International Standard ISO 5826

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Transformers for resistance welding machines — General specifications applicable to all transformers

Transformateurs pour machines à souder par résistance — Spécifications générales applicables à tous les transformateurs

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 5826 was developed by Technical Committee ISO/TC 44, *Welding and allied processes*, and was circulated to the member bodies in February 1982.

It has been approved by the member bodies of the following countries:

Australia	India	Romania
Belgium	Ireland	Spain
Canada	Italy	Sweden
Czechoslovakia	Korea, Dem. P. Rep. of	Switzerland
Egypt, Arab Rep. of	New Zealand	USA
Finland	Norway	USSR
France	Pakistan	
Germany	Poland	

The member bodies of the following countries expressed disapproval of the document on technical grounds:

Japan
United Kingdom

Printed in Switzerland

Transformers for resistance welding machines — General specifications applicable to all transformers

1 Scope and field of application

This International Standard lays down specifications for transformers supplied with single phase current and used in resistance welding installations. It also specifies the tests these transformers shall undergo when they are not an integral part of a machine.

This International Standard applies to single phase transformers used in resistance welding and sold separately from the machine.[1] These transformers may be cooled either by water circulation in the secondary winding and possibly the magnetic core, or by air.

2 References

ISO 669, *Rating of resistance welding equipment.*

IEC Publication 417, *Graphical symbols for use on equipment.*

3 Operating conditions

Unless otherwise stated, the transformer is assumed to be operating under the following conditions[2] :

a) altitude :

It is assumed to be not more than 1 000 m above sea-level;

b) temperature of the cooling medium:

It is assumed that the maximum temperature of the cooling water does not exceed 30 °C at the transformer entry point and that, in the case of air cooled transformers, none of the following maximum temperatures are exceeded :

— maximum ambient temperature :	40 °C
— average daily temperature :	30 °C
— average annual air temperature :	20 °C

4 Definitions

Annex A gives further information to assist comprehension of some of these definitions.

See also the definitions given in ISO 669[3].

4.1 continuous duty : Periodic service when the duty factor is 100 %.

4.2 no-load secondary voltage : Voltage between the secondary terminals when the welding circuit is open.

4.3 continuous output (S_p) (see annex A): The highest electrical output, expressed in kilovoltamperes, for a 100 % duty factor, without exceeding the specified heat rise limits:

$$S_p = U_{20} \times I_{2p}$$

1) When the transformer is supplied with a machine of which it forms an integral part, ISO 669 applies to the whole assembly. The parties may agree that the transformer fitted in a machine can be of a type that has undergone the type tests in accordance with this International Standard.

2) For transformers designed to operate in different service conditions the correction tables in annex B are to be used.

3) In accordance with a recent agreement, the determining values for classification of transformers have been adopted for the continuous secondary current (I_{2p}) and secondary no-load voltage (U_{20}).

In ISO 669 the rated values still relate to 50 % duty factor.

In this International Standard, contrary to ISO 669, terms relating to 50 % duty factor are not taken as nominal (rated) values.

4.4 output at a given duty factor (S_X) (see annex A) : The output at a duty factor X, without exceeding the specified heat rise limits. This output is related to the continuous output (S_p) and the output at the duty factor 50 % (S_{50}) by the formulae :

$$S_X = S_p \sqrt{\frac{1 - e^{-T/\tau}}{1 - e^{-\frac{XT}{100\tau}}}} \text{ and,}$$

$$S_X = S_{50} \sqrt{\frac{1 - e^{-T/2\tau}}{1 - e^{-\frac{XT}{100\tau}}}}$$

where

T is the duration of the cycle;

X is the duty factor;

τ is the thermal time constant of the primary winding.

In practice, where the ratio $\frac{\tau}{T}$ is higher than five, it is possible to use the simplified formulae :

$$S_X = S_p \sqrt{\frac{100}{X}} \text{ and,}$$

$$S_x = S_{50} \sqrt{\frac{100}{2\,X}}$$

4.5 output at the duty factor 50 % (S_{50}) : The output at the duty factor X = 50 % without exceeding the specified heat rise limit, with a cycle time duration conventionally taken equal to 1 min. This output is related to the continuous output (S_p) by the formula :

$$S_{50} = S_p \sqrt{1 + e^{-30/\tau}}$$

where τ is the thermal time constant of the secondary winding *in seconds.*

In practice, where the ratio $\frac{\tau}{T}$ is higher than five, it is possible to use the simplified formula :

$$S_{50} = S_p \sqrt{2}$$

4.6 continuous secondary current (I_{2p}) (see annex A) : The highest current that can be passed by the transformer at a 100 % duty factor without exceeding the specified maximum heat rises.

4.7 secondary current at a given duty factor (I_{2X}) (see annex A) : The highest current that can be passed by the transformer for a given duty factor X without exceeding the specified maximum heat rises.

This current is related to the continuous secondary current and the secondary current at the duty factor 50 % by the formulae :

$$I_{2X} = I_{2p} \sqrt{\frac{1 - e^{-T/\tau}}{1 - e^{-\frac{XT}{100\tau}}}} \text{ and,}$$

$$I_{2X} = I_{50} \sqrt{\frac{1 - e^{-T/2\tau}}{1 - e^{-\frac{XT}{100\tau}}}}$$

where

T is the duration of the cycle;

X is the duty factor;

τ is the thermal time constant of the primary winding.

In practice, where the ratio $\frac{\tau}{T}$ is higher than five, it is possible to use the simplified formulae :

$$I_{2X} = I_{2p} \sqrt{\frac{100}{X}} \text{ and,}$$

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

4.8 secondary current at the duty factor 50 % (I_{50}) : The highest current that can be passed by the transformer, for a duty factor 50 % and a cycle time duration of 1 min without exceeding the specified maximum heat rises. This current is related to the continuous current by the formula :

$$I_{50} = I_{2p} \sqrt{1 + e^{-30/\tau}}$$

Formula in which τ is the thermal time constant of the primary winding *in seconds.*

In practice, where the ratio $\frac{\tau}{T}$ is higher than five, it is possible to use the simplified formula :

$$I_{50} = I_{2p} \sqrt{2}$$

4.9 magnetic circuit — maximum duty factor (X_m) (see annex A) : The maximum admissible duty factor that ensures that the heat rise in the magnetic circuit of the transformer does not exceed the values laid down.

4.10 short circuit voltage (U_{cc}) : The voltage at the rated frequency that has to be applied to the primary winding to cause the continuous current to flow therein when the terminals of the secondary winding(s) are short circuited.

4.11 no-load losses (P_o) : Active input power taken when the rated voltage at the rated frequency is applied to the terminals of the primary winding(s), with the secondary winding(s) on open circuit.

4.12 no-load current (I_0) **:** The current circulating in the primary winding when the rated voltage at rated frequency is applied to the winding, with the secondary winding(s) on open circuit.

The no-load current is expressed in amperes.

4.13 cooling liquid flow : The minimum flow in litres per minute necessary to cool the transformer at continuous output.

5 Construction

5.1 Earthing

For the conditions of earthing of the transformers, an International Standard is in preparation.

5.2 Cooling water circuit

The cooling water circuit shall ensure effective cooling of the transformer for a rated flow not more than 4 l/min for transformers of output at the duty factor 50 % $S_{50} < 150$ kVA and not more than 8 l/min, for transformers having an output at the duty factor 50 % between 150 and 500 kVA. It shall be leak-tight at a pressure of 10 bar[1)].

For the rated water flow the pressure drop of the water shall not be more than the indicated value. It is recommended that this value shall not exceed 0,6 bar.

6 Specifications

6.1 Secondary voltages

Secondary no-load voltages shall be indicated by the manufacturer to an accuracy of ± 2 % for all settings.

6.2 Secondary current at the duty factor 50 %

For all settings, the transformer shall pass the same secondary current at the duty factor 50 % without exceeding the specified heat rise limit.

6.3 Heat rise and temperature limits

The heat rise of secondary windings and, if it is not accessible, the magnetic circuit, shall not exceed the maximum heat rise shown in table 1.

The temperature of the accessible parts of the switch and the external frame work shall not exceed 65 °C.

If the magnetic circuit and the secondary winding(s) are accessible, their temperatures shall not exceed that admissible for the external frame work.

6.4 Dynamic behaviour

The transformer shall be able to withstand without failure occuring the dynamic stress caused by the repeated application of a current as high as possible up to a maximum of nine times the continuous secondary current (I_{2p}) under the conditions specified in 7.6.

6.5 Short circuit voltage

In the case of transformers having two independent secondary windings, the values measured for each winding, as indicated in 7.3., may not differ from one another by more than 5 % of the highest value.

6.6 No-load losses — No-load current (r.m.s.) output

The values measured during routine tests on a transformer shall remain close to the values obtained during the type test carried out on the prototype of the same model. This specification applies to the highest setting of no-load secondary voltage.

6.7 Insulation resistance

The insulation resistance measured as indicated in 7.7 shall not be less than 50 MΩ.

Table 1 — Heat rise and temperature limits

Type of cooling	Part	Method of determination	Limits of temperature rise, °C for classes of insulation A	E	B	F	H
Air	Windings	Resistance	60	75	85	105	130
		Internal indicators	60	75	85	110	135
		Probe	55	70	80	100	120
	Magnetic circuit	Thermometer	50	65	75	95	120
		Internal indicators	60	75	85	110	135
Water	Windings	Resistance	70	85	95	115	140
		Internal indicators	70	85	95	120	145
		Probe	65	80	90	110	130
	Magnetic circuit	Thermometer	60	75	85	105	130
		Internal indicators	70	85	95	120	145

1) 1 bar = 100 kPa, 1 Pa = 1 N/m^2.

6.8 Dielectrical resistance[1)]

During the dielectric test indicated in 7.8 no deterioration of the insulation shall occur.

7 Tests

7.1 Checking of the no-load voltages (routine test)

This test shall be carried out on all tappings. For the setting under consideration, the no-load voltage shall be verified by applying a voltage U'_1 as close as possible to the rated voltage U_1, to the primary terminal. The secondary no-load voltage shall be :

$$U_{20} = U'_{20} \times \frac{U_1}{U'_1}$$

U'_{20} being the voltage measured at the secondary terminals for the primary voltage U'_1.

7.2 Measurement of the heat rise in the windings (type test)

This test shall be carried out on all tappings.

The heat rise test shall be carried out at low voltage, the transformer being short-circuited as indicated in 7.3.

7.2.1 Condition of the transformer

The heat rise tests are for new and dry transformers. For water cooled transformers the cooling circuit shall have the water flow indicated.

7.2.2 Start of the test

Unless the temperature of the part is determined by resistance variation, the test may be started without waiting for the temperature of the transformer to be in balance with that of the cooling liquid.

If the temperature of the winding is determined by resistance variation :

a) when the transformer is water cooled, the liquid is circulated;

b) the test shall not be started until the temperature of the winding is within ± 1 °C of that of the cooling liquid;

c) the temperature t_1 of the cooling liquid shall be taken as the initial temperature of the winding the initial resistance R_1 of which has been measured.

7.2.3 Duration of the heat rise tests

The tests shall be carried out until the rate of temperature rise in the primary and secondary windings does not exceed 2 °C/h.

7.2.4 End of the test

The end of the test is the moment when the current is switched off. The purpose of the requirements of 7.2.5.2 is to determine, taking into account the essential requirements of the measuring method adopted, temperatures as close as possible to those reached by the parts at the time of measurement.

7.2.5 Conditions under which temperature measurements are taken

7.2.5.1 Determination of the cooling medium temperature

7.2.5.1.1 Thermometer placing

a) air-cooled transformer :

The thermometers shall be placed around the transformer, at a distance of approximately 1 m from it and at a height approximately half that of the transformer.

They shall be shielded from heat and draughts; the thermometer bulbs may be placed in small holders filled with oil with a view to equalizing the temperature variations;

b) water-cooled transformer :

The thermometers shall be placed in the cooling water where this enters the transformer.

7.2.5.1.2 Evaluation of the cooling liquid temperatures

To calculate the heat rises, the average of the temperatures obtained during the last quarter of the tests shall be taken for the cooling liquid temperatures.

7.2.5.2 Determination of the primary and secondary winding temperatures

7.2.5.2.1 Methods and measuring equipment used

a) measurement by resistance variation;

This method may only be used for the primary windings, whether the transformers are air- or water-cooled. In this method, the temperature of the windings is determined by increasing the resistance. For copper windings, the final temperature is obtained by the formula :

$$\frac{t_2 + 235}{t_1 + 235} = \frac{R_2}{R_1}$$

In practice, it is convenient to calculate the heat rise directly $t_2 - t_a$ by the following equivalent formula :

$$t_2 - t_a = \frac{R_2 - R_1}{R_1} (235 + t_1) + (t_1 - t_a)$$

1) Until the publication of an IEC document currently in preparation, indications are given in HD 389, *Safety rules concerning the electric equipment of machines for resistance welding and allied processes* published by CENELEC.

where

t_2 is the temperature of the winding at the end of the test, in degrees Celsius;

t_1 is the temperature of the winding when the initial resistance is measured, in degrees Celsius;

t_a is the temperature of the cooling liquid at the end of the test, in degrees Celsius;

R_1 is the initial resistance of the winding;

R_2 is the resistance of the winding at the end of the test.

b) internal temperature indicator :

This is a thermocouple incorporated in the winding during manufacture. It can be used for measuring the temperature of the secondary winding(s) of air- and water-cooled transformers and also the primary windings of water-cooled transformers.

c) bulb thermometers and detachable thermocouples :

These are used in the cases referred to in 7.2.5.2.2. They shal be in the closest possible contact with the windings and be placed at the hottest accessible point.

7.2.5.2.2 Instructions regarding determinations

a) air-cooled transformers :

The temperatures shall be determined in the case of primary windings either by resistance variation, thermometers or detachable thermocouples or, in the case of secondary windings, by thermometers (or detachable thermocouples) or internal temperature indicators.

Measurements shall be taken immediately after the current is switched off; the highest temperatures taken shall be recorded.

b) water-cooled transformers :

The temperatures shall be determined by resistance variation either with internal temperature indicators or detachable thermocouples in the case of primary windings, or, in the case of secondary windings, with thermometers (or detachable thermocouples) or internal temperature indicators.

If internal temperature indicators are used both for measuring the temperatures of the primary windings and for those of the secondary windings or even when thermometers (or detachable thermocouples) are used to measure the temperature of the secondary windings, the measurements shall be taken on load, i.e. immediately before switching off the current, while the cooling water circulates.

If the resistance variation method is used, the water circulation shall be stopped immediately before switching off the current. The resistance R_2 shall be measured as soon as possible after the flow has been stopped.

In all cases, the highest temperatures taken shall be recorded.

7.3 Measurement of the short-circuit voltage (type test)

This measurement shall be carried out when the transformer has reached its operating temperature on the tappings giving the highest secondary no-load voltage.

After the secondary winding(s) has (have) been short-circuited under the conditions indicated below, the primary voltage shall be adjusted to the value U_{1cc} until the exact admissible continuous current circulates in the primary circuit :

$$I_{1p} = \frac{S_p}{U_1}$$

Short-circuit voltage is given as a percentage by the formula :

$$U_{cc} = \frac{U_{1cc}}{U_1} \times 100$$

Where the transformer has two secondary windings the measurement is made under the following conditions :

— with the two secondary windings short-circuited in parallel;

— with the two secondary windings short-circuited in series;

— with one of the secondary windings short-circuited, the second open.

7.4 Measurement of the heat rise in the magnetic circuit (type test)

7.4.1 Condition of the transformer

The heat rise test of the magnetic circuit is for a new and dry transformer. The water flow in the water-cooled transformer shall be cut off, except if the magnetic circuit is itself cooled by water.

7.4.2 Input of the transformer

The transformer shall be supplied at rated voltage and at the maximum admissible duty factor X_m by the magnetic circuit (see 4.9). If a number of values for X_m are indicated in relation to the transformer installation conditions, the test shall be carried out for each of these values, taking a conventional one minute cycle. The highest setting shall be used.

7.4.3 Start of the test

The test may be started without waiting for the transformer to reach ambient air temperature.

7.4.4 Duration of the test

The test shall be continued until the rate of temperature rise of the magnetic circuit reaches 0,5 °C/h.

7.4.5 End of test

The test shall end when the last loading is completed.

7.4.6 Temperature determination

The ambient temperature shall be ascertained as indicated in 7.2.5.1.

The temperature of the magnetic circuit shall be determined by thermometer (or detachable thermocouple) or internal indicator, in accordance with 7.2.5.2.

7.5 Measurement of the no-load losses, P_o, and the no-load current, I_o, (routine test)

Either during the above test or a special test, with the transformer supplied at rated voltage and with the secondary circuits open, the no-load losses P_o, the no load current I_o, and the no-load apparent power $S_o = U_1 I_o$ of the transformer shall be measured.

7.6 Verification of the dynamic behaviour (type test)

The transformer shall be supplied at rated voltage. The current to test the dynamic behaviour shall be as high as possible up to a maximum of nine times the continuous secondary current I_{2p}.

The transformer shall be tested with this load for four hours at a 1,23 % duty factor and a 30 s cycle time.

The connexion of the load shall be made with flexible cables to simulate actual practice on the secondary terminals as nearly as possible.

7.7 Insulation resistance (type test)

This test shall be carried out immediately after the heat rise test. The insulation resistance between the primary and secondary windings and between the windings and the frame shall be measured at a continuous voltage of 500 V.

7.8 Dielectric tests (type and routine tests)

These tests are carried out on a fully equipped, new and dry transformer.

An a.c. voltage with rated mains frequency ± 10 % practically sinusoidal of 2 500 V rms shall be applied between a terminal of the primary winding and the frame and then between one terminal of the primary and one of the secondary circuit.

The test voltage of 2 500 V shall be applied gradually in order that the specified value is reached in approximately 20 s.

A similar a.c. voltage of 1 000 V rms shall be applied between one terminal of the secondary winding and the frame.

The test voltage of 1 000 V shall be applied instantaneously.

In both cases, the test voltage shall be kept at the specified value continuously for 60 s and then removed as quickly as the installation allows, without however causing any over-voltage.

NOTE — Dielectric tests should not normally be repeated on the same transformer. If for any reason they have to be, they should be carried out at voltages equal to 75 % of the above mentioned voltages.

7.9 Polarity of windings (routine tests)

The polarity of the secondary voltages, one in relation to the other, and in relation to the primary winding, shall be verified on all the transformers.

7.10 Water flow in and leak-tightness of the water circuit (routine test)

The water-tightness of the cooling circuit shall be verified at a pressure of 10 bar for 10 min.

It shall also be checked whether the load loss for the indicated flow is equal to or less than the stated value.

8 Marking

8.1 Rating plate

Each transformer shall have a rating plate on which the following details shall appear. In the case of transformers designed for several rated input voltages, the characteristics shall be given for each input voltage, either by means of several plates, or by an appropriate table.

1 Manufacturer's name.

2 Indication of the transformer type or design.

3 Reference to this International Standard.

4 Manufacturer's number. This number shall never be obliterated.

5 U_1 symbol : rated input voltages followed by the frequency of the input current in hertz.

6 Symbol U_{20} : in the form of a table, secondary no-load voltages on the various transformer taps. In case of difficulty, the maximum and minimum values of voltages, together with an indication of the number of steps shall be shown.

7 Symbol I_{2p} : continuous secondary current (see 4.6). The secondary current at the duty factor 50 % I_{50} (see 4.8) shall also be indicated when taking precautions to avoid mistakes with the continuous current.

8 Symbol S_{50} : output at the duty factor 50 % (see 4.5). It shall be also indicated the continuous output S_p (see 4.3) in taking precautions for avoiding mistakes with the output at the duty factor 50 %.

9 Symbol X_m : maximum admissible duty factor in percent and given at maximum no-load voltage (see 4.9). This indication shall be given if the duty factor is lower than 100 %.

Symbol τ : thermal time constant of the primary winding in seconds (given optionally).

10 Indication of insulation class.

11 Indication of the weight of the transformer.

12 Cooling liquid flow and pressure drop.

13 Indication of the conventional designation of the magnetic sheets according to Euronorm 106 and 107.[1)]

Annex C shows specimen rating plates.

8.2 Earth terminal

The earth terminal for connecting the protective conductor (see 5.1) shall be marked with the symbol (see IEC 417).

8.3 Polarity of the windings

The polarity of the terminals of the different transformer windings shall be suitably indicated.

9 Technical notice

In addition to the data specified in 8.1, the manufacturer may provide the following into the technical notice relating to the transformer :

no-load losses P_o (see 4.11);

no-load current I_o (see 4.12);

short-circuit voltage U_{cc} (see 4.10).

1) Until the publication of an IEC document currently in preparation, this indication is given according to the national standards or Euronorm 106 and 107.

Annex A

Notes on some physical concepts and comments on the definitions

A.1 Heat rise and cooling of a transformer

When a transformer is in operation it heats up and the temperature of its various parts tends to rise towards a maximum balancing value θ_m. Distinction has to be drawn between :

a) the heat rise in the windings : the final balancing temperature is a quadratic function of the current flowing through the windings;

b) the magnetic circuit heat rise : the final temperature varies with the inductive effect and therefore with the voltage applied to the terminals of the primary windings.

These maximum temperatures vary also with the conditions of manufacture and installation of the transformer, including the heat exchange conditions with the cooling liquid.

When the transformer no longer operates, it cools and the temperature of its various parts tends to fall towards the temperature of the cooling liquid. Two alternatives have therefore to be considered :

a) the transformer remains under voltage but the load is removed. Only the windings cool down, the magnetic circuit continues to heat up if it has not reached the balancing temperature or stays at the said temperature;

b) the transformer is switched off. The windings and the magnetic circuits will then cool down.

The temperature variation of the transformer (see figure 1) follows an exponential law related to time, i.e. in accordance with the expressions :

$\theta = \theta_m - (\theta_m - \theta_o) e^{-t/\tau}$ for heat rise;

$\theta = \theta_o + (\theta_n - \theta_o) e^{-t/\tau}$ for cooling;

where

θ_m is the final balancing temperature;

θ_o is the temperature of the cooling liquid;

θ_n is the temperature when the transformer starts to cool.

The coefficient $\frac{1}{\tau}$ appearing as an exponent is a physical quantity depending on the design of the transformer and its installation and particularly the heat exchange conditions with the cooling liquid.

The inverse of the coefficient, τ, is called the thermal time constant of the transformer (see 4.4).

It will be noted that this thermal time constant is a measurable physical quantity, characteristic of a transformer part. It establishes in fact the speed of heat rise and cooling. It corresponds to the time after which the temperature would reach its maximum if it maintained its original rate of variation. It also corresponds to the time after which the temperature variation in relation to that at a given moment t has reached approximately 63 % of the temperature difference between the final temperature and the temperature at the moment t.

A.2 Operation of the resistance welding machine transformer

Generally speaking, a resistance welding machine transformer does not operate continuously but in a periodic cycle comprising an on-load work time followed by a rest time.

The ratio $\frac{t_1}{T}$ of the load time to the cycle time is called the duty factor. This duty factor is expressed as a percentage.

$$X = \frac{100\, t_1}{T}$$

According to the work done and the conditions of use of the transformer, the cycle time values and the duty factor can vary.

During an operating cycle, (see figure 2), the transformer heats up during the duty time and cools down during the rest time. The heat rise in relation to the temperature of the cooling liquids varies between two extreme values θ_1 and θ_2.

A.2.1 Windings

The maximum heat rise θ_2 reached by the windings varies with the current flow, the cycle time, the duty factor and the thermal time constant of the transformer. This heat rise shall never exceed the maximum values established in relation to the insulation class used. Consequently, if for example the duty factor is low, it will be possible to have a higher current pass through the transformer than if the duty factor were high.

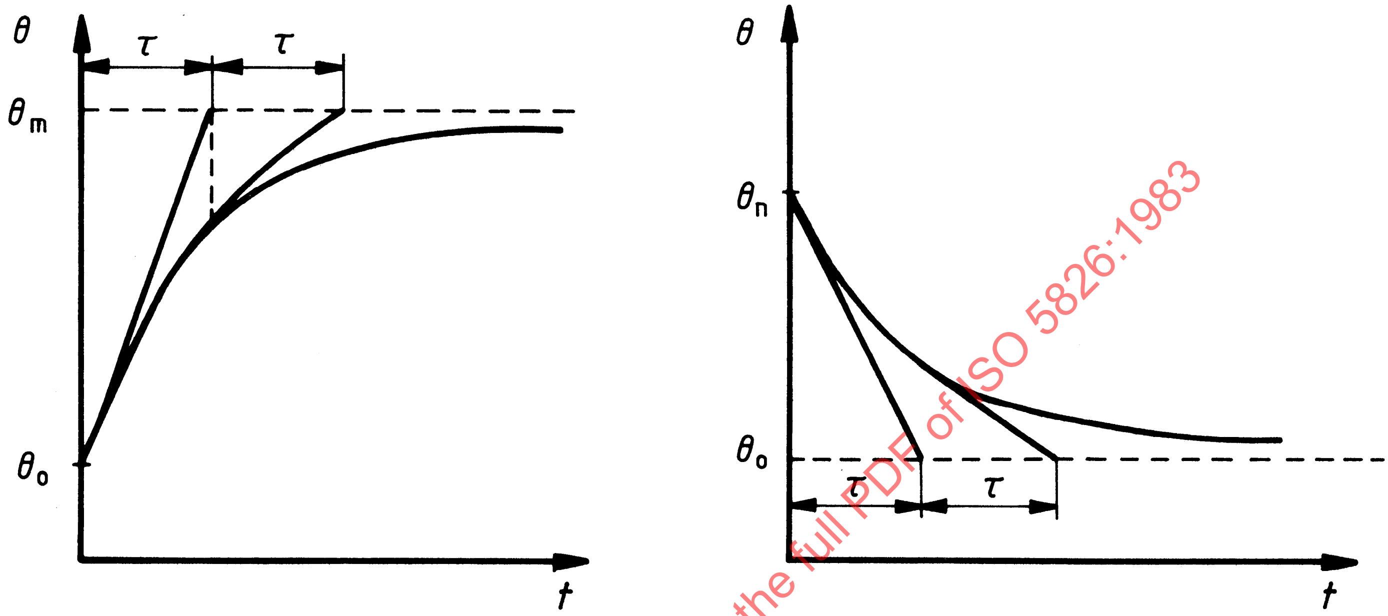
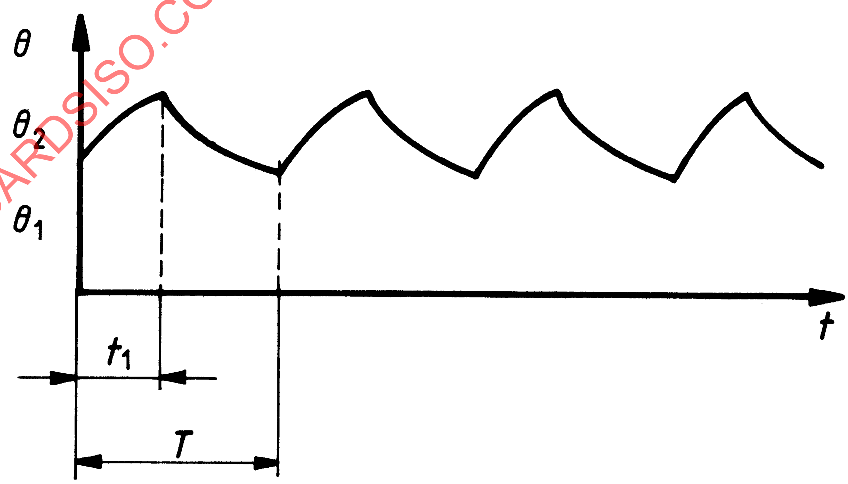


Figure 1 — Temperature variation of a transformer



NOTE — Curve drawn assuming the established operating conditions.

Figure 2 — Transformer operating cycle

If the continuous output S_p (see 4.3), verified by the heat rise test and entered on the rating plate, or the continuous secondary current I_{2P} (see 4.6) and also the thermal time constant τ of the transformer, also entered on the rating plate, are known, it is possible to ascertain the output S or the secondary current I_2 admissible for a given duty factor X corresponding to a cycle time T. These outputs and currents are in fact related by the formulae :

$$S_X = S_p \sqrt{\frac{1 - e^{-\frac{T}{\tau}}}{1 - e^{-\frac{XT}{100\tau}}}}$$

$$I_{2X} = I_{2p} \sqrt{\frac{1 - e^{-\frac{T}{\tau}}}{1 - e^{-\frac{XT}{100\tau}}}}$$

In current practice, if the ratio $\frac{\tau}{T}$ between the thermal heat constant and the cycle time is above five, the following simplified formulae can be used :

$$S_X = S_p \sqrt{\frac{100}{X}}$$

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

A.2.2 Magnetic circuit

The maximum heat rise, θ, reached by the magnetic circuit of the transformer is no longer a function of the current passed but of the induction effect in the metal, and accordingly of the primary voltage. This heat rise is also of course related to the time during which current passes and therefore to the cycle and 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 primary voltage. The heat 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 primary circuit, the heat 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 heat 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 heat rise tests on the windings under continuous condition is not in contradiction with what has been said above. The heat rise test is in fact carried out at low voltage so that the heat rise in the magnetic circuit is negligible.

A.3 Practical application

If the thermal time constant of the transformer, its continuous output, S_p, and/or the admissible continuous secondary current, I_{2p}, and also the maximum duty factory, X_m, are known, it is possible for the user to determine the possibilities of the transformer accurately.

The formulae indicated in A.2.1 make it possible in fact :

a) to determine the admissible output and secondary current for a given cycle and duty factor corresponding to the work to be done; or,

b) to calculate the admissible cycle and duty factor knowing the current necessary to do the required work.

If the thermal time constant does not permit use of the simplified formulae given in A.2.1, the complete formulae should be used noting that, in the second case, the known characteristics is generally the time the current passes t_1 which is equal by definition to $\frac{XT}{100}$.

A start should therefore be made by determining the admissible cycle time T by using the formula :

$$I_2 = I_{2p} \sqrt{\frac{1 - e^{-\frac{T}{\tau}}}{1 - e^{-\frac{t1}{\tau}}}}$$

and then calculating

$$X = \frac{100 t_1}{T}$$

In both cases, whether the desired or calculated duty factor is equal to or more than maximum admissible duty factor, X_m should be noted.

NOTE — The user should also check that the conditions of installation of the transformer in the machine do not cause a reduction in the currents or the maximum admissible duty factor.

A.4 Determination of the thermal time constant of the primary winding

The thermal time constant may be determined by one of the following methods :

After having loaded the transformer at the duty factor X = 100 %, under the conditions indicated in 6.2.1, the following temperatures are measured :

θ_0 at the initial time,

θ_1 at the end of time $t = t_1$

θ_2 at the end of time $t = 2\ t_1$