starting sequences and excessively long activation times of the starter. This inevitably leads to damage and failure of the starter.

In principle, a start game may consist of a maximum of 3 consecutive start attempts of 12 seconds each. If no speed signal is detected within 3 seconds, the start procedure must be stopped. The time between 2 start attempts has to be at least 20 seconds. A break of 300 seconds must be observed until the next start attempt.

The number of starts must be documented in a tamper-proof way by a start counter.

11.2.2 Permissible temperature of the starter

The housing temperature of the starter motor may not exceed 95°C during engine operation, measured at the pole housing on the side facing the crankcase. During the starting circuits 115°C are permitted for a short time. If necessary the starter motor has to be cooled by blowing air, see also chapter "engine compartment ventilation".

11.3 Operations monitoring

Danger of component damage or engine damage due to engine operation outside the limit values.

Therefore:

- If faults arise, determine and eliminate their cause immediately so that no major damage occurs! If necessary, consult MAMotec GmbH.

During operation, the system parameters such as oil pressure, coolant temperatures, differential pressure, cooling water shortage have to be constantly monitored.

11.4 Shutdown

The load reduction must be reduced by a ramp control from 100% to 0% over a period of at least 3 minutes and then run after 2 minutes without load. This minimises the thermal load on the motor.

11.4.1 Shutdown sequence

- Switch off the release of the gas line
- Engine runs out
- Switch off ignition and regulation after approx. 5 seconds after engine standstill

Danger of component damage due to thermal load

Therefore:

- The coolant pump has to run for at least 5 minutes after the engine has stopped. This minimises the thermal load on the engine block and dissipates the accumulated heat.

⚠ DANGER

Risk of burns due to re-ignition

Therefore:

- The gas supply has always to be switched off before the ignition, so that no unburned gas residues can enter the exhaust pipe when switching off.
- In case of damage to the engine shutdown never switch off via the ignition.
- Close the main shut-off valve.
- Only switch off the ignition after the engine has stopped.