Operating Manual

Transformer for Resistance Welding
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1 General

- This Operation Manual “Transformers for Resistance Welding” contains – apart from the Technical Description section – important information on selecting, handling, mounting & installation of EXPERT transformers and components to ensure utmost safety both for men and machine and proper functionality.

- The following regulations of the European Union apply for the product and its use as specified.
  
  2006/95/EEC Electrical Equipment for Use Within Certain Voltage limits (Low Voltage Directive)
  
  
  98/37/EEC Safety of Machines (Machine Directive)

Additionally, the national regulations for the erection and operation of electro technical facilities and safety regulations must be observed.

Please peruse section “Notes on Safety” before you start working
Damages caused by nonobservance of these notes will render void both warranty claims and liability by EXPERT Maschinenbau.

- This Operating Manual addresses following user groups:
  
  - Projects and Design
  
  - Installation and Commissioning
  
  - Maintenance and Repair
  
  - Transport and Storage
2 Notes on Safety

2.1 General Notes

- Inappropriate handling of transformers and nonobservance of the danger warnings stated here may cause damage to property, bodily harm, and may lead in an extreme case to one’s death.

- A proper and safe operating presupposes appropriate transport, adequate storage, mounting, and installation as well as careful operation.

- Skilled worker:
  A skilled worker is considered a trained person with knowledge and experience, and is well grounded in the relevant standards pertinent to the work to be carried out. A passed exam as skilled worker, foreman, technician, or certified electrical engineer is considered proof of the required professional skills. Beyond this, qualified personnel must be knowledgeable about current standards applicable for the concerning field of activity, and they must have sufficient experience in a certain scope of work to assess the work assigned to them and to anticipate dangers. Furthermore, qualified personnel are trained, instructed, and authorized to switch on or off electric circuits and to ground and mark them according to the regulations. Qualified personnel have appropriate equipment and are trained in first aid.

- Only spare parts approved by EXPERT Maschinenbau GmbH must be used.

- Furthermore, safety instructions and safety regulations must be observed for the application in hand.

- The transformers are meant for installation in machines and plants in industrial areas.

- The transformer must only be operated with the protective ground fixed at all times. This also applies to short-time operation for check and test purposes.

- Electrical terminals of the components are not allowed to be touched when activated.

- Before the transformer is switched on, live parts must be safely covered in order to prevent persons from touching them.

- Before installation and maintenance works is to commence, the machine resp. plant must be put into a condition that permits work without danger (e.g. basic position).
• The part of the machine resp. plant (including transformer) where you want to work on must be switched dead. As for transformers, you must count with reserve voltages. Take care of dangerous moving parts from neighboring system sections. If these dangers should be evident, you must switch dead the neighboring system sections too.

**Caution:** Even with the gate control switched off, semiconductor power modules (thyristors, IGBT, etc.) do not realize contact separation of the circuit! In any case, the main switch has to be actuated anyway!

• Switches that have been used for safety isolation must be secured against inadvertent reclosure. Electrical equipment must bear a warning sign e.g. “DO NOT SWITCH ON! – Repair Work in Progress – “ stating duration of repair and name of the employee in charge.

• Before you set to work on the transformer, you must ensure de-energized terminals everywhere by an appropriate measuring resp. test equipment (e.g. circuit tester, mobile voltage meter, etc.).

• The transformer primary and secondary circuits must be grounded and short-circuited.

• Cover neighboring live parts appropriately.

• You must enter machines or plants in the specified way only (e.g. by entering through the protective door).

• The supply to the cooling-water inlet for the transformer must be shut.

### 2.2 Protection for Handling and Installation

• Owing to their high weight and by improper line of procedure, handling and installation of transformers may cause injuries.

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**Danger by improper handling!**

There is danger of bodily harm by squashing, shearing, cutting, and pushing!
• Only use appropriate installation and transportation facilities at any time.
• Hoisting gear and tools have to be used professionally. Mind the allowed ultimate load.
• Take care to wear appropriate protective outfit (e.g. safety shoes, protective gloves).
• Do not stay beneath hanging loads.
• Instantly remove possibly leaking refrigerant (danger of slipping!)
• A transformer is an electrical equipment and, therefore, must not be used as tread during installation or repair work.

2.3 Protection against direct and indirect contact with electrically conductive parts

2.3.1 Protection against direct contact

EXPERT transformers operating in welding installations necessarily have certain components such as accessible parts of the welding circuit and the part to be welded itself connected to the low-voltage side of the welding transformer. On touching these parts, operating voltages up to the secondary open-circuit voltage of the transformer will occur.

These voltages are generally below the tolerance limits for permissible shock hazard voltages.

DIN VDE 0100 Part 410 determines the maximum values for touch voltages.

These are for:
• AC installations (50 – 60 Hz) \( U_L = 25 \text{ V} \)
• DC installations \( U_L = 60 \text{ V} \)

**Danger by life-threatening voltage**

If the secondary windings of one or more transformers are switched in series connection, voltages higher than the permissible ones may be generated!

When higher voltages than the permissible ones are generated by cascading, the user has to take appropriate action against direct touch (covers, safety enclosures, etc.).
2.3.2 Protection against indirect contact in case of fault

Welding transformers from EXPERT comply with DIN VDE 0551 Part 1 of safety class I. In addition to the above, further protective measures must be taken as protection against impermissible high touch voltages in case of fault (protection against indirect touch) according to EN 50 063 (DIN VDE 0545, Part 1; connecting secondary circuits with protective ground, ground-fault circuit interrupter, and the like).

Via a primary protective ground terminal, all parts of the transformer’s housing are metal-connected to protective ground.

<table>
<thead>
<tr>
<th>Protective measures against indirect touch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owing to a wide number of switching options and application of various protective measures, secondary circuits of welding transformers generally are not connected to protective ground when made ready for shipment. It will be the user’s responsibility to determine and carry out necessary and suitable protective measures according to EN 50 063 (DIN VDE 0545, Part 1).</td>
</tr>
</tbody>
</table>

Exceptions are welding transformers that are manufactured and shipped already with internal ground connection made according to general or customer-specific standards (e.g. gun transformers or special transformers for suspending equipment). This internal grounding-wire connection mostly is detachable, and is marked on the transformer.

In any case, take care of the instruction plate notes on the transformers, and the notes in the data sheets.

<table>
<thead>
<tr>
<th>Prevention of circulating currents</th>
</tr>
</thead>
<tbody>
<tr>
<td>If the required protective measure is realized by directly connecting the secondary circuit to protective ground, it will be up to the user’s responsibility to ensure for more complex welding installations that circulating currents (crossover currents) may not occur via protective ground connection due to potential transfer during the welding process.</td>
</tr>
</tbody>
</table>

| Protective ground must not be live under field conditions! |

Transient current e.g. may occur if several welding power supplies weld together on a common work piece, and if welding is made on an additionally grounded work piece with already grounded transformer.
When putting the welding station into operation, you must check to ensure by appropriate measuring equipment (e.g. current probe) that the protective ground conductor is not live.

Transient currents must be principally avoided as they may disrupt the internal grounding-wire connection in extreme cases. A disruption of the grounding-wire connection cancels the protective measure and may endanger human life’s!

If you cannot avoid transient currents due to direct connection of the secondary circuit to protective ground, the protective-ground connection may be neutralized for most of the transformers.

As alternative, however, another protective measure according to EN 50 063 must be installed instead.

For further inquiries please turn to the addresses stated on the reverse side.

2.4 Protection from the influence of electromagnetic fields

You will experience more or less strong magnetic fields during resistance welding that physically depend on whatever the amperage has been. Owing to the amperage, the strongest concentrations of magnetic fields mainly develop in the area of the secondary lines.

This must be considered designing resistance welding plants, and when setting up operator’s consoles.

Avoidance of possible excess of permissible electromagnetic radiation at the place of work must, if needed, be verified by measuring.

In a wide frequency range and depending on kind and functioning of the power setting (e.g. phase angle control), conducted and radiated spurious radiation from electromagnetic waves develop besides of the formation of magnetic alternating fields.

The regulations for EMC guidelines apply for that matter.
Danger by the influence of electromagnetic fields

Individuals with auxiliary medical devices (such as pacemakers, etc.) must **NOT** stay in the vicinity of the welding facilities and their power supply lines! There is danger of dysfunctions that might cause death or severe health injuries.

**Additional notes:**

- You must observe the limit values for electromagnetic radiation (VDE 0848 Part4 A2) when erecting welding machines and welding installations.
- Provide appropriate protective devices (e.g. shielding) if need be and mind concerning safety distance for the operator consoles.
- In the vicinity of the welding machine resp. welding installation, information on magnetically stored data media (e.g. tapes or video tapes, Money Cards, etc.) can be deleted or changed.
- The magnetic fields that develop during welding can damage precision-mechanical products like watches.
- In the very vicinity of a welding circuit, currents can be induced in metallic objects (also jewelry, e.g. rings or necklaces) depending on the strength of the magnetic field. This can lead to local heating of the metal parts (danger of burns).
3 Technical Data

3.1 General

Common resistance welding procedures such as spot, projection, or pulsed current arc welding are characterized such that the energy for welding is not applied continuously but pulsed onto the point of weld (see also section 4.2). The welding times required are mostly less than 1 second. Between the welding pulses, there are more or less process-bound intervals. This operation mode (intermittent operation) allows the transformer used as welding power supplies to be subjected to a calculated overload, meaning that much higher pulsed currents may be drawn without thermally overloading the transformer during a short period of time as opposed to the permissible continuous currents for a transformer. This allows manufacturing of cost and weight optimized welding transformers tailored to the concrete application. However, on the other hand this means that the calculated overload of these transformers must be precisely defined to ensure safe operation. DIN ISO 5826 describes the overall scheme:

The on time $X$ in percent is the essential characteristic for intermittent operation, i.e. the sum of all conduction intervals in relation to clock time $T$. The ratio can assume a value between 0 and 1, and is specified in percent (also see section 4.3.1).

The technical data of the welding transformers are stated in the pertinent data sheets. Welding transformers are subject to technical modifications made in the interest of technical progress. If required, please ask us for the current dimensional drawing.

3.2 Information on type designation plates

From the type designation plate on EXERT’s welding transformers, the user will receive important information.
Figure 3-1 Type designation plate of a welding transformer from EXPERT

Explanation of the electrical characteristic values:

$S_n$ at 50% ED  
Rated output of transformer at X = 50 % duty factor (specification of full-rate power possible, v. section 4.3.1)

$U_{in}$  
Nominal supply voltage, number of phases and specification of nominal frequency

$U_{20}$  
Secondary open-circuit voltage, number of voltage steps

$S_n$ at 50% ED  
Secondary rated current at X = 50 % duty factor

$u_{cc}$  
Impedance voltage of transformer in percent

$\cos \varphi_{cc}$  
X / R ratio of transformer

$Q$  
Required cooling water in Liters/min, max. 30 °C
4 Using the transformer as specified

EXPERT transformers have been specially developed and manufactured to be used for resistance welding.

General design and technical dimensioning are according to ISO5826, ISO669, and ISO10656. Type-specific standards beyond have been considered.

Danger by using the transformer not as specified

Using the transformer not as specified can result in injuries to persons, and property as well as environmental damages. Due to high short-circuit currents and their associated high welding energies the danger of material evaporation will exist. Only use the transformer the way they have been designed for.

4.1 Field of applications for transformers

The transformers are supplied as sealed-tank type (resin filling), i.e. the windings are protected optimally against humidity, dirt retention, and effects of electrodynamic forces. Encapsulation of the primary terminals is carried out as IP 54 as standard. The protection class for the secondary terminals is IP00 (open terminals).

Exceptions are gun current transformers according to ISO10656 being supplied with their primary terminals in IP00 too.

The transformer must not be operated at locations subject to explosive hazards. Please observe the permissible environmental conditions.

System of protection

The transformers must only be used and operated at locations that correspond with the specified system of protection (according to data sheet). These transformers must not be operated at locations subject to explosive hazards.
4.2 Materials for resistance welding, methods of resistance welding

Definition of resistance welding: DIN 1910 Part 5

The required heat for welding is generated by current flow through the electrical resistance of the welding zone (resistance heat, Joule effect). Welding is carried out with or without force and with or without filler metal.

As for the above definition, the minimum requirement for material to be welded is that it must be electrically conductive. Furthermore, the material must be weldable when in kneadable condition.

Suitable materials:

- uncoated steel sheets in different strengths (often up to 3.0 mm)
- coated steel sheets, e.g. galvanized
- nichrome steel
- nonferrous metals, e.g. aluminum, copper, and silver

Danger be using wrong material
Bodily harms resp. damage to machines can result if non-weldable and not recommended materials are used due to their non-foreseeable reactions on induction of welding energy into the material.

“Welding processes are determined by the kind of the external energy source having effect on the work piece, the kind of base material, the purpose of welding, the physical process of welding, and the kind of production.” (DIN 1910 Part1)

The most common resistance welding procedures are:

- Spot welding

Concentration of current at the welding spot is determined by the shape of the electrode. The welding current would be applied into the welding spot pulsed.
• Seam welding:
Concentration of the current in the seam is determined by the shape of the seam roller (track width and reel diameter of the pair of reels). The welding current can be applied into the seam both pulse-shaped or continuously.

• Projection welding:
Concentration of current at the welding spot is determined by the shape of the projection. Like spot welding, the welding current would be applied into the welding spot pulsed.

• Butt-seam welding:
The current density should be even and equal across the entire mating surface of the two work pieces. The locations of the joints are heated by the welding current induced until the temperature required for welding is reached. Afterwards, the parts are continuously pressed together or an operation program is run.

4.3 Dimensioning welding transformers
Two important criteria must be observed to dimension transformers correctly.

• thermal dimensioning (determination of the equivalent secondary continuous current).

• short-circuit dimensioning (determination of the required secondary voltage).

4.3.1 Thermal dimensioning
The power stated in the dimensional drawings is the measure of electric energy that transformers can pick up per unit of time and deliver – reduced by efficiency – without exceeding the allowed temperature limits. Most older standards state the nominal power at an on time of 50 % which corresponds with about a \( \sqrt{2} \) fold full-load power. Only later standards (e.g. DIN ISO 7284) define full-load power as nominal power.

While the full-load power of a transformer corresponds with the power installed, i.e. the power capability on the base of which the aggregate was dimensioned, performance assessment at an on time of 50 % is a mere arithmetical value without relationship to practice, since but in the least of cases welding is carried out with an on time of 50 %.

Transformers for resistance welding are employed as current source in most cases. It is, therefore, reasonable to dimension by secondary currents. For continuous duty, the
values given in the dimensional drawing can directly be taken as maximum values (provided that the magnetic circuit was dimensioned for continuous duty).

Intermittent operation common for resistance welding allows a short-time overload of the transformer. Depending on the duty time and the perspectives from DIN ISO 5826, one can conclude from both the continuous currents and currents at 50 % any max. load current. The maximum overload capacity for transformers up to 100 kVA is nine times the continuous current. This value reduces itself for larger transformers because of their limited mechanical stability. For gun transformers, the value should not exceed the continuous current by 5 or 6 times.

There are following interrelationships according to DIN ISO 5826:

\[ I_{2x} = I_{2p} \sqrt{\frac{1 - e^{-\frac{T}{\tau}}}{1 - e^{-\frac{X\cdot T}{100\tau}}}} \]
\[ I_{50} = I_{50} \sqrt{\frac{1 - e^{-\frac{50\cdot T}{100\tau}}}{1 - e^{-\frac{X\cdot T}{100\tau}}}} \]

Legend:

- \( I_{2x} \) - max. secondary current with a duty time \( X \)
- \( X \) - duty time/\% (sum of all current-flow times in relation to clock time \( T \))
- \( I_{2p} \) - secondary continuous current of transformer
- \( I_{50} \) - secondary current at 50 \% duty time
- \( T \) - clock time (cycle time)
- \( \tau \) - thermal time constant of transformer

Since the above mentioned, formal interrelationships are usually not practical for the user, the following simplifications will help.

If the ratio is \( \frac{\tau}{T} \geq 5 \), calculate by the following simplified equations:

\[ I_{2x} = I_{2p} \sqrt{\frac{100}{X}} \]
\[ I_{2x} = I_{50} \sqrt{\frac{100}{2X}} \]
Example:
In the course of one cycle time of 30 seconds, 5 spots must be welded with 15 kA, 12 periods; 3 spots with 8 kA, 5 periods, and 2 spots with 10 kA, 10 periods.

What strength the required equivalent secondary continuous current $I_{2p}$ of the transformer must have?

Solution:

1. determination of welding time $t_s$:

$$t_s = \frac{N}{f} \quad [s]$$

$N$ - number of welding cycles

$f \ [Hz]$ - frequency of mains

2. determination of duty time $X$

$$X = \frac{\sum_{k} t_s \times 100\%}{T}$$

$$X = \frac{5 \cdot 12 \text{Per} + 3 \cdot 5 \text{Per} + 2 \cdot 10 \text{Per}}{30 \cdot 50 \cdot \frac{\text{Per}}{s}} \cdot 100\%$$

$$X = 6.3\%$$

2. Determination of the equivalent secondary continuous current $I_{2p}$ (geometric mean):

$$I_{2p} = \sqrt[n]{I_{2x1} \cdot I_{2x2} \ldots I_{2xn}} \cdot \frac{X}{100}$$

$n$ - number of spots / cycle

$$I_{2p} = \sqrt[6]{(15\text{kA})^5 \times (8\text{kA})^3 \times (10\text{kA})^2} \cdot \frac{6.3}{100}$$

$$I_{2p} = 2.9\text{kA}$$
In practice, determination by the geometric mean is not always simple. Because the various welding currents \( I_{2x} \) are within the same range, calculation of the arithmetic mean is permissible:

\[
I_{2p} = \frac{\sum I_{2x_n}}{n} \sqrt{\frac{X}{100}}
\]

\[
I_{2p} = \frac{5 \times 15kA + 3 \times 8kA + 2 \times 10kA}{10} \sqrt{\frac{6.3}{100}}
\]

\[
I_{2p} = 3.0kA
\]

The secondary continuous current of the employed transformer must be minimum 3.0 kA. Differences in the results of both calculation methods are negligible in this case.

### 4.3.2 Determination of the required secondary voltage of a transformer

For its operation, the transformer employed has to be dimensioned concerning maximum secondary continuous current such that the permissible temperature rise will not be exceeded (see section 4.3.1).

To reach the desired maximum welding current it is, furthermore, necessary to determine the required secondary open-circuit voltage of a welding transformer according to the impedance of the welding circuit.

The secondary open-circuit voltage as driving source determines, in connection with the no-load losses of a transformer resp. a complete welding installation, its short-circuit properties.

One distinguishes between a transformer short-circuit current and a machine short-circuit current. Both short-circuit currents shall be illustrated in the following.

**Transformer short-circuit current:**

The current is only limited by the no-load losses of the transformer. At the same time this is the maximum current that theoretically might be drawn from the transformer at
nominal primary voltage of a given ideal, loss-free supply. The transformer short-circuit current would be drawn if the secondary terminals would be short-circuited under the conditions mentioned. This means that the outside impedance would be very small, reaching zero. Therefore, the transformer short-circuit current is a mere arithmetical reference unit, and can only be determined by indirect measurement. That is stated in the data sheets for the EXPERT transformers.

Short-circuit current of a machine:

The machine short-circuit current is the maximum possible current that can develop in a welding machine. It is limited by the resistances of the power lines, the transformer, the secondary cables, of conductor railings and electrodes, etc. as well as their inductances. The impedance resulting therefrom is a measure of the total losses of the installation. This current can be measured on the machine online as real value.

Depending on the size of the parts to be welded, overhang and horn spacing of the secondary arrangement (welding tongs, tools for multiple electrode spot weld, etc.) must be appropriately designed; size, electrical cross sections, and conductivity of the material used have determining influence on the impedance and thus the losses in the welding circuit. With the electrodes short-circuited and at nominal primary voltage, a maximum current depending on the impedance of the arrangement will be drawn (machine short-circuit current, also known as tongs short-circuit current for welding tongs).

If steels sheets to be welded are between the electrodes, the impedance of the secondary circuit will additionally rise. The maximum attainable welding current will be approx. 10–20 % below the machine short-circuit current as a rule. This means that but 10 – 20 % of the energy applied will be directly used for the welding process.

The impedance of the welding circuit is composed of an ohmic and an inductive part. The ohmic part can roughly be determined from the cross-sectional areas, length, and conductivity of the material used. For alternating currents, the frequency influences on conductivity must be considered too.

Essentially, the inductive part results from the geometric shape of the welding circuit, and is largely material-independent.
Determination of welding-circuit inductance, too, is only approximately possible via calculation models for idealized geometric shapes inductances. There is a rule that says the smaller the area enclosed by the welding circuit (size of the welding “window”) the smaller the inductance of the circuit.

Gathering of the impedance of a secondary circuit via measurement of the maximum attainable welding current is faster and more precise. This procedure can be applied for installations already erected.

In approximation:

\[ Z_L = \frac{U_{20}}{I_s} - \frac{U_{20}}{I_{2CC}} \]

Legend:
- \( Z_L \) - Impedance of the entire secondary circuit
- \( U_{20} \) - transformer open-circuit voltage (see data sheet)
- \( I_s \) - maximum attainable welding current (welding-current meter)
- \( I_{2CC} \) - transformer short-circuit current (see data sheet)

When designing welding installations, and since resistance welding has a low energy utilization it will be essential always to take care of shortest possible wiring and minimizing of the area enclosed by welding cables and electrode holders (“welding windows”). High losses mean high running costs.

The data sheets of the standard EXPERT transformers comprise load characteristics (Figure 4-1) that describe the two-terminal performance \( I_{S_{max}} = f ( Z_L ) \) of the transformers.

To simplify preparation of the diagrams we assumed the power factor \( \cos \varphi \) to be nearly equal both for the transformer and the welding circuit (ratio of active power to apparent power).
**Note:**
You have to observe that the currents stated are those max. attainable ones in **intermittent operation** at a certain overhang, and which are only limited by the impedance of the outside wiring. This consideration is independent from the thermal conditions inside the transformer. Depending on amperage, concerning interval times must be considered according to the thermo properties of the transformer! (see also section 4.3.1)

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*Figure 4-1*  **Load characteristics** $I_{S_{max}} = f ( Z_L )$ of a transformer for resistance welding

By means of these diagrams you can determine the max. attainable welding current $I_{S_{max}}$ in dependance on the impedance of the load circuit $Z_L$ (i.e. vectorial sum of all resistances and reactances connected to the secondary side of the transformer).

As per definition, the functional value at point $Z_L = 0$ corresponds to the short-circuit current of the transformer.

As the example (*Figure 4-1*) shows, the max. attainable welding current is approx. 14 kA for a secondary impedance of approx. 250 $\mu\Omega$.

In reversal conclusion, these load diagrams are apt for an approximated determination of the secondary circuit impedance by measuring the max. attainable welding current, and then obtain the value of $Z_L$ from the load diagram of the transformer used.

---

Please note for transformers with 2 secondary circuits that the transformer short-circuit current has different values for the various wiring models (parallel, single, series wiring). The technical data sheets will mostly show the values for parallel wiring only. For different wiring please take the short-circuit currents from the pertinent diagrams.
Concerning its max. attainable secondary current, the load diagrams make selection of a suitable transformer easier, if you know the impedance of the welding circuit. In doing so you should take care to always include a reserve welding current of minimum 30% in order to make good for signs of wear of secondary cables and terminals that can cause higher resistance of the welding circuit. Additional current reserves, e.g. are necessary for shunts via neighboring welding spots and utilization of stepper functions.

Load diagrams are calculated from the pertinent data of the concerning transformer. AC power dips are not considered in this case. If you have to expect larger AC power dips of more than 5% due to long power lines, etc. you must plan additional reserves for welding current.

### 4.4 Wiring models for transformers

Depending on their design, welding transformers have one resp. two secondary windings. There is a possibility for transformers with two separate secondary windings to build up one resp. two separate welding circuits at choice.

If you need only one welding circuit, you can use parallel wiring (single voltage, max. current) resp. series wiring (double voltage, half current) of the transformer secondary windings depending on requirements.

To avoid transient currents via the transformer windings, single transformers must not be parallel-connected on their secondary sides.

**Exception:** Parallel connection of the secondary windings of one transformer described below is feasible owing to a symmetric windings design of EXPERT transformers.

### 4.4.1 Connecting a secondary circuit / parallel wiring

For transformers with two secondary windings (A and B side), you can always use parallel wiring of the secondary windings, if you want to use only one secondary circuit for welding, and a single secondary voltage will do to attain the welding current required. This will grant you an even current split for the single windings in the
transformer, the no-load losses of the transformer are minimized, and efficiency of the welding installation is improved.

Since both incorporated measuring coils for the CCC (constant-current control) signal sense the partial currents of the shunt-connected secondary windings, the sum of both measuring signals represents the measuring voltage for the transformer’s total current. This is attained by series-connecting both measuring coil outputs in correct phase sequence (also see section 5.2.2).

Should several welding circuits be run by one transformer (single secondary voltage), we also recommend shunting of both transformer outputs, and to carry out welding in sequential order such that only the active of the welding cylinders is closed. Thus a defined welding current can be realized for each welding spot. Operation with CCC is possible without problems too.

However, we do not recommend to connect e.g. 2 welding circuits separately to one secondary winding (A resp. B side) of a transformer at a time.

If simultaneous welding via both welding cylinders were performed, a defined attribution of welding currents would not exist due to a possibly unsymmetrical current division.

If the welding cylinders are controlled one after the after, this will avoid undefined current division yet at the sacrifice of higher transformer losses. Furthermore, there is only a qualified CCC function possible for one of both sides because only one current-measuring coil can be connected to the usual welding controls.

### 4.4.2 Series connection

Secondary voltages add up when both secondary windings are series-connected. According to the power budget, the max. permissible welding current, however, is only half of the maximum current as would be in shunt connection in this case.

For feedback of the current actual value to a CCC, only either of the toroid measuring coils has to be connected. Because both measuring coils would measure the same welding current it will be unimportant which coil to use. The unused coil can remain unwired.
4.5 Operation of transformers under different mains frequencies

As a rule, transformers may be operated under a slightly higher operating frequency without negative influence on performance. This, too, applies for transformers with nominal frequency 50 Hz that are operated with 60 Hz (frequency rise by 20 %).

Because of the higher frequency, losses will insignificantly rise in the transformer windings depending on type (approx. 2 – 3 %), however, these are negligible if the transformer is properly cooled according to data sheet specification, and have a water feed temperature of max. 30 °C.

Due to the frequency rise, losses in the core bar will also rise yet little. Because core geometry is maintained, however, this effect will be compensated by a transformer induction lowered by 20 % at 60 Hz so that the absolute, mass-related core bar losses will even drop at 60 Hz.

Thus a transformer with a nominal voltage of 380 V / 50 Hz can run with a nominal voltage of 380 V / 60 Hz without problem.

However, the reverse case is not possible without problems!

Technically, furthermore, it is feasible to run a 50 Hz transformer at 60 Hz with the mains voltage increased by 20 % (480 V / 400 V = 60 Hz / 50 Hz = 1.2).

Therefore, a transformer with a nominal voltage of 400 V / 50 Hz can be connected to 480 V / 60 Hz.

When operated in a welding installation (e.g. robot electrode holder) with a higher frequency, however, both tongs impedance and self-impedance of the transformer will rise.

Essentially this may be attributed to the nearly linear rise of reactance in tongs and transformer depending on frequency as well as frequency-dependent skin effects in conductors, electrode holders and electrodes. The impedance of an electrode holder operated at 60 Hz will rise by approx. 10 % compared with 50 Hz (increasing reactance) depending on cos φ of the tongs.

Depending on the design of the electrode holders, this value can rise by further 5 – 10 % owing to the skin effect which in extreme cases lowers the max. attainable tongs short-circuit current by approx. 15 – 20 % at 60 Hz as compared with 50 Hz.
However, if the 400 V/50 Hz transformer is run with the max. permissible primary voltage of 480 V/60 Hz, the secondary voltage will also rise in a ratio of 480 V/400 V = 1.2.

The higher driving voltage will then allow to draw nearly the same tongs short-circuit current as would be with 400 V/50 Hz.

For further inquiries on this subject please contact one of the addresses stated overleaf.

4.6 Requirements on welding-current controls

As for transformers in resistance welding installations, they considerably differ from power and supply transformers concerning their operating mode. Depending on the welding process, the transformer is switched on and off in fast sequence, mostly with repetitive action after a couple of mains cycles. The amperage of the welding current is mostly controlled via phase angle control during the power-up phase.

If an inductive load (e.g. transformer with connected welding circuit) is switched on, there will be high, physical-related inrush peaks in connection with transient aperiodic components. On the other hand, the current will decay more or less swiftly on account of energy storage and associated time constant.

These are the reason why welding-current controls for resistance welding are subjected to high demands:

- to reduce inrush peaks and minimize transient aperiodic components, the first half cycle of the first period must have a fixed cut-in delay greater than the phase angle (approx. 70 to 90 degrees).
- Since resistance welding transformers run at very high magnetic inductions near to saturation there are very high demands concerning synchronization and symmetry of phase angle control. The primary current must be almost free of aperiodic components across the entire control range.
- Conditional on transformer and welding circuit inductance, there will be always a phase shift between current and voltage (current lag by phase angle $\varphi$). This effect causing a delayed thyristor turn-off is termed as “inductive overhang”. The counter half-cycle thyristor in antiparallel configuration can only fire after a positive anode voltage has built up against its cathode. This means in practice that under inductive load the theoretically available control range of 180° is reduced by the “inductive
overhang”. Most of the manufacturers of welding controls factory-adjust the minimum firing angle such that a close sinusoidal wave will develop at a \( \cos \varphi \) of 0.86 corresponding with a load angle of 30°. This corresponds with a power scaling of 100%. If \( \cos \varphi \) is below 0.86 for a machine resp. electrode holder, the current control range will be “clipped off” in the upper values. To correct the control range, many controls allow a \( \cos \varphi \) modification to correct the control range.

- The power module of a welding control must be designed to cope with the occurring high pulse peaks including over current protection device.

For running EXPERT welding transformers please exclusively use controls specifically designed for resistance welding.

For further inquiries on this complex of problems please contact one of the addresses stated overleaf.

4.7 Actions of force in the welding circuit, secondary terminals

When dimensioning secondary circuits within the scope of the welding installations for resistance welding you must allow for actions of force and resulting mechanical stress due to high welding currents.

Because of the magnetic field, current-bearing parallel conductors are subjected to attracting forces under equal current direction, and to repulsive ones when in opposite direction.

In a closed welding circuit, the direction of force action during the welding process is such that the conductors forming the welding circuit will always try to occupy a larger area. Depending on amperage, thus very high actions of force can come about.

If e.g. a current \( I = 25kA \) traverses two parallel conductor bars with length \( l = 1.0m \) and spacing \( a = 0.05m \) a force \( F \) distributed across length \( l \) will develop according to the following equation:
The result of the concrete example is a force of $2.5\, \text{kN}$.

As these forces occur during any welding process dynamically, you must take care to design the welding circuit such that no leverage effects will occur, e.g. when using rigid conductor bars. Already existing, considerable electro-mechanical forces will be further enhanced by leverage effects anyway. On account of the flow properties of copper, this can gradually lead to a deformation of the transformer terminals and conductor bars up to rupture.

Connecting the transformer

On their secondary side, transformers shall be connected to flexible welding cables or laminated contact strips. This will largely help to avoid leverage effects. When using rigid bars, these must be additionally supported on their both ends according to the developing electro-mechanical forces. Suspension equipment with long secondary cables and high dead weight must be fitted with stress relief.

Owing to a large variety of welding installations (mechanical design, operating parameters, and in-service conditions), no further general specifications concerning the design of welding circuits can be given at this point. The general guidelines for high-current circuit design under observance of dynamic electro-magnetic forces must be taken into account.

As for design, EXPERT welding transformers correspond with the requirements of DIN ISO 5826. This ensures the transformer to withstand dynamic operating stress when operated at up to nine times the nominal continuous current and those internal and external electro-mechanics forces involved.

Beyond this, the user must ensure by appropriate design that no further forces can have an effect on the transformer, such as retroaction of forces from welding cylinders, forces caused by the dead load of equipment components, retroaction of forces by robot collision, etc.
Danger by mechanical damages
A welding transformer is a complicated electro technical device run with mains power. To avoid inadmissible high touch voltages, protective measures such as direct protective ground terminal are carried out. Great outer forces affecting and before the equipment can be switched off, it cannot be ruled out that protective ground is disconnected or other functional components of the protective measure are harmed when the transformer is mechanically damaged. This will render the protective measures inoperative, and there is danger of inadmissible high touch voltages on system sections causing danger of life for the operating staff.

4.8 Power connection of welding equipment

4.8.1 Conditions for power connection
Connection of a resistance welding machine to a three-phase power supply is made by two-phase as a rule. Connecting two-phase transformers and peak loads present, you must allow for unbalance (zero offset) to be expected in the three-phase supply. When connecting a number of transformers, these should be evenly connected across all three phases as much as can be.

To run resistance welding equipment, three-phase supply transformers with connection symbols Dy5 (delta-star) or Yz5 (star-interconnected-star connection) should be used. The required complex power for the supply transformer is to be determined under consideration of the max. permissible heating of the transformer winding and the voltage losses derived from that.

You should by all means consult with the relevant power supply company if you plan resistance welding installations.

4.8.2 Specified performance data, characteristics
DIN ISO 669 defines important ratings of resistance welding equipment.

- Rated voltage in V:
  
  Rated primary voltage of the welding equipment (mains voltage).

Rated output in kVA:
Characterizes operating performance of resistance welding equipment at $X = 50\%$ ON-time (according to ISO the full-load power is increasingly defined as rated output at $X = 100\%$ ON-time).

If only one transformer is employed for a machine, then this output will correspond with a rated transformer output at $X = 50\%$ ON-time.

- Short-circuit power in kVA:
  Product of rated voltage and primary machine short-circuit current. This value can be measured with the welding electrodes (without welding device) short-circuited (see section 4.3.2).

- Power rating in kVA:
  Specified performance data for dimensioning connection (power supply lines, switching units, etc.). It is not entirely modeled after the permissible heating but also allows for power losses across line resistances.
  The power rating is calculated with approx. 60\% of the short-circuit power. Dimensioning is different for the various resistance welding procedures and, therefore, is meant as orientation only.

- Maximum welding power in kVA:
  Product of max. primary current (welding) and rated voltage. This value is approx. 80\% of the short-circuit power.

Depending on type and operating conditions in a resistance welding installation, calculation of the cross-sectional area of connecting cables and dimensioning of switching units will either refer to the max. permissible power loss across the supply lines, or max. permissible heating (VDE 0100).

The permissible power loss is determined by the max. welding power (short-time peak power), and the heating is derived from the expected equivalent full-load power.

For dimensioning circuit-breakers and over current protection devices for welding equipment you best orient to the rated power of the installation. Setting of overload and
short-circuit releases depends on the concrete operating parameters of the welding equipment.
5 Design and function of transformers

5.1 Transformer design

Type-independently, EXPERT welding transformers feature a characteristic design. The secondary winding is cooling water circulated and thus directly water-cooled. Primary winding and iron core are indirectly cooled. The cooling water connection of non-isolated type is directly connected to the secondary circuit of the transformer. There is a secondary voltage potential difference between inlet and outlet of the cooling water.

<table>
<thead>
<tr>
<th>Danger by potential-bound cooling-water connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simultaneous touching resp. bridging cooling-water inlet and outlet by metallic objects such as tools can lead to very high short-circuit currents. There is risk of injury by burns or metal splash.</td>
</tr>
</tbody>
</table>

The primary winding of the transformer can be tapped. Thus the secondary voltage is adjustable in steps by switching on or off individual windings. Generally the total control range is \(1: \sqrt{2}\) but can be expanded to \(1:2\) in special cases.

According to the autotransformer principle, higher voltages than the connected mains supply may exist at the non-wired terminals on account of this specific feature.

Depending on the control range of the transformer and the voltage step selected, voltages twice as high as the value of the mains voltage can exist at non-wired terminals!

<table>
<thead>
<tr>
<th>Danger by voltage transformation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depending on the winding construction, the non-wired terminals on the primary side of multistep transformers can have voltages double as high as the value of the mains voltage! Please take care if you want e.g. carry out live measurements</td>
</tr>
</tbody>
</table>

5.2 Auxiliary circuits

EXPERT transformers can be equipped with monitoring devices (e.g. to monitor temperature, welding current, secondary circuit, enclosure). The mentioned monitoring facilities will be described in the following.
5.2.1 Thermal protection

Bimetallic temperature relays with double-break feature serve as thermal protectors. The contacts are of break type.

Typical design:

- Mechanical life: $10^4$ (according to VDE test class 1)
- Rated insulation voltage: 1.5 kV
- Max. ambient temperature: +180 °C (operating)
- Rated voltage: 250V AC / 50-60Hz
- Rated current: 2.5 A at $\cos \varphi = 1$ resp. 1.6 A at $\cos \varphi = 0.6$
- Permissible no. of operating cycles: 10,000 cycles
- Standard version: 2 primary circuit break contacts, current-insensitive, in series connection, floating

The contact type is current-insensitive, i.e. the threshold temperature is independent from load. Two temperature relays per transformer with 140 °C threshold temperature attached to and encapsulated within the primary winding are standard.

For monitoring transformer temperature, PTC thermistor detectors, resistometric thermometry, or thermocouples can be built-in optionally. Due to the compact mass of transformers, operations-related temperature changes are burdened with concerning large time constants. This means that thermal balancing will be but very slow. Therefore, the incorporated thermal relays will exclusively signal an overload of the transformers or absence of sufficient cooling. The thermal relays are not in a position to react or trip on short-term overloading such as overvoltage, surge load, etc.

5.2.2 Welding-current monitoring, constant-current control (CCC)

Most of the EXPERT transformers are available with built-in toroid measuring coils to order. These are air-induction coils concentrically arranged around the secondary conductor. Into these coils a measuring voltage directly proportional to the welding
current is induced. The standardized measuring voltage is 150 mV/kA across a load resistor of 1 kΩ (input resistance of the electronic evaluation unit).

As actual value of the current, and in combination with suitable welding controls, this induced voltage can be used for current control. The employment of a constant-current control (CCC) is especially recommended for applications with robot electrode holders.

For actual-current sensing, EXPERT transformers with toroid measuring coils can be connected to all KSR systems with standard calibration.

The inherent accuracy of the toroid coils used for EXPERT transformers is ±1.5%, and after installation the calibration accuracy will be ±3.0% for standard types.

Normally, connection to the measuring coil would be made via plugging or clamping elements on the primary side of the transformer.

Transformers with 2 secondary circuits (A and B side) will be fitted with one toroid measuring coil for each circuit, i.e. each built-in measuring coil supplies a voltage signal that is proportional to the current in the secondary winding concerned.

When the secondary windings are wired up (e.g. series or shunt connection) the toroid measuring coils, too, will have to be wired up correspondingly to obtain a measuring signal that corresponds with the resultant welding current (see section 4.4).

5.2.3 Monitoring the secondary circuit
Some installations experience circulating currents via protective ground connection, if a permissible protective measure is carried out according to VDE 0545 Part 1 (EN50 063) by direct connection of the secondary winding of resistance welding transformers with protective ground. In this case another protective measure is required.

This is the reason why various suppliers offer emergency shutdown systems for secondary circuit monitoring. The principle is founded on a voltage-based RCB procedure. This means that the shutdown of the equipment via an electronic evaluation unit is effected by an error voltage reaching a threshold value.

On customer's requirement, the necessary test cables will be connected to the secondary circuit of the transformer, and further to an outlet via a suitable plug system resp. terminals. Mostly this is designed as double line in closed-circuit operation to be safe from interruptions along the error voltage measuring line.
5.2.4 Enclosure monitoring

Analogue to the principle of secondary circuit monitoring, enclosure monitoring can be realized additionally.
6 Transport and Storage

Before shipment, the transformers are thoroughly checked and properly packed. At the point of destination, the transformer must be inspected for any transport damages. If damage has been noticed the carrier resp. forwarding agent must be notified immediately. Later complaints cannot be considered thereafter.

6.1 Transport

By reason of high transformer weight, several persons must transport it, or use permissible auxiliary equipment. Improper transport may cause the transformer to tip over or fall down. There is danger of bodily harm and damage to the transformer.

**Danger by improper transport**

Only use appropriate auxiliary equipment for transport! Do not stay beneath hanging loads! There is danger of bodily harm by squashing, shearing, cutting, and pushing! The transformer itself can be damaged too.

**General protective measures:**

- Use appropriate transportation means.
- Take precautions against getting caught and against bruises.
- Employ hoisting gear (take care of permissible load) and tools professionally.
- Wear appropriate protective outfit (e.g. safety boots, protective gloves).
- Do not stay beneath hanging loads.
- Instantly remove possibly leaking refrigerant (danger of slipping).

**Auxiliary transport means:**

In most of the cases proper transport will only be possible by appropriate auxiliary means such as hoists, cranes, forklifts, and trolleys. If you use hoists for transportation, the lifting eye bolts must only be fixed to the mounting holes destined for that purpose.

**Straining the lifting eye bolts:**

Observe the allowable loads for lifting eye bolts according to DIN 580.
DIN 580 determines the allowable loads for lifting eye bolts. There are two principal ways to lift the cargo (see figure 6-1).

- with one lifting eye bolt (load 1)
- with two and more lifting eye bolts (load 2).

You have to note that load specifications always refer to one lifting eye bolt only.

<table>
<thead>
<tr>
<th>Thread</th>
<th>Load 1 in kg</th>
<th>Load 2 in kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>M8</td>
<td>140</td>
<td>100</td>
</tr>
<tr>
<td>M10</td>
<td>230</td>
<td>170</td>
</tr>
<tr>
<td>M12</td>
<td>340</td>
<td>240</td>
</tr>
<tr>
<td>M16</td>
<td>700</td>
<td>500</td>
</tr>
<tr>
<td>M20</td>
<td>1200</td>
<td>860</td>
</tr>
</tbody>
</table>

6.2 Storage

If transformers are subjected to strong magnetic fields from outside, e.g. in the vicinity of induction furnaces, lifting magnets, etc., then these fields can induce voltages into the
windings of the transformer. Depending on the nature and structure of the transformer, you cannot rule out that these induced voltages will not assume inadmissible high values. Therefore, storage within the zone of exposure to great magnetic alternating fields is not allowed.

Storing EXPERT transformers is generally subject to the following conditions.

**Storage conditions:**

- Permissible storage height above M.S.L.: no limitation
- Permissible ambient temperature: –25 to +60 °C, (water circuit emptied)
- Permissible relative humidity: 20 to 85 % (no condensation)
- Stack height: Max. 2 transformers flat one on top of the other, mind projecting screw connections.

**Danger by frost damages!**

Storing water-cooled transformers below freezing point may result in crack formation on the condenser. Empty by all means the entire water circuit of the transformer (blow out).
7 Installation, electrical connection and start-up

This section is to give special instructions for transformer installation. Non-compliance of the following instructions will lead to preclusion of warranty by EXPERT Maschinenbau GmbH for any claims.

Demands on installation personnel

Electrical connections (installation) as well as subsequent start-up must only be carried out by qualified electricians.

7.1 Mounting and electrical installation

Please observe the following instructions:

- be careful to keep accessible the terminals for primary, secondary, and auxiliary circuits.

- the type designation plate should be visible without more ado, or the technical data should be copied to places that are visible.

- on account of the high weight of resistance welding transformers, installations sites and mounting hardware must allow for their weights.

- connection to the cooling water must only be made by an experienced plumber. Because of direct secondary winding cooling the cooling-water connections on the transformer have secondary-voltage potential too. To avoid short circuits via the water connections, you must only use non-conducting cooling hoses of min. 0.5 m length and a resistance of min. 1 MΩ/m. the resistivity of the water column must be min. 20 Ωm (cf. EN 50 063 section 5.1.3.1)

- Before start-up and on regular basis later on, the cooling water connection must be checked for tightness and function according to DIN ISO 5826.

- the terminal areas of the primary and secondary conductors must be plane and have clean contacts.

- only an experienced electrician must carry out electrical connections.

- the terminal studs in the primary area must be tightened by a torque wrench (tightening torque according to Table 7-2).
• all live parts must be covered according to DIN VDE 0545 Part 1 “Safety requirements for the construction and the installation of equipment for resistance welding and allied processes”, and thus protect against direct touch.

• mounting screw connections, the following tightening torques must be kept and checked:

**Table 7-1** Tightening torques, general for transformer mounting (transformer enclosure) in Nm, strength of screw 8.8

<table>
<thead>
<tr>
<th>Thread M5</th>
<th>M6</th>
<th>M8</th>
<th>M10</th>
<th>M12</th>
<th>M16</th>
<th>M18</th>
<th>M20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tightening moment 5.75</td>
<td>9.9</td>
<td>24</td>
<td>48</td>
<td>83</td>
<td>200</td>
<td>275</td>
<td>390</td>
</tr>
</tbody>
</table>

**Table 7-2** Screw connections for electrical terminals at different material pairing (specification in Nm for screws, and strength of bolts 8.8)

<table>
<thead>
<tr>
<th>Thread</th>
<th>Cu flange / Cu bar</th>
<th>Cu flange / Cu flexible</th>
<th>contact maker / cable lug</th>
</tr>
</thead>
<tbody>
<tr>
<td>M5</td>
<td>5,5</td>
<td>5,5</td>
<td>5,5</td>
</tr>
<tr>
<td>M6</td>
<td>9</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>M8</td>
<td>23</td>
<td>23</td>
<td>20</td>
</tr>
<tr>
<td>M10</td>
<td>45</td>
<td>45</td>
<td>42</td>
</tr>
<tr>
<td>M12</td>
<td>85</td>
<td>85</td>
<td>80</td>
</tr>
<tr>
<td>M16</td>
<td>160</td>
<td>160</td>
<td>150</td>
</tr>
<tr>
<td>M18</td>
<td>220</td>
<td>220</td>
<td>200</td>
</tr>
<tr>
<td>M20</td>
<td>250</td>
<td>250</td>
<td>220</td>
</tr>
</tbody>
</table>
Table 7-3  Tightening torques for mounting contact pins at gun transformers with primary plug system Multi-Contact

<table>
<thead>
<tr>
<th>Contact pin</th>
<th>Moment / Nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>M6</td>
<td>6,0 +0,5</td>
</tr>
<tr>
<td>M8</td>
<td>17,0 +1,0</td>
</tr>
</tbody>
</table>

There are no standards for max. permissible tightening torques for Cu screw connections right now. The tightening torques stated in Table 7-2 have been established by experiments.

Overstraining Cu screw connections must be avoided since otherwise deformations due to the creep behavior of copper will occur.

Connecting the transformer
Connections to the secondary side terminals to be established only by flexible lines (laminated flexible strip or extra-fine wire lines). Rigid links (e.g. conductor bars) are of restricted use, and this only under observance of the notes in section 4.7

7.2  Permissible environmental conditions

The standard version of the transformer complies with protection class IP54 for the primary terminal. The protection class for the secondary terminal is IP00. According to ISO10656, gun current transformers of series H and J have protection class IP00 on their primary side too.

Employment in rooms subject to explosive hazards is not permitted.

There are following environmental conditions for operation:
Permissible, guaranteed site altitude: 1000 m above M.S.L.
Permissible ambient temperature: + 5 to + 40 °C
Cooling water temperature: max. 30 °C (cooling water inlet temperature)
Permissible relative humidity: 30 to 95 %
8 Notes on operating transformers

8.1 Quality of cooling water

Proper functioning of a transformer can be considerably impaired if the quality of the cooling water is insufficient. Employment of a closed-circuit cooling system that recools conditioned water would be advantageous anyway. To not further increase the low specific conductivity of the cooling water, it is advisable for larger installations to have an ion exchanger incorporated in the cooling circuit. Due to electrode voltage in the cooling pipes, metal ions, e.g. iron, copper, etc. are emitted into the cooling water, and this will help increase the specific conductivity of the cooling water. As the secondary circuit has directly circulated cooling water, it should have relatively good insulation properties to prevent potential transfers (cf. EN 50 063 section 5.1.3.1).

Requirements for cooling water:

- mechanically clean, degree of filter fineness 100 micrometer
- natural water, optically clear, no turbidity, no dregs

pH value: 7-8
Specific conductivity: max. 500 µS / cm
Water hardness: max. 6 °DH
Iron: < 0.3 mg/l
Manganese: < 0.05 mg/l
Sulfates: < 250 mg/l
Chlorides: < 100 mg/l
Ammonia: must be not detectable
Aggressive carbonic acid: must be not detectable
Cooling water inlet temp.: approx. 18 °C to max. 30 °C

- if relevant inhibitors to prevent corrosion and furring are added to the cooling water, we recommend organic inhibitors above all, as these will only insignificantly help in rising the specific conductivity of the cooling water.
Danger of overheating the transformer
If there is too much dirt retention resp. depositing in the cooling pipes, the dissipated heat can no longer be sufficiently transferred to the cooling water. The specified volume of cooling water (see data sheet) must be met.

Formation of condensation water (perspiration water)
The transformer cooling water inlet temperature should be approx. 18 °C up to max. 30 °C. If the cooling water inlet temperature should be considerably lower than the ambient temperature, there will be danger of condensation water formation.

8.2 Volume of cooling water, differential pressure of the cooling circuit
Water-cooled welding transformers are designed such that nearly the entire dissipated heat generated in the windings must be dissipated via the cooling water. Heat emission by convection via the enclosure is negligible.

According to DIN ISO 5826, the following maximum values for cooling water flow rates in dependence on full-load power of transformers are specified below:

- Up to 100 kVA  max. 4 l/min
- 101 to 350 kVA  max. 8 l/min
- Pressure drop in the transformer can be max. 0.6 bar (difference in pressure between water inlet and water outlet)

There will be additional pressure losses in the external cooling circuit (hosepipes, screw connections, etc.).

The user has to set up the differential pressure between flow pipe and return pipe of the cooling circuit such that the volume of cooling water according to the transformer data sheet is reached. To check the water volume we recommend the installation of a flow meter.

Depending on the magnitude of the transformer no-load losses the outlet temperature of the cooling water is approx. 10 – 25 K higher than the inlet temperature.
9 Maintenance

Regular maintenance of welding installations essentially influences the quality of the welded joints to be produced, and the dependability of the entire equipment. This will reduce the risk of machine and plant breakdowns.

On account of a compact and fully encapsulated type of construction, EXPERT transformers need but little maintenance.

Depending on operational employment, ambient temperatures as well as quality of cooling water, we recommend carrying out maintenance work described in the following:

9.1 Primary and secondary terminals

Maintenance intervals depend on the dynamic stress of the clamping elements and the degree of machine workload. We recommend maintenance periods of 4 to 6 weeks. Inspect the condition of connecting points (corrosion and solidity of terminals) as well as welding cables themselves for wear and damages. Sometimes there are welding splashes clinging to the secondary terminals of the transformer, and thus act as shunts at times. These must be removed regularly. In doing this take care not to damage the transformer.

- Before starting the work you must consult the Notes on Safety in section 2.
- The transformer must be safety isolated and secured against reclosure (see section 2).
- If primary or secondary lines are damaged (e.g. insulation or other deficiencies), you must exchange the connecting cables.
- Check the tightening torques of the primary and secondary terminals (see Table 7-1 resp. Table 7-2).

The new start-up will be made under observance of sections 2 and 7.1.
9.2 Cooling circuit

The frequency of the maintenance measures described herein depends from the quality of the cooling water used (see also section 8).

Deposits in the cooling ducts of the transformer can drastically reduce cooling power. This will have the consequence of thermal transformer overload (e.g. tripping thermal protection). Furthermore, furring reduces the hydraulic cross section in the cooling ducts. The outcome will be that pressure will further drop in the transformer.

Realization of cleaning work for the cooling circuit:

- Before starting the work you must consult the Notes on Safety in section 2.
- Supply to the cooling-water inlet of the transformer must be cut off.
- Remove hoses for transformer cooling water connection.
- Rinse transformer cooling circuits with appropriate solvents for the decomposition of furring and lime deposits. Observe solvent manufacturer’s instructions on safety and use. If the deposits are too strong it may become necessary to repeat the rinsing process several times or prolong reaction time.
- Deposits in cooling circuits can best be removed by industry-standard agents based on organic acids or similar.