

# **Power plants layout**

with

## **Gas Engines**

**(Planning and Installation Notes)**

**06-2014**

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Figures, drawings, diagrams and circuit diagrams within the handbook represent general information for the project planning. The relevant order documentation is binding for orders.

There is no revision service for the drawings of the installation guidelines. They will only be updated with the next edition of the installation guidelines.

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## FOREWORD

The guidelines of this handbook are not operating instructions for the final machine user. They apply to all designers and manufacturers of products who use one of our gensets. Thus the guidelines are not user information as defined by DIN standard 8418, but fulfil a similar purpose, because their observance ensures the engine functioning and thus protects the product user from danger which could result from genset use.

Operating safety and a long service life can only be expected from perfectly installed systems. This also allows maintenance work to be carried out simply and quickly. These guidelines provide information for mounting and give information about limit values to be observed.

The safety provisions, which are a component of the gensets and/or system documentation, must be complied with during layout, maintenance and operation of the systems.

The wide range of installation options does not allow for generally applicable and strict rules. Experience and special knowledge are necessary in order to ensure optimum installation. The standards, directives and regulations listed have no claim to completeness. Therefore the local requirements must be investigated and duly taken into account in each individual case.

Therefore we recommend an installation consultation with Caterpillar Energy Solutions GmbH or an authorized sales partner during the planning stage.

Caterpillar Energy Solutions GmbH does not accept warranty claims and is not responsible for damage or loss occurring from failure to comply with the information and instructions given in this handbook.

Your suggestions on how to enhance or supplement these guidelines are always highly appreciated.

Caterpillar Energy Solutions GmbH, VD-S, 06-2014

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# **Power plants layout**

## **Chapter 1**

### **Layout of gas engine-powered gensets for combined power and heat generation at power plants (CHP's)**

**06-2014**

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## 1. Layout of gas engine-powered installations for combined power and heat generation at power plants (CHPs)

A gas engine-powered genset comprises a combustion engine, generator, coupling, base frame and mounting arrangement. The engine and generator are rigidly mounted on the base frame. This unit is described as a CHP genset and is used to generate electricity and heat.

A CHP set comprises a CHP genset and the following components:

- Cooling water heat exchanger
- Exhaust heat exchanger
- Exhaust silencers
- Exhaust gas cleaning system
- Fuel tank or gas supply
- Lube oil supply
- Monitoring system

A CHP plant may comprise one or more CHP sets: the electrical switchgear with control system, the air supply system and the exhaust air system.

The basic principles, requirements, components, implementation and maintenance of electricity generating sets are described in DIN 6280, Part 14 (see Fig. 1.1).

### **Attention !**

It is not allowed to change any parts in the gensets, components and control cabinets which are delivered by the manufacturer.

To avoid EMC problems, the parts on the system side, e.g. frequency converters, must be connected with shielded lines in accordance with the manufacturer's specifications. See also Chapter 14 and 17.

### 1.1 Types of use

Depending on its use, the system may be primarily used to generate either electricity or heat.

#### 1.1.1 Heat-led operation

In the case of heat-led operation, the demand for heat is the lead factor which determines the output of the CHP plant. To cover the demand for heat during peaks, the CHP plant may be supported by other heating systems.

## **1.1.2 Electricity-led operation**

In the case of electricity-led operation, the demand for electricity is the lead factor which determines output of the CHP plant.

### **1.1.2.1 Mains parallel operation**

In system-parallel operation, the CHP plant supplies consumers e.g. until the maximum electrical output is reached according to the nominal power of the engine. Any further additional demand is covered from the mains power supply. During high-tariff periods, the gensets can be used to offset peak loads.

In the event of a mains fault, the CHP plant can be operated in isolated mode.

### **1.1.2.2 Isolated operation mode**

When operating in isolated mode, the CHP plant supplies the power demand of the consumers by itself.

The gensets are required to supply the power for all connected consumers at any time of operation. This applies both to load switching and load shedding.

The switching system's load management has to ensure that the gensets are never overloaded. Load surges should not exceed the maximum permissible load steps as specifically determined for each engine type under any circumstances (refer to Chapter "Load steps"). This applies both to load switching and load shedding. The required switching power of the respective consumers is of particular consideration here, not the nominal power (See also Chapter 15 "Isolated operation mode" and Chapter 16 "Load steps").

#### **1.1.2.2.1 Back-up power operation**

Taking due account of the appropriate additional measures required, the CHP plant can also be used to provide a back-up power supply, covering the demand for power in the event of a network power failure as per :

DIN VDE 0100-710 and DIN VDE 0100-560

DIN EN 50172 and DIN VDE 0100-718

The back-up power operation must be clarified and approved in each individual case. Not all gensets are capable of providing a back-up power supply as stated by the standards mentioned above. The engine-specific load steps must be adhered to.

The heat energy simultaneously produced by the CHP plant should, if possible, be utilized (e.g. for heating or refrigeration), for which purpose heat accumulators should be employed where necessary. When providing a back-up power supply, heat dissipation must be guaranteed under all circumstances, if necessary with the aid of dump cooling facilities and/or accumulators.



#### **1.1.2.2 Black start**

The black start is an emergency function of the gas gensets and should be used only for emergency situations. If a gas genset is "black-started", it starts without auxiliary drive power for prelubrication and cooling water pumps. The gas genset is started directly after the TEM demand contact has been closed. The cooling pumps start as soon as the auxiliary drive power supply is available. Furthermore, the gas genset will be started without prior leak monitoring of the gas control line.

The engines of the series TCG 2016 and TCG 2020 are capable of black-starting. The engines of the series TCG 2032 cannot be black-started. (See also Chapter 15.7).

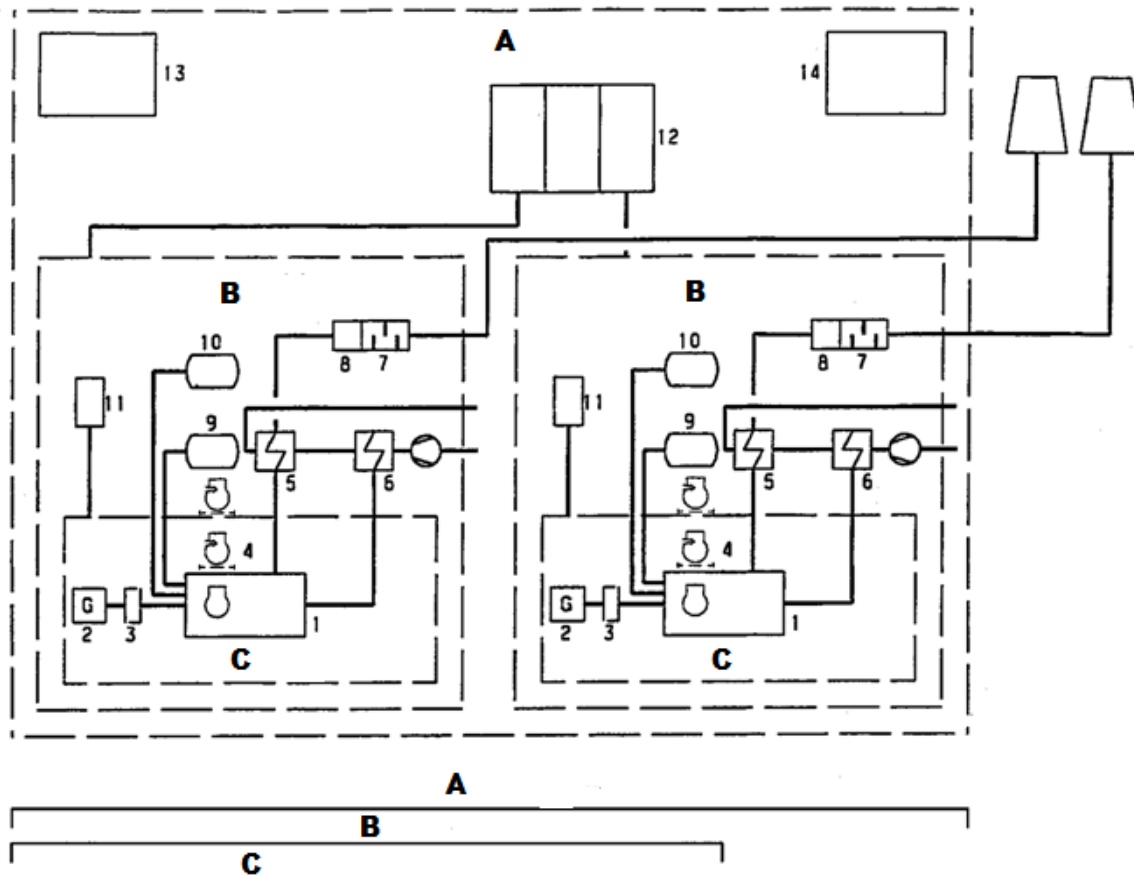
#### **1.1.3 Operation dependent on the availability of combustion gas**

With this type of operation, the lead factor is the available supply of combustion gas (e.g. landfill gas, sewage gas, biogas, etc.). In the case of multi-engine systems, gensets are switched on or off depending on the amount of gas available. For single engine systems, the engine power is adjusted to the available gas amount.

#### **1.1.4 Dual gas operation**

For special applications, the gas gensets can be equipped with two gases for the operation. If, for example, natural gas and sewage gas are available, it is possible to change over from sewage gas to natural gas if sewage gas is lacking. For the changeover between the two gases, the genset must be stopped.

**Fig. 1.1**  
**Definition and demarcation of CHP components as per DIN 6280-14**



- A Combined heat and power plant (CHP)
- B CHP set
- C CHP genset
- 1 Reciprocating pistons, internal combustion engine
- 2 Generator
- 3 Coupling and flexible mounting
- 4 Combustion air filter  
(optionally installed separately from the engine)
- 5 Exhaust heat exchanger
- 6 Cooling water heat exchanger
- 7 Exhaust silencers

- 8 Exhaust gas cleaning system
- 9 Fuel tank or gas supply
- 10 Lube oil supply
- 11 Monitoring system
- 12 Switchgear with control system
- 13 Air supply system
- 14 Exhaust air system



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Chapter 2

## **Genset output**

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## **2. Genset output**

To plan the size of the genset, it is necessary to determine the demand for electricity and heat on the basis of annual consumption curves.

### **2.1 Demand for heat**

The heat demand curve can be used to determine the size and number of gensets required for heat-led operation. However, with heat-led operation, it is essential to consider the generation and demand for electricity. The choice of operating mode may lead to negative feed and/or to power being drawn from the mains.

### **2.2 Demand for electricity**

The electricity demand curve is decisive in determining the demand for electricity in mains parallel operation. At the same time, it is necessary to investigate whether it is appropriate to split the total output between several gensets. For back-up power operation, in addition to the demand for electricity in mains parallel operation, the back-up power output must also be considered. A distinction must be drawn between "important" and "non-important" consumers and their permitted downtimes.

Not all consumers are connected or achieve their maximum current consumption simultaneously (simultaneity factor).

Some consumers purely consume real power, while others merely consume an apparent power output (power factor "cos phi"). Particular consumers, such as those with impact load characteristics or which make extreme demands in terms of constant voltage and frequency, must be taken into account.

Under special climatic mounting conditions (high altitude, high air temperatures and air humidity), the engine and generator are unable to produce their normal output (reduction in output as per ISO 8528-1, DIN VDE 0530 and DIN EN 60034).

### **2.3 Available fuel supply**

The genset output and number of gensets will be dependent on the available gas volume. The gensets must be operated only in the 50 – 100 % output range. For continuous operation, the output should be above 70%.

## 2.4 Performance data on the rating plates

In the case of a generator genset, the engine, generator and genset each have their own rating plate.

### 2.4.1 Rating plate of the engine

In the case of gas engines, the output SCN (continuous output, cannot be overloaded) is outlined according to DIN 3046-7. On the test bench, gas engines are run with natural gas. In the case of engines which are run with other types of gases in later operation, the output for the type of gas is additionally outlined on the rating plate. The type of gas is specified after the output description.

For example, the following outputs can be indicated on the rating plate:

SCN n: continuous output during operation with natural gas; n means natural gas; the output is run on the test bench.

SCN b: continuous output during operation with biogas; b means biogas

Further extensions may be:

m mine gas

s sewage gas

l landfill gas

### 2.4.2 Rating plate of the generator

The rating plate of the generator lists the apparent power of the specific type according to IEC 60034 and the power factor ( $\cos \Phi$ ) of the generator. The specification is given in kVA (Kilo Volt-Ampere), the power factor is dimensionless.

### 2.4.3 Rating plate of the genset

The electric nominal output of the genset is given on the rating plate. The name of the output category is outlined according to DIN 8528-1. The output is given in kW<sub>el</sub> (Kilowatt electric).

Gensets with gas engines are designed for continuous operation; therefore, the genset rating plate shows the power category COP (continuous power of the genset).



# **Power plants layout**

**Chapter 3**

## **CHP genset**

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### **3. CHP genset**

#### **3.1 Genset design**

Gensets comprise the following main components:

- Gas engine
- Generator
- Torsionally flexible coupling
- Base frame
- Flexible bearing elements

Engine and generator are linked by a torsionally flexible coupling and rigidly mounted to the base frame. The base frame is mounted to the foundation by flexible bearing elements.

All flexible connections for the operating media are installed at the genset. Auxiliary units such as prelubricators and lubricating oil level monitors are mounted to the base frame.

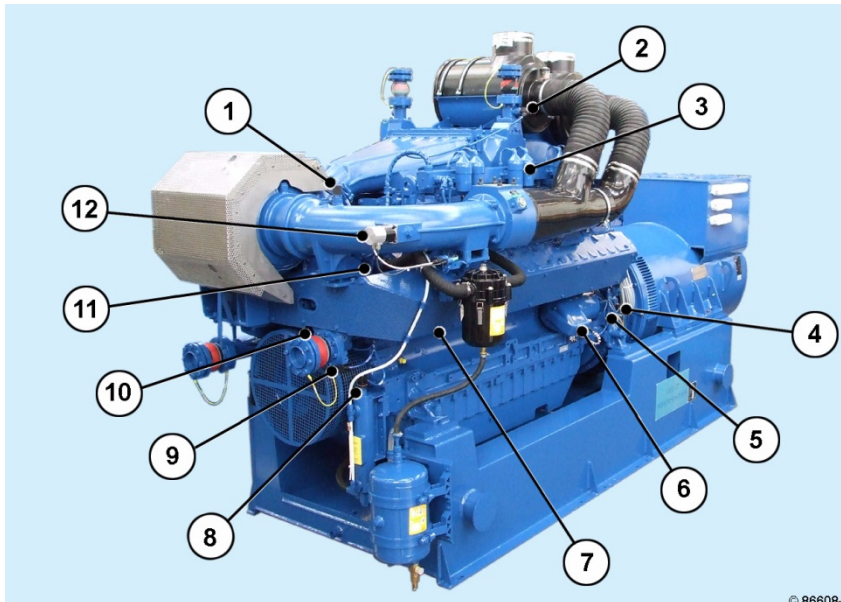
Preheating must be provided for every engine. Dependent on the design of the system, this may be installed either at the genset or in the system.

#### **3.2 Genset**

##### **3.2.1 Engine monitoring and cabling**

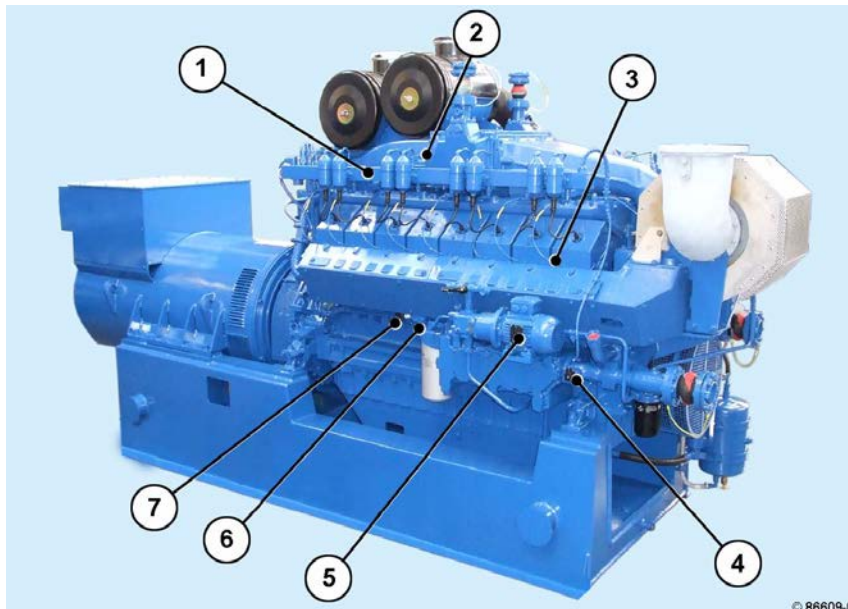
The gas engine is equipped with sensors for monitoring and control purposes. The sensors are wired to a multifunction rail at cylinder rows A and B. A bus cable runs from each multifunction rail to the TEM system (TEM see Chapter 14.1). At the engine, all parts needing to be grounded are connected to the copper rail. This rail must therefore be connected to the earthing system of the switchgear. An overview of the monitoring facilities is shown in the following engine drawings.

**Fig. 3.1a Engine TCG 2016 V08 C, V12 C and V16 C – Sensor arrangement**



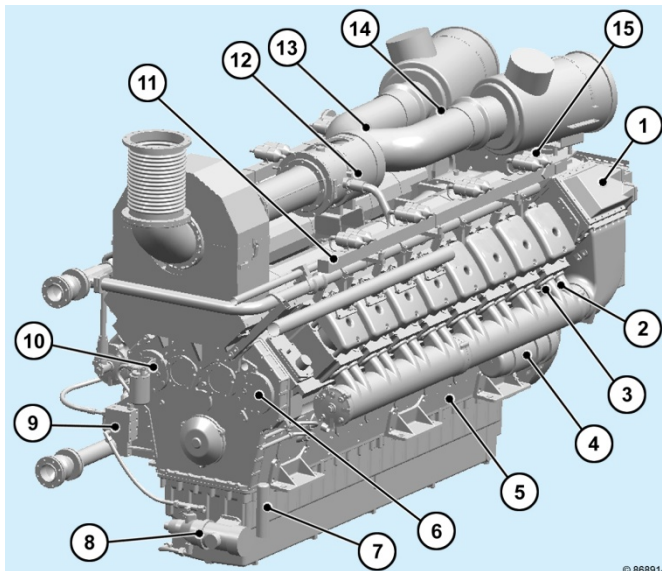
- 1 Mixture temperature sensor in front of turbocharger  
in the TEM system parameter intake air
- 2 Coolant temperature sensor (low-temperature circuit, inlet)
- 3 Ignition coil  
One ignition coil per cylinder
- 4 Flywheel pulse sensor –location depending on model
- 5 Starter relay
- 6 Starter
- 7 Knock sensor  
One sensor for every two cylinders
- 9 Coolant temperature sensor (engine outlet)
- 10 Camshaft sensor
- 11 Crankcase pressure sensor
- 13 Stepper motor gas-air mixer

**Fig. 3.1b Engine TCG 2016 V08 C, V12 C and V16 C – Sensor arrangement**



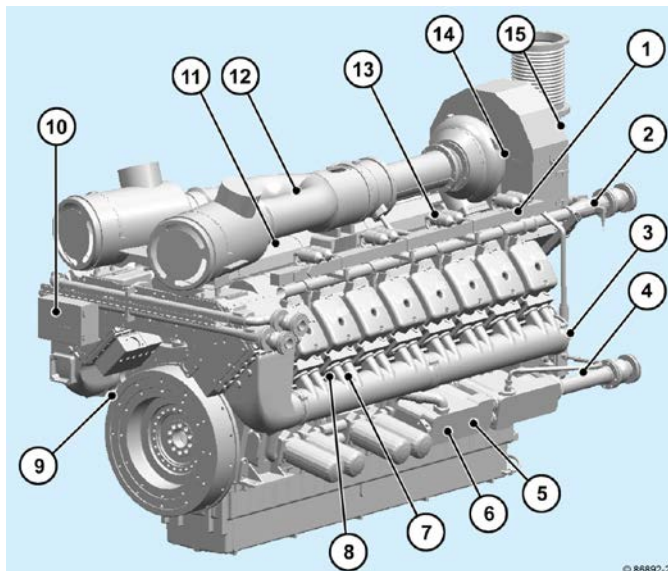
- 1 Multifunction rail cylinder row B
- 2 Charging mixture temperature sensor after mixture cooler in TEM system parameter receiver
- 3 Combustion chamber temperature sensor  
One sensor per cylinder
- 4 Coolant temperature sensor (high-temperature circuit inlet)
- 5 Prelubrication pump
- 6 Lube oil temperature sensor
- 7 Lube oil pressure sensor

Fig. 3.2a Engine TCG 2020 V12(K) and V16(K) – Sensor arrangement



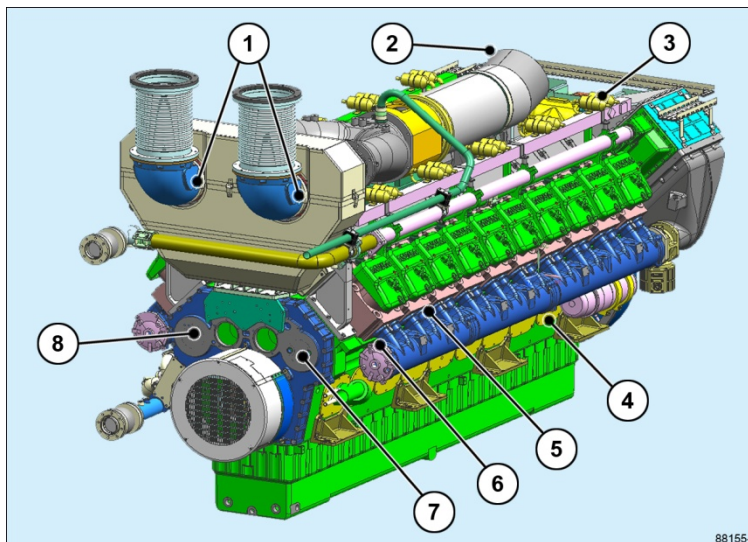
- 1 Coolant temperature sensor before mixture cooler
- 2 Knock sensor  
One sensor for every cylinder
- 3 Combustion chamber temperature sensor  
One sensor for every cylinder
- 4 Starter
- 5 Starter relay
- 6 Crankcase pressure sensor
- 7 Lubricating oil level sensor
- 8 Prelubrication pump
- 9 Lube oil pressure sensor
- 10 Camshaft sensor
- 11 Multifunction rail cylinder row A
- 12 Proximity switch gas-air mixer
- 13 Intake air temperature sensor  
V16 engine
- 14 Intake air temperature sensor  
V12 engine
- 15 Ignition coil  
One ignition coil for every cylinder

**Fig. 3.2b Engine TCG 2020 V12 and V16 – Sensor arrangement**



- 1 Multifunction rail cylinder row B
- 2 Coolant temperature sensor (engine outlet)
- 3 Mixture temperature sensor
- 4 Coolant temperature sensor (engine inlet)
- 5 Lube oil temperature sensor
- 6 Lube oil pressure sensor
- 7 Knock sensor  
One sensor for every cylinder
- 8 Combustion chamber temperature sensor  
One sensor for every cylinder
- 9 Flywheel pulse sensor
- 10 Ignition control unit
- 11 Actuator
- 12 Stepping motor gas-air mixer
- 13 Ignition coil  
One ignition coil for every cylinder
- 14 Exhaust turbocharger speed sensor
- 15 Exhaust turbocharger temperature sensor

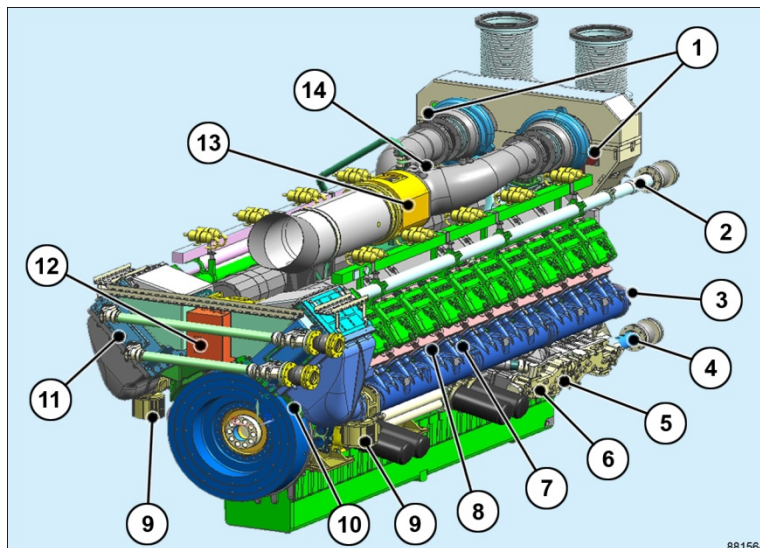
**Fig. 3.3a Engine TCG 2020 V20 – Sensor arrangement**



- 1 Exhaust turbocharger temperature sensor
- 2 Intake air temperature sensor
- 3 Ignition coil  
One ignition coil for every cylinder
- 4 Starter relay
- 5 Combustion chamber temperature sensor  
One sensor for every cylinder
- 6 Knock sensor  
One sensor for every cylinder
- 7 Crankcase pressure sensor
- 8 Camshaft sensor

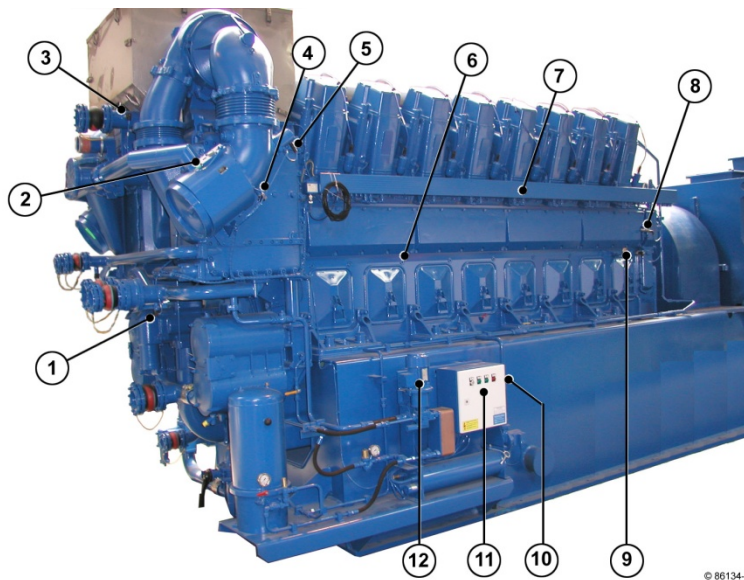


Fig. 3.3b Engine TCG 2020 V20 – Sensor arrangement



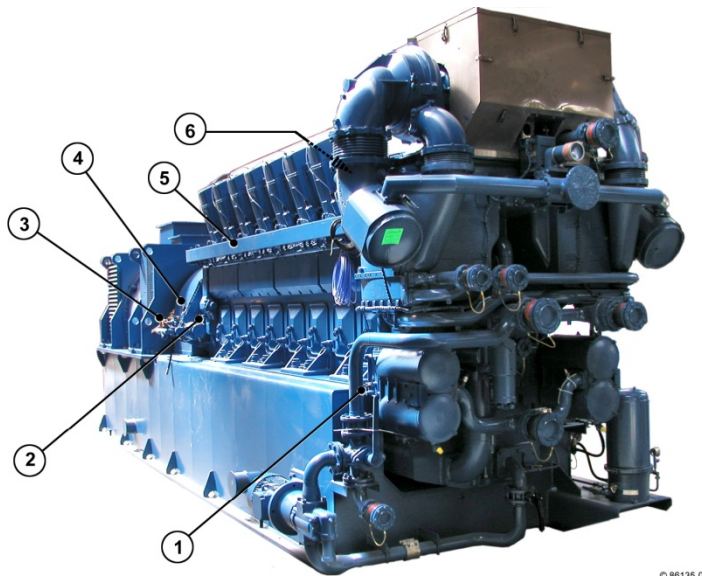
- 1 Exhaust turbocharger speed sensor
- 2 Coolant temperature sensor (engine outlet)
- 3 Mixture temperature sensor
- 4 Coolant temperature sensor (engine inlet)
- 5 Lube oil temperature sensor
- 6 Lube oil pressure sensor
- 7 Knock sensor  
One sensor for every cylinder
- 8 Combustion chamber temperature sensor  
One sensor for every cylinder
- 9 Actuator
- 10 Flywheel pulse sensor
- 11 Coolant temperature sensor before mixture cooler
- 12 Ignition control unit
- 13 Proximity switch gas-air mixer
- 14 Stepping motor gas-air mixer

**Fig. 3.4a Engine TCG 2032 V12 and V16 – Sensor arrangement**



- 1 Coolant temperature sensor (high-temperature circuit inlet)
- 2 Proximity switch gas-air mixer  
One switch for each gas-air mixer
- 3 Coolant temperature sensor (high-temperature circuit outlet)
- 4 Mixture temperature sensor  
One sensor for each gas-air mixer
- 5 Stepping motor gas-air mixer  
One stepping motor for each gas-air mixer
- 6 Depending on version – Base bearing temperature sensor
- 7 Multifunction rail cylinder row A
- 8 Camshaft sensor
- 9 Crankcase pressure sensor
- 10 Electric pump for preheating unit (coolant)
- 11 Electrical preheater  
for coolant and lubricating oil
- 12 Electric pump for preheating unit (lubricating oil)

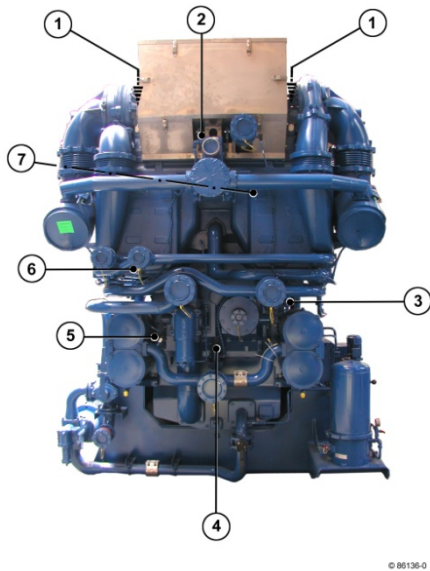
**Fig. 3.4b Engine TCG 2032 V12 and V16 – Sensor arrangement**



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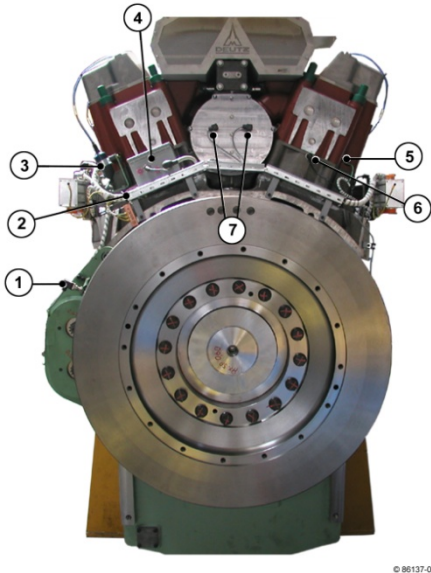
- 1 Lube oil temperature sensor
- 2 Start backup for engine turning device
- 3 Solenoid valve for compressed air starter
- 4 Flywheel sensor – installation location depending on version
- 5 Multifunction rail cylinder row B
- 6 Charging mixture temperature sensor  
One sensor each for A and B side  
V12 engine: Between cylinder A4 and A5 as well as before B6  
V16 engine: Between cylinder A6 and A7 as well as before B8

**Fig. 3.4c Engine TCG 2032 V12 and V16 – Sensor arrangement**



- 1 Exhaust turbocharger speed sensor  
One sensor for every exhaust turbocharger
- 2 Actuator
- 3 Coolant temperature sensor (high-temperature circuit inlet)
- 4 Lubricating oil level sensor
- 5 Lube oil pressure sensor  
(Lube oil pressure before lubricating oil filter)
- 6 Coolant temperature sensor (low-temperature circuit, inlet)
- 7 Charging mixture pressure sensor A side, mixture cooler – Depending on version

**Fig. 3.4d Engine TCG 2032 V12 and V16 – Sensor arrangement**



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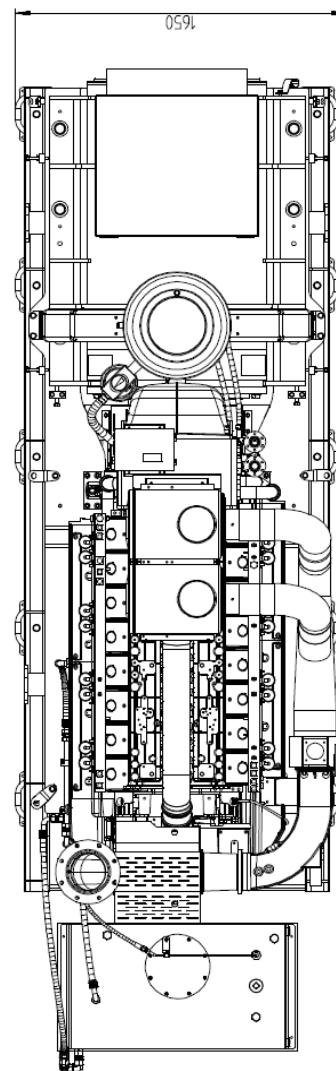
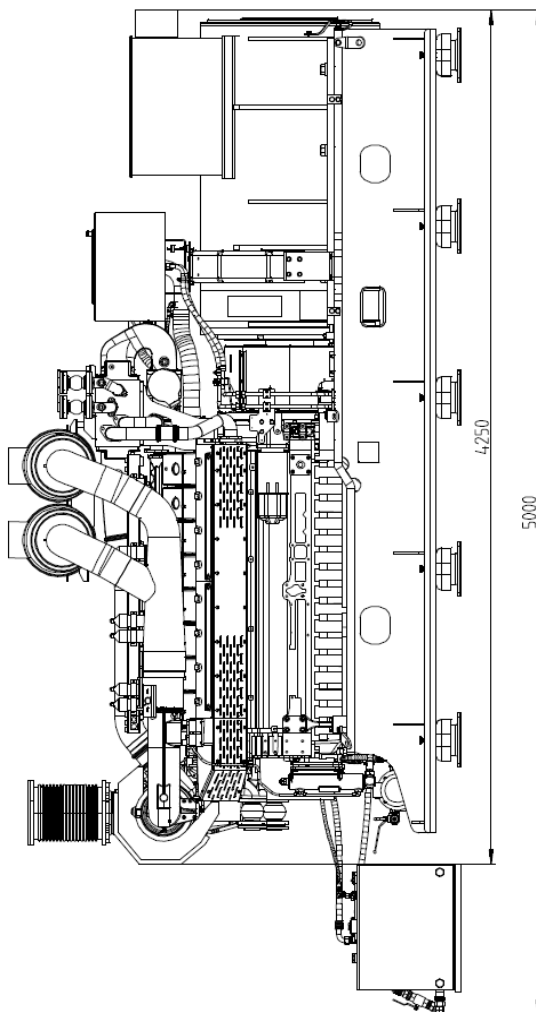
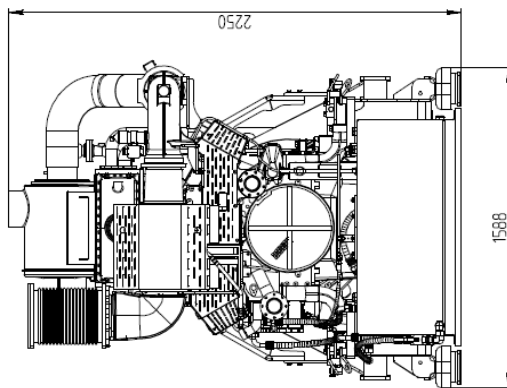
- 1 Flywheel sensor – installation location depending on version
- 2 Lube oil pressure sensor  
(Lube oil pressure after filter)
- 3 Ignition coil  
One ignition coil for every cylinder
- 4 Ignition control unit
- 5 Combustion chamber temperature sensor  
One sensor for every cylinder
- 6 Knock sensor  
One sensor for every cylinder
- 7 Charging mixture pressure sensor  
One sensor each for A and B side

### 3.2.2 Genset examples

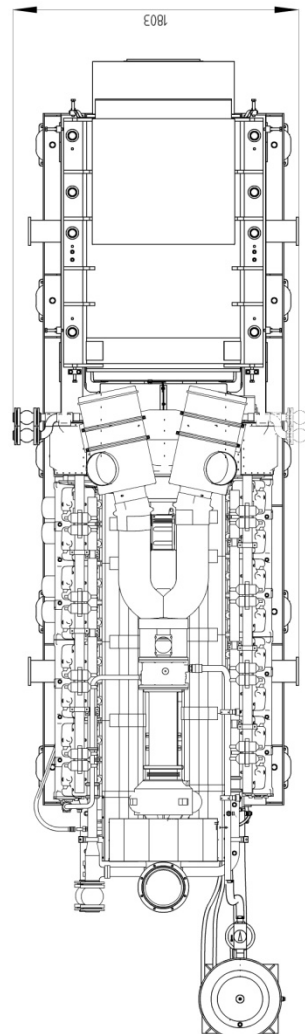
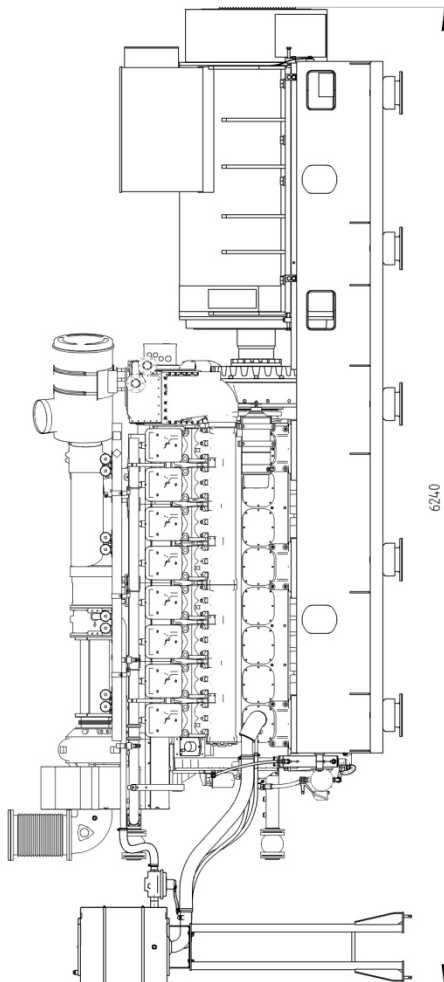
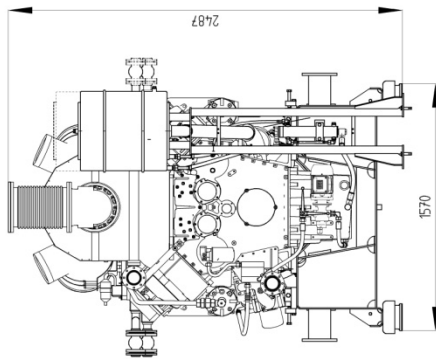
Figures 3.6 to 3.9 illustrate gensets with gas engines of the series 2016, 2020, 2032.

**Binding genset dimensions are contained in the contract-specific genset drawing.**

**Fig. 3.5 Engine TCG 2016 V16 C with Marelli generator MJB 450 MB 4**  
**Genset weight approx. 8450 kg (transport)**

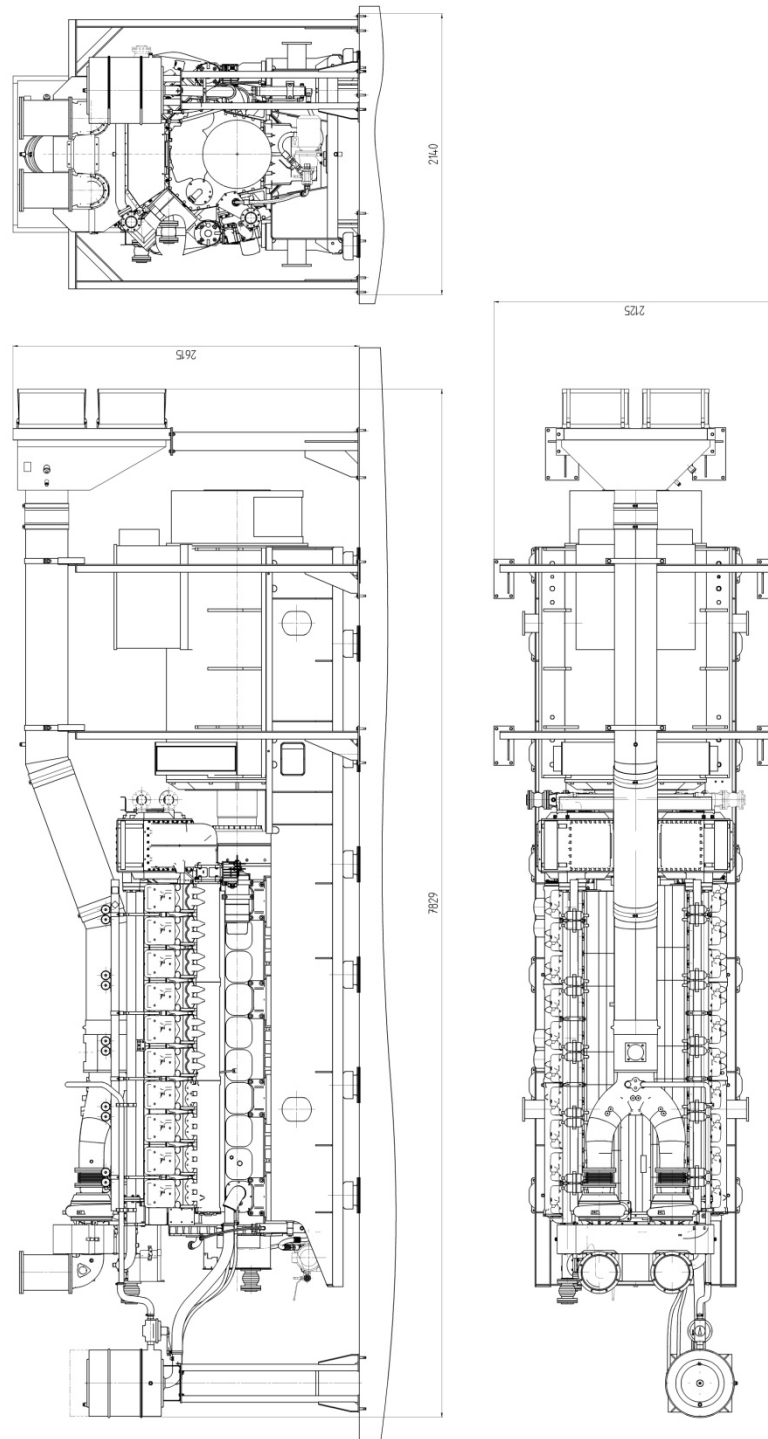


**Fig. 3.6 Engine TCG 2020 V16 with Marelli generator MJB 500 LA4**  
**Genset weight approx. 13320 kg (transport)**

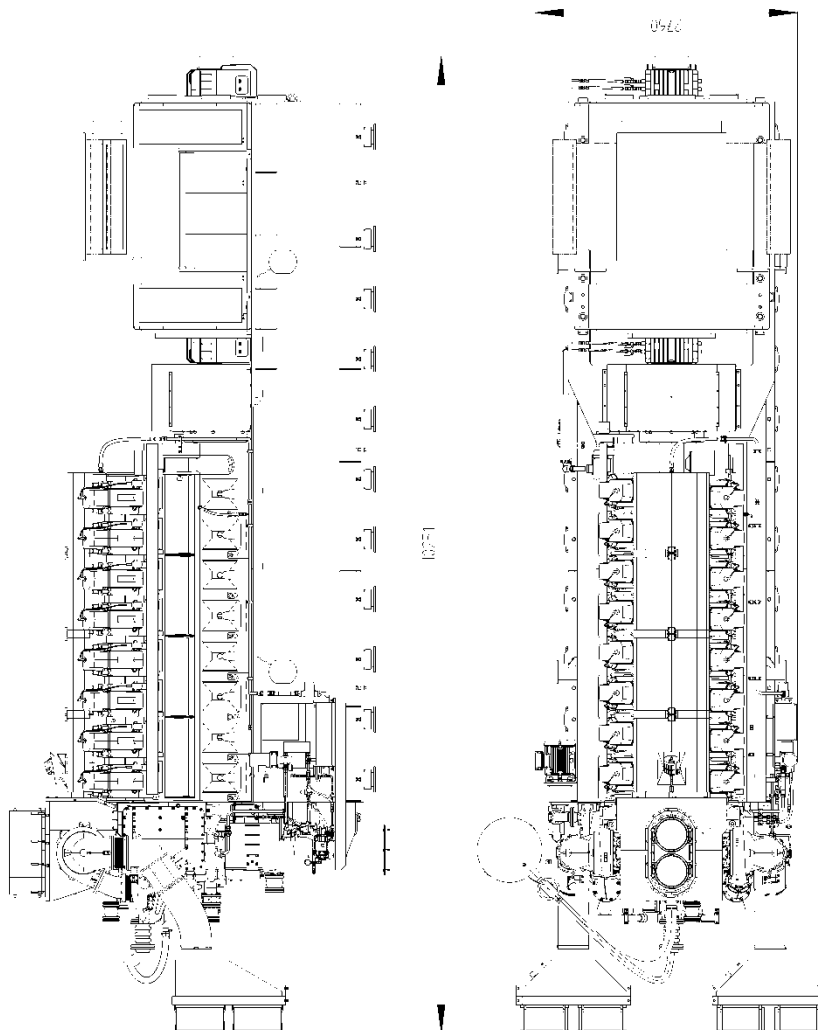
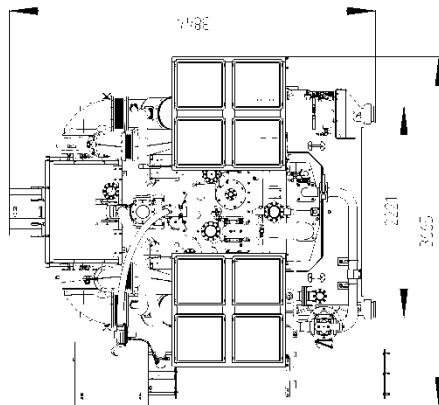




**Fig. 3.7 Engine TCG 2020 V20 with Marelli generator MJB 560 LB 4**  
**Genset weight approx. 17900 kg (transport)**



**Fig. 3.8 Engine TCG 2032 V16 with Marelli generator MJH 800 MC6**  
**Genset weight approx. 51400 kg (transport)**



### 3.3 Generators

#### 3.3.1 General

The types used as standard are brushless synchronous generators, which, depending on the application, may be suitable for mains parallel and/or back-up power operation.

Depending on output and the available mains supply, these may be 400 V to 690 V three-phase generators or 3 kV to 15 kV medium-voltage generators.

The efficiency of the generators dependent upon size and power factor value ( $\cos \phi$ ) is between 95.0 % and 97.8 %.

Thus, for example, a 494 kVA generator with a power factor of 0.8 has an efficiency level of 95.5 % and a 5336 kVA medium-voltage generator with a power factor of 0.8 has an efficiency level of 97.2 %. If the generator is operated at a power factor of 1, efficiency is increased by approx 1-1.5 %.

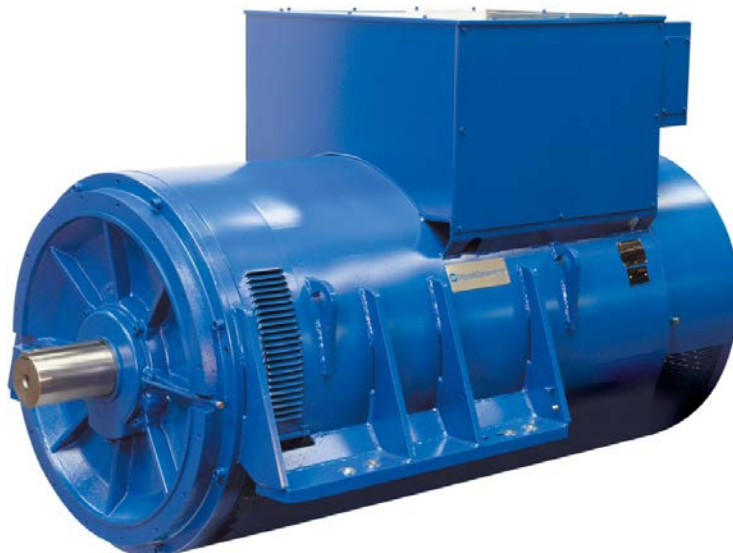
As per DIN VDE 0530 / DIN EN 60034, the generators are designed for an ambient temperature of 40° C and an installation altitude of 1000 m. At higher ambient temperatures or higher altitude, the output must be reduced in accordance with the manufacturer's specifications.

These generators can operate as standard in a power factor range of 0.8 - 1 inductive (lagging). Thus, in the case of mains parallel operation, it is possible to improve the mains handover power factor in the event that the generators are to be used as "phase shifters".

Generators must be specially designed for use in the capacitive range! There are different country-specific regulations for static and dynamic mains support, which have to be considered when designing the gas engine gensets.

In back-up power operation, the max. permissible unbalanced load for the generator must be taken into account. (Dependent upon generator output and manufacturer, 30 % between maximum and minimum phase current)

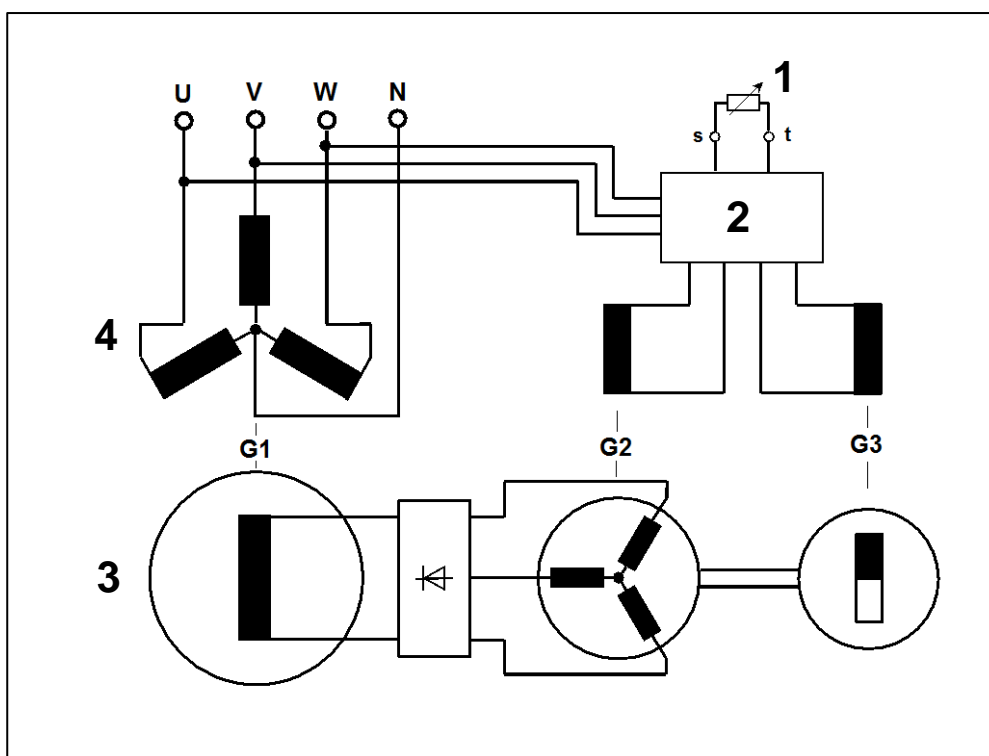
**Fig. 3.9 Generator**



### 3.3.2 Generator voltage regulation

The voltage regulator keeps the generator voltage constant. The voltage regulator is generally either installed in the generator's terminal box or in the switchgear. The principle function of the voltage regulator is shown in Figure 3.10.

**Fig. 3.10 Generator voltage regulation**



- |    |                          |
|----|--------------------------|
| 1  | Setpoint adjuster        |
| 2  | Voltage regulator        |
| 3  | Rotor                    |
| 4  | Stator                   |
| G1 | Three-phase main machine |
| G2 | Three-phase exciter      |
| G3 | Auxiliary exciter        |

### **3.3.2.1 Basic function of the voltage regulator**

The power supply of the voltage regulator is provided from the auxiliary exciter G3. The brushless three-phase exciter G2 receives its voltage supply from the actuating element of the voltage regulator. The voltage delivered from the three-phase rotor winding of the exciter G2 is rectified and supplied as direct current to the rotor of the generator G1. In order to obtain a constant voltage level at the generator terminals with alternating load, it is necessary to adjust the current supply to the rotor accordingly. This function is assumed by the voltage regulator.

### **3.3.2.2 Setpoint adjustment of the voltage regulator**

The inputs to the voltage regulator are the voltage setpoint from the setpoint adjuster and the actual generator voltage measured at the terminals U,V and W. The readjustment of the generator voltage is done via adjustment of the current supply to the rotor.

The adjustment of the voltage setpoint has to be done on site with regard to the voltage level at the local conditions. The range for the voltage adjustment is normally within 5% to 10% of the generator's nominal voltage.

### **3.3.3 Generator protection**

To protect the generators, monitoring facilities as per ISO 8528 must be employed. Those monitoring facilities are not included in the TEM system.

#### **3.3.3.1 Monitoring facilities for generators as per ISO 8528, Part 4**

The following generator monitoring facilities are absolutely essential and must be provided in the switchgear:

- Protection in case of short circuit
- Protection in case of overload

The following protection facilities are urgently recommended:

- Protection in case of time-delayed overcurrent
- Protection in case of voltage-related overcurrent
- Protection in case of directionally dependent overcurrent
- Reverse power protection
- Mains isolation facility
- Reactive current restriction
- Differential current protection

Also, the following protection facilities are recommended:

- System earth fault protection
- Stator earth fault protection
- Unbalanced load protection

### **3.3.4 Earthing**

The generator is connected to the base frame by an earthing wire. The earthing connection of the genset must be connected to the earthing system for the CHP system.

The local power supply company rules or safety regulations must be complied with in order to ensure that the genset earthing is correct.

# **Power plants layout**

**Chapter 4**

## **Requirements for genset installation**

**06-2014**

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## **4. Requirements for genset installation**

### **4.1 Genset room**

Having carefully selected and established the output of the genset, there are a series of preconditions which must be fulfilled by the client to achieve a safe, low-maintenance, and fault-free operation.

The most important questions associated with the setup and installation of the genset must therefore be clarified at the time when buildings intended to house the energy generation units are being planned. Alterations and special solutions introduced at a later date are generally expensive and often unsatisfactory. Right from the start, consideration should be given to possible future expansion.

#### **4.1.1 Site**

The planning process begins with the selection of the site at which to set up the genset. In order to minimize losses in the transmission of energy to the consumer, it makes practical sense to arrange the genset in the vicinity of the consumer. However, requirements in terms of noise and vibration often lead to gensets being set up far away from residential properties.

Where a building is reserved for energy generation, the problems of ventilation, vibration damping, fuel supplies and storage, and also of bringing in and providing access to the genset are generally easier to resolve.

Genset rooms inside large buildings such as e.g. department stores, hospitals and administration buildings should be located as near as possible to an outside wall, so there is no difficulty in drawing in and discharging air for cooling and ventilation. The genset room can be designed at ground level, below ground, or in the case of smaller gensets, even on one of the upper floors.

The choice of building materials must take account of the need for sound and vibration damping.

#### **4.1.2 Requirements for the genset room**

The genset room should be of adequate size. Aside from the added complication of operation and maintenance, the problem of ventilation in small rooms is also not easy to resolve.

For TCG/TCD 2016 and 2020, a clear space of approx. 1 m in width should, under all circumstances, be allowed for all round the genset, increasing to 2 m for bigger engines. Care must be taken to ensure that the starter batteries are installed as close as possible to the electric starter. For installations with engines TCG 2032, it is necessary to provide a free area of 2 meters by 5 meters suitable for acceptance of heavy weights. Preferably, this area should be arranged close to the engine in order to achieve access by the same crane both for the pre-assembly area and the engine itself. Furthermore, the size of the room will be determined by the other components to be installed, such as e.g. heat utilization unit, switchgear, gas control line, fuel tank, lube oil tank, batteries, exhaust pipe and silencer. The silencers for the inlet and exhaust air

also require enough available room. It is essential to design large enough openings to bring in the genset, and to ventilate the system (see Chapter 5, Engine room ventilation).

No genset room should be without permanently installed lifting gear (crane), the load-bearing capacity of which corresponds to the heaviest single item in the room. It must, however, in all cases be guaranteed that, when carrying out maintenance work, dependent on the engine type, e.g. pistons, con-rods, cylinder heads or even a complete engine can be lifted. Both assembly and subsequent maintenance can then be carried out more quickly and more practically.

The genset room should be of sufficient height to allow pistons and connecting rods to be withdrawn upwards, taking into account the lifting gear. The size of the room must permit work to be carried out unobstructed at all points around the genset and there must be space to park individual genset components and spares.

Together with the planning of the engine room, the elastic mounting, the design of the foundation block, the pipe and cable work must be clarified. Also to be considered in the early stages of planning is the implementation of any special noise protection and anti-vibration insulation measures.

For smaller installations, the genset and the switchgear can generally be set up in one room. For larger installations, it may be more practical to install the switchgear in a separate, sound-proofed operating room.

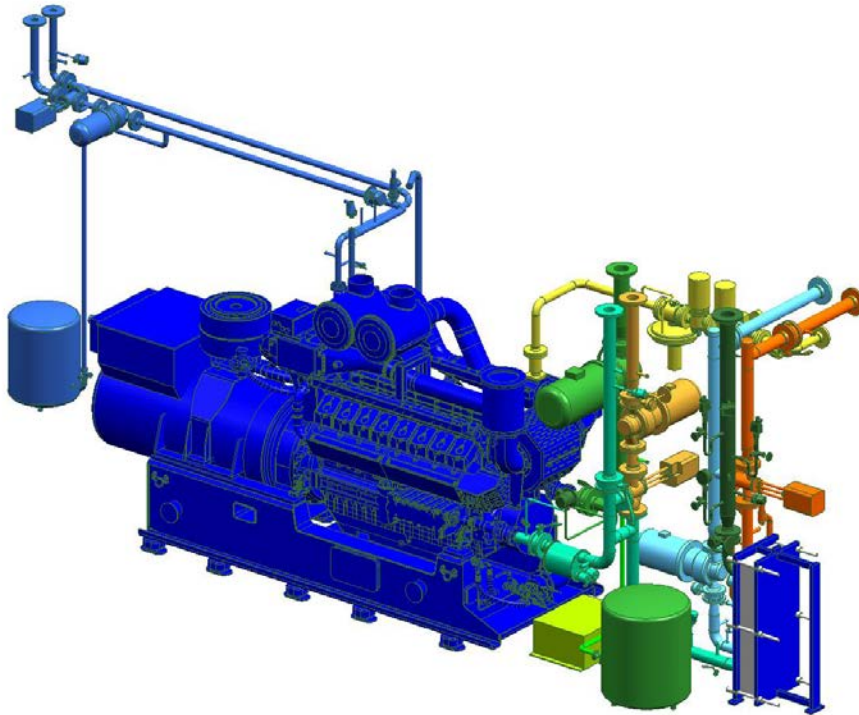
When planning the genset room, consideration must also be given to the transport route, so that if necessary, an engine or generator can be dismantled and reinstalled (floor loading and space available).

The example in figure 4.1 illustrates a practical and proven genset installation.

If access to the genset and its components is heavily restricted due to the engine room not being designed large enough, the manufacturer may claim additional costs when performing maintenance or repair work within the scope of the manufacturer's warranty.

When operating and when performing maintenance work on the genset, lubricating oil and/or coolant can enter the genset room under certain circumstances. Restraining devices must be provided in the genset room drainage system which reliably prevent environmental damage from these materials.

**Fig. 4.1 Typical installation TCG 2016 V16 C**



Before detailed planning work starts, the manufacturer would also assist prospective clients with further documentation on standard installations. For major planning tasks, construction or draft construction drawings are requested by us.

## **4.2 Foundation and vibration damping**

In the case of gensets with piston engines, gravity forces and moments of inertia cannot, in all cases, be completely balanced. The transmission to the foundation of the vibration and noise thus created can be significantly reduced by the use of elastic mountings. When installing gensets, the elastic mounting elements must therefore always be provided between the base frame and the foundation block.

### **4.2.1 Foundation block**

For the base of the foundation, which must be implemented with special care, it is recommended that a soil investigation be carried out by an expert. The costs for this bear no relation to the expense involved in the subsequent work required, if, for example, it is found that vibration is being transmitted to the surrounding area.

There must be no groundwater veins either beneath or in the vicinity of the foundation block, as these can transmit vibrations over very long distances. This also applies to a high groundwater level which leads to

stronger transmission of vibration than occurs in dry ground. Depending on local conditions, the foundation block may have to be set on a sole plate or pilework.

Sinking and basing the foundation are in any case the responsibility of the construction company or architect. The latter must assess the load-bearing capacity of the soil and determine the solidity of the foundation block by specifying the requisite concrete mix and reinforcements to suit the local conditions.

For calculation purposes, clients will be provided with data on the foundation load imposed by the genset and the natural frequencies of the elastic bearings.

With the reasons mentioned above the foundation block as built should not have any contact with the foundation walls of the building or with the floor. The gap between the foundation block and the floor can be sealed with an elastic material. To accept the elastic bearing elements, the surface of the foundation must be horizontal and disked, without being smoothed with a trowel. The foundation surface must be flat to a tolerance of max.  $\pm 2$  mm. It is not permissible to mount the genset on tiles or pavement.

#### **4.2.2 Elastic support**

In order to insulate the genset as far as possible from the foundation in terms of vibration and structure-borne noise, steel spring bearing elements are used. These bearing elements reduce the transmission of dynamic forces to the foundation. The insulation of low frequencies in buildings is of great importance. This is also achieved with a soft steel spring bearing support. Structure-borne noise insulation is guaranteed by means of reflection from the base plate of the bearing, thanks to the insulation effect of the steel / rubber plate arrangement.

The elastic support must be recalculated for each application. The natural frequency of the system constituted by the genset / elastic support must be sufficiently far below the operating speed of the genset. Insulation levels of approx. 88 - 94 % are achieved with the bearing elements used.

The spring elements which are used in gensets can be adjusted in height over a certain range. They have to be properly adjusted; meaning the load on each element has to be equal. A wrong setting of the spring elements leads to their destruction on a long term basis and the oscillations cannot be isolated anymore. Spring elements can compensate unevenness of the foundation only to some extent. Due to an uneven load, too great an unevenness of the foundation and a wrong setting of the spring elements lead to the deformation of the genset's base frame. As a consequence, the alignment between the generator and the engine is no longer efficient. This can result in an incalculable destruction of the components.

#### **4.2.3 Assessing vibrations**

DIN ISO 8528 - 9 must be applied for gensets. This standard deals with the measurement and evaluation of the mechanical vibrations in electricity generating units with reciprocating piston combustion engines.

#### **4.2.4 Cable and pipe ducts**

Cooling water and exhaust pipes can be laid in ducts beneath the floor. The requisite dimensions must be adapted to the size of the pipes and to local conditions.

In general, care must be taken to ensure that ducts for pipes and ducts for cables are implemented separately from one another, whereby a further distinction must be drawn between power cables, control cables and signal cables. Ducts are laid with a fall leading away from the foundation block, with drains fitted with oil separators provided at the lowest points. The ducts can be covered with treadplate or grilles. Ducts and covers must always be provided by the client.

#### **4.3 Noise issues**

Since the acoustic requirements imposed by various laws and regulations on the installation of gensets with combustion engines are constantly increasing, a brief reference is appropriate here to the contexts and possible solutions to noise problems.

Noise sources mainly include the combustion noise of the engine, mechanical engine noises and the air intake and exhaust noises from the engine. The fans, pumps and other auxiliary drives can also be the cause of nuisance noise.

Likewise, excessive air speeds can cause noise (see Chapter 5.5, Planning notes).

There is nothing that effective resources can do to reduce the source of noise themselves. Thus most measures to mitigate noise are directed towards reducing the transmission of noise outside of the genset room.

### 4.3.1 Acoustic dependencies

Noise is made up of pressure waves of varying frequencies. All measurements of noise are thus frequency dependent pressure measurements. Lower-frequency noises are more easily tolerated by human beings than those of higher frequencies. Sound waves above 16,000 - 20,000 Hertz, on the other hand, are generally beyond detection by the human ear.

The need to compare the loudness of sound events at different locations has led to the development of objective measuring procedures. Assessments are conducted in accordance with specific frequency curves, as defined in DIN EN 61672-1 and DIN EN 61672-2. These are assessment curves A, B, C and D (Table 4.1). The assessment curves replicate in a somewhat simplified manner the frequency response of the ear to narrow-band noises. Curve A applies to the low-volume range, Curves B and C cover the range of loud and very loud noises, whilst D applies to aircraft noise.

**Table 4.1**

Frequency	Assessment curve			
Hz	A dB	B dB	C dB	D dB
31.5	-39.4	-17.1	-3.0	-16.5
63	-26.2	-9.3	-0.8	-11.0
125	-16.1	-4.2	-0.2	-6.0
250	-8.6	-1.3	0.0	-2.0
500	-3.2	-0.3	0.0	0.0
1000	0.0	0.0	0.0	0.0
2000	1.2	-0.1	-0.2	8.0
4000	1.0	-0.7	-0.8	11.0
8000	-1.1	-2.9	-3.0	6.0

Engine noises are normally assessed in dB (A).

A measured value at 125 Hz is for example perceived as 16.1 dB quieter than the same value at 1000 Hz.

The strength of the noise is dependent on the range at which it is measured and on the installation site.

When measured a short distance from the source, the sound pressure level is higher, and at long distance it is lower. This reduction in sound level is referred to as dispersion damping.

**For point sources, the following applies:**

$$L_{(r2)} = L_{(r1)} - 10 \log \left( \frac{r2}{r1} \right)^2$$

L(r1) = sound pressure level 1

L(r2) = sound pressure level 2

r1 = distance 1

r2 = distance 2

**Example:**

$$L_{(r2)} = 70 - 10 \log \left( \frac{20}{10} \right)^2 = 64 \text{ dB}$$

L(r1) = 70 dB

r1 = 10 m

r2 = 20 m

As the distance doubles, the sound pressure level falls by 6 dB.

For installations comprising several gensets, the total noise level may be determined according to the laws of acoustics:

$$L_{\Sigma} = 10 \log \sum_{i=1}^n 10^{\frac{L_i}{10}}$$

$L_{\Sigma}$  = total level

$L_i$  = individual level

**Example:**

$$L_{\Sigma} = 10 \log \left( 10^{\frac{70,5}{10}} + 10^{\frac{71,5}{10}} + 10^{\frac{72,5}{10}} + 10^{\frac{75,5}{10}} + 10^{\frac{77,0}{10}} \right) = 81,1 \text{ dB}$$

$L_1 = 70.5 \text{ dB}$     $L_2 = 71.5 \text{ dB}$     $L_3 = 72.5 \text{ dB}$

$L_4 = 75.5 \text{ dB}$     $L_5 = 77.0 \text{ dB}$

In simplified terms, when adding  $n$  equal levels  $L$ , the following applies:

$$L_{\Sigma} = L + 10 \log n$$

When 2 equal sound levels are added, the level rises by 3 dB.

Where a genset is erected in a closed room, the noise is greater than in the open air as a result of the impeded dispersal of the noise. In small rooms with no acoustic material, the noise distribution is equal almost everywhere.

Large rooms with sound-absorbent walls offer acoustic benefits; tiles or similar construction materials should be avoided.

#### 4.3.2 Possible means of mitigating noise

Normal wall thicknesses of 24 cm or 36 cm damp the noise coming from within by 40 to 50 dB. Nevertheless, silencer sections 2 to 3 m in length must be provided for the air inlet and exhaust ducts, with approx. 40 dB noise reduction. Taking into account the volume of cooling air (see Chapter 5, Machine room ventilation) in the silencer section, the air speed should not exceed approx. 8 m/s on the delivery side and approx. 6 m/s on the extraction side.

If acoustic materials such as sound insulating panels are installed in the genset room, the noise level can be reduced by approx. 3 dB, and indeed at considerable expense even by approx. 10 dB. Particular care should be taken to control the exhaust noise. With suitable silencers, reductions in noise levels of up to approx. 60 dB can be achieved here.

Questions of sound insulation can only be solved on an individual basis, as they are highly dependent on local circumstances. By way of assistance, the manufacturer provides octave analyses of exhaust gas and engine noises.

Sound insulation measures should be designed in collaboration with specialist firms.

Such measures might, for example, include :

- Exhaust silencing with the aid of reflection silencers, absorption silencers, active sound deadening
- Installing the genset so as to insulate against structure-borne noise
- Arrangement of absorption baffles for the genset room air inlet and outlet openings
- Housing the genset inside a sound-insulating enclosure
- Fitting the engine room with sound insulation and installing a floating floor (tasks for specialist firms).



No fiber materials (e.g. Heraklit) may be used to clad the interior of the room. Vibrations in the air cause particles to be released which then block the air filters and can even destroy the engine.

When sound-proofing the building, it is necessary to consider not only the walls but also the windows, doors and so on.

Technical sound-proofing considerations should also extend to additional sound sources such as auxiliary drives or horizontal-type radiators which are located outside of the engine room. Also gas control lines, pre-pressure control lines or zero-pressure control lines, which are installed outside the engine room or outside a sound capsule, can represent an additional noise source and must be considered in the technical sound design.

### 4.3.3 Noise data in genset data sheets

In the genset data sheets, the noise values for airborne noise and exhaust noise are specified as sound power levels. There are third octave spectra for the airborne noise and octave spectra for the exhaust noise. The specified levels in the third octave and octave bands are linear levels, meaning that no correction was made according to one of the assessment curves A, B, C and D. The overall noise levels are specified as total levels with an A assessment of the individual levels. In Table 4.2, the correction values are listed according to assessment A, B, C and D for the third octave bands.

Fig. 4.2 Noise data for a TCG 2020 V12

Frequency band f [Hz]	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k	6.3k	8k	10k	12.5k	16k	L <sub>wa</sub> [dB(A)]	S [m <sup>2</sup> ]
<b>Air-borne noise</b> <sup>4)</sup> L <sub>W,Tert</sub> [dB(lin)]	94	95	98	100	106	109	108	109	106	115	115	115	109	110	109	109	109	108	108	108	107	109	103	102	114	107	101	104	98	121	114
<b>Exhaust noise</b> <sup>5)</sup> L <sub>W,Octave</sub> [dB(lin)]				128			135			134			131			123			122			120			119					132	15,5

4) DIN EN ISO 3746      5) DIN 45635-11 Appendix A (±3 dB)      L<sub>w</sub>: Sound power level      S: Area of measurement surface (S<sub>0</sub>=1m<sup>2</sup>)

Tab. 4.2 Correction values for the third octave bands according to curves A,B,C and D

Frequency	Assessment curve			
	A dB	B dB	C dB	D dB
25	-44.7	-20.4	-4.4	-18.5
31.5	-39.4	-17.1	-3.0	-16.5
40	-34.6	-14.2	-2.0	-14.5
50	-30.2	-11.6	-1.3	-12.5
63	-26.2	-9.3	-0.8	-11.0
80	-22.5	-7.4	-0.5	-9.0
100	-19.1	-5.6	-0.3	-7.5
125	-16.1	-4.2	-0.2	-6.0
160	-13.4	-3.0	-0.1	-4.5
200	-10.9	-2.0	0.0	-3.0
250	-8.6	-1.3	0.0	-2.0
315	-6.6	-0.8	0.0	-1.0
400	-4.8	-0.5	0.0	-0.5
500	-3.2	-0.3	0.0	0.0
630	-1.9	-0.1	0.0	0.0
800	-0.8	0.0	0.0	0.0
1000	+0.0	0.0	0.0	0.0
1250	+0.6	0.0	0.0	+2.0
1600	+1.0	0.0	-0.1	+5.5
2000	+1.2	-0.1	-0.2	8.0
2500	+1.3	-0.2	-0.3	+10.0
3150	+1.2	-0.4	-0.5	+11.0
4000	+1.0	-0.7	-0.8	11.0
5000	+0.5	-1.2	-1.3	+10.0
6300	-0.1	-1.9	-2.0	+8.5
8000	-1.1	-2.9	-3.0	+6.0
10000	-2.5	-4.3	-4.4	+3.0

#### 4.3.3.1 Conversion of sound power levels into sound pressure levels

The sound power is of a size that is independent on the distance and room and is suitable as a starting point for all technical sound calculations. It is not directly measurable and is established via specified measuring procedures.

The sound power level  $L_W$  is the specified technical sound size for a sound source. Contrary to the sound pressure level  $L_p$ , the sound power level  $L_W$  is completely independent on the sound field; in other words, it is independent on the size of the room and the distance to the source. The emitted sound power of a sound source is determined here by the measurement of the sound pressure at several points of a closed measuring surface  $S$ . The sound power of a source is calculated using the sound pressures measured on the defined cover surface. The sound pressure levels are calculated at different distances to the sound source using the established sound power.

The following correlation applies to the sound pressure level at a distance of  $x$  from the sound source:

$$L_p = L_W - 10 \cdot \log (S/S_0) \text{ [dB]}$$

The following results from specification with A-assessed levels:

$$L_{pA} = L_{WA} - 10 \cdot \log (S/S_0) \text{ [dB(A)]}$$

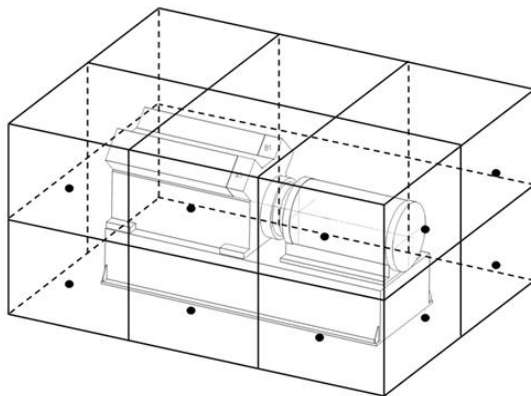
The following apply here:

$L_p$	Sound pressure level, linear (without assessment)
$L_{pA}$	Sound pressure level, assessment according to curve A
$L_W$	Sound power level, linear (without assessment)
$L_{WA}$	Sound power level, assessment according to curve A
$S$	Measuring surface at a distance of $x$ to the sound source
$S_0$	Reference surface, always $1\text{m}^2$

#### 4.3.3.2 Measuring surfaces for the genset

When determining the sound power level for the genset, a cuboid measuring surface at a distance of one meter from the genset is implied, see Fig. 4.3. The measuring surface is divided into a grid with a measuring point in the center of each individual grid surface. This procedure corresponds to DIN EN ISO 3476.

Fig. 4.3 Cuboid measuring surface for the genset



#### 4.3.3.3 Measuring surfaces for the exhaust sound

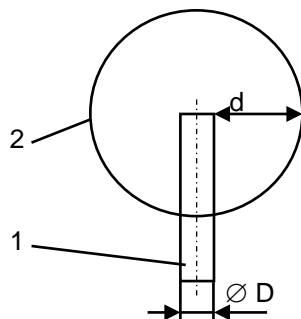
With exhaust sound, a spherical measuring surface at a distance of one meter from the outer edge of the exhaust pipe is implied. The measuring surface is calculated with the equation:

$$S = 4 * \pi * (D/2 + d)^2 \text{ [m}^2\text{]}$$

The following apply here:

S	measuring surface [m <sup>2</sup> ]
D	Diameter of the exhaust pipe [m]
d	Measurement distance [1 m]

Fig. 4.4 Spherical measuring surface for the exhaust gas



1	Exhaust pipe
2	Measuring surface S

#### 4.3.3.4 Examples of conversion sound power level – sound pressure level

Example 1:

How high is the sound pressure level for a genset TCG 2020 V12 at a 1 meter and 10 meter distance?

The sound power level of the genset is specified in the data sheet as 121 dB(A).

The measuring surface S at a 1 meter distance is specified in the data sheet as 114 m<sup>2</sup>.

The basic dimensions of a TCG 2020 V12 genset are:

Length L	[m]	5.7
Width W	[m]	2.1
Height H	[m]	2.5

An equivalent cuboid at a distance of 10 m has the dimensions:

Length L	[m]	5.7 + 2*10
Width W	[m]	2.1 + 2*10
Height H	[m]	2.5 + 10

This results in a measuring surface S of approx. 1763 m<sup>2</sup> at a distance of 10 meters.

The following calculations are obtained with the equation mentioned above:

Sound pressure level at a 1 meter distance:

$$L_{pA} = L_{WA} - 10 * \log (S/S_0)$$

$$L_{pA} = 121 - 10 * \log (114/1)$$

$$L_{pA} = 121 - 10 * \log 114 = 121 - 10 * 2.06$$

$$L_{pA} = 100.4 \text{ dB(A)}$$

Sound pressure level at a 10 meter distance:

$$L_{pA} = L_{WA} - 10 * \log (S/S_0)$$

$$L_{pA} = 121 - 10 * \log (1763/1)$$

$$L_{pA} = 121 - 10 * \log 1763 = 121 - 10 * 3.25$$

$$L_{pA} = 88.6 \text{ dB(A)}$$

Example 2:

How high is the exhaust sound pressure level for a genset TCG 2020 V12 at a 1 meter and 10 meter distance from the exhaust outlet?

The sound power level for the exhaust gas is specified in the data sheet as 132 dB(A).

The reference surface S for a spherical surface with a radius of 1 m is specified in the data sheet as 15.5 m<sup>2</sup>.

The surface S of a sphere with a 10 meter radius is 1257 m<sup>2</sup>:

The following calculations are obtained with the equation mentioned above:

Sound pressure level at a 1 meter distance:

$$L_{pA} = L_{WA} - 10 * \log (S/S_0)$$

$$L_{pA} = 132 - 10 * \log (15.5/1)$$

$$L_{pA} = 132 - 10 * \log 15.5 = 132 - 10 * 1.19$$

$$L_{pA} = 120.1 \text{ dB(A)}$$

Sound pressure level at a 10 meter distance:

$$L_{pA} = L_{WA} - 10 * \log (S/S_0)$$

$$L_{pA} = 132 - 10 * \log (1257/1)$$

$$L_{pA} = 132 - 10 * \log 1257 = 132 - 10 * 3.1$$

$$L_{pA} = 101 \text{ dB(A)}$$

# **Power plants layout**

## **Chapter 5**

# **Engine room ventilation**

**06-2014**

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## 5. Engine room ventilation

An engine room is heated by convection and radiation from the engines, generators, heat recovery and piping systems installed therein.

To avoid impermissibly high temperatures for the engines, components and switchgear, this heat must be dissipated with the aid of a ventilation system.

Also, for systems operating in areas with extremely low ambient temperatures, it must be ensured that the minimum intake air temperatures specified in the genset data sheet are complied with. For this, it is recommended to utilize the radiation heat of the components to heat the engine room. In these cases, the engine room walls must be tight and good thermal insulation should be provided.

In this respect, the design of the ventilation system is of particular importance; on the one hand, for the removal of the radiation heat in summer, and on the other hand, for the utilization of the radiation heat for engine room heating in winter.

**General note: Intake air temperatures (and minimum temperatures) must comply with the values specified in the genset data sheets!**

**It must be ensured that the intake air temperature does not fall below the permissible starting temperature. See also Chapter 9.2, Requirements for the combustion air.**

In the case of multi-engine systems, each genset should have its own adjustable ventilation system if possible.

The kind of ventilation systems feasible for engine rooms may be divided into three types (see Fig. 5.1):

## **5.1 Ventilation systems**

### **5.1.1 Pressurized system (recommended)**

Air at ambient temperature is drawn in from the outside by a fan, forced through the engine room and returned to the environment via exhaust openings. An overpressure prevails inside the engine room.

The use of this system is especially recommended in environments with a high dust content (desert regions, etc.). The overpressure inside the engine room prevents dust from penetrating into the room through leaks in the walls of the building or through open doors or windows. The ventilation systems must be fitted with appropriate filters to separate out the dust, e.g. inertia cyclone filters, dry type filters, etc. The filtration efficiency of the supply filters for the ventilation system must be of the degree achieved by filters class G3. See also Chapter 5.4.4.

### **5.1.2 Extraction system (not recommended)**

Outside air is sucked into the engine room via the air supply system (weather protection grille, filter, silencer and louvre); it then flows through the engine room before being extracted by a fan and returned to the environment. Negative pressure prevails inside the engine room.

The ventilation system is arranged on the suction side in such a way that the underpressure adjusting in the engine room lies considerably below 1 mbar. Particularly in the case of gas engine systems that extract combustion air from the engine room, there may be complications on startup if the underpressure in the engine room is too high (see also Chapter 5.6, Notes on operating the ventilation system for gas engines). Furthermore, the doors of the engine room, which serve as escape doors in emergencies and open outwards, are not easy to open if the underpressure is too high. The system works like a large vacuum cleaner and unfiltered secondary air enters as a result of leaks in the engine room doors and windows, which leads to the engine room becoming contaminated more and more over time. The degree of separation to be reached with the air supply filters used must correspond with the degree of separation of a class G3 filter. See also Chapter 5.3.4.

### **5.1.3 Combined system (recommended)**

The air to ventilate the engine room is blown into the engine room by a supply air fan and extracted by another fan on the exhaust side. By suitably tuning the supply and exhaust systems, the air pressure in the engine room is approximately equal to the external ambient pressure.

This system must definitely be used for systems which exhibit significant pressure losses at both the supply side and the exhaust side. This is particularly the case where the air for the engine room ventilation must be drawn in and discharged again over great distances and the pressure loss is compounded by components such as weather protection grilles, sound-proofing baffles, louvres and filters.

#### **5.1.4 Ventilation by use of frequency-controlled fans**

When operating gas engines, the intake air temperature must be kept in a relatively narrow range. The minimum air temperature indicated in the data sheet must not be fallen below, as otherwise the compressor of the exhaust turbocharger will pump. Engines with an exhaust wastegate permit a further range of the intake air temperature.

In the case of a ventilator with a fixed speed that is designed for summer conditions, the required minimum intake temperatures for the engine may not always be maintained in winter. By adapting the ventilation volumetric flow rate and the use of radiant heat from the engine and generator, the use of frequency controlled ventilators allows the intake air temperature to be kept in the permissible range even at varying ambient temperatures using a control. It is possible to control the intake air temperature by adapting the ventilation volumetric flow up to ambient air temperatures of approx. 0°C; a circulation system is required for lower ambient temperatures.

#### **5.1.5 Circulating air temperature control**

To avoid unacceptably low temperatures in the engine room, the room temperature can be controlled by mixing exhaust air in with the supply air.

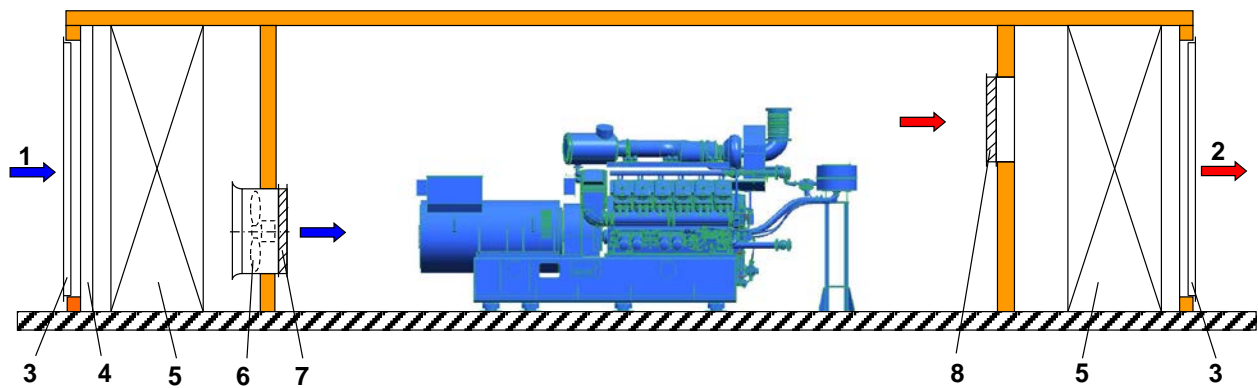
For all systems, the air flow must be so designed as to ensure that the air flows through the entire engine room; there must be no short-circuit currents from the supply opening to the exhaust opening, thus ensuring that there is adequate air circulation around the heat-producing components. If necessary, air ducts must be installed which provide an air flow specifically targeted towards the individual components in the engine room.

In order to minimize the radiated heat occurring in the engine room and thus the volume of air required, silencers and exhaust pipes inside the engine room must be insulated. It is generally necessary to insulate exhaust systems inside buildings.

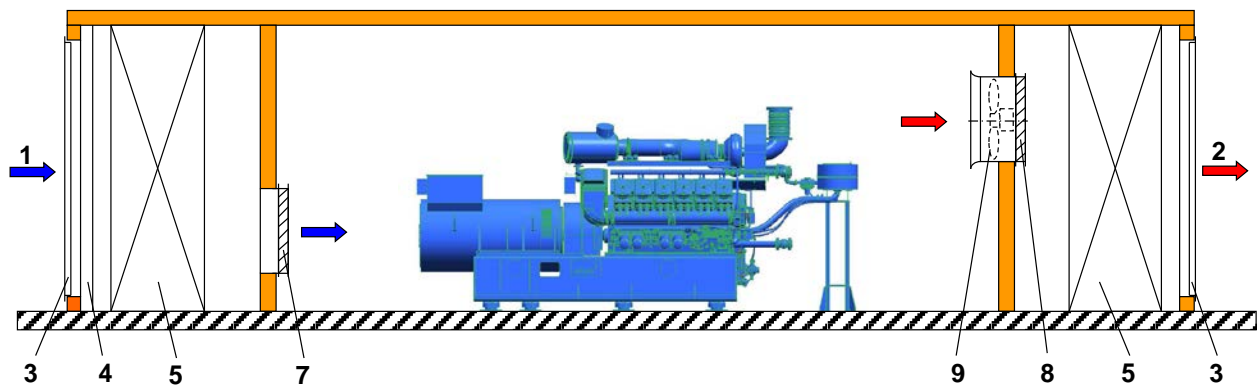
In many cases, the combustion air for the engines is drawn from the engine room. This additional volume of air must be taken into consideration when designing the supply air fans. Dependent on the design of the system, the engine air filters could be located in areas in which the air has already undergone considerable heating. In such cases, cold air must be conducted to the air filters via separate ventilation ducts.

Fig. 5.1a Ventilation systems

Pressurized system



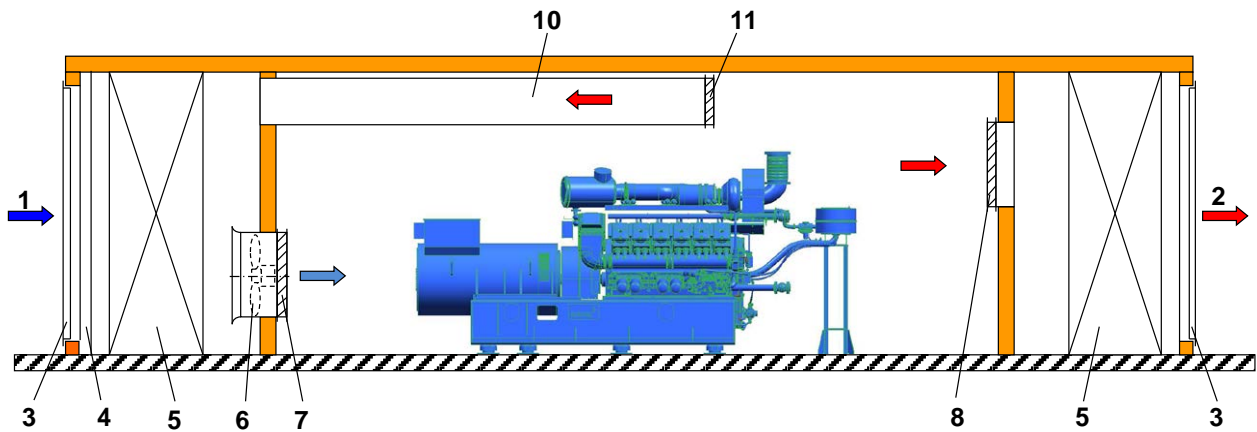
Extraction system (not recommended)



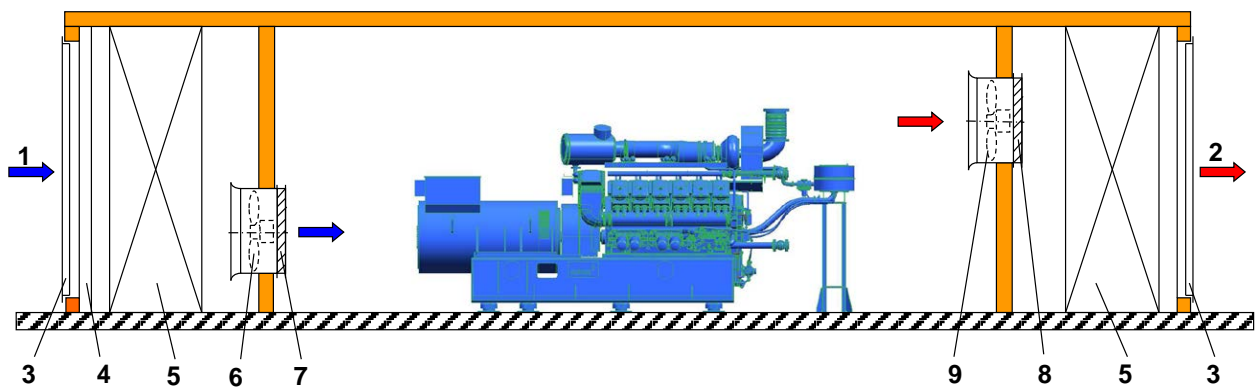
- 1 Supply air
- 2 Exhaust air
- 3 Weather protection grille
- 4 Filter
- 5 Sound-proofing baffle
- 6 Supply air fan
- 7 Supply air louvre
- 8 Exhaust air louvre
- 9 Exhaust air fan

Fig. 5.1b Ventilation systems

System with circulating air temperature control (recommended)



Combined system (recommended)



- 1 Supply air
- 2 Exhaust air
- 3 Weather protection grille
- 4 Filter
- 5 Sound-proofing baffle
- 6 Supply air fan
- 7 Supply air louvre
- 8 Exhaust air louvre
- 9 Exhaust air fan
- 10 Circulating air duct
- 11 Circulating air louvre

## **5.2 Determining the demand for air**

The required volume of air to be determined in order to design the ventilation system is composed of the following individual requirements:

### **5.2.1 Combustion air requirement**

If the combustion air is drawn from inside the engine room, it must be included in the layout of the ventilation air system for the engine room. The combustion air temperature is one of the factors which influence the location-dependent output achievable by the engine. It must therefore be guaranteed that the air temperature in the area of the intake neither exceeds nor falls short of the value established to determine the location-dependent output.

### **5.2.2 Cooling air requirement for the engine and components**

The radiation heat from the engine, the generator and / or other components in the engine room which radiate heat, such as e.g. auxiliaries, including pumps, separators, heat exchangers, boilers, etc must be discharged via the engine room ventilation system.

Components such as e.g. compressors which operate only intermittently are likely to be neglected in most cases when determining the demand for cooling air.

### 5.3 Determining the radiation heat

To determine the demand for air, the heat radiated from the engine and generator must be determined first.

#### 5.3.1 Radiation from the engine

The heat levels radiated from the engine ( $Q_M$ ) are always stated in the current data sheets.

#### 5.3.2 Radiation from the generator

The heat levels radiated from the generator ( $Q_G$ ) are always stated in the current data sheets.

#### 5.3.3 Radiation from auxiliaries

The heat radiated from pipes, especially exhaust pipes, exhaust silencers, radiators and pump units can be determined only with considerable effort. Experience indicates that this radiated heat equates to approx. 10 % of the heat radiated from the engine.

$$Q_H = 0,1 * Q_M$$

$Q_H$	[kW]	heat radiated from auxiliaries
$Q_M$	[kW]	heat radiated from the engine

#### 5.3.4 Radiation from the heat recovery unit

If components are installed in the engine room to utilize the heat energy, experience indicates that the heat radiated from the cooling water and exhaust heat exchangers will be approx. 1.5 % of the respective available heat as per the data sheet.

$$Q_W = 0,015 * (Q_{KW} + Q_{Abg})$$

$Q_{WN}$	[kW]	heat radiated from the heat recovery unit
$Q_{KW}$	[kW]	engine cooling water heat
$Q_{Abg}$	[kW]	available engine exhaust heat

### 5.3.5 Total radiated heat

The total radiated heat  $Q_S$  is the sum of the above-mentioned proportions:

$$Q_S = Q_M + Q_G + Q_H + Q_W$$

Depending on ambient conditions, some of the radiated heat is dissipated via the engine room walls. This proportion can be determined only with great difficulty owing to variable circumstances such as e.g. the ambient temperature or the design of the engine room walls, and is therefore not taken into account.

### 5.3.6 Required ventilation air (excluding the combustion air for the engine)

Finally, the required air is a function of the total radiated heat, the permissible rise in air temperature in the engine room and the specific heat capacity of the air:

$$m_{Lerf} = \frac{Q_S * 3600}{\Delta T * c_p}$$

$m_{Lerf}$	[kg/h]	required air mass flow for cooling
$Q_S$	[kW]	total radiated heat
$\Delta T$	[K]	permissible rise in temperature
$c_{pL}$	[kJ/kgK]	specific heat capacity of the air (1.005 kJ/kgK)

The above equation calculates the required air mass flow. To determine the required volume flow, the density of the air must be taken into account.

The density depends on the air temperature, the air pressure and the relative humidity. The required volume flow is:

$$V_{Lerf} = \frac{m_{Lerf}}{\rho_L}$$

$m_{Lerf}$	[kg/h]	required air mass flow
$V_{Lerf}$	[m <sup>3</sup> /h]	required air volume flow
$\rho_L$	[kg/m <sup>3</sup> ]	air density (e.g. 1.172 kg/m <sup>3</sup> at 1002 mbar and 25°C)

The air pressure reduces as the geodetic altitude increases. The following table indicates pressures and densities depending on temperature and the geodetic altitude.

The specified values apply to dry air. With moist air, the density falls as relative humidity rises. At a relative humidity of 60 %, the drop in density can be up to 10 %.



Table 5.2

Air pressure and air density at 25°C depending on geodetic altitude									
Geodetic height		Temperature		Geodetic height		Temperature		Geodetic height	
in m		25°C		in m		25°C		in m	
		mbar	kg/m <sup>3</sup>			mbar	kg/m <sup>3</sup>		
<b>0</b>		1013	1.184	<b>700</b>		940	1.099	<b>1800</b>	
<b>100</b>		1002	1.172	<b>800</b>		930	1.087	<b>2000</b>	
<b>200</b>		991	1.159	<b>900</b>		920	1.075	<b>2200</b>	
<b>300</b>		981	1.147	<b>1000</b>		910	1.064	<b>2400</b>	
<b>400</b>		970	1.135	<b>1200</b>		890	1.041	<b>2600</b>	
<b>500</b>		960	1.122	<b>1400</b>		871	1.019	<b>2800</b>	
<b>600</b>		950	1.11	<b>1600</b>		853	0.997	<b>3000</b>	

The densities can be converted for other temperatures by applying the following equation:

$$\rho_L(t) = \rho_L(25^\circ\text{C}) * \frac{(273 + 25)}{(273 + t)}$$

$\rho_L(25^\circ\text{C})$  [kg/m<sup>3</sup>] air density at 25°C  
 $\rho_L(t)$  [kg/m<sup>3</sup>] air density at temperature t  
t [°C] air temperature

In the case of systems which extract air from the engine room, on the supply side, the volume of air for combustion in the engine must also be taken into account. Chapter 9.2 contains guide values for the specific combustion air volume required for the individual engine models.

## **5.4 Ventilation system components**

The principal components of an engine room ventilation system are the weather protection grilles, silencers, louvres, filters, air ducts and fans.

### **5.4.1 Weather protection grille**

Weather protection grilles are installed on the outside wall of the engine room on both the supply and the exhaust sides. They prevent rain and snow from entering into the ventilation system. A bird screen must also be integrated into the weather protection grille to stop small animals, etc., from entering the system.

### **5.4.2 Sound-proofing baffles**

Especially when systems are installed in residential areas or areas with restricted noise levels, significant effort may be required in terms of measures to sound-proof the ventilation system. In such cases, sound-proofing baffles must be fitted at the air supply and exhaust air sides. The principal data required for their design are the air flow to be supported through the screen, the required level of sound-proofing and the available duct opening. Thereafter, the depth of the baffles, their thickness and distance to each other are determined.

The sound-proofing baffles must be designed by specialized companies, a task which calls for an appropriate degree of care, as subsequent improvements are very costly if the required figures are not achieved.

### **5.4.3 Louvres**

Louvres are used to block the ventilation system link between the engine room and the external environment when the system is at a standstill, especially in winter to prevent excessive cooling of the room. The louvres are activated by electric drives which are controlled from the switchgear. In large systems, cool air can be admitted to certain areas of the system by actively controlling the louvres. In winter, the engine room temperature can be regulated by controlling the louvres.

### **5.4.4 Filter**

Generally, filters should be installed in the ventilation system. This particularly applies to systems located on industrial sites where the ambient air is heavily contaminated, e.g. landfills, coal mines, cement works, metallurgical plants, etc. It is also applicable for systems located in regions where sand storms may occur. Here the appropriate filter type must be selected according to the degree of the contamination. Heavy particles are easily separated via inertia filters, whilst for example, where lightweight fibers occur,

conventional fibrous filters must be fitted, which in view of the relatively large quantities of air, can achieve considerable dimensions.

Filters as per DIN EN 779, Filter Class G3, are suitable. In case of specific requirements, a correspondingly higher filter class needs to be chosen. An effective filter monitoring is necessary.

#### **5.4.5 Ventilators**

The ventilators are designed mostly as axial fans - rarely as radial fans - and must be of a suitable size depending on the required quantity of air and pressure difference. To control the engine room temperature, the volume of air being blown can be adjusted by using variable-speed fans or by switching individual fans on and off.

**Important:** When using individual fans - particularly axial types -, it must be considered that standing fans can be driven in reverse by a difference in pressure. With large fans, this can lead to problems.

When determining the size of the fans, the pressure reserve must be correctly selected with respect to the components installed in the ventilation system, such as weather protection grilles, sound-proofing baffles, louvres, etc., in order to ensure that the designed quantity of air is actually achieved.

#### **5.4.6 Air ducts**

Depending on the design of the system or the location of the engine room inside a larger building, e.g. in the basement in the case of emergency power systems, the air to ventilate the engine room may have to be brought in over longer distances. For this purpose, air ducts are employed. The pressure losses in these ducts must be considered when designing the fans. To avoid condensation, outside air ducts should be insulated.

## 5.5 Planning notes

Having determined the required quantities of air, the openings and ducts must be so designed as to ensure compliance with the following air speeds.

**Table 5.3**

Component	Air speed (m/s)
Supply / exhaust opening	1.5 - 2.5 / 2.5 - 4
Ventilation duct	10 - 20
Free flow in the engine room	0.3
Silencer section	6 - 8

Additional restrictions owing to flow noise must be taken into account.

### 5.5.1 Changes of air

The number of air changes also may be taken as a characteristic figure for a ventilation system. It represents the number of air changes per hour, i.e. saying how often the complete volume of air in the engine room is exchanged.

From experience, the number of air changes should not exceed 100 for big systems in buildings.

With extremely small engine rooms (e.g. containers) or at high ambient temperatures, the number of air changes may rise up to 500 per hour.

## 5.6 Notes on operating ventilation systems for gas engines

The operation of the ventilation system may affect the pressure conditions at the combustion air intake of the engine in such a way as to cause engine starting problems, or even making starting impossible. In such cases, before starting the engine, only the supply and exhaust louvres must be opened. During start or synchronization, the fans must operate without pressure peaks in the engine room, i.e. during the genset starting phase, the fans must be operated with constant speed.

## **5.7 Position of supply and exhaust openings**

Supply openings must be positioned in such a way that the air drawn in is as clean and cool as possible.

The position for the outlet of exhaust air must be selected so that the function of other system components such as cooling systems are not restricted by the warm exhaust air flow.



# **Power plants layout**

Chapter 6

## **Engine cooling systems**

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## **6. Engine cooling systems**

The coolants employed have water as a cooling medium and from an engine perspective must be closed systems.

The genset engines essentially feature two types of cooling: single-circuit and dual-circuit.

The layout must follow the illustrations included hereinafter. Deviations require approval in writing.

### **6.1 Single-circuit cooling**

The coolant of gas engines with a single-circuit passes through the lubricating oil cooler, the mixture coolers and the engine, i.e. the total heat is discharged in one single circuit.

### **6.2 Dual-circuit cooling**

Along with an engine water cooling circuit, engines with a dual-circuit also have a low-temperature mixture/charge air cooling circuit. As the temperature level in the mixture cooling circuit is comparably low, the heat from those circuits is normally discharged to the environment via fan coolers or cooling towers with a separate circuit.

#### **6.2.1 Gas engines**

All gas engines of the series TCG 2016 C, TCG 2020 and TCG 2032 are equipped with a two-stage mixture cooler on the engine. The high temperature stage is integrated into the engine cooling circuit and the heat from low temperature stage is discharged in the external mixture cooling circuit.

For the engines TCG 2032, the lube oil cooler is not mounted on the engine and has to be installed in the external cooling system. Depending on the layout of the system as a whole, it can be installed on the water side in the engine circuit, in the low temperature mixture circuit or in the heating water circuit. Please see also Chapter 8.2.

### 6.2.1.1 Example for the layout of cooling systems with gas engines

The heat absorbed by the cooling water is transferred via a heat exchanger to be provided by the client for use in a heating water circuit or other technical process. If there is no means of heat recovery to hand, it must be discharged into the atmosphere via a radiator or cooling tower. It is not permitted to run the cooling tower water straight through the engine! A decoupling heat exchanger or closed cooling tower must be provided.

The inlet temperature of the cooling water is generally controlled, whereby dependent on the design of the system, the temperature regulator may be installed directly in the engine circuit or in the heating circuit. Electric pumps are always used as cooling water pumps, the fine adjustment of the cooling water flow being achieved via an adjustable throttle. The expanding volume is accommodated in a diaphragm expansion vessel, the level in the cooling water circuit being monitored by the so-called monitoring group. Integrated in this group are a safety valve, venting and blow-off valves and the low-water level safety device.

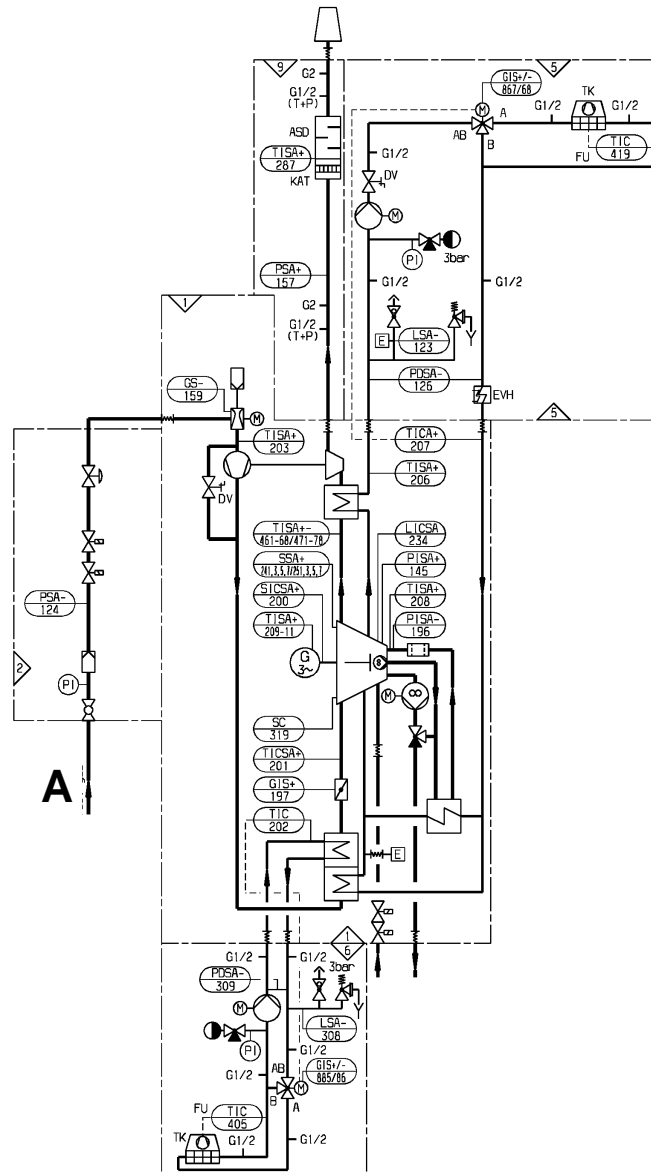
As with the engine circuit, the mixture circuit is equipped with an electrical circulating pump, diaphragm expansion vessel, monitoring group and temperature regulator.

With multi engine plants, it is not permitted to connect the jacket water circuits together, because the definitive regulating of each HT-inlet-temperature cannot be guaranteed.

Fig. 6.1 shows a cooling system without heat utilization.

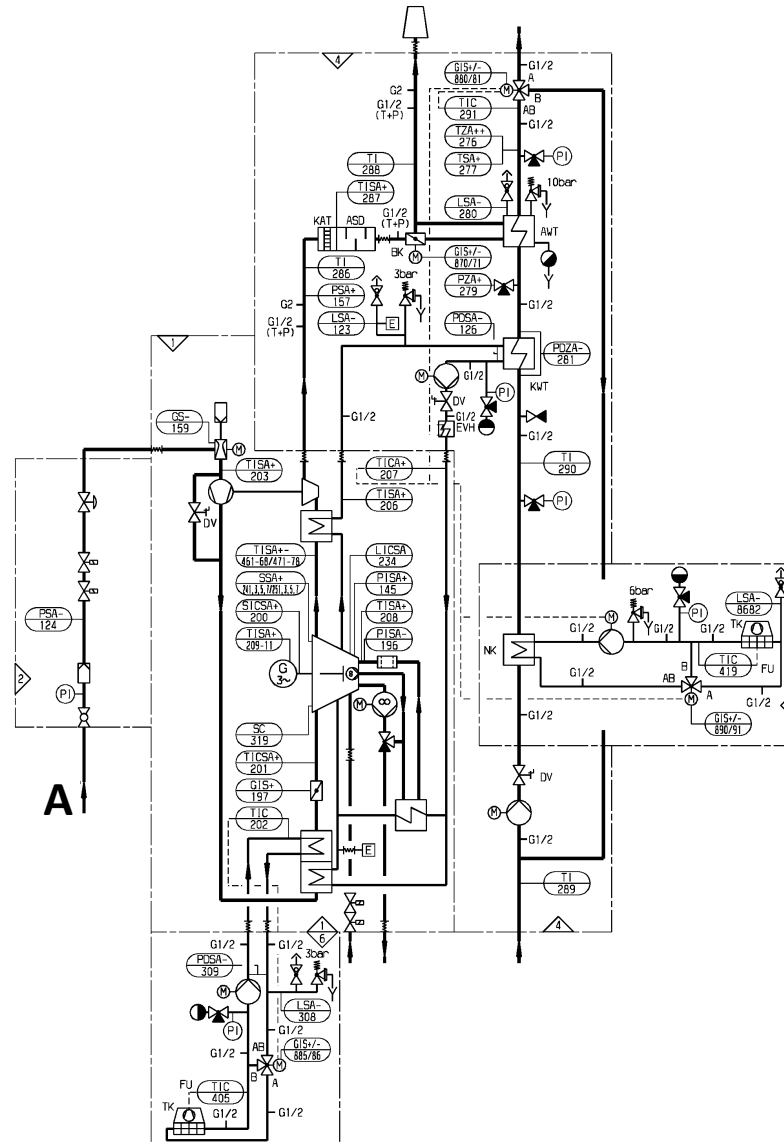
Fig. 6.2 shows a cooling system with heat utilization.

Fig. 6.1 P&I flowchart for system without heat utilization



- |   |                        |     |                      |
|---|------------------------|-----|----------------------|
| A | Combustion gas         | ASD | Exhaust silencer     |
| 1 | Genset                 | DV  | Throttle valve       |
| 2 | Gas control line       | EVH | Electric pre-heating |
| 5 | Engine cooling system  | FU  | Frequency converter  |
| 6 | Mixture cooling system | KAT | Catalyst             |
|   |                        | TK  | Table cooler         |

Fig. 6.2 P&I flowchart for system with heat utilization



- |   |                                |     |                              |
|---|--------------------------------|-----|------------------------------|
| A | Combustion gas                 | ASD | Exhaust silencer             |
| 1 | Genset                         | AWT | Exhaust heat exchanger       |
| 2 | Gas control line               | BK  | Bypass flap                  |
| 4 | Heat utilization               | DV  | Throttle valve               |
| 6 | Mixture cooling system         | EVH | Electric pre-heating         |
| 7 | Emergency/dump cooling circuit | FU  | Frequency converter          |
|   |                                | KAT | Catalyst                     |
|   |                                | KWT | Cooling water heat exchanger |
|   |                                | NK  | Emergency cooler             |
|   |                                | TK  | Table cooler                 |

## 6.3 Reference values for the layout of cooling systems

### 6.3.1 Pressures

All pressures for fluids are generally indicated in bar overpressure.

All heat exchangers, pumps and table coolers should be designed as standard for 10 bar, the lube oil heat exchanger of the TCG 2032 for 16 bar.

#### 6.3.1.1 Minimum pressure

The minimum required operating pressure at the engine outlet is 1.5 bar. All gas engines have a monitoring of the pressure at the cooling water outlet in the cooling circuit. If the pressure falls below 1.5 bar, there is a warning; if it falls below 1.0 bar, the engine is switched off. The diaphragm expansion vessels should be dimensioned in such a way that a minimum pressure of 1.5 bar is obtained when the system is stopped.

#### 6.3.1.2 Maximum pressure

The maximum permissible pressure at the engine outlet is 2.5 bar. The safety valve mounted close to the engine outlet opens at approx. 3 bar.

### 6.3.2 Pump location

If there are high pressure losses as a result of external resistance in the engine circuit (heat exchangers, regulating valves, etc.), the pump must be installed on the outlet side of the engine, otherwise the maximum permitted pressure on the outlet side or the minimum pressure is out of limit.

### 6.3.3 Max. permissible temperature gradient

If the inlet temperature of the engine, mixture cooling and emergency cooling circuit as well as the inlet temperature of the heating circuit are regulated by the customer, the max. temperature modification speed of 1 K/min needs to be maintained.

In order to maintain a stable behavior of the temperature control for the engine cooling circuits, it is necessary to minimize the influence of disturbing parameters from external systems.

**It is essential that all coolers and pumps have an adequate reserve in capacity and flow rate.**

## 6.4 Cooling water system components

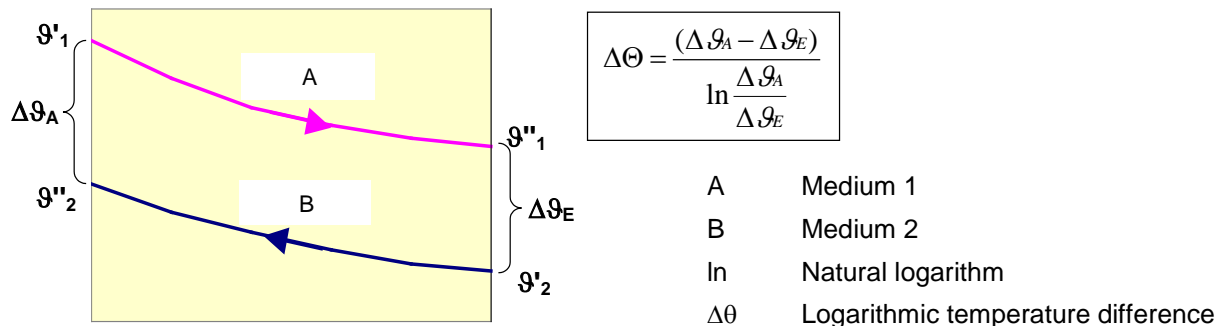
### 6.4.1 Cooling water heat exchanger

Reserve capacity and surface area reserve according to Table 6.3 must be observed. The specified engine inlet and outlet temperatures must be observed (see engine data sheet).

In order to keep the heat exchangers in a good condition from an economic point of view, the logarithmic temperature difference should not be lower than 4K. The temperature difference between in- and outlet (primary / secondary circuit) should be greater than 2K (see also Fig. 6.4).

In the case of liquid coolants, plate heat exchangers or pipe radiators are used on the secondary side. Plate heat exchangers are highly compact in construction and easy to clean. Their performance can, within certain limits, be varied at a later date by altering the number of plates.

**Fig. 6.3 Logarithmic temperature difference**



#### Example

A cooling water heat exchanger in the heating circuit has the following design data:

Engine side:	Inlet temperature $\vartheta'_1$ :	90°C	
	Outlet temperature $\vartheta''_1$ :	84°C	
Heating circuit side:	Inlet temperature $\vartheta'_2$ :	70°C	
	Outlet temperature $\vartheta''_2$ :	85°C	
This yields:	$\Delta\vartheta_A$ :	(90°C-85°C)	= 5 K
	$\Delta\vartheta_E$ :	(84°C-70°C)	= 14 K
	$(\Delta\vartheta_A - \Delta\vartheta_E)$ :	(5-14) K	= -9 K
	$\ln(\Delta\vartheta_A/\Delta\vartheta_E)$ :	$\ln(5/14)$	= -1.0296
	$\Delta\Theta$ :	(-9 K/-1.0296)	= 8.74 K

This plate heat exchanger therefore complies with the minimum requirements  $\Delta\Theta \geq 4$  K,  $\Delta\vartheta_A$  and  $\Delta\vartheta_E \geq 2$  K.

### 6.4.1.1 Implementation of cooling water heat exchangers with emergency cooling by raw water

For emergency cooling systems with raw water cooling via heat exchanger, the temperature control for the emergency cooler outlet temperature should be arranged in the primary circuit (see Fig. 6.5a).

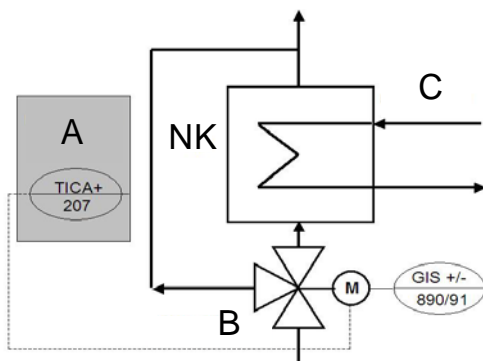
With this design, hot water flow over the emergency cooler will only occur when emergency cooling is requested. The water outlet temperature on the secondary (raw water) side of the emergency cooling heat exchanger must be kept below 45° C in order to prevent sedimentation of lime.

In any case, the temperature control should not be as per Fig. 6.5b. In this case, there is always hot water flow through the emergency cooling plate heat exchanger. In the case of no or low water flow rate on the secondary side, the raw water temperature in the heat exchanger will rise and reach the temperature level of the hot water side. The plate heat exchanger will become calcified over time.

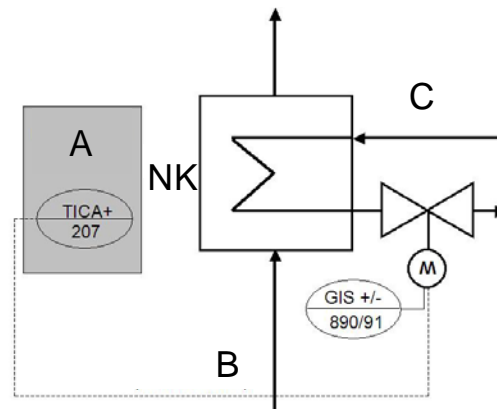
The temperature gradient on the raw water side must not exceed +/- 1 K/min.

For the actuators of the temperature control valves, the I/O controller of the TEM-system has a digital output +/- (24V signal) for opening/closing the valve. In order to achieve a reasonable control behavior, the running time of the valve from limit position open to limit position close and vice versa should be in the range of 1 minute.

**Fig. 6.4a Correct layout**



**Fig. 6.4b Incorrect layout**



- A Engine cooling circuit
- B Primary side (engine / heating circuit)
- C Secondary side
- NK Emergency cooler

## 6.4.2 Exhaust heat exchanger

Reserve capacity and surface area reserve according to Table 6.3 must be observed. For the setting of the exhaust gas cooling temperature, the amount of H<sub>2</sub>S and sulfur in the combustion gas must be considered. This setting is to avoid acid condensate in the exhaust which will damage the exhaust heat exchanger.

Recommended exhaust gas cooling temperatures:

Natural gas:	≥ 120 °C
Sewage gas:	≥ 150 °C
Landfill gas and NAWARO gas:	≥ 180 °C

The minimum volume flow specified by the manufacturer must be complied with in order to guarantee sufficient cooling of the exhaust heat exchanger. After stopping the genset, it is necessary to keep the cooling water pump running for a while in order to discharge the accumulated heat from the exhaust heat exchanger. This function is part of the TEM system.

## 6.4.3 Cooling systems

**Each cooling system must be capable of discharging the generated heat even with maximum ambient temperatures.**

Where air is used as the secondary side coolant, fan coolers and cooling towers are employed.

Up to a certain size, fan coolers can be implemented as front coolers (vertically arranged cooling network); larger systems take the form of table coolers. In the case of front cooling systems, the fans push the air through the cooling network; with table cooling systems, the air is pulled through the cooling network.

The occasionally high noise level of the fans must be taken into account when installing systems in residential areas. Either slow-moving fans can be used here, or special sound-proofing measures will be needed.

### 6.4.3.1 Table cooler

Reserve capacity and surface area reserve according to Table 6.3 must be observed. Where there is a risk of contamination resulting from the environment (e.g. leaves, pollen, sand, carbon dust etc.), an appropriate fin spacing must be selected. An enlarged space between the fins prevents the cooler from becoming clogged too fast. Otherwise the heat can not be discharged anymore due to the deterioration of the heat transfer.

In the case of air coolers, because of the risk of freezing, anti-freeze must be added to the cooling water.

When installing the table cooler, it must be ensured that there is sufficient space beneath to allow a proper air flow. Where several coolers are installed, there must be an adequate spacing between them to prevent a short-circuit.



If the table coolers are arranged at a level higher than 15 m above the engine level, it is necessary to install a heat exchanger in order to keep the pressure level in the engine in the permissible range mentioned in section 6.3.1.2.

#### 6.4.3.1.1 Table cooler control

The capacity of table coolers is influenced both by the ambient temperature and the number of running fans or the fans' speed. When controlling the table cooler capacity via the number of operating fans, we talk about step control; for control via the speed of the fans via FU control. The FU control offers the advantage of continuous adaptation of the cooler capacity to thermal output which should be discharged. For the different engine types, the fan control for the table coolers in the different cooling circuits should be as per Table 6.2. For the discharge of the heat in the mixture cooling circuit, and/or engine/emergency cooling circuit, the following assignment must be ensured for the gas engines.

**Table 6.2:**

	<b>Cooler GK</b>	<b>Cooler MK</b>	<b>Cooler NK</b>
<b>TCG 2032</b>	FU controlled	FU controlled	FU controlled
<b>TCG 2020</b>	FU controlled	FU controlled	FU controlled
<b>TCG 2016 C</b>	FU controlled	≥ 6 steps	≥ 6 steps

FU = frequency converter; GK = mixture cooling circuit; MK = engine cooling circuit ; NK = emergency cooling circuit;

In summary, the heat in the mixture cooling circuit must be discharged via frequency controlled table coolers for all gas engine types.

For the engine type TCG 2016, the engine cooling circuit (MK) and the emergency cooling circuit (NK) may be equipped with at least a 6-step cooler (6 fans). Less than 6 steps is not permissible. Alternatively, the FU controlled variant is recommended.

With extremely low ambient temperatures, i.e. regularly low temperatures below -15°C, all cooling circuits must be FU controlled.

By this requirement, the boundary conditions for proper operation of the gas engines can be kept for a wide range of altering ambient conditions.

#### **6.4.3.1.2 Sandwich table cooler (not recommended)**

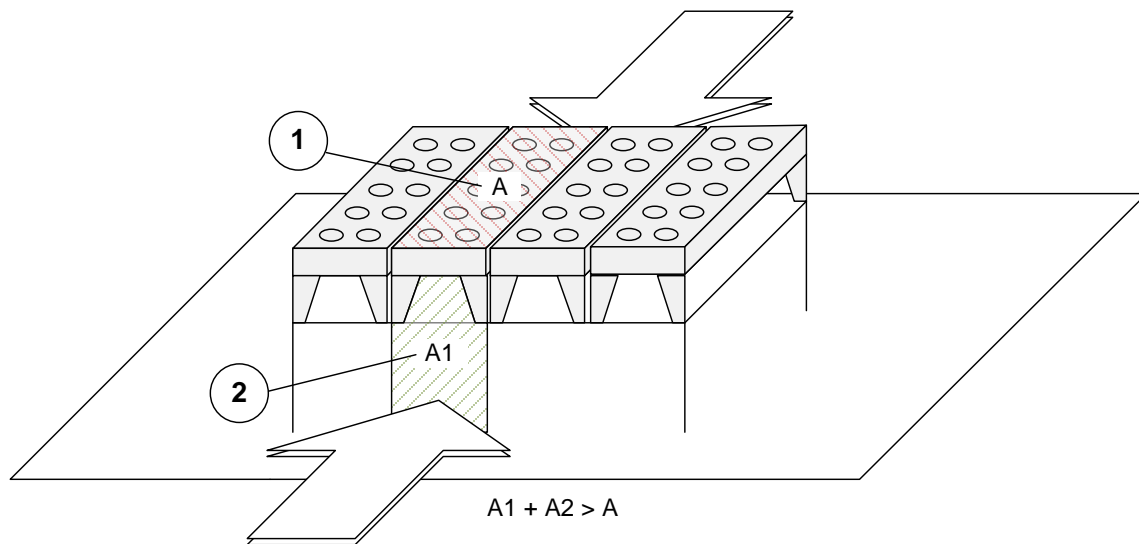
One special design of the table cooler is the sandwich table cooler. With this fan cooler type, there are two cooling stages arranged one upon the other and the air supply is provided by common fans. The first stage is the LT-stage (LT=Low Temperature), the second stage the HT-stage (HT=High Temperature). Normally, the heat from the mixture cooling circuit is discharged in the LT-stage and the heat from the engine in the HT-stage. This cooler type is applied for systems with power generation, because, only for this application, the load on both stages is uniform for the whole power range of the engine. For CHP systems, normally the HT-stage of a sandwich table cooler is used for emergency cooling purposes. With heat utilization (no heat rejection via emergency cooler), the speed of the common fans is defined by the heat to be discharged from the mixture cooling circuit. For this mode of operation, the emergency cooler (HT-stage of the sandwich table cooler) might be ineffectively oversized and, as a consequence, the temperature control for the system might become unstable. Therefore the use of sandwich coolers is not agreed for CHP systems.

#### **6.4.3.1.3 Installation and design of table coolers**

Reserve capacity and surface area reserve according to Table 6.3 must be observed. Where there is a risk of contamination resulting from the environment (e.g. leaves, pollen, sand, carbon dust etc.), an appropriate fin spacing must be selected. An enlarged space between the fins prevents the cooler from becoming clogged too fast. Otherwise the heat cannot be dissipated anymore due to the worsening of the heat transfer.

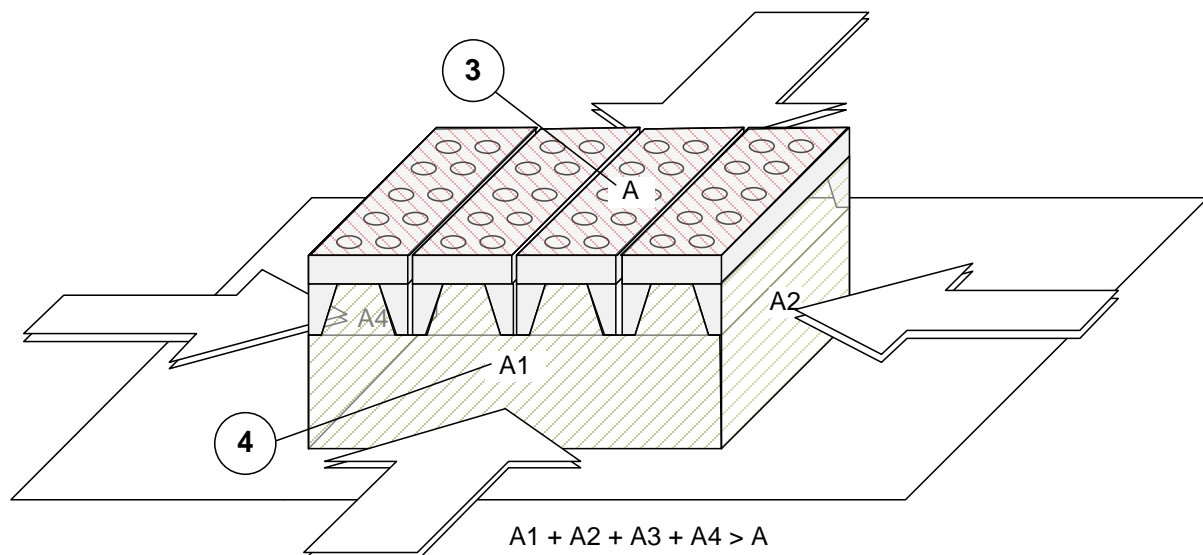
In the case of air coolers, because of the risk of freezing, anti-freeze must be added to the cooling water. When installing the table cooler, it must be ensured that the installation height above the ground is sufficient to allow a proper air flow. The free inflow area for the air supply must correspond at least to the floor space of the table cooler. Where several coolers are installed, the short-circuiting of air flows must be prevented. Table coolers should therefore be installed either flush next to each other or with sufficient space between them. When doing so, erect the table coolers so that the required inflow area for the air supply is ensured at the free sides.

**Abb. 6.5a Installation of table coolers**



- 1 Floor space of an individual table cooler A
- 2 Inflow areas for cooling air A1 and A2 (not visible) for this table cooler

**Abb. 6.5b Installation of table coolers**



- 3 Floor place for all table cooler A
- 4 Inflow areas for cooling air A1, A2, A3 (not visible) and A4

### 6.4.3.2 Cooling towers

Cooling towers exploit the evaporation cooling effect and are used in both closed and open forms. With an open cooling tower, part of the circulating cooling water (approx. 3 %) evaporates. The volume of water lost to evaporation must always be replenished. In addition, a blow-down device is to be provided in order to avoid an undue increase in concentration of dissolved salts in the supplementation water in the cooling tower.

Since all corrosion- and/or frost-protected engine cooling circuits require the use of treated water, these cooling circuits may only be connected to an open cooling tower via a decoupling heat exchanger.

With open cooling towers, it is necessary to clean the decoupling heat exchanger more often because the open water circuit favors the formation of algae polluting the heat exchanger. The thicker the layer of algae in the heat exchanger, the worse the heat transfer. No more heat is dissipated in the circuits to be cooled.

In the case of closed cooling towers, the cooling water tubes are sprayed with water, causing the water to evaporate and thereby cooling the medium in the tube. Since there is no loss of water in the cooling circuit itself, closed cooling towers can be linked directly to the engine cooling circuit. The most important design parameters for economic cooling tower operation are the air temperature and, above all, the humidity.

#### 6.4.4 Layout of components - Reserves

In the case of the layout of components for the cooling water system, the reserves must be observed. The heat amounts given in the data sheets are nominal values, which do not consider tolerance for possible increased fuel consumption. In the following table, the reserves for capacity and area are specified which have to be considered for the design.

Tab. 6.3

Components	Reserve capacity [%]	Surface area reserve [%]
Heat exchanger water/water	15	5
Heat exchanger water/oil	15	5
Ventilator cooler	15	5
Exhaust heat exchanger	7	10 for natural gas 0 for biogas, sewage gas and landfill gas etc.

Example:

In a data sheet for a TCG 2020 V20, a cooling water heat of 1000 kW is specified.

The cooling water heat exchanger must be designed for a capacity of 1150 kW with an area reserve of 5%.

#### 6.4.5 Chillers

Chillers should not be directly integrated in the engine cooling circuit. In case of leakages, the engine cooling water might be contaminated by Li Br. This is prevented by the coupling heat exchanger in the engine cooling circuit.

There are cases in which the required water-temperature level of the chiller can only be achieved via a direct integration in the cooling water circuit of the engine. In this case, one has to comply with the following conditions:

- The requirements with respect to the quality of the cooling water of the engine, corrosion protection or freezing protection have to be met
- The cooling water additives which are released by the manufacturer of the engines need to be released for the chiller as well
- In case of leakages in the heat exchanger of the chiller, both the cooling system and the engine can be damaged. The manufacturer of the engine accepts no liability for those damages.

#### **6.4.6 Cooling water pumps**

Cooling water pumps with fixed speed which are driven by electric motors are installed in all series.

In the case of systems with heat recovery from the cooling water, to achieve the maximum efficiency and component service life, the engine inlet temperature and outlet temperature must be exactly maintained. In order to more accurately and individually coordinate the required pump capacity and the lift needed for each installation, electric pumps are used for these systems. The heat reserve capacities as mentioned already in 6.4.1, 6.4.2 and 6.4.3.1 must be considered by an increased volume flow, whilst maintaining the design temperatures as per the genset data sheet. When determining the size of the pump, the increased volume flow according to the reserve and the associated higher pressure losses must be taken into account. The exact setting of the cooling water flow rate is done by manual control valves/throttles. The adjustment of flows is done with regard to the design temperature differences for the individual cooling circuits.

For the engine cooling circuit, the mixture cooling circuit and for the cooling circuits incorporating an exhaust heat exchanger, it is absolutely necessary to maintain a constant flow rate, whereby the flow rate must not fall below the given minimum flow rate. Otherwise the engine or the exhaust heat exchanger might overheat or become damaged. Therefore, it is not allowed to use frequency-controlled water pumps in those circuits.

#### **6.4.7 Expansion vessels**

Diaphragm expansion vessels are provided in the cooling system to balance the volume expansion as the cooling water heats up. The expansion in volume as the cooling water heats up is compensated for by compressing a gas bubble. The resulting static increase in pressure in the system is dependent on the size of the expansion vessel selected. Expansion vessels must be connected on the inlet side of the pump. Where a diaphragm expansion vessel is used, the cooling water circuit must be protected against overpressure by a safety valve. In the engine and mixture cooling circuit, safety valves with a response pressure of 3.0 bar are generally used. The installation site should be as close as possible to the engine cooling water outlet.

When designing the expansion vessel, the static pressure, the flow pressure loss between the safety valve and the expansion vessel must be considered, as must the water supply. The water supply in the engine and mixture cooling circuit must equate to 10-15 % of the cooling water content, subject to a minimum of 20 liters.

#### **6.4.8 Temperature regulators**

The temperature regulators are electronic regulators with electric actuators.

Electronic temperature regulators can control the set temperature at a constant setpoint value; the regulating variable may be located in an external circuit. Precise temperature regulation is needed, especially in the case of systems where heat is recovered and, at the same time, high overall efficiency is called for.

The nominal diameters of the temperature regulators must be determined so as to ensure that, at the respective rate of flow, the pressure loss via the regulator lies within a range of 0.2-0.5 bar in straight flow (bypass closed).

#### **6.4.9 Cooling water monitoring group**

There are three functions integrated into the cooling water monitoring group: security against overpressure, venting the cooling circuit and cooling water level monitoring. The cooling water monitoring group must be installed at the highest point in the cooling water system directly after the engine and the vent line from the engine TCG 2016 C must run to the monitoring group. For engines of the series TCG 2016 C, a ventilation line must be fed to the monitoring group.

In addition, it is also necessary to monitor the flow of cooling water through the engine via differential pressure.

#### **6.4.10 Cooling water preheating**

Gas engine gensets must, as a matter of principle, be equipped with a cooling water preheating to ensure reliable engine starting. For the engine series TCG 2032, complete preheating gensets with a pump, heat exchanger with heating elements and electrical control are used as a preheating system for the engine water

and oil. For the series TCG 2016 and TCG 2020, a preheating system has also been developed which is installed in the cooling water line ahead of the engine. The electrically driven cooling water pump is used for circulation. It is controlled via the TEM system.

## 6.5 Pipes

The pipes for the cooling water systems must, on principle, be implemented using seamless steel tube. Galvanized steel or copper pipes are not permissible.

Please also see the relevant notes in Chapter 20.

**When determining the size of the pipes, the following guide values must be observed:**

- Flow speed, system-side pipework: < 3.5 m/s
- The economic speed for fluids in pipes from DN 50 to DN 300 lies in the range of 2 m/s
- For the design volume flow, the flow pressure loss in the cooling circuit must be lower than the discharge pressure head of the pump being used

Piping should be kept short and laid without tension. All components must be firmly fixed in place and, if necessary, vibration-decoupled. Sharp pipe elbows and reducers must be avoided. The materials used for seals, rubber sleeves and hoses must be resistant to anti-corrosives and to the external effects of fuel and lubricating oil.

## 6.6 Ventilation of the cooling systems

The cooling water system must be constantly vented. In systems with balance tanks, permanently rising vent lines must be run from below to vent into the balance tank. The cooling water system must be constantly vented. In plants with diaphragm expansion vessels, the system is vented via the vent valve integrated into the monitoring group or a vent valve which is installed in the pipe. The cooling water pipes must be run in such manner as to avoid air becoming trapped in the system; if necessary, permanent vents or vent cocks need to be provided at the systems high points.

For a safe operation of the cooling system without any pressure surges, it is necessary that the system is ventilated properly and that the air bubbles which might have formed are automatically exhausted.

In systems with balance tanks, the balance line must run constantly downwards with the minimum resistance to the inlet side of the circulating pump.

## 6.7 Quality of the coolant

For liquid cooled engines, the coolant must be treated and monitored, as otherwise damage may arise due to corrosion, cavitation or freezing.



The Technical Circular for coolant contains comprehensive details of water quality, anti-corrosives and antifreeze. There is also a list of approved coolant additives from reputable manufacturers. No substances may be used other than those which are approved.

## **6.8 The heating circuit**

In the case of systems with heat recovery, the heat generated by the engine is transferred to the heating circuit. The principal components integrated into the heating circuit on the module side are the cooling water heat exchanger, the exhaust heat exchanger, the circulating pump, the throttle valve and the three-way temperature regulating valve. The heat output from the engine contained in the cooling water and the exhaust gas, and the associated flow rates and temperature differences have been established for the engines in their respective operating modes. The capacity of the circulating pump in the heating circuit is determined by the temperature difference between the flow and return in this circuit. When determining the size of pump, the increased volume flow according to the reserve and the associated higher pressure losses must be taken into account. See also Fig. 6.2 System boundary 4.

The heating circuit must also include a pressure keeping device; generally this is arranged as a collecting system in the return flow.

The heating circuit should be designed in such a way that, independent of the adjusting and regulating processes, the flow, which is described on the heating network section (Chapter 6.7, part 1), has to be ensured without fluctuation of differential pressure (hydraulic disconnection). Heat storage tanks are particularly suited for this purpose (see Fig. 6.6). They decouple the heat generating side from the heat utilizing side.

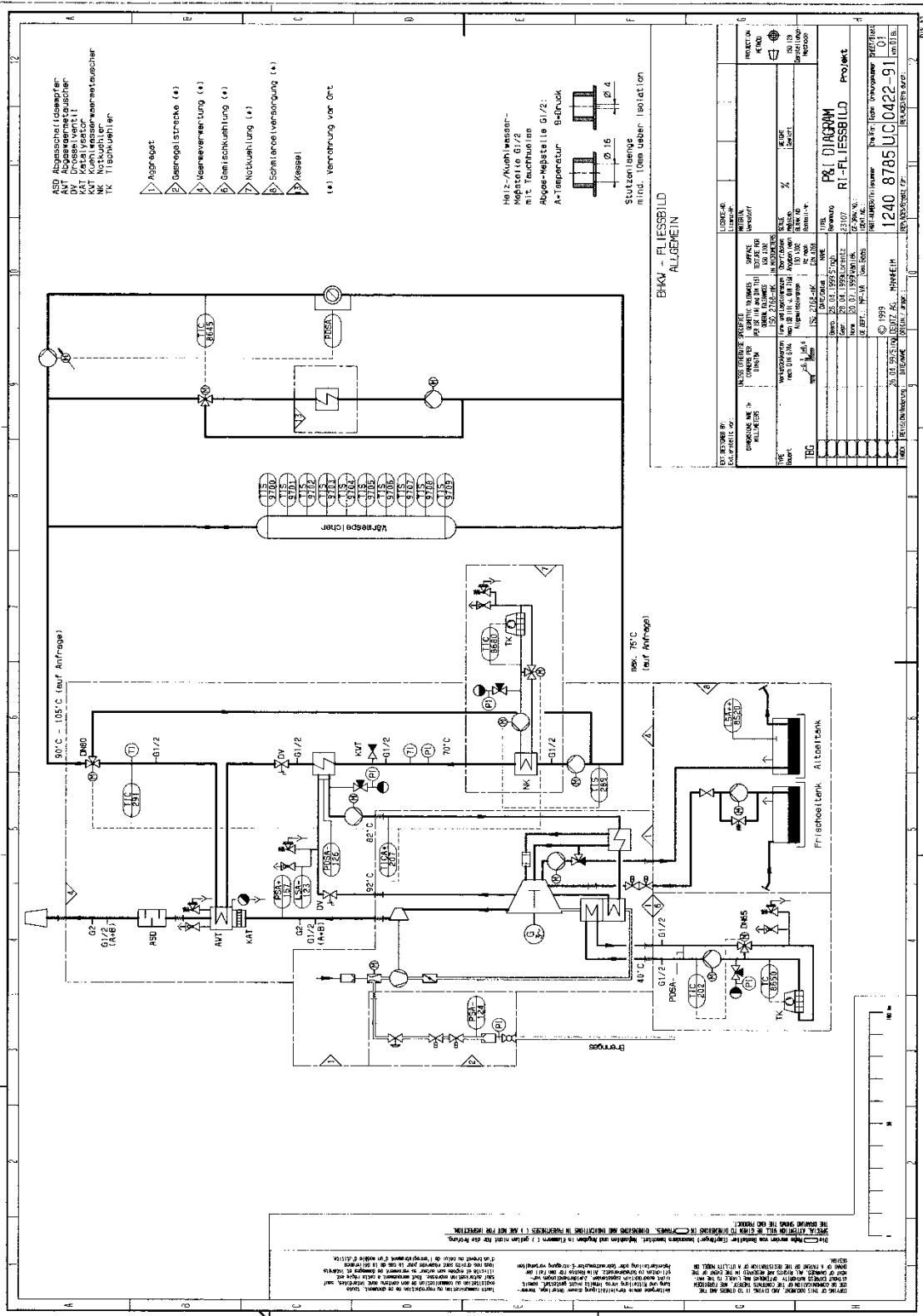
## **6.9 Coolant in the heating circuit**

The heating circuit is a closed circuit. In this circuit too, a certain water quality must be maintained. Oxygen, chlorides and hydrogen sulfide in particular promote corrosion in the system. Salts in solution are precipitated as crystals at high heat transfer locations, leading to deposits, which have a negative impact on heat transfer (e.g. boiler scale). Especially in the exhaust heat exchanger because of the high water temperatures at the heat transfer points, there is a risk of crystalline deposits.

These phenomena can be reduced by adding inhibitors to the heating water medium and by selecting suitable materials for the heat exchangers. This must be investigated for each individual application.

The minimum water quality for heating circuits is summarized in the Technical Circular for cooling water. If the exhaust heat exchanger is installed in the heating circuit and if the water quality in the heating circuit does not comply with the figures stated in the Technical Circular, it is necessary to provide a separate decoupling circuit with an additional heat exchanger between the exhaust heat exchanger and heat consumer. Now the exhaust heat exchanger is protected against damage from contamination in the heating water.

Fig. 6.6 P&I flowchart with hydraulic decoupling of heat generation from heat utilization



Legend for P&I flowchart in Fig. 6.6

1	Genset
2	Gas control line
4	Heat utilization
6	Mixture cooling system
7	Emergency cooler
8	Lube oil supply
13	Boiler
ASD	Exhaust silencer
AWT	Exhaust heat exchanger
DV	Throttle valve
KAT	Catalyst
KWT	Cooling water heat exchanger
NK	Emergency cooler
TK	Table cooler

## 6.10 Heating circuit design regulations

The regulations for water heating systems and steam boiler systems also apply to the design of the heating circuit.

These are inter alia:

- DIN EN 12828 Heating systems in buildings (for max. operating temperature to 105°C)  
When planning or designing CHP systems requiring temperature monitoring/limiting temperatures above 110°C, it is recommended to consult the local authority responsible for the certification of the system. The favored scope of necessary equipment and the setting of the inspection periods (German Health and Safety at Work Regulations) can be agreed between both parties.
- DIN EN 12953 Shell boilers
- TRD 604 Sheet 1 Operation of steam boiler systems with Group IV steam generators without constant supervision
- TRD 604 Sheet 2 Operation of steam boiler systems with Group IV hot water generators without constant supervision
- TRD 702 Steam boiler systems with Group II hot water generators

Depending on the flow temperature in the heating water circuit (90°C, 100°C or 120°C), the appropriate sensors must be installed to protect and maintain the security chain for the exhaust heat exchanger and to secure the heating circuit. The signals from the sensors are processed by the TEM system.

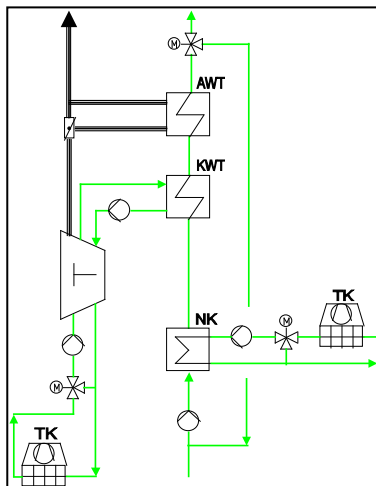
An approval has been granted by the TÜV for the monitoring systems (sensors plus processing of signals via the TEM system), with the result that the individual inspections to be carried out on each system by the TÜV can be completed quickly.

## 6.11 Emergency/dump cooling circuit

In systems where the dispersal of heat via a heating circuit is not always guaranteed, yet the electrical output of the system must still be available, the heat generated by the engine is dissipated via the so-called emergency cooling circuit. The arrangement of the emergency cooling circuit depends on the system design. Depending on the arrangement of the exhaust heat exchanger or the lube oil cooler for systems with TCG 2032 engines, the emergency cooling must ensure a safe heat discharge from those components even if there is no heat discharge via the heat utilization of the system.

Normally, the heat is dispersed via an emergency cooling heat exchanger integrated into the heating circuit and linked to a table cooler or cooling tower. See Fig. 6.7. When determining the size of pump, the increased volume flow according to the reserve and the associated higher pressure losses must be taken into account.

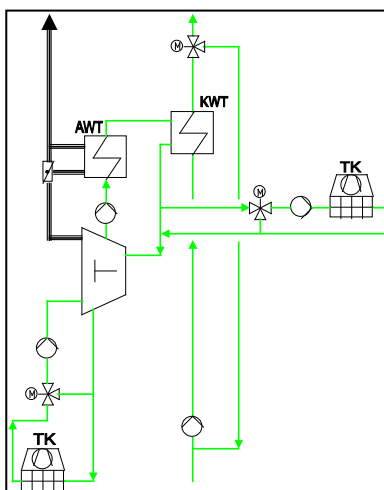
**Fig. 6.7 Emergency cooling with coupling heat exchanger in the heating circuit**



- AWT Exhaust heat exchanger
- KWT Cooling water heat exchanger
- NK Emergency cooler
- TK Table cooler

If the heat produced by the engine cooling water, the exhaust and lube oil (for 2032) is transferred to the heating circuit by one common heat exchanger, the emergency cooler can be implemented directly into the engine cooling circuit without an additional coupling heat exchanger. See Fig. 6.8.

**Fig. 6.8 Direct implementation of emergency cooling system into the engine circuit**



- AWT Exhaust heat exchanger
- KWT Cooling water heat exchanger
- TK Table cooler



# **Power plants layout**

**Chapter 7**

## **Fuel system**

**06-2014**

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## **7. Fuel system**

### **7.1 Gaseous fuels**

The engines operated by combustible gas work as 4-stroke engines following the Otto cycle. The gas-air mixture is fed to the combustion chamber; combustion is then initiated by external ignition via a spark plug.

The fuel gases mainly used are natural gas, sewage gas, landfill gas and biogas. Because of their low heat value compared to natural gas, sewage gas, landfill gas and biogas are also known as weak gases. The principal constituents of these gases are hydrocarbons (methane, ethane, butane and propane) as well as nitrogen and carbon dioxide.

The minimum combustion gas characteristics must be maintained according to the data given in the Technical Circular for fuel gas.

Operating engines with special gases such as flare gas, mine gas etc. is subject to technical approval from the head office.

#### **7.1.1 Methane number**

An important characteristic determining the use of a gas in a gas engine is its knock resistance, i.e. the gas mixture must not self-ignite before ignition, nor must any self-ignition effect cause it to explode suddenly after ignition.

Its methane number gives the knock resistance of a gas. This indicates when a combustion gas in a test engine shows the same knock characteristics as a comparable mixture of methane and hydrogen. To ensure knock-resistant operation with different gases to be used, the methane number must comply with the data sheets. If a gas analysis is available, the respective methane number can be evaluated by the head office. A job card describes the procedure on how to take gas samples. This job card is included in each operating manual.

#### **7.1.2 Accompanying gases / materials**

Sewage gases and biogases are primarily accompanied by a proportion of hydrogen sulfide. Landfill gases are mainly contaminated with chlorinated and fluorinated hydrocarbons. As a result, during combustion, sulfuric, hydrochloric and fluoric acids are produced, which damage the motor, the service life of the oil and the entire exhaust gas system. In order to avoid damages to the external exhaust system because of acid temperatures falling below dew point, the exhaust temperatures should not fall below 180°C. With exhaust temperatures below 180°C, it is necessary to provide suitable treatment of the combustion gas (e.g. desulfurization).

Additionally, landfill gases are often contaminated with gaseous siloxanes. During the combustion in the gas engine, those landfill gases become silicon dioxide and form deposits, which leads to premature wear in the motor, pistons and cylinder liners. A gas treatment is necessary here.

The minimum combustion gas characteristics are outlined in the Technical Circular for combustion gas. These data apply only to the use of gases in gas engines. If systems are to be equipped with catalytic converters in the exhaust system, in addition to the minimum characteristics specified for the engine, further restrictions must be taken into account depending on the catalytic procedure selected. In general, a gas treatment has to be planned.

The gases to be used must be carefully tested for pollutants and assessed on the basis of the respective limit values.

### **7.1.3 Water vapor, hydrocarbon vapors, dust in the gas**

In order to exclude condensation in the engine under all operating conditions which may arise (including cold starting), the water vapor content in the engine must be limited. The relative humidity of the combustion gas must not exceed 80% for the lowest gas temperature. Higher humidity levels require approval.

Vaporized higher hydrocarbons lead to a reduction in the methane number. When these vapors condense in the intake tract, the result is heterogeneous droplet combustion. There is a risk of knocking combustion. Also, it is no longer possible to comply with the exhaust emissions cleansing limits.

The dust content (particle size 3-10  $\mu\text{m}$ ) of the gas is limited to 10 mg/m<sup>3</sup>nCH<sub>4</sub> in the combustion gas. Higher dust contents of this grain size lead both to the possibility of deposits in the combustion chamber and to increased contamination of the lubricating oil, which causes increased wear.

### **7.1.4 Gas cool drying**

The combustion gas must be dried for all biogenic special gases and all gases that exceed the limit of 80% relative humidity. A technically effective variant of this is gas cool drying. Biogas (from renewable raw materials), sewage gas and landfill gas are generally saturated with moisture and hence too damp for direct use. As a side effect of the gas cool drying, pollutants are also washed out of the gas. In particular, water-soluble substances (e.g. ammonia) can be found in the condensate.

The minimum setup for gas cool drying comprises a gas cooling system, a drop separation and a heating of the gas. The gas cooling system, mostly equipped with a cold water chiller, lowers the dew point and hence the absolute moisture content in the combustion gas. The drop separation must ensure that small drops that are carried away by the gas flow are also separated and do not vaporize again in the reheating phase. Although the reheating does not change the absolute humidity, it does change the relative humidity. The gas can only be dried in this step. The reheating comprises either a water-heated gas heater, a gas-gas heat exchanger, which utilizes the heat of the gas entering the cooling system, or the heat input of a compressor.

Other structures are possible if the function is ensured. Gas lines laid in the ground are not really advisable in the power classes in which the genset manufacturer offers products, because they are not usually suitable for cooling the gas throughout the year.

#### **7.1.5 Activated carbon filter**

Doped/impregnated activated carbon has proven to be effective for fine desulfurization. Although the higher hydrogen sulfide contents in the biogas can be degraded very reliably and cheaply with biological methods, biological methods are not usually enough to desulfurize the biogas to the extent that an oxidation catalyst with subsequent exhaust heat exchanger can be safely installed in the exhaust tract.

The doped/impregnated activated carbon (frequently potassium iodine) adsorbs the hydrogen sulfide ( $H_2S$ ) on the carbon surface and oxidizes it there catalytically to elementary sulfur (S). While  $H_2S$  as gas can also be desorbed again (one reason can be warm or damp combustion gas, e.g. due to failure of the gas cool drying), elementary sulfur cannot be desorbed. As a result of this chemical reaction, the sulfur is therefore bound more strongly on the carbon. The load-bearing capacity of the activated carbon is also therefore higher. Thus the loading-bearing capacity with good activated carbon in good operating conditions (see manufacturer's notes) is 500 g sulfur per 1 kg activated carbon and more. As a result, relatively long operating times of 2000-8000 operating hours can be attained in many biogas systems.

If the activated carbon of the gas flow (flowing speed and pressure loss) is correctly designed and the necessary retention times of the combustion gas in the activated carbon layer are complied with, iodized activated carbon will be able to lower the  $H_2S$  flow to the extent that this can no longer be validated with the field measuring instrumentation. This degree of purification is retained over the entire service life. The reactivity of the activated carbon is very high with the result that the activated carbon can theoretically be divided into three layers: The unpolluted activated carbon before the adsorption zone, the adsorption zone in which the adsorption occurs (small in relation to the container) and the polluted layer after the active layer. The adsorption zone migrates in the direction of gas flow through the adsorber. At the gas outlet, this migration of the adsorption zone cannot be measured by measuring the  $H_2S$  content. It is therefore not possible to determine the pollution of the adsorber at the outlet.

When the adsorption zone reaches the outlet from the adsorber, the  $H_2S$  flow rises within a few days to the full input concentration. This process is referred to as break point and must be prevented technically because it progresses rapidly.

One option is to provide a permanent  $H_2S$  monitoring in the activated carbon layer at some distance to the gas outlet, so that an advanced warning can be generated by sampling the gas from the activated carbon layer. In this way, the activated carbon can be replaced before the break point of the adsorption front by the activated carbon, whereby a certain amount of non-polluted activated carbon has to be disposed of.

Another approach is to reserve two separate activated carbon fillings. A working filter, in which adsorption occurs, and a control filter, which ensures at the break point of the working filter that the gas continues to be finely desulfurized. A continuous  $H_2S$  concentration measurement between the two layers makes a statement concerning the break point of the working filter possible. Upon replacement, the working filter,

which is now fully polluted, is disposed of, the control filter becomes the new working filter and the control filter is filled with fresh activated carbon. This can be realized by refilling or by means of a corresponding flap system. If the control filter is designed large enough (e.g. as large as the working filter), replacement of the working filter can be delayed. In this way, the activated carbon replacement can be synchronized with maintenance work on the engine.

The activated carbon must not be able to be bridged with a bypass. Firstly, it is then difficult to demonstrate that this bypass has not been activated and that the combustion gas therefore had the required quality. Secondly, short operating times with combustion gas containing  $H_2S$  are also sufficient to form sulfuric acid via the exhaust gas catalyst, which condenses in the exhaust heat exchanger.

The load-bearing capacity of the activated carbon also depends on the gas humidity and temperature. In general, the gas should be dried (but not be too dry) and should not be too cold either, as the chemical reaction on the surface of the activated carbon is impeded by this. The exact target values can be found in the data sheets of the activated carbons. Owing to the gas states that are better to control, gas cool drying with reheating should take place upstream for conditioning when using activated carbon.

The adsorption of silicon-organic hydrocarbons cannot be compared with the  $H_2S$  adsorption. These can be found in sewage gas and landfill gas and sometimes also in the combustion gas of biogas systems serving for waste recycling.

Non-doped activated carbon filters are used for silicon-organic compounds. These adsorb the pollutants on the surface. However, no chemical reaction occurs there, meaning that the adsorbed substances can be desorbed again.

Two further hurdles are: firstly, that the loading capacity for hydrocarbons is not very high and tends to be in the magnitude of percent, and secondly, not only silicon-organic compounds are adsorbed but all hydrocarbons are adsorbed (although pure hydrocarbons in the engine combustion do not present any problems and would not therefore have to be cleaned).

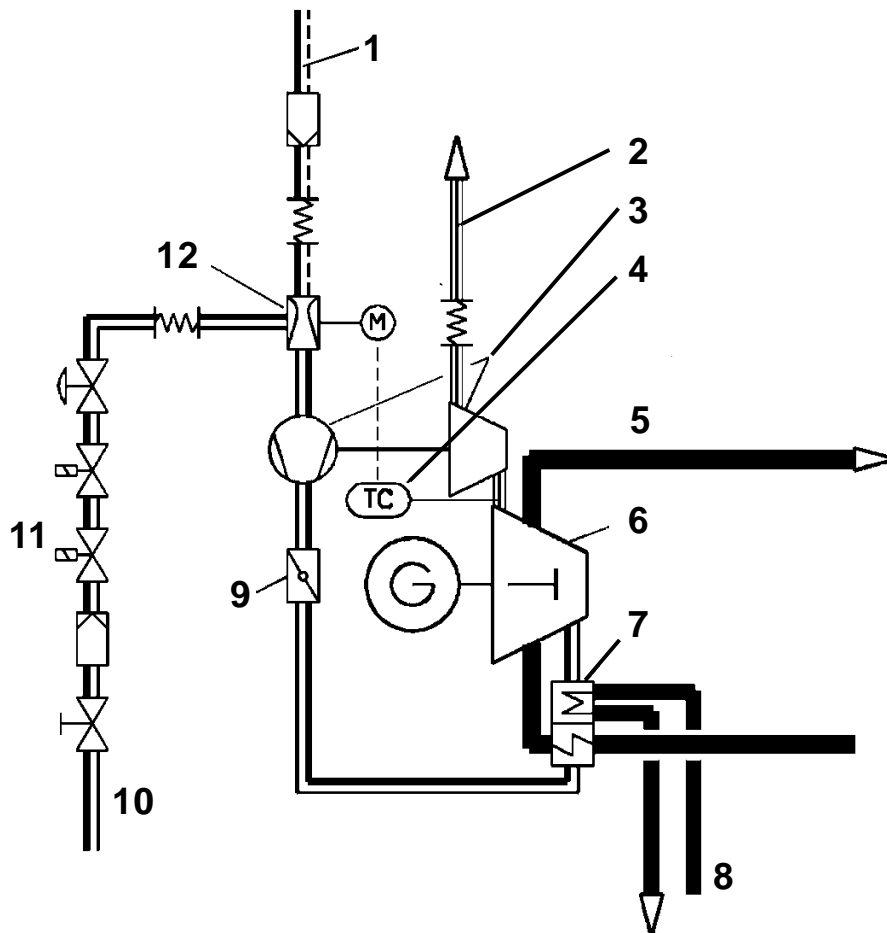
Although no economical system is available for the fine desulfurization, the removal of other pollutants using activated carbon is significantly more complex and expensive with the result that a corresponding estimation has to be made here.

### 7.1.6 Mixture treatment

The exhaust emissions of the gas engine are regulated by controlling the air-gas ratio. The principal components for the processing of the air-gas mixture before it enters the combustion chamber are the gas control unit, the venturi mixer and the throttle valve.

Fig. 7.2 shows, among others, the components for air-gas mixture treatment for lean-burn combustion.

**Fig. 7.2** Principle of lean-burn combustion with turbocharging, dual-circuit cooling and combustion chamber temperature control

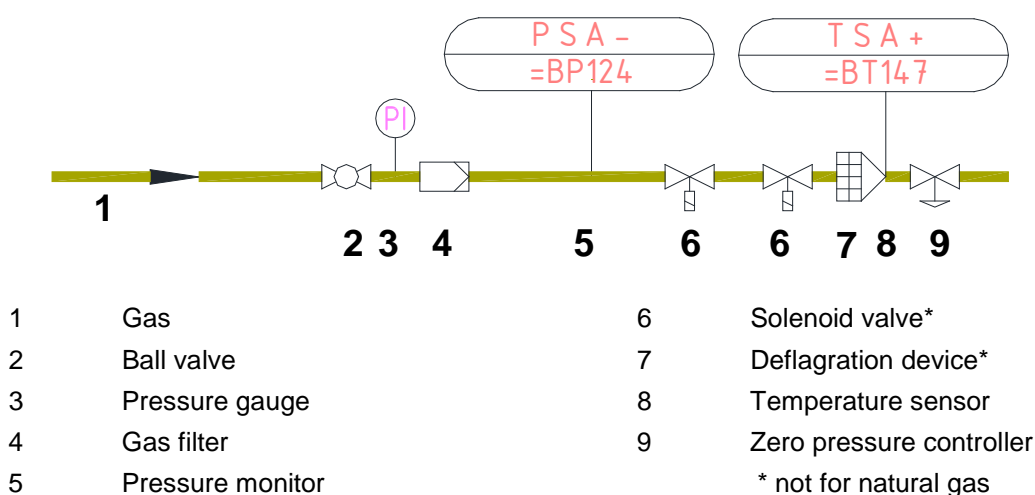


- |    |  |
|----|--|
| 1  | Combustion air                             |
| 2  | Exhaust gas                                |
| 3  | Turbocharger                               |
| 4  | Combustion chamber temperature measurement |
| 5  | Cooling water                              |
| 6  | Engine                                     |
| 7  | Gas mixture cooler                         |
| 8  | LT mixture cooling water                   |
| 9  | Throttle valve                             |
| 10 | Gas  |
| 11 | Gas control line                           |
| 12 | Mixer with actuator for mixture formation  |

### 7.1.7 Gas control line

Generally, gas engines may only be operated with gas control lines approved by genset manufacturer. Before the gas and air are mixed in the venturi mixer, the pressure of gas must be reduced to atmospheric pressure. This is performed by the membrane zero pressure regulator in the gas control line. Fig. 7.3 shows, in principle, how the gas control line is designed. The zero pressure regulators have no auxiliary energy supply. At the inlet to the gas control line is a manually operated ball valve. This is followed by a gas filter as protection against major impurities. The filter insert comprises a filter mat; filtration rate is approx. 85 % for particles >5 µm. Then come two shut-off valves, which are implemented as solenoid valves or pneumatically operated valves depending on the nominal width. When using combustion gases which may contain oxygen, e.g. landfill gas and sewage gas, a deflagration device with temperature monitor is fitted after the shut-off valves. Finally, there is the zero pressure regulator. A minimum pressure sensor is always installed in advance of the solenoid valves. Dependent on the safety requirements for the system, the gas control lines may be equipped with leakage sensors, intermediate vent valves or maximum pressure monitors. Zero-pressure gas control lines are operated at a pre-pressure of up to 200 mbar. In the case of higher pre-pressures, either a special design of gas control line or a pre-pressure control line will be required.

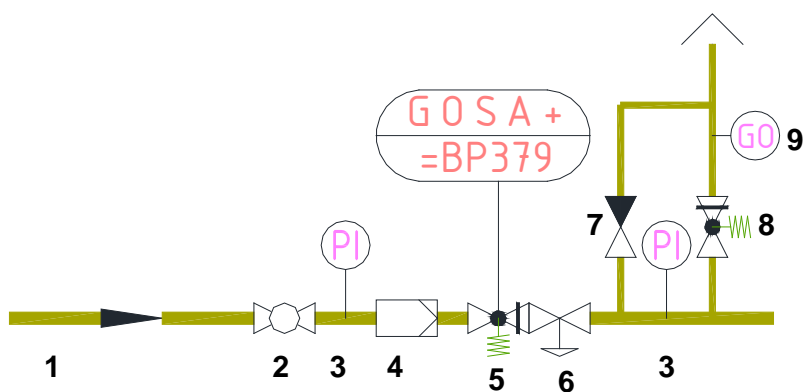
**Fig. 7.3 Gas control line**



### 7.1.7.1 Pre-pressure control line

The pre-pressure control line reduces the gas pressure below 200 mbar. The principal components of the pre-pressure control line are the ball valve at the entry to the unit, the gas filter, the gas pressure regulator with safety shut-off device (SAV) and the safety blow-off valve (SBV). The safety shut-off valve shuts off the gas supply when the outlet pressure after the pre-pressure control line exceeds the preset limit value. Small pressure surges which occur e.g. when the solenoid valves close in the downstream gas control line are intercepted by the blow-off valve which opens against spring force. Fig. 7.4 shows a pre-pressure control line.

**Fig. 7.4 Pre-pressure control line**



1	Gas	6	Pressure regulator
2	Ball valve	7	Air vent cock
3	Pressure gauge	8	Safety blow-off valve (SBV)
4	Gas filter	9	Gas leakage display
5	Safety shut-off valve (SAV)		



### **7.1.7.2 Dual gas operation**

Each type of gas requires its own gas control line with filtration, shut-off valves and precise pressure keeping. After passing through the gas control lines, the two gases are fed to the engine via a common pipeline.

Dual gas operation is possible only with a multigas mixer (adjustable gap).

The changeover from one gas to another takes place automatically when the engine is at a standstill by switching over the solenoid valves at the gas control lines.

In addition, when specially requested, the gas can be mixed before the gas control line. This must be tested and designed in each case.

### **7.1.7.3 Combustion gas system with multi-engine systems and high gas pressures**

With multi-engine systems that are connected to a gas network with higher pre-pressures (0.5-10 bar), it is recommended to equip each genset with a pre-pressure and zero-pressure control line. This design has the advantage that the gas collection line to the gensets can be designed with a smaller cross section. Furthermore, the system has a higher stability against pressure fluctuations, which are caused by starting and stopping the individual gensets.

#### 7.1.7.4 Notes on installing gas control lines

The gas control line must be arranged in the same room as the gas engine in order to allow the pressure regulator to respond to changes in intake air pressure.

For corrosive gases like landfill gas, biogas or sewage gas, non-ferrous metal (brass) must not be used for parts carrying gas.

Gas pressure regulating devices and pipelines must not be installed under tension. The arrow on the actuator housing must point in the direction of flow. The gas control line must be installed horizontally. Regulators and control devices must, as a matter of principle, be arranged in a normal position.

Blow-off lines from the safety blow-off valve (SBV) must be routed from the engine room into the open air with a sufficient cross section.

The gas control lines must be arranged as close to the gas engine as possible. The maximum distance between the outlet from the gas control line and the inlet into the gas mixer at the engine must not exceed 3 m and there may be a maximum of three 90° elbows in this line.

**Note:** As no further filtration of the gas occurs before the inlet into the gas engine, the line between the gas control line and gas mixer must be cleaned inside. See also Chapter 20.1.

In combustion gas mixtures which also contain oxygen as a component (e.g. sewage gas, biogas and landfill gas), backfiring may occur in the gas line. To prevent flames from penetrating the gas supply line, standard gas control lines include long-term fire-resistant deflagration devices with temperature monitoring. Where deflagration devices are installed, the maximum permitted distance between the engine and the gas control line is 40xDN of the gas line. Where the distance is greater, a long-term fire-resistant anti-detonation device must be provided.

The connection to the engine is made via a flexible hose which is laid as a 90° bend, or a specially designed expansion joint which must be installed without tension.

Depending on the system, a gas flow meter may be installed in the feed line to the engines ahead of the control line.

The evaluation units for temperature monitoring at the deflagration device, the SAV in the pre-pressure control line and the gas flow meter must be integrated in the switchgear.

To safeguard the gas engine system, there must be a shut-off device in the gas connection line suitable for manual operation outside of the engine room in a non-hazardous location. This shut-off device must be closed quickly in the event of danger. Remote-operated valves with a permanent auxiliary energy supply (e.g. closing spring) are recommended.

#### 7.1.7.5 Blow-off and breather lines for gas control lines

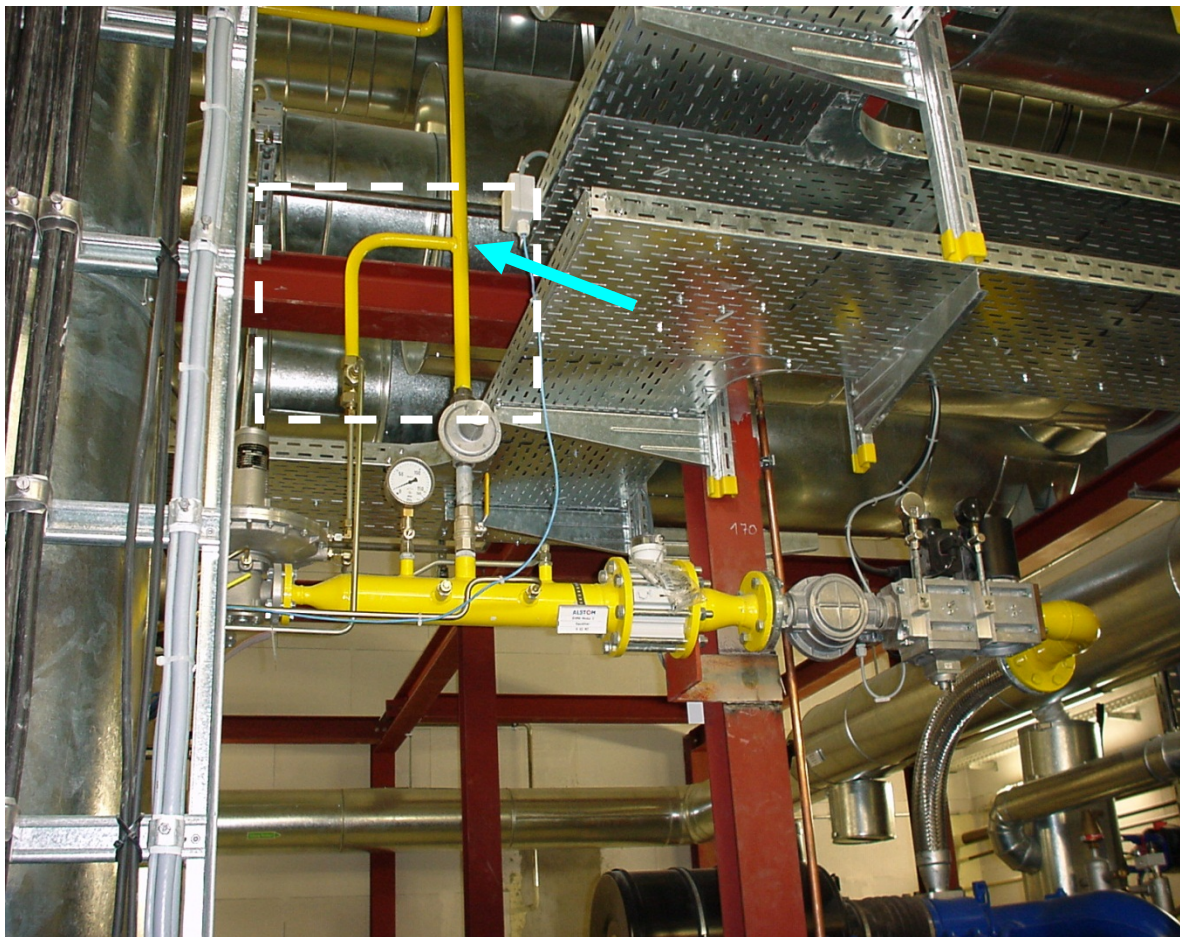
Lines to atmosphere have to be laid without restriction in the diameter (observe pressure loss) as indicated by the manufacturer of the gas pressure regulator and safety device.

Shut-off valves are not allowed in breather lines. Blow-off and relief lines must not be connected to breather lines into a collection line. Only lines to atmosphere are exempted where breather and safety blow-off

devices are already connected inside the units. Fig. 7.5 shows a pre-pressure control line, which does not fulfil this requirement as the blow-off and breather lines are connected to one common line. This is not permissible.

The outlets of the discharge lines into the open air have to be far enough away from ignition sources, protected against external corrosion, equipped with protection against blocking and arranged in a way that no leaked gas can penetrate the closed rooms or cause other annoyance or danger.

**Fig. 7.5 Pre-pressure control line with impermissible arrangement of blow-off and breather lines**



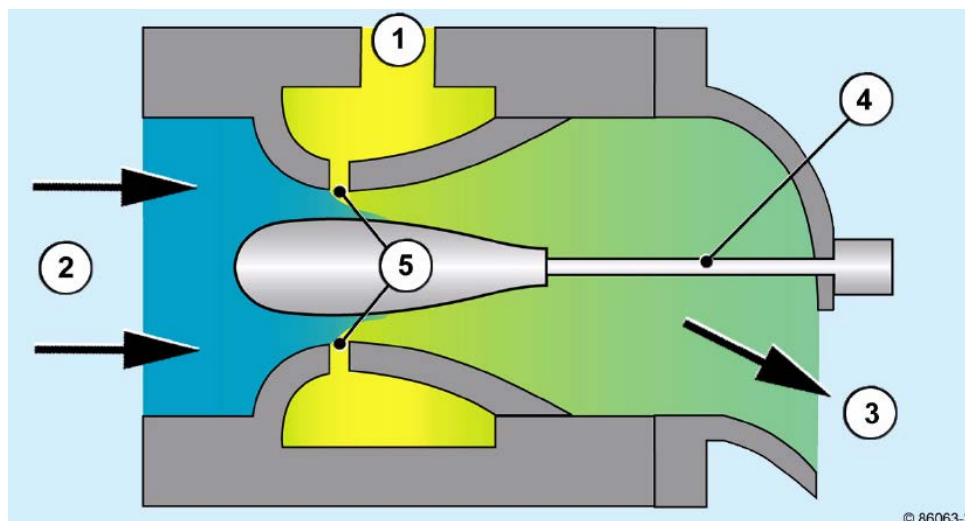
### 7.1.8 Gas mixer

Air and gas are combined in the mixer, which is designed as a venturi pipe. The air flows through a nozzle-like constriction and then through a gradually expanding diffuser. The constriction accelerates the flow, which is then slowed down again with minimal loss in the diffuser. The acceleration at the constriction (nozzle) creates an underpressure, so that the gas is automatically drawn in through a gap at the point of minimum cross-section. Thanks to the subsequent deceleration, the pressure then increases again until it is virtually equal to atmospheric pressure, with the result that the mixing process takes place without any great loss of pressure.

The advantage of this type of mixing is that the quantities of air and gas remain in the same proportion to one another even when output is varied by altering the throttle valve setting and thereby varying the central air volume flow.

A multi-gas mixer is used with which the gap geometry in the mixer itself can be altered via an actuator. The exact maintenance of the gas-to-air ratio in the mixture depends on the gas pressure ahead of the mixing gap being equal to the air pressure ahead of the venturi pipe. Fig. 7.6 shows the principle of a gas-air mixer with adjustable gap.

**Fig. 7.6 Multi-gas mixer**



- 1 Gas inlet
- 2 Air inlet
- 3 Gas-air mixture outlet
- 4 Connection piping to the stepper motor
- 5 Gas gap

### 7.1.9 Throttle valve

The power output or the speed of the engine is regulated via the throttle valve by means of controlling the amount of the compressed mixture to the engine.

### 7.1.10 Startup of biogas systems

If there is no biogas in the initial phase, alternative gases can be used to start the engine. Permissible alternative gases and engine settings are defined in a Technical Circular.

The installed biogas control line is normally a little too big because of the restricted maximum mechanical power and probably a higher heat value  $H_u$  of the alternative gas. Therefore, the inlet pressure of the alternative gas must be adjustable in order to achieve as low a pressure level as possible (approx. 5-30 mbar).

It is not possible to install fixed faceplates in order to lower the inlet pressure because the flow rate necessary for engine startup and engine idling is too low.

The zero-pressure regulator must be correspondingly adjusted by an authorized commissioning engineer.

## 7.2 Notes on installing and maintaining gas systems

### 7.2.1 Regulations

When installing gas lines and gas system components, increased safety requirements must be complied with.

Both when carrying out works on the system and when selecting components, the DIN, TRD, DVGW, etc. regulations must be complied with. The most important ones are listed in the following table:

DIN 6280-14	"Combined power and heat generation at power plants (CHPs) with reciprocating internal combustion engines – basic principles, requirements, components, designs and maintenance"
DIN 6280-15	"Combined power and heat generation at power plants (CHPs) with reciprocating internal combustion engines - testing"
DIN EN 161	"Automatic shut-off valves for gas burners and gas appliances"
DIN EN 14382	Safety devices for gas pressure regulating systems and installations – Gas safety shut-off devices for operating pressures up to 100 bar
DIN 3394	"Automatic actuators" (Part 2 of DIN 3394 has been replaced by DIN EN 161)
G 262	"Use of gases from regenerative sources for the public gas supply"

G 490/I	"Gas pressure regulating systems for inlet pressures up to 4 bar"
G 491	"Gas pressure regulating systems for inlet pressures above 4 to 100 bar"
G 493/I	"Qualification criteria for manufacturers of gas pressure regulating and measuring systems"
G 495	"Gas pressure regulating systems and bulk gas measurement systems – Monitoring and maintenance"
G 600	"Technical regulations for gas installation"
GUV-R 127	"Safety regulations for landfills"
GUV 17.5	"Safety regulations for waste water treatment plants – construction and equipment"
BGV – D2 50	"Working with gas lines"

- Following the installation of the gas line and valves, an expert must be commissioned to confirm that the installation has been performed in a technically correct manner and in accordance with the legal regulations.
- Before commissioning the gas line, a corresponding application must be submitted in good time to the relevant authorities.

### **7.2.2 Servicing and maintenance**

When working on gas lines, among others, the regulation BGV-D2 and DVGW worksheet G 495 must be complied with. In particular it must be ensured that works to the gas system (e.g. opening a gas train, disassembling and servicing a device) are carried out only when the system is depressurized. Such works must be carried out by trained and qualified specialist personnel only. With regard to service intervals, it is essential to comply with the manufacturer's recommendations for the particular type of operation in terms of visual checks, inspections, function testing and maintenance.

# **Power plants layout**

**Chapter 8**

## **Lubricating oil system**

**06-2014**

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## 8. Lubricating oil system

### 8.1 Genset

The lubricating oil systems of the engines are implemented as wet sump lubricating systems. Table 8.1 shows the various lubricating oil systems used for the different engine series.

**Table 8.1**

Engine type	Wet sump Oil pan at engine	Extended oil tank in base frame	External oil tank in the system
TCG 2016 C	■		■
TCG 2020	■	■	
TCG 2032	■		

All engine series have integral lubricating oil pumps; the oil is filtered and cooled by either engine-mounted or separate filters and oil coolers.

The external oil-coolers and assembly parts have to be designed for a minimum-pressure of 16 bar.

The gensets with engines of the series TCG 2020 can optionally be implemented with an additional oil tank in the base frame. With the series TCG 2016 C there is the option of providing an external oil tank. Due to an increased lubricating oil volume, considerably increased lubricating oil service lives are achieved depending on the oil quality and type of combustion gas.

### 8.2 System

For the TCG 2032 engines, the external lubricating oil circuit components (e.g. heat exchanger) must be arranged at the same level as the genset or lower in order to prevent the oil from draining back into the oil pan when the engine is at a standstill. For systems with TCG 2032, the external lube oil cooler should be installed as close to the genset as possible so that the lube oil volume is kept as low as possible in the plant system.

### **8.2.1 Clean oil tank**

The fresh oil tank must be arranged in a way which prevents it from emptying into the engine due to gravity. In general, lubricating oil is replenished using a gearwheel pump, which provides a defined filling amount. Compared to replenishment with gravity flow a replenishing by gearwheel pump is preferred. The size of the supply tank will be dependent on the operating mode of the plant and the associated oil supply required. The minimum recommended size is equal to the quantity required for one oil change plus the amount consumed during two intervals between changes.

### **8.2.2 Waste oil tank**

The minimum recommended size is equal to the quantity yielded by two oil changes.

### **8.2.3 Service tank**

If a service tank is provided for refilling, it should hold sufficient lube oil for approx. 200 oh (e.g. for TCG 2032, approx. 600 dm<sup>3</sup>).

### **8.2.4 Container applications**

In containers, the available free space might be heavily restricted due to the size of the genset itself and also due the auxiliary equipment. For those applications, the recommendations given above for the size of the oil tanks do not have to be fully adhered to.

## **8.3 Lubricating oil treatment**

The quality of the lubricating oil is one of the main criteria determining the service life of the engine components in contact with the oil and hence also the fault-free operation of the system. Particular attention should therefore be paid to maintaining the lubricating oil filters and, if appropriate, the separators.

### **8.3.1 Lubricating oil filter**

The lubricating oil filters fitted to gas engines are designed for unlimited operation and no further measures are required on the part of the client to treat the lubricating oil.

#### **8.4 Lubricating oil types**

Technical circulars for lube oil contain a list of lubricating oils available from notable manufacturers and approved for gas and diesel engines. No other lubricating oils may be used without written approval. Also included in these Circulars are details of lubricating oil change intervals, used oil analyses and maintenance of the lubricating oil filters fitted to the engine.

Before commissioning, an analysis of the fresh oil supplied must be compared with the manufacturer's specification.

#### **8.5 Lube oil with biogas applications**

Further information regarding the lube oil with biogas applications can be found in the technical circular "Optimizing the lube oil management for biogas applications."

#### **8.6 Engine prelubrication**

Prelubrication is generally provided for all engine types, as this significantly reduces engine wear. For this purpose, electrically driven pre-lubricating pump modules are used, which in most cases are mounted on the genset base frame. The prelubricating pump must be integrated in the lubricating oil system in such a way that when prelubrication is activated, oil flows through all components (filters, coolers) installed between the oil pump and the engine. The capacity and supply pressure of the pump modules must be matched to the respective engine type.

Engine prelubrication takes place immediately before the start when the engines are at a standstill. Optionally, a process called interval prelubrication can be provided, i.e. the engine is prelubricated at preset intervals for a defined period of time.

In the case of systems equipped with gas engines, prelubrication is controlled by the TEM system.

Prelubrication is inactive when the engine is running.

**The TCG 2032 does not have an interval prelubrication and therefore it must be prelubricated before each start.**

#### **8.7 Changing and replenishing the lube oil**

Lube oil changes must be carried out in accordance with the operating instructions for the respective engine, and in the case of modules in continuous operation, lube oil consumption must be compensated by topping up the system with fresh oil.

When changing the lube oil, make sure that the oil in the system-side components e.g. pipes, heat exchangers etc. is changed. Drainage options for the lube oil are provided at the lowest points of the system for this. Depending on the system layout, it is effective to provide a permanently installed or mobile emptying pump.

Fresh lube oil is filled from the fresh oil tank via the top-up pump. This operation can be either manual or automatic. In the case of systems equipped with gas engines, the lube oil replenishment is controlled via the TEM system.

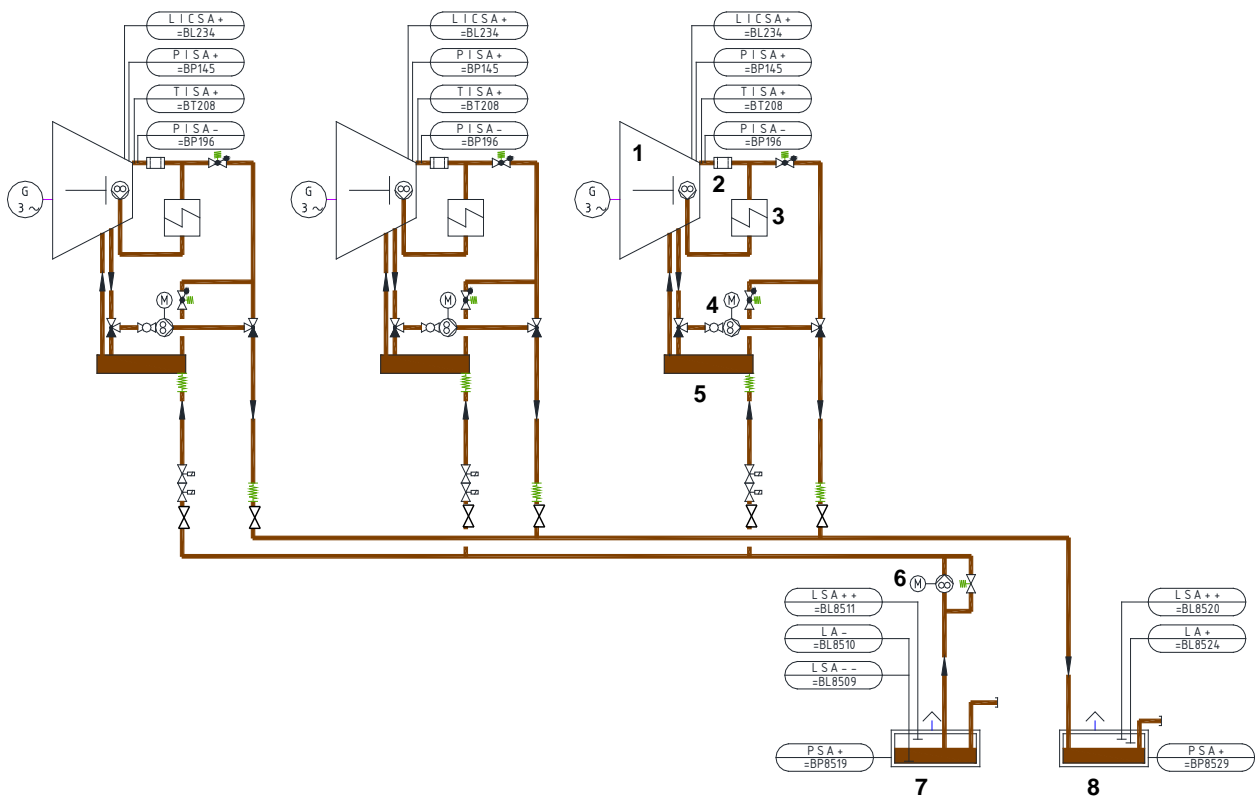
Two solenoid valves are installed in series in the lubricating oil top-up line before the engine. When the minimum level in the oil pan is reached, the solenoid valves are opened by the TEM system (and/or the top-up pump is started) and oil is replenished. When the maximum level is restored, the solenoid valves close (and/or the top-up pump is stopped).

When topping up under gravity from the service tank, it must be ensured that the lines are large enough and that the oil does not become too viscous due to low temperatures.

To empty out the oil pan when changing the lubricating oil, the pressure line from the pre-lubricating pump must be connected to the used oil tank via a three-way valve. To change the lube oil, the three-way valve is switched over and the lubricating oil is pumped out of the oil pan and into the used oil tank. The top-up pump is then used to fill up with clean oil. The three-way valve behind the prelubricating pump is switched back to the "prelubricate" position. By activating the prelubricating pump, the complete lubricating oil system is refilled with oil.

**Safety and other legal regulations for the use and storage of clean and/or waste oils must be observed at all costs.**

**Fig. 8.1 Lubricating oil system**



- 1 Gas engine
- 2 Lubricating oil filter
- 3 Lube oil cooler
- 4 Prelubrication pump
- 5 Oil tank base frame
- 6 Clean oil pump
- 7 Clean oil tank
- 8 Waste oil tank



# **Power plants layout**

Chapter 9

## **Combustion air system**

06-2014

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## **9. Combustion air system**

### **9.1 Definitions**

#### **9.1.1 Ambient air**

The air of the free environment and the air with which a gas engine is supplied is called ambient air. The ambient air temperature is the temperature measured close to the ground, normally 2 meters above ground level, neither with influence from sunlight nor influence from ground heat or effects of thermal conduction.

#### **9.1.2 Intake air / combustion air**

The intake air or combustion air is provided to the gas engine directly before its combustion air filter. It passes through the plant's ventilation system before reaching the engine's combustion air filters. The ventilation system includes filtering of the air, and depending on the layout of the ventilation system (layout of air ducts and amount of ventilation air), the intake or combustion air may face a certain temperature rise against the ambient air temperature.

### **9.2 Requirements for the combustion air**

#### **9.2.1 Combustion air temperature and pressure**

In the data sheets, the engine power is indicated as per ISO 3046-1 and the electrical terminal power of the power supply unit as per ISO 8528-1. In both standards, the following standard reference conditions are defined in respect to the combustion air parameters:

Air temperature:	298 K (25°C)
Air pressure:	1000 mbar (100 kPa)
Relative humidity:	30%

These standard references are sometimes deviated from and special reference conditions defined depending on the engine type for the power data in the Caterpillar Energy Solutions GmbH standard data sheets.

The power is reduced for combustion air temperatures and installation heights diverging upwards from the reference conditions.

The following requirements in respect to the combustion air temperature apply for the start and operation of the engines:

**When operating the engines, the combustion air temperatures (minimum / design) have to be kept within the limits as per the data sheets or P&I flow diagrams.**

**For the start of engines, the following combustion air temperatures have to be maintained in the engine room:**

<b>Gas engines with air preheating or wastegate:</b>	<b>≥ 5 – 10°C</b>
<b>Gas engines without air preheating and wastegate:</b>	<b>≤ 10 K below design temperature as stated per data sheet and/or P&amp;I diagram</b>

### 9.2.2 Composition of the combustion air

The normal composition of combustion air is considered to be dry air with a certain amount of steam. The steam content in the air is defined by the relative humidity at a defined air pressure and air temperature. Basically the combustion air must be free of components forming acids or bases; e.g. sulfur dioxide (SO<sub>2</sub>) forms sulfurous acid when combined with water (H<sub>2</sub>O). The main components of dry air at sea level (NN) are given in Table 9.1.

**Table 9.1**

Main components of dry air	
gas storage	Volume fraction [%]
Nitrogen N <sub>2</sub>	78.084
Oxygen O <sub>2</sub>	20.946
Carbon dioxide CO <sub>2</sub>	0.035
Argon Ar	0.934
Total	99.999

The remaining 0.001% of the volume fraction are trace gases, mainly the inert gases like neon (18 ppm), helium (5 ppm) and krypton (1 ppm).

In the surrounding area of industrial or chemical plants, the composition of the combustion air may face some negative influence from process gases such as, for example, hydrogen sulfide (H<sub>2</sub>S), chlorine (Cl), fluorine (F), ammonia (NH<sub>3</sub>) etc.

The technical circular states limit values for the content of "harmful" attending gases like sulfur (S), hydrogen sulfide (H<sub>2</sub>S), chlorine (Cl), fluorine (F) and ammonia in the combustion gas. Those given limiting values imply that the composition of the combustion air itself is as per above in Table 9.1, i.e. the combustion air is

free of any sulfur, hydrogen sulfide, chlorine, etc. With the given limiting values for the combustion gas, it is possible to deduce limiting values for the content of "harmful" gases in the mixture combustion gas / combustion air and combustion air alone.

Example:

The technical circular states the limit value for ammonia in the combustion gas at  $30 \text{ mg/m}_n^3 \text{ CH}_4$ . When burning natural gas (100%  $\text{CH}_4$  assumed), for example, 17 standard cubic meters of combustion air are required per cubic meter of natural gas. By use of this ratio, it can be stated that the content of ammonia in the combustion air must not exceed  $1.8 (30/17) \text{ mg/m}_n^3$  in order to keep a condition corresponding to the limit value of  $30 \text{ mg/m}_n^3 \text{ CH}_4$  given for the combustion gas. If the fuel gas itself contains ammonia too, the limit value for the combustion air must be reduced accordingly.

Similarly, the upper limit values for other "harmful" gases in the combustion air can be calculated. Those values are given in Table 9.2.

**Table 9.2**

Permitted contamination of the combustion air	
Component	Content [ $\text{mg/m}_n^3$ air]
Sulfur (total) S or Hydrogen sulfide $\text{H}_2\text{S}$	< 130 < 135
Chlorine (total) Cl Fluorine (total) F or Total chlorine and fluorine	< 5.9 < 2.9 < 5.9
Ammonia $\text{NH}_3$	< 1.8
Oil vapors $>\text{C}5<\text{C}10$ Oil vapors $>\text{C}10$	< 176 < 14.7
Silicon (organic) Si	< 0.59

As a rule, it is not permissible for acid formers such as  $\text{SO}_2$ ,  $\text{SO}_3$ , HCl or HF (but also other substances) to be in the combustion air. As condensation can occur in the mixture cooler, especially in hot and humid conditions (e.g. tropics), acid attacks would result here. Acid formers in the exhaust tract are less critical because the dew point is not fallen below here.

Components in the combustion air as mentioned in Table 9.2 might be a reason for shortening the maintenance intervals and they may damage or even destroy emission lowering systems located downstream.

When designing combustion air systems, care must be taken that the air is not drawn from areas in which increased concentrations of these accompanying gases exist or might exist as a result of the equipment installed (e.g. refrigeration systems) or the processes conducted therein.

### 9.2.3 Cleanliness of the combustion air

Fine sand or dust as well as chemically aggressive vapors significantly reduce the service life of the engine if they are directly drawn in by the engine.

The combustion air supplied to the engine must therefore fulfil certain requirements in terms of cleanliness. It is essential to provide air filters which must be implemented as Class F6 to F7 fine dust filters. The mean efficiency of these filters in combating atmospheric dust is specified in DIN EN 779. The separation rates to be achieved with these filter classes are given in Table 9.3:

Table 9.3

Particle size >μm	Separation rate in %	
	Class F6	Class F7
0.5	30	65
1.0	50	85
1.5	70	95
2.0	80	98
2.5	85	>99
3.0	95	>99
4.0	>99	>99
Mean efficiency (%) as per DIN EN 779	$60 \leq E_m \leq 80$	$80 \leq E_m \leq 90$

Depending on the ambient conditions under which the engine obtains its combustion air, a type of filtration or filter combination must be selected suitable for these conditions.

As already mentioned in Chapter 5 (engine room ventilation), it is required to provide a ventilation system for the engine room including a coarse filtering acc. to filter class G3. After the coarse filter, the particle size of the dust in the air is in the range of 1 μm and the dust concentration in the air should be in the range of 0.5 – 1 mg/m<sup>3</sup>. This concentration corresponds to a dust concentration assumed for the design of combustion air filters of truck engines operating in normal European traffic.

### 9.2.4 Tropical conditions

In tropical and subtropical areas, the rainfall exceeds the possible atmospheric evaporation for some months of the year. This circumstance causes a high humidity at comparably high medium ambient temperature, about 25°C average annual temperature. The water content (steam) in the air/combustion air is therefore very high.

When operating high charged combustion engines with charge air cooling or mixture cooling, there may be condensation of the steam entering the engine together with the combustion air. This condensate may lead to corrosion and wear for engine components like charge air/mixture cooler, throttle, receiver, valves etc. If, in addition, the combustion air is affected by acid or base-forming attending gases like sulfur dioxide (SO<sub>2</sub>), this might lead to accumulation of sulfurous acid. The corrosion for the above mentioned components will escalate.

Depending on the engine type, a "tropical version" is available under these operating conditions in order to reduce corrosion of the affected components. It is also necessary to prevent the intake air from containing acid formers.

### 9.3 Combustion air quantity

The combustion air quantity required for gas engines varies with the composition of the combustion gas and with the combustion air ratio being used. The specific combustion air values given in Table 9.4 apply to the most frequent gas engine application, i.e. operation with natural gas on the lean-burn principle.

**Table 9.4**

Engine type	Combustion air quantity m <sub>L</sub> [kg/kWh]
TCG 2016 C	5.2
TCG 2020(K)	5.2
TCG 2032	5.0

For precise data, please refer to the specific data sheets.

## **9.4 Types of filtration for the combustion air**

### **9.4.1 Air filter – Paper/Plastic**

In the majority of applications where the air is relatively clean (dust concentration < 1 mg/m<sup>3</sup>), paper filters are used for air filtration: these may be either plate type filters, pocket or circular air filters. With the series TCG 2016, TCG 2020 V12 and TCG 2020 V16, such filters with appropriate filter housings are fitted to the engine. For the TCG 2032 engines a separately mounted filter, containing four filter elements each, is planned per cylinder row. Depending on the design, this filtering unit also incorporates the heat exchanger for the combustion air preheating. The same filtering unit may be used optionally with engines of the series TCG 2020, especially with regard to low ambient temperatures.

Because of the sharp increase in pressure loss in the event of contamination, where these filters are used, a negative pressure monitoring facility or vacuum pressure indication must, on principle, be provided. The cleaner the combustion air, the slower the filter gets contaminated. A contaminated filter consumes more energy than a clean filter. Consequently, this leads to a slight increase of the fuel consumption and to an unfavorable operating point of the compressor. In extreme cases, the compressor pumps and the genset cannot be operated safely anymore. The filter needs to be renewed before it leads to a critical operational state.

## **9.5 Silencer**

In the case of air filters installed outside of the genset room, the compressor noise of the turbocharger in particular can be transmitted outside via the air supply pipe, where it makes its presence felt as a high-frequency whistle. In such cases, silencers must be provided in the intake lines, the size of the silencers being determined in accordance with the respective plant.

## **9.6 Air intake line**

Where the air filters are not installed in the engine, an intake line must be installed between the engine and the air filter. Smooth and clean, e.g. painted or galvanized piping must be used for these lines. The line must not bear directly on the engine, i.e. there must be a rubber sleeve or corrugated hose fitted between the air inlet housing and the air line. Sleeves and hoses must not be constricted by bending. All joints in the intake line between the filter and the engine connection must be tightly sealed. If the intake line is routed with a fall towards the engine, a water trap must be provided with a drain-off in front of the engine.

A useful guide to determining the correct size for the air lines is the air speed in the intake pipe. The air speed should be  $\leq 20$  m/s.

## 9.7 Pressure losses

The air intake system with pipes, elbows, filters, silencers, etc. is itself the cause of pressure losses. The pressure loss occurring at nominal volume flow must not exceed the values laid down for the individual engine series.

These values are given in Table 9.5.

**Table 9.5**

Engine series	Max. permissible underpressure [mbar]
TCG 2016 C	5*
TCG 2020(K)	5*
TCG 2032	5*

\* permissible underpressure before air filter

## 9.8 Venting the crank case

Series TCG 2016 and TCG 2020 and TCG 2032 engines have a closed crankcase venting system, i.e. vapors from the crankcase are directed back to the intake manifold via an oil separator. The separated oil is routed back to the engine crankcase.





# **Power plants layout**

**Chapter 10**

## **Exhaust system**

**06-2014**

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## **10. Exhaust system**

The function of the exhaust system is to transfer gases produced by combustion in the engine to the atmosphere. In order to comply with the environmental regulations that apply at the installation site in respect to both the emission of exhaust gases and noise, the exhaust system must be designed to fulfil these necessary requirements.

If the internal combustion process in the engine itself cannot be made to fulfil the local regulations for the emission of exhaust gases, it will be necessary to treat them, e.g. by use of catalytic converters or thermal reactors.

The exhaust noise emissions can be minimized by installing silencers.

Every engine must be fitted with a fully independent exhaust system.

### **10.1 Permissible exhaust backpressure**

Besides the exhaust mass flow and the exhaust temperature, the most important design parameter determining the size of the exhaust system is the permissible exhaust backpressure.

Exceeding the permissible exhaust backpressure has a significant influence on performance, fuel consumption and the thermal load of the engine. The exhaust backpressure is measured immediately behind the turbine at full load and must not be exceeded.

Flow resistance in pipes, elbows, expansion joints, exhaust heat exchangers, catalytic converters, silencers, spark arresters, deflection hoods and stacks creates the exhaust backpressure. All resistance must be taken into account when determining the backpressure.

The volume flow dependent resistance in exhaust pipes and elbows can be determined with the aid of the diagram in Fig. 10.1.

For the resistance of components installed in the exhaust system, please refer to the data sheets of these components.

The permissible exhaust backpressures for the individual engine series are listed in Table 10.1.

**Table 10.1**

Engine model series	Permissible exhaust backpressure Minimum / Design [mbar]
TCD 2016	- / 35
TCG 2016 C	30 / 50
TCD 2020	- / 20
TCG 2020(K)	30 / 50
TCG 2032	30 / 50

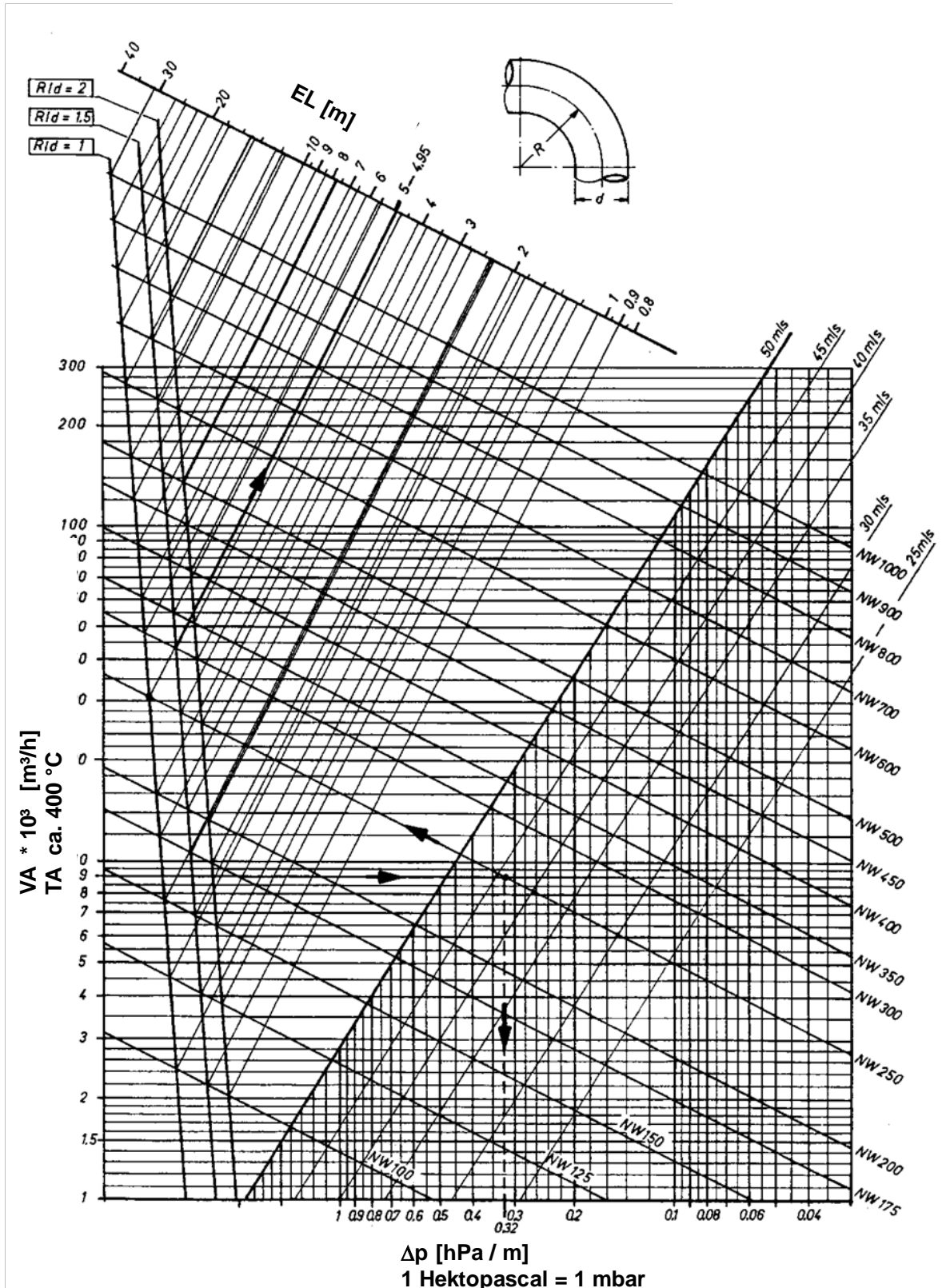
Exhaust backpressure measured behind the turbine

In designing the exhaust system, the information contained in the data sheets for the individual engine series must be taken into account.

A useful guide to the design of the exhaust system is the speed of the exhaust gas in the exhaust pipe. This should be in the range of 20-35 m/s.

When selecting materials, the temperature increase in the partial load range must be borne in mind.

Fig. 10.1 Flow resistance for exhaust pipes



### Legend to Fig. 10.1

VA	Exhaust volume flow
TA	Exhaust reference temperature
$\Delta p$	Pressure loss per meter of straight pipe
EL	Substitute length for a pipe bend 90°
NW	Nominal width of the exhaust pipe in millimeters
R	Radius of the bend
d	Pipe diameter in millimeters

### Example for Fig. 10.1

Specified:	VA = 9000 m <sup>3</sup> /h	
	Straight pipe:	l = 10 m
	Bends:	3 bends 90° with R/d=1
Wanted:	$\Delta p$ of the pipe	
Solution:	NW 250	
	approx. 44 m/s	
	$\Delta p = 0.32$ hPa / m straight pipe	
Substitute length for a bend:	4.95 m	
Total pipe length:	$L_{ges} = 10 + (3 \cdot 4.95) = 24.85$ m	
	$\Delta p_{ges} = 24.85 \cdot 0.32 = 8$ hPa (mbar)	

## **10.2 Exhaust system components**

### **10.2.1 Catalytic converters**

All gas engines operate on the lean-burn principle, where thanks to the large surplus of air, the NO<sub>x</sub> emissions produced by the combustion process are already below the limits prescribed in TA-Luft<sup>1</sup> (NO<sub>x</sub> ≤ 500 mg/m<sup>3</sup>). Dependent on engine type and emissions requirements, it may be necessary to install an oxidation catalyst for the further reduction of CO components. The process is particularly economical and, with regard to all aspects of operation, it is both clean and reliable over the long term. Of all catalytic converter systems, the oxidation type catalyst is the most resistant to harmful components in the fuel gas. The catalytic converter must be the first element in the exhaust system.

#### **10.2.1.1 Planning notes for catalytic converters**

##### **10.2.1.1.1 Lifting lugs**

As the catalyst housing can weigh more than 100 kg (especially for big engines), installation should be considered at an early stage of planning. Housings fitted with cones on both sides can be suspended using round slings. In very tight spaces or with other housing shapes, it may also be advisable to provide lifting eyelets. This is important for larger catalyst disks, which are installed on the heads of heat exchangers or silencers.

##### **10.2.1.1.2 Insulation**

The catalyst insulation must be designed in such a way that it can be easily dismantled in order to clean or replace the catalytic converter. This is also beneficial for retightening the flange connections.

---

<sup>1</sup> TA-Luft = Technische Anleitung zur Reinhaltung der Luft (Technical instructions on air quality control)

### 10.2.1.1.3 Installation

If not otherwise specifically indicated, catalysts can be installed in any position, i.e. horizontally, vertically or diagonally. The flow direction only needs to be taken into account where the housings have different length cones. The inlet cone is usually longer and slimmer than the outlet cone.

When installing a catalytic converter, it is very important that the exhaust gas flow is even through the catalyst. If this is not the case, the emission conversion is not at its optimum and the stress on certain parts of the catalyst is out of proportion and can cause damage.

To avoid this, two different installation options are available:

Where the unit is to be installed in the exhaust line, the diameter of the line must be adapted to that of the exhaust catalyst with the aid of a cone. To ensure that the flow into the catalytic converter is as even as possible, the taper of the cone on the inlet side must be between  $10^\circ$  and  $20^\circ$  and the exhaust line must be arranged accordingly (smoothing path) (Fig. 10.2). The nominal bore of the exhaust pipe in front of the taper of the cone on the inlet side must be large enough to ensure an exhaust speed of  $< 40$  m/s.

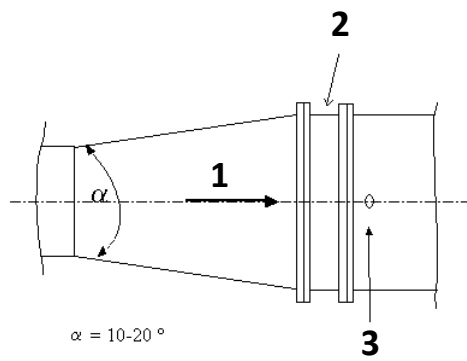
In case of installation into a silencer or an exhaust heat exchanger, a head pipe with radial exhaust inlet according to figure 10.3 is used which guarantees an even flow into the catalyst. The distance between the center line of the inlet pipe and the flange connection of the catalyst should at least be as long as the catalyst's diameter. The nominal bore of the inlet nozzle in front of the catalyst must be large enough to ensure an exhaust speed of  $< 40$  m/s.

Both the installation into the head pipe of the silencer described and the design with cones serve to achieve as high a homogeneous flow into the catalyst as possible. Only a homogeneous flow will achieve the full effect of the catalyst.

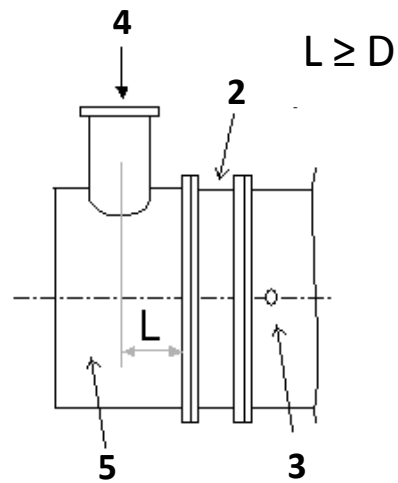
During operation, the catalysts and their housings must remain free of tensions which result from expansion of the exhaust pipes at operating temperature. Expansion joints must be in suitable positions in the exhaust system.



**Fig. 10.2**



**Fig. 10.3**



- 1 Exhaust flow direction
- 2 Catalyst
- 3 Temperature measuring nozzle
- 4 Exhaust inlet
- 5 Head pipe
- D Catalyst diameter
- L Spacing from catalyst inlet to center of exhaust inlet

#### **10.2.1.1.4 Inspection**

The catalyst should be checked against mechanical damage or contamination at regular intervals. If the engine runs with particle free natural gas and low oil consumption, a yearly inspection is sufficient. For other types of gases or in case of high oil consumption, an inspection is recommended every 2-6 months.

These regular inspections should prevent the system from being shut down.

It must be ensured that good access to the catalyst is possible and that inspections can be carried out efficiently right from the planning stage.

#### **10.2.1.2 Installation specification oxidation type catalysts**

The catalytic converters are supplied complete with hole flange housing for installation in the silencer (head pipe) or as cone catalysts with connection flanges for installation in the exhaust pipe.

For the catalyst flange connection, the installation specification 1240 2390 UE 0499-41 must be complied with:

##### **10.2.1.2.1 Seals**

The seals are designed for medium temperatures up to max. 650 °C. The seals are made up of segments; one seal set comprises two layers. It is essential to ensure that the segment butt joints are offset between the individual layers. The special properties of the seal in the high temperature range require that these installation specifications be adhered to exactly.

##### **10.2.1.2.2 Screws**

The screws are composed of high-temperature resistant steel, which is especially suitable for use at high temperatures.

### 10.2.1.2.3 Installation

- The system must be cooled.
- Direction of flow through the catalyst; cross bracing for the matrix on the outflow side.
- Clean and check the sealing surfaces.
- Install the catalyst and seals, fit the screws with a little high-temperature paste and tighten gently by hand.
- Check that seals are positioned correctly.
- Tighten the screws in alternate groups of 2-6 with a torque wrench to 40 Nm.
- Then tighten all the screws one after another around the perimeter to the nominal torque of 50 Nm.
- The system can now be commissioned.
- For exhaust temperatures above 400 °C, because of the characteristics of the seal, the flange connection must be retightened with the nominal torque after approx. 20 hours in operation. This must be done when the flange connection has cooled down.
- In order to avoid damage to the housing during operation, it is important not to put pressure or tensile stress onto the catalyst housing. For this reason, catalyst housings always have to be installed stress free.
- As the catalyst must be placed as close as possible to the engine for temperature reasons, there are usually no long pipes or other components running from the catalyst. For this reason, a simple expansion joint which can withstand axial and radial forces by means of a pipe elbow is sufficient. If there is a longer pipe after the catalyst housing, an additional expansion joint is recommended.
- In the event that the catalyst housing is installed in the piping, this must be supported by means of one or more columns on the foundation or on a steel structure. Suspensions are also possible. If the catalyst housing is installed in the head pipe of a heat exchanger or a silencer by means of a flange connection, it may be necessary to support the head pipe separately by means of a sliding seat. The fixing point in this case must be on the heat exchanger or the silencer. This will not only ensure that the housing is installed free of tension, but also that it can be easily installed and removed.

### 10.2.1.3 Cleaning the catalyst

If the flange connection is opened to clean the catalyst, new seals and screws must subsequently be fitted. Remnants of the old seals must be completely removed beforehand. Installation must take place as described above.

### 10.2.1.4 Operating recommendations for oxidation type catalysts

Removing hydrocarbons and carbon monoxide with an oxidation type catalyst is a simple method of cleaning the exhaust and this catalyst has a wide operating range.

To ensure reliable catalytic converter operation, the following points must be noted:

- Misfiring must be avoided as non combusted fuel in the catalytic converter can lead to undesired after-burning with unduly high exhaust temperatures. Even temperatures below the melting temperature of the supporting material (above 700 °C) cause premature aging. Increasing temperatures may also lead to damage of the catalyst.
- Explosive ignitions in the exhaust pipe can lead to the mechanical destruction of the catalyst if the client has not provided explosion flaps.
- To avoid thermal aging, the exhaust temperature on admission to the catalytic converter should be between 400 - 560 °C. Because of the exothermic reaction in the catalytic converter, the temperature of the exhaust is increased. This temperature must not exceed 650 °C. A temperature-monitoring device must therefore be provided after the catalytic converter, which will cut off the fuel supply if this limit is exceeded.
- Low-ash, low-alloy engine oils must be used in order to minimize deposits in the catalytic converter. Blockages of the ducts caused by lube oil incineration ash can significantly impair the functioning of the catalyst.  
Moisture or solvents must be prevented from affecting the catalyst; passing through the dew point when starting up and shutting down the system is an exception to this rule.
- If the catalyst is wet, it must be protected from the effects of freezing. The only exception is residual moisture, which comes out from the condensate caused by a cold start at low external temperatures. For example, an installation above a container is permissible if it is ensured that moisture never gets into the exhaust pipe from outside.

- In the case of biogas systems, the use of oxidation catalysts is only possible if the combustion gas has been break-proof fine desulfurized beforehand (see Chapter 9 Combustion Gas). The oxidation catalysts even age through the sulfur compounds. However, the greater damage occurs in the exhaust heat exchanger. The oxidation of  $\text{SO}_2$  (resulting from sulfur compounds in the engine exhaust gas) to  $\text{SO}_3$  shifts the dew point so that the dew point is fallen below here with conventional designs of exhaust heat exchangers, and sulfuric acid condenses correspondingly. This leads to massive contamination of the exhaust heat exchanger and to subsequent acid attacks through to destruction of the exhaust heat exchanger.
- When running on landfill or sewage gas, there is only limited potential for the use of oxidation type catalysts, even when a gas purifier is fitted ahead of the engine
- The following substances are harmful to the catalyst and must be avoided in the fuel gas: silicon, silicon products, sodium, calcium, lead, bismuth, mercury, manganese, potassium, iron, arsenic, antimony, cadmium; under certain circumstances also compounds of chlorine, sulfur and phosphorus; as well as organic and inorganic compounds.
- The catalytic converter should be installed before the silencer, in order to prevent obstruction of the catalytic converter due to the detachment of absorbent wool. Obstruction of the catalyst will lead to an increase in the exhaust backpressure and the reduction of pollutants becomes worse. It is not easy to remove the wool from the channels of the catalyst. On the other hand, installation after a pure reflection silencer without sound-absorbent wool is permissible provided that exclusively stainless steel parts are used.
- In order to protect the catalyst against overheating, the catalyst should only be installed in the exhaust system when the engine has been adjusted and is running trouble free. This applies to both initial commissioning and subsequent maintenance work.
- Sulfur in the form of  $\text{SO}_2$  has hardly any influence on the catalytic converter at temperatures over  $420\text{ }^\circ\text{C}$ . However, it must be ensured that some of the  $\text{SO}_2$  is oxidized to  $\text{SO}_3$  in the catalytic converter. So if the dew point in the exhaust system is undershot, sulfurous acid is generated for  $\text{SO}_2$  and for  $\text{SO}_3$ . Sulfuric acid. The dew point is approx.  $140\text{ }^\circ\text{C}$ .
- Even though solid substances, which are found in the exhaust gas flow and deposited on the catalyst, will not directly damage the catalyst, the emission reduction will be degenerated over time. The active surface will be partially covered. If there is an increase in the amount of deposits, the individual channels will become blocked. The exhaust gas then has to go through the channels still open. Therefore, the flow velocity and the emission reduction will decrease. The increase of the backpressure results in a power reduction, or worse still, the shut down of the engines. This can be monitored by measuring the differential pressure.

### 10.2.1.5 Limit values for exhaust composition<sup>2</sup>

The life expectancy of the catalyst largely depends on the concentration of catalyst toxins. Therefore, the exhaust should be free from the known compounds which cause damage to the catalyst, e.g. silicon, silicon products, sulphur, phosphorus, arsenic and heavy metals. The concentration of catalyst toxins should not exceed the following values:

Catalyst toxin	Warranty period 8000 operating hours or 1 Year	Warranty period 16000 operating hours or 2 years
Silicone	0 $\mu\text{g} / \text{Nm}^3$	0 $\mu\text{g} / \text{Nm}^3$
Silicon	0 $\mu\text{g} / \text{Nm}^3$	0 $\mu\text{g} / \text{Nm}^3$
Arsenic	< 1 $\text{m g} / \text{Nm}^3$	< 1 $\text{m g} / \text{Nm}^3$
Mercury	< 1 $\text{m g} / \text{Nm}^3$	< 1 $\text{m g} / \text{Nm}^3$
Lead	< 2 $\text{m g} / \text{Nm}^3$	< 1 $\text{m g} / \text{Nm}^3$
Cadmium	< 10 $\text{m g} / \text{Nm}^3$	< 10 $\text{m g} / \text{Nm}^3$
Zinc	< 100 $\text{m g} / \text{Nm}^3$	< 50 $\text{m g} / \text{Nm}^3$
Bismuth	< 1 $\text{m g} / \text{Nm}^3$	< 1 $\text{m g} / \text{Nm}^3$
Antimony	< 1 $\text{m g} / \text{Nm}^3$	< 1 $\text{m g} / \text{Nm}^3$
Hydrogen sulfide	< 10 $\text{mg} / \text{Nm}^3$	< 5 $\text{mg} / \text{Nm}^3$
Sulfur	< 10 $\text{mg} / \text{Nm}^3$	< 5 $\text{mg} / \text{Nm}^3$
Ammonia	< 100 $\text{mg} / \text{Nm}^3$	< 100 $\text{mg} / \text{Nm}^3$
Phosphorous compounds and halogens	< 5 $\text{mg} / \text{Nm}^3$	< 1 $\text{mg} / \text{Nm}^3$
Chlorine	< 10 $\text{m g} / \text{Nm}^3$	< 10 $\text{m g} / \text{Nm}^3$
Sodium	< 10 $\text{m g} / \text{Nm}^3$	< 10 $\text{m g} / \text{Nm}^3$
Calcium	< 10 $\text{m g} / \text{Nm}^3$	< 10 $\text{m g} / \text{Nm}^3$
Manganese	< 10 $\text{m g} / \text{Nm}^3$	< 10 $\text{m g} / \text{Nm}^3$
Potassium	< 10 $\text{m g} / \text{Nm}^3$	< 10 $\text{m g} / \text{Nm}^3$
Iron	< 10 $\text{m g} / \text{Nm}^3$	< 5 $\text{mg} / \text{Nm}^3$

<sup>2</sup> Source: Air Sonic  
Chapter\_10 - Exhaust system.docx  
02999408

### 10.2.1.6 Oxidizing catalysts for bio- and sewage gas engines<sup>3</sup>

Most manufacturers will not cover their catalysts for warranty if the engine is operated with landfill or sewage gas. The terms of warranty need to be clarified in the design stage in case a catalyst should be installed for bio and sewage gas operation.

The problem with these systems is that no operator can forecast what the pollutants will be in the exhaust in the coming weeks, months or years.

Even a comprehensive analysis, which shows low pollutants, is only a momentary record. In most cases, the exhaust is not tested for all possible pollutants, and on the other hand, the composition may already be different after a few days.

This is also confirmed by the fact that similar sewage gas systems do achieve different life expectancy for the same catalysts.

For biogas, the situation is a little different. In special cases, it can be considered whether a warranty can be granted. However, an accurate exhaust analysis and accurate description of the system is necessary.

Without a sufficient gas cleaning system, no guarantee for the pollutant conversion of the catalyst will be given for sewage gas, landfill gas and biogas.

## 10.2.2 Exhaust silencers

The task of an exhaust silencer is to dampen the exhaust noise produced when the engine is operating to a level commensurate with the respective surrounding environment. The silencers used take the form of reflection, absorption or combination type silencers. Reflection silencers achieve their maximum effect in the lower 125-500 Hz frequency range, whilst absorption silencers are most effective in the 250-1000 Hz range. In the case of combination silencers, the first part is designed as a reflection silencer and the second as an absorption silencer. The combination silencer unites the characteristics of both silencer types and so achieves a significant silencing effect over a broad frequency range.

In cases in which the required level of silencing cannot be achieved with a combination silencer, additional absorption silencers must be fitted after the combination silencer. An expansion joint must be installed between the silencers to insulate against structure-borne noise.

See also Chapter 4.3, Noise issues.

The exhaust silencers go through heat expansion at operating temperature. Fixed and loose supports must be provided accordingly during planning.

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<sup>3</sup> Source: Air Sonic  
Chapter\_10 - Exhaust system.docx  
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### 10.2.3 Exhaust heat exchanger

Exhaust heat exchangers are used to recover the heat from the exhaust. These exhaust heat exchangers are built in accordance with the European pressure vessel guideline (PED 97/23/EC). The testing procedures are based on national regulations, for example the TRD<sup>4</sup> and AD leaflets<sup>5</sup> of the manufacturing country.

In CHP systems, the exhaust heat exchangers are usually made of stainless steel (1.4571). For natural gas applications, the exhaust temperature at the heat exchanger outlet is normally 120°C. To prevent corrosion, it must be ensured that the exhaust gas does not fall below the dew point.

In all systems where the exhaust heat exchangers are mounted higher than the engine, a continuous condensate drain / separator generally has to be installed. This will prevent water from finding its way into the engine via the exhaust pipe in the case of a water breakthrough in the exhaust heat exchanger.

In the case of systems which are operated on landfill gas or sewage gas, the increased content of sulfur, chloride, hydrochloric acid and hydrofluoric acid in the exhaust must be borne in mind when selecting materials. These components have a highly corrosive effect and can even damage stainless steel exhaust heat exchangers.

If there is a risk of increased concentration of chlorine or other halogenated components in the burning gas, exhaust tubes made of thick low alloyed boiler steel are preferable to stainless steel tubes due to danger of local pitting and stress corrosion. This steel is less sensitive against this type of corrosion. In order to avoid wide-spread corrosion, it is absolutely necessary to prevent condensation of the above mentioned acids and water out of the exhaust gas. In this case, the exhaust temperature should be > 180 °C.

For systems with sulfur in the combustion gas and with an oxidation catalyst pre-connected to the exhaust heat exchanger, a fine desulfurization of the combustion gas must be carried out. In the oxidation catalyst, sulfur dioxide in the exhaust gas is oxidized to form sulfur trioxide. When cooling the exhaust gas in the connected exhaust heat exchanger, sulfur trioxide reacts with water and forms concentrated sulfuric acid. Concentrated sulfuric acid has a highly corrosive reaction and can quickly cause destruction to the exhaust heat exchanger. Furthermore, operating faults may be caused by an increased exhaust backpressure, which has been created by sulfurous deposits. Effective protection for this system design can only be guaranteed with a fine desulfurization of the combustion gas.

The water qualities in respect to the heating requirements must be complied with (Technical Circular for coolant).

In large heating circuits, complying with the minimum requirements for the water quality may pose a problem. In this case, the installation of a small closed decoupling circuit between exhaust heat exchanger and heating circuit is urgently recommended. In the technical circular for cooling water, a chloride content smaller than 20 mg/l is required for the coolant in the heating circuit. For increased chloride ion content and increased flow temperatures in the heating circuit, the stainless steel pipes usually used in the exhaust heat exchangers are subject to stress corrosion cracking, which can lead to the exhaust heat exchanger being damaged. Therefore, providing there are no contrary requirements on the exhaust side, an exhaust heat

<sup>4</sup> TRD = Technische Regeln für Dampfkessel = Technical Directions for Steam Boilers

<sup>5</sup> AD = Arbeitsgemeinschaft Druckbehälter = Pressure Vessels Working Party



exchanger with water-bearing components (pipes, pipe plate and casing) made of normal steel should be envisaged for decoupling of the exhaust heat exchanger in the heating circuit and water temperatures  $>110\text{ }^{\circ}\text{C}$ .

(Also see Chapter 6.7, The heating circuit & 6.8, Coolant in the heating circuit)

The exhaust heat exchangers go through heat expansion at operating temperature. Fixed and loose supports must be provided accordingly during planning.

#### 10.2.4 Exhaust components in biogas systems

The following items must be considered when selecting exhaust systems for biogas systems:

- For biogas systems with a maximum permissible sulfur content (total) of  $< 2.2 \text{ g/m}^3\text{n}$  or a  $\text{H}_2\text{S}$  content of  $< 0.15 \%$  volume in the biogas, the exhaust gases should not be cooled below  $180 \text{ }^\circ\text{C}$ . The limit values must be kept permanently. In this case an oxidation catalyst must not be used.
- To cool down an exhaust to  $120 \text{ }^\circ\text{C}$ , in addition to our "Minimum characteristics of combustion gases in gas engines", the sulfur content of the biogas has to be limited to  $< 0.1 \text{ g/m}^3\text{n}$  or the  $\text{H}_2\text{S}$  content to  $< 70 \text{ ppm}$ .
- When using oxidation catalysts, a fine desulfurization of the combustion gas must be carried out. This must always completely remove the  $\text{H}_2\text{S}$  (validation limit of the field measuring instrumentation, but maximum  $5 \text{ ppm H}_2\text{S}$ ). This can be implemented technically with an activated carbon adsorber with doped/impregnated active carbon.
- In biogas systems, the exhaust silencers are to be preferably mounted ahead of the exhaust heat exchanger, as the risk of acid condensation is lower at higher exhaust temperatures.
- Furthermore, a continuous condensate drain has to be installed. The condensate drain has to be checked at regular intervals during operation and must be protected against freezing in the winter.
- The exhaust side of the heat exchanger must be cleaned regularly
- All components carrying exhaust gas must be insulated due to the risk of condensation; this is imperative outdoors, too.

#### 10.2.5 Exhaust flaps

For most applications, the layout of the exhaust system is individual for each engine. In these systems, exhaust flaps are used for by-passing exhaust components. With multi-engine installations where engines must be connected to one common exhaust system, exhaust flaps must be provided for the disconnection of the individual engine from the common exhaust system. This is, for example, the case if the exhaust gas of several engines is combined for the operation of a common absorption chiller.

Exhaust flaps are not completely tight in the fully closed position, there is always a small amount of leakage flow.

The requirements concerning the tightness of exhaust flaps have to be considered with the individual application demands (e.g. TRD 604 Bl. 2).

### 10.2.5.1 By-passing of components in the exhaust system

For by-passing exhaust components such as, for example, exhaust heat exchangers and/or steam boilers, exhaust flaps are used. The flaps' drive is via an electric motor or pneumatic actuator. They simply have an open/close function and no control function. Preferably, flap combinations are used, i.e. there is only one drive mounted on one of the flaps whereas the other flap drive is via a reverse-acting mechanical link.

### 10.2.5.2 Multi-engine installations with common exhaust pipe

For multi-engine systems with a common exhaust pipe, exhaust gas must be prevented from uncontrolled backflow to the engines currently not in operation. Uncontrolled backflow of exhaust gas will cause corrosion in this engine. There are different possibilities for avoiding backflow of exhaust gas by a respective arrangement of exhaust flaps. They are described in the following.

#### Exhaust flap arrangement with separate exhaust pipe

With this system, an exhaust flap is arranged behind the engine. Using a bypass flap combination, the exhaust gas is either led to the common exhaust manifold or to the open air via a separate exhaust pipe (see also Figure 10.4). When the engine is not in operation, the exhaust flap behind the engine (flap 1) and the flap in the pipe branch to the common exhaust manifold (flap 2) are closed, whereas the flap in the pipe branch to the open air (flap 3) is open. In the common exhaust manifold, there will be an overpressure when the other engines are running and, in consequence, there will be a slight leakage flow via flap 2 into the space between. As the leakage flow is comparably small regarding the large free cross section to the open air (flap 3 open), the leakage gas will go to the open air and the engine will be protected by closed flap 1.

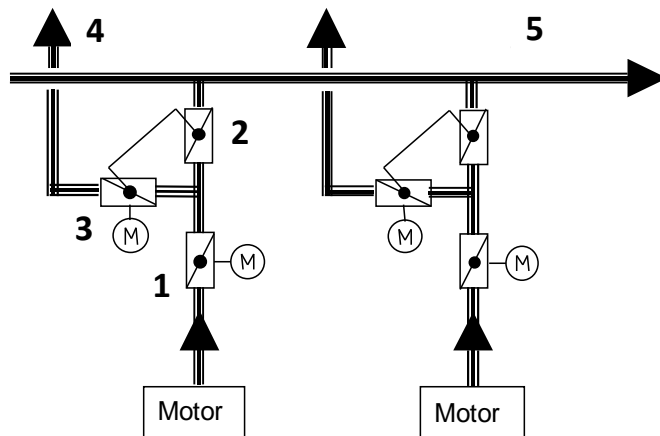
Before starting the engine, the exhaust flap 1 behind the engine will be opened; in the first instance, the exhaust flow is via flap 3 to the open air. After the running up phase of the engine, the exhaust can lead to the common exhaust pipe via operation of the exhaust by-pass flap combination. The exhaust flow via flap 3 to the open air is closed and, simultaneously, the path to the exhaust manifold is opened.

This arrangement has the following advantages:

- Each engine can be operated individually, i.e. it is independent on the conditions in the common system.
- The engine can be started without exhaust backpressure.
- With electricity-led operation, the exhaust heat can be adjusted to the active demand by switching the by-pass to the open air.

This arrangement is highly recommended with several engines connected to one common exhaust system.

**Fig. 10.4 Common exhaust system with by-pass to the open air**



- 1 Exhaust flap 1
- 2 Exhaust flap 2
- 3 Exhaust flap 3
- 4 Bypass to open air
- 5 Exhaust manifold

#### **Exhaust flap arrangement with air lock**

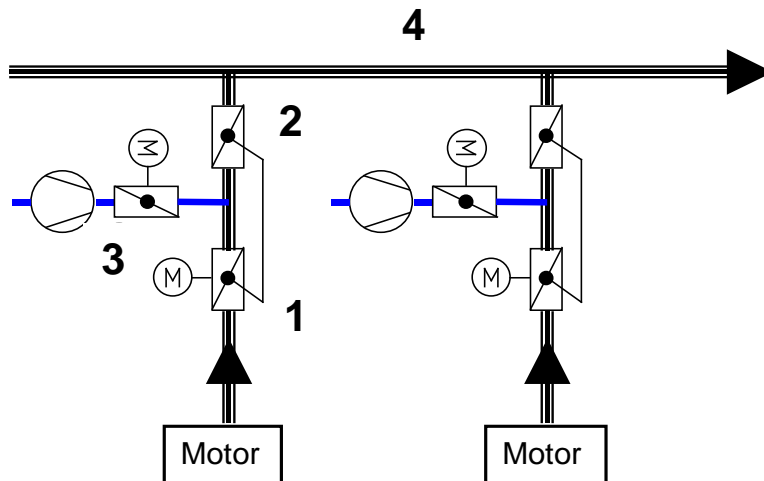
With this system, there are two exhaust flaps arranged one after another in the exhaust pipe to the common exhaust manifold. The flaps can be opened and closed via an actuator. The sealing air line is connected in the space in-between both flaps. The supply of sealing air is via blower with successive flap (see also Figure 10.5).

When the engine is not running, both flaps (flap 1 and 2) are closed and sealing air is blown into the space between the flaps. The pressure of the locking air must be higher than the maximum pressure in the exhaust manifold and the volume flow of the sealing air must be greater than the leaking rate of the exhaust flaps. There is no possibility of exhaust backflow to the non-running engine.

Before starting the engine, both exhaust flaps must be opened, flap 3 after the blower will be closed and the sealing air blower will be switched off. The engine has to start at the increased exhaust pressure level existing in the exhaust manifold. The engine has to start at the increased exhaust pressure level existing in the exhaust manifold.

Advantage: No additional exhaust pipe to the open air is necessary.

**Fig. 10.5 Common exhaust system with air lock**



- |   |                  |
|---|------------------|
| 1 | Exhaust flap 1   |
| 2 | Exhaust flap 2   |
| 3 | Air flap         |
| 4 | Exhaust manifold |

#### **Exhaust flap arrangement with intermediate venting**

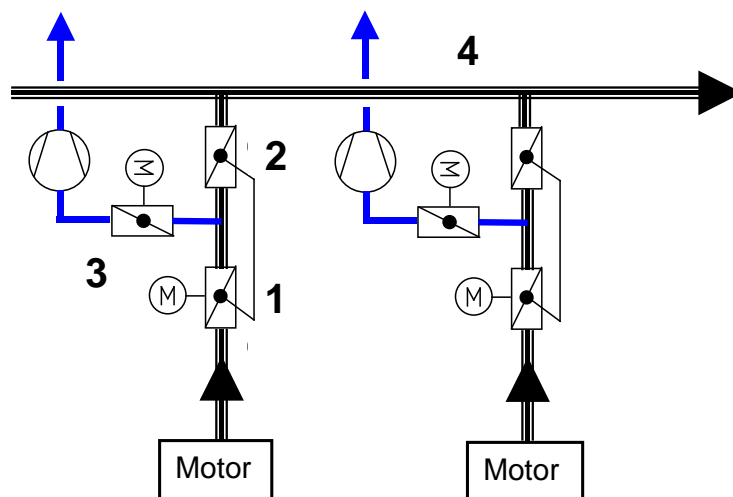
With this system, too, there are two exhaust flaps arranged one after another in the exhaust pipe to the common exhaust manifold. The flaps can be opened and closed via an actuator. The sealing air line is connected in the space in-between both flaps. The leakage gas in the space between the flaps is extracted by the extracting fan and routed to the open air (see also Figure 10.6).

When the engine is not running, both flaps (flap 1 and 2) are closed and a slight negative pressure is maintained in the space between the exhaust flaps. The leakage gas flowing via the exhaust flaps is routed to the open air via the extractor fan. Leakage gas flowing into the engine when not running is avoided.

Before starting the engine, both exhaust flaps must be opened, flap 3 before the blower will be closed and the extractor will be switched off. The engine has to start at the increased exhaust pressure level existing in the exhaust manifold. The engine has to start at the increased exhaust pressure level existing in the exhaust manifold.

Disadvantage: A separate pipe to the open air must be provided, but the cross section is comparably small in relation to a full-sized exhaust pipe as per Fig. 10.4 above.

**Fig. 10.6 Common exhaust system with intermediate venting**



- 1 Exhaust flap 1
- 2 Exhaust flap 2
- 3 Air flap
- 4 Exhaust manifold

### 10.2.6 Laying exhaust pipes

Because of the relatively high exhaust temperatures, heat expansion is quite considerable (approx. 1-1.5 mm/m and 100 °C).

To avoid unacceptably high stresses in the exhaust pipes, expansion joints must be fitted at suitable locations to compensate for the heat expansion in the pipes and components. Depending on how the exhaust line is laid, the supports should be fixed and moveable. They must not be fixed on the exhaust turbocharger or the engine. The first fixed point must be located directly after the expansion joint at the turbocharger outlet. In particular, components integrated in the exhaust system such as heat exchangers, catalytic converters, silencers, etc. must be protected against stresses arising from the expansion of the exhaust pipe by fitting expansion joints on the inlet and outlet sides. The exhaust expansion joints must be installed in accordance with the manufacturer's directions (permissible axial and lateral offset must be complied with). Because of the high operating temperatures, the exhaust system is permanently provided with insulation. When installing pipes outside, a contact protection is only sufficient for exhaust pipes after exhaust heat exchangers.

## **10.2.7 Additional hints for the design of exhaust heat exchangers and silencers**

### **10.2.7.1 Lifting lugs**

For better handling of the components during installation, lifting lugs should be provided.

### **10.2.7.2 Structure-borne noise**

When affixing the unit, it is important to note that where appropriate, sound-technology aspects also play a role here. In this case, it must be ensured that minimal sound is transmitted to other components. For this reason, vibration dampers are installed in the feet or the mounting. This applies equally to standing as well as suspended versions. As the piping and the catalyst housing are insulated for temperature reasons, no further sound insulation of these components is necessary in the majority of units.

### **10.2.7.3 Installation**

When installing catalyst housings, exhaust heat exchangers and silencers, careful handling is essential to ensure that protruding parts such as probes, feet, etc will not be damaged.

This inevitably leads to damage to the housing and components. Mounting feet are only for taking the design load. The client is requested to find out about the installation situation, preferably when placing the order. If a housing has sliding supports which are not directly fixed to concrete or steel frames but mounted to a sliding plate, it must be ensured that a lubricant is used between foot and sliding plate. Periodic checks should be conducted to ensure that enough lubricant is always present during operation.

### **10.2.7.4 Cleaning of exhaust heat exchangers**

When installing the exhaust heat exchangers, enough free space must be considered for cleaning purposes.

### 10.2.8 Exhaust stacks

Especially in the vicinity of residential areas, it is necessary to avoid impermissible engine exhaust emissions. Stacks are used to transport the exhaust gas up to a high level in the atmosphere.

The exhaust stacks must be insulated to avoid condensation in the exhaust system. The speed of the exhaust gas in the stack should be between 15-20 m/s. Above 20 m/s, there is a risk of resonance vibrations in the gas column. A high outlet speed leads to a dynamic increase in effective stack height and improves the dispersal of the gases, but it also increases the flow noise.

The draught effect of the stack, which is dependent on stack height, lessens the backpressure in the exhaust system. However, installing deflector hoods at the mouth of the stack can partially or even entirely offset the stack draught, with the result that, in a worst-case scenario, the backpressure of the stack must also be regarded.

Exhaust stacks must be equipped with permanent drainage and weather-induced contamination (e.g. rain, snow) must be excluded.

All components must be provided with a permanent drainage facility at their lowest point. Condensate disposal must be clarified on a case-by-case basis and, where necessary, it must be directed to a neutralization facility.



# **Power plants layout**

**Chapter 11**

## **Compressed air system**

**06-2014**

## Contents

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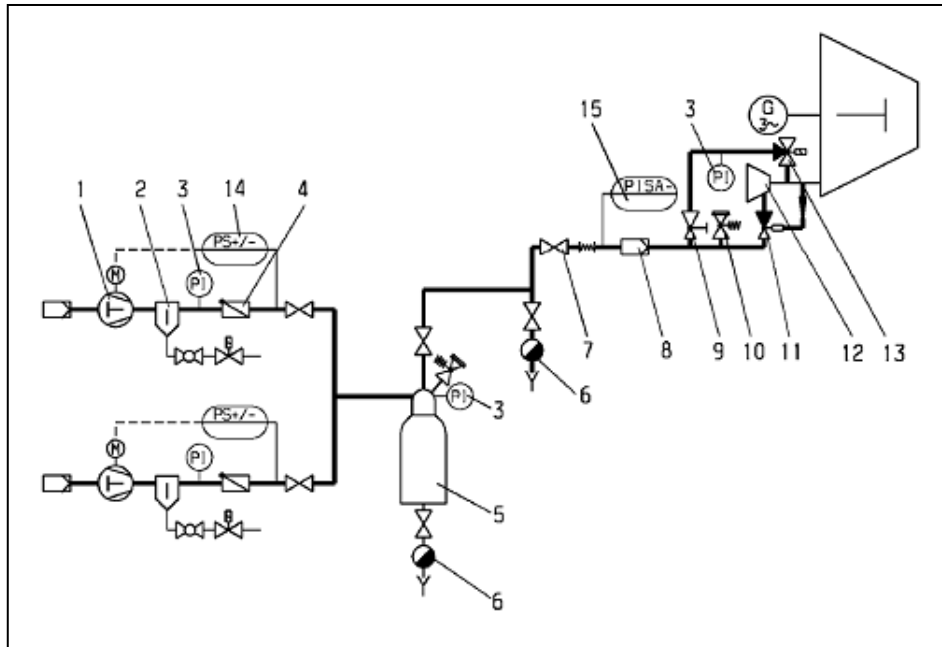
## 11. Compressed air system

Some engine models are started with compressed air. In this case, the engine is started with a compressed air starter which acts on a flywheel gear rim. Table 11.1 shows the starting systems employed for the various series.

**Table 11.1**

Engine type	Compressed air starter via gear rim	Electric starter
TCG 2016		■
TCG 2020(K)	■	■ (Standard
TCG 2032	■	

Fig. 11.1 shows a starting air system for an engine with a compressed air starter.



- 1 Compressor
- 2 Oil separator
- 3 Pressure gauge
- 4 Non-return valve
- 5 Compressed air bottle
- 6 Condensation deflector
- 7 High-pressure shut-off valve
- 8 Dirt trap
- 9 Pressure regulator
- 10 Safety valve
- 11 Starting valve
- 12 Starter
- 13 Control valve
- 14 Pressure switch / Compressor ON / OFF
- 15 Pressure switch / Alarm min. pressure

The compressor (1) fills the compressed air bottle (5), which is equipped with a water separator (6) via the non/return valve (4) and the oil separator (2). The filling pressure of the bottle can be read from the pressure gauge (3). The high-pressure shut-off valve (7) and the dirt trap (8) provide the starter valve (11) with compressed air. When the engine starts, the starter valve is opened by the control valve (13) and the starter (12) is pressurized with compressed air. The engine starts.

## **11.1 Compressed air system components**

### **11.1.1 Compressors**

Redundant diesel or electric compressors are provided with the appropriate equipment for pressure released starting. Compression generally takes place in two stages with intermediate cooling, the final pressure is 30 bar.

The design must be matched to the total volume of the compressed air bottles connected to the system.

### **11.1.2 Compressed air bottles**

The compressed air bottles are implemented as either vertically or horizontally installed vessels. The volume of the bottles is dependent on the type and number of engines connected and the required number of starts to be achieved without refilling the air bottles.

Compressed air containers must be drained regularly. Vertical vessels can be drained via the valve head, horizontal vessels must be installed with a slope towards the base of the vessel, so that they can be properly drained through the base. Generally automatic drainage facilities must be provided. These must always be arranged beneath the vessel; the line from the vessel to the drain must always be laid with a continuous slope.

### **11.1.3 Compressed air pipes**

An oil and water separator must be installed in the filling pipe between the compressor and the compressed air bottle if this is not provided on the compressor.

The starting pipe between the compressed air bottle (head of vessel) and the main starter valve must be as short as possible and must include the minimum number of elbows. Dependent on how the pipes are laid, an automatic drain facility must be fitted at the lowest points.

It is recommended that a dirt trap with drain-off valve be installed in the starter line. When fitting the dirt trap, pay attention to the orientation (sieve always to be removed from below) and the direction of flow. The dirt trap is a component of the start system for gensets with a compressed air starter.

In the case of multi-engine systems, a ring circuit may increase the starting availability of the system.

Welding deposits and any other contamination must be avoided in the compressed air pipe.

The starting air pipes must always be stainless steel pipes (see also chapter 20.2)!

## **11.2 Low-pressure air system**

In the case of series TCG 2032, the pneumatic shut-off valves in the gas control line are supplied as standard with compressed air at max. 10 bar via a connection to the starter group. The low-pressure connection is not required if gas control lines are used with solenoid valves.

## **11.3 Safety Note**

When carrying out work on the engine, it is essential to shut off the compressed air supply to the engine to prevent the engine from being started unintentionally.

## **11.4 Compressed air quality**

The compressed air must be free from dust and oil. The compressors and air filters must be designed accordingly.

# **Power plants layout**

Chapter 12

## **Measuring, monitoring and limiting devices**

06-2014

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## 12. Measuring, monitoring and limiting devices

These are used to protect and control the CHP set, as well as to fulfil the safety requirements for heat generators.

Declarations of conformity and CE markings are necessary for the measuring, monitoring and limiting devices -pursuant to the Low Voltage Directive 2006/95/EC and the Electromagnetic Compatibility Directive 2004/108/EC.

The instructions for operation and use and the manufacturer's maintenance instructions must be taken into account when installing the measuring, monitoring and limiting devices.

When installing, it is essential to take account of the following:

- permissible ambient temperature
- permissible operating medium
- permissible medium temperature
- permissible operating pressure
- permissible installation site
- permissible flow speed
- requisite minimum immersion depth
- Choice of cables as described in chapter 17 (shielded sensor connection line)

### 12.1 Monitoring as per DIN EN 12828

In order to limit temperature, pressure, flow and low water level, the devices must fulfil the following requirements:

- Temperature sensors and limiters must be tested according to DIN EN 14597 (limiters with reactivation lock)
- Pressure limiters must be component-tested to VdTÜV Notice "Pressure 100/1" with reactivation lock
- Flow limiters must be component-tested to VdTÜV Notice "Flow 100"
- Water level limiters must be component-tested to VdTÜV Notice "Water level 100/2"

### 12.2 Monitoring as per TRD 604

In order to limit temperature, pressure and low water level, devices of a particular design must be used. Flow limiters must comply with VdTÜV Notice "Flow 100".

## 12.3 Temperature measurement

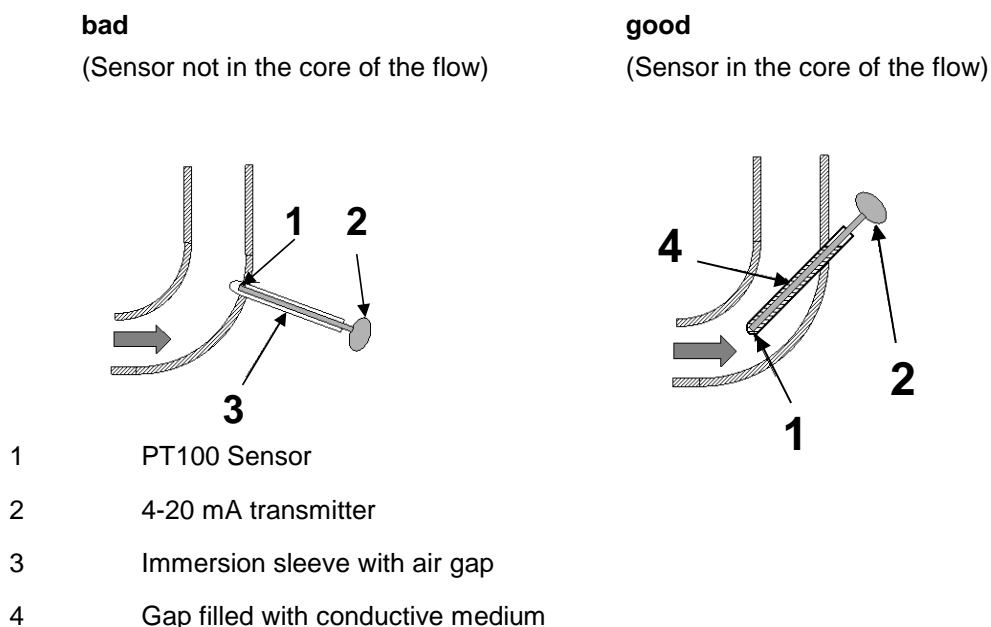
Temperatures are detected with the aid of resistance thermometers in the water circuits and thermocouples in the exhaust. The temperature-dependent changes in resistance and thermoelectric voltage are converted via transmitters in the sensor head into a standardized 4 – 20 mA signal.

### 12.3.1 Installation note for temperature sensors

Fast measuring of dynamical temperature changes is an absolute requirement for a good control system. The installation position has a great influence on the response times and measuring errors.

Figure 12.1 shows good and bad examples for installation in tubes. The length of the immersion sleeves has to be designed so that the sensor measures the temperature in the core of the flow. The sensor has to be connected to the immersion sleeve thermally by a conductive medium. Temperature-proof oils and heat-conductive pastes are suitable for this. Insulating air gaps between the immersion sleeve and sensor should be avoided in all cases.

**Fig. 12.1 Installation of the temperature sensor**



#### **12.4 Differential pressure monitoring**

Differential pressure switches are used to monitor differential pressures.

#### **12.5 Exhaust backpressure monitoring**

A special design of gas pressure monitor in the sense of VdTÜV Notice "Pressure 100/1" is used to monitor the exhaust backpressure. The measuring line must always slope upwards towards the sensor.



# **Power plants layout**

Chapter 13

## **Requirements for CHP systems in accordance with the medium-voltage directive June 2008 version (with 4th amendment in January 2013)**

06-2014

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## **13. Requirements in accordance with the medium-voltage directive**

Among other things, the medium-voltage directive regulates the behavior of power generators in the medium-voltage network under defined operating conditions. Prior to 2008, there was a requirement to immediately disconnect from the network in the event of a fault when using CHP systems. Special protection devices such as the vector surge relay were developed and implemented for a fast disconnection. In network technology, CHP systems were treated as so-called "negative consumers". Only the consumer load was reduced when a CHP system failed.

### **13.1 Medium-voltage directive, 2008 version with 4th amendment**

As a result of the progressing decentralization of power generation with photovoltaic, wind, water and CHP systems, these systems are becoming more and more significant within the supply network. In line with this, the connection conditions of power generators in the medium-voltage network have been revised in the following directive:

Generating plants connected to the medium-voltage network  
Directive for generating plants' connection to and parallel operation with the medium-voltage network  
June 2008 version with the 4th amendment as of 2013-01-01

According to this new directive, CHP systems must also engage in the static and dynamic network support alongside the photovoltaic, wind and water systems.

### **13.2 Static voltage stability**

Static voltage stability is the voltage stability in the medium-voltage network for the normal operating state. For this, slow voltage changes in the distribution network are kept in acceptable boundaries.

### **13.3 Dynamic network support**

Dynamic network support is voltage stability when the voltage drops in the medium-voltage network. This prevents large feeder lines from disconnecting and the network from collapsing.

### 13.4 Requirements for the CHP system

With the technical conditions for the static and dynamic network support described above, the requirements for the CHP unit (engine and generator) and for the operating mode of the system have been changed. Before now, CHP systems were designed for maximum efficiency and maximum power at  $\cos\phi=1$ . With the new medium-voltage directive, other requirements have to be taken into account:

- increased voltage and frequency range
- reduced power over the frequency
- external power demand
- variable  $\cos\phi$
- dynamic network support

For dynamic network support, the CHP system must be able to remain above the characteristic line in the network as specified in Fig. 15.1 in the event of a voltage drop and be able to ride through the following voltage characteristic line in the event of an FRT (Fault Ride Through).

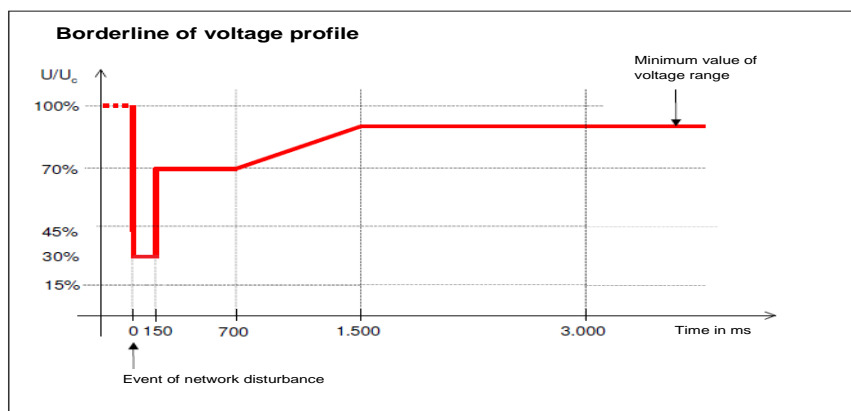


Fig 15.1: Borderline for the voltage profile at the network connection point (in the event of an FRT)

The CHP system may only be disconnected from the network when the voltage at the network connection point falls below the limiting curve. If the voltage at the connection point falls below 30% of the nominal voltage, the CHP system can be disconnected from the network. If the voltage drops below 70%, the system may only be disconnected after 150ms.

The dynamic network support lays down technically high requirements for the CHP system. The genset control and the components (e.g. moment of inertia of the generator) must be adapted for safe operation in the event of an FRT.



### **13.5 Certification of the gensets**

The appropriateness of the gensets for operation in the medium-voltage network must be validated and confirmed with a certificate by an accredited certification institute in accordance with EN45011.

For the PGU (Power Generating Unit), the certifier issues a PGU certificate and there is a component certificate from the relevant manufacturer for the protection device.

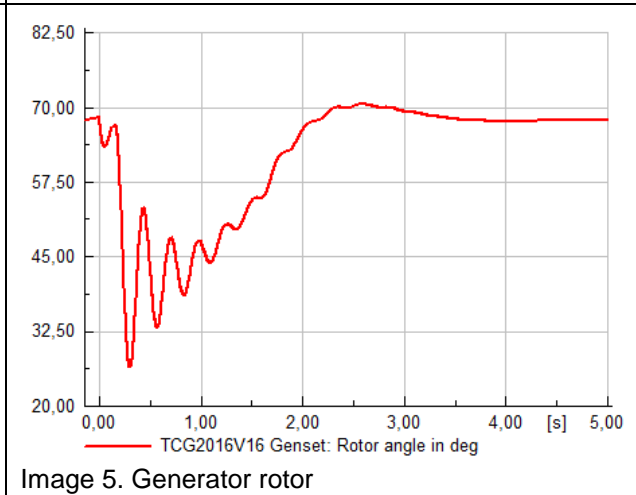
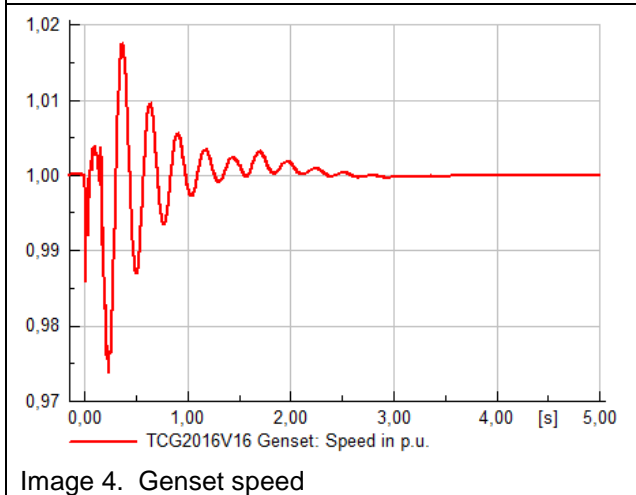
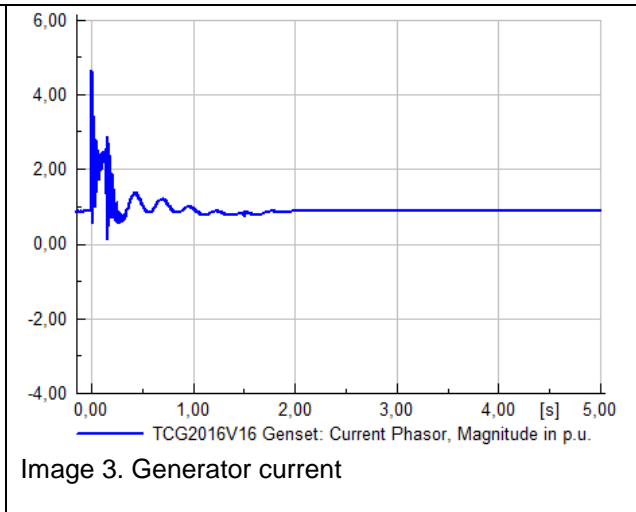
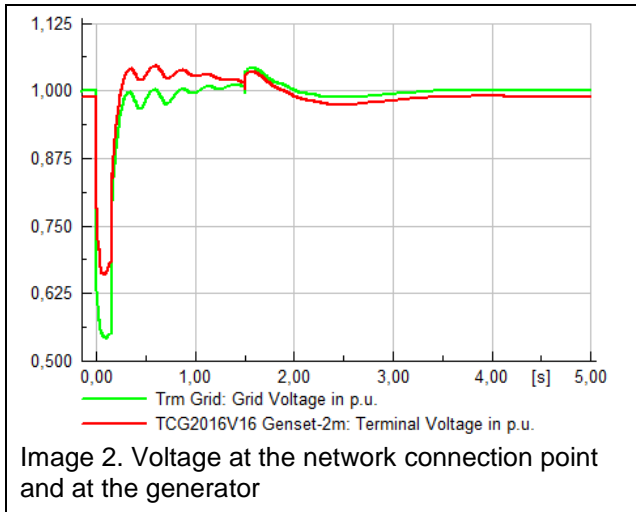
For the complete system PGS (Power Generating System), the certifier issues a PGS certificate.

### **13.6 Simulations and measurements**

Simulations were performed for the gensets for the event of an FRT using a model. The generators for achieving dynamic network support have been designed based on these simulations.

The following tests were carried out on the real network. The network voltage was lowered to the corresponding value and the behavior of the genset was measured using a test container.

As the measurement and the simulation for this example both show, the genset supports the voltage to approximately 55% of the nominal voltage in the event of a voltage decrease to 30% for 150msec at the network connection point. For this, the generator voltage is approx. 67% of the nominal value (image 2). The generator current increases to 4.7xIn (image 3). Image 4 and 5 show the speed fluctuations and the rotor angle.



### 13.7 Assignment of generators for network connection conditions

To fulfil the network connection conditions, the generators have been reassigned for the individual engine types. With the exception of the genset TCG 2016 V08 C, generators with a higher mass moment of inertia have been established.

Genset	Generator	Mass moment of inertia for generator [kgm <sup>2</sup> ]
TCG 2016 V08 C	Marelli MJB 355 MB4	13.12
TCG 2016 V12 C	Marelli MJB 400 LC4	26
TCG 2016 V16 C	Marelli MJB 450 MB4	33.8
TCG 2020 V12K1	Marelli MJB 450 LB4	33.8
TCG 2020 V12 / V12K	Marelli MJB 500 MB4	50
TCG 2020 V16 / V16K	Marelli MJB 500 LA4	59
TCG 2020 V20	Marelli MJB 560 LB4	96.5

Table 17.1 Assignment of the generators

### 13.8 International network connection conditions

Along with the medium-voltage directive applicable in Germany, there are country-specific regulations which specify the framework conditions for the parallel operation with the network in other countries, both inside and outside of the EU. More and more countries are revising these regulations in consideration of the decentral supply with renewable energy.

Regulations in Europe were prepared by the European Network of Transmission System Operators for Electricity ENTSO-E. The framework conditions for the country-specific directives/regulations are defined in the *Requirements for Network Connection Applicable to all Generators* requirement. Once it is adopted, this regulation must be considered in the country-specific directives.

Furthermore, a standard for the network connection conditions applicable in Europe is being prepared by CENELEC (European Committee for Electrotechnical Standardization). This standard will subsequently be published as a DIN EN regulation.

Since the regulations in many countries are currently being revised or redeveloped, it must be checked for each genset/system whether the conditions are complied with.



# **Power plants layout**

**Chapter 14**

## **Electrical switchgear systems**

**06-2014**

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## **14. Electrical switchgear systems**

When equipping and installing switchgear systems, in addition to the acknowledged rules of engineering, particular attention should be paid to the following regulations: low voltage directive 2006/95/EC, EMC directive 2004/108/EC, VDE 0116, VDE 0660 Part 500 and BGV A2. When working in control- / switch cabinets with electrical components, as well as handling electrostatically sensitive components (e.g. circuit boards), the service bulletin including the specially set out DIN EN 61340 – 5 – 1 and DIN EN 61340-5-2, has to be observed. The switchgear systems must be designed for ambient temperatures of 0 °C to 40 °C and for a relative humidity of 5-70 %. The switch cabinet internal temperature must not exceed 45 °C.

An exception to this is the TEM-control cabinets. Here, the internal temperature of the cabinet may rise to 50 °C.

If necessary, the lost heat of the control devices has to be dissipated by means of thermostatic controlled fans in order to avoid an excess of the permissible internal temperatures. An air-conditioning device in the switchgear or switch cabinet room should be provided when the ambient temperature is higher. Direct sunlight contact on the cabinets is to be avoided by means of an appropriate arrangement.

### **14.1 TEM System for gas engines**

The TEM System is the brains of the entire gas engine module, including engine management, control and monitoring of the gas engine, and optionally also the emergency cooling, heating circuit control and monitoring. It is a user interface for operating and observing the system, it regulates and optimizes the combustion of gas in the cylinders, and it controls and monitors the engine/genset with all its auxiliary equipment. Through its monitoring functions, it protects the genset against impermissible boundary conditions and guarantees long service life. Thanks to the integrated regulatory functions, it ensures optimum, reproducible engine status values in all operating conditions.

The integral short- and long-term history stores the relevant measurement values on retentive data storage media and provides a transparent view of its own procedures.

#### **14.1.1 TEM-EVO System**

With the TEM-EVO System, the functions described in Chapter 14.1 are integrated in modular form.

In addition, by choosing from a wide range of options, the TEM-EVO System can be adapted to suit specific applications (e.g. anti-knocking regulation (AKR), engine room ventilation, control and regulation of the table coolers in the heating circuit, engine circuit, emergency cooling circuit and mixture cooling circuit as well as parameterizable measured values, counter values and control circuits, CH<sub>4</sub>-value led operation etc.). The result is a simple-to-operate system with high operational reliability and optimized economic efficiency.

### 14.1.2 Layout

The TEM-EVO System comprises 3 components:

- Genset control cabinet (AGS) complete with connected cables to the genset; contains the genset control and the TÜV-tested safety chain. The length of cable between the gas engine and the TEM cabinet is 8 m (optionally 15 m).
- I/O-Controller for installation in auxiliary drives cabinet (HAS, max. 250 m distance from the genset control cabinet; cabling to comprise shielded 3-core bus line)
- Operating computer (max. 100 m distance from genset cabinet; cabling to comprise shielded 3-core line) for installation in the auxiliary drives cabinet or external control cabinet.

This layout minimizes the time it takes for cabling in the system.

The genset control cabinet is mounted in immediate proximity to the genset. Together with the factory-tested engine cabling, the cables fitted and tested on the genset control cabinet and connected to the genset (with plug connections on the genset end) ensure smooth commissioning and a high level of operational reliability. Signals relating to the power part are exchanged with the TEM-EVO System directly at the auxiliary unit panel cabinet via the I/O-Controller. Data is transmitted to the genset control via a fail-safe CAN bus connection.

The operating computer can be located on the system as desired, in the auxiliary unit panel if required or in the control room. The max. distance from the TEM cabinet is 100 m.

### 14.1.3 Operating log and histories

The recording functions of the electronic operating log kept by the TEM-EVO System take the place of a manual log. All operating messages and operationally relevant switching actions are recorded with a precise time stamp (date/time), as are all parameter changes.

As a whole, the TEM-EVO System can monitor and distinguish between over 600 different events. This makes it possible to provide fast and detailed analyses of genset operating modes, including TEM-EVO-controlled auxiliary functions.

The history function records up to 84 measured values. Up to 20 measured value curves can be jointly illustrated in one graph. The user is himself able to assemble the measured value curves.

TEM-EVO records histories at three speed stages:

- Working cycle history: records actual values in each working cycle (1 working cycle = 2 crankshaft revolutions)
- 6 min. history: records current values at one second intervals
- 40 h-history: records 6 min. measured values.

### 14.1.4 Diagnosis and service functions



In addition to the history and operating log, the basic TEM-EVO system also includes further diagnosis and service functions which make a valuable contribution to the early detection of abnormalities and allow system operation to be optimized. Fault situations are thus more quickly eliminated and also commissioning becomes significantly simpler and faster. This contributes decisively towards the overall economic efficiency of the gas engine set.

The following service and diagnostic functions are available

- Auxiliary genset test mode
- Digital speed governor
- Electronic ignition system
- Parameterization
- Oil replacement
- Electronic operating hours counter
- Selection of language and printer
- System setup (software versions, serial numbers, color settings, screen saver, etc.)
- Other diagnosis/service masks for some options (e.g. anti-knocking regulation, dual gas operation)

The service and diagnosis masks, like all other masks, can also be accessed by analog modem via the normal telephone network, IP modem via the internet, or radio modem for remote data transfer (option). In this way, remote diagnosis and remote repair can be provided with very short response times via Customer Service or the operator's own on-call staff.

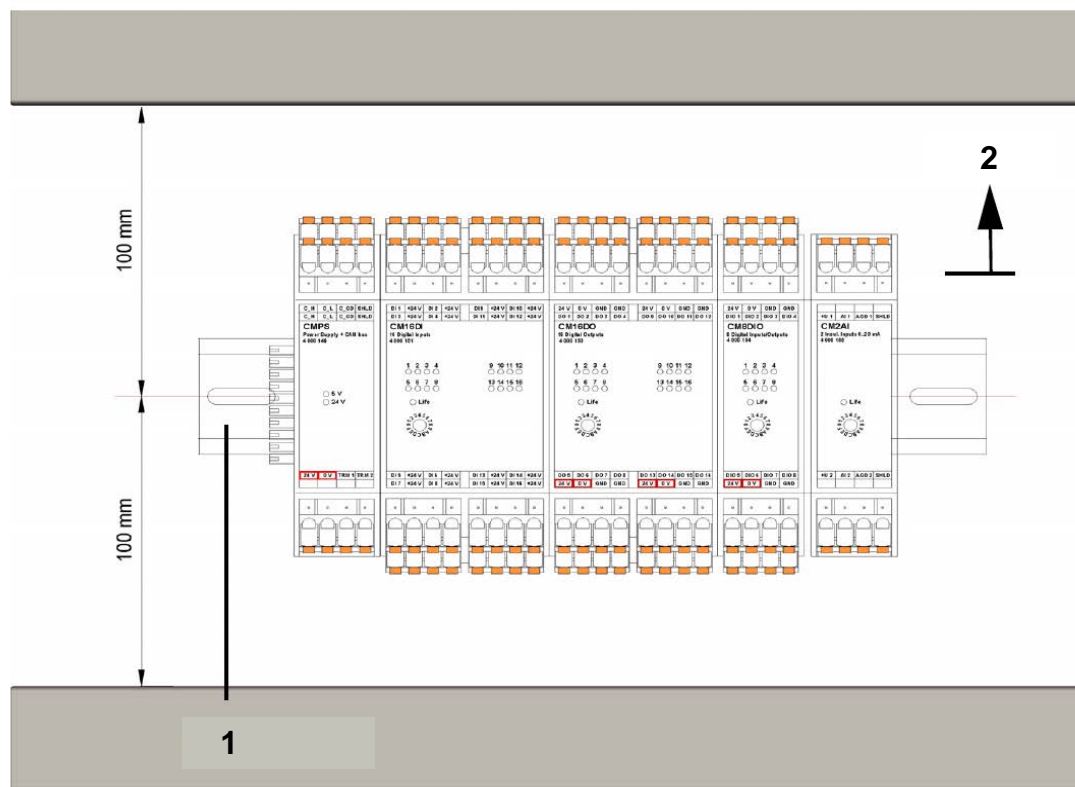
#### **14.1.5 Technical data**

- Genset control cabinet: standard dimensions: 1200x800x300 mm (HxWxD); protection type: IP 54, operating temperatures: 5-50°C, cables enter from below.
- I/O- Controller: dimensions: 114.5x112 mm (DxH); length dependent on number of options; protection type: IP 20, operating temperatures: 5-45°C
- Operating computer: dimensions: 311x483x101 mm (HxWxD) including front plate; installation depth 95 mm; cutout for mounting 282 x 454 mm (HxW) front-side protection type: IP 65, operating temperatures: 5-40°C

### 14.1.6 Installation notes for the I/O controller

The I/O-controller must be installed in a horizontal 35-mm top-hat rail (EN 50022) in a switch cabinet. It should be installed vertically (Figure 1), so that sufficient airing is guaranteed. The distance between two cable ducts should be 200 mm (at least 160 mm). Along with the IO module, space is provided for possible retrofitting of other IO modules. This space may not be blocked by other components when installing the controller in the switch cabinet.

Fig. 1 : I/O Controller



- 1 Top-hat rail
- 2 top

## 14.2 Advantages for the user

TEM-EVO offers the user the following advantages:

- Compact structure and integration of numerous additional peripheral functions such as heat recovery, etc.
- High engine efficiency by controlled operation at optimum operating point.
- Permanently low exhaust emissions.
- High level of system reliability thanks to automatic plausibility checks.
- Rapid elimination of faults thanks to the display of measured values and warning and fault messages.
- Fast, cost-effective service thanks to extended diagnosis options backed up by short and long-term histories.
- Effective remote operation and remote diagnosis via the central control room or other external computer by telephone or radio modem (option).
- Additional remote diagnosis options from the Service via telephone modem (option).

## 14.3 Auxiliary drives control and supply – Auxiliary drive panel "HAS"

In addition to the TEM System, a typical system includes a cabinet for each genset for auxiliary drives, synchronization and generator protection, as well as the appropriate charging equipment.

Auxiliary drives include all power supplies for pumps, control valves, flap valves, fans, etc.

The synchronization function ensures synchronous connection to the network by precision balancing. Control of engine speed is balanced to the power frequency under consideration of voltage and phase relation.

Generator protection covers all necessary and recommended monitoring facilities for generators as per ISO 8528 - 4.

The battery charging devices charge the batteries during normal operation in accordance with the constant voltage/constant current curves.

## 14.4 Power part – Generator power field "GLF"

The power part includes the generator circuit breaker and the corresponding transformers to protect the generator. The current and voltage transformers are likewise located in the power part.

With small systems, it is possible to accommodate both power part and auxiliary drive cabinet in one cabinet.

With larger or medium-voltage systems, the power parts are installed in a separate switchgear room.

#### 14.5 Central control - Central system control "ZAS"

The central control undertakes all common control and monitoring functions which need to be taken into account with multi-engine systems.

Functions of the central control for the individual gensets:

- Selection and deselection
- Specifying genset output
- Specifying operating mode
- System-parallel, isolated or back-up operation

Possible additional functions of the central control:

- Controlling the different operating modes
- Gas type selection
- Network failure monitoring
- Controlling and monitoring the lubricating oil supply and used oil disposal (lubricating oil service tank, used oil tank)
- Controlling and supplying central pumps
- Controlling and supplying central emergency cooling facilities
- Monitoring and controlling a heat storage tank
- Gas tank level-dependent operation
- Controlling and supplying the ventilation system
- Controlling and supplying the gas warning system
- Controlling and supplying fire protection facilities, etc.

In addition, a manual operating level must also be provided to allow local control of the system in the event of a failure of the process management system.

# **Power plants layout**

**Chapter 15**

## **Isolated operation mode**

**06-2014**

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## **15. Isolated operation mode with gas engines**

### **15.1 General description of isolated operation mode**

On the electrical side, there are different possibilities for operating gas engines. In the majority of cases, the engines run parallel to the public network. The network is to be seen as a large system with very high inertia which will not drop or increase the level of voltage or frequency depending on the local load of the individual consumers. Gas engines are designed to operate parallel to the network as described with optimized efficiency. But, in some cases, the customer has no or no continuous public network available. For this reason, isolated operation mode is available as an additional feature.

In isolated operation mode, it is not possible to control the power of the gas genset via the TEM system. Thus, the power controller will be deactivated and the genset will be operated by speed control to maintain a constant frequency. In isolated operation mode, the TEM system on its own can have no effect on the load of the engine. For this reason, the boundary conditions such as inlet air temperature and engine cooling water inlet must be followed. Therefore, the load switching to any gas genset - and especially for the highly turbocharged gas gensets (TCG2016, TCG 2020, TCG2032) - and the load shedding must be controlled by the customer's load management system. For this case, maximum permissible load steps for each gas genset were defined (see also Chapter 16, Load Steps).

For isolated operation mode with gas gensets, the whole system concept must be planned in detail from the beginning of the design process. Therefore, the system single line diagram and the knowledge of the customer's consumers (real starting power and start-up characteristic), especially for the large consumers like pumps and large fans, are important in order to achieve a good project status. Another important fact is to analyze the earthing concept for the whole system. In order to reach an effective integrated concept, coordination during project planning is offered to the customers.

Two possibilities of isolated operation are classified:

- Isolated operation after a changeover from mains parallel operation
- Isolated operation without a public network

## 15.2 Isolated operation after a changeover from mains parallel operation

In normal operation, the gas gensets run parallel to the public network. Each genset is controlled by the power controller of the TEM system. The frequency and voltage level will be held by the public network.

In the case of a network failure, the network circuit breaker will be opened immediately. The gas gensets will supply the consumers of the customer system without interruption.

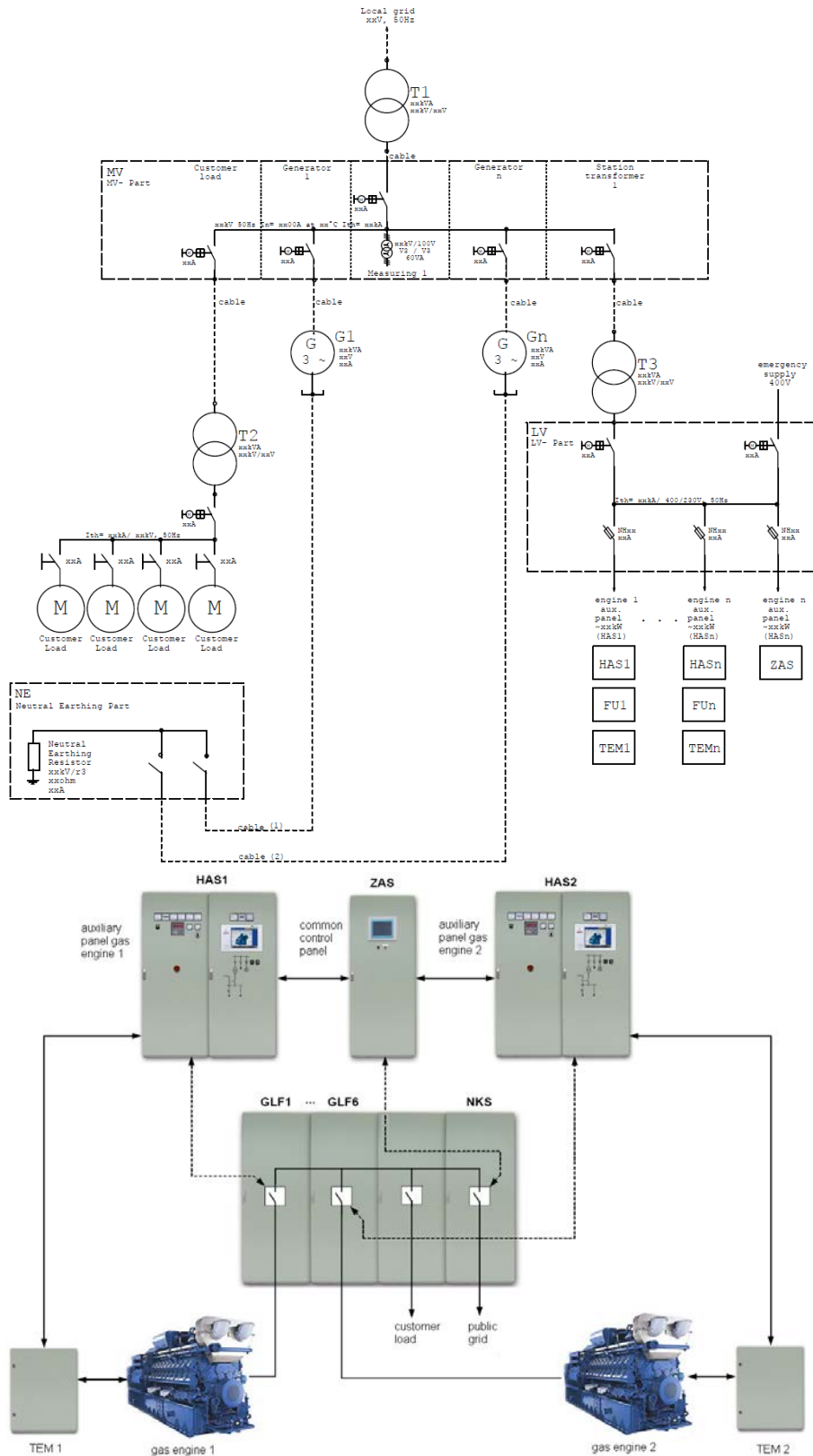
The single line diagram (Fig 15.1) shows a typical layout for an emergency power supply. The gas engine auxiliary drives are supplied by an auxiliary transformer.

If there is a network failure, the network circuit breaker is opened and the gas genset will supply the consumers to the plant. Normally, the transition from mains parallel to isolated operation causes rapid load changing. If this load changing exceeds the relevant load steps, the turbocharger of the gas engine will start to pump and, in extreme cases, the gas engine will be switched off. A total power outage of the complete system may follow.

To solve this problem, various solutions are available which will be coordinated according to the requirements of the whole system during project planning. It is important to analyze the behavior of the gas engines together with the consumers to create an adequate concept.



Fig. 15.1 Isolated operation after a changeover from mains parallel operation



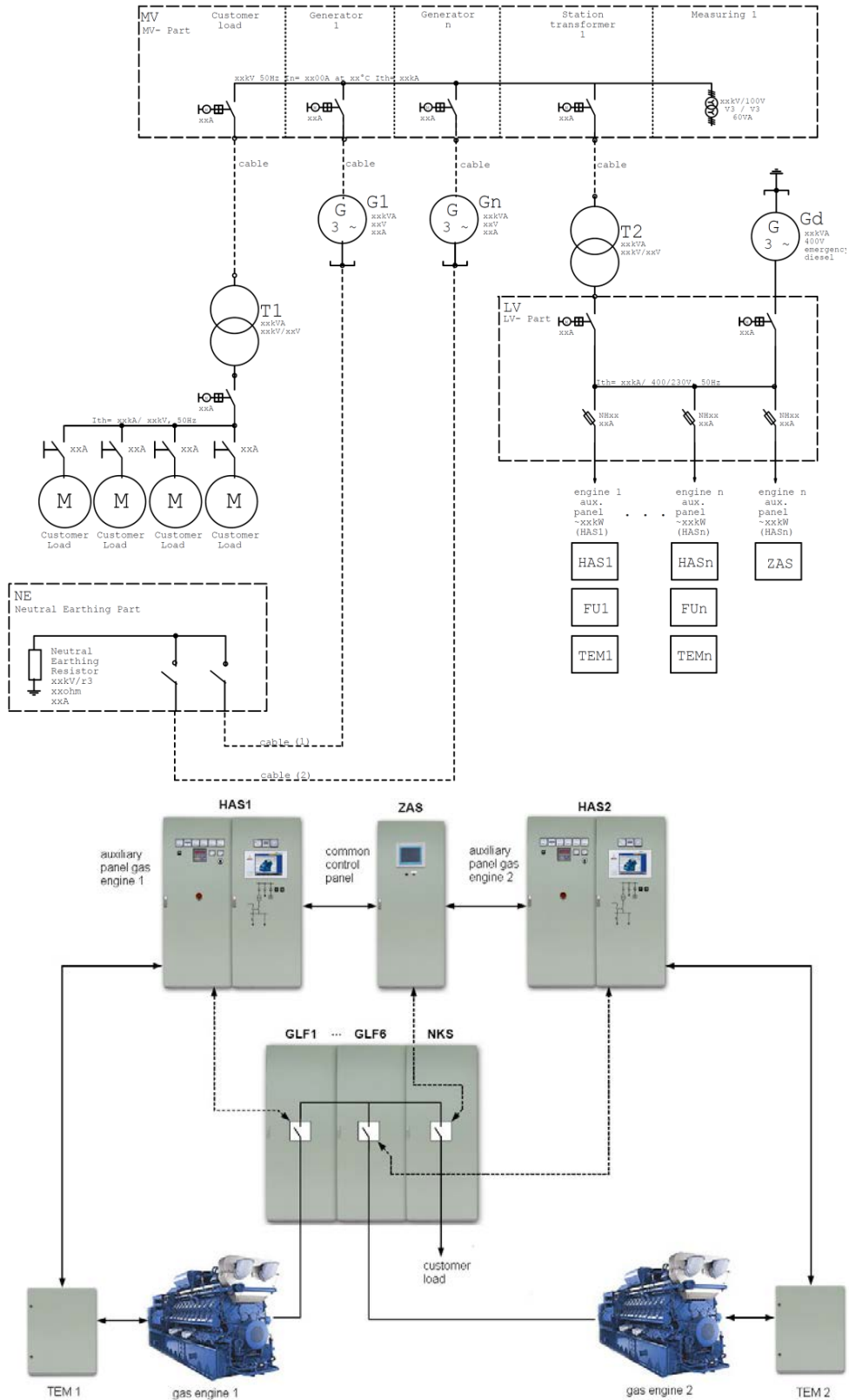
### **15.3 Isolated operation without a public network**

In isolated operation, it is important to analyze the start procedure and the load switching as well as the load shedding. In some cases, it is necessary to provide an emergency diesel or a UPS as auxiliary supply for prelubrication and after-cooling of the engine (see also Chapter 15.7, Black start).

The single line diagram (Fig.15.2) shows a typical layout for isolated operation mode. An emergency diesel is connected to the 400 V panel. The diesel starts at first and supplies the auxiliary panels. Then the first gas genset starts and supplies the customer's consumers and the auxiliaries as well via the auxiliary transformer. Now the diesel can be stopped.

If the operator wants to stop the whole system, all gas gensets except one are stopped subsequently and the stopped gas engines are cooled down. The diesel genset is now started and synchronized with the auxiliary busbar. After this, the breaker of the auxiliary transformer can be opened and the last gas genset can be stopped and cooled down. It is very important that the heat at the turbocharger is discharged after switching off each gas genset in order to protect it from overheating. When the after-cooling period has expired, the TEM will stop the genset auxiliary drives and the diesel genset can be stopped as well.

**Fig. 15.2 Isolated operation without a public network**



#### **15.4 Back-up power operation according to DIN VDE 0100-710 / DIN VDE 0100-560 / DIN EN 50172/ DIN VDE 0100-718**

For some special applications, it is necessary to supply power to important consumers for emergency reasons within 15 seconds. In order to realize this kind of emergency power supply, the function and load must be clearly defined in the project planning phase. The power available from the genset within 15 seconds corresponds to the first load step as per the load table (see also chapter 16). For this application, the gas engine must be able to black start. This condition can only be fulfilled by single-engine systems of the series TCG 2016 C and TCG 2020 V12 and TCG 2020 V16. The TCG 2020 V20 is not suitable for back-up power operation because its startup up time is too long.

In isolated operation mode with more than one gas genset, the first genset will supply the back-up power. The other gas gensets will start once the power supply of the first engine is stable. The auxiliary drive power for the other gas gensets will be supplied by the first one. The other engines will be synchronized to the first one. In some special cases, it is possible to start more than one gas genset to cover a higher amount of back-up supply as well. The available back-up power will be calculated according to the first load step multiplied by the number of running gensets. This is a very special application of the gas gensets and must be planned in detail.

#### **15.5 Active load distribution in isolated operation**

If more than one gas genset is running parallel in isolated operation, the load must be distributed between these gensets. Therefore, an active load balancer is integrated in the overall control system. The system provides the following features: common frequency control for all synchronized gas gensets and optimized signals to increase or decrease the power of each genset in order to avoid load oscillations between the gensets.

#### **15.6 Starting of large consumers**

Some consumers such as pumps or fans have an effective starting power, which is a multiple of the nominal power. In the case of a high effective starting power, it is necessary to use special starting procedures, for example, star / delta starting or soft starting. If there are consumers with a heavy starting torque, it is sometimes necessary to use load banks to start these large consumers. For this reason, it is necessary to check the customer system consumers and to coordinate the load switching during project planning.

## 15.7 Black start

If a gas genset is "black-started", it starts without auxiliary drive power for prelubrication and cooling water pumps. The gas genset is started directly after the TEM demand contact has been closed. The cooling water pumps start as soon as the auxiliary drive power supply is available. Furthermore, the gas genset will be started without prior leak monitoring of the gas control line.

The black start is an emergency function of the gas gensets and should be used only for emergency situations. Due to the high wear of the gas engine, this function should not be used more than three times a year.

The following gas engines are able to black-start:

- TCG 2016 V08 C / V12 C / V16 C
- TCG 2020 V12 / V16 / V20
- TCG 2020 V12K / V16K

The black-start is purely a function for isolated operation and is not possible in mains parallel operation.

The TCG 2032 V12/V16 is not able to black-start. Because of the necessary prelubrication for this series before the engine starts, a power supply for the auxiliary drives is required, for example using an emergency diesel or UPS.

## 15.8 Earthing system

The earthing system for the system design must also be considered in good time; it must be studied according to the customer single line diagram of the whole system. Due to the complexity of some systems, the earthing concept must be adapted to the individual requirements. The genset manufacturer offers its customers coordination during project planning in order to develop an effective integrated concept.

## 15.9 Emissions

During isolated operation, the TEM system regulates the exhaust gas emissions automatically. The typical value is 500 mg NO<sub>x</sub>/Nm<sup>3</sup> (in relation to 5% O<sub>2</sub>, dry) or higher and can be parameterized by the commissioning staff. The higher enrichment of fuel / air ratio provides a better load changing behavior of the gas engine, but leads to a higher NO<sub>x</sub> level. If the emissions value must be smaller than 500mg/Nm<sup>3</sup> in isolated operation, the fuel / air ratio has to be leaner. In this case, the load step table (see also Chapter 21) must be readjusted. The step levels must be decreased and, as a result, the number of step levels from idle to full load will increase.

## 15.10 Summary

To design a fault-free isolated operation, it is important to analyze the whole system and the customer's requirements during project planning. For this reason, it is necessary to check the following customer documents according to the requirements of the gas engine (for example load steps):

- Single line diagram of the whole system
- Actual starting power and starting conditions of large consumers
- Operating mode of the system

# **Power plants layout**

**Chapter 16**

## **Load steps**

**06-2014**

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## 16. Load steps

In the following tables and diagrams, the capability of load acceptance and load shedding is shown for the different engine types. The capability of load acceptance depends on the engine type itself and the active engine load.

### 16.1 Conditions for the load steps

**Generally, the load steps specified for the different engine series are only valid with the following operating conditions:**

- Exhaust emission 500 mg NO<sub>x</sub> (stationary)
- Natural gas operation
- Warm engine
- ISO conditions
- Line from the zero-pressure controller of the gas control line to the gas mixer valve max. 1.5 m long
- Minimum gas pressure before the zero-pressure control line 100 mbar (note for system design)

The load steps change in the case of deviating conditions.

When connecting electric drives (pumps, compressors), it is necessary to consider the switching power in addition to the nominal power of the drive.

### 16.2 Variables influencing the load steps

The following operating parameters influence the height of the load steps:

- air filter, clean / contaminated
- increased exhaust counter-pressure
- fuel heat value
- engine wear
- installation height
- air inlet temperature
- NO<sub>x</sub> emissions requirements

### 16.3 Load steps in tables

The first column in the table shows how the engine can be loaded stepwise from zero load up to 100% load. The second column shows the recovery time necessary between the individual load steps. The indicated recovery times are in accordance with DIN ISO 8528 Part 5. The third column shows the speed drop the engine will have when the load is applied. These given load steps must also be observed when relieving load from the engine.

Load shedding from any load to 0% is generally allowed.

Example: The engine type TCG 2016 C can be loaded with 25% in the first load step. In the second load step, this figure is 17% and, in the third load step, 13%. The last load step is 7% (from 93% load to 100% load). The engine needs 15 seconds to recover between the load steps.

### 16.4 Load steps as diagrams

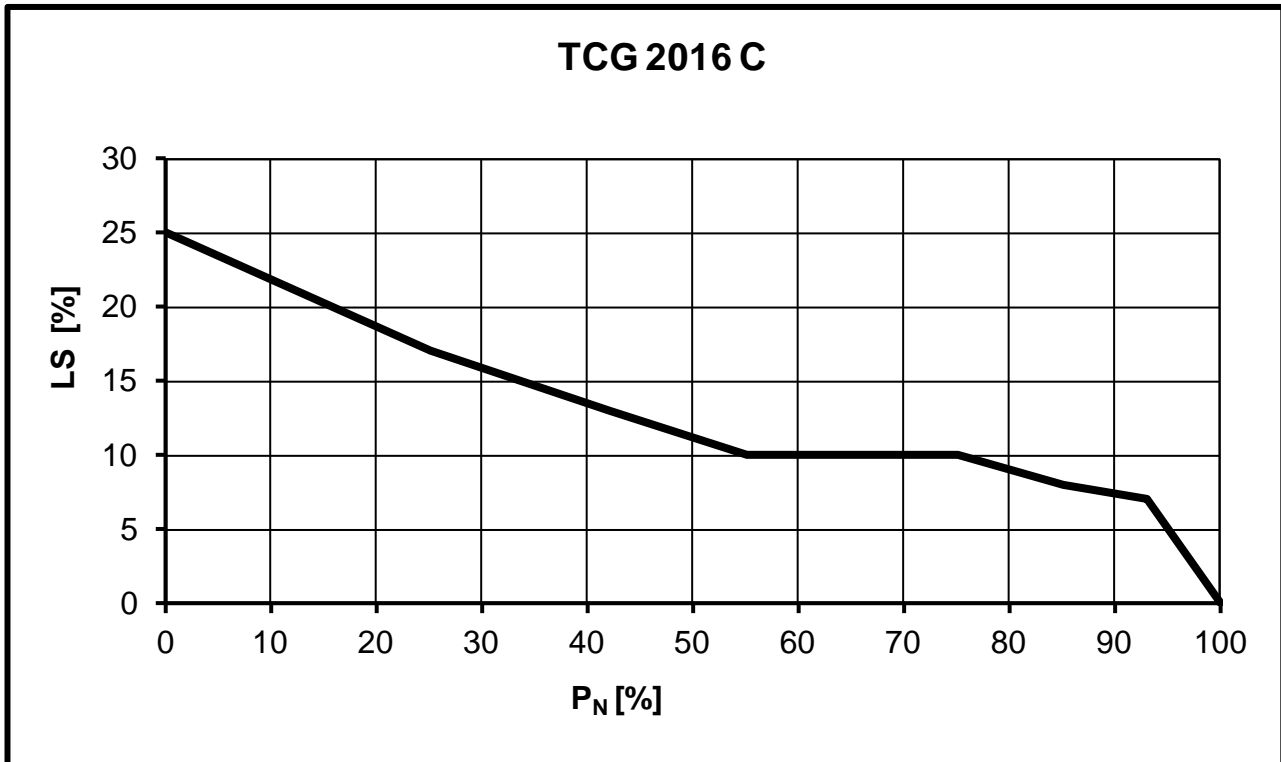
In the diagrams, the permitted load acceptance of the engines is given as curves. On the x axis, you have the active load of the engines and the y axis shows the possible load acceptance related to the active engine load. If we refer to the same example as mentioned above (TCG 2016 C), the diagram shows a sloping curve in the engine load range between 0% and 55%. In this load range, the permitted load application decreases from 25% to 10% if the engine output is increased. In the load range from 55% to 75%, the permitted load application is 10%. Above 75% to 100%, the permitted load application continues to decrease. Upon reaching 100% load, no additional load application is possible.

## Load steps for TCG 2016 C

Conditions		
Air intake temperature		30 °C
Intercooler inlet temperature	Natural gas	40 °C
	Biogas	40 °C

Moment of inertia of generator	
TCG 2016 V08	≥ 13.1 kgm <sup>2</sup>
TCG 2016 V12	≥ 19.9 kgm <sup>2</sup>
TCG 2016 V16	≥ 26.0 kgm <sup>2</sup>

$P_N$ [%]	$t_{f,in}$ [s]	n [%]
0 - 25	15	13
25 - 42	15	11
42 - 55	15	10
55 - 65	15	10
65 - 75	12	9
75 - 85	12	9
85 - 93	10	6
93 - 100	8	6



$P_N$  Active load  
 LS Load step

$t_{f,in}$  Recovery time  
 n Speed drop

## Load steps for TCG 2020

### Conditions

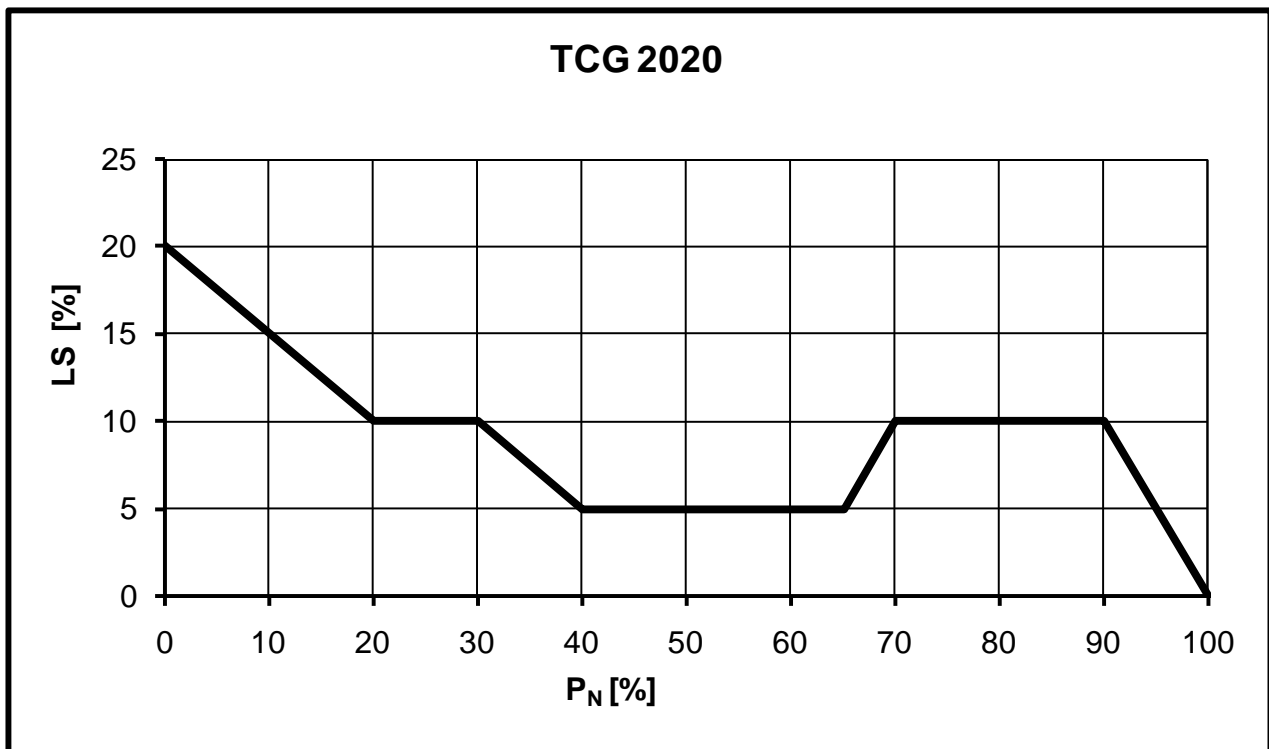
Air intake temperature		30 °C
Intercooler inlet temperature	Natural gas	40 °C
	Biogas	50 °C

### Moment of inertia of generator

TCG 2020 V12	≥ 44.6 kgm <sup>2</sup>
TCG 2020 V16	≥ 57.0 kgm <sup>2</sup>
TCG 2020 V20	≥ 95.0 kgm <sup>2</sup>

$P_N$ [%]	$t_{f,in}$ [s]	n [%]
0 - 20	15	11
20 - 30	15	10
30 - 40	15	9
40 - 45	15	9
45 - 50	15	8
50 - 55	15	7

$P_N$ [%]	$t_{f,in}$ [s]	n [%]
55 - 60	15	7
60 - 65	15	7
65 - 70	12	7
70 - 80	12	7
80 - 90	12	7
90 - 100	12	7



$P_N$  Active load  
 LS Load step

$t_{f,in}$  Recovery time  
 n Speed drop

## Load steps for TCG 2020 K

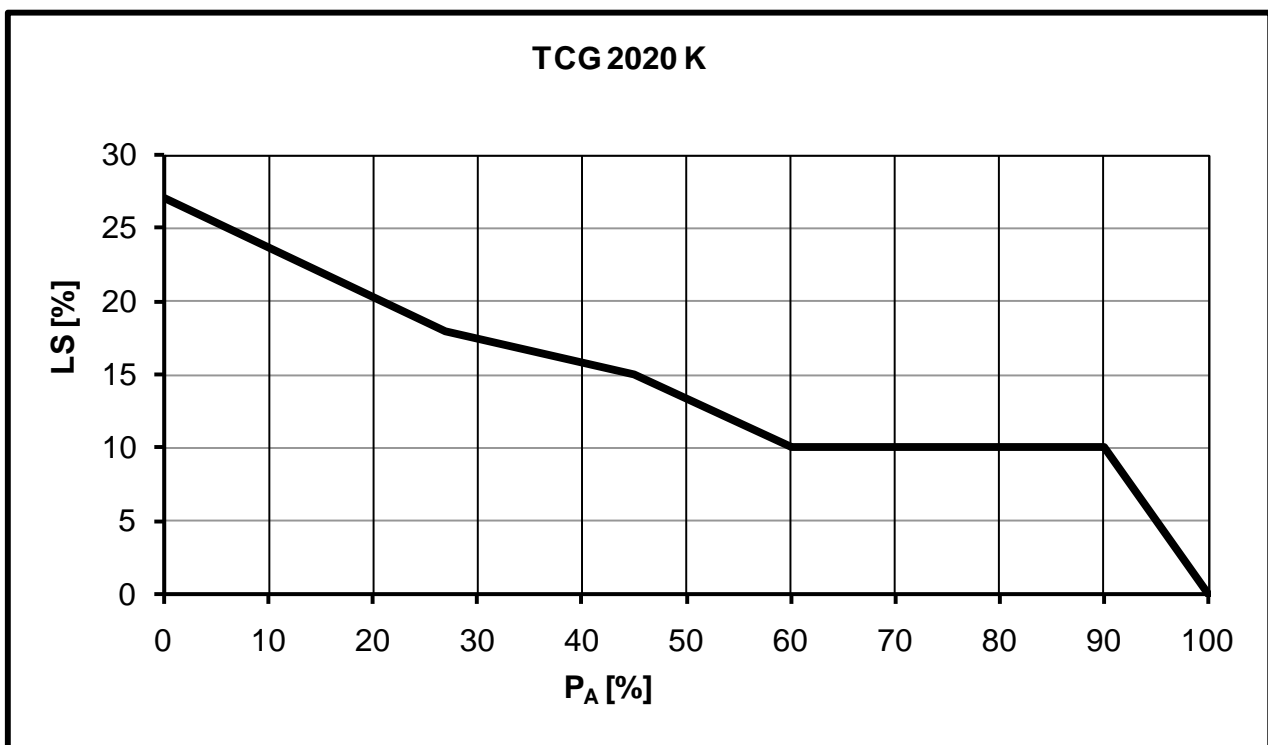
### Conditions

Air intake temperature		30 °C
Intercooler inlet temperature	Natural gas	40 °C

### Moment of inertia of generator

TCG 2020 V12K	≥ 44.6 kgm <sup>2</sup>
TCG 2020 V16K	≥ 57.0 kgm <sup>2</sup>

$P_N$ [%]	$t_{f,in}$ [s]	$n$ [%]
0 - 27	15	10
27 - 45	15	9
45 - 60	15	8
60 - 70	15	8
70 - 80	15	5
80 - 90	15	4
90 - 100	15	4



$P_N$  Active load  
 $LS$  Load step

$t_{f,in}$  Recovery time  
 $n$  Speed drop

## Load steps for TCG 2032 V12 (50 Hz) , TCG 2032 V16 (50Hz, 60 Hz)

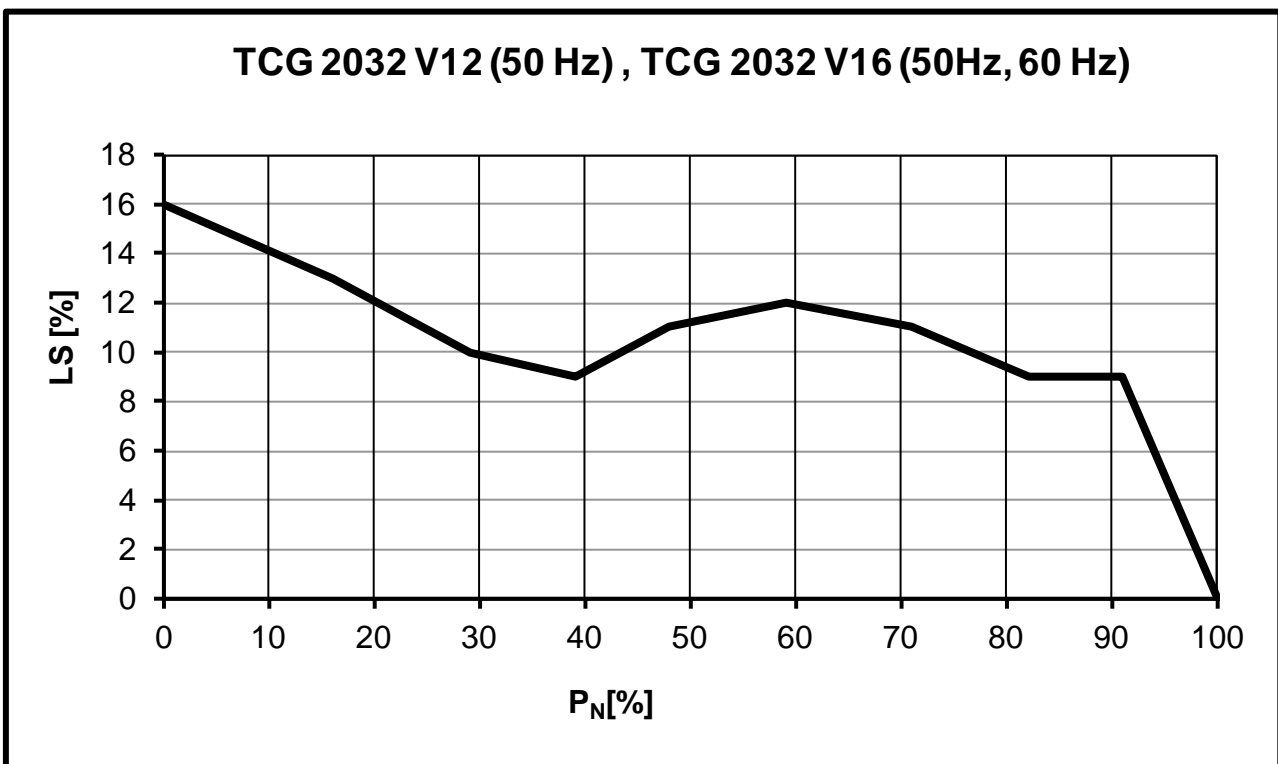
### Conditions

Air intake temperature	25 °C
Intercooler inlet temperature	Natural gas 40 °C

### Moment of inertia of generator

TCG 2032 V12	≥ 550 kgm <sup>2</sup>
TCG 2032 V16	≥ 710 kgm <sup>2</sup>

$P_N$ [%]	$t_{f,in}$ [s]	$n$ [%]
0 - 16	10	8
16 - 29	10	8
29 - 39	10	8
39 - 48	10	8
48 - 59	10	8
59 - 71	10	8
71 - 82	10	8
82 - 91	10	8
91 - 100	10	8



$P_N$  Active load  
 LS Load step

$t_{f,in}$  Recovery time  
 $n$  Speed drop

## Load steps for TCG 2032 V12 (60 Hz)

### Conditions

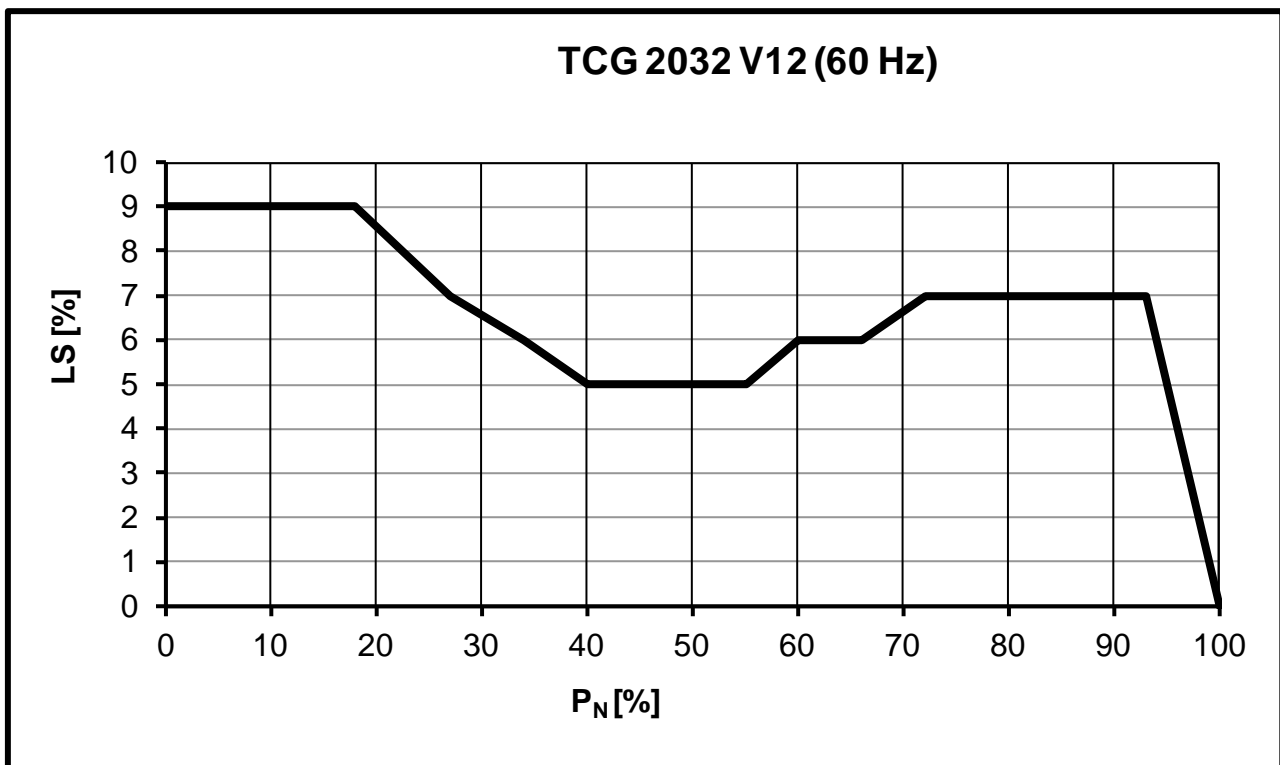
Air intake temperature	25 °C
Intercooler inlet temperature	Natural gas 40 °C

### Moment of inertia of generator

TCG 2032 V12	≥ 520 kgm <sup>2</sup>
--------------	------------------------

$P_N$ [%]	$t_{f,in}$ [s]	n [%]
0 - 9	15	5
9 - 18	15	5
18 - 27	15	5
27 - 34	15	5
34 - 40	15	5
40 - 45	15	5
45 - 50	15	5
50 - 55	15	5
55 - 60	15	8

$P_N$ [%]	$t_{f,in}$ [s]	n [%]
60 - 66	15	5
66 - 72	15	5
72 - 79	15	5
79 - 86	15	5
86 - 93	15	5
93 - 100	15	5



$P_N$  Active load  
 LS Load step

$t_{f,in}$  Recovery time  
 n Speed drop





# **Power plants layout**

**Chapter 17**

## **Cabling**

**06-2014**

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## 17. Cabling

The cabling for a CHP system comprises power cables, supply lines for auxiliary drives, control cables and signal lines. Power cables, supply lines for auxiliary drives, control cables and signal lines must be laid separately.

It is essential to use flexible, oil-resistant, fine-wire control lines (e.g. H05VV5-F). Signal transmission lines must also be shielded (shielding to be composed of tinned copper braid with a minimum of 85 % coverage such as H05VVC4V5-K, not aluminum foil).

For the supply lines to the auxiliary drives, flexible, oil-resistant, fine-wire engine connection lines must be laid (e.g. H05VV5-F).

Cables for outside installation need to be suitable for installation in open air (weatherproof, UV-resistant, e.g. ÖLFLEX Robust 215C).

The supply lines for frequency controlled drives need additional shielding (e.g. TOPFLEX EMV-UV-2YSLCYK-J). For frequency controlled drives, the total length of 100m for the pipeline must not be exceeded. For the generator power cables, multi-wire power cables (25 mm<sup>2</sup> upwards) made of copper must be used (e.g. NSGAFÖU for low voltage and N2XSY for medium voltage). Single-core power cables must be installed as per Figures 17.1a and 17.1b. The cables arriving at the generator should be secured either below or above the level of the terminal box at an adequate distance from the center line of the generator in order to prevent an excessively tight radius at the entry point through the wall of the terminal box and to allow for movement of the genset on its vibration dampers without resulting in excessive mechanical strain on the cable.

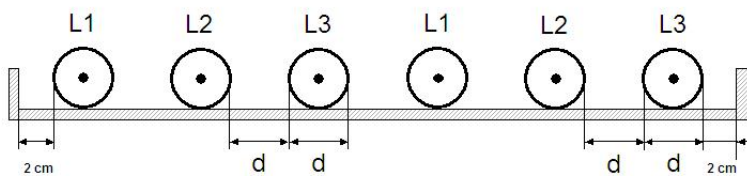
As protection against overload and short circuit, the lines must be fitted with line protection switches as per DIN VDE 0641 and/or DIN EN 60898; circuit breakers as per DIN EN 60947-2 / IEC 947-4 must be provided for the engines. The layout of the cabling should always be based on the currently applicable version of DIN VDE 0100. The cables must be routed through appropriate installation ducts and cable support systems. The cables must be laid in such a way as to prevent damage to the cable sheathing. This is of particular importance where cables are laid on a cable support system, i.e. adequate edge protection must be provided. As a matter of principle, cables must be fixed / secured in such a manner as to prevent tension on the terminals (strain relief).

When laying cables, attention must be paid to measures designed to safeguard electromagnetic compatibility. ( see Chapter 17.3 ).

Cable glands with integral strain relief must be used. The size must be selected to suit the external diameters of the cables.

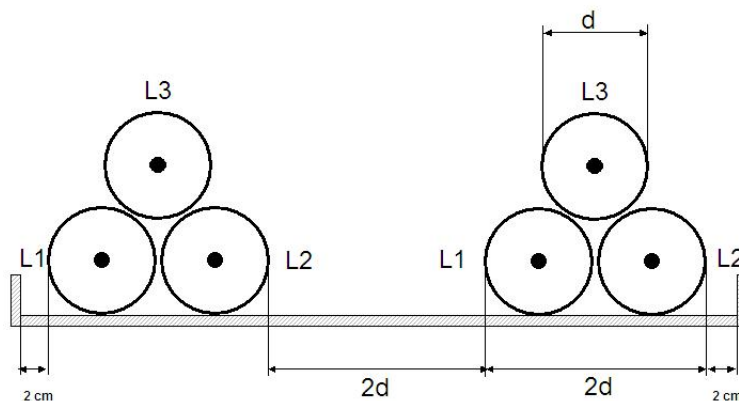
**Fig. 17.1a:**

Single-core cables, adjacent to each other with a gap of one cable diameter between. (installation in air)



**Fig. 17.1b:**

Single-core cables in the three phase system, installation as triangle. (installation in air)



When choosing and laying lines, the following points must be considered:

- Avoid possible mechanical or electrical interference between neighboring circuits.
- Consider the heat given off by lines and the chemical/physical effects of the line materials on adjacent materials such as e.g. structural or decorative materials, insulating conduits, fastenings.
- The heating effect of the current on the materials used for conductors, couplings and connections has to be considered as well.
- Short-circuit-proof routing  
To ensure a short-circuit-proof routing, the cables must be wound with five wraps of cable bundling tape every 0.5 meters. The cables or cable bundles should be fastened to the cable ladders or cable trays with cable clips every 1.5 to 2 meters.
- Protective earth conductor  
The protective earth conductor (PE) is connected to the generator housing, at the holes provided for this on the generator feet and routed on the PE in the switchgear. The line is routed parallel to the power cables.

The recommendation for the cross section of this line for low voltage is:

TCG 2016: 240 mm<sup>2</sup>                      TCG 2020: 300 mm<sup>2</sup>

A design according to VDE 0100 results in lower cross sections. The cross sections indicated apply for copper conductors.

- Protective equipotential bonding

The protective equipotential bonding is necessary in order to keep the contact voltage below the limit of 50 V.

All metallic objects must be provided with a protective equipotential bonding.

The generator housing is connected to the base frame via a copper band (70 mm<sup>2</sup>). The base frame, engine etc. are connected to the main equipotential bonding with a copper line (min. 70 mm<sup>2</sup>).

A compilation of corresponding Standards and VDE Regulations is contained in Table 17.1.

**Table 17.1**

**Extract from the respective standards:**

**Power systems**

DIN VDE 0100	Conditions for the erection of power installations with rated voltages below 1000 V
DIN VDE 0100 Part 100	General requirements, scope
DIN VDE 0100 Part 410	Protective measures and protection against electric shock
DIN VDE 0100 Part 430	Protection of cables and lines against overcurrent
Supplement 1 to part 430	Recommended values for current carrying capacity
DIN VDE 0100 Part 482	Choice of protective measures, protection against fire
DIN VDE 0100 Part 520/Part 530	Erection of electric operating cables, lines and busbars
	Erection of electrical operating material – switch and control devices
DIN VDE 0100 Part 559	Lights and lighting equipment
DIN VDE 0100 Part 720	Industrial premises which are hazardous to fire
DIN VDE 0100 Part 726 to Part 738	Hoists
DIN VDE 0101	Erection of power installations with rated voltages above 1 kV
DIN VDE 0105	Operation of power installations
DIN VDE 0107	Electrical installations in hospitals and locations for medical use outside hospitals
DIN VDE 0108 Part 1 to Part 100	Erection and operation of power installations and safety
	power supply in communal facilities, stores and shops and exhibition rooms, multi-story buildings, restaurants, closed parking
	lots and working or business premises
DIN VDE 0165	Erection of electrical equipment in hazardous areas
DIN VDE 0166	Electrical installations and apparatus thereof for use in atmospheres potentially endangered by explosive material
DIN VDE 0170/0171	Electrical apparatus for potentially explosive atmospheres
DIN VDE 0185	Lightning protection systems, protection of structures against lightning
DIN VDE 0207 Part 1 to Part 24	Insulating and sheathing compounds for cables and insulated lines
DIN VDE 0245 Part 1	Lines for electrical and electronic equipment in power installations
DIN VDE 0245 Part 101 to Part 202	PVC-insulated control lines
DIN VDE 0250 Part 1 to Part 819	Insulated power lines
DIN VDE 0253	Isolated heating lines

**Energy conductors**

DIN VDE 0262	XLPE (cross linked PE) insulated and PVC sheathed installations cable up to 0.6/1 kV
DIN VDE 0265	Cables with plastic-insulated lead-sheath installations cable
DIN VDE 0267	Halogen-free cables with improved characteristics in the case of fire; rated voltage from 6 to 30 kV
DIN VDE 0271	PVC-insulated cables and sheathed power cables for rated voltages up to and including 3.6 / 6 (7.2) kV
DIN VDE 0276 Part 603	Power cables with rated voltages of 0.6 / 1 kV
DIN VDE 0276 Part 604	Power cables with rated voltages of 0.6 / 1 kV with special fire performance for use in power stations
DIN VDE 0276 Part 604/605	Additional test methods
DIN VDE 0276 Part 620	Distribution cables with rated voltages of 3.6 kV to 20.8/36 kV
DIN VDE 0276 Part 1000	Current carrying capacity, general; conversion factors
DIN VDE 0276 Part 1001	Tests on cables laid with rated voltages of 6/10 kV up to 18/30 kV
DIN VDE 0281 Part 1 to Part 404	PVC insulated power line
DIN VDE 0282 Part 1 to Part 808	Rubber-insulated electrical power lines: heat-resistant rubber and silicon single core, halogen free single core, welding cable; rubber-insulated elevator control line, rubber hoses
DIN VDE 0284	Mineral insulated lines of up to 750 V
DIN VDE 0289 Part 1 to Part 101	Definitions for power cables and insulated power lines.
DIN VDE 0292	Code designation for harmonized cables and lines for power installations
DIN VDE 0293	Core identification for power cables and insulated power lines of up to 1000 V
DIN VDE 0295	Conductors for cables and insulated lines for power installations
DIN VDE 0298 Part 1 to Part 300	Application of cables and insulated lines in power installations, recommended current load ratings

## Testing, measurements

DIN VDE 0472 Part 1 to Part 818	Testing of cables and insulated lines
DIN VDE 0473 to Part 811	Insulating and sheathing materials of electric cables and lines, common test methods
DIN VDE 0482 to Part 268	Measurement of smoke density of cables and lines

## Telecommunication, switchboard and Installation cables

DIN VDE 0811	Ribbon cables with round conductors, with a pitch of 1.27 mm
DIN VDE 0812	Equipment wires and stranded equipment wires with PVC insulation sleeves
DIN VDE 0839	Electromagnetic Compatibility
DIN VDE 0881	Equipment wires and stranded equipment wires with extended temperature range
DIN VDE 0891 Part 1 to Part 10	Special directions and guiding principles of cables and insulated lines
DIN VDE 0899 Part 1 to Part 5	Special specifications for optical fibres, single cores, indoor and outdoor cables

### 17.1 Safety requirements for the safe use of cables and lines

#### 17.1.1 Fundamental requirements

When used in the manner intended, cables and lines should be regarded as safe; they present no unacceptable risk to life or property. Unless otherwise specified, insulated cables and lines must be used only to conduct and distribute electrical energy.

#### 17.1.2 General Requirements

The lines selected must be adequate to accommodate the voltages and currents which may occur in all anticipated operating conditions in the operating equipment, system or components thereof in which they are used. They must be so structured, laid, protected, deployed and maintained as to, as far as possible, avoid any hazards.

#### 17.1.3 Cable design for normal operation

The conductor cross-section must be selected to ensure that, at the current load specified for the conductor, the permissible operating temperature is not exceeded at any time or at any point. The heating or the current carrying capacity of a cable or line is dependent on its structure, material characteristics and operating conditions.



The additional heating effect of heating ducts, solar radiation, etc. on bundled cables or lines should be considered and avoided. Where covers are used, it is important to ensure uninterrupted air circulation.

#### **17.1.4 Operating mode**

The mode of operation defines the time characteristic of the current. Continuous operation represents constant current operation, the duration of which is at least sufficient for the operating equipment to reach thermal steady-state, but is not otherwise limited in time. The design values for cables and lines are based on continuous operation, whereby the permissible operating temperature of the conductor is reached.

#### **17.1.5 Ambient Conditions**

Ambient conditions are marked by, among other things, the ambient temperature, heat loss and heat radiation. The ambient temperature is the temperature of the ambient air when the cable or line concerned is not under load. The reference temperature is + 30 °C.

The operating conditions for cables and lines may vary both in the case of heat loss, for example in closed rooms, underfloor cable ducts, etc., and under the influence of radiated heat, e.g. the effects of the sun.

#### **17.1.6 Conditions and requirements for permanently laid lines**

Among others, the requirements for lines which are to be permanently laid are as follows:

- Lines must not come into contact with nor be laid in immediate proximity to hot surfaces, unless they are suitable for the purpose.
- Lines must not be laid directly in the soil.
- Lines must be secured in an appropriate manner. When selecting the distance between fixings, the weight of the line must be considered.
- The line must not be damaged by the mechanical means of fixing employed.
- Lines which have been in use for some time can be damaged if changes are made to the manner in which they are laid. This is due to the natural effect of aging on the physical characteristics of the materials used for insulating sleeves and sheathing. This process is accelerated by higher temperatures.

### 17.1.7 Requirements for flexible lines

- The length of connecting lines must be selected so as to be certain that the short-circuit protection devices will respond.
- The lines should not be subjected to excessive stresses due to strain, pressure, friction, twisting or kinking.
- Strain relief devices and connections must not be damaged.
- The lines must not be laid beneath covers or other operating equipment. There is a risk that they may suffer damage due to excessive heat build-up or mechanical damage due to being walked on.
- The lines must not come into contact with nor be laid in the immediate proximity of hot surfaces.
- The minimum bending radii must be observed.

## 17.2 Boundary conditions for the safe use of cables and lines

### 17.2.1 Operating conditions

The lines selected must be suitable for the operating conditions and the respective protection class of the equipment concerned.

The operating conditions include, among others:

- Voltage
- Current
- Protective precautions
- Bundling of lines
- Type of laying
- Accessibility

The lines selected have to be suitable to withstand all external influences which may arise.

These external influences include, among others:

- Ambient temperature
- Rain
- Water vapor, or accumulated water
- Presence of corrosive, pollutant or other chemical substances
- Mechanical stresses (e.g. sharp edges of metal structures)
- Animals (e.g. rodents)
- Plant life (e.g. mold fungus)
- Radiation (e.g. sunlight)

**Note:** In this context, it should be borne in mind that color is of great importance, and that the color "black" offers greater protection against solar radiation (high resistance to UV radiation) than other colors.

### 17.2.2 Voltage

The nominal voltage of a line is the voltage for which the line is designed and which is used as a definition for electrical tests. The nominal voltage is specified in Volts using two values  $U_0/U$  where:  $U_0$  is the r.m.s. value of the voltage between an external conductor and earth (metal sleeves of the line or surrounding medium).  $U$  is the r.m.s. value between two external conductors of a multi-core line or a system of single-core lines. In an a.c. voltage system, the nominal voltage of a line must at least correspond to the  $U_0$  and  $U$  values of the system.

### 17.2.3 Current carrying capacity

The nominal cross-section of a conductor should be selected so that its current carrying capacity is not less than the maximum continuous current flowing through the conductor under normal conditions. The limit temperatures to which the current carrying capacity relates must not be exceeded either for the insulating sleeve or sheathing of the respective line type. Among the defined conditions is also the manner in which the line is laid. Attention should be paid here to the specified permissible current loads.

The conditions to be taken into account include, among others:

- Ambient temperature
- Bundling of lines
- Type of overcurrent protection
- Heat insulation
- Rolled or coiled lines (should be avoided)
- Frequency of the current (in deviation from 50 Hz)
- Effects of harmonics.

The conductor cross-section should not be selected simply in accordance with the requisite current carrying capacity (DIN VDE 0298-4). Rather, the requirements for protection against hazardous shock currents, overload and short-circuit currents and voltage drop should be considered. Where lines are to be operated for extended periods at temperatures higher than those specified, they may suffer serious damage which can lead to premature failure or to a significant impairment of their characteristics and life threatening situations.

#### **17.2.4 Thermal Influences**

Lines should be selected, laid and installed so as to ensure that the anticipated release of current-induced heat is not obstructed and there is no risk of adjacent materials catching fire. The limit temperatures for the individual line types are specified by the manufacturer. The specified values must, under no circumstances, be exceeded due to the interaction between internal current-induced heat and ambient conditions. The typical temperature range for permanently laid standard cables is - 40°C to + 80°C. If higher temperatures occur, heat-resistant cables must be used.

#### **17.2.5 Mechanical influences**

When assessing the risks of mechanical damage to the lines, consideration must be given to all mechanical stresses which might arise:

##### **17.2.5.1 Tensile load**

The strain values specified for the cables must not be exceeded. Typical values are 50 N/mm<sup>2</sup> for permanently installed lines and 15 N/mm<sup>2</sup> for flexible lines. In cases in which the above-mentioned values are exceeded, it is recommended that a separate strain relief element or similar be fitted. Such strain relief elements should be connected to the line in such a way that they do not damage the line.

##### **17.2.5.2 Bending stresses**

The internal bending radius of a line should be selected in order to avoid damage to the line. The internal bending radii for the different types of control lines are approx. 10 x line diameter (dependent on cable type and manufacturer) and for power cables approx. 15 x cable diameter. The minimum bending radius must in each case be checked for the particular lines/cables used.

When stripping the insulation, care must be taken not to damage the conductors, as otherwise their bending behavior will be seriously impaired.

The specified bending radii apply at ambient temperatures of 20°C (± 10 K). For other ambient temperatures, account must be taken of the manufacturer's specifications.

Bends should be avoided in the immediate vicinity of external or internal fixing points.

##### **17.2.5.3 Pressure load**

Lines should not be subjected to such pressure as might damage them.

#### **17.2.5.4 Torsional stresses**

Flexible lines are generally not intended to support torsional stresses. Where such torsional stresses are unavoidable, this must be clarified on a case-by-case basis with the cable manufacturer.

#### **17.2.6 Room types**

Electrical operating premises are rooms or locations used primarily for the operation of electrical equipment and generally accessible only to trained personnel, e.g. switch rooms.

Sealed electrical operating premises are rooms or locations used exclusively for the operation of electrical equipment and kept under lock and key. Access is permitted only to trained personnel, e.g. sealed switching and distribution systems.

Dry rooms are rooms or locations which are generally devoid of condensation, or in which the air is not saturated with moisture.

Damp and wet rooms are rooms or locations in which the safety and reliability of the operating equipment is impaired by moisture, condensation, chemical or similar influences.

General notes:

To assign rooms to one of the above listed types often requires a precise knowledge of local and operational conditions. If for example a high level of moisture occurs only at one specific point in a room, but the room itself remains dry thanks to regular ventilation, it is not necessary to classify the whole room as a wet room.

Since in CHP systems it is impossible to exclude oil and water leaks, oil and chemical-resistant cables must be used.

#### **17.2.7 Types of use and stresses**

Electrical lines may be divided between the following types of use:

- Cables for use in interior rooms, e.g. CHP system room
- Cables for use in the open air, e.g. supply line for table coolers

### **17.2.8 Subdivision of stresses**

The term "stress" defines the suitability of a line for use in certain areas, on or in a piece of operating equipment, and for certain combinations of external influences which occur in these areas.

In terms of stresses, electrical lines are divided into four categories:

- Very low stress, e.g. computer systems
- Low stress, e.g. air conditioning, data processing
- Normal stress, e.g. mechanical engineering, CHP systems, system manufacturing
- Heavy stress, e.g. mining

#### **17.2.8.1 Use in interior rooms**

The line is installed or connected to a piece of equipment which is permanently located inside a building, namely within the "specified environment". The building may be used for commercial, industrial or residential purposes.

#### **17.2.8.2 Permanent open-air use**

The line is designed to resist the widely varying stresses which may occur in the "specified environment", namely the open air (including the effects of weather).

### **17.3 Measurement to safeguard EMC**

The line arrangement contributes to an essential part of the EMC of a system. The lines have to be graded in four groups:

- Group I: Very interference-susceptible (analog signals, measuring lines)
- Group II: Interference-susceptible (digital signals, sensor cables, 24VDC-switch signals)
- Group III: Fault source (control cables for inductive loads, unswitched power cables)
- Group IV: -Strong fault source (output cables of frequency converters, switched power cables)

Crossing should be avoided when arranging the cables. If there are unavoidable crossings, the lines of the different groups have to cross at right angles.

### 17.3.1 EMC instructions for use of frequency converters

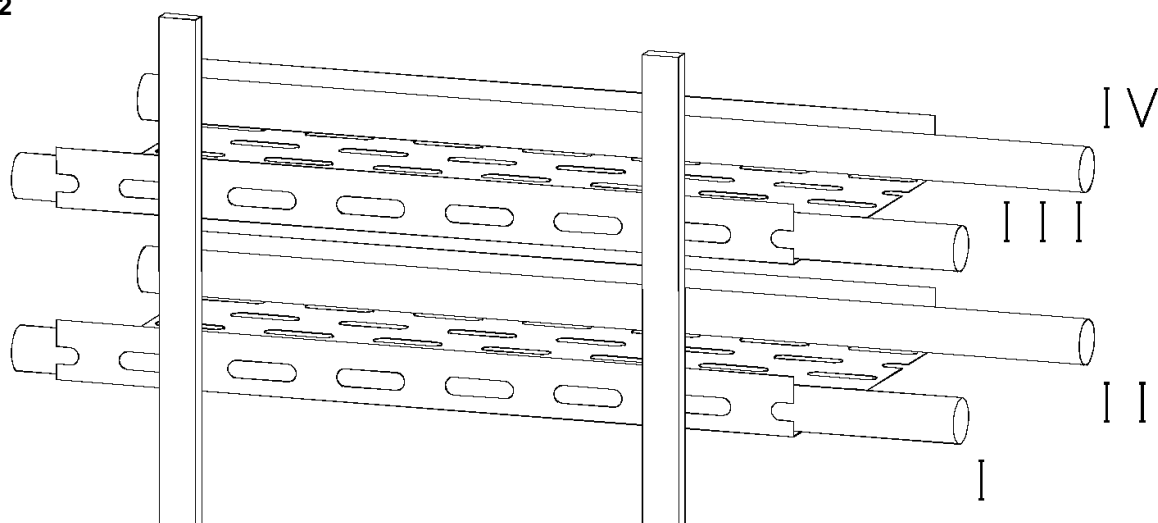
Depending on the EMC requirement (environmental class 1 or 2) and type of frequency converter, EMC filters are required.

Attention must be paid to the cabling and EMC instructions in the operation manual.

### 17.3.2 Cable ducts

- Metallic cable ducts have to be connected to the ground (earthing). They must be connected constantly
- Reduction of the magnetic field through distance of the cable troughs (Fig. 17.1)
- Lines are installed in various cable ducts
- Lines separate through metallic partition

Fig. 17.2



The recommended minimum distance between cable troughs is 0.15 m. The troughs should be electrically connected to the vertical carriers.

In general, the power cables of generators should be laid separately. In the case of power cables, it must be noted that the type of routing has a significant influence on the current carrying capacity of the line. The correction factors in the standards must be observed here. The standard VDE 0298 specifies a distance of 0.3 meters between the cable trays/ladders and to the ceiling when routing cables on cable trays/ladders.

### 17.3.3 Cable fittings

In the case of particular EMC requirements, EMC-type cable fittings should be used. In general, chromed brass fittings are used.

### 17.4 Examples for cable arrangements

**Fig. 17.3**

shows a starter cable arrangement. The cables are laid symmetrically and secured with cable clamps. This prevents damage due to abrasion.

**correct**

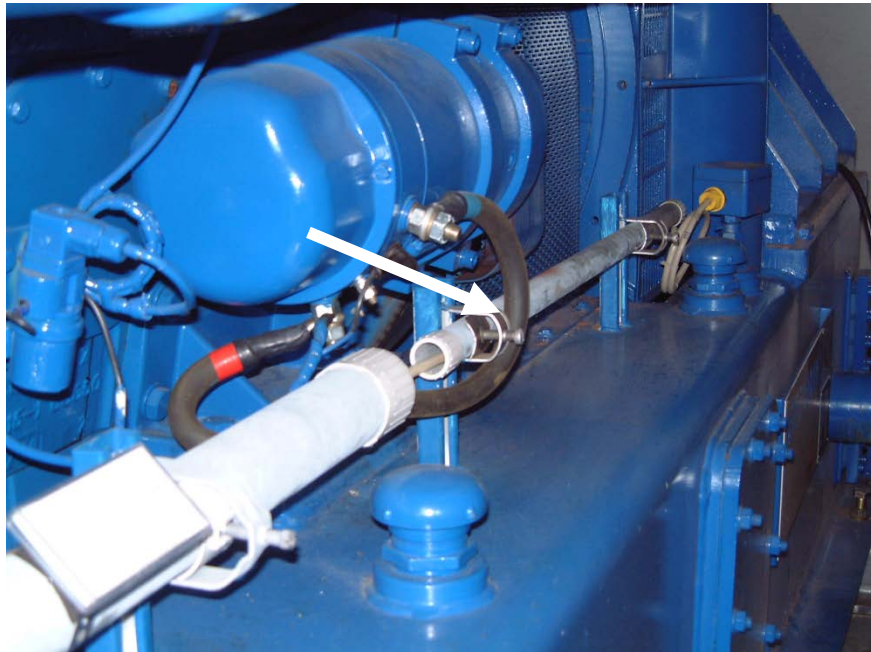




**Fig. 17.4**

Shows a starter cable which is installed incorrectly.  
Abrasion danger! Possible short-circuit danger!!

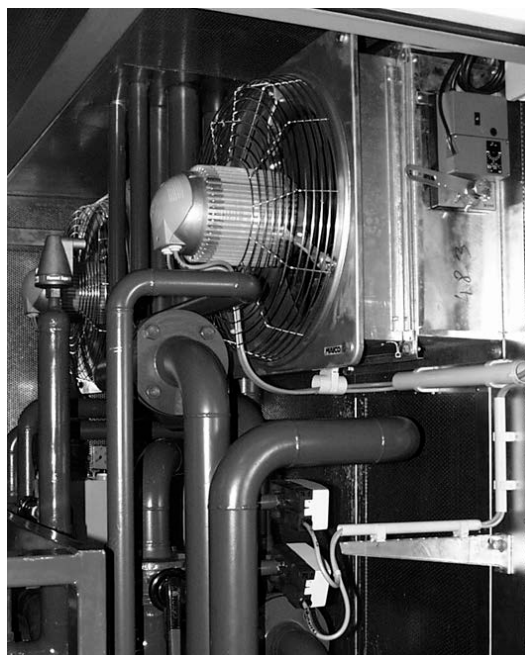
**incorrect**



**Fig. 17.5**

shows the arrangement of temperature sensor and fan motor cables.  
The power supply cables are connected to the equipment in an installation system. The cables should be connected to the equipment from below. It must be ensured that the cable entry point is properly sealed.

**correct**



**Fig. 17.6**

shows an incorrect cable installation. Rolling up the cables as a coil at the engine is not permitted because of additional load of the plugs and EMC problems.

**Abrasion danger! EMC problems!**

**incorrect**



**Fig. 17.7**

shows the vertical arrangement of engine cables up to a cable trough at ceiling height. The access point into the cable trough is fitted with the necessary edge protection and the cables are secured with cable clamps (do not use cable ties)

The line to the gas mixer regulating valve is poorly laid and therefore constitutes a negative example. **The cable should not be fixed directly to a pipe (danger of abrasion)** and it must not be rolled up in a coil (faults, mechanical wear).

correct



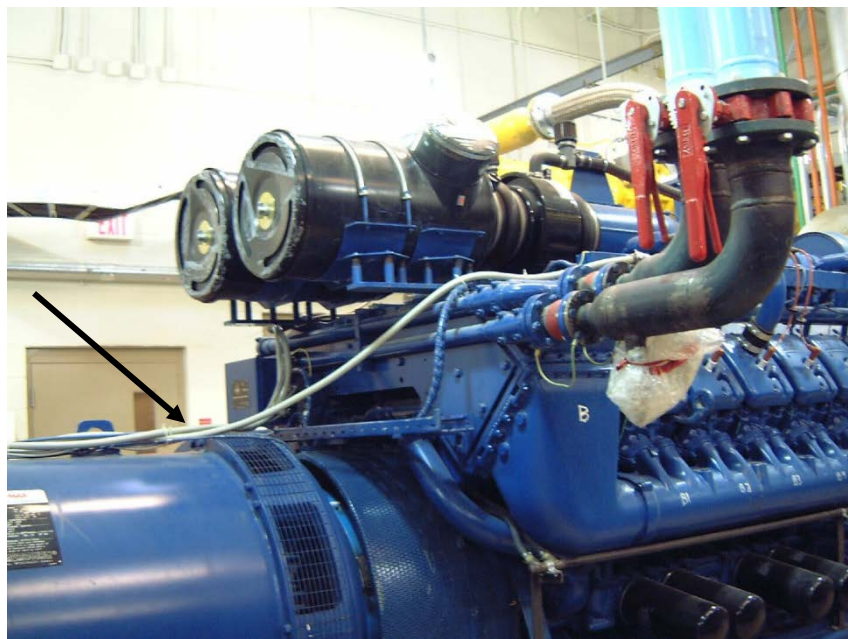
incorrect

**Fig. 17.8**

This picture shows a cable, which is laid loose and directly on the engine and the generator. Cable damages and EMC problems are the result of this.

**Abrasion danger! Danger of short circuit! EMC problems!**

**incorrect**

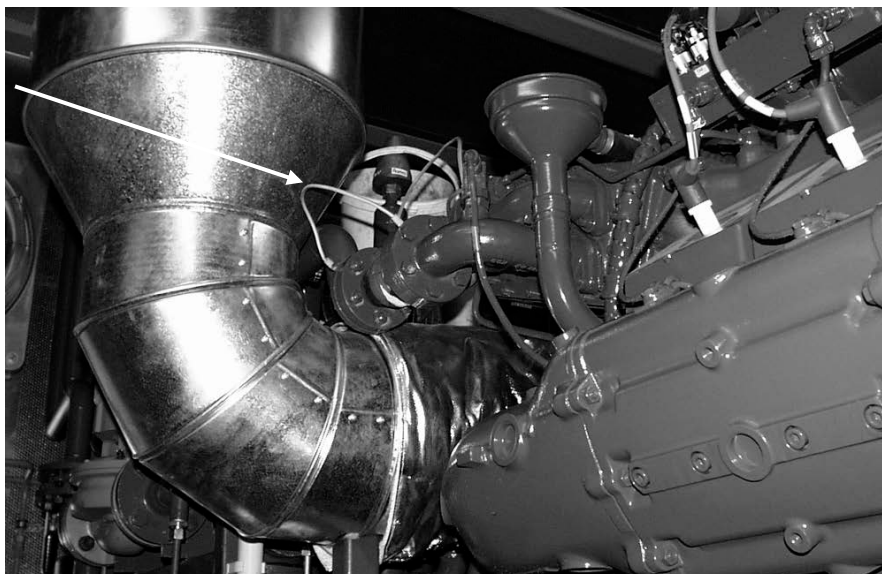


**Fig. 17.9**

shows the equipotential bonding for the cooling water pipe across the rubber expansion joint. The cable is too long and is resting against the exhaust pipe insulation.

**Abrasion danger! Impermissible heating!**

**incorrect**

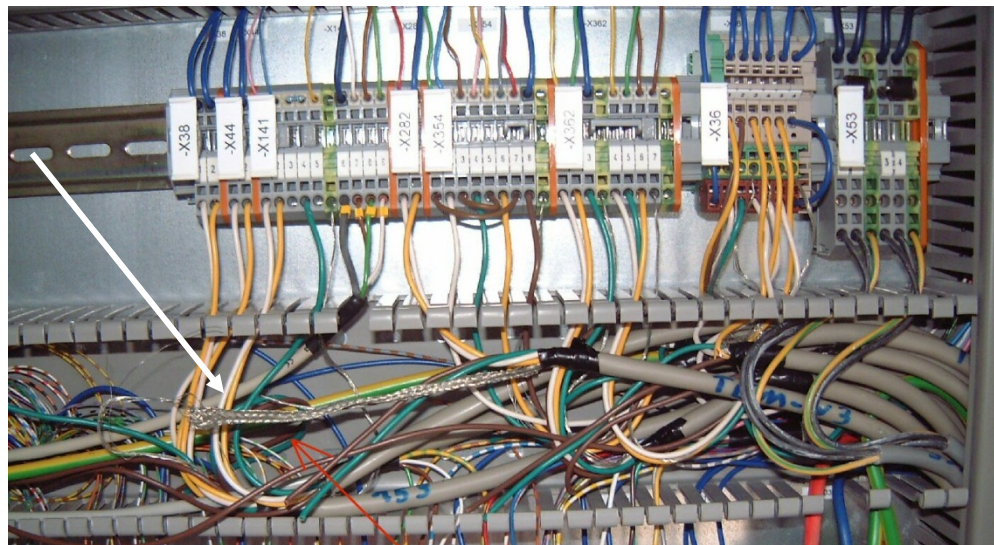


**Fig. 17.10**

The skinning of the shield is too long and not laid to the terminal with separate isolation. The wires are laid on the terminals as long loops. This causes the risk of EMC problems and short-circuits.

EMC problems! Danger of short circuit!

**incorrect**

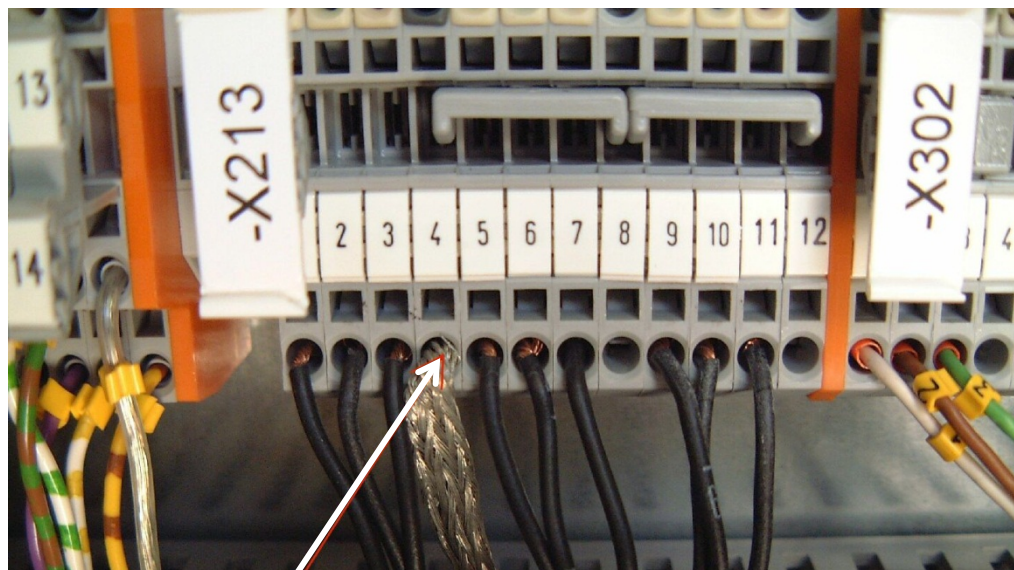


**Fig. 17.11**

In the following picture, the shielding is too long and not isolated. On the external black cables, the wire terminal sleeves are missing.

Danger of short circuit!

**incorrect**

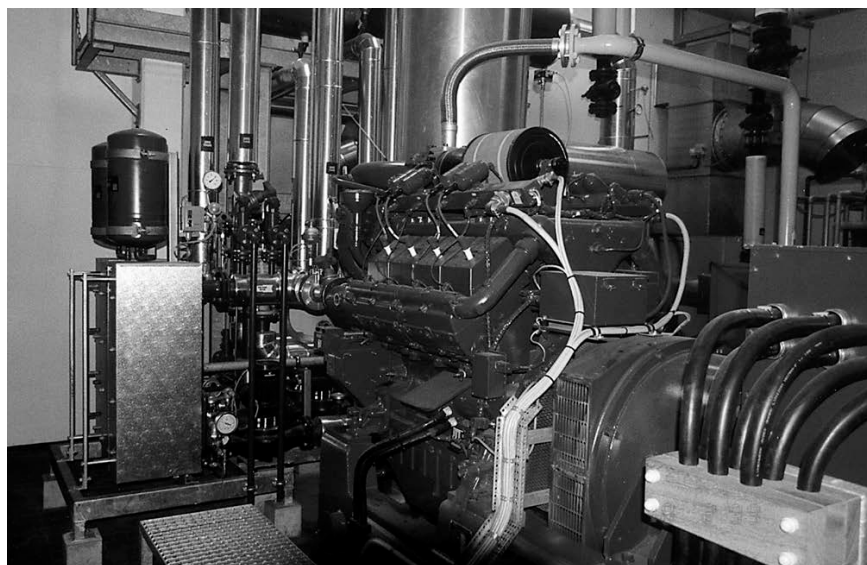


**Fig. 17.12**

shows an arrangement of TEM cables running to the genset. These are fed to the engine in cable troughs. The power cables are secured after the 90° bend in order to prevent abrasion and to ensure the appropriate strain relief.

The 90° bend in the power cables absorbs vibrations which thus do not place strain upon the cable fittings at the connections.

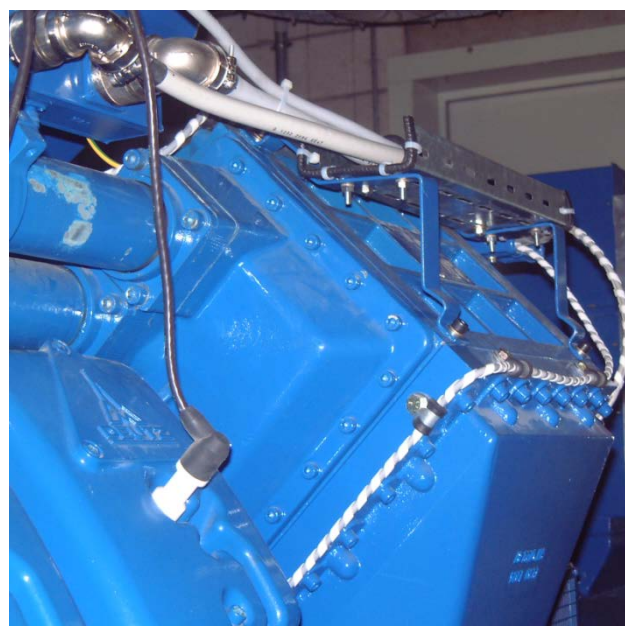
**correct**



**Fig. 17.13**

shows correctly laid cables with clamps and cable ducts.

**correct**



**Fig. 17.14**

shows correctly laid cables with clamps and cable ducts.

**correct**

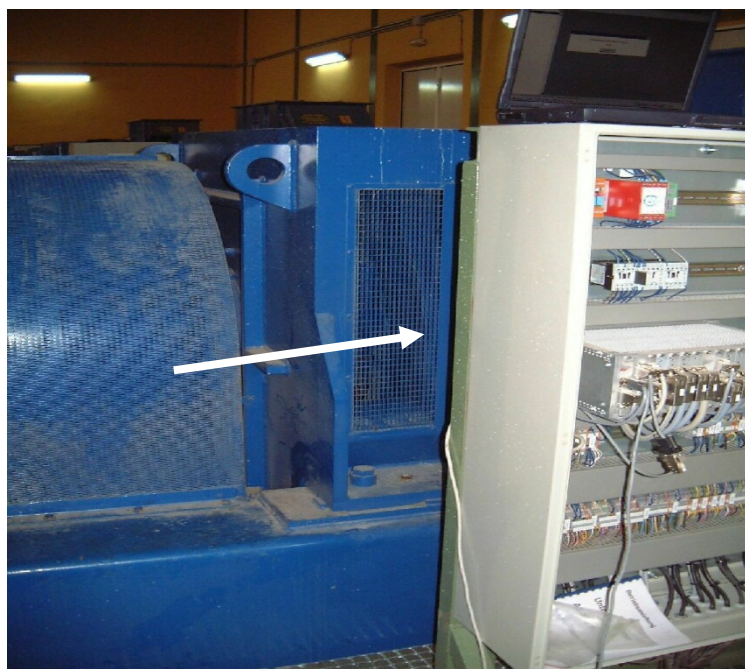


**Fig. 17.15**

shows a TEM-cabinet, which is standing directly in front of the generator's exhaust air. This causes the TEM cabinet to overheat. The temperature inside the cabinet is therefore too high and this is what causes the problems.

Temperature problems!

**incorrect**

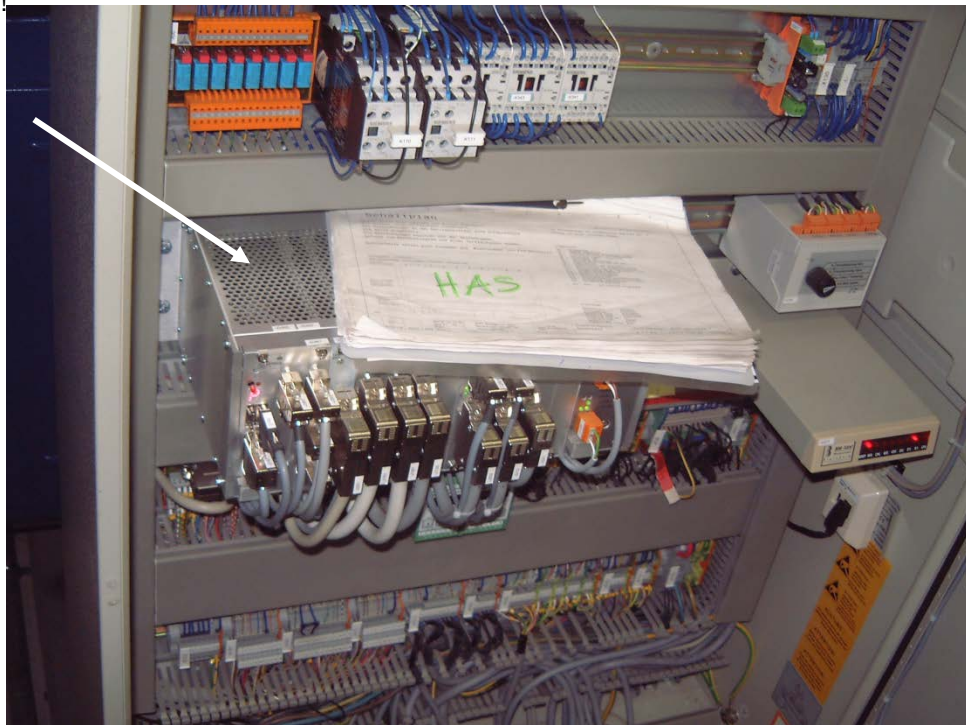


**Fig. 17.16**

It is impermissible to close or to cover the air ducts.

Heat accumulation!

**incorrect**



**Fig. 17.17**

The power cables should be connected to the generator professionally

Danger to life! Danger of short-circuit! Danger of fire!

**incorrect**





**Fig. 17.18**

The cable entrance is covered with sheet metal, so that no object can fall into the opening and cause a short-circuit.

correct



**Fig. 17.19**

The requested bending radii for the generator power cables are kept and the weight off the cables is captured by the fix supports.

correct



**Abb. 17.20**

The requested bending radii of the generator power cables are kept, but the weight of the cables is acting onto the cable glands and cable clamps. This arrangement is not short-circuit proof.

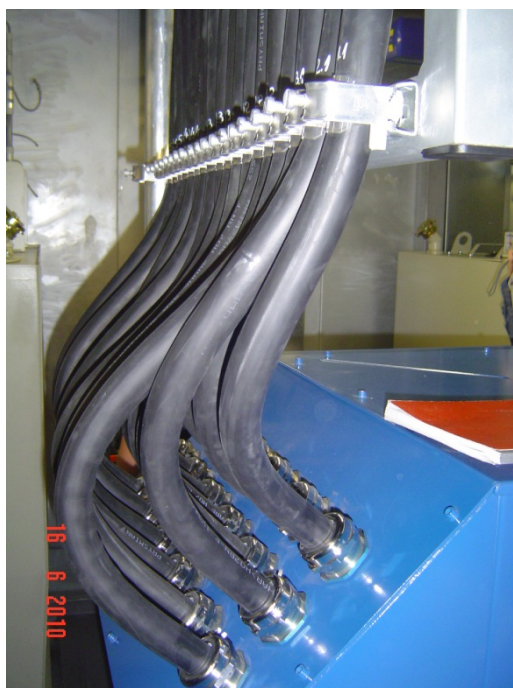
**incorrect**



**Abb. 17.21**

The bending radii of the generator power cables are too small. Several cables are rubbing at the screw nuts of the cable glands.

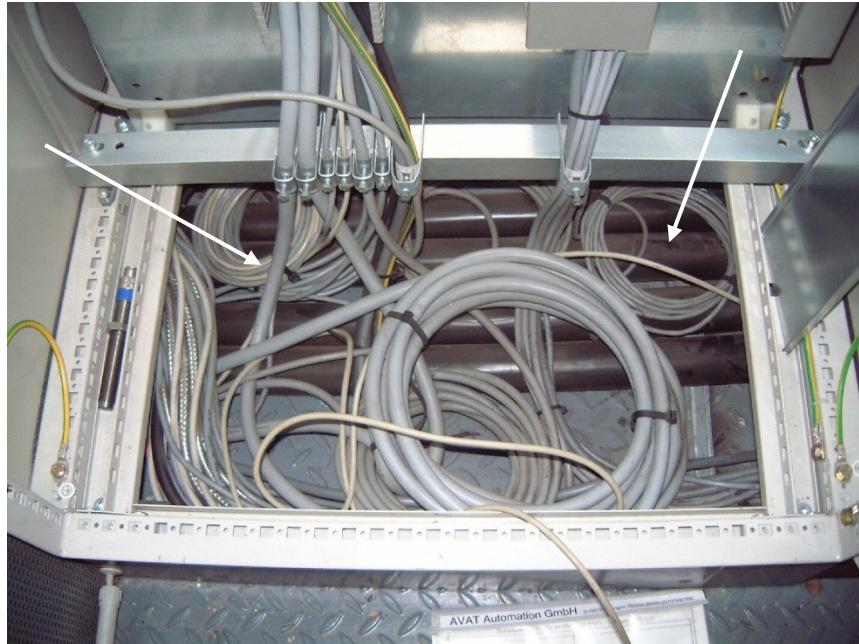
**incorrect**



**Fig. 17.22**

It is not permissible to lead the power cables through the control cabinets and TEM cabinet.  
EMC problems!

**incorrect**





# **Power plants layout**

**Chapter 18**

## **Transport and positioning of gensets**

**06-2014**

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## **18. Transport and positioning of gensets**

### **18.1 Preliminary notes**

The transport of a genset from the factory to its final destination can be divided into the following steps:

- Loading of the genset onto truck by stationary crane or mobile crane
- Transport by truck to destination or to harbor for shipping
- Reloading in harbor or when changing truck
- Unloading at destination by mobile crane or mobile crane
- Positioning and placement on the foundation

### **18.2 Loading by crane**

The loading of gensets in the factory is either carried out using an indoor crane or by mobile crane. The gensets are either equipped with load support points (bollards) which are arranged on each side of the genset's base frame or, in special cases, with two double-T members which are arranged below the base frame. Those double-T members are equipped with shackles for fixing the lifting devices (ropes or chains). The position of the load support points is symmetric to the center of gravity of the genset. The genset will take a stable horizontal hanging position when using four ropes or chains of equal length for lifting.

One end of the chains or ropes must be hooked to the crane's hook or to a cross member.

The opposite ends have to be fastened to the load support points of the genset. The fastening must be secured against unexpected sudden loading.

For this reason, chains and ropes must only be secured using either clamps (lifting clamps) or textile slings when fastening them onto the transport brackets of the genset.

When arranging chains or ropes for lifting a genset, it must be ensured that the chains or ropes are only touching the genset at the load support points, thus preventing damage to genset components due to slanting chains or ropes. Special cross members are used for this, see image 18.1. If there are no suitable cross members available for lifting, it is necessary to arrange special devices for spreading the chains or ropes used for lifting.

**Fig. 18.1 Lifting a genset**



### **18.2.1 Load support equipment / hoists**

Load support equipment, hoists and fastening equipment which are used for lifting and transporting of heavy loads are subjected to special monitoring and test procedures both when this equipment is produced and during its operation life. The rules and regulations of the industrial health and safety ordinance and of the accident prevention and insurance associations apply in the EU. The main items to be observed are listed in the following.

- Only trained persons may use the lifting and transport equipment.
- The permissible load may not be exceeded on any equipment.

Before using any of this equipment, it has to be checked for proper condition, i.e. it must not show any damage affecting its safety and function (for example breaks, chamfers, cracks, wear, deformations, damages caused by exposure to heat or cold etc.).



The equipment must not be overloaded with joints.

There must not be any knots or twists in the ropes and chains.

Ropes and chains may not be taken over sharp edges without the appropriate protective equipment; edge protection must always be used.

Asymmetric loading of the equipment must be avoided.

Ropes and chains must be shortened correctly.

### **18.2.2 Maintenance of load support equipment / hoists**

The load support equipment and hoists must be checked for visible damages, deformations, wear and corrosion, cracks and breaks by an authorized expert. These checks have to be done in fixed time intervals, but at least once a year. For the case of unacceptable failures, the respective device must be withdrawn from further use. When carrying out maintenance, it is forbidden to make any change affecting the function and the load capacity of the load support equipment.

### **18.2.3 Service limits for load support equipment / hoists**

When exposed to high or low temperatures, the capacity of load support equipment and hoists must be reduced accordingly.

## **18.3 Transport on vehicles and ships**

When transporting gensets on trucks or on board ships, an appropriate intermediate layer between the loading platform and the base frame must be provided. Providing anti-slip mats or blocks made of hard rubber or wood is recommended. In addition, it is necessary to attach tensioning straps, lashing chains, mounting links and cradles to keep the genset safe against slipping or tilting. When transporting, the genset must be protected from the effects of weather using an appropriate transport cover. A package for carrying overseas will be provided for marine transport.

## **18.4 Reloading and unloading**

Gensets are normally reloaded and unloaded using mobile cranes. As far as the choice of hoists is concerned, the same notes, rules and instructions as mentioned per item 18.2 for the loading of gensets can be referred to.

## 18.5 Storage of gensets and system components

Due to project requirements, gensets, switchgears and system components might have to be stored until they are installed. The following points should be observed during storage:

- the storage area must be dry and properly ventilated
- the storage area must be heated if the temperature is likely to fall below the dew point due to daily or seasonal change.
- the storage area must be frost-proof

On the technical data sheets for the specific components, storage temperatures are indicated which depend on the materials installed in the components. In particular seals made of elastomers grow brittle as a consequence of frost and can be easily destroyed.

For switch cabinets with semiconductor electronic circuits, storage temperatures in the range from -10 to +50 °C are indicated.

Especially during transport and also during storage in harbors or at hauler's, it is not always possible to comply with the conditions described above. We accept no liability for damages caused by frost or dampness.

Corrosion protection is applied to the inside and outside of the diesel and gas engines for a period of 24 months. If the engine is stored for longer than the protection allows, an additional protection treatment is necessary. The length of protection provided is valid only if the storage conditions described above are complied with.

Generators must be rotated every 6 months, regardless of whether they are individually stored or installed in a genset.

System components which are installed in the open air during operation can also be stored in the open air. These are, for example, ventilator coolers or exhaust silencers.

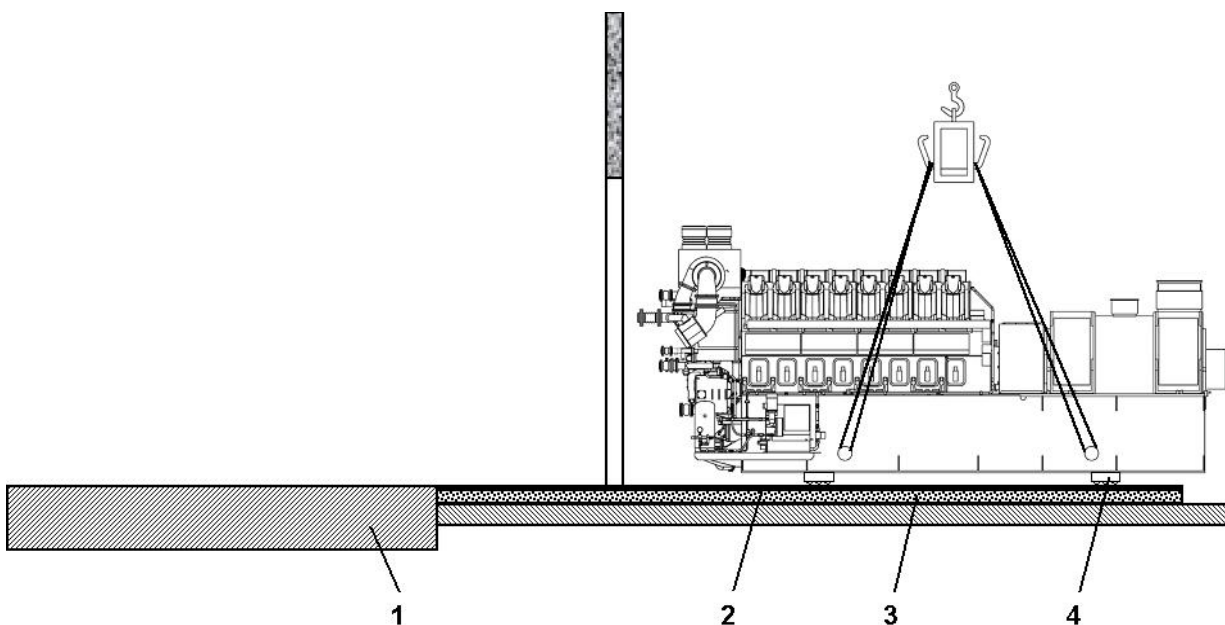
## 18.6 Positioning and placement on the foundation

The positioning of a genset is described for a genset with an engine such as the TCG 2032 V16.

### 18.6.1 Preparations for positioning

In normal conditions, the genset has to be pulled onto the foundation via the access opening of the engine room. It is recommended to provide a two-track ramp with covering steel plates and gravel below. The ramp is arranged in the longitudinal direction of the foundation; the upper edge of the ramp is in alignment with the top of the foundation. The free accessible length of the ramp on the outside of the engine room must be at least the full length of the genset in order to place the complete genset on the ramp. Before placing the genset on the ramp, steel rollers are arranged at the four corners of the base frame. See figure 18.2.

**Fig. 18.2 Preparations for the positioning**

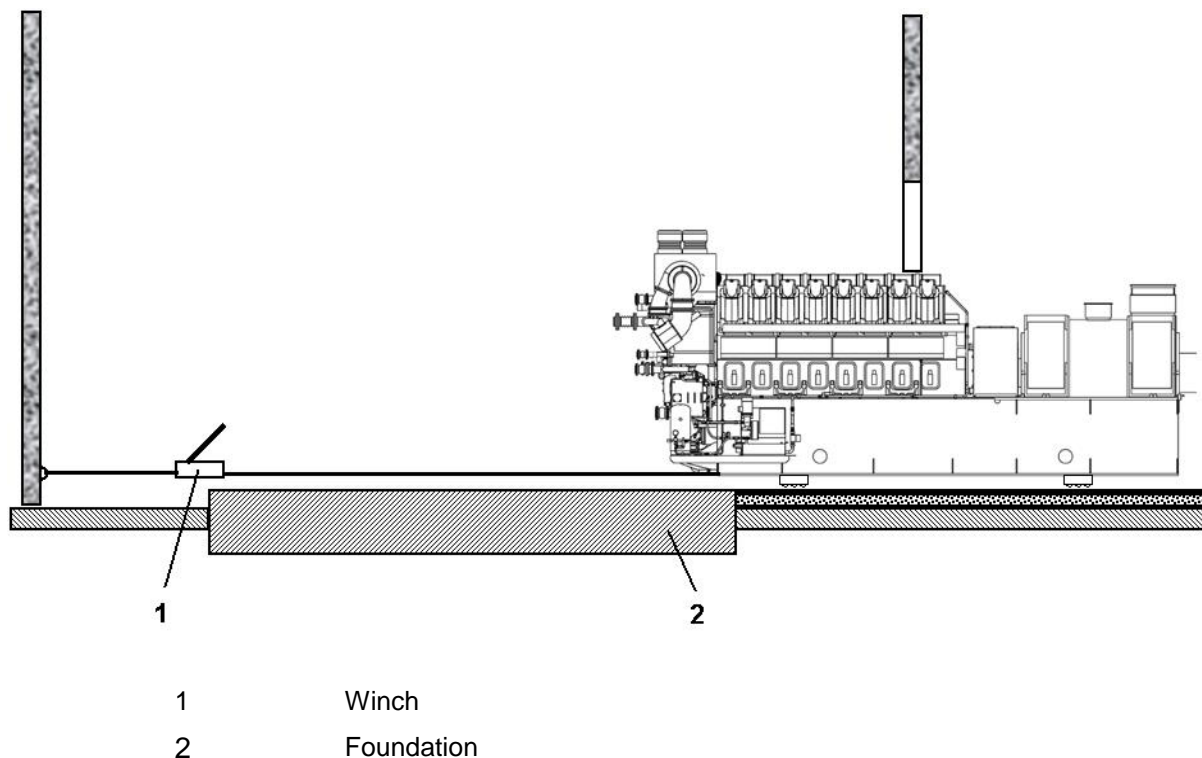


- |   |              |
|---|--------------|
| 1 | Foundation   |
| 2 | Steel plates |
| 3 | Gravel bed   |
| 4 | Steel roller |

### 18.6.2 Pulling the genset onto the foundation

After placing the genset on the ramp, two ropes with winches will be attached to the two front corners of the base frame. The ropes are to be fastened to the base frame using shackles. For fastening the opposite ends of the ropes, load support points should be provided at the opposite wall, for example. With use of the winches, the genset can then be pulled to its final position on the foundation. See also figure 18.3. When placing the genset onto the ramp, attention should also be paid to aligning of the genset's longitudinal axis to the longitudinal axis of the foundation.

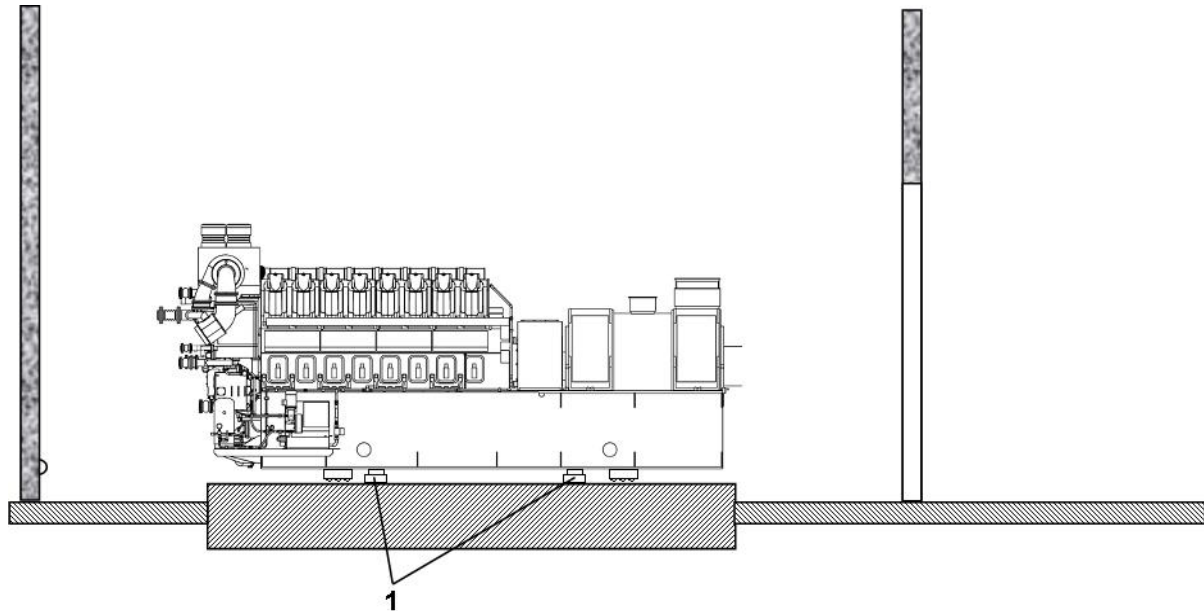
**Fig. 18.3 Pulling the genset**



### 18.6.3 Placing the genset on the foundation

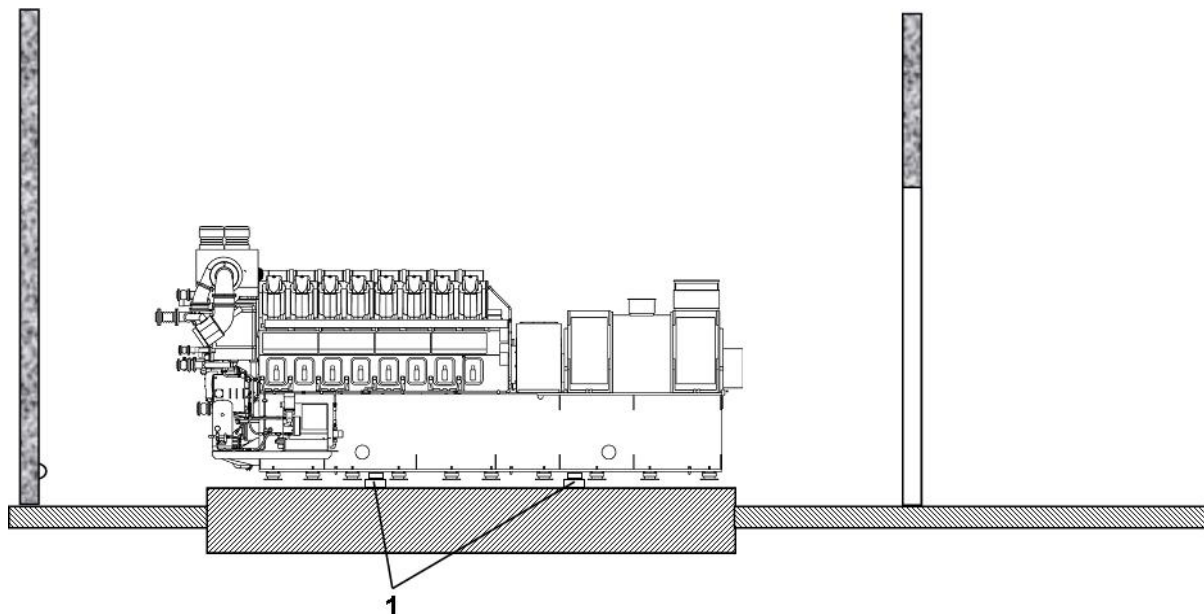
After maneuvering the genset to its final position on the foundation, it has to be placed on the foundation. At least four hydraulic jacks have to be placed below the base frame. By using the hydraulic cylinders, the genset can be lifted uniformly (see figure 18.4). After removing the steel rollers, the spring elements can be bolted to the base frame. When lowering the hydraulic cylinders, the genset's weight will be taken by the spring elements. To get equally balanced load on the spring elements, they have to be adjusted with regard to the individual alignment specification (see figure 18.5 and 18.6).

**Fig. 18.4 Arrangement of the hoist cylinder**



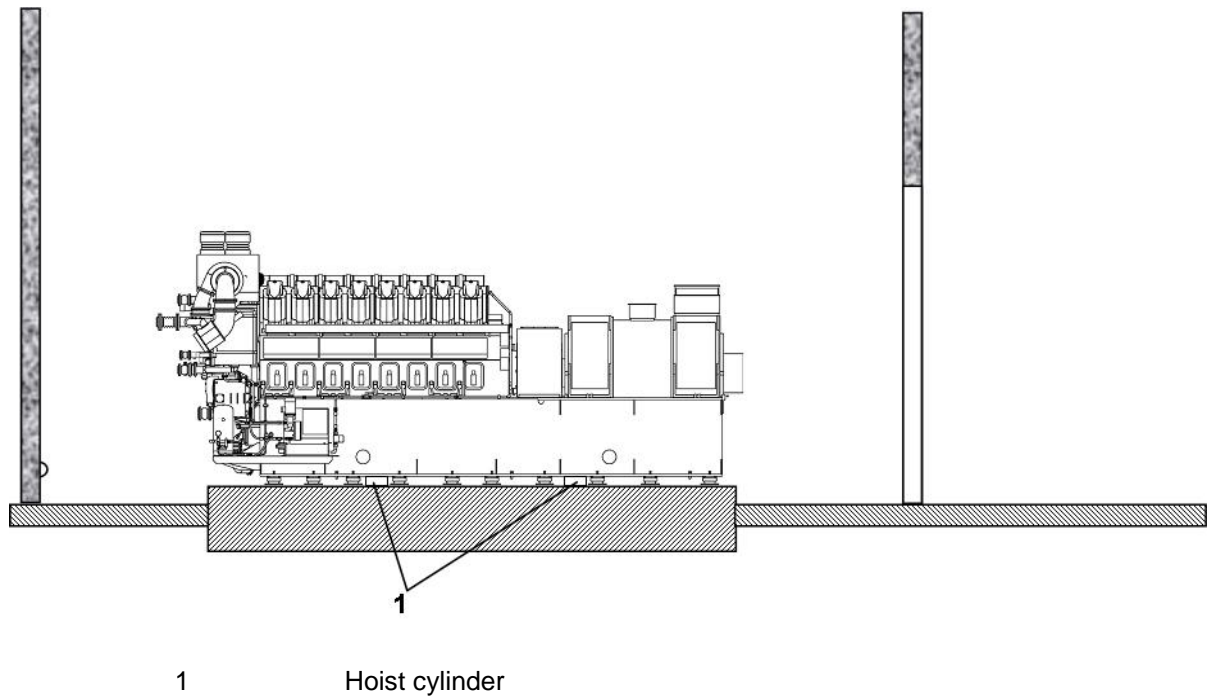
1 Hoist cylinder

**Fig. 18.5 Arrangement of the spring elements**



1 Hoist cylinder

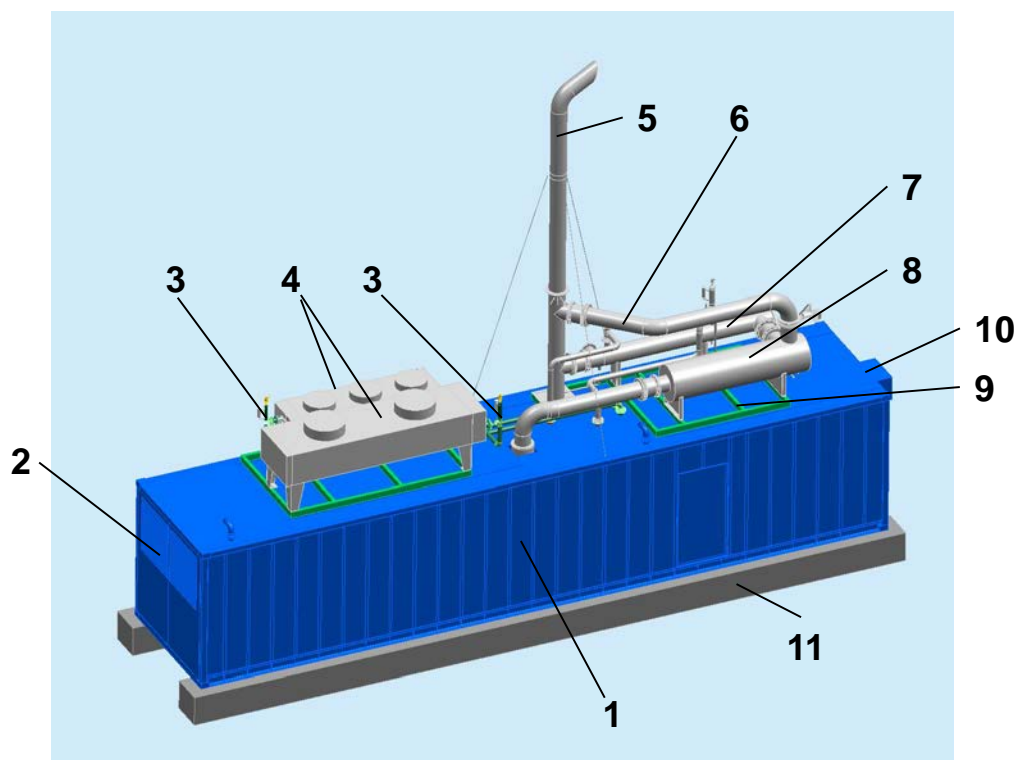
Fig. 18.6 Placing the genset on the foundation



## 18.7 Transporting and setting up containers

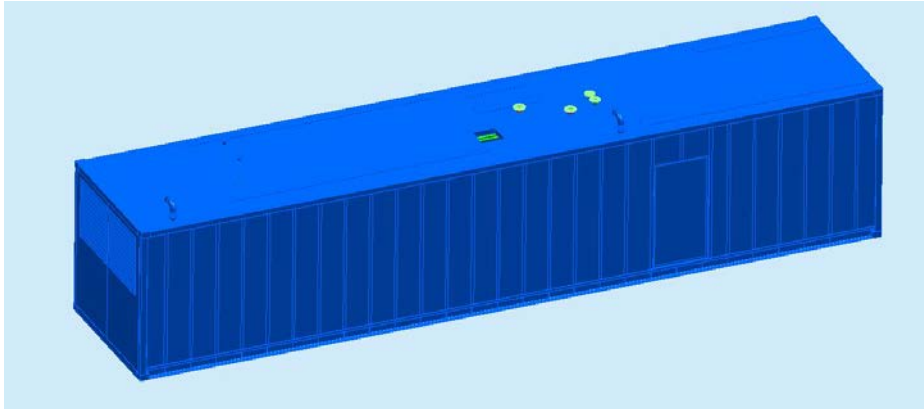
In the case of container systems, the genset is ready mounted and installed in the container. System components such as exhaust silencers, exhaust heat exchangers and horizontal-type radiators are arranged on a common frame or several separate frames made from square tubes on the container roof. These frames are located loose on the container roof. For transporting a container system, the components located on the roof are removed and transported next to the container as separate freight. Figure 18.7 shows the container system ready mounted, Figures 18.8-18.10 show the division of the components into individual batches for the transport. The system shown involves a CHP container in which the components are mounted on separate frames on the roof.

**Fig. 18.7 Container system, complete**

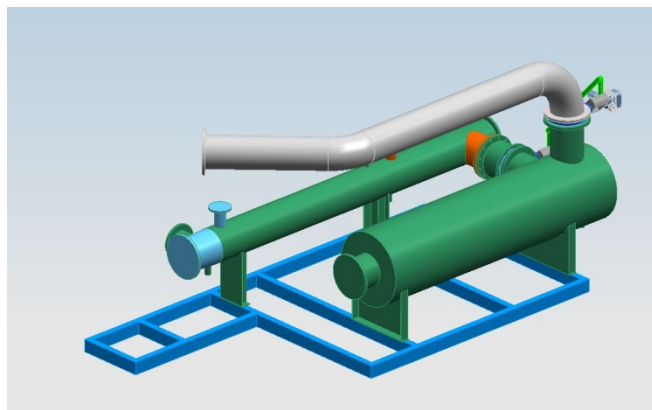
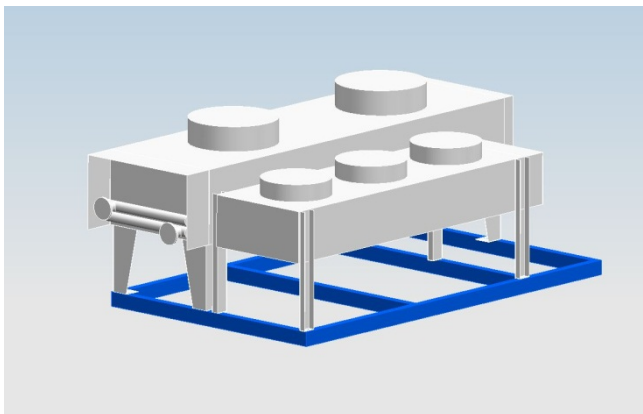


1	Container	7	Exhaust heat exchanger
2	Inlet air components	8	Exhaust silencers
3	Water pipe	9	Frame
4	Table cooler	10	Air-conditioning unit
5	Exhaust flue	11	Strip foundation (at customer)
6	Exhaust bypass		

**Fig. 18.8 Container without roof structures and air-conditioner**

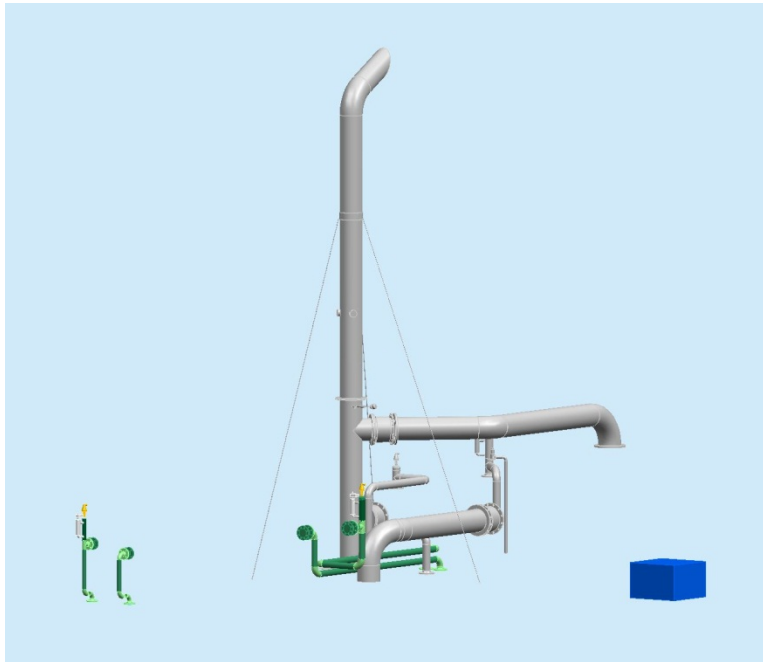


**Fig. 18.9 Components with frame**





**Fig. 18.10 These components are packed together loosely**



### 18.7.1 Lifting the container

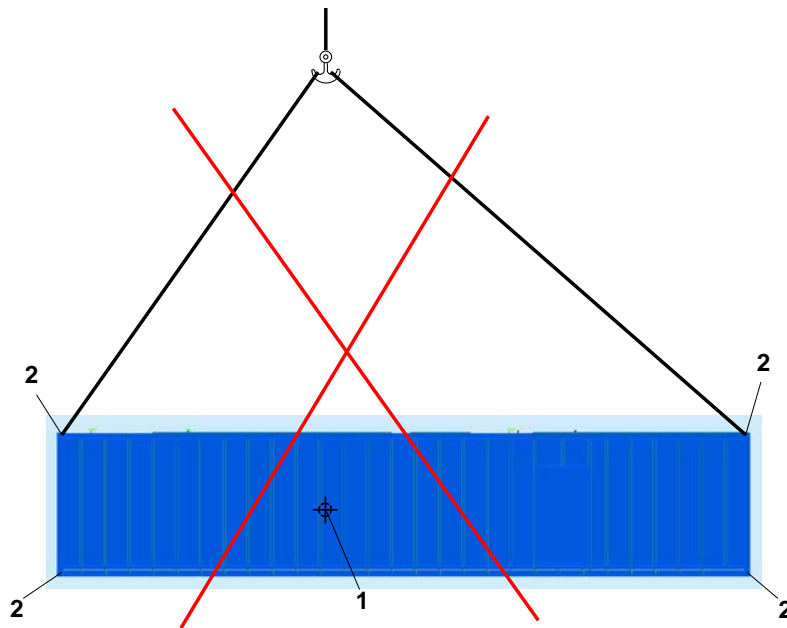
For loading the container for transport, in the case of potential reloading and unloading at the construction site, the container must be lifted and moved suspended on a crane. The components inside the container, in particular the elastically mounted genset, are secured for the transport. The genset is firmly interlocked using several threaded rods and underlays comprising hardwood blocks between the genset base frame and foundation rail. In addition to this, the genset is firmly strapped at the four corners of the base frame using tensioning straps with holding lugs attached to the container structure. Components for commissioning or other parts that are transported loosely along with the container are also secured for the transport.

Nevertheless, it must be ensured that the container is lifted as evenly and horizontally as possible during hoisting. The container corner plates welded in the roof and in the floor of the container are used as load support points. The rope lengths must be chosen so that the crane hook is located in the level of the container center of gravity. The position of the container center of gravity is marked outside on the side wall of the container. See also Figure 18.11. and 18.14.

When lifting the container by using the upper container corner plates it must be made sure that the acting forces are into direction vertical upwards. For this case a suitable traverse is necessary or the lifting must be undertaken by use of two cranes.

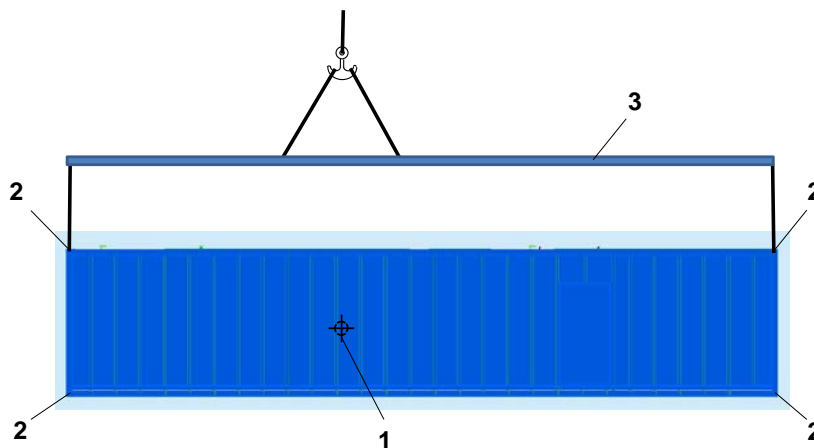
**Fig. 18.11 Lifting the container with ropes**

Lifting the container with the method as shown is not permitted.



**Fig. 18.12 Lifting the container with traverse**

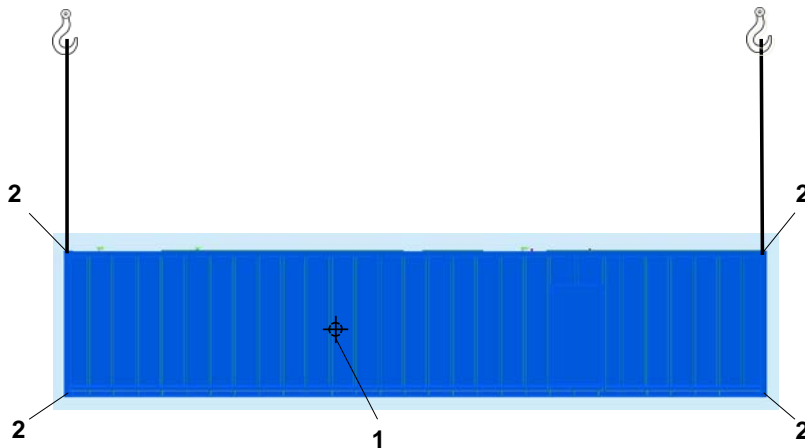
Lifting the container by use of a traverse at upper container corner plates



- 1 Center of gravity marking
- 2 Container corner plate
- 3 Traverse

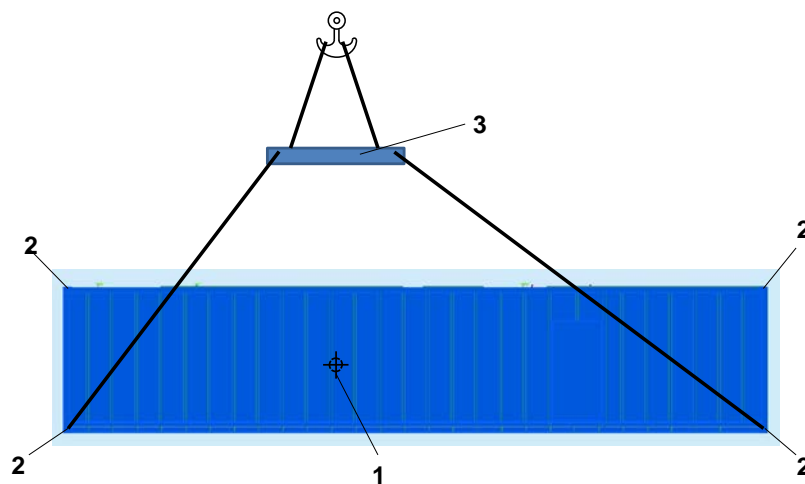
**Fig. 18.13 Lifting the container with two cranes**

Lifting the container at upper container corner plates and use of two cranes



**Fig. 18.14 Lifting the container with traverse**

Lifting the container at lower container corner plates and use of traverse



- 1 S Center of gravity marking
- 2 Container corner plate
- 3 Traverse

**Fig. 18.13 Lifting a container with cross members**

Picture will follow

### **18.7.2 Transporting containers**

In most cases, the container and accessories are transported directly to the destination by truck. If plants are to be shipped overseas, the containers are transported to a seaport and loaded onto the ship. The containers are usually transported from the destination port to the installation site by truck again.

**Fig. 18.14 Transporting a container with a low loader**



Depending on the specifications, it can also be the case that the containers are packed in a crate for sea transport.

Both the container and the components mounted on the frame must be secured for transport. The container corner plates must be used on the underside for fastening the container on the low loader. If using the upper container corner plates as fastening points, the container will generally be damaged. Dents and damage to the paintwork cannot be avoided.

**Fig. 18.15 This fastening leads to dents and paint damage on the container**



### 18.7.3 Setting up containers

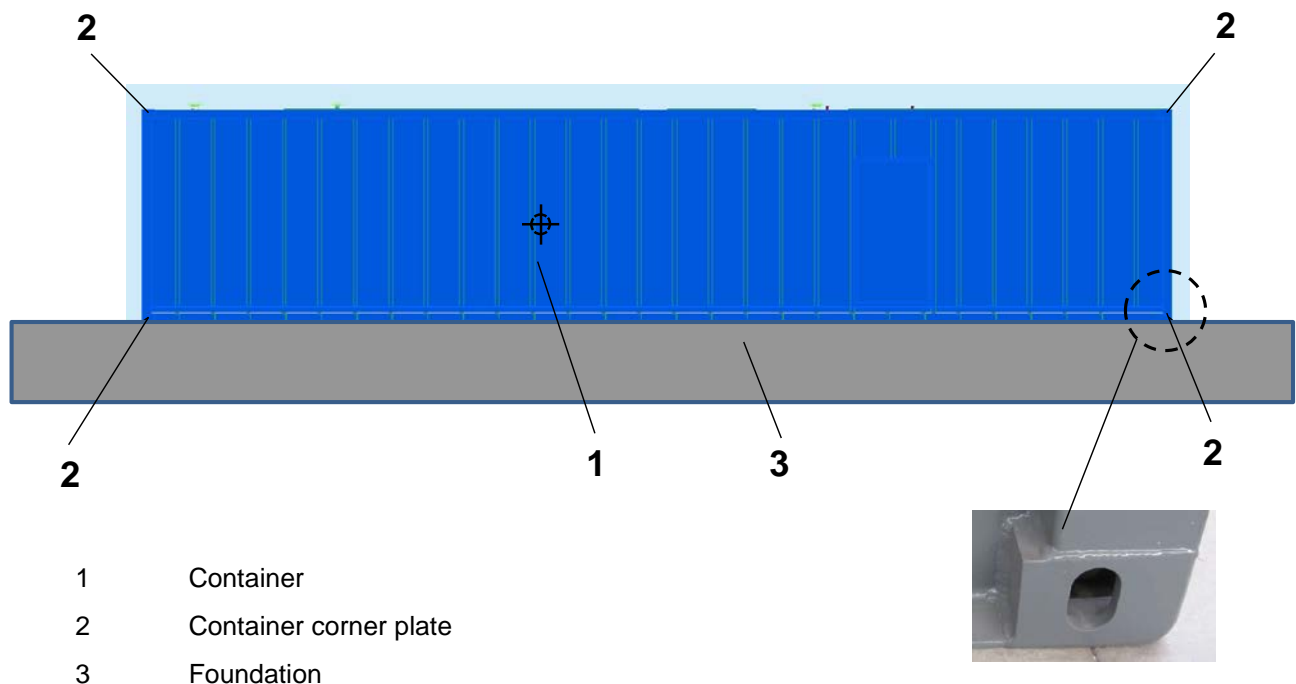
The container is set up either on a continuous foundation plate or several strip foundations. In the case of strip foundations, two strips are normally provided below the two longitudinal sides of the container. Depending on the arrangement of the cable outlets in the container, suitable ducts or recesses must be provided in the foundation or in the foundation strips. The implementation of the foundation, i.e. foundation height, choice of concrete grade and reinforcement, must be carried out at the customer by a structural engineer. The unevenness of the foundation should not exceed 5 mm in the longitudinal direction and 2 mm in the transverse direction.

The following points must be checked before placing the container down on the foundation:

- Check foundation for evenness and cleanliness
- Check location of the recesses for cable outlets
- Check container underside for cleanliness

After this, the container is first placed onto the foundation.

**Fig. 18.16 Setting up the container on the foundation**



After setting up the container, the components are mounted on the roof and connected. In addition, the external lines must be provided for the gas, oil, heating water circuit and the electrical connection. If any doors are stiff or jammed, the adjustment must be recalibrated at the hinges.

# **Power plants layout**

**Chapter 19**

## **Genset installation and alignment instructions**

**06-2014**

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## 19. Genset installation and alignment instructions

The object of these instructions is to ensure that the genset is correctly positioned and installed in the engine room and to avoid possible consequential damage arising from incorrect installation.

### 19.1 Transport and positioning of gensets

Chapter 18, "Transport and Placement" describes what action has to be taken for placing the genset at its final position.

### 19.2 Protecting the genset

After the genset has been mounted and aligned on its foundation and before piping and cabling works can begin, the genset must be protected against dust and dirt, for example with a tarpaulin.

To protect the electronics and the bearings in the engine and generator, welding should not be carried out on the genset!

It must also be ensured that components installed at the genset, such as transmitters, temperature sensors or attachments such as pumps, filters, etc. are not used as "conductors" during the installation.

**In order to maintain the value and reliability of the system, we draw your attention to the following points:**

- The genset room as well as the switchgear room should as far as possible be kept free from dust. Dust reduces the service life of the engine, shortens the lifetime of the generator and restricts the functioning of the control system.
- Condensation and dampness in engine rooms encourage corrosion of both the genset and the switchgear. High-quality CHP system installations require dry, preferably heated rooms (above 5°C).
- After the test run at the factory, the engine will receive interior corrosion protection as per our works standard. The standard treatment lasts 24 months.
- If the genset is to remain shut down for an extended period, the insulation resistance of the generator must be checked before commissioning. In the event of dampness, the generator must be dried (stationary heating or other suitable means).
- If the genset is set up in a container, the genset must be fully emptied (risk of freezing) and secured against movement for storage or transportation.

### 19.3 Elastic mounting

For the elastic mounting of the gensets, steel bellows are used as standard. These are equipped with a leveling device as standard. Beneath the footplate of the bearing element is a rubber plate which can be set directly onto the foundation. It must be ensured that the foundation surface is free of grease, lube oil, fuel or other contaminants. The foundation surface should be level  $\pm 2$  mm and have a roughness equivalent to standard concrete foundations. The foundation must not be tiled.

It is not necessary to screw down or dowel the spring elements with the foundation. However, the 4 bearing elements can be screwed (doweled) at the corner points of the genset to fasten the genset to the foundation, or, in the container installation, they can be fastened with steel stoppers.

The quantity and the arrangement of the bellows is shown in the order-specific genset drawing, as is the note on the installation and alignment specification of the steel spring used.

For those regions most at risk of earthquakes, there are special requirements for mounting the gensets. For those installations, the mounts must be doweled to the foundation. A recalculation of this connection must be carried out by a structural engineer.

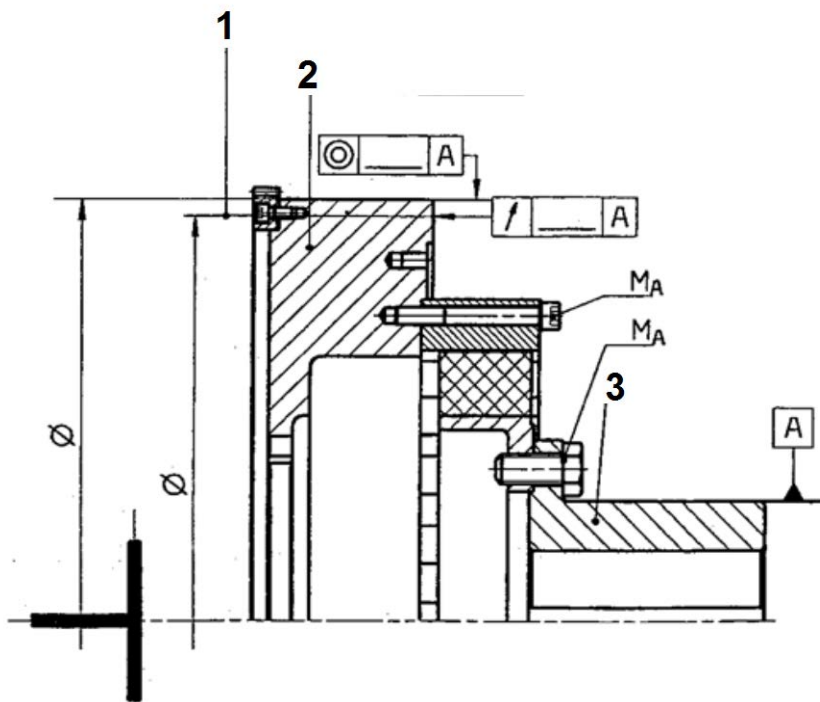
If a genset is installed in a container, a transportation lock must be provided between the genset's base frame and the foundation plates in the container base. This will prevent movement of the genset on the steel bellows. The transportation locks must be removed when commissioning the genset.

### 19.4 Torsionally flexible coupling

After aligning the genset on the foundation, the axial and radial runout of the coupling must be checked. This is performed using dial gauges. The positioning of the dial gauges is illustrated in principle in Fig. 19.1. For dimensions, alignment tolerances and screw torque settings, please refer to the order-specific genset drawing.

The alignment is corrected by moving the generator or by placing shims beneath the foot of the generator.

Fig. 19.1 Positioning the dial gauges



- 1 Reference dimension for checking axial runout
- 2 Flywheel
- 3 Coupling

## 19.5 Rubber expansion joints and hoses

Expansion joints and hoses are used in the system to elastically decouple media bearing pipes from the elastically mounted genset. Expansion joints and hoses are also used to insulate structure-borne noise which would otherwise be transmitted through the pipes into the building.

Furthermore, rubber expansion joints and hoses must be provided in the external piping system in order to compensate heat expansion. The quantity of expansion joints depends on the pipe routing itself and the heat expansion caused by the temperature of the media inside the pipe.

### Note:

Before installing expansion joints and hoses, the genset must be aligned on its foundation as per Chapter 19.2 (Elastic mounting elements). The external pipes are connected without filling the engine previously with water and lubricating oil. After filling the water and lubricating oil, the genset only moves down an additional 1 - 2 mm on the engine side. If necessary, the height-adjustable elastic mounts can be readjusted.

Listed in Tables 19.1 and 19.2 are the flange connection dimensions and the specific values for the expansion joints.

**Table 19.1 Expansion joints with flanges as per DIN 2501**

		1							2			3				4
5	6	PN	ØD	ØK	nxØd2	b	BL	Ødi	7	8	9	10	11	12	13	14
DN										ØC	W					
[mm]		[bar]	[mm]						cm <sup>2</sup>	[mm]				[°]	[kg]	
32	42,4x2,6	16	150	100	4xØ18	16	125	35	28	75	74	30	10	10	25	4,4
40	48,3x2,6	16	150	110	4xØ18	16	125	35	28	75	74	30	10	10	25	4,4
50	60,3x2,9	16	165	125	4xØ18	16	125	43	40	85	86	30	10	10	25	4,5
65	76,1x2,9	16	185	145	4xØ18	16	125	64	68	104	110	30	10	10	25	4,9
80	88,9x3,2	16	200	160	8xØ18	18	150	73	108	117	137	40	10	10	20	5,9
100	114,3x3,6	16	220	180	8xØ18	18	150	88	124	136	146	40	10	10	15	7,2
125	139,7x4	16	250	210	8xØ18	18	150	115	187	164	175	40	10	10	15	9,1
150	168,3x4,5	16	285	240	8xØ22	18	150	145	245	190	198	40	10	10	12	10,9
175	193,7x5,4	16	315	270	8xØ22	18	150	167	320	215	225	40	10	10	10	15,7
200	219,1x5,9	16	340	295	8xØ22	20	175	194	425	265	260	45	15	15	8	19,8

Legend for column headers

Position	Figure	Designation
1		Flange dimensions as per DIN 2501 *1)
2		Bellow
3		Movement absorption
4		Expansion joint
5	DN	Nominal diameter
6		Pipe as per DIN 2448
7		Active bellows cross section
8	ØC	Sealing surface
9	W	Bellow diameter (without pressure)
10		Compression
11		Extension
12		lateral ±
13		angular
14		Weight

\*1) Counter flanges as per DIN 2633-PN 16 with screws and self-locking nuts as per DIN 985, but without any seals, to be ordered separately

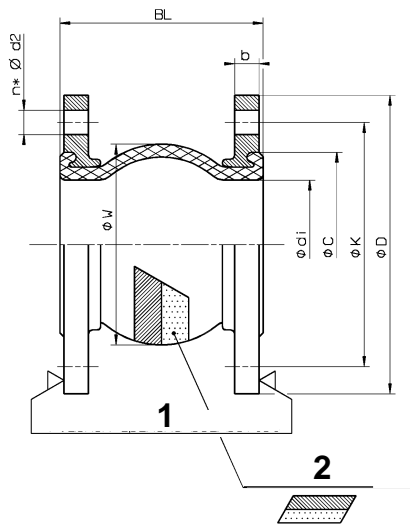
For DN 200, counter flanges as per DIN 2632-PN 10

See counter flanges for Stenflex expansion joint type AS-a, complete 1214 0948 UE 0112-38

Stenflex expansion joint AS-a complete 0311 2808 UC 0999-38

Installation Notes No: 6.000.9.000.242 sheet 1-4

Pressure stages					Vacuum at installation length $\leq$ BL
Temperature load up to	°C	+ 50	+ 100	+ 110	
Max. perm. operating pressure *)	bar	16	10	6	Special measures are necessary in this connection and must be asked for !
Test pressure (+20 °C)	bar	25	25	25	
Burst pressure	bar	60	60	60	
*) in case of loads produced by jerks, the max. operating pressure should be reduced by 30% !					



- 1 Surfaces machined by cutting
- 2 Rating plate red/blue

**In the case of interfered motions, these values have to be enquired from the manufacturer.**

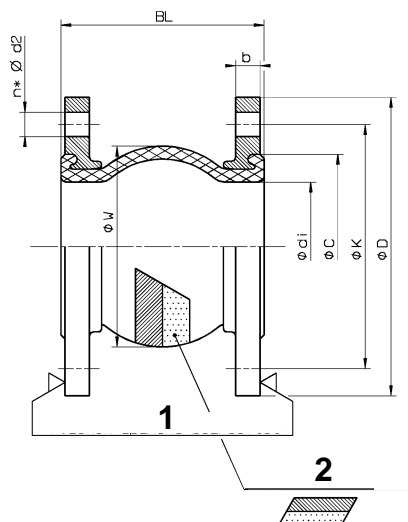
**Table 19.2 Expansion joints with flanges to VG 85356**

		1							2			3				4
5	6								7	8	9	10	11	12	13	14
DN		PN	ØD	ØK	nxØd2	b	BL	Ødi		ØC	W					
[mm]	[bar]	[mm]							cm <sup>2</sup>	[mm]				[°]	[kg]	
40	42	25	108	84	6xØ11	16	125	34	28	73	74	30	10	10	25	4,4
50	50	25	120	96	6xØ11	16	125	43	40	85	88	30	10	10	25	4,5
65	60	25	140	116	8xØ11	16	125	63	68	104	112	30	10	10	25	4,9
80	80	25	150	126	8xØ11	18	150	75	108	117	139	40	10	10	20	5,9
100	100	25	172	148	10xØ11	18	150	95	124	136	148	40	10	10	15	7,2
125	120	10	200	176	10xØ11	18	150	120	187	165	178	40	10	10	15	9,1
150	159	10	226	202	12xØ11	18	150	145	245	190	202	40	10	10	12	10,9

Legend for column headers

Position	Figure	Designation
1		Flange dimensions as per VG 85356 Part 1
2		Bellow
3		Movement absorption
4		Expansion joint
5	DN	Nominal diameter
6		Pipe diameter outside
7		Active bellows cross section
8	ØC	Sealing surface
9	W	Bellow diameter (without pressure)
10		Compression
11		Extension
12		lateral ±
13		angular
14		Weight

Pressure stages					Vacuum at installation length $\leq$ BL
Temperature load up to	°C	+ 50	+ 100	+ 110	
Max. perm. operating pressure *)	bar	16	10	6	Special measures are necessary in this connection and must be asked for !
Test pressure (+20 °C)	bar	25	25	25	
Burst pressure	bar	60	60	60	
*) in case of loads produced by jerks, the max. operating pressure should be reduced by 30% !					



- 1 Surfaces machined by cutting
- 2 Rating plate red/blue

**In the case of interfered motions, these values have to be enquired from the manufacturer.**



To ensure correct installation, the following instructions must be observed:

### 19.5.1 Rubber expansion joints

#### Installation notes for Stenflex rubber expansion joints type AS-1

##### 19.5.1.1 Storage

Expansion joints must be stored in a clean and dry condition, protected from all damage, and must not be rolled using the bellows. In the case of storage and installation in the open air, they must be protected from intense sunlight, such as through the use of a covering sheet.

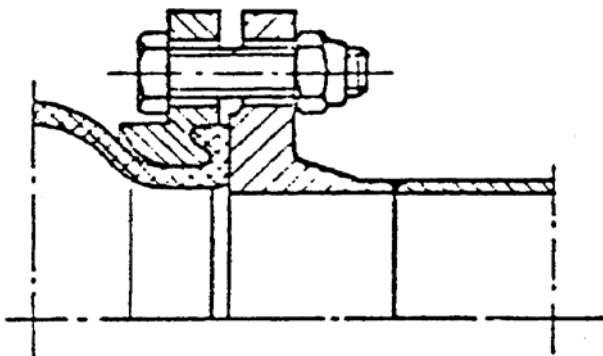
##### 19.5.1.2 Arrangement and installation

The expansion joint should be arranged in an accessible location where it can be monitored.

Before starting the installation, the gap into which the joint is to be fitted must be checked and the expansion joint compressed to the correct installation length BL.

Before the expansion joint is installed, it must be checked in its consistency and with regard to state of the rubber bellows, if for example a strong embrittlement, caused by the high temperature, has occurred.

Fig. 19.2



**Flange with smooth sealing surface through to internal diameter**

The higher the operating temperature on the expansion joint, the faster the elastic elements will age and embrittle (in other words, harden) and the rubber bellows have a tendency to form cracks.

If a strong crack formation has occurred on the surface, the expansion joint should be replaced for safety reasons.

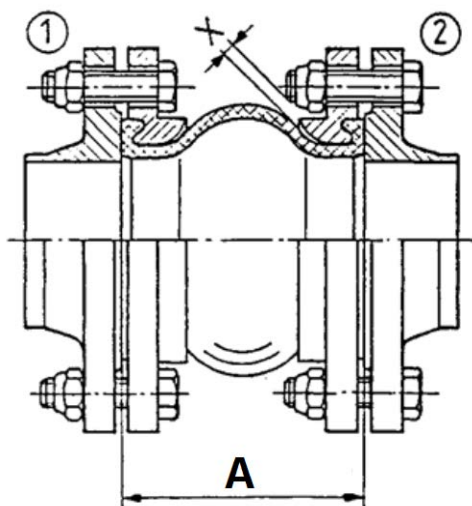
Noting the maximum permissible amount of movement which may be accommodated (and which must not be exceeded in operating mode), the expansion joint must be installed without torsion. The joint should preferably be subjected to compression.

Attention should also be paid to the effect of external heat radiation. The bores in the flanges must remain in alignment.

When using DIN welding neck flanges and VG flared flanges, no additional seals are required as the rubber lip is sufficient. Other flange designs are not permissible owing to the risk of damage to the rubber lip.

### 19.5.1.3 Installation

**Fig. 19.3**



A = overall length =  
installation length

The expansion joints are installed using normal hexagon screws and self-locking hexagon nuts as per DIN 985.

Only DIN welding neck flanges or VG flared flanges are to be used as counter flanges.

The nuts should be located on the counter flange side, installation type (1). If this is not possible, the length of the screws should be selected so that the measurement X is not less than 15 mm, installation type (2). (See Fig. 19.3)

Installation type (1) should be preferred.

The screws should be tightened evenly several times on a diagonally alternate basis; if necessary, they should be retightened slightly after initial commissioning. Excessive tightening can crush the rubber lip.

To avoid tool damage to the rubber bellows, the wrench on the bellows side should be held steady whilst the wrench on the counter flange side is turned.

In order not to destroy the rubber seal by overtightening the flanges, Table 19.3 with the tightening torques has to be observed.

**Fig. 19.3 Tightening torques for rubber expansion joints**

Nominal width DN	Tightening torque [Nm]
40	10
50	10
65	10
80	10
100	10
125	15
150	15

The tightening torques listed apply to new expansion joints. The values can be exceeded by 50 % if necessary.

After 24 hours operation, the deformation has to be compensated by retightening the screws.

The installation notes of the expansion joint supplier must be observed.

#### **19.5.1.4 Arrangement of pipe brackets**

When arranging expansion joints, pipe brackets/guides must be always provided before and after the joint. For expansion joints that are only installed for the decoupling of vibrations (e.g. the joints of an elastically mounted genset) fixing points must be provided at each side of the expansion joint.

Expansion joints installed for the compensation of heat expansions in the pipe generally have a pipe bracket as a fixing point on one side and a pipe guide as a free-running point on the other side. Depending on the individual installation situation, it might be feasible to provide free-running points on both sides. The distance between the fixed or free-running point and the expansion joint should not exceed 3 x DN.

See also Chapter 20.4 Pipe brackets / supports

#### **19.5.1.5 Protective measures after installation**

After installation, expansion joints should be covered as protection against welding heat (e.g. weld spatter, beads) and external damage. The expansion bellows must be kept clean and must not be painted.

#### **19.5.1.6 Underpressure loading**

If an expansion joint is to be subjected to underpressure (vacuum), it must under no circumstances be stretched when it is installed. It is better to compress the joint slightly, making it more vacuum-resistant. However, special measures will be called for here which should be asked for separately. The installation notes of the expansion joint supplier must be observed here.

### **19.5.2 Hoses**

#### **Installation notes for rubber hoses DN 8 to DN 40 (flame-proof)**

##### **19.5.2.1 Storage**

Hoses must be stored in a clean and dry condition and above all protected against external damage. They should not be dragged on the ground or over sharp edges.

Lay the hose out straight by unrolling the coil of the hose. Pulling on one end of the hose ring will bend the hose beyond its minimum bending radius and subject it to an impermissible torsional stress.

Fig. 19.4



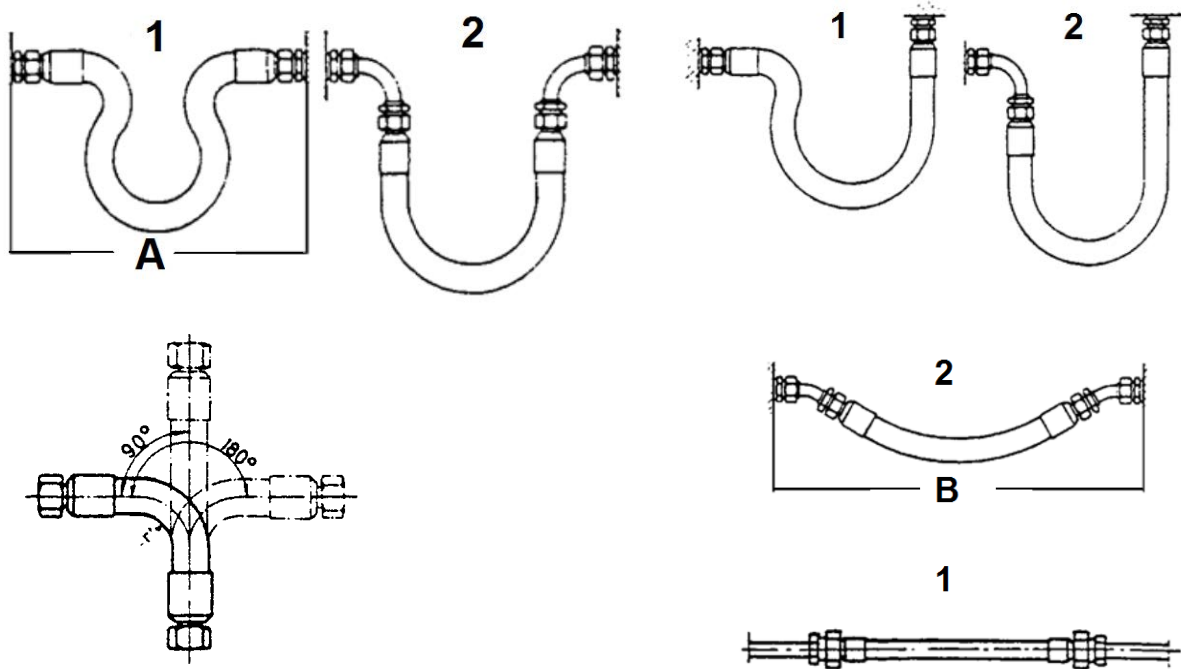
### 19.5.2.2 Arrangement and installation

Hoses should be arranged in an accessible location where they can be monitored.

Hoses should not come into contact with one another or with other objects during operation.

Hoses must not be bent beyond their permissible bending radius (Table 19.4). It is not permissible to overbend or stretch the hoses.

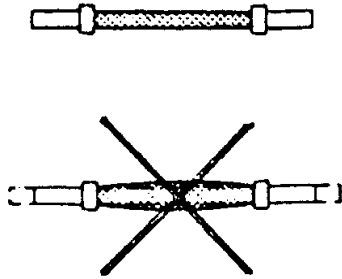
Fig. 19.5



1 incorrect  
2 correct

A Installation length too short  
B Installation length satisfactory

Install hose without tension. Axial compression is not permissible. The braiding detaches itself from the hose and pressure resistance is no longer guaranteed.



Hoses must not be bent at sharp angles or buckled, i.e. the hose must not be kinked. No movements or bending stresses must act directly on connections (screw connections). The so-called neutral part of the hose ends must be of adequate size.

If necessary, standard commercially available elbows, manifolds or ring-type screw connections must be provided at the connection ends. When selecting the connecting parts, the stress from pressure temperature and type of medium must be observed. In the event of movement, the hose must be mounted so that its axis lies in the same plane as the direction of movement in order to prevent torsion.

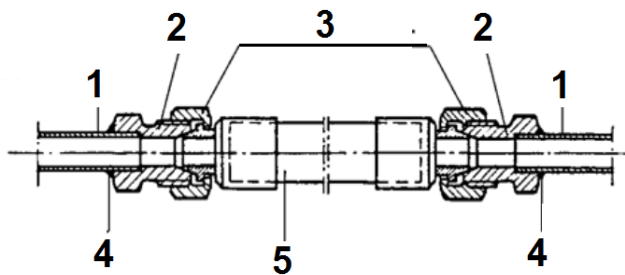
The So Ms 59 F 50Z (= special brass) soldered connectors on the hose screw connections can be removed from the connections and hard-soldered to the respective pipe ends.

After determining the gap in which to install the joint between the pipes to be connected, first solder the connector in place on one side, then check the possible bending radius for the hose before soldering the connector on the other side.

The permissible bending radii listed in the following Table 19.5 must be observed.

The ends of the connection pipes must be cut off precisely at right-angles to the axis of the pipe.

Fig. 19.6



- |   |                    |
|---|--------------------|
| 1 | Connection pipe    |
| 2 | Soldered connector |
| 3 | Union nut          |
| 4 | hard-soldered      |
| 5 | Hose line          |

The minimum bending radii specified in Table 19.4 relate to rigidly laid hoses.

If the movement in the hose (where the bending radius is tight) is very often repeated (= continuous operation), it is recommended that an attempt be made to increase the radius (if necessary, by using turning knuckles). This will prevent the hose from kinking and extend its service life.

**Table 19.4**

1	DN [mm]	L [mm]	rmin. *1 [mm]	L2 [mm]	2 ØD [mm]	t [mm]	3 [bar]		4 [bar]	5 [°C]	6
							7	8			
10	8	300	75	12,5	10x1,0	5	25	10	38	70	GCNA 2277
	10	300	80	16,5	14x1,5	6	25	10	38		
11	20	500	130	21,5	25x1,5	8	25	10	50	80 (14) 90 (15) 125 (16)	OLNWV 2298
	32	700	180	21,5	35x2,0	8	25	10	50		
12	32	700	240	23,5	40x2,0	10	22	10	45		80
	20	500	130	21,5	25x1,5	8	25	10	50		
	32	700	180	21,5	35x2,0	8	25	10	50		
13	8	300	115	12,5	10x1,0	5	215	170	510	90 (14) 100 (17) 100/125 (16)	1STT 2432
	10	300	130	16,5	14x2,0	6	180	150	435		
	20	500	240	21,5	25x2,0	8	105	80	255		
	32	700	350	21,5	35x2,0	8	63	60	150		
	40	700	450	23,5	45x2,5	10	50	40	120		

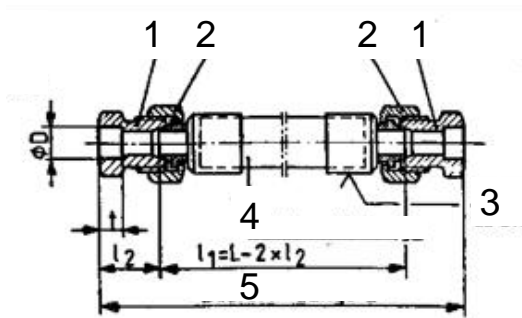
\*1) rmin = smallest bending radius



Legend for column and row headers

Position	Figure	Designation
1		Medium
2	ØD	Diameter for pipe
3		Nominal pressure
4		Test pressure
5		Temperature max.
6		Hose designation
7		Normal
8		Upon acceptance
9		Short term
10		Diesel-Fuel
11		Diesel-Fuel, water and lubricating oil
12		Sea water
13		Lube oil, compressed air and water
14		Diesel-Fuel
15		Water
16		Lube oil
17		Compressed air

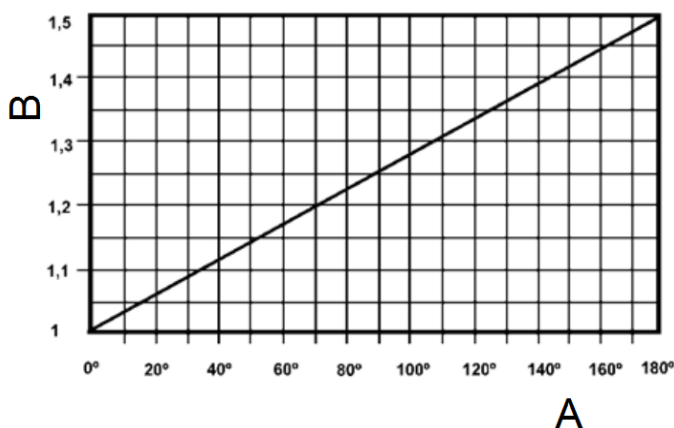
Fig. 19.6



- 1 Soldered connector
- 2 Union nut
- 3 up to DN 60 press version  
from DN 70 screw version
- 4 Hose line
- 5 Ordering length L

The following graph (Fig. 19.7) shows - dependent on the bending angle of the hose - the bending factor by which the minimum bending radius must be multiplied to determine the permissible bending radius for continuous operation.

Fig. 19.7

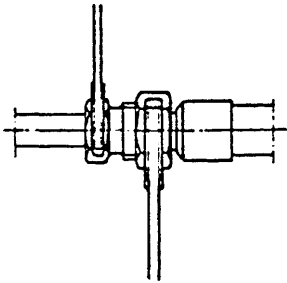


- A Bending angle
- B Bending factor

### 19.5.2.3 Installation

When installing the hose, tighten the connection on one side only. To begin with, leave the connection at the other side loosely fixed. Move the empty hose 2 or 3 times in the desired direction, to allow it to align itself without twisting, then tighten the loose end as well. In the case of hoses with screw connections, it is essential to use a second wrench to hold the connection (Fig. 19.8).

**Fig. 19.8**



Connect hose without twisting.  
Use a second wrench to hold rotating threaded connections.

### 19.5.2.4 Pipe brackets

When arranging hose lines, fixed and free-running points (pipe guides) must always be provided before and after the hose. The distance between the fixed or free-running point and the hose should not exceed  $3 \times \text{DN}$ .

### 19.5.2.5 Protective measures after installation

After installation, hose lines should be covered as protection against welding heat (e.g. welding spatter, beads) and external damage. The hose line must be kept clean and must not be painted.

### 19.5.2.6 Type approval test

The hoses are flame resistant (flame-proof) and fulfil the requirements of all classification organizations.

### 19.5.3 Exhaust expansion joints

#### Installation instructions for axial expansion joints and axial double expansion joints for the exhaust systems of stationary systems

##### 19.5.3.1 Storage

Axial expansion joints must be stored in a clean and dry condition, protected from all damage, and must not be rolled using the bellows. Always lift expansion joints for transportation.

##### 19.5.3.2 Arrangement and installation

The expansion joint should be arranged in an accessible location where it can be monitored.

Before starting the installation, the gap into which the joint is to be installed must be checked to ensure the correct installation length.

Noting the maximum permissible amount of movement which may be accommodated (and which must not be exceeded in operating condition), the expansion joint must be installed so that it is not subjected to torsion stresses either during installation or during operation due to adverse pipe tension. The joint should preferably be subjected to compression. The ideal installation is when the expansion joints are installed free of tension as far as possible whilst the system is in operation.

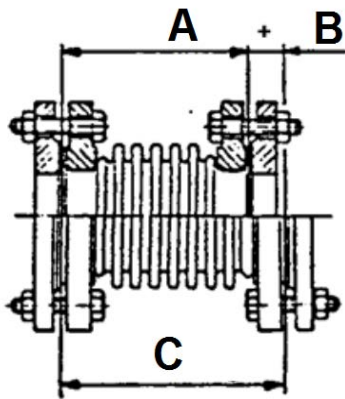
The holes in the flanges must line up, and the seal must be located centrally. It must be assured that the pipes to be connected are also in precise alignment.

When specifying the length of the expansion joints, please note these different terms.

The **overall length** is the length of the expansion joints as generally supplied by the manufacturer (= delivered length). The overall length is indicated on the rating plate of the expansion joint.

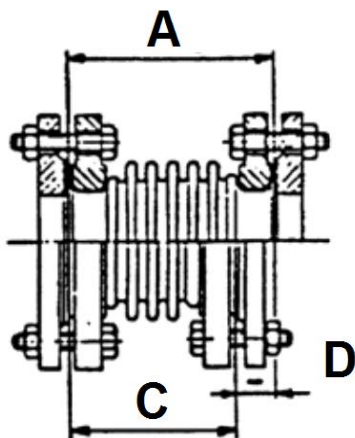
The **installation length** comprises the overall length with pre-tension (stretch + or compression -) according to Fig. 19.9 and Fig. 19.10.

Fig. 19.9



- A Overall length
- B Extension
- C Installation length

Fig. 19.10



- A Overall length
- C Installation length
- D Compression

In cold condition, the expansion joint should be installed half pre-tensioned (either half stretched + or half compressed -), dependent on how the expansion joint is to be used. This is recommended even if the axial movement of the expansion joint is not to be fully utilized. For example, if total expansion is only 30 mm whilst the expansion joint allows for 66 mm of expansion, it is better - likewise in terms of service life - to preload the expansion joint to  $\pm 15$  mm rather than - 30 mm.

### 19.5.3.2.1 Installation on the engine (turbocharger)

An alignment is necessary when connecting the exhaust pipe on the system side to the exhaust expansion joint on the engine side. A poor alignment of the engine-side exhaust expansion joint leads to impermissible forces acting on the housing of the exhaust turbocharger.

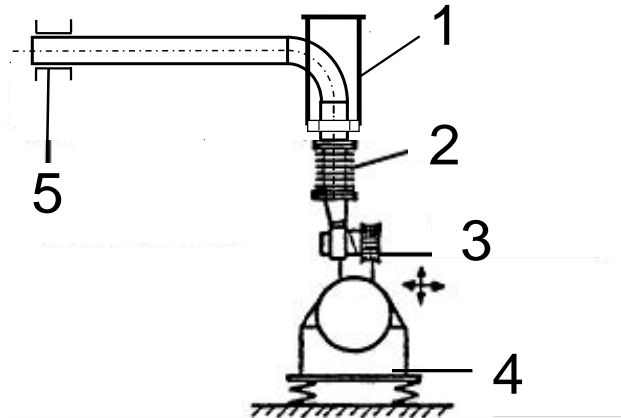
To avoid the above problems, we provide installation specifications in the form of a drawing for the TCG 2032, TCG 2020 V12 and V16 with the turbocharger type TPS 52 and for the TCG 2020 V20 with the turbocharger type TPS 48.

The drawings for the installation specifications are:

- TCG 2020 V20 /TPS 48: 1242 0623 UB
- TCG 2020 V12/V16 / TPS 52: 1242 0619 UB
- TCG 2032 V16: 1228 2504 UB

It must always be ensured that there is no stress imposed on the engine, and in particular on the turbocharger, due to heat expansion in the connecting pipework. In operation, the expansion joint should accommodate only the vibrations in the genset on its elastic mountings (Fig. 19.11). The expansion joint must be mounted at the turbocharger in such a way that the expansion joint returns to its overall length (delivered length) when the exhaust pipe warms up. The following fixed point must be arranged directly after the expansion joint.

**Fig. 19.11 Arrangement of the fixed point after the engine in the exhaust line**



- 1 Fixed point
- 2 Axial expansion joint
- 3 Turbocharger
- 4 Elastically mounted genset
- 5 Free-running point (pipe guide)

#### **19.5.3.2.2 Installation in the pipe section**

To determine heat expansion in a pipe, the following rule of thumb applies:

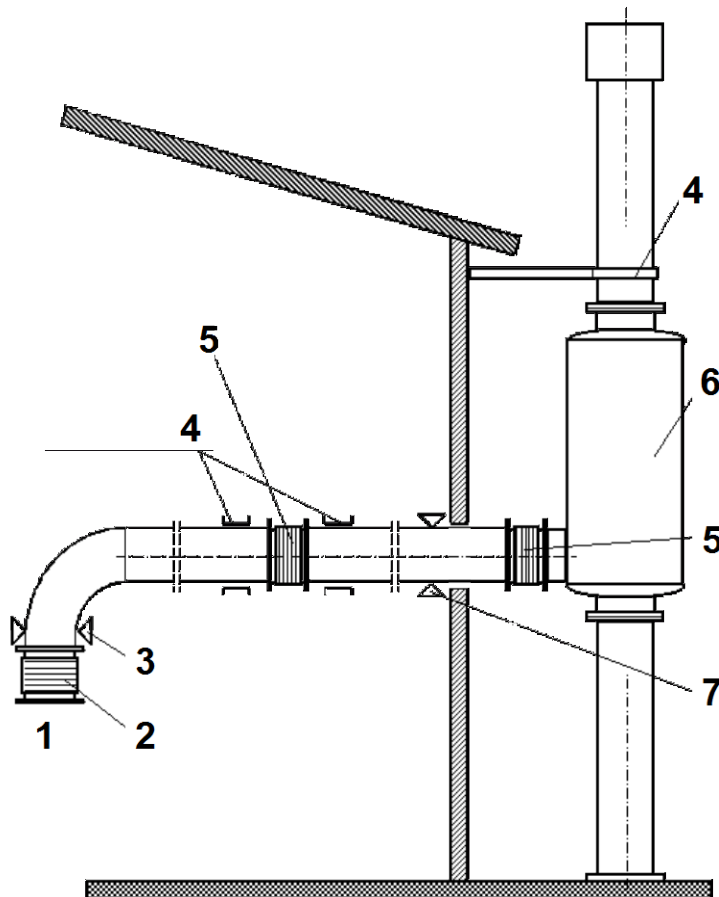
for mild steel approx. 1 mm heat expansion per meter of pipe and per 100 °C.

for stainless steel approx. 2 mm heat expansion per meter of pipe and per 100 °C.

That means that, for example for a 1 meter section of pipe at 500° C, the heat expansion is approx. 5 mm for mild steel and 10 mm for stainless steel.

Normally, axial expansion joints are fitted in an exhaust pipe to accommodate the heat expansion. The arrangement of the expansion joints will be shown on the installation plan for the respective order, whereby the installation guidelines laid down by the manufacturer must be observed. It will generally be adequate to continue the exhaust pipe as illustrated in Fig. 19.12.

Fig. 19.12 Fixed supports, loose supports and expansion joints in an exhaust line



- 1 Engine
- 2 Expansion joint after engine
- 3 Fixed point after engine
- 4 Free-running point / pipe guide
- 5 Expansion joint
- 6 Silencer
- 7 Fixed point



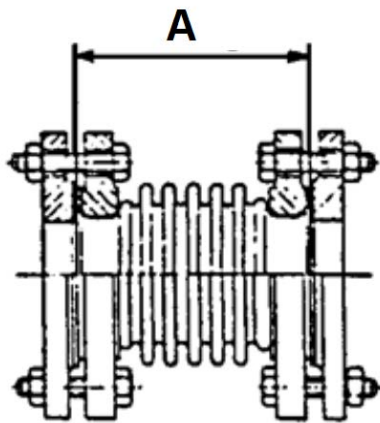
### 19.5.3.3 Installation

Check that the bellows corrugations are free from foreign bodies (dust, cement, insulation material), first inside before installation and then outside after installation.

The expansion joints are fitted using normal hexagon screws and nuts.

Smooth flanges or flared flanges are used as counter flanges. The nuts must be fitted on the counter flange side, see Fig. 19.13.

**Fig. 19.13**



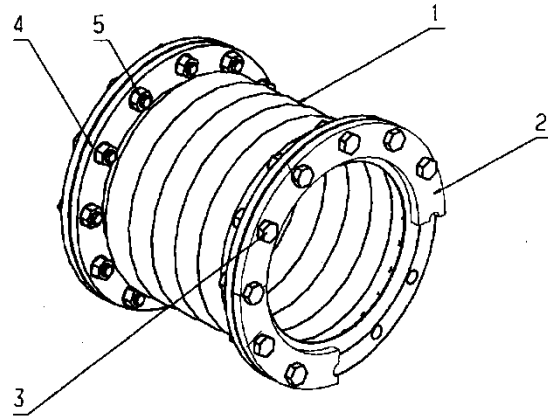
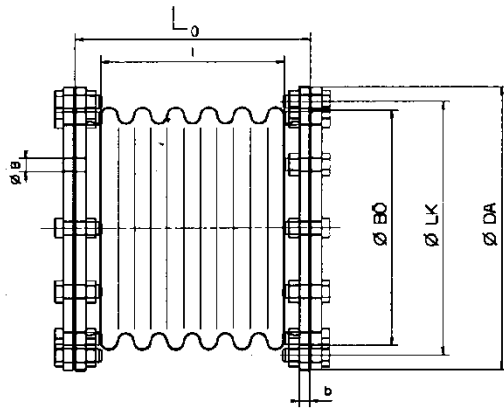
A Overall length

The screws should be tightened evenly several times on a diagonally alternate basis; if necessary, they should be retightened slightly after initial commissioning.

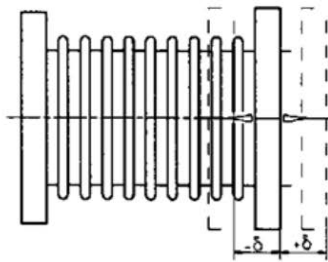
To avoid tool damage to the expansion joint, the wrench on the bellows side should be held steady whilst the wrench on the counter flange side is turned.

For dimensions and connection sizes, please refer to Fig. 19.14 and Table 19.5.

Fig. 19.14

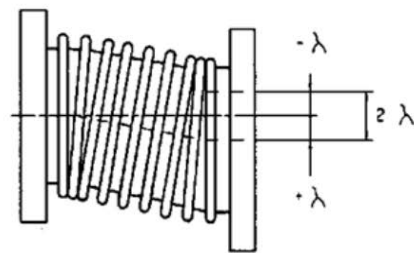


**A**



A Axial movement of bellows

**B**



B Lateral movement of bellows

Table 19.5

1						2							*1) 9
3	4			5	6	7					8		
	10	11	12			13	14	15	16	17	18	19	
DN	26N	2AN	â	L0	l	DA	LK	B	BÖ	b	N	-	G
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	Stück	M	kg
100	50	6	1,0	118	60								5,4
100	80	12	2,5	184	2x47	210	170	18	147	14	4	M16	5,9
125	50	7,7	0,2	140	75	240	200	18	178	10	8	M16	5
125	200	114	2,0	340	272								6
150	50	6,9	0,2	145	78	265	225	18	202	10	8	M16	6
150	200	101,1	2,0	350	286								7
200	50	5,1	0,2	150	73	320	280	18	258	16	8	M16	11
200	200	81,2	2,0	370	291								14
250	50	3,6	0,1	150	65	375	335	18	312	16	12	M16	14
250	200	64,5	1,9	370	286								17
300	50	3,3	0,1	150	69	440	395	22	365	16	12	M20x2	18
300	200	54,4	1,6	365	285								21
350	50	3,3	0,1	155	74	490	445	22	415	16	12	M20x2	24
350	200	48,1	1,4	355	272								28
400	60	4,4	0,1	180	84	540	495	22	465	16	16	M20x2	29
400	180	39,2	1,2	365	279								35
450	60	4,1	0,1	185	98	595	550	22	520	16	16	M20x2	33
450	180	34,1	1,0	355	272								40
500	60	3,8	0,1	190	100	645	600	22	570	16	20	M20x2	36
500	180	30,4	0,9	360	270								44
600	60	2,8	0,1	190	89	755	705	26	670	20	20	M24x2	53
600	180	25,2	0,8	370	267								63
700	60	2,6	0,1	200	95	860	810	26	775	20	24	M24x2	63
700	180	21,3	0,6	365	262								74
800	60	1,9	0,1	185	79	975	920	30	880	20	24	M27x2	77
800	180	18,3	0,5	365	257								90

\*1) Without counter flange, screws and nuts

The specified values apply at room temperature; in operating mode, lower values are to be expected.

At temperatures of up to 300 °C, deviations may be disregarded for practical purposes.

For correction values  $K\Delta\vartheta$  for higher temperatures, please refer to Table 19.6.

The total of all relative stresses must not exceed 100% of the temperature factor  $K\Delta\vartheta$ .

#### Legend for column headers

Position	Figure	Designation
1		Technical data – axial expansion joint
2		Flanges as per DIN 2501 PN 6
3	DN	Nominal diameter
4		Nominal accomodated movement over 1000 load cycles
5	L0	Overall length - unstressed
6	l	Corrugated length
7		Diameter
8		Screws
9	G	Weight
10	2δN	Axial
11	2λN	Lateral
12	â	Axial / radial
13	DA	Outside diameter
14	LK	Hole circle
15	B	Drilled holes
16	BÖ	Flared tube end
17	b	Blade thickness
18	N	Quantity
19		Thread

Likewise, where heat expansion and vibration coincide, the travel and amplitude elements must each be considered separately as per the formula below:

$$\left( \frac{2\delta_{axial,Design}}{2\delta_{axial,Nominal}} \right) + \left( \frac{2\lambda_{lateral,Design}}{2\lambda_{lateral,Nominal}} \right) + \left( \frac{\hat{a}_{Design}}{\hat{a}_{Nominal}} \right) \leq K_{\Delta\vartheta} \times 100\%$$

Nominal (*Nenn*): Nominal value from Table 19.5

Design (*Auslegung*): Maximum movement in operation

An expansion joint comprising multi-wall bellows 1.4541 (X6 CrNiTi 18 9) and flared flange RST 37-2 may be used at operating temperatures of up to 550 °C.

The expansion joint only fully undertakes **one** of the indicated movements. The operating pressure may be up to 1 bar (PN1).

The installation length (overall length + pre-tension) is dependent on the total system-side expansion.

The overall length  $L_0$  refers to the neutral position.

**Tab. 19.6 Temperature influence on the available movement<sup>1</sup>**

$\vartheta$	°C	100	200	300	400	500	600
$K_{\Delta\vartheta}$	--	1	0.9	0.85	0.8	0.75	0.7
Material	1.4541						

#### 19.5.3.4 Arrangement of pipe brackets in the exhaust line

When arranging expansion joints, pipe brackets must always be provided before and after the joint, otherwise the pipe may bend out sideways. Depending on the installation situation, the pipe brackets can be arranged as fixed and/or free-running points. The distance between the fixed or free-running point and the expansion joint should not exceed 3 x DN of the pipe.

When doing this, it must be ensured that the fixed points are actually fixed. The elasticity of a fixed point should not be so great as to allow the exhaust pipe to move a few millimeters before it is actually held tight.

Free-running points (pipe guides) are pipe clamps which surround the pipe but allow it to slide without tension. To avoid high levels of friction resistance, possible contamination or obstructions must be prevented between the pipe guide and the pipe.

Depending on the weight and size of the pipe, it may be necessary to fit extra pipe brackets.

<sup>1</sup> Witzenmann, "Kompensatoren" p. 99, 1990

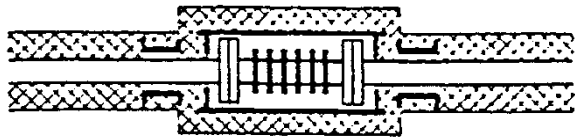
### 19.5.3.5 Protective measures after installation

After installation, expansion joints should be covered as protection against welding heat (e.g. weld spatter, beads) and external damage. The expansion bellows must be kept clean and must not be painted.

### 19.5.3.6 Insulation

Because of the considerable heat radiation, it may under circumstances be advisable to insulate an expansion joint particularly inside the engine house. For this purpose, a sliding tube or sheet-metal sleeve should be laid around and at some short distance from the expansion joint, to prevent the insulation material from resting directly on the expansion joint, see Fig. 19.16. Otherwise there is a risk that the insulation material will jam between the sides of the bellows corrugations. For the insulation, it is recommended to use asbestos-free plaited insulation strands or matting; glass wool or diatomite should not be used because of their tendency to produce dust.

**Fig. 19.16**



## 19.6 Notes on commissioning

Before commissioning and handover to the client, the genset should be thoroughly cleaned.

The following points should be noted :

Check the adjustment of the elastic mounting elements

Check the alignment of the coupling

Check that the expansion joints have been installed as specified

No tension on cooling water expansion joints

Hoses exhibit prescribed bending radius

Specified pre-tension on exhaust expansion joint

Cables fitted with strain relief and laid with specified bending radius

Air filters free from dirt and contamination

# **Power plants layout**

**Chapter 20**

## **Laying pipes**

**06-2014**

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## 20. Laying pipes

### 20.1 General installation notes

- After bending and welding and before laying, all pipes must be cleaned inside, i.e. they must first be thoroughly steeped in an acid solution, then cleaned with an alkaline solution (soda or similar) and flushed pH neutrally with hot water. Finally, the inside of the pipes must then be treated with corrosion protection.
- When commissioning the system, all pipes must be thoroughly cleaned inside to remove dirt, scale and swarf, so as to ensure that no foreign bodies are allowed to enter the pumps, valves, heat exchangers, sensor systems and the combustion engine etc. A pressure test must be carried out.
- Where pipe diameters do not match the connections to components (pumps, compressors, radiators, etc.), they must be adapted by fitting reducers or reducer connectors. For the location and size of the connections to this apparatus, please refer to the individual component drawings.
- When installing measuring instruments (e.g. calorimeters, gas meters, etc.), the guidelines specified by the manufacturer must be observed. This applies in particular to the installation location and the inlet and outlet sections.
- In systems which are to be filled with fluids, connections for draining and filling must be available at the lowest points. At all high points, air vents must be provided. At the low points, taps for filling and draining with end cap and hose connection must be installed. At the high points, bleeding taps or automatic breathers are to be attached.
- In the case of pipes carrying gaseous media, a condensate collector with drain cocks must be provided at the lowest points. The pipes must be laid with a slope to the condensate collector.
- Copper piping is however permissible for fresh oil filling lines (pipe connections to be soldered using silver solder). As an alternative, unsheathed ERMETO steel piping may be used (pipe connections generally assembled using special screw connections, never welded!). After they have been laid, the fresh oil lines should be thoroughly flushed with new oil.
- Fresh oil lines of copper or steel may be compressed with oil-resistant fittings. Since the sealing material is not oil-resistant, it is not permitted to use standard fittings for the sanitary area.

## 20.2 Material for pipes

Table 20.1 shows an overview of materials which have to be used for the pipes by the different media:

Table 20.1:

Medium	Subdivision	Pipe material
Distillate fuel		Steel, copper
Blended fuel		Steel
Natural gas, mine gas		Steel, galvanized steel, between gas control line and engine steel or stainless steel; these lines must be absolutely "clean".
Biogas, sewage gas, landfill gas, associated gas		generally stainless steel
Water	Engine circuit, mixture cooling circuit, charge air circuit, heating circuit, emergency cooling circuit, raw water circuit	generally steel, depending on the water quality, higher-grade materials may have to be used, for example sea water in the emergency cooling / raw water circuit
Lube oil, hot engine oil bypass pipes,		Stainless steel
Fresh oil filling pipes and waste oil pipes		Steel, copper, stainless steel
Compressed air	Starter pipes	Stainless steel
	Filling pipes	Steel
	Control air pipes (low pressure)	Steel, copper
Exhaust gas	Operation with natural gas, mine gas	in front of exhaust heat exchanger and interior installation: heat-resistant steel (e.g. 15 Mo 3) behind AWT and outdoor installation: stainless steel
	Operation with biogas, sewage gas, landfill gas, associated gas	Stainless steel (e.g. 1.4571)
	in front of catalytic converter	always stainless steel 1.4571
Condensate	With content of acid components	Stainless steel
	Rest	Steel, copper, galvanized steel

When using materials other than those specified in Table 20.1, technical approval from the head office is required.

### **20.3 Notes on welding / soldering pipes**

Welded connections form a homogeneous part of the piping and guarantee absolute impermeability during operation. They represent the most economical method of connecting pipes and are therefore used in preference to other methods. The quality of the weld joint is dependent on how the pipes are fitted together, the ends being perfectly centered and the edges properly prepared for welding.

Attention: When performing welding work in the pipe system, it is absolutely necessary to disconnect all electrically conductive connections to the genset. Steel compensators on the genset must be dismantled.

In the case of E weldings, the electrode mass has to be placed as near as possible to the welding point in order to ensure a good ground connection. Rubber and steel expansion joints must be covered during the welding work to avoid damages from the welding sparks.

See also Chapter 19.2.

#### **20.3.1 Welding steel pipes**

The following points should be noted:

The roughness of the severance cuts must not exceed max. Rz 100

Permissible welding procedures as per

DIN ISO 857-1, manual arc welding, MIG or TIG

DIN EN 439, argon inert gas, at 5-7 liter/min argon to protect weld root

Weld seam preparation as per

DIN EN ISO 9692-1

Directive on assessment categories for irregularities

DIN EN ISO 5817 or

Filler metals

- Manual arc welding : Rod electrode DIN EN ISO 2560
- TIG: Solid rod DIN EN 440, DIN EN 439, DIN EN 1668
- MIG: Wire electrode DIN EN 440, DIN EN 439, DIN EN 1668

#### **20.3.2 Hard-soldering pipes**

Brazed joints should be manufactured in accordance with our works standard H0340.

## **20.4 Releasable pipe connections**

### **20.4.1 Flange connections**

Flange connections are notable for their ease of assembly and are generally used for the pipe connections at engines, pumps, heat exchangers, tanks, etc. Preference should be given to flanges which comply with DIN 2501, PN10 or PN16; for high-pressure media (e.g. compressed air), they should have a correspondingly higher nominal pressure.

When servicing or maintaining engines or system components, it is often necessary to dismantle pipes to improve accessibility. In such cases, it is particularly recommended that flange connections be installed at suitable locations.

The materials used to seal between the flanges should be selected to suit the load imposed by the medium itself as well as the pressure and temperature of the medium. In order to avoid leaks, flange connections need to be monitored. Therefore, as far as possible, flange connections should be accessible in order to replace the seals or retighten the screws. The facility to check the connections visually must, under all circumstances, be guaranteed.

### **20.4.2 Screw connections with sealed thread**

Whitworth pipe threads as per DIN EN 10226 are used exclusively for cylindrical, internal threaded connections to mountings, fittings, etc. and for tapered external pipe threads. To increase the sealing tightness before fitting, the threads must be packed with sealant in the form of hemp with sealing putty or plastic sealing tape.

Plastic sealing tape should be used for lubricating oil, fuel and gas pipes.

### **20.4.3 Screw pipe connections**

With screw pipe connections, the sealing tightness is achieved with the aid of a progressive ring which creates a positive-fit, leak-proof pipe connection.

In such cases, exclusively precision steel pipes should be used, preferably with external diameters from 6 to 38 mm. Depending on the wall thickness and external diameter, it may be necessary to use reinforcing sleeves.

Care must be taken in tightening the progressive ring.

## **20.5 Pipe brackets / supports**

Pipes should be fastened to consoles or walls with clamps, round steel clips, etc. In the case of pipes running horizontally, the mounting span must be selected according to the pipe diameter. In the case of pipes subject to expansion because of the high temperature of the medium they carry, the mounting supports must be implemented in fixed or free-running form to suit the conditions. Where appropriate, the possibility of structure-borne noise should be considered.

## **20.6 Insulating pipes**

Depending on the temperature of the medium they carry, pipes must be fitted with heat insulation to provide contact protection. The insulation thicknesses must be selected to avoid the surface temperatures of the insulation exceeding 60° C. Contact protection can also be achieved by other means, for example by fitting perforated metal sheeting or wire mesh at an appropriate distance from the hot parts.

## **20.7 Surface treatment, coloring**

It is essential that all piping, with the exception of stainless steel pipes, is painted. For this purpose, the pipes must be thoroughly cleaned and primed to a dry film thickness of approx. 30 µm. A top coat must then be applied, coating thickness approx. 40 µm.

Insofar as no particular colors are otherwise specified, the colors should be selected in accordance with DIN 2403. This standard lays down the requisite colors for pipes dependent on the media they carry.

Pipes provided with heat insulation should be coated in primer only.

Steel exhaust pipes must be painted with heat-resistant paint. A high-temperature-resistant zinc silicate-based paint should be used, preferably applied in 2 coats, each of 40 µm dry film thickness.



# **Power plants layout**

Chapter 21

**Health and safety at work, accident prevention,  
environmental protection**

06-2014

## Contents

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## **21. Health and safety at work, accident prevention, environmental protection**

When planning, installing and maintaining a system incorporating engine-driven gensets, the general rules governing health and safety at work and the accident prevention must be observed.

In the EU, the German Health and Safety at Work Regulations (BetrSichV) for the safety of working appliances and systems requiring monitoring have been applicable since October 03rd 2002.

Basic health and safety requirements in the design and construction of machines are laid down in the EU Directive 2006/42/EC. The present aim is to draw attention to certain measures.

The safety provisions, which are a component of the gensets and/or system documentation, must be complied with during layout, maintenance and operation of the systems.

### **21.1 Scaffolding, staging, ladders**

- When installing systems, it is usual for components to be installed at such heights that scaffolding or staging is required. Scaffolds and stages must be equipped with safety railings. If heavy components are to rest on the scaffolding, this must be adequate to bear the load.
- If frequently operated fittings or instruments to be read on a regular basis are installed at a height which is not normally reachable, stationary platforms must be provided.
- Only TÜV-approved ladders may be used.
- When installing series TCG 2032 engines, it is essential that engine maintenance stages are provided by the client.

### **21.2 Noise protection**

In the engine room, when the gensets are operating, noise levels of above 100 dB(A) are reached. Over time, these will cause persons present in the engine room to suffer hearing damage if protective measures are not taken. Ear protection must therefore be worn in the engine room when the gensets are operating. Warning notices requiring ear protection to be worn must be provided at the entrances to the engine room.

### **21.3 Fire safety, escape plan**

- The fuels, gaseous or liquid, used for the gensets and the engine lubricating oil can easily ignite in the atmosphere. Uncontrolled fuel escapes must therefore be avoided or monitored. Cleaning cloths soaked in oil or fuel must be disposed of immediately, since if these catch fire, they can easily become the cause of a major conflagration. Depending on the safety requirements for the design of the respective plant, stationary fire extinguishing facilities must be provided along with appropriate alarm and triggering devices. There must be notices identifying the location of fire extinguishing equipment such as e.g. manual fire extinguishers, hydrants, etc.
- The appropriate width (min. 600 mm) and height (min. 2000 mm) of escape routes must be observed. In case of fire in the engine room, the escape routes must be identified. An escape plan must be available. This is of particular importance where the engine room is located within a larger building.
- The statutory regulations are to be followed.

### **21.4 Contact protection**

All components involving moving parts - in the engine room, this will primarily include the gensets with the engine-driven generators, compressors and electric pumps - must be fitted with the appropriate protective devices to prohibit direct contact with rotating parts. The protective devices may be removed for service and maintenance work only. When carrying out such works, the starters must be isolated to prevent the engines from being started unintentionally.

When the gensets are in operation, the media bearing lines, especially the cooling water and exhaust lines, can reach temperatures which would cause burns to the skin in the event of direct contact. These lines must be fitted with heat insulation or with appropriate contact protection.

### **21.5 Emergency Stop facilities**

In addition to the emergency stop buttons at each genset, a secured emergency stop button must be located at an easily accessible point in the engine room, preferably in the vicinity of the escape door, to shut down the system in the event of a hazard.

## 21.6 Storage and disposal of hazardous materials

Fuels, lubricating oils, cooling water treatment agents, battery acid, cleaning agents, etc, constitute hazardous materials, which should be stored in large containers, barrels or other vessels in the engine room or in an adjacent room. The storage locations for such materials must be so designed that even if a container is damaged, the substances cannot enter the waste water system.

## 21.7 Electrical protection

The VDE regulation VDE 0100 defines measures to protect against hazardous contact voltages.

It distinguishes between:

- Protection against direct contact  
Live parts of electrical operating equipment - parts carrying a voltage - must either be insulated in their entirety or protected against direct contact by virtue of their design, location or arrangement, or by way of special regulations.
- Protection in the event of indirect contact  
Even in the case of operating equipment which was fine at the time of manufacture, insulation defects may occur due to aging or wear, as a result of which touchable, conductive parts may carry high contact voltages (50 V and above).

Work should only be carried out on potentially live electrical installations whilst these are isolated from the voltage supply.

In order to render the equipment voltage-free and secure, there are 5 safety rules to be followed:

- Disconnect
- Secure against reconnection
- Check that equipment is voltage-free
- Earth and short-circuit
- Cover or cordon off adjacent parts which are electrically live

The responsible supervisor must not approve the workplace for works to commence until all 5 safety rules have been complied with.

Once work has been completed, the safety measures must be lifted.

The order to switch the equipment on must not be given until the system has been released at all workplaces and all switch points have reported that they are ready to connect.

## **21.8 Accident prevention regulations for electrical systems**

### **The accident prevention regulations must be observed!**

Especially the "General Regulations" BGV A1 and "Electrical systems and operating equipment" VBG4. For the installation of power systems, please refer to VDE 0100 (up to 1 kV) or VDE 0101 (over 1 kV); for operation, DIN EN 50191 or VDE 0105 applies.

#### **Note:**

Electrical systems and power installations may be installed and operated by trained personnel only. Personnel must be specially trained in order to commission medium-voltage generators.

## **21.9 Risk assessments**

Risk assessments have been carried out and documented for all gensets. The possibilities of a hazard during installation, starting, operation and maintenance of the gensets are outlined and evaluated in the risk assessments. The measures to be undertaken for limiting the hazard are also described.