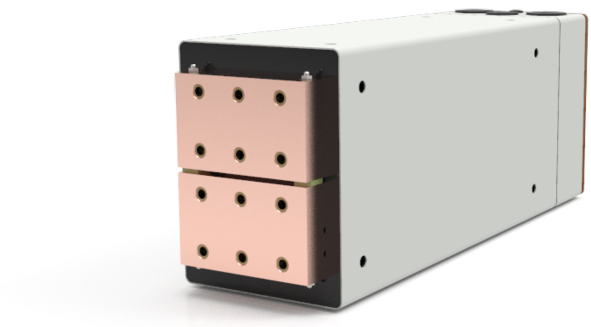
Operating instructions

Transformers
for resistance welding



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1 General

In addition to the technical description of the product, this operating manual "Transformers for resistance welding" contains important information for the selection, handling, assembly and installation of EXPERT transformers and components to ensure the best possible safety for man and machine and proper functioning.
The following Directives of the European Union apply to the product and its intended use:

- 73/23/EEC Electrical equipment for use within certain voltage limits (Low Voltage Directive)
- 89/336/EEC Electromagnetic compatibility (EMC Directive)
- 89/392/EEC Safety of machinery (Machinery Directive)
- 93/68/EEC CE marking

In addition, the national regulations for the construction and commissioning of electro-technical installations and the applicable safety regulations must be observed.

WARNING
The transformers are intended for class A resistance welding equipment in accordance with EN 50240. They are not intended for use with a public low-voltage grid that supplies residential areas. It can cause radio interference.

The user receives the necessary safety instructions below (see Section 1).
This user manual is intended for the following user groups:

- Employees Project Planning and Design
- Installation and commissioning
- Employee Maintenance and Repair
- Employees Transport and Storage

2 Safety

2.1 General information

- Proper and safe operation requires proper transport, professional storage, assembly and installation as well as careful operation and maintenance of the transformers.
- The transformers are intended for installation in machines and systems in commercial areas. The specific safety rules and regulations for the present application must be observed.
- The operation of transformers is only permitted with effective protective measures against indirect contact with electrically conductive parts in the event of a fault. This also applies to short-term operation for inspection and test purposes.
- Before switching on the transformer, live parts must be safely covered to prevent contact.
- Before the start of assembly or maintenance work, the machine or system must be brought into a condition that allows safe operation (e.g., basic position).
- The machine or plant part in which the work is to be carried out must be switched off from voltage. Under certain conditions, back stresses may occur. In such cases, the primary and secondary pages must be activated. Attention must be paid to dangerous moving parts from adjacent plant components. In the event of such hazards, the adjacent plant components must then also be activated.
- **Attention:** Power modules based on semiconductors (thyristors, IGBT, etc.) do not realize galvanic isolation of the circuit even when the control is switched off! In any case, the main switch must also be operated!
- Switches that have been activated must be secured against unintentional reactivation. Equipment is equipped with a warning sign, e.g. *"DO NOT TURN ON! - Repair work"* with an indication of the repair period and the name of the responsible employee.
- The all-pole freedom from voltage must be checked with a suitable measuring or testing device (e.g. voltage tester, voltage measuring device) on the transformer.
- Adjacent parts under tension shall be covered.
- Machines or systems may only be entered in the prescribed manner (e.g. by opening the safety gates).
- The cooling water supply shall be interrupted.

2.2 Protection against direct and indirect contact with electrically conductive parts

2.2.1 Protection against direct contact

When welding transformers are operated in welding systems, certain components such as accessible parts of the welding circuit or the welded part itself are inevitably in direct contact with the low-voltage side of thewelding transformer. When these parts are touched, voltages up to the level of the secondary open circuit voltage occur operationally.
In general, these voltages are below the limits for permissible contact voltages.
According to DIN VDE 0100 Part 410, the maximum values of the contact voltages are specified.
These are for:

- AC voltage systems (50 - 60Hz) U_L = 25 V
- For DC systems, U_L = 60 V

⚠	**Danger due to unacceptably high contact voltage!** When connecting secondary windings of one or more transformers in series, higher voltages than the permissible contact voltages can be generated! If higher voltages than the permissible contact voltages are generated by cascading, the user must provide suitable protective measures against direct contact (covers, cladding, etc.).

The specified maximum values of the permissible contact voltages according to DIN VDE 0100 Part 410 apply to applications in dry rooms.
When touching live parts over a large area with damp hands, noticeable electric shocks can occur even at voltages below 10 V.
This circumstance must be considered in the design of welding guns, especially in the case of hand-operated pliers.
All touchable metallically conductive parts must be connected to the protective conductor. Potential-carrying plier arms should have additional insulating sleeves, bandages, or the like in order to exclude the unprotected touching of the two clamp arms, for example in the case of possible two-man operation.

⚠	In the case of extensive skin contact in conjunction with damp hands, sensitive electric shocks can already be caused at DC or AC voltages below 10 V! In the case of hand pliers, all contactable conductive parts must be connected to the protective conductor. Potential-carrying pincer arms must be covered to a large extent.

In addition, operators should wear appropriate protective gloves.

2.2.2 Protection against indirect contact in the event of a fault

The transformers from EXPERT comply with protection class I in accordance with DIN VDE 0551 Part 1.
As protection against unacceptably high contact voltages in the event of a fault (protection in the event of indirect contact), additional protective measures in accordance with EN 62135-1 (DIN VDE 0545, Part 1) must be applied (connecting the secondary circuits to a protective conductor, residual current protection circuit, etc.).
All housing parts of the transformer are galvanically connected to the protective conductor via the primary-side protective conductor connection.

⚠	**Protective measures against indirect contact** The secondary circuits of the welding transformers are generally not connected to the protective conductor due to the wide range of interconnection options and the applicability of different protective measures in the delivery state. The necessary and appropriate protective measure in accordance with EN 62135-1 (DIN VDE 0545, Part 1) must be defined and implemented by the user.

Exceptions are welding transformers, which are already manufactured and delivered with an internal protective conductor connection on the basis of existing general or customer-specific standards (e.ISO g. clamptransformers according to 10656 or special transformers for suspension point systems).
This internal protective conductor connection is usually detachable and is marked with MPE.
In any case, please note the information on the signs on the transformers and the information in the data sheets.

	Avoidance of balancing currents If the required protective measure is implemented by a direct connection of the secondary circuit to the protective conductor, the user must ensure that compensatory currents (crosscurrents) over the protective conductor connection cannot occur in more complex welding systems because of potential shifts during welding. The protective conductor must not carry any current in operational terms!

Balancing currents can occur, for example, when several welding power sources weld simultaneously on a common workpiece or when welding to an additionally grounded workpiece with an already grounded TRANSFORMER.
When commissioning the welding station, it is therefore necessary to check by means of suitable measuring devices (e.g., current measuring clamp) that the protective conductor does not carry any

	Balancing currents must be avoided in principle, because in extreme cases they can interrupt the internal protective conductor connection. **An interruption of the protective conductor connection leads to the cancellation of the protective measure and can endanger human lives!**

current during welding.
If balancing currents are unavoidable because of the direct connection of the secondary circuit to the protective conductor, the protective conductor connection can be cancelled for most transformers. In this case, however, another protective measure permitted under EN50063 must be installed as an alternative.

	For systems with residual current protective devices according to EN 60947-2 in TN or TT networks (rated residual current ≤ 30mA), transformers with built-in residual current protection resistor can be supplied. The residual current resistance must be checked optically and electrically cyclically (at least twice a year) for perfect condition. It must be ensured that the RCD protective device is suitable for the application.

2.3 Protection against electromagnetic fields

During resistance welding, depending on the amount of the welding current, strong magnetic fields occur for physical reasons. Due to the current level, the highest magnetic field concentrations occur mainly in the secondary lines.
This must be considered in the design of resistance welding devices and the definition of operating stations.
To avoid a possible exceeding of the permissible workplace concentrations of electromagnetic radiation, metrological proof must be carried out if necessary.
In addition to the formation of magnetic fields, welding also produces conducted and radiated interference emissions from electromagnetic waves in a wide frequency range, depending on the type and functioning of the power setting.

	Danger due to the influence of electromagnetic fields Persons with medical auxiliary units (such as pacemakers, etc.) must not be in the welding equipment and their supply lines! There is a risk of malfunctions, which may lead to death or serious damage to health.

For this purpose, the specifications according to the EMC Directive apply.

Additional notes:

- When setting up welding machines or systems, the limit values for electromagnetic radiation must be observed (see appendix Standards).
- If necessary, appropriate protective devices (e.g., shielding) must be provided or the operating stations must be set up at an appropriate distance.
- In the area of the welding machine or system, the information of magnetically stored data carriers (e.g., sound and video tapes, EC cards, etc.) can be deleted or changed.
- The magnetic fields that occur during welding can damage motor-driven precision mechanical products such as wristwatches.
- In the immediate vicinity of the welding circle, currents can be induced in metallic objects (including jewelry, e.g., rings or chains). Depending on the strength of the magnetic field, this can lead to local heating in the metal parts (risk of burns).
- The EMF/EMC guidelines for resistance welding equipment have not yet been defined in full detail, or there are uncertainties in the guidelines for welding circuits. Therefore, please note the new publications in the relevant literature.

3 Specifications

3.1 General

The common resistance welding processes such as point, hump and seam welding are characterized by the fact that the welding energy is not continuously but pulsed into the welding point.
The required welding times are usually much less than 1 second. Due to the process, there are usually long break times between the welding impulses.
This operating mode (*intermittent operation*) makes it possible to overload the transformers used as welding power sources during the current on phase, i.e. in contrast to the permissible continuous currents of a transformer, significantly higher pulse currents can flow for a short time without thermally overtaxing the transformers. This makes it possible to produce cost- and weight-optimized devices tailored to the specific application. On the other hand, however, this means that the targeted overload must be precisely defined to ensure safe operation.
An essential feature for the intermittent operation is the percentage duty cycle *X*, i.e., the sum of all current flow times in relation to the cycle time *T*. The ratio can take a value between 0 and 1 and is expressed as a percentage. In addition, the length of the individual welding pulses is also decisive for the overload capacity. The behavior in case of overload is shown in type-related diagrams. The technical data of the are contained in the respective data sheets. The devices are subject to technical changes in the sense of technical progress. If necessary, the current documentation must be requested.

3.2 Type plate information

The type-plate specifications of EXPERT welding transformers contain the characteristic values that are important for the user.

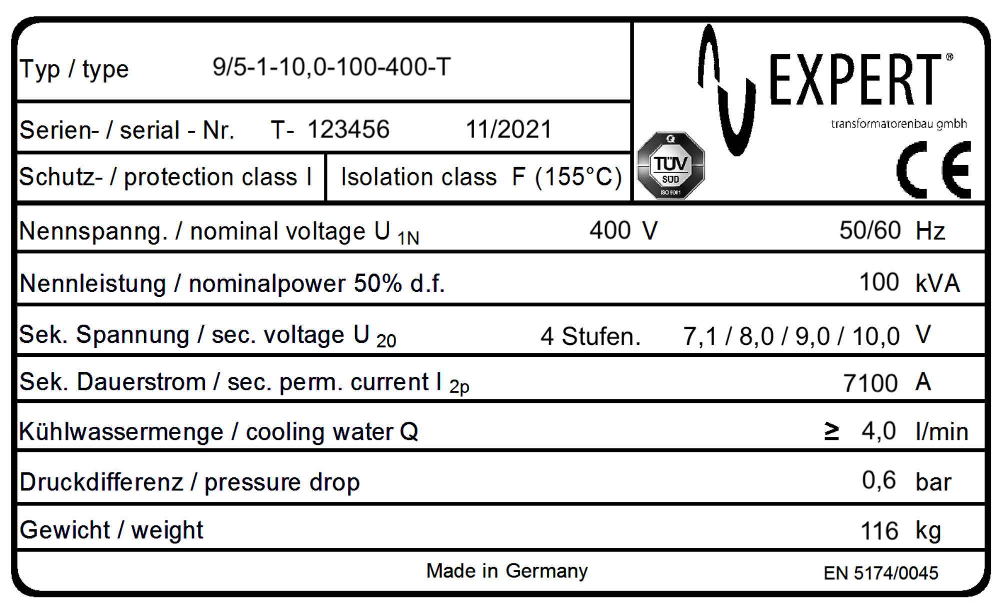

Figure 3-11 Type plate of an EXPERT welding transformer

4 Intended use

EXPERT welding transformers are specially developed and manufactured for resistance welding technology. The general design and technical design is carried out in accordance with ISO5826, ISO669. In addition, applicable type-bound standards are considered.

⚠	**Danger due to improper use** Improper use can cause personal injury, property damage and the environment. Due to high short-circuit currents and the associated high welding energies, there is a risk of material evaporation. Use the transformers only as intended.

4.1 Areas of application for transformers

The transformers are designed in a fully encapsulated design (cast resin filling), i.e., the windings are optimally protected against moisture, contamination and the effect of dynamic current forces.
The primary side connections are encapsulated as standard in protection class IP 54. Protection class IP00 (open clamping points) applies to the secondary connection.
Exceptions are clamp transformers according to ISO 10656, which are also delivered in IP 00 as components on the primary side.
The transformer must not be used in potentially explosive atmospheres. Please note the permissible environmental conditions (see section 7.2).

⚠	**Protection** The transformers may only be used and operated in those areas that correspond to the specified degree of protection (according to the data sheet). These transformers may not be used for operation in potentially explosive atmospheres.

4.2 Materials for resistance welding, resistance welding process

Definition of resistance welding (DIN 1910 Part 5):

The heat required for welding is generated by current flow through the electrical resistance of the welding zone (*resistance heat, Joule heat*). Welding is done with or without force and with or without welding consumable.
Regarding the above definition, the minimum requirement of a material to be welded is that it must be electrically conductive. Furthermore, the material must be weldable in the kneadable state.
Suitable materials:

- uncoated steel sheet in different material thicknesses (often up to 3.0mm)
- coated steel sheet e.g., galvanized
- Chrome-nickel steel
- Non-ferrous metals e.g., aluminum, copper and silver

⚠	**Danger from the use of incorrect materials** The use of non-weldable or non-recommended materials can cause physical damage or damage to machines because of unpredictable reactions when the welding energy is introduced into the material

'The welding processes shall be classified according to the type of energy source acting on the workpiece from the outside, the type of base material, the purpose of welding, the physical process of welding and the type of production.' (DIN 1910 Part 1)

The most common resistance welding methods are:

- • Spot welding:

The concentration of the current on the welding point is determined by the shape of the electrode. The welding current is usually introduced into the welding point impulsively.

- • Seam welding:

The concentration of the current into the weld seam is determined by the shape of the seam roller (track width and roll diameter of the roller pair). The welding current is introduced into the weld seam impulsively or continuously.

- • Projection welding:

The concentration of the current on the welding point is determined by the shape of the hump. Like spot welding, the welding current is introduced into the welding point as a pulse.

- • Flash butt welding:

If possible, the current density should be uniform and of the same size over the entire contact surface of the two workpieces. By introducing a welding current, the joint points are heated until the temperature required for welding is reached. The parts are then pressed together continuously or according to a sequence program.

4.3 Dimensioning of welding transformers

For the correct dimensioning of a transformer, two essential criteria must be observed.

- The thermal design (determination of the equivalent secondary continuous current).
- The short circuit design (determination of the required secondary voltage).

Both values are independent of each other and must be determined for each application.

4.3.1 Thermal dimensioning

The power specified in the dimension sheets is a measure of the electrical work that a transformer can absorb per unit of time and remit reduced by efficiency without exceeding the permissible limit temperature values. In most older standards, the rated power is given with a duty cycle of 50%, which $\sqrt{2}$ corresponds to about - times the continuous power. Only in newer standards (e.g., DIN ISO 7284) is the continuous power defined as a nominal power.
While the continuous power of a transformer corresponds to the installed power, i.e.dem the performance capacity used as the basis for the design of a unit, the performance analysis with a duty cycle of 50% is a purely mathematical quantity, which has no relation to practice, since only in the rarest of cases is welded with a duty cycle of 50%.
Transformers for resistance welding are usually used as a power source. Therefore, it makes sense to dimension the secondary currents. In continuous operation, the corresponding values specified in the dimension sheet can be adopted directly as maximum values (assuming the magnetic circuit was designed for continuous operation).
The intermittent operation, which is common in resistance welding technology, enables the transformer to be overloaded for a short time. According to the relationships specified in DIN ISO 5826 , both the continuous currents and the current values at 50% can be used to infer any maximum load current, depending on the duty cycle. The maximum overload capacity for transformers up to 100kVA is about 9 times the value of the continuous current. For larger transformers, this value is reduced because the mechanical strength is limited. For clamp transformers, the value should not exceed 5 or 6 times the continuous current.
<u>According to DIN ISO 5826, the following relationships apply:</u>

$$I_{2x} = I_{2p} \cdot \sqrt{\frac{1 - e^{\frac{-T}{\tau}}}{1 - e^{\frac{-xT}{100\tau}}}}$$

or

$$I_{2x} = I_{50} \cdot \sqrt{\frac{1 - e^{\frac{-T}{2\tau}}}{1 - e^{\frac{-xT}{100\tau}}}}$$

Legend:

I_{2x}	- maximum secondary current at a duty cycle X
X	- Duty cycle/% (sum of all current flow times based on cycle time T)
I_{2p}	- Secondary continuous current of the transformer
I_{50}	- Secondary current at 50% duty cycle
T	- Cycle time (playing time)
τ	- Thermal time constant of the transformer

Since the above-mentioned formal relationships are generally not practicable for the user, the following simplifications can be consulted.
If the ratio $\frac{\tau}{T} \geq 5$ is, the calculation can be performed using the following simplified equations:

$$I_{2x} = I_{2p} \cdot \sqrt{\frac{100}{X}}$$

or

$$I_{2x} = I_{50} \cdot \sqrt{\frac{100}{2X}}$$

Example:

During a cycle time of 30 seconds, a total of n = 10 welding points with different parameters must be welded. Specifically, 5 points with 15 kA, 240ms, 3 points with 8kA, 100ms and 2 points with 10kA, 200ms are to be welded.
What must be the required equivalent secondary continuous current of the transformer?I_{2p}

Solution:

$$I_{2p} = \sqrt{\frac{1}{T}\left(I_{S_1}^2 \cdot t_{S_1} + I_{S_2}^2 \cdot t_{S_2} + I_{S_3}^2 \cdot t_{S_3} + \cdots + I_{S_n}^2 \cdot t_{S_n}\right)}$$

$$I_{2p} = \sqrt{\frac{1}{30s}(5 \cdot 15\, kA^2 \cdot 240\, ms + 3 \cdot 8\, kA^2 \cdot 100\, ms + 2 \cdot 10\, kA^2 \cdot 200\, ms)}$$

$$I_{2p} = 3{,}3\, kA$$

The secondary continuous current of the transformer used must be at least 3,3 kA.

Determination of the percentage duty cycle X for this welding process:

$$X = \frac{\sum t_s}{T} \cdot 100\%$$

$$X = \frac{5 \cdot 240\, ms + 3 \cdot 100\, ms + 2 \cdot 200\, ms}{30\, s} \cdot 100\%$$

$$X = 6{,}33\%$$

4.3.2 Determination of the required secondary voltage of a transformer

The transformer used must be dimensioned for the application regarding its maximum secondary continuous current in such a way that the permissible heating is not exceeded (*see also 4.3.1*).
To achieve a desired maximum welding current, it is also necessary to define the required secondary open circuit voltage of a welding transformer according to the impedance of the welding circuit.
The secondary open circuit voltage as a driving source in conjunction with the self-losses of a transformer or a complete welding device determines its short-circuit properties.
A distinction is made between *transformer short-circuit current* and *machine short-circuit current*. Both short-circuit currents are briefly explained below.

Transformers short-circuit current

The current is limited only by the transformer's own losses. At the same time, this is the maximum current that could theoretically be taken from the transformer at nominal primary voltage in an ideal loss-free grid. The transformer short-circuit current would flow if the secondary connections were short-circuited under the assumed conditions. This means that the outer impedance would be very small and would be close to zero. The transformer short-circuit current is thus a purely mathematical reference value and can only be determined indirectly by measurement. It can be found in the data sheets of the EXPERT transformers.

Machines short-circuit current

The machines short-circuit current is the highest possible current that can occur in the welding machine. It is limited by the resistances of the mains supply lines, the transformer, the secondary cables, busbars and electrodes, etc., as well as by their inductances. The resulting impedance is a measure of the total losses of the system. This current can be measured in real terms at the machine.
Depending on the size of the parts to be welded, the throat and arm spacing of the secondary arrangement (gun, multi-spot tool, etc.) must be designed, whereby the size, the electrical cross-sections and the conductivity of the material used have a determining influence on the impedance and thus on the losses in the welding circuit. With short-circuited electrodes and nominal primary voltage, the maximum current that depends on the impedance of the arrangement flows (machine short-circuit current, also called gun short-circuit current in the case of guns).
If the sheets to be welded are located between the electrodes, the impedance of the secondary circuit is also increased. The maximum welding current that can then be achieved is usually about 10-20% below the machine short-circuit current. This means that only 10 - 20% of the energy input is used directly for the welding process.
The impedance of the welding circuit is composed of a resistive and an inductive component. The ohmic component can be approximately determined from the cross-sectional areas, the length and the conductivity of the materials used. In the case of alternating currents, the frequency influences on the conductivity must also be considered.
The inductive component essentially results from the geometric shape of the welding circuit and is largely independent of the material.
The inductance of a welding circuit can also only be determined approximately using calculation models for inductances of idealized geometric shape. The principle applies that the smaller the area enclosed by the welding circuit (size of the "welding window"), the smaller the inductance of the circuit.
A faster and more accurate method is to measure the impedance of the secondary circuit by measuring the maximum achievable welding current. This method can be used in existing systems and is also referred to as a load characteristic.

The approximation is:

$$Z_L = \frac{U_{20}}{I_s} - \frac{U_{20}}{I_{2cc}}$$

Legend:

Z_L - Impedance of the entire secondary circuit

U_{20} - Transformer open circuit voltage (see data sheet)

I_s - Maximum achievable welding current (welding current meter)

I_{2cc} - Transformershort circuitcurrent (see data sheet)

Due to the low energy utilization in resistance welding, it is particularly important in the design of welding equipment to always pay attention to the shortest cable routing and to the minimization of the area enclosed by the welding cables or the clamp arms ("welding window"). High losses are synonymous with high operating costs.
Load diagrams are added to the data sheets of the most common EXPERT transformers (Fig. 4 1), which describe the two-pole behavior $I_{S_{max}} = f(Z_L)$ of the transformers.
For simplicity, a power factor of about the same size $cos\varphi$ for the transformer and for the welding circuit is required when creating the diagrams (ratio of active and apparent power).

Hint: It should be noted that the specified currents are the maximum currents achievable in **the intermittent mode** at a certain projection, which are limited only by the impedance of the external circuitry. The analysis is independent of the thermal conditions in the transformer. Depending on the current level, correspondingly long break times must be provided for cooling down according to the thermal capacity of the transformer! (see 4.3.1)

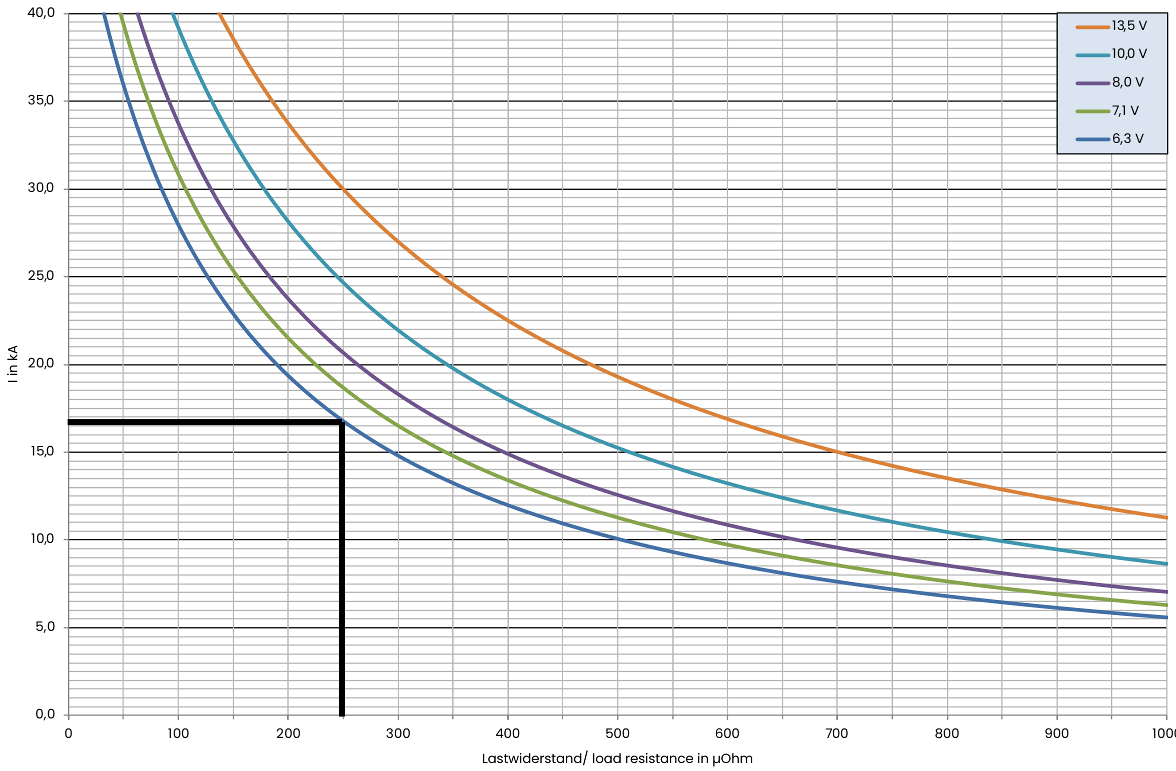

Figure 4-11 Load diagram of a resistance welding transformer $I_{S_{max}} = f(Z_L)$

With the help of this type-dependent characteristic curve, the maximum achievable welding current can be determined $I_{S_{max}}$ as a function of the impedance of the load circuit (i.e. the $Z_L$vector sum of all resistors and reactances connected to the transformer on the secondary side).

The function value at the point $Z_L = 0$ corresponds to the transformer short-circuit current according to the definition.
In the example (Figure 4-1) at a secondary circuit impedance of approx. $250\ \mu\Omega$ maximum achievable welding current for the selected transformer with 6.3V approx. 17 kA.
Conversely, these load diagrams are also suitable for the approximate determination of the impedance of the secondary circuit by measuring the maximum achievable welding current and then taking the value for transformers used from the load diagram of theZ_Ls.

⚠	For transformers with 2 secondary circuits, it should be noted that the transformer short-circuit current is different for the different circuit variants (parallel, single, series connection). In the data sheets, usually only the values for the parallel connection are indicated. For other circuits, take the short-circuit currents from the corresponding diagrams.

The load diagrams thus facilitate the selection of as suitable transformer regarding the maximum achievable secondary current while knowing the impedance of the welding circuit. It should be noted that a welding current reserve of at least 30% should always be planned, e.g. to compensate for signs of wear on secondary cables and clamping points, which lead to an increase in resistance in the welding circuit. Additional current reserven are also required, for example, for shunts via adjacent welding points or when using stepper functions.

⚠	The load diagrams are calculated from thedata of the respective transformer . Mains voltage drops are not taken into account. If larger mains voltage drops than 5% are to be expected due to long mains supply lines, etc., additional welding power reserves must be planned.

4.4 Circuit variants of transformers

Depending on the design, welding transformers have one or two secondary windings. For transformers with two separate secondary windings, it is possible to optionally set up one or two separate welding circuits.
If only one welding circuit is required, a parallel connection (single voltage, maximum current) or a series connection (double voltage, half current) of the secondary windings of a transformer can be used, depending on the requirements.

⚠	In order to avoid balancing currents via the transformer windings, the secondary parallel connection of individual transformers is not permitted. Exception: The parallel connection of secondary windings of a transformer, as described below, is possible due to the symmetrical winding structure of EXPERT transformers.

4.4.1 Connection of a secondary circuit / parallel connection

If only one secondary circuit is used for welding and the simple secondary voltage is sufficient to achieve the required welding current, the parallel connection of the secondary windings must always be used for transformers with two secondary windings (A and B side), even under low load. This achieves a uniform current distribution on the individual windings in the transformer, minimizes the transformer's own losses and improves the efficiency of the welding device.
Since in this case the two built-in measuring coils for the KSR signal each record the partial currents of the secondary windings connected in parallel, the sum of the two measuring signals results in the measuring voltage for the total current of the transformer. This is achieved by connecting the two measuring coil outputs in series in the correct phase (see also section 5.2.2).

If several welding circuits are to be operated with one transformer (simple secondary voltage), we also recommend connecting both transformer outputs in parallel and performing the welding one after the other by closing only the active welding cylinder. As a result, a defined welding current can be realized for each welding point. Operation with KSR is also possible without any problems.
On the other hand, it is not recommended, for example, to connect 2 welding circuits separately to a secondary winding (A or B side) of a transformer.
With simultaneous welding via both welding cylinders, a defined welding current assignment would not be given due to the possibly asymmetrical current distribution.
If the welding cylinders are controlled one after the other, the undefined current distribution is avoided, but higher transformer losses occur. In addition, in both cases, a KSR function can only be implemented to a limited extent for one of the two sides, since only one current measuring coil can be connected to the usual welding controls.

4.4.2 Series connection

When the two secondary windings are connected in series, the secondary voltages add up. In this case, however, the maximum permissible welding current according to the power balance is only half of the maximum current in parallel connection.
To return the actual current value to a KSR, only one of the two toroid measuring coils must then be connected. Since both measuring coils measure the same welding current, it is irrelevant which coil is used. The unused measuring coil can remain unwired.

4.5 Operation of transformers at other mains frequencies

As a rule, transformers can be operated at a slightly higher operating frequency without negatively affecting the operating behavior. This also applies to transformers with a nominal frequency of 50 Hz operating at 60 Hz (*frequency increase 20%*)..
Due to the higher frequency, depending on the design, there are slightly higher losses in the transformer windings (*approx. 2-3%*), which, however, are negligible with sufficient cooling according to the data sheet and a water input temperature of a maximum of 30°C.
The losses in the core iron also increase somewhat as a result of the frequency increase. However, since the core geometry is retained, this effect is compensated by the 20% lower induction of the transformer at 60 Hz, so that the absolute mass-related losses in the core iron at 60 Hz even decrease.
A transformer with a nominal voltage of 380 V / 50 Hz can therefore be operated without any problems with a nominal voltage of 380 V / 60 Hz.
However, the reverse case is not readily permissible!
In addition, it is technically possible to operate a 50 Hz transformer at 60 Hz at a 20% higher mains voltage (480V/400V = 60Hz/50Hz = 1.2).
A transformer with a nominal voltage of 400V/50Hz can therefore also be connected to 480V/60Hz.
When operating a welding system (e.g. robot welding gun) with a higher frequency, however, the clamp impedance and the intrinsic impedance of the transformer increase.
This is mainly due to the increase in reactive resistance in clamps and transformers, which is roughly linear with frequency, as well as frequency-dependent current displacement effects in the conductors, clamp arms and electrodes (skin effect). When operating at 60 Hz, the alternating current resistance of a welding gun increases by about 10% compared to 50 Hz (reactive resistance increase) depending on the cos of the clamp.φ
Depending on the design of the clamp arms, this value can also increase by a further 5-10% as a result of the skin effect, so that in extreme cases the achievable clamp short-circuit current at 60 Hz compared to 50 Hz can be about 15-20% lower.
However, if the 400V/50Hz transformer is operated at 60 Hz at the maximum possible primary voltage of 480V, the secondary voltage also increases in the ratio 480V/400V = 1.2.
Due to the higher driving voltage, about the same clamp short-circuit currents as at 400 V/50 Hz can then be achieved.

4.6 Requirements for welding controllers

Transformers in resistance welding systems differ considerably from mains or supply transformers in terms of their operating mode. Depending on the welding process, the transformer is switched on and off at different speeds, whereby the process is often repeated after a few network periods. The level of the welding current is usually influenced during the switch-on phase by means of phase cut control.
If an inductive load (*e.g. transformer with connected welding circuit*) is switched on, high inrush current peaks occur for physical reasons in conjunction with transient DC components. When switched off, on the other hand, the current subsides slowly depending on the time constant due to the energy storage.
Therefore, special requirements are placed on welding current controls for resistance welding:

- To reduce the inrush current peaks and minimize the transient DC components, the first half-wave of the first period of a welding pulse must have a fixed switch-on delay, which should be greater than the phase angle (about 70 to 90 degrees).
- Since the resistance welding transformers work with very high magnetic inductions close to saturation induction, very high demands are placed on the synchronization and symmetry of the phase cut control. The primary current must be virtually free of DC components over the entire operating range.
- Due to the inductance of the transformer and the welding circuit, there is always a phase shift between current and voltage (lagging of the current around the phase angle φ). The resulting delayed deletion of the thyristor is called an "inductive overhang". The antiparallel thyristor of the counter-half-wave can thus only ignite when a positive anode voltage has built up against its cathode. In practice, this means that the theoretically available operating range of 180° is reduced by the "inductive overhang" under inductive load. With most manufacturers of welding controls, the minimum ignition angle is set at the factory so that a cos φ of 0.86 results in a closed sine wave corresponding to a load angle of 30°. This corresponds to a performance scaling of 100%. If the cos φ is worse than 0.86 on a machine or welding gun, the current adjustment range is "trimmed" at the upper values. With many controllers, a cos φ adjustment can be carried out to correct the operating range.
- The power assembly of a welding controller, including the overcurrent protection device, must be designed for the high pulse currents that occur.

⚠	Please use only CE-compliant controls specially designed for resistance welding to operate EXPERT welding transformers.

4.7 Force effects in the welding circuit, secondary connections

When designing welding equipment for resistance welding, the force effects and the resulting mechanical stresses as a result of the high welding currents must be considered when designing the secondary circuits.
Due to the magnetic field, attractive forces act on current-flowing parallel conductors in the same direction of current and *repulsive* forces in the opposite direction of current.
In the case of a closed welding circuit, the direction of action of the forces during welding is such that the conductors forming the welding circuit always want to occupy a larger area. Depending on the current level, very large force effects can occur.

If, for example, two parallel conductor rails of length $l = 1m$, which are laid at a distance from are flowed through $a = 0{,}05m$ by a current $I = 25kA$, for example, a force *F* distributed over the length *l* results according to the following relationship:

$$F = 2{,}0 \cdot I^2 \cdot \frac{l}{a} \cdot 10^{-7} N$$

For the this example, there is a force of $2{,}5\ kN$.
Since these forces occur dynamically with each weld, care must be taken in the design of the welding circuit to ensure that no leverage effects occur, for example when using rigid busbars. Leverage additionally increases the already considerable current forces. Due to the flow behavior of copper, this can lead to a gradual deformation of the secondary connections and busbars up to breakage.

⚠	**Transformer connection** Transformers must be connected secondarily with flexible welding cables or lamellar belts. As a result, leverage effects are largely avoided. When using rigid busbars, these must be additionally mechanically supported at least at the beginning and end in accordance with the current forces that occur. In the case of suspension point systems with long secondary cables and with a high dead weight, a strain relief must be provided for

Due to the diversity of welding systems (mechanical design, operating parameters, and operating conditions), no general specifications for the design of welding circuits can be given. The general guidelines for the design of high-current circuits under consideration of dynamic current forces must be considered.
It must be ensured that the electrodynamic forces are within the permissible range when operating within the working range specified in the data sheet.
The user must take suitable design measures to ensure that no additional forces can act on the transformer beyond this, such as force feedback from welding cylinders, forces caused by the dead weight of system parts, force feedback in the event of robot collision and the like.

⚠	**Risk of mechanical damage** A welding transformer is a complicated electrotechnical device that is operated at high voltage. To avoid unacceptably high contact voltages, protective measures such as a direct protective conductor connection are carried out. If large additional external forces are applied, it cannot be ruled out that mechanical damage to the transformer may also lead to an interruption of the protective conductor or damage to other functional parts of the protective measure before the system is switched off via it. In this case, the protective measure becomes ineffective and there is a risk of the occurrence of inadmissibly high contact voltages on system components and thus danger to the life of the operating personnel!

4.8 Mains connection of welding systems

4.8.1 Grid connection conditions

The connection of a resistance welding machine to the three-phase network is usually 2-phase. When connecting 2-phase transformers and a shock load, the expected unbalance (zero point shift) in the 3-phase feed-in network must be observed. When connecting several transformers, they should be connected as evenly as possible over all 3 phases.

As 3-phase supply transformers for the operation of resistance welding systems, those of the switching groups Dy5 (delta-star) or Yz5 (star zigzag circuit) are suitable. The apparent power required for the supply transformer shall be determined taking into account the maximum permissible heating of the transformer winding and the voltage loss occurring therein.
When planning resistance welding systems, the responsible energy supply company (EVU) should always be consulted.

4.8.2 Performance data, parameters

DIN ISO 669 defines important parameters of resistance welding equipment.

- Nominal voltage in V:

  Nominal primary voltage of the welding device (mains voltage).

- Rated power in kVA:

  The operating power characteristic of the resistance welding device at X = 50% ED (acc.ISO the continuous power at X = 100% ED is increasingly defined as the rated power).
  When using only one transformer in a machine, this power corresponds to the rated power of the transformer at X = 50 % ED.

- Short-circuit power in kVA:

  Product of nominal voltage and primary side machine circuit current. This value can be measured for short-circuited welds (without welded part) (see4.3.2).

- Connected load in kVA:

  Power specification for the design of the connection (*supply lines, switchgear, etc.*). It is not only based on the permissible heating, but also takes into account the voltage losses at the line resistors.
  The connected load is calculated to be about 60% of theshort-circuit power. The design is different for the different resistance welding processes and thus represents only one orientation.

- Maximum welding performance in kVA:

  Product of maximum primary current (*during welding*) and nominal voltage. This value corresponds to about 80% of the short-circuit power.

Depending on the type and operating conditions of a resistance welding system, the calculation of connection cross-sections and the design of switchgear will be based either on the maximum permissible voltage loss of the supply lines or on the maximum permissible heating (*VDE 0100*).
The permissible voltage loss is determined by the maximum welding power (*short-term peak power*), the heating in turn results from the expected equivalent continuous power.
For the design of the circuit breakers and overcurrent protection devices of welding equipment, the nominal power of the system is used. The setting of the overload and short circuit triggers depends on the specific operating parameters of the welding device.

5 Structure and function of transformers

5.1 Design of a transformer

EXPERT welding transformers have a characteristic design regardless of type. The secondary winding is flowed through by the cooling water, and is therefore directly water-cooled. The primary winding and the iron core are cooled indirectly. The cooling water connection is directly potential-bound with the secondary circuit of the transformer. There is a secondary voltage difference between the cooling water inlet and outlet.

⚠	**Danger due to potential-bound cooling water connections** When simultaneously touching or bridging cooling water inlets and outlets with metallic objects, e.g. tools, this can lead to very high short-circuit currents. There is a risk of injury due to burns or metal splashes.

The primary winding of the transformer can be provided with taps.
By switching individual turns on or off, the level of the secondary voltage can be changed in several stages. The total setting range is general and can be extended to 1:2 in special cases.
Due to this special feature, higher voltages than the connected mains voltage occur at the unconnected connection terminals of the primary winding in accordance with the economy transformer principle.
Depending on the operating range of the transformer and the selected voltage level, voltages up to 2 times the mains voltage can occur at the non-connected terminals!

⚠	**Danger due to voltage transformation** With multi-stage transformers, voltages up to 2 times the mains voltage occur at the unconnected connection terminals on the primary side of the transformer, depending on the winding structure! This circumstance must be observed, for example, for measurements under voltage

5.2 Auxiliary circuits

The transformers can be equipped with monitoring devices *(e.g. temperature, welding current, secondary circuit, voltage monitoring)*.
The integration of such auxiliary circuits into the transformer avoids the need for sensitive cables and sensors to be additionally installed in the secondary circuit.
The risk of contamination and damage does not exist in this case.

5.2.1 Temperature

Bimetal switches with double contact interruption are used as temperature monitors. The contacts are used as openers.
Typical design:

Mechanical service life:	10^4 (according to VDE test class 1)
Rated insulation voltage:	1.5 kV
Maximum ambient temperature:	+180°C (in operation)
Rated Voltage:	250V AC / 50-60Hz
Rated current:	2.5 A at $cos\varphi = 1$
	1.6 A at $cos\varphi = 0{,}6$
Switching number:	10,000 cycles

The contact design is current-insensitive, i.e. the response temperature is independent of the current load. As standard, two temperature monitors with a response temperature of 140°C per transformer are attached to the primary winding and poured in.
On request, PTC temperature sensors, temperature measuring resistors or thermocouples can also be installed to monitor the transformer temperature. Due to the compact mass of the transformers, operational temperature changes are associated with correspondingly large time constants. This means that the temperature compensation is very slow. Built-in temperature monitors therefore only signal an overload of the transformers or a lack of sufficient cooling. The temperature monitors are not able to react or trigger short-term overload.

5.2.2 Welding current monitoring, constant current control (KSR)

On order, most EXPERT transformers can be supplied with built-in toroid measuring coils. These are air induction coils arranged concentrically around the secondary conductor. In these coils, a measuring voltage directly proportional to the welding current is induced. The standardized measuring voltage is 150 mV/kA at a load resistance of $1k\Omega$ (input resistance of the evaluation electronics).
This induced voltage can be used as an actual current value in conjunction with suitable welding controls for current control. The use of constant current control (KSR) is particularly suitable for the use of robot welding guns.
EXPERT transformers with toroid measuring coils can be connected to all KSR systems with standard calibration for current-actual value acquisition.
The toroid measuring coils used for EXPERT transformers have a basic accuracy of $\pm 1{,}5\%$, after installation the calibration accuracy for the standard types is $\pm 3{,}0\%$.
The measuring coil is usually connected by plug-in or terminal connections on the primary side of the transformer.
For transformers with 2 secondary circuits (A and B side), a toroid measuring coil is installed per circuit, i.e. each built-in measuring coil provides a voltage signal proportional to the current in the respective secondary winding.
If the secondary windings are interconnected (e.g. series or parallel connection), the toroid measuring coils must also be connected accordingly in order to obtain a measurement signal corresponding to the resulting welding current (see 4.4).4.4

5.2.3 Secondary circuit monitoring

The direct connection of the secondary winding of resistance welding transformers with the protective conductor as a possible protective measure in accordance with VDE 0545 Part 1 (EN50 063) leads to compensatory currents via the protective conductor connection in some systems. In this case, another protective measure must be applied.
For this reason, various suppliers offer quick shutdown systems for secondary circuit monitoring. The principle is based on the FU procedure. This means that when a threshold value of a fault voltage is reached, the system is switched off via an evaluation electronics.
The necessary measuring cables on the secondary circuit of the transformer are installed in the transformer at the customer's request and routed outwards via a suitable plug-in system or connection terminals. To protect against interruptions in the fault voltage measuring line, this is usually designed as a double line and flowed through by a quiescent current.

5.2.4 Chassis Monitoring

In accordance with the principle of secondary circuit monitoring, housing monitoring can also be implemented.

6 Transport and storage

The transformers are inspected and properly packed before shipping. Upon arrival, the transformer must be inspected for any transport damage. Any damage that has occurred must be notified to the carrier or forwarding company .dem immediately. Later complaints can no longer be considered.

6.1 Transport

Due to the high weight in relation to the volume, the transport of transformers must be carried out with suitable aids. In case of improper transport, the device may tilt or fall. There is a risk of injury.

	Danger due to improper transport! Use only suitable transport aids! Don't stay under floating loads! There is a risk of injury from squeezing, shearing, cutting, bumping! The transformer itself can also be damaged.

<u>General protective measures:</u>

- Use appropriate transport facilities.
- Prevent entrapment and crushing by taking appropriate precautions.
- Use lifting devices (*observe permissible payload*) and tools professionally.
- use appropriate protective equipment (e.g. safety shoes, protective gloves).
- Do not stop under floating loads.
- Remove any leaking coolant immediately (*risk of slipping*).

<u>Transport aids:</u>

Proper transport is usually only possible with suitable aids such as hoists, cranes, forklifts and transport trolleys. If hoists are used for transport, the eye bolts may only be attached to the attachment holes

	Load on the eye bolts: Note the maximum loads for eye bolts according to DIN 580.

provided for this purpose.

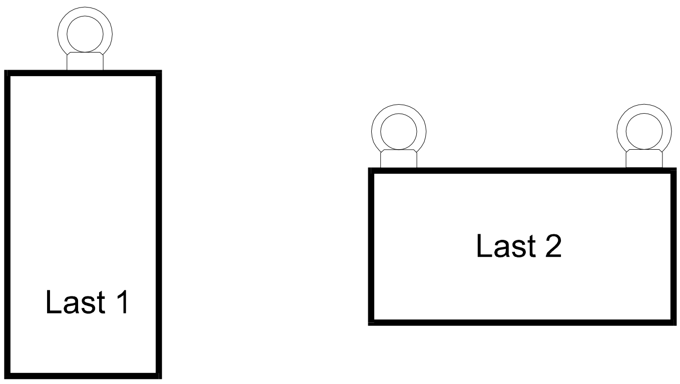

Figure 1Variants for attaching the transformers

DIN 580 specifies the maximum permissible loads for eye bolts. There are two basic ways to lift the transported goods (*see Figure 1*).

- with an eyebolt (load 1)
- with two or more eye bolts (load 2).

It should be noted that the load information always refers only to a eye bolt.

Thread	Load 1 in kg	Load 2 in kg
M8	140	95
M10	230	170
M12	340	240
M16	700	500

Table 6.2 Maximum load values for eye bolts according to DIN 580

6.2 Storage

If transformers are exposed to strong external magnetic fields, such as in the immediate vicinity of induction furnaces, solenoids, etc., these fields can induce voltages in the windings of the MF-TGE. Depending on the nature and design of the transformers, it cannot be ruled out that these induced voltages may assume unacceptably high values. Storage in the sphere of influence of large alternating magnetic fields is therefore not permitted.
The following general conditions apply to the storage of EXPERT transformers.

Storage:

Permissible bearing height above N.N.:	no restriction
Permissible ambient temperature:	- 25 to +60 °C, (emptied water circuit)
Permissible relative humidity:	20 to 85% (no condensation)
Stack height:	max. 2 transformers flat on top of each other, if necessary, pay attention to protruding screw connections.

⚠	**Danger of frost damage!** When water-cooled transformers are stored below freezing, cracks can occur in the cooling pipe. Be sure to completely empty the entire water circuit of the transformer (blow-out).

7 Installation, electrical connection, and commissioning

Failure to observe the following information may lead to the exclusion of the warranty by EXPERT Transformatorenbau GmbH in the event of damage.

⚠	**Requirements for assembly personnel:** The electrical connection (assembly) as well as the subsequent commissioning may only be carried out by electrical personnel!

7.1 Installation and electrical assembly

Please note the following:

- During the handling and assembly of transformers, hazards occur due to the relatively high weight.

⚠	**Danger due to improper handling!** There is a risk of bodily injury from squeezing, shearing, cutting, pushing!

- The installation locations and fasteners must be designed for their weight.
- Suitable assembly and transport equipment must always be used.
- Lifting devices and tools must be used professionally. The permissible payload must be observed.
- Make sure that the connections remain accessible to the primary, secondary, and auxiliary circuits.
- The nameplate should be readily visible or thetechnical data should be repeated in a visible place.
- The cooling water connection must be carried out professionally. The cooling water connection points on the transformer may have potential differences. In order to avoid a short circuit via the water connections, only non-conductive hoses or pipes with a length of at least 0,5 m and an electrical resistance of at least 1MΩ/m may be used. The specific resistance of the water column should be at least 20 Ωm.
- Check the cooling water connection for tightness and function.
- The electrical connection may only be carried out by an electrician.

Explanation of the term "specialist":

- Anyone who has knowledge and experience as well as knowledge of the relevant standards for the work assigned to him based on his professional training is a specialist. A passed professional vocational training as a skilled worker, master craftsman, technician or engineer are regarded as proof of the required professional training. A specialist must also be familiar with the standards applicable to the respective field of activity and have sufficient experience in a particular field of work to be able to assess transferred work and identify hazards. Furthermore, the specialist is trained, instructed or entitled to switch on and off, ground and mark circuits and devices in accordance with the provisions. She has adequate equipment and is trained in first aid.

- The connection surfaces of the primary and secondary conductors must be flat and contact flat.
- The primary-side connection pins/contact pins shall be tightened with a torque wrench. Depending on the order request, threaded or contact pins are loosely enclosed with most transformer types.
- Tightening torques are Table 7.2 Screw connections for electrical connections with different material pairing (expressed in Nm for screws and nuts strength 8.8)recommended according to Table 7.1-7.3.
- All live parts must be covered and thus secured against direct contact.
- In the case of screw connections, the following tightening torques must be observed and checked:

Thread	M5	M6	M8	M10	M12	M16	M18	M20
Tightening torque / Nm	5,75	9,9	24	48	83	200	275	390

Table 7.1 Tightening torques, generally for housing mounting of MF-TGE

Thread	Cu flange / Cu Rail	Cu flange/ Cu flexible	Contact piece/ Cable lug
M5	5,5	5,5	5,5
M6	9	9	8
M8	23	23	20
M10	45	45	42
M12	85	85	80
M16	160	160	150
M18	220	220	200
M20	250	250	220

Table 7.2 Screw connections for electrical connections with different material pairing (expressed in Nm for screws and nuts strength 8.8)

Wiring pin	Torque / Nm
M6	6,0 +0,5
M8	15.0 ±1.0

Table 77.3 Tightening torques for mounting contact pins in clamp transformers with plug-in system from Multi-Contact

There is currently no standard regulation for maximum permissible tightening torques of Cu screw connections. The tightening torques listed in Tables 7.1 to 7.3 were determined experimentally. Make sure that there are no overstresses on the Cu screw connections . Tightening too tightly can lead to deformations due to the flow behavior of copper.

7.2 Permissible environmental conditions

Transformers are usually delivered as components to be processed on the primary and secondary sides in protection class IP54 or IP00. The information on the respective data and dimension sheets is valid.
Use in potentially explosive atmospheres is not permitted.

The following environmental conditions apply to operation:

Permissible guaranteed installation height:	1000m N.N.
Permissible ambient temperature:	+ 5 to + 40 °C
Cooling water temperature:	max. 30°C (flow)
Permissible relative humidity:	30 to 95 %

8 Notes on the operation of transformers

8.1 Cooling water quality

If the cooling water quality is insufficient, the function of the transformer can be significantly restricted. The use of a closed circulation cooling, in which treated water is recooled, is advantageous in any case. In order not to increase the low specific electrical conductivity of the cooling water, it is advisable to install an ion exchanger in the cooling circuit for larger systems. In the cooling pipes, metal ions, e.g. iron, copper, etc., are released into the cooling water, which increase the specific electrical conductivity of the cooling water.
In addition, the metal ions contained in the cooling water in the cooling circuit of the MF-TGE (copper tube) can form local corrosion sources according to their position in the galvanic voltage series.
Since the secondary circuit is flowed directly through by the cooling water, it should have a low electrical conductance to avoid potential carryovers.

Cooling water requirements:

- mechanically pure, filter fineness approx. 100 microns
- natural water, optically clear, without turbidity, no sediment

pH:	7-8
spec. electr. Conductivity:	max. 800 µS/cm
Water hardness:	max. 6 °DH
Iron:	< 0.3 mg/l
Copper:	< 0.2 mg/l
Zinc:	< 0.2 mg/l
Magnesium:	< 30 mg/l
Calcium:	< 80 mg/l
Sulphates:	< 150 mg/l
Chlorides:	< 50mg/l
Nitrides:	< 1.5 mg/l
Nitrates:	< 40 mg/l
Phosphates:	< 1.0 mg/l
Ammonia:	must not be detectable
Aggressive carbonic acid:	must not be detectable
Cooling water inlet temperature:	approx. 18 °C to max. 30 °C

- If appropriate inhibitors are added to the cooling water to avoid corrosion and limescale deposits, we recommend organic inhibitors, as these only slightly increase the specific electrical conductivity of the cooling water.

⚠	**Danger of overheating of the transformer!** If there is too much contamination or deposits in the cooling pipes, the heat loss cannot be sufficiently transferred to the cooling water. The specified amount of cooling water (see data sheet) must be adhered to.

⚠	**Condensation (condensation)!** The cooling water inlet temperature on the transformer should be approx. 18 °C to a maximum of 30 °C. If the cooling water inlet temperature is significantly lower than the ambient temperature, there is a risk of condensation.

8.2 Cooling water quantity, differential pressure of the cooling circuit

Water-cooled welding transformers are designed in such a way that almost all the heat generated in the windings must be dissipated via the cooling water. The heat dissipation by convection via the housing is negligible.
Depending on the continuous power of a transformer, the following maximum values for the cooling water flow rates are specified in accordance with DIN ISO 5826:

- Up to 100 kVA max. 4 l/min
- 101 to 350 kVA max. 8 l/min
- The pressure drop in the transformer may not exceed 0.6 bar (pressure difference between water inlet and outlet)

Additional pressure losses occur in the external cooling circuit (hose lines, fittings, etc.).
The differential pressure between the flow and return of the cooling circuit shall be determined by the user in such a way that the amount of cooling water recorded in the transformer's data sheet is achieved. To control the amount of water, we recommend the installation of a flow measuring device.
Depending on the amount of the transformer's own power loss, the outlet temperature of the cooling water is about 10 - 25 K higher than the inlet temperature.

⚠	**Water supply!** The cooling water inlet temperature on the transformer must not exceed 30 °C. Series connection of cooling circuits of several transformers is not permitted. **The pressure in the cooling system must not exceed 8 bar higher than the external pressure (atmosphere).**

9 Maintenance and repair

Regular maintenance and servicing of welding equipment significantly influences the quality of the welded joints to be produced and the reliability of the systems. The risk of machine and plant failures can thus be reduced.
Due to their compact and fully encapsulated design, EXPERT transformers don't require much maintenance.

9.1 Primary and secondary connections

The maintenance intervals depend on the dynamic load on the terminal connections and the degree of utilization of the machines. We recommend maintenance cycles of 4 to 6 weeks. The nature of the connection points *(corrosion and strength of the connections*) as well as the welding cables themselves must be inspected for wear or damage. Welding spatter adhesions partially form shunts at the secondary connection points of the MF-TGE. These must be removed regularly. Care must be taken to ensure that there is no damage to the MF-TGE.

- Before starting the work, the safety instructions in section 2 must be observed.1
- The transformer must be activated freely and secured against reactivation.
- In the event of damage to the primary or secondary lines (e.g. insulation or other defects), the connection cables must be replaced.
- The tightening torques of the primary and secondary connections shall be checked.
- The effectiveness of the protective measures against indirect contact in the event of a fault must be checked with suitable measuring instruments (e.g. nature and function of the protective conductor connections, function FI protection circuit or similar).

9.2 Cooling circuit

The frequency of the maintenance measures described here depends on the quality of the cooling water used.
Due to deposits in the cooling channels of the transformer, the cooling capacity can be drastically reduced. As a result, the transformer is thermally overloaded (*e.g. triggering temperature monitoring*). In addition, deposits reduce the hydraulic cross-section in the cooling channels. As a result, the pressure loss in the transformer increases.
Carrying out the cleaning work of the cooling circuit:

- Before starting the work, the ones in section 2 must be followed.1
- The cooling water supply of the transformer must be interrupted.
- The hoses for the cooling water connection of the transformer must be removed.
- The cooling circuits of the transformer are flushed with suitable solvents for the degradation of lime and scale residues. The safety and instructions for use of the solvent manufacturer must be observed. In the case of heavy deposits, it may be necessary to repeat these rinsing processes several times or to extend the exposure time.
- For the removal of deposits from the cooling circuits, commercially available agents are suitable, e.g. based on citric acid or similar.

10 Literature

10.1 Standards and regulations

DIN EN 294	Safety of machines. Safety distances against reaching danger points with the upper limbs
DIN EN 418	Safety of machines, emergency stop equipment, functional aspects, design principles
DIN EN 62135-1	Resistance welding equipment - Part 1: Safety requirements for design, manufacture and erection)
DIN EN 60204	Safety of machines – Electrical equipment of machines-General requirements
DIN ISO 669	Parameters for resistance welding equipment
DIN EN 50240	Electromagnetic compatibility (EMC) - Product standard for resistance welding equipment
DIN EN ISO 5826	Transformers for resistance welding equipment-Basic specifications for all transformers
DIN EN ISO 5828	Resistance welding equipment Secondary connection cables with connections for water-cooled cable lugs - Dimensions and characteristic values
DIN EN ISO 7284	Resistance welding equipment-Special specifications for transformers with two separate secondary windings for multi-point welding, as usual in the automotive industry
DIN EN ISO 8205-1	Water-cooled secondary connection cables for resistance welding Part 1: Dimensions and requirements for two-wire connectioncables
DIN EN ISO 8205-2	Water-cooled secondary connection cables for resistance welding-Part2: Dimensions and requirements for single-conductor connection cables
DIN VDE 0100-410	Construction of low-voltage systems – Part 4 - 41: Protective measures – Protection against electric shock
DIN VDE 0100-600	Construction of low-voltage systems – Part 6: Tests

10.2 DVS Guidelines and Information Sheets

DVS 2903	Electrodes for resistance welding
DVS 2904	Controls for point, hump and seam welding machines
DVS 2907	Recommendations for the selection and comparison of resistance point, hump and seam welding equipment as well as resistance point and seam welding equipment
DVS 2917	Operation and maintenance of resistance welding machines
DVS 2937-1	Resistance welding with industrial robots