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Resistance welding equipment — Transformers — General specifications applicable to all transformers

Matériel de soudage par résistance — Transformateurs — Spécifications générales applicables à tous les transformateurs

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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The committee responsible for this document is ISO/TC 44, *Welding and allied processes*, Subcommittee SC 6, *Resistance welding* and allied mechanical joining.

This third edition cancels and replaces the second edition (ISO 5826:1999), which has been technically revised.

Requests for official interpretations of any aspect of this standard should be directed to the Secretariat of ISO/TC 44/SC 6 via your national standards body, a complete listing of which can be found at www.iso.org.

Resistance welding equipment — Transformers — General specifications applicable to all transformers

1 Scope

This International Standard gives specifications applicable to the following types of transformers for use in resistance welding equipment:

— single-phase transformers for a.c. welding, typically operating at 50 Hz or 60 Hz;

— single-phase transformers with connected rectifier for d.c. welding, typically operating at 50 Hz or 60 Hz;

— single-phase inverter transformers with connected rectifier for d.c. welding, typically operating at 400 Hz to 2 kHz;

— three-phase transformers with connected rectifier for d.c. welding, typically operating at 50 Hz or 60 Hz.

For the purposes of this International Standard, the term *transformer* can refer to the transformer alone or with connected rectifier (transformer-rectifier unit).

This International Standard applies to transformers built to protection class I or II according to IEC 61140.

NOTE The requirements of this International Standard can be supplemented by other resistance welding transformer standards, e.g. ISO 22829 and ISO 10656.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 669, *Resistance welding — Resistance welding equipment — Mechanical and electrical requirements*

IEC 60085, *Electrical insulation — Thermal evaluation and designation*

IEC 60529, *Degrees of protection provided by enclosures (IP code)*

IEC 61140, *Protection against electric shock — Common aspects for installation and equipment*

ISO 17657-3, *Resistance welding — Welding current measurement for resistance welding — Part 3: Current sensing coil*

ISO 17657-4, *Resistance welding — Welding current measurement for resistance welding — Part 4: Calibration system*

ISO 17677-1, *Resistance welding — Vocabulary — Part 1: Spot, projection and seam welding*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 17677-1 and ISO 669, and the following apply.

3.1
transformer-rectifier unit
transformer with connected rectifier
transformer incorporating a full-wave rectifier in its output circuit

3.2
input voltage
U_1
RMS value of the voltage applied to the primary terminals of the transformer

3.3
rated supply voltage
U_{1N}
RMS value of the supply voltage (applied to the input terminals) for which the transformer is constructed

Note 1 to entry: This voltage can be different from the mains voltage.

3.4
d.c. no load voltage
U_{2d}
for transformers, RMS value of the voltage at the output when a load resistance is connected across the output terminals

3.5
input current
I_1
RMS value of the current at the input terminals of the transformer

3.6
output current
I_2
RMS value of the current at the output terminals of the transformer

3.7
output current at a given duty factor
I_{2X}
RMS value of the current at the output terminals of the transformer at a duty factor, X

3.8
no-load input current
I_{10}
RMS value of the current at the input terminals of the transformer with open circuit output terminals

3.9
permanent input current
I_{1p}, I_{Lp}
maximum rated value of the current at the input terminals corresponding to the permanent output current

Note 1 to entry: The relationship between input and output currents depends on the type of transformer.

Note 2 to entry: I_{1p} is used for single-phase transformers; I_{Lp} is used for three-phase transformers.

3.10
permanent output current
I_{2p}
highest output current on all settings of the regulator, for continuous operation (100 % duty factor)

[SOURCE: ISO 669]

Note 1 to entry: The permanent output current is a standardized parameter that is used for comparison and characterization between different transformers. The value of the permanent output current is dependent on the test conditions as described in this standard.

3.11
output current under load condition
I_{2R}
instantaneous RMS value of the output current delivered by the transformer with a load resistance, R

3.12
rated permanent apparent input power
S_{1p}
rated permanent apparent power calculated by $U_{1N} \times I_{1p}$

Note 1 to entry: Welding equipment permanent power, S_p, determined in accordance with ISO 669, may be different from its welding transformer rated permanent apparent input power, S_{1p}.

4 Symbols and abbreviated terms

The symbols used in this International Standard are listed in Table 1.

Table 1 — Symbols

Symbol	Description	Used in [section]
I_1	input current	3.5, 9.3
I_{10}	no-load input current	3.8, Clause 11
I_{1p}	rated permanent input current (single-phase transformers)	3.9, 9.1, Clause 12
I_{Lp}	rated permanent input current (three-phase transformers)	3.9, 9.1
I_2	output current	3.6, 9.3, Annex C
I_{2p}	permanent output current at 100 % duty factor	3.10, 9.1, 9.3, 16.2, Annex C
I_{2R}	output current on load condition	3.11, Clause 13
I_{2X}	output current at a given duty factor	3.7, Annex C
m	mass	16.2
S_X	input power at a given duty factor	Annex C
S_{1p}	rated permanent apparent input power	3.12, 9.1, 16.2, Annex C
Q	rated cooling liquid flow	Clause 14, 16.2
R_1	initial resistance of a winding	9.3.5, 9.4.3
R_2	resistance of a winding at end of heating test	9.4.3
T	Time	Annex C
t_1	on-load time	Annex C
T	cycle time	Annex C
U_1	input voltage	3.2, Clause 13
U_{cc}	rated short-circuit voltage	Clause 12, Annex C
U_{1cc}	input short-circuit voltage	Clause 12

Table 1 *(continued)*

Symbol	Description	Used in [section]
U_{1N}	rated supply voltage	3.3, 9.1, 9.3, 10.2, 10.3, Clauses 11, 13, 16.2, Annex C
U_{20}	a.c. no-load voltage	10.1, 10.2, 16.2
U_{2d}	d.c. no-load voltage	3.4, 10.1, 10.3, 16.2
X	duty factor	9.3, Annex C
X_m	duty factor of magnetic circuit	Annex C
Z_2	total impedance referred to output	Clauses 12 and 17
Δ_p	pressure drop of cooling liquid circuit	Clause 14, 16.2
$\Delta\theta_{1, 2}$	temperature differences	Annex C
θ	temperature	Annex C
θ_a	cooling medium temperature	9.4.3, Annex B, Annex C
θ_m	equilibrium temperature	Annex C
θ_n	temperature when transformer starts to cool	Annex C
$\theta_{0, 1, 2}$	temperatures for calculation of thermal time constant or winding temperatures during heating test	9.3.5, 9.4.3, Annex C
τ	thermal time constant	Annex C
τ_2	thermal time constant at given on-load time	Annex C
τ_{2p}	thermal time constant at permanent output current	Annex C

5 Construction, additional equipment

5.1 Thermal protection

If the transformer and/or the rectifier are equipped with thermoswitches, they shall have a normally closed contact. The insulation shall be suitable for the test conditions prescribed in this standard.

5.2 Output current sensing coil

If the transformer is equipped with an output current sensing coil, the degree of protection of an externally mounted coil shall be lP 55.

The conversion coefficient shall be:

— 50 Hz mains frequency: 150 mV/kA with a load resistance of 1 000 Ω under full sine wave up to 80 °C;

— 60 Hz mains frequency: 180 mV/kA with a load resistance of 1 000 Ω under full sine wave up to 80 °C

The tolerance of the conversion coefficient after mounting in the transformer shall be ± 3 %.

The current sensing coil shall be a Rogowski type. The internal resistance of the current sensing coil shall be 5 to 50 Ω. White and brown colour coding shall be used for the wiring.

6 Physical environment and operating conditions

6.1 General

Transformers shall be suitable for use in the physical environment and operating conditions as specified below.

When the physical environment and/or operating conditions are outside those specified below, an agreement may be needed between the supplier and the user, (see, for example, IEC 60204-1:1997, Annex B).

NOTE Examples of these conditions are: outdoor use, different altitude, different temperature of cooling medium, high humidity, unusually corrosive fumes, steam, excessive oil vapour, abnormal vibration or shock, excessive dust, unusual sea coast or shipboard conditions.

6.2 Ambient air temperature

Transformers shall be capable of operating correctly in an ambient air temperature between + 5 °C and + 40 °C.

In case of other maximum temperatures of the cooling medium, see Annex B.

6.3 Humidity

Transformers shall be capable of operating correctly with a relative humidity up to 95 %.

Harmful effects of condensation shall be avoided by:

— appropriate design of the transformer (e.g. application of electrical potting or encapsulation);

— appropriate design of the welding equipment (e.g. built in heaters, air conditioners, drain holes);

— additional measures (e.g. cooling liquid temperature regulation).

6.4 Altitude

Transformers shall be capable of operating correctly at altitudes up to 1 000 m above mean sea level.

In case of other altitudes, see Annex B.

NOTE At altitudes over 1 000 m, additional electrical safety considerations can be required: see IEC 60664–1.

6.5 Transportation and storage

Transformers shall be designed to withstand, or suitable precautions shall be taken to protect against, transportation and storage temperatures between – 25 °C and + 55 °C and for short periods not exceeding 24 h up to + 70 °C. Suitable means shall be provided to prevent damage from humidity, vibration and shock.

Consideration should be given to frost or freezing protection and draining of the cooling water before shipping or storage.

6.6 Provisions for handling

Transformers that weigh over 25 kg shall be provided with suitable means for handling by hoists, cranes or similar equipment such as threaded holes or lifting lugs as appropriate.

6.7 Cooling liquid temperature

The temperature of the cooling liquid can be up to 30 °C at the inlet of the transformer.

For cooling liquid temperatures above 30 °C, see Annex B.

Condensation caused by high cooling liquid flow or low cooling liquid temperature in relation to the relative humidity should be prevented.

NOTE For air cooled transformers, see 6.2 and Annex B.

7 Tests

7.1 Test conditions

The tests shall be carried out on a new, dry and completely assembled transformer at an ambient air temperature between + 10 °C and + 40 °C. The ventilation shall be identical with that prevailing under normal service conditions. The measuring devices used shall not interfere with the normal ventilation of the transformer or cause transfer of heat to or from it.

Liquid cooled transformers shall be tested with liquid conditions as specified by the manufacturer.

The accuracy of measuring instruments shall be:

a) electrical measuring instruments: ± 1,0 % full-scale;

b) output current measuring instruments: ± 5 % full-scale, except for instruments used for verification of the current sensing coil: ± 2 % full scale;

c) temperature measuring devices: ± 2 K.

Unless otherwise specified, the tests required in this International Standard are type tests.

7.2 Type tests

All type tests shall be carried out on the same transformer except otherwise specified.

Those type tests given below shall be carried out in the following sequence without delay between g), h), i) and j).

a) general visual inspection;

b) insulation resistance (see 8.1) preliminary check;

   NOTE The preliminary check on insulation resistance is required to determine whether the transformer is safe before carrying out the remaining tests.

c) thermal rating (see Clause 9);

d) short-circuit voltage, where applicable (see Clause 12);

e) output current under load condition, where applicable (see Clause 13);

f) protection provided by the enclosure (see 8.4);

g) insulation resistance (see 8.1);

h) dielectric strength (see 8.2);

i) dynamic characteristic, where applicable (see Clause 15);

j) general visual inspection.

The other tests not mentioned above that are required by this International Standard can be carried out in any convenient sequence.

7.3 Routine tests

The following routine tests shall be carried out in the sequence given:

a) general visual inspection;

b) dielectric strength (see 8.2);

NOTE The dielectric strength test is required to determine whether the transformer is safe before carrying out the remaining tests.

c) rated output voltage (see Clause 10);

d) cooling liquid circuit (see Clause 14);

e) general visual inspection.

8 Protection against electric shock

8.1 Insulation resistance

The insulation resistance shall not be less than 50 MΩ.

Compliance is checked by measuring the insulation resistance using a d.c. voltage of 500 V between

a) the input and output windings, and

b) the windings and the frame.

For transformers with connected rectifier, the diodes shall be short circuited during this test.

Liquid-cooled transformers shall be tested without cooling liquid.

8.2 Dielectric strength

The insulation shall withstand the following test voltages without any flashover or breakdown:

a) first test of a welding transformer: test voltages given in Table 2;

b) repetition of the test of the same welding transformer: test voltage 80 % of the values given in Table 2.

Table 2 — Dielectric test voltages

Maximum rated voltage[a] V r.m.s.	a.c. dielectric test voltage[c] V r.m.s.			
All circuits	Output circuit to input circuit/ thermoswitches and sensing coil circuits to input and output circuits		Input circuit to transformer frame[d]	
	Class I transformers[b]	Class II transformers[b]	Grounded frame (accessible or not accessible) or not grounded, not accessible, frame	Not grounded, accessible, frame
Up to 50	250	500	—	—
200	1 000	2 000	1 000	2 000
450	1 875	3 750	1 875	3 750
700	2 500	5 000	2 500	5 000
1 000	2 750	5 500	2 750	5 500

NOTE The maximum rated voltage is valid for earthed and unearthed systems.

[a] For intermediate values, except between 200 V and 450 V, interpolation of the test voltages is allowed. Interpolation of the test voltage between 200 V and 450 V is allowed for equipment designed to be installed on delta corner grounded supply networks only

[b] See 8.5.

[c] As equipment design is not known, this standard specifies the same value for both input and output circuits. Where no value is stated, a test may be not be required.

[d] Transformer frame can be accessible or not accessible depending on manufacturer installation specifications (i.e. installation inside enclosures)

The a.c. test voltage shall be of an approximate sine wave-form with a peak value not exceeding 1,45 times the r.m.s. value, having a frequency of approximately 50 Hz or 60 Hz.

The test voltage generator shall deliver the prescribed voltage up to the tripping current. Tripping is regarded as a flashover or a breakdown. The tripping current setting can be selected according to the transformer capacitive dispersion current. The maximum permissible setting of the tripping current shall be 100 mA.

For operator safety, the lowest setting of the tripping current (less than 10 mA) is recommended.

Optionally, testing can be carried out with a d.c. test voltage of 1,4 times the r.m.s. test voltage in accordance with Table 2.

Transformers with connected rectifier shall be tested after assembly. Rectifiers, their protective devices and other solid-state electronic components or capacitors, can be short-circuited or disconnected as required.

Liquid-cooled transformers shall be tested without cooling liquid.

The test voltage may be raised to the full value slowly at the discretion of the manufacturer.

Conformity shall be checked by application of the test voltage for 60 s.

8.3 Calibration of output current sensing coil

Testing shall be carried out in accordance with ISO 17657-3 and ISO 17657-4.

8.4 Protection against electric shock in normal service (direct contact)

The minimum degree of protection for transformers provided by the enclosure shall be IP 54 as specified in IEC 60529.

If the transformer is intended to be in-built, the degree of protection may be IP 00.

Compliance shall be verified in accordance with IEC 60529.

8.5 Protection against electric shock in case of fault condition (indirect contact)

Protection against indirect contact is intended to prevent hazardous situations due to an insulation fault between live parts and exposed conductive parts of the equipment. Protective measures are selected in welding equipment design. They can include use of transformers with double or reinforced isolation of the output circuit

NOTE For different types of welding equipment indirect contact protective measures, see IEC 62135–1.

Regarding the output circuit fault condition only, resistance welding transformers are classified as follows.

a) **Class I resistance welding transformers**

Transformers with output circuit(s) without any provisions for fault protection. Fault protection is implemented at welding equipment design by protective bonding or other suitable measures.

b) **Class II resistance welding transformers**

Transformers with output circuit(s) provided by double or reinforced insulation.

8.6 Class II transformer insulation requirements

The welding circuit shall be designed to electrically isolate the input circuit and all other circuits having a voltage higher than the no-load voltage by use of reinforced or double insulation.

NOTE Specific requirements for insulation can be found in IEC 62135–1, IEC 60664–1 and IEC 61140.

9 Thermal rating

9.1 General

Thermal rating of the transformer output is specified by the parameter permanent output current, I_{2p}.

The declared I_{2p} value is verified by performing the thermal test.

Thermal rating of the transformer input is specified by the parameters permanent input current, I_{1p}, and permanent input power, S_{1p}.

These parameters are determined by performing a transformer thermal test as specified by this standard.

The permanent output current, I_{2p}, is an input parameter of the test. For inverter transformers, the permanent input current, I_{1p}, is calculated as $I_{1p} = I_{2p} / (N_1/N_2)$, where (N_1/N_2) is the transformer turns ratio. For all other transformers, the permanent input current, I_{1p}, is measured during the test.

The rated permanent apparent input power, S_{1p}, is calculated by:

— $S_{1p} = I_{1p}\, U_{1n}$ (for single-phase transformers);

— $S_{1p} = I_{Lp}\, U_{1n} \sqrt{3}$ (for three-phase transformers).

9.2 Limits of temperature rise

9.2.1 General

The thermal requirements for transformers are given as follows:

a) for windings, as specified in 9.2.2;

b) for accessible surfaces, as specified in 9.2.3;

c) for other components, as specified in 9.2.4.

9.2.2 Windings

The temperature rise of the windings shall not exceed the values given in Table 3.

No part shall be allowed to reach any temperature that will damage another part even though that part might be in compliance with Table 3.

Table 3 — Temperature limits for windings

Class of insulation in accordance with IEC 60085 °C	Peak temperature in accordance with IEC 60076-12 °C	Limits of temperature rise K			
		Air-cooled windings		Liquid-cooled windings	
		Embedded temperature sensor	Resistance method	Embedded temperature sensor	Resistance method
105 (A)	150	65	60	75	70
120 (E)	165	80	75	90	85
130 (B)	175	90	80	100	90
155 (F)	190	115	105	125	115
180 (H)	210	140	125	150	135
200 (N)	230	160	145	170	155
220 (R)	250	180	160	190	170

NOTE 1 *Surface temperature sensor* means that the temperature is measured with non-embedded sensors at the hottest accessible spot of the outer surface of the windings.

NOTE 2 Normally, the temperature at the surface is the lowest. The temperature determined by resistance measurement gives the average between all temperatures occurring in a winding. The highest temperature occurring in the windings (hot spot) can be measured by embedded temperature sensors.

NOTE 3 Other classes of insulation having higher values than those given in Table 3 are available (see IEC 60085).

NOTE 4 In case of liquid cooled windings the limit of temperature rise should be increased of 10 K.

Compliance is checked by measurement in accordance with 9.3.

9.2.3 Accessible surfaces

The temperature rise of accessible surfaces that can be touched by the equipment operator shall not exceed the values given in Table 4.

NOTE Transformer surfaces can be accessible or non-accessible depending on manufacturer installation specifications (i.e. installation inside enclosures).

Table 4 — Limits of temperature rise for external surfaces

External surface	Limits of temperature rise[a] K	
	Unintentional contact	Intentional contact
Bare metal enclosures	40	25
Accessible metallic welding circuit surfaces	45	30
Painted metal enclosures	50	35
Non-metallic enclosures	60	45

[a] Values can be increased by 15 K, by agreement between transformer and equipment manufacturers, and the equipment is specified for use with personal protective equipment (e.g. gloves, protection dresses) or marked with the hot surface symbol IEC 60417–5041.

9.2.4 Other components

The maximum temperature of other components shall not exceed their rated maximum temperature, in accordance with the relevant standard. The difference between the temperature of the cooling medium of the component and its maximum value shall be taken into account.

Rectifiers can be used in the input or output circuit. The temperature reached by the rectifier elements during the heating test shall not exceed those specified by the manufacturer of the rectifier elements.

Attention is drawn to the intermittent duty characteristic of rectifier elements.

Compliance shall be checked by temperature measurement during the heating test.

9.3 Heating test conditions

9.3.1 General

The test is carried out on a new transformer.

Inverter transformers shall be tested with a load resistor installed at transformer output (see 9.3.3). All other transformers shall be short circuited at the output. In case of two output windings, the windings shall be short circuited in parallel.

For transformers with multiple output voltages, the test shall be carried out for the highest voltage setting.

For liquid cooled transformers, the flow rate shall be set up as specified on the rating plate.

During the last 60 min of the heating test the following tolerances shall be met:

a) output current: ± 2 % of the permanent output current;

b) cooling liquid flow (if applicable): ± 5 % of the rated value.

9.3.2 Test conditions for single-phase transformers for alternating welding current and single-phase transformers with connected rectifier

The transformer is operated at the permanent output current, I_{2p}, in one of the following possible operating conditions:

a) with pulsed output current, using a pulse current corresponding to the maximum short-circuit current obtained during the test, I_2, at the duty factor corresponding to the permanent output current, I_{2p}, calculated by the formula:

$$X = \frac{\left(I_{2p}\right)^2}{\left(I_2\right)^2}$$

Since pulse duration setting does not influence the test result, the value may be selected to match equipment and test instrumentation requirements. It is recommended that the pulse duration be representative of the typical operating condition of the equipment.

b) with permanent output current (100 % duty factor), obtained with reduced transformer supply voltage, adjusted to obtain the rated permanent output current, I_{2p}.

9.3.3 Test conditions for single-phase inverter welding transformer with connected rectifier

D.c. current welding transformers operating at medium frequency (inverter equipment) shall be tested under the following operating conditions:

The input voltage waveform supplying the test object shall be a full wave square waveform at the nominal transformer supply frequency. The test shall be carried out at the rated supply voltage, U_{1N} ± 5 %.

The transformer shall be operated with pulses of duration of 240 ms and a duty factor, X, of 20 %.

NOTE 1 These values may need to be adjusted for inverter transformers that are not integrated into welding guns.

A load resistor shall be installed at transformer output, with a resistance value such that the output current is limited to

$$I_{2d} = I_{2p}\sqrt{5}$$

where the term $\sqrt{5}$ is equal to $\sqrt{\frac{100\,\%}{20\,\%}}$, 100 % and 20 % being duty factor values.

The output current shall be measured using an integration time equal to the pulse duration (i.e. 240 ms).

NOTE 2 The performance results are only valid up to a duty factor of 20 % but many transformers of this type are operated at duty factors above 20 %. The manufacturer may supply additional thermal performance for higher duty factors, e.g. 100 %.

9.3.4 Test conditions for three-phase transformers with connected rectifier

For three-phase transformers with connected rectifier, the test shall be carried out under the following operating conditions:

— to achieve the maximum heating condition of the transformer(s) and rectifier, the input current I_1 of each transformer shall be adjusted so that the conduction angle is between 45° and 60°. If the resulting output current I_2 is lower than permanent output current I_{2p}, the conduction angle shall be increased to achieve the permanent output current I_{2p};

  NOTE In star (wye) connected transformers, input current I_1 of each transformer is controlled by two separate current switching devices (thyristors) connected to different mains phases. In this case, the conduction angle measurement is performed on a single current switching device.

— at the duty factor corresponding to the permanent output current (I_{2p}) considering the equipment output current during test I_2, measured using an integration time equal to the pulse duration, calculated by the formula:

$$X = \frac{\left(I_{2p}\right)^2}{\left(I_2\right)^2}$$

Since pulse duration setting does not influence the test result, the value may be selected to match equipment and test instrumentation requirements. It is recommended that the pulse duration be representative of the typical operating condition of the equipment.

9.3.5 Start of heating test

a) in the case of embedded or surface temperature sensors (see 9.4.2 or 9.4.4) the test can be started before a temperature balance between the transformer and the cooling liquid is reached.

b) in the case of resistance measurement (see 9.4.3) of liquid cooled transformers the test shall be started only when the temperature difference between cooling liquid inlet and outlet is within 1 K.

The temperature, θ_1, of the cooling liquid shall be taken as the initial temperature of the winding during which the initial resistance, R_1, is measured.

9.3.6 Duration of heating test

The heating test shall be carried out until the rate of the temperature rise does not exceed 2 K/h on any component of the transformer.

9.4 Methods of temperature measurements

9.4.1 General

One of the following methods to determine the temperature of any particular part is sufficient.

The temperature shall be determined at the end of the load time as follows:

a) for windings, by surface or embedded temperature sensors or by measurement of the resistance (only input windings);

b) for other parts, by surface temperature sensors.

9.4.2 Embedded temperature sensor

The temperature is measured by one or more embedded thermocouples or other suitable temperature measuring instruments of comparable size applied during the manufacturing of the transformer to the predicted hottest points of the windings.

A thermocouple applied to the hottest point of a single layer winding shall be considered as embedded.

Recording of measurement results shall be carried out under load, which means immediately before cutting off the current.

9.4.3 Resistance

This method only applies to input windings. The temperature rise of windings is determined by increase of resistance and is obtained for copper windings in accordance with Formula (1):

$$\theta_2 - \theta_a = \frac{(235 + \theta_1)(R_2 - R_1)}{R_1} + (\theta_1 - \theta_a) \quad (1)$$

where

θ_2 is the temperature of the winding at the end of the test (calculated value) in degrees Celsius (°C);

θ_a is the temperature of the cooling liquid at the end of the test in degrees Celsius (°C);

θ_1 is the temperature of the winding at the moment of the initial resistance measurement in degrees Celsius (°C);

R_2 is the resistance of the winding at the end of the test in ohms (Ω);

R_1 is the initial resistance of the winding in ohms (Ω).

For aluminium windings, the number 235 in the above formula shall be replaced by the number 225.

Recording of measurement results shall be carried out in the following steps, without delay between them:

a) stop of the cooling liquid flow (if applicable);

b) cut off of the current;

c) record of the resistance, R_2.

9.4.4 Surface temperature sensor

The temperature is determined by a temperature sensor (e.g. thermocouple, resistance thermometer) under the following conditions:

— temperature sensors shall be placed at accessible spots where the maximum temperature is likely to occur. It is advisable to locate the predictable hot spots by means of a preliminary check;

— efficient heat transmission between the point of measurement and the temperature sensor shall be ensured, and protection shall be provided for the temperature sensor against the effect of air currents and radiation.

Recording of measurement results shall be carried out as follows:

a) cut off of the current;

b) record the highest temperature obtained.

9.4.5 Determination of ambient air temperature

Temperature measurement devices shall be protected against heat radiation and air currents.

9.4.6 Determination of cooling liquid temperature

The temperature measurement devices shall be placed at the cooling liquid inlet of the transformer.

For recording the measurement results the average temperature obtained during the last quarter of the test shall be taken.

10 Rated output voltage

10.1 General

The following parameters are used to specify rated output voltage characteristics:

— U_{20}, transformers without connected rectifier;

— U_{2d}, transformers with connected rectifier.

10.2 a.c. no-load voltage (U_{20})

The a.c. no-load voltage, U_{20}, for all settings shall be determined with transformers operating with open output terminals and shall be indicated with a tolerance of ± 2 %.

Compliance is checked by measurement at a rated supply (primary) voltage, U_{1N}, for all settings.

NOTE If the supply voltage, U'_{1N} differs from U_{1N}, the no-load voltage U'_{20} is measured. U_{20} is calculated by

$$U_{20} = U'_{20} \frac{U_{1N}}{U'_{1N}}$$

10.3 d.c. no-load voltage (U_{2d})

The test shall be carried out at the rated supply voltage, U_{1N} ± 5 %.

For inverter transformers, the input voltage waveform supplying the test object shall be a full wave square waveform at the nominal transformer supply frequency.

A load resistor of R = 10 Ω (±10 %) shall be connected across the output connections of the transformer-rectifier unit.

The RMS values of voltage at the output connections, U_{2d}, shall be measured using an integration time of 100 ms.

The d.c. no-load voltage, U_{2d}, shall not deviate by more than ± 5 % from the value specified on the rating plate.

NOTE If the supply voltage, U'_{1N}, differs from the rated supply voltage U_{1N}, then U'_{2d} is measured. U_{2d} is calculated by

$$U_{2d} = U'_{2d} \frac{U_{1N}}{U'_{1N}}$$

11 No-load input current (I_{10})

11.1 General

The no-load input current, I_{10}, is an optional value and may be provided if agreed upon between the manufacturer and the purchaser.

No limits are defined by this standard but may be defined in relevant product standards (e.g. ISO 22829).

11.2 Measurement procedure

The RMS value of the no-load input current I_{10}, is measured, using an integration time of 100 ms, under the following conditions:

— the transformer is supplied at the rated supply voltage, U_{1N} ± 5 %;

— transformer is operating with open output terminals;

— if the transformer has multiple output voltages, the transformer shall be adjusted to provide the maximum output voltage.

12 Short-circuit voltage (U_{cc})

For single-phase transformers for alternating welding current, the manufacturer shall specify the value of the short-circuit voltage, U_{cc}.

For transformers with two separate output windings, the values measured for each winding can differ up to ± 5 %from the maximum value.

The value of U_{cc} shall be determined using the following procedure after completion of the heating test.

a) Short circuit the output winding(s).

   If the transformer has two output windings, the measurements are performed under the following conditions:

   1) both output windings are short circuited in parallel,

   2) both output windings are short circuited in series,

   3) one output winding is short circuited the other is open.

b) Adjust the input voltage, U_{1cc}, to the value for which the admissible permanent input current, I_{1p}, is reached:

$$I_{1p} = \frac{S_{1p}}{U_{1N}}$$

   with I_{1p} expressed in amperes (A).

c) Calculate the short-circuit voltage, percentage, using Formula (2):

$$U_{cc} = \frac{U_{1cc}}{U_{1N}} \times 100 \qquad (2)$$

d) Calculate the total impedance referred to the output (Z_2), in ohms, using Formula (3):

$$Z_2 = \frac{U_{cc} \times U_{20}^2}{100 \times I_{1p} \times U_{1N}} \qquad (3)$$

13 Output current under load condition

For single-phase inverter welding transformers with connected rectifier, the manufacturer shall specify the value of the output current under load condition, I_{2R}.

The value of I_{2R} shall be determined as follows:

The test shall only be started when the temperature difference between the cooling liquid inlet and the cooling liquid outlet is less than 1 K.

The input voltage waveform supplying the test object shall be a full wave square waveform

The input voltage, U_1, shall correspond to U_{1N} ± 15 %. The input voltage, U_1, shall be recorded and a correction formula shall be used if the input voltage, U_1, is different from U_{1N}.

A load resistance, R, shall be connected across the output connections of the transformer-rectifier unit.

The value(s) of the load resistance shall be selected by the manufacturer according to the intended application of the transformer. The recommended nominal load resistance values are: 50 µΩ, 100 µΩ, 200 µΩ, 400 µΩ or 800 µΩ. During the test, the value of R shall be maintained within ± 5 % of the selected value.

NOTE If the load resistance, R', differs from nominal load resistance R, the output current under load condition, I_{2R}, is calculated from the measured output current under load condition I'_{2R}, using

$$I_{2R} = I'_{2R} \frac{R'}{R}$$

The RMS value(s) of output current under load condition I_{2R} shall be measured using an integration time of 100 ms.

The value(s) of the load resistance used shall be declared together with the value(s) of I_{2R}. This information may also be provided as a graph.

14 Cooling liquid circuit

For water cooled welding transformers, the cooling liquid circuits shall enable a sufficient flow in order to ensure efficient cooling.

The cooling liquid circuit:

a) shall be leak-tight at a pressure of 2,5 times the specified maximum operating pressure up to a maximum of 8 bar for a minimum of 60 s; and

b) shall not have a cooling liquid pressure drop, at the rated flow rate (Q), higher than that stated on the rating plate (Δ_p).

Compliance is checked by leak tightness and pressure drop check.

15 Dynamic behaviour

Dynamic behaviour tests are defined in relevant product standards (e.g. ISO 10656 and ISO 22829).

16 Rating plate

16.1 General

A clearly and indelibly marked rating plate shall be fixed securely to or printed on each transformer.

If the transformer is designed for several rated supply voltages, the electrical characteristics for each supply voltage shall be indicated. This can be made by several rating plates or by an appropriate table.

Compliance is checked by visual inspection and by rubbing the marking by hand for 15 s with a piece of cloth soaked in water and again for 15 s with a piece of cloth soaked in petroleum spirit.

After the test the marking shall be easily legible; it shall not be easy to remove the rating plates and they shall show no curling.

NOTE The purpose of the rating plate is to inform the user of the electrical and mechanical characteristics of the equipment in order to enable correct selection, installation and use.

16.2 Description

The rating plate shall be divided into sections containing at least the following information:

a) **Identification**

Box 1	Name and address of the manufacturer and — optionally —a trade mark and the country of origin if required.
Box 2	Type (identification) as given by the manufacturer.
Box 3	Traceability of design and manufacturing data (e.g. serial number) and year of production.
Box 4	Reference to this International Standard and year of publication, i.e. ISO 5826:2014 (confirming the data presented has been determined using the methods presented in the standard).

b) **Electrical characteristics**

Box 5	U_{1N} = ... V/ ... ~ ... Hz	Rated supply voltage; number of phases, e.g. 1 or 3;symbol for alternating current (~) and the rated frequency, e.g. (50 or 60) Hz.
Box 6	S_{1p} = .. kVA	Rated permanent apparent input power
Box 7	U_{20} = ... V – ... V – ... V	a.c. no-load voltage values, or
	U_{20} = ... V to ... V in ... steps	Range of a.c. no-load voltage values and number of adjustable steps.
	U_{2d} = ... V – ... V – ... V	d.c. no-load voltage values, or
	U_{2d} = ... V to ... V in ... steps	Range of d.c. no-load voltage values and number of adjustable steps.
Box 8	I_{2p} = ... kA	Permanent output current.
Box 9	I_{2R} = ... kA	Output current under load condition, if applicable.

c) **Other characteristics**

Box 10	Q = ... l/min	Rated cooling liquid flow.
Box 11	Δ_p = ... bar	Rated cooling liquid pressure drop.
Box 12		Insulation class.
Box 13		Protection class.

Box 14	m = ... kg	Mass of the transformer.
Box 15		Additional information, if applicable (e.g. type code as given in Annex D or as defined in relevant product standards such as ISO 10656 and ISO 22829).

The arrangement and sequence of the data shall comply with the principle shown in Figure 1 (for examples see Annex A).

a) Identification:

1)
2)
3)
4)

b) Electrical characteristics:

5)
6)
7)
8)
9)

c) Other characteristics:

10)	11)
12)	13)
14)	15)

NOTE 1 Other useful information can be added to the rating plate or given in technical literature supplied by the manufacturer.

NOTE 2 The dimensions of the rating plate are not specified and can by chosen freely.

Figure 1 — Principle of rating plate

17 Instruction manual

Each transformer shall be delivered with an instruction manual which shall include the following:

a) a general description including all information given on the rating plate;

b) correct methods of handling (e.g. by fork lift or crane) and precautions to be taken;

c) correct operational use of the transformer (e.g. location and cooling requirements to prevent overheating or condensation);

d) duty factor limitations;

e) basic guidelines regarding protection against personal hazards for operators and persons in the work area (e.g. danger of metal objects shorting output terminals or being propelled by the magnetic field);

f) maintenance;

g) adequate circuit diagram together with a list of essential parts;

h) installation and mounting.

Other useful information can be given [control device, indicators, maximum time per pulse, power factor, impedance (Z_2), type code, meaning of indications, markings and graphical symbols, thermal time constant, etc.].

Compliance is checked by reading the instruction manual.

Annex A
(informative)

Example of a rating plate

See Figure A.1.

a) Identification:

1) Manufacturer, Country	Trade mark
2) Resistance welding transformer	
3) Serial number	Year of production
4) ISO 5826: (including edition/year of publication)	

b) Electrical characteristics:

5) U_{1N} = 400 V/1 ~ 50 Hz
6) S_{1p} = 71 kVA
7) U_{20} = 7,1 to 10 V in 4 steps
8) I_{2p} = 7,1 kA
9) I_{2R} = 5,0 kA

c) Other characteristics:

10) Q = 4 l/min	11) Δp = 0,3 bar
12) Class F	13) Class II
14) m = 35 kg	15)

Figure A.1 — Transformer with one rated input voltage

Annex B
(normative)

Corrections for higher altitudes and cooling medium temperatures

B.1 Altitude above 1 000 m

For air cooled transformers designed for operation at an altitude above 1 000 m, the temperature rise, if measured at an altitude lower than 1 000 m, shall not exceed the values given in Table B.1 less 0,5 % per 100 m if the place of installation is above 1 000 m.

B.2 Cooling medium temperatures above standardized values

If the temperature of the cooling medium is higher than the standardized values, the admissible temperature rise limits are modified as follows

Table B.1 — Reduction of temperature rise limits

Cooling medium	Cooling medium temperature, θ_a °C	Reduction of temperature rise limit K
Liquid	$\theta_a \leq 30$	0
	$31 \leq \theta_a \leq 35$	5
	$36 \leq \theta_a \leq 40$	10
Air	$\theta_a \leq 40$	0
	$41 \leq \theta_a \leq 45$	5
	$46 \leq \theta_a \leq 50$	10

Annex C
(informative)

Notes on physical concepts and comments on some definitions

C.1 Temperature rise and cooling of single phase transformers for a.c. current

During operation, the temperature of a transformer generally rises to a maximum equilibrium temperature, θ_m.

The equilibrium temperature is a quadratic function of the current flowing through the windings and depends on

a) manufacture and assembly conditions, and

b) the heat transfer to the cooling medium.

When the transformer stops operation, its various parts are cooling down to the temperature of the cooling medium.

After the transformer has been cooled down and is in thermal equilibrium with the cooling medium, it is loaded with a current $I_2 = 1{,}26 \times I_{2p}$. The time to reach the same temperature as before with I_{2p} and 100 % duty factor is equal to the measured time constant, τ.

The temperature variation of the transformer (see Figure C.1) follows a time related exponential law according to the following formulae:

— for the temperature rise:

$$\theta = \theta_m - (\theta_m - \theta_a)\, e^{\frac{-t}{\tau}} \quad (C.1)$$

— for the cooling:

$$\theta = \theta_a + (\theta_n - \theta_a)\, e^{\frac{-t}{\tau}} \quad (C.2)$$

where

θ_m is the equilibrium temperature in degrees Celsius (°C);

θ_a is the cooling medium temperature in degrees Celsius (°C);

θ_n is the temperature when the transformer starts to cool in degrees Celsius (°C).

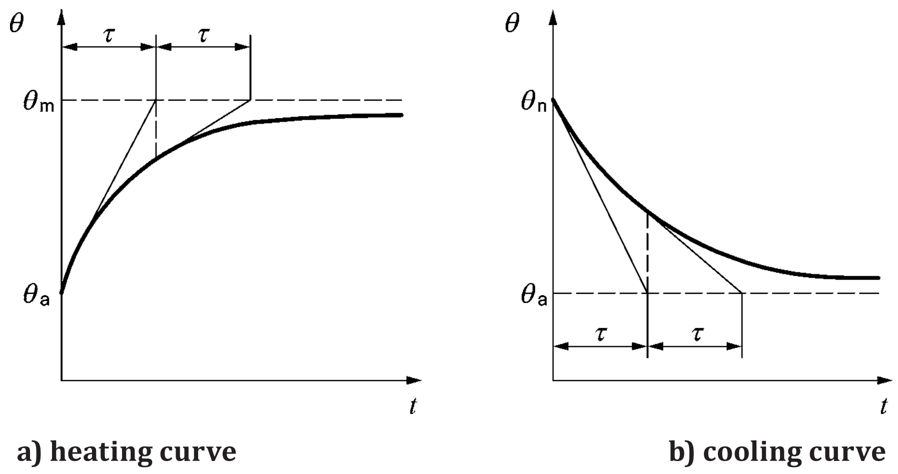


Figure C.1 — Temperature variation of a transformer

The coefficient, $1/\tau$, appearing as an exponent, is a physical quantity that depends on the following:

a) design and assembly of the transformer;

b) the heat transfer to the cooling medium; thermal time constant τ

  1) is a measurable physical quantity,

  2) is a characteristic of a transformer part,

  3) determines the speed of temperature rise and cooling,

  4) corresponds to the time after which the temperature has reached its maximum value if it maintains its initial variation speed, and

  5) corresponds to the time after which the temperature variation has reached 63 % of the difference between the equilibrium temperature and the temperature at a time, t.

C.2 Determination of thermal time constant τ of input winding

The thermal time constant can be determined by one of the following methods.

a) **Method 1**

  1) Load the transformer:

    i) under conditions indicated in 9.3 at 100 % duty factor;

    ii) until it is in thermal equilibrium with the cooling medium, whatever the method of temperature measurement.

  2) Measure the following temperatures:

    i) θ_0 at the beginning;

    ii) θ_1 at the end of the time $t = t_1$;

    iii) θ_2 at the end of the time $t = 2 \times t_1$.

  3) Calculate using the formulae:

  $\Delta\theta_1 = \theta_1 - \theta_0$

$\Delta\theta_2 = \theta_2 - \theta_1$

$$\tau = \frac{t_1}{\ln\frac{\Delta\theta_1}{\Delta\theta_2}}$$

where temperature is expressed in Kelvin and thermal time constant τ in seconds.

b) **Method 2**

1) Cut off current after the heating test. (For liquid-cooled transformers, maintain the cooling liquid flow.)

2) Plot the cooling curve by using thermocouples fixed on the windings by

i) permanent plotter, or

ii) readings at the beginning of the cooling and the end of the times t_1, 2 × t_1, 3 × t_1, etc., calculated from the time the current is cut off. It is necessary to take readings for a maximum number of points, particularly when cooling starts.

3) Determine the thermal time constant (τ), in seconds,

i) by carefully tracing the sub-tangent to the cooling curve (see Figure C.1), or

ii) by the formula:

$$\tau = \frac{t}{\ln\frac{(\theta_2 - \theta_a)}{(\theta - \theta_a)}}$$

where

θ_2 is the maximum temperature at the end of the heating test in degrees Celsius (°C);

θ_a is the cooling medium temperature in degrees Celsius (°C);

θ is the temperature after time t, in degrees Celsius (°C).

c) **Method 3**

The transformer in thermal equilibrium with the cooling medium is loaded with a current I = 1,26 × I_{2p} for the time t. After time t the temperature rise is the same as if the transformer were loaded with the current I_{2p} at 100 % duty factor.

The thermal time constant τ is equal to this time t.

C.3 Operation of transformer

C.3.1 General

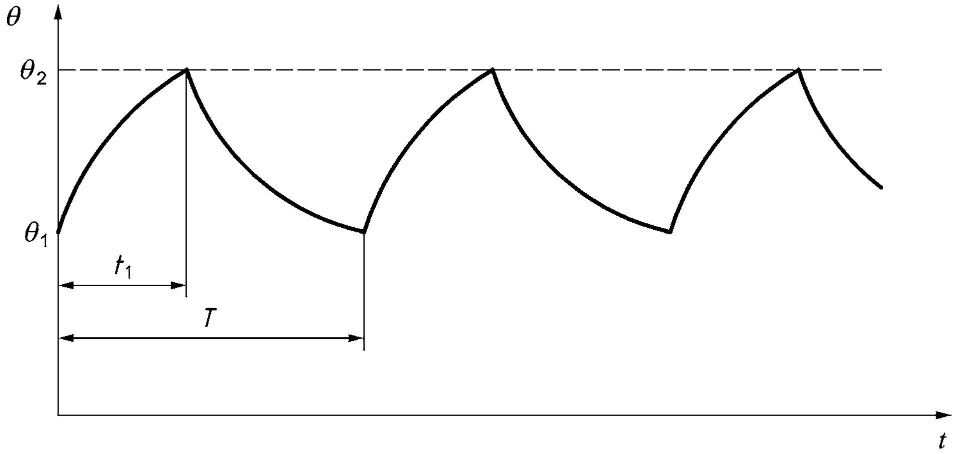
In general, transformers do not operate continuously but periodically with on-load and no-load times by switching them on and off.

The ratio of the on-load time (t_1) and the cycle time (T) is the duty factor (X). Its value is expressed in %:

$$X = \frac{t_1}{T} \times 100 \qquad \text{(C.3)}$$

The cycle time and the duty factor can vary according to the welding operation and the condition of use of the transformer.

During an operation cycle (see Figure C.2) the temperature of a transformer rises during the on-load time and cools during the no-load time. The temperature varies between θ_1 and θ_2.



NOTE The curve shows the equilibrium.

Figure C.2 — Operating cycle of a transformer

C.3.2 Windings

The maximum temperature of windings θ_2 depends on the

a) current,

b) cycle time,

c) duty factor, and

d) thermal time constant.

The temperature rise of the windings shall not exceed the limit specified for their insulation class. Consequently, if e.g. its duty factor is low, it will be possible to have a higher current pass through the transformer than if its duty factor is high.

If the rated permanent apparent input power, S_{1p}, or the permanent output current I_{2p} and the thermal time constant, τ, of the transformer are known, the input power S_X or the output current I_{2X} at a duty factor X and a cycle time, T, can be determined by the formulae:

$$S_X = S_{1p}\sqrt{\frac{1-e^{\frac{-T}{\tau}}}{1-e^{\frac{-XT}{100\tau}}}} \quad \text{(C.4)}$$

$$I_{2X} = I_{2p}\sqrt{\frac{1-e^{\frac{-T}{\tau}}}{1-e^{\frac{-XT}{100\tau}}}} \quad \text{(C.5)}$$

where S_X is expressed in kVA and I_{2X} in kA.

NOTE In general, if the ratio between the thermal time constant and the cycle time is above 5 ($\tau / T > 5$), the following simplified formulae can be used:

$$S_X = S_{1p}\sqrt{\frac{100}{X}} \quad \text{(C.6)}$$

$$I_{2X} = I_{2p}\sqrt{\frac{100}{X}} \quad \text{(C.7)}$$

where S_X is expressed in kVA and I_{2X} in kA.

C.3.3 Magnetic circuit

The maximum temperature (θ) reached by the magnetic circuit of the transformer is no longer a function of the current passed out of the induction effect in the metal, and accordingly of the input voltage. The rise in temperature is also of course related to the time during which current passes and therefore to the cycle time, the duty factor and the thermal time constant.

In contrast to the current passed, which is variable, the induction is constant since it is fixed by the input voltage. The temperature rise of the magnetic circuit of a given transformer does not therefore depend on the time of switch-on. With the load of the welding transformer broken by the input circuit, the temperature rise of the magnetic circuit varies directly with the duty factor and the cycle time.

The above observation has led to a maximum duty factor (X_m) being defined, beyond which the temperature rise of the magnetic circuit would become too high.

Since the thermal time constant of the magnetic circuit is very large, the value of the maximum duty factor (X_m) can be regarded as independent of the cycle time.

NOTE The fact of carrying out the heating test on the windings under continuous condition is not in contradiction with what has been said above. The heating test is in fact carried out at low voltage so that the temperature rise of the magnetic circuit is negligible.

C.4 Practical use

An operating condition can be determined if the following values are known:

a) the thermal time constant (τ);

b) the rated permanent apparent input power (S_{1p}) or

c) the admissible rated permanent output current (I_{2p}).

The formulae given in C.3.1 enable

— determination of the admissible input power and the output current for a given cycle time and a duty factor according to the welding operation, or

— calculation of the admissible cycle time and duty factor if the current necessary to the welding operation is known.

If the simplified formulae indicated in C.3.1 cannot be used (thermal time constant $\tau \leq 5\ T$), the calculation shall be made with the complete formulae. In this case attention shall be drawn to the fact that the known quantity is the time t_1 during which the current is flowing:

$$t_1 = T \times \frac{X}{100} \quad \text{(C.8)}$$

where t_1 is expressed in seconds.

Therefore, the admissible cycle time, *T*, shall be determined first by the formula:

$$T = \tau \left\{ 2\ln I_{2p} - \ln \left[I_{2p}^2 - I_{2X}^2 \left(1 - e^{\frac{-t_1}{\tau}} \right) \right] \right\} \quad \text{(C.9)}$$

and then *X*, in percent, shall be calculated using

$$X = \frac{t_1}{T} \times 100 \quad \text{(C.10)}$$

It should be checked that the installation conditions of the transformer do not cause a reduction of the current or of the admissible duty factor.

Annex D
(informative)

Type code for single-phase transformers for alternating welding current

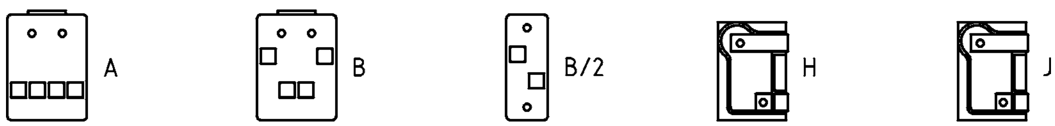
The transformers are described using a type code.

EXAMPLE ISO 5826[1)] - B[2)] - 7[3)] - 10[4)] - 71[5)] - 400[6)]

Explanation of type code:

1) Reference to this International Standard (i.e. ISO 5826)

2) Arrangement of the output connection terminals:



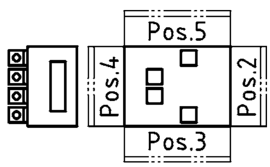
and *X* for transformers with very special connection arrangements.

NOTE For transformers which are not according to the type code given above, but which are very common in industry, numbers can be used instead of letters.

3) Positions of the tap switch:

1 end position

2 to 5 side positions:



6 external position

Without tap switch:

0 for transformers without output taps

7 for transformers with output taps changeable by a set of connectors

4) The rated no-load voltage (e.g. 10 V).

5) The rated short-circuit voltage U_{cc} (e.g. 71 %).

6) The rated supply voltage U_{1N} (e.g. 400 V).

Attention is drawn to the fact that ISO 10656 contains codes H and J different from those given here.

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