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Edition 2

SOUTH AFRICAN NATIONAL STANDARD

Rewound and refurbished rotating electrical machines

Part 1: Low-voltage three-phase induction motors

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1 dr lategan road groenkloof ✉ private bag x191 pretoria 0001
tel: 012 428 7911 fax: 012 344 1568 international code + 27 12
www.stansa.co.za

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Table of changes

Change No.	Date	Scope

Foreword

This South African standard was approved by National Committee StanSA TC 61, *Rotating machinery,* in accordance with procedures of Standards South Africa, in compliance with annex 3 of the WTO/TBT agreement.

This edition cancels and replaces edition 1 (SABS 1561-1:1992).

Annex A forms an integral part of this part of SANS 1561. Annexes B, C and D are for information only.

Contents

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Rewound and refurbished rotating electrical machines

Part 1:
Low-voltage three-phase induction motors

1 Scope

1.1 This part of SANS 1561 specifies the characteristics of low-voltage three-phase alternating-current induction motors of the cage and wound rotor (slip-ring) types that are to be refurbished and, if applicable, rewound.

1.2 The maximum rated output of a motor covered by this part of SANS 1561 is 800 kW for rated voltages not exceeding 1 100 V between phases.

1.3 The level of insulation covered by this part of SANS 1561 is at least class B for existing windings of refurbished motors and at least class F for motors that are rewound.

1.4 This part of SANS 1561 covers the finished product only.

NOTE Induction motors for use in hazardous areas have to comply with requirements of applicable standards such as SANS 61241-1-1 and SANS 60079-15. See SANS 10108 for more details.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitutes provisions of this part of SANS 1561. All standards are subject to revision and, since any reference to a standard is deemed to be a reference to the latest edition of that standard, parties to agreements based on this part of SANS 1561 are encouraged to take steps to ensure the use of the most recent edition of the standard indicated below. Information on currently valid national and international standards can be obtained from Standards South Africa.

SANS 60034-1/IEC 60034-1, *Rotating electrical machines – Part 1: Rating and performance.*

3 Definitions

3.1 For the purposes of this part of SANS 1561, the following definitions from SANS 60034-1 apply.

3.1.1
bearing temperature stabilization
state reached when the temperature rise of the bearing as measured on the bearing housing does not vary by more than 2 °C over a period of 1 h

3.1.2
duty
statement of the load(s) to which the machine is subjected, including, if applicable, starting, electric braking, no-load and rest and de-energized periods, and including their durations and sequence in time

3.1.3
duty type
continuous, short-time or periodic duty, comprising one or more loads remaining constant for the duration specified, or a non-periodic duty in which, generally, load and speed vary within the permissible operating range

NOTE Diagrams illustrating the duty types are given in SANS 60034-1.

3.1.3.1
continuous running duty — Duty type S1
operation at a constant load of sufficient duration for thermal equilibrium to be reached

3.1.3.2
short-time duty — Duty type S2
operation at a constant load during a given time, less than that required to reach thermal equilibrium, followed by a rest and de-energized period of sufficient duration to re-establish machine temperatures within 2 °C of the temperature of the coolant

3.1.3.3
intermittent periodic duty — Duty type S3
sequence of identical duty cycles, each cycle consisting of a period of operation at constant load and a rest and de-energized period

NOTE In this duty, the cycle is such that the starting current does not significantly affect the temperature rise.

3.1.3.4
intermittent periodic duty with starting — Duty type S4
sequence of identical duty cycles, each cycle consisting of a significant period of starting, a period of operation at constant load and a rest and de-energized period

3.1.3.5
intermittent periodic duty with electric braking — Duty type S5
sequence of identical duty cycles, each cycle consisting of a period of starting, a period of operation at constant load, a period of rapid electric braking and a rest and de-energized period

3.1.3.6
continuous-operation periodic duty — Duty type S6
sequence of identical duty cycles, each cycle consisting of a period of operation at constant load and a period of operation at no load

NOTE There is no rest and de-energized period.

3.1.3.7
continuous-operation periodic duty with electric braking — Duty type S7
sequence of identical duty cycles, each cycle consisting of a period of starting, a period of operation at constant load and a period of electric braking

NOTE There is no rest and de-energized period.

3.1.3.8
continuous-operation periodic duty with related load/speed changes — Duty type S8
sequence of identical duty cycles, each cycle consisting of a period of operation at constant load corresponding to a pre-determined speed of rotation, followed by one or more periods of operation at other constant loads corresponding to different speeds of rotation (carried out, for example, by means of a change of the number of poles in the case of induction motors)

NOTE There is no rest or de-energized period.

3.1.3.9
duty with non-periodic load and speed variations — Duty type S9
duty in which, generally, load and speed vary non-periodically within the permissible operating range

NOTE 1 This duty includes frequently applied overloads that may greatly exceed full loads.

NOTE 2 For this duty type, suitable full load values can be taken as the basis of the overload concept.

3.1.4
load
numerical values of the electrical and mechanical quantities that signify the demand to be made on a rotating machine by an electrical circuit or a mechanism at a given instant

3.1.4.1
full load
highest value of load specified for a machine that operates at rated output

3.1.4.2
full-load power
highest value of shaft power specified for a machine that operates at rated output

3.1.4.3
no load
<operation>
state of a machine rotating with zero output power (but otherwise normal operating conditions)

3.1.5
locked-rotor current
measured steady-state root-mean-square current taken from the line, with the rotor locked and with rated voltage applied at rated frequency

3.1.6
locked-rotor torque
measured torque that the motor develops with the rotor locked and with rated voltage applied at rated frequency

3.1.7
rated output
numerical value of the output included in the rating

3.1.8
rated value
numerical value of a quantity included in the rating

3.1.9
rating
entire number of numerical values of the electrical and mechanical quantities with their durations and sequence assigned to the machine by the manufacturer and stated on the rating plate, the machine complying with the specified conditions

3.1.10
rest and de-energized
complete absence of all movement and of all electrical supply or mechanical drive

3.1.11
thermal equilibrium
state reached when the temperature rises of several parts of the machine do not vary by more than 2 °C over a period of 1 h

3.1.12
thermal equivalent time constant
time constant that replaces several individual time constants and that determines approximately the temperature course in a winding after a step-wise current change

3.1.13
time constant
given factor for time that is invariable

3.2 For the purposes of this part of SANS 1561, the following definitions apply:

3.2.1
acceptable
acceptable to the authority administering this part of SANS 1561, or to the parties concluding the purchase contract, as relevant

3.2.2
class of insulation
specific insulation for the winding that is determined by the insulation material or by an element of a compound material within the insulation system that has the lowest temperature index

3.2.3
standard direction of rotation
clockwise direction when the driving end of a motor is viewed

3.2.4
duty cycle
variation of load with time

3.2.5
purchaser
person, company or store that commissions the rewinding and refurbishing of a motor

3.2.6
repair contractor
organization (or its agent) that undertakes the rewinding or refurbishing (or both) of a motor

4 Rewinding and refurbishing

4.1 Categories for rewinding and refurbishing

The work that has been carried out on a rewound or refurbished motor shall be categorized by the use of category-of-work designations (see 7.3(a)), and shall be as required (see annex A).

The category-of-work designations are as follows:

a) **IW1** indicating that no rewinding is necessary, existing windings were refurbished by being cleaned, dried in the oven, subjected to a varnish/resin treatment and then cured in an oven. The winding shall be subjected to electrical resistance balance checks, insulation resistance to earth and between phases, as well as any auxiliaries fitted;

or

b) **IW2** indicating that rewinding of the stator or rotor (or both) was necessary, new windings were subjected to a treatment of double dipping in a varnish/resin and curing in an oven, or to a treatment of vacuum pressure impregnation (VPI), vacuum impregnation (VI) in varnish/resin and baking in an oven, or to a trickle method of impregnation.

4.2 Workmanship and finish

All work shall be properly executed and finished, and so arranged as not to constitute any kind of hazard.

5 Electrical and physical requirements

5.1 High-voltage withstand

5.1.1 When a motor is tested in accordance with 6.3, it shall withstand a high-voltage test for 1 min, without puncture of the insulation and without flashover, at the application of a power-frequency alternating voltage or voltages of the appropriate value(s) given in table 1. The insulation resistance shall be measured before and after any high-voltage withstand test.

5.1.2 The high-voltage withstand test at full voltage made on the windings on acceptance shall not be repeated. If a second test is done at the request of the purchaser, the motor shall be subjected to further drying and the test voltage applied shall be 80 % of the voltage specified in table 1.

5.1.3 Motors with original windings shall be cleaned and dried and then subjected to a test voltage equal to 75 % of the voltage given in table 1.

5.2 Current balance at no load

5.2.1 When a motor is tested in accordance with 6.4, the current measured in each line shall not differ by more than 2,5 % from the average value of the currents in all three lines at balanced voltage.

5.2.2 The average value of current at no load

a) shall be within 10 % of the original design value, or

b) when it is not possible to obtain the original design value, shall be as agreed upon (see annex A).

NOTE 1 Typical values for no-load current with respect to rated voltage, rated output and rated revolutions per minute for motors with cast iron frames are given in annex B.

NOTE 2 Unbalanced currents can be the result of an out-of-balance supply voltage. It is advisable to ensure that the supply voltage is balanced at the time of the test (see annex C).

Table 1 — Test voltages

1	2
Components to which the voltage is applied	**Test voltage**, **r.m.s.** V
Insulated components	1 000 V plus twice the rated voltage, with a minimum of 1 500 V
Secondary (usually rotor) insulated windings:	
a) for non-reversing motors, and motors reversible from standstill only	1 000 V plus twice the open-circuit voltage (as measured at standstill between secondary terminals with rated voltage applied to the primary windings), with a minimum of 1 500 V
b) for motors that are reversed or braked by reversal of the primary supply while the motor is running	1 000 V plus four times the open-circuit standstill secondary voltage as measured in (a) above, with a minimum of 1 500 V

5.3 Vibration (horizontal foot-mounted motors only)

5.3.1 The maximum levels of vibration severity, measured on the bearing housings or as close as practically possible, with the motor securely and rigidly mounted, preferably in accordance with the original design criteria for horizontal machines in both the vertical and lateral planes, shall not exceed the maximum root-mean-square values of vibration velocity for the motors having shaft heights (H), in millimetres, as specified in table 2 (see annex A.1(b) and A.2(b)).

5.3.2 The vibration tests shall include measurements of vibration in the vertical, horizontal and axial planes of both the drive end and non-drive end bearing housings. A motor shall not be accepted if the overall axial vibration is larger than either the overall horizontal or overall vertical vibrations on the same bearing housing.

Table 2 — Limits of vibration severity for mounted motors

1	2	3	4	5
Nominal speed (r/min)	**Maximum r.m.s. values of the vibration velocity** (mm/s) **for different shaft heights** (H, in mm)			
	56 ≤ H ≤ 132	132 < H ≤ 225	225 < H ≤ 400	H > 400
≥ 600 ≤ 1 800	0,71	1,12	1,4	1,8
> 1 800 ≤ 3 600	1,12	1,8	2,12	2,8

5.4 Bearing temperature

When a motor is tested during the current balance at no load, the maximum temperature rise of any bearing shall be not more than 30 °C after 30 min from cold start-up. In the event of the temperature rise exceeding 30 °C after 30 min, the motor shall be run until the bearing temperature stabilises.

An acceptable bearing temperature rise cannot be prescribed, but the following factors shall be taken into consideration when deciding if the temperature rise is acceptable:

a) the motor running speed;

b) if an oil seal is fitted that could be generating heat;

c) the temperature differential between the driving end (DE) and the non-driving end (NDE) bearings;

NOTE A large differential could indicate that the bearing with the high temperature has been damaged or incorrectly installed.

d) the source of the heat (i.e. whether the heat is being generated by the stator or rotor winding temperature and being transferred to the bearing); and

e) the motor operating conditions.

5.5 Current balance with locked rotor at reduced voltage

When a motor is tested in accordance with 6.5, the current measured in each line shall not differ by more than 2,5 % from the average r.m.s. current in all three lines at balanced voltage.

5.6 Current balance, input power and torque with locked rotor at reduced voltage (cage motors, test categories IT2 and IT3 only (see table 6 for test categories))

When the current, input power and torque are measured in accordance with 6.6, the power shall be within 10 % of the original design values; or when it is not possible to obtain the original design values, the values of locked-rotor torque, locked-rotor current and locked-rotor input power shall be as agreed upon (see annex A).

NOTE Typical values of locked-rotor power for standard motors with cast iron frames can be calculated from the relevant information given in annex B. The calculated locked-rotor torque and current can be compared with the values given in annex B.

5.7 Open circuit rotor voltage (only motors with wound rotors)

When a wound rotor (slip-ring) motor is tested in accordance with 6.7, the measured open circuit rotor voltages shall be balanced within 2,5 % and the average r.m.s. voltage shall be equal to or 5 % higher than the design value.

5.8 Temperature rise (test category IT3 only (see table 6 for test categories))

5.8.1 General

5.8.1.1 When a motor is tested in accordance with 6.8, the temperature rise of each component shall not exceed the appropriate value given in table 3, applicable to the class of insulation of the motor and, when relevant, to the method of measurement.

5.8.1.2 In cases where any material or a component of the system has a lower thermal classification (known as a graded insulation system) than the overall system, test evidence of the performance of the system shall be provided, the results of which are produced by an accredited test facility.

5.8.1.3 In cases where any individual element of a composite material has a lower temperature index than the composite material as a whole, test evidence of the performance of the composite material shall be provided by an accredited test facility.

Table 3 — Limits of temperature rise

1	2	3	4	5	6	7	8	9	10
Component	**Maximum temperature rise**[a] °C								
	Class of insulation[b]								
	B			**F**			**H**		
	T	**R**	**ETD**	**T**	**R**	**ETD**	**T**	**R**	**ETD**
Three-phase insulated windings[c]	—	80	90	—	105	110	—	125	135
Permanently short-circuited insulated windings	80	—	—	100	—	—	125	—	—
Iron cores and other components in contact with windings	80	—	—	100	—	—	125	—	—
Slip rings[d]	80	—	—	90[e]	—	—	100[e]	—	—
Iron cores and other components not in contact with windings; permanently short-circuited, uninsulated windings	The temperature rise of these components shall be such as not to cause any risk of damage to adjacent components								

[a] The **T** values are applicable to temperature rises measured by a thermometer, the **R** values to those measured by the resistance method, and the **ETD** values to those measured by embedded temperature detectors.

[b] Insulation is classified as follows:

Class of insulation	**Maximum continuous permissible temperature**, °C
B	130
F	155
H	180

[c] Although, in the case of an insulated coil winding, the resistance method is the preferred method, the temperature rise may be checked by a thermocouple applied directly to the insulation of the conductor of the winding. However, because of the possibility of contact having been made at a "hot spot" (an isolated hot position not indicative of the general temperature of the motor), the temperature rise measured by means of a thermocouple may exceed the appropriate **R** value. In such a case, provided that the appropriate **R** value has not been exceeded by more than 10 °C, the temperature rise check shall be deemed satisfactory.

[d] These temperature rises apply to open and to enclosed slip rings, and are permissible provided that insulation appropriate to the temperature rise is used, except that, if the slip ring is adjacent to windings, the temperature rise shall not exceed that for the winding insulation class.

[e] These maximums may necessitate the use of special brushes.

5.8.2 Adjustments to limits of temperature rise to take account of operating conditions

5.8.2.1 The adjustments detailed in 5.8.2.2 to 5.8.2.7 (inclusive) relate to conditions at the operating site and shall be made to the limits of temperature rise for motors indirectly cooled by air, to take account of specified conditions of altitude or maximum ambient temperature (or both).

5.8.2.2 No adjustment is to be made to the temperature rise limits specified in table 3 when the maximum ambient temperature is 40 °C and the altitude is between sea level and 1 000 m.

5.8.2.3 If the specified maximum temperature of the coolant is between 40 °C and 60 °C, the limits of temperature rise given in table 3 shall be reduced by the amount by which the temperature of the coolant exceeds 40 °C.

5.8.2.4 If the specified maximum temperature of the coolant exceeds 60 °C or is less than 0 °C, the limits of temperature rise shall be as agreed upon (see annex A).

5.8.2.5 If the specified maximum temperature of the coolant is between 0 °C and 40 °C, no increase in the limits of temperature rise shall normally be made. However, if so agreed upon (see annex A), an increase may be made but this shall not exceed the difference between the maximum temperature of the coolant and 40 °C, with a maximum of 30 °C.

5.8.2.6 If a motor is to operate at an altitude between 1 000 m and 4 000 m and the maximum temperature of the coolant is not specified, it shall be assumed that the reduced cooling resulting from altitude is compensated by a reduction of maximum ambient temperature below 40 °C, and that the limiting total temperatures will therefore not exceed 40 °C plus the temperature rises specified in table 3.

NOTE Assuming that the necessary decrease is 1 % of the limiting temperature rise for every 100 m of altitude above 1 000 m, the assumed maximum ambient temperature at the operating site, based on a 40 °C maximum ambient temperature for altitudes up to 1 000 m, is shown in table 4.

5.8.2.7 If the motor is to operate at an altitude exceeding 4 000 m, the maximum limits of temperature rise shall be as agreed upon (see annex A).

Table 4 — Assumed maximum ambient temperatures

1	2	3	4
Altitude m	**Temperatures** °C		
	Class of insulation		
	B	**F**	**H**
1 000	40	40	40
2 000	32	30	28
3 000	24	19	15
4 000	16	9	3

5.8.3 Adjustments to limits of temperature rise to take account of altitude and ambient temperature of the test site

5.8.3.1 The adjustments in 5.8.3.2 to 5.8.3.3 shall be made to the limits of temperature rise for motors indirectly cooled by air, to take account of the difference in altitude between the test site and the operating site or the difference between the specified maximum temperature of the coolant at the operating site and the temperature of the coolant at the test site.

5.8.3.2 If the operating site is higher than the test site but not higher than 4 000 m, the temperature rise on test shall be as in table 3 (corrected, if appropriate, in accordance with 5.8.2) minus an adjustment calculated on the basis of 1 % change in the permitted temperature rise in table 3 per 100 m of the difference between the altitude of the test site and the operating site.

5.8.3.3 For the purposes of the calculation, altitudes below 1 000 m shall be assumed to be equal to 1 000 m. If the test site is higher than the operating site but not higher than 4 000 m, the corresponding adjustment shall be added, not subtracted. If this positive temperature rise adjustment, when added to the ambient temperature at the test site, results in a total temperature considered excessive by the purchaser, the testing procedure shall be as agreed upon (see annex A).

5.9 Efficiency (test category IT3 only (see table 6 for test categories))

When a motor is tested in accordance with 6.9, the actual efficiency measured might be higher than the guaranteed efficiency but shall be not less than the limits given in table 5, unless otherwise agreed upon (see annex A).

Table 5 — Efficiency limits

1	2
Output of motor kW	**Minus tolerance permitted on guaranteed efficiency**
up to and including 50	15 % of (100 − η)
above 50	10 % of (100 − η)
NOTE Where η is the agreed efficiency, as a percentage.	

6 Methods of test

6.1 Test categories

Test a finished motor in accordance with one of the two test categories indicated in table 6, as required (see annex A).

6.2 Procedure to measure insulation resistance

6.2.1 Before measuring insulation resistance, earth the winding and the frame for a few seconds in order to ensure that any residual electric charges that might exist in the insulation of the winding are completely discharged to earth. Insulation resistance measurements will be incorrect if there is residual charge in the insulation.

6.2.2 Measure the insulation resistance between each phase winding and the frame and also between all three phase windings. Take the value of each insulation resistance reading after the reading has stabilized. One of the more effective ways of carrying out these tests is to measure the insulation resistance in turn between each phase winding and the frame, with the other phase windings, not under test, connected to the frame. Thus the insulation resistance between phases is also tested. In the case of a winding that is internally connected in star or in delta, the measurements are taken between the lines connected together and the frame (for the insulation resistance and the high-voltage withstand test), or between the lines (for the line resistance comparison test).

Table 6 — Test categories

1	2	3	4
Tests	**Subclause**	**Test category**	
		IT2	**IT3**
High-voltage withstand test	5.1	x	x
No-load tests:			
a) Current balance and speed	5.2	x	x
b) Overall amplitude of vibration only	5.3	x	x
c) Amplitude of vibration (full spectrum)	5.3	–	x
d) Documented bearing temperature	5.4	x	x
Locked rotor tests:			
a) current balance at reduced voltage and at rated current	5.5	x	x
b) current balance, input power and torque at full induced current and reduced voltage with kilogram value and bar length also documented	5.6	x	x
c) open circuit rotor voltage at full stator voltage	5.7	x	x
Full-load test to determine efficiency and temperature rise by resistance method.	5.9	–	x

6.2.3 During the measurement of the insulation resistance, record the temperature of the winding.

6.2.4 If the temperature of the winding differs from 40 °C, correct the measured insulation resistance to a reference temperature of 40 °C by using the following equation:

$$R_c = K_t \times R_t$$

where

R_c is the insulation resistance corrected to 40 °C, in mega ohms;

K_t is the appropriate insulation resistance temperature coefficient at a temperature of t °C;

R_t is the measured insulation resistance at a temperature of t °C, in mega ohms.

6.2.5 Check whether each corrected insulation resistance value is equal to or exceeds the minimum recommended value that is obtained from the following equation:

$$R_m = 1 + k$$

where

R_m is the recommended minimum insulation resistance at 40 °C, in mega ohms;

k is the ratio of the rated motor voltage in volts to 1 000 V, in numerical ratio.

Example of calculation

Rated motor voltage = 550 V

$$R_m = \left(1 + \frac{550\ \text{V}}{1\ 000\ \text{V}}\right)\ \text{M}\Omega$$

$$= (1 + 0{,}55)\ \text{M}\Omega$$

$$= 1{,}55\ \text{M}\Omega$$

NOTE In the case of insulation in good condition, insulation resistance readings of 10 times to over 100 times the value of the recommended minimum insulation resistance R_m are not uncommon in practice.

6.3 High-voltage withstand test

6.3.1 Conduct an insulation resistance test in accordance with 6.2 before the high-voltage withstand test is carried out.

6.3.2 In the case of a motor that has both ends of each phase winding individually accessible, apply the test voltage in turn between each phase winding and the frame, with the core and the other phase windings not under test connected to the frame.

6.3.3 In the case of a motor that has only one end of each phase winding accessible (e.g. a motor internally star connected), apply the test voltage between any one end of the windings and the frame.

6.3.4 Start the test at a voltage not exceeding one-half of the appropriate test voltage given in column 2 of table 1. Increase the voltage to the full test voltage, steadily or in steps of not more than 5 % or over a period of at least 10 s.

6.3.5 Maintain the full test voltage for 1 min and then reduce the voltage to not more than one-half of this value before switching off.

6.3.6 Check whether the winding withstands the test voltage without flashover or breakdown of the insulation.

6.3.7 Check for compliance with 5.1.

6.4 Current balance at no-load measurement

6.4.1 After bolting the motor onto the test bedplate, switch the motor on to the rated power supply, with the voltmeter(s) and ammeter(s) connected in the motor test circuit.

6.4.2 Measure and record the current in each line. Record also the actual voltage between phases.

6.4.3 Calculate the average value of the current in the three lines.

6.4.4 Check for compliance with 5.2.

6.5 Procedure for measuring current balance with locked rotor

6.5.1 Securely bolt the motor onto the test bedplate.

6.5.2 Adjust the voltage of the power supply to not more than 20 % of the rated voltage of the motor in the case of the variable voltage supply, or to the lowest voltage tapping in the case of the supply with fixed voltage tappings.

6.5.3 Check the direction of rotation of the motor by momentarily switching the motor on and off.

6.5.4 Lock the rotor of the motor securely by means of a torque arm or other suitable means, taking the direction of rotation of the motor into account.

6.5.5 Switch on the power supply and observe the current in each line. So adjust the voltage of the power supply (by either varying the voltage or by selecting a suitable voltage tapping) that the current in each line is at least equal to the rated full-load current of the motor, but preferably equal to twice the rated full load current. Record the current in each line and the voltage between phases after allowing the motor to be energized for not longer than 60 s.

6.5.6 Calculate the average current in the three lines.

6.5.7 Check for compliance with 5.5.

6.6 Measuring current balance, input power and torque (cage motors only)

6.6.1 Securely bolt the motor onto the test bedplate.

6.6.2 Adjust the voltage of the power supply to not more than 20 % of the rated voltage of the motor in the case of the variable voltage supply, or to the lowest voltage tapping in the case of the supply with fixed voltage tappings.

6.6.3 Check the direction of rotation of the motor by momentarily switching the motor on and off.

6.6.4 Lock the rotor of the motor securely by coupling the torque measuring device(s) to the motor shaft, taking the direction of rotation of the motor into account.

6.6.5 Use the two wattmeters method or other equivalent method of measuring input power to the motor.

6.6.6 For the two wattmeters method, connect the wattmeters, ammeter(s), voltmeters(s) and, when relevant, current transformers, into the motor test circuit. Ensure that when current transformers are being used, the secondary winding of each current transformer is shorted-out by suitable means before the power supply to the test circuit is switched on.

6.6.7 Switch the motor test circuit on to the power supply and, when relevant, remove the shorting link on the secondary windings of the current transformers. Observe the current in each line. So adjust the voltage of the power supply (by either varying the voltage or selecting a suitable voltage tapping) that the current in each line is at least equal to the rated full-load current of the motor.

6.6.8 Record the current in each line, the voltage between phases and the readings on the two wattmeters, and measure the torque on the shaft of the motor. When measuring the torque by means of a torque arm, ensure that the arm is in a horizontal position and the force-measuring device is perpendicular with respect to the torque arm.

6.6.9 One of the wattmeters might indicate a zero or a reverse reading (depending on the power factor of the motor circuit). In the case of a reverse reading, interchange the connections to the voltage-coil on the wattmeter. Record the forward reading on the wattmeter and take this value to be a negative reading.

6.6.10 Calculate the average current in the three lines and check for compliance with 5.6.

6.6.11 Take the algebraic sum of the two wattmeter readings to be the locked-rotor input power, in kilowatts, to the motor at the reduced voltage.

6.6.12 Calculate or use other means to determine the locked-rotor torque, in newton metres, of the motor at the reduced voltage.

6.6.13 Calculate the locked-rotor input power to the motor and the locked-rotor torque of the motor at the rated voltage by using the following equation:

a) $$P = 1{,}2\,(W_1 + W_2)\left[\frac{E}{E_t}\right]^2$$

where

P is the locked-rotor input power to the motor, in kilowatts;

1,2 is the allowance for flux saturation effect at full voltage;

W_1 is the reading of wattmeter No. 1, in kilowatts;

W_2 is the reading of wattmeter No. 2, in kilowatts;

E is the rated voltage of the motor, in volts;

E_t is the reduced test voltage of the motor, in volts.

b) $$T = 1{,}2 \times \text{kg} \times L \times 9{,}81 \times (E / E_t)^2 \times (I / I_t)$$

where

T is the locked-rotor torque at rated voltage, in newton metres;

1,2 is the allowance for flux saturation effect at full voltage;

kg is the scale reading, in kilograms;

L is the torque arm length, in metres, from the shaft centre to the connection point of the force-measuring device;

E is the rated voltage of the motor, in volts;

E_t is the reduced test voltage of the motor, in volts;

I is the motor rated current, in amperes;

I_t is the test current, in amperes.

6.6.14 Check for compliance with 5.6.

NOTE If, after allowance has been made for the flux saturation effect, the estimated values of input power and torque do not comply with the specified requirements, the test can be repeated at higher values of the supply voltage in order that the flux saturation of the iron core is effective.

6.7 Measurement of open circuit rotor voltage

6.7.1 Ensure that the connections to the slip rings are on open circuit.

6.7.2 Lock the rotor of the motor securely.

6.7.3 Apply the rated voltage or a voltage within 5 % of the rated voltage to the stator connections.

6.7.4 Measure the voltage between two of the slip rings in turn.

6.7.5 Check for compliance with 5.7.

6.8 Temperature rise test

6.8.1 Procedure

6.8.1.1 Mount the motor in a reasonably draught-free room.

6.8.1.2 After having positioned the ambient temperature measuring equipment as described in 6.8.2.3, operate the motor, at rated voltage and frequency and on rated load, under the conditions specified in 6.8.2 for the duration of the temperature rise test specified in 6.8.6.

Determine the temperature rise of the component parts of the motor in accordance with 6.8.3, using one of the methods specified in 6.8.4. Apply any correction of measurements taken after the motor has come to rest and is de-energized in terms of 6.8.5. Unless otherwise required (see annex A), test a motor that is rated for operation over a range of voltages at the voltage that produces the highest temperatures. In cases where this voltage cannot be predetermined, test the motor at each rated voltage, and use the highest values so obtained when calculating the temperature rise.

6.8.1.3 Check for compliance with 5.8

6.8.2 Conditions during the temperature rise test

6.8.2.1 A motor can be tested at any convenient value of coolant temperature. If the temperature of the coolant at the end of the temperature rise test differs by more than 30 °C from that specified (or assumed from table 4) for operation on site, the corrections given in 6.8.5 shall be made.

6.8.2.2 The value to be adopted for the temperature of the coolant during a test shall be the mean of the readings of the temperature detectors taken at equal intervals of time during the last quarter of the duration of the test. In order to avoid errors due to the time-lag between the temperature of large motors and the temperature of the coolant, all reasonable precautions shall be taken to reduce variations in the temperature of the coolant.

6.8.2.3 In the case of open motors or motors without heat exchangers (cooled by surrounding ambient air), the ambient air temperature shall be measured by means of several temperature detectors placed at different points around and half-way up the motor at a distance of 1 m to 2 m from it and protected from all heat radiation and draughts.

6.8.2.4 Motors cooled by air from a remote source through ventilation ducts, and motors with separately mounted heat exchangers, shall have the temperature of the primary coolant measured where it enters the motor.

6.8.3 Determination of temperature rise

6.8.3.1 The temperature rise of a part of a motor is the difference in temperature between that part of the motor (measured by the appropriate method in accordance with 6.8.4) and that of the coolant (measured in accordance with 6.8.2).

6.8.3.2 The following methods of determining the temperature of windings and other parts may be used:

a) the resistance method; or

b) the embedded temperature detector (ETD) method; or

c) the thermometer method.

NOTE The different methods are not to be used as a check against one another.

6.8.3.3 In the resistance method, the temperature rise of the windings is determined from the increase in resistance of the winding.

6.8.3.4 In the embedded temperature detector method, the temperature is determined by means of temperature detectors (e.g. resistance thermometers, thermocouples and the like) which are built into the motor during refurbishing at points that are inaccessible after the motor has been assembled.

6.8.3.5 In the thermometer method, the temperature is determined by thermometers applied to accessible surfaces of the assembled motor. The term "thermometer" also includes non-embedded thermocouples and resistance thermometers, provided they are applied to points accessible to the usual bulb thermometers. When bulb thermometers are used in places where there is a strong magnetic field that varies or moves, alcohol thermometers shall be used in preference to mercury thermometers.

6.8.4 Choice of method for measuring the temperature of windings

6.8.4.1 General

Use the resistance method to measure the temperature of the winding of a motor.

In the case of motors of rated power between 200 kW and 800 kW, the repair contractor shall choose either the resistance method or the ETD method, unless otherwise agreed upon (see annex A).

6.8.4.2 Determination of temperature rise of windings by resistance method

Calculate the temperature rise ($t_2 - t_a$) by using the following equation:

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

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 cold winding at the moment of the initial resistance measurement, in degrees celsius;

t_a is the temperature of the coolant at the end of the test, in degrees celsius;

R_2 is the resistance of the windings at the end of the test, in ohms;

R_1 is the resistance of the winding at temperature t_1 (cold), in ohms.

For practical purposes, the following alternative formula might be found convenient:

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

When the temperature of the winding is determined by the resistance method, the temperature of the winding before the test, measured by means of a thermometer, shall be practically equal to that of the coolant.

In the case of materials other than copper, replace the temperature constant 235 in the above formulae with the reciprocal of the temperature coefficient of resistance at 0 °C of the material. For aluminium, unless otherwise specified, 225 shall be used as temperature constant.

6.8.4.3 Determination of temperature rise by embedded temperature detector (ETD) method

When the ETD method is used, suitably distribute at least six embedded detectors throughout the motor winding in each of the three phases.

Make all reasonable efforts consistent with safety requirements to place the detectors at the various points at which the highest temperatures are likely to occur, in such a manner that they are effectively protected from contact with the primary coolant.

Use the highest reading of the ETD elements (excluding unreliable readings) to check for compliance with requirements for temperature rise or temperature limits. When the winding has two or more coil sides per slot, locate the temperature detectors between the insulated coil sides within the slot, in positions at which the highest temperatures are likely to occur.

When the winding has one coil side per slot, locate embedded detectors between the wedge and the outside of the winding insulation in positions at which the highest temperature is likely to occur.

When temperature detectors are fitted in the end windings, locate them between two adjacent coil sides within the external range of the end windings in positions at which the highest temperatures are likely to occur. The temperature sensing point of the temperature detector should be in close contact with the surface of the coil side and adequately insulated against the coolant influence.

NOTE If there is only one coil side per slot or if the end-winding temperature has to be measured, the ETD method of temperature measurement is not a recognized method for determining temperature rise or temperature limits in order to check for compliance of the rating with this part of SANS 1561.

6.8.5 Correction of measurements taken after the motor has come to rest and is de-energized

Using the resistance method to measure temperatures after shut down requires a quick shut down of the motor at the end of the temperature test. A carefully planned procedure and an adequate number of people are required to obtain readings quickly enough to give reliable data.

Accept initial resistance readings taken within the time interval indicated in table 7 as the temperature measurement. Extrapolation of observed temperatures to the instant of switching off power is unnecessary.

Table 7 — Time interval after switching off power

1	2
Rated output of motor kW	**Time interval after switching off power** s
≤ 50	30
> 50 ≤ 200	90
> 200 ≤ 5 000	120

If the initial resistance reading is not taken within the required time interval, take it as soon as possible, take additional resistance readings at intervals of approximately 1 min until the readings have begun a distinct decline from their maximum values. Plot a curve of these readings as a function of time and extrapolate back to the time interval specified in table 7 for the rated output of the motor. A semi-logarithmic plot is recommended where temperatures are plotted on the logarithmic scale (see annex D). Consider the value of the temperature thus obtained as the temperature at shut down. If successive measurements show increasing temperatures after shut-down, take the highest value.

If the initial resistance reading cannot be taken until after twice the time interval specified in table 7, use the extrapolation method only if so agreed upon (see annex A).

6.8.6 Duration of temperature rise test

6.8.6.1 Duty type S1

Continue the temperature rise test until thermal equilibrium has been reached. (That is when the temperature variation of an agreed upon temperature device does not increase by more than 1 °C in 30 min.)

6.8.6.2 Duty type S2

The duration of the test is that given in the rating. At the beginning of the test, the temperature of the motor is within 5 °C of the temperature of the coolant.

6.8.6.3 Duty types S3 to S8

In the case of intermittent loads, apply the load cycle specified and continue until practically identical temperature cycles are obtained. The criterion for this is that a straight line between corresponding points of duty cycles has a gradient of less than 2 °C/h. If necessary, take measurements at reasonable intervals over a period of time. Record the temperature rise in the middle of the period that causes the greatest heating in the last cycle of operation.

6.8.6.4 Duty type S9

Carry out the temperature rise test at the equivalent continuous rating assigned by the original manufacturer, if this is known, or the rating shall be as agreed upon (see annex A). The equivalent continuous rating takes into account all the required rated load speed variations and overload allowances based on the duty.

6.8.7 Determination of the thermal equivalent time constant for motors for duty type S9

The thermal equivalent time constant (with ventilation as in normal operating conditions) suitable for approximate determination of the temperature course can be determined from the cooling curve plotted as in 6.8.5. Its amount is 1,44, i.e. $\left[\frac{1}{\ln 2}\right]$ times the delay between disconnection of the motor and the attaining of a temperature representing a point on the cooling curve that corresponds to one-half of the temperature rise of the motor.

NOTE In the case of a motor with more than one time constant, all the time constants should be considered and the value likely to cause the most detrimental temperature should be used for determining the temperature rise.

6.9 Efficiency test

6.9.1 Measure the electrical input power of the motor at the culmination of the temperature rise test of 6.8 at the required load. Calculate the efficiency of the motor from the following equation:

$$\eta = \frac{P_o}{P_i} \times 100$$

where

η is the efficiency, as a percentage;

P_o is the output power measured at the shaft, or the electrical input power minus the total losses, in kilowatts;

P_i is the input power, in kilowatts.

6.9.2 Check for compliance with 5.9

7 Marking

7.1 All existing nameplates other than the nameplate fitted by the original manufacturer shall be removed. Any marking fitted by the purchaser for his own identification shall be retained.

7.2 A plate that contains the repairer’s name and job or reference number shall be fitted as a basic minimum.

7.3 An additional data plate, which contains the following information, shall be fitted:

a) the category-of-work designation IW1 or IW2 to identify whether the motor has been rewound or refurbished (or both) (see 4.1);

b) the test category (see table 6);

c) the class of insulation (the insulation class of a cage rotor, the bars (winding) of which are not insulated shall be designated class O); and

d) the date of the rewinding or refurbishing (or both), or a code number to indicate such.

e) motor performance at 100 %, 75 % and 50 % load efficiency as determined in 6.9 and within the tolerances given in 5.9.

7.4 The following additional information, if not available on the original nameplate, shall be included on a data plate:

a) the rated output, in kilowatts;

b) the rated voltage, in volts, and the method of connection of the primary winding;

c) the rated current, in amperes;

d) the rated frequency (i.e. 50 Hz);

e) the number of phases;

f) the speed at rated output, in revolutions per minute;

g) in the case of a wound rotor (slip-ring) induction motor,

   1) the rotor (secondary) current at rated output, and

   2) the rotor (secondary) voltage between slip rings (or secondary terminals) at open circuit, and the method of connection of the secondary winding;

h) the bearing sizes and clearances;

i) the type of grease used in the bearings;

j) the motor no-load current;

k) the no-load watts at rated voltage;

l) if applicable, the grade of the slip-ring brushes;

m) motor terminals to which the flexible leads of stator windings are connected, shall be marked, preferable in accordance with SANS 60034-8;

n) in the case of slip-ring motors, terminals of conductors connected to slip rings shall be marked by preferably “R”, "S" and “T”.

Annex A
(normative)

Notes to purchasers

A.1 The following requirements shall be specified in tender invitations, in tenders, and in each order or contract:

a) clarification of the category of rewinding and refurbishing (see 4.1);

b) identification of alternative limits of amplitude of vibration other than those identified in this part of SANS 1561 (see 5.3);

c) the efficiency at partial loads, if required (see 5.9);

d) the category of testing (see 6.1); and

e) when relevant, the voltage at which the temperature rise test is carried out (see 6.8.1).

A.2 The following requirements shall be agreed upon between the repair contractor and the purchaser:

a) when relevant, the average value of current at no load at rated voltage (see 5.2.2(b));

b) when relevant, the limits of vibration amplitude for vertical and flange-mounted motors or a horizontal foot-mounted motor with synchronous speed of less than 600 r/min (see table 2);

c) when relevant, the limits of current, input power and torque with the rotor locked and with rated voltage applied at rated frequency (see 5.6);

d) the temperature rise of the bearing, if 30 °C or more (see 5.8);

e) when relevant, the factor for reducing the standard rated output of the motor when the motor is required to operate with a coolant, the specified maximum temperature of which exceeds 60 °C or is less than 0 °C (see 5.8.2);

f) if the specified maximum temperature of the coolant exceeds 60 °C or is less than 0 °C, the limits of temperature rise (see 5.8.2);

g) any increase in temperature rise limits if the specified maximum temperature of the coolant is between 0 °C and 40 °C (see 5.8.2);

h) if the motor is to operate at an altitude that exceeds 4 000 m, the temperature rise limits (see 5.8.2);

i) the temperature rise testing procedure, if the adjustments result in excessive temperatures (see 5.8.3);

j) the limits of efficiency of the motor (see 5.9);

k) the method of measuring the temperature of windings, if other than that specified (see 6.8.4);

l) whether the extrapolation method may be used to determine temperature rises when the resistance of windings is measured after the time interval given in table 7 (see 6.8.5); and

m) the equivalent continuous rating at which the temperature rise test is to be carried out if the rating assigned by the original manufacture is not known (see 6.8.6.4).

Annex B
(informative)

Typical performance of standard motors with cast iron frames

The performance of standard motors with cast iron frames is given in table B.1.

Table B.1 — Performance of standard motors with cast iron frames

1	2	3	4	5	6	7	8	9	10	11	12	13
Rated output kW	**Rated r/min**	**Full-load current at 380 V**[a]	**Full-load torque N·m**	**Efficiency**			**Power factor**					**NLA at 380 V**
				FL	**¾**	**½**	**FL**	**¾**	**½**	**NL**	**SC**	
0,25	1 445	0,85	1,65	63	58	52	0,67	0,58	0,47	0,18	0,86	0,76
	940	0,92	2,54	68	64	59	0,62	0,52	0,40	0,14	0,77	0,76
0,37	2 870	0,95	1,23	75	73	70	0,79	0,70	0,62	0,19	0,95	0,60
	1 445	1,2	2,45	72	71	65	0,69	0,59	0,45	0,18	0,81	1,0
	920	1,3	3,84	69	67	64	0,60	0,50	0,40	0,14	0,79	1,1
0,55	2 880	1,3	1,82	75	73	68	0,83	0,75	0,64	0,20	0,95	0,76
	1 425	1,5	3,69	73	72	69	0,73	0,66	0,54	0,17	0,87	1,1
	920	1,6	5,71	72	72	70	0,67	0,60	0,50	0,13	0,61	1,1
0,75	2 850	1,8	2,51	75	75	71	0,85	0,77	0,63	0,18	0,88	0,82
	1 420	2,1	5,0	73	72	68	0,72	0,64	0,51	0,14	0,78	1,5
	925	2,3	7,74	71	71	68	0,71	0,63	0,50	0,14	0,54	1,5
	685	2,5	10,6	68	64	56	0,67	0,60	0,44	0,18	0,70	1,9
1,1	2 860	2,3	3,67	78	78	76	0,87	0,84	0,71	0,18	0,87	1,2
	1 410	2,9	7,45	73,5	73	70	0,78	0,68	0,54	0,16	0,81	1,9
	930	3,6	11,3	72	70	65	0,65	0,55	0,42	0,12	0,48	2,4
	670	3,8	15,7	68	66	60	0,65	0,54	0,40	0,15	0,68	2,8
8,5	2 820	3,4	5,07	77	76	73	0,87	0,80	0,73	0,13	0,56	1,6
	1 410	3,9	10,2	75	73	69	0,78	0,68	0,54	0,12	0,63	2,9
	935	3,7	15,3	76	76	72	0,80	0,74	0,61	0,17	0,60	2,0
	685	4,8	20,9	70	70	67	0,68	0,58	0,44	0,13	0,63	3,4
2,2	2 830	4,8	7,42	80	80	79	0,86	0,79	0,68	0,15	0,49	1,9
	1 430	5,3	14,7	78	78	74	0,81	0,74	0,60	0,15	0,66	3,0
	935	5,9	22,5	77	77	76	0,73	0,68	0,57	0,11	0,63	3,7
	710	6,9	29,6	74	74	71	0,65	0,58	0,47	0,12	0,50	4,9
3,0	2 800	6,2	10,2	80	80	79	0,92	0,90	0,83	0,22	0,66	1,8
	1 430	6,9	20,0	80	80	78	0,83	0,75	0,65	0,13	0,59	3,4
	950	7,5	30,1	81	81	78	0,75	0,69	0,55	0,11	0,48	4,1
	695	8,9	41,2	78	78	76,5	0,66	0,62	0,47	0,10	0,39	5,4
4,0	2 800	8,2	13,7	81	81	80	0,92	0,91	0,84	0,22	0,66	2,2
	2 430	9,0	26,7	82	82	80	0,82	0,73	0,62	0,12	0,59	4,6
	940	10,3	40,6	81	81	80,5	0,73	0,70	0,57	0,10	0,56	5,1
	725	11,1	52,6	83	83	80	0,66	0,60	0,49	0,09	0,48	6,6

NOTE The abbreviations have the following meanings:

FL: Full load
NL: No load
NLA: No-load current
SC: Short-circuit

[a] For 433 V, multiply by 0,878. For 525 V, multiply by 0,724.

Table B.1 *(continued)*

1	2	3	4	5	6	7	8	9	10	11	12	13
Rated output kW	**Rated r/min**	**Full-load current at 380 V[a]**	**Full-load torque N·m**	**Efficiency**			**Power factor**					**NLA at 380 V**
				FL	**¾**	**½**	**FL**	**¾**	**½**	**NL**	**SC**	
5,5	2 860	11,6	18,3	82	81	78	0,88	0,86	0,81	0,26	0,55	3,5
	1 445	12,1	36,3	85	85	84	0,81	0,76	0,69	0,12	0,54	5,1
	940	13,4	55,9	82	82	81	0,76	0,71	0,58	0,09	0,57	7,1
	725	14,1	72,4	83,5	83,5	81	0,71	0,63	0,51	0,09	0,48	9,0
7,5	2 845	15,6	25,1	83	83	81	0,88	0,87	0,81	0,26	0,55	4,0
	1 435	16,6	49,9	84,5	84,5	82,5	0,81	0,79	0,68	0,11	0,50	7,3
	965	18,5	74,2	84,5	83,5	81	0,73	0,66	0,54	0,10	0,49	10,3
	715	19,5	100	84,5	84,5	83	0,69	0,65	0,55	0,08	0,44	10,7
11,0	2 915	22,5	36,0	86,5	85,5	82	0,86	0,84	0,74	0,19	0,43	8,7
	1 445	22,3	72,7	87	87	86	0,86	0,82	0,73	0,11	0,47	8,0
	970	24,7	108	88	88	86	0,77	0,71	0,58	0,08	0,46	13,0
	720	29,3	146	84	84	82	0,68	0,61	0,51	0,09	0,42	15,5
15,0	2 900	29,0	49,3	88	87,5	85	0,88	0,87	0,82	0,17	0,44	8,5
	1 445	29,8	99,1	88	88	87,5	0,87	0,84	0,77	0,10	0,49	8,9
	970	35,6	148	86,5	86,5	84,5	0,74	0,69	0,56	0,09	0,49	19,5
	720	38,0	198	86,5	86,5	85	0,69	0,62	0,51	0,07	0,39	21,5
18,5	2 900	35,7	61	88,5	88	86	0,89	0,87	0,82	0,16	0,47	11,0
	1 450	37,6	122	88	88	87	0,85	0,82	0,77	0,12	0,48	11,0
	980	41	180	90	89	87	0,76	0,70	0,59	0,08	0,35	23,0
	725	43	244	89	88,5	86	0,74	0,69	0,59	0,07	0,42	26,0
22,0	2 910	42	72,1	89,5	89	87,5	0,89	0,85	0,80	0,15	0,46	11,8
	1 445	43	145	89,5	89,5	88	0,87	0,86	0,80	0,12	0,49	12,7
	980	48	214	90	89,5	87,5	0,78	0,74	0,60	0,08	0,34	25,0
	725	54	290	88	87,5	85,5	0,70	0,63	0,52	0,07	0,42	31,0
30	2 960	61	96,8	89,5	87	83	0,84	0,82	0,73	0,16	0,33	21,5
	1 465	60	196	91	91	89,5	0,84	0,82	0,73	0,09	0,39	21,7
	980	68	292	90	89	86,5	0,75	0,67	0,56	0,08	0,36	35,0
	735	62	390	92,5	92	91,5	0,80	0,76	0,66	0,06	0,32	27,0
37	2 940	80	120	88,5	86,5	82,5	0,79	0,73	0,64	0,16	0,46	30,5
	1 465	73	241	91,5	91	89	0,84	0,80	0,72	0,09	0,39	31,0
	985	70	359	93,5	93	92,5	0,86	0,83	0,76	0,07	0,34	24,0
	735	74	481	93	93	92,5	0,82	0,79	0,69	0,05	0,30	28,0
45	2 950	90	146	89	87,5	82,5	0,85	0,80	0,73	0,18	0,47	31,3
	1 470	87	292	91,5	91	90	0,86	0,82	0,75	0,09	0,36	31,9
	985	86	436	93,5	93,5	92	0,85	0,81	0,75	0,06	0,35	28,0
	740	90	581	93,5	93	92,5	0,81	0,78	0,69	0,05	0,33	32,2
55	2 970	100	177	93	92	90	0,90	0,87	0,83	0,13	0,34	28,0
	1 480	101	355	94	93,5	92,5	0,88	0,85	0,77	0,07	0,32	33,0
	985	102	533	94	94	93,5	0,87	0,85	0,78	0,06	0,36	28,0
	740	110	710	93	93	92,5	0,82	0,79	0,69	0,05	0,33	40,0
75	2 965	134	242	93,5	92,5	90	0,91	0,88	0,85	0,12	0,32	32,0
	1 480	143	484	94	93,5	92,5	0,85	0,82	0,72	0,08	0,30	44,0
	985	138	727	94	94	93,5	0,88	0,86	0,80	0,06	0,36	38,0
	740	156	968	93,5	93	92	0,78	0,74	0,64	0,05	0,30	63,0

NOTE The abbreviations have the following meanings:

FL: Full load
NL: No load
NLA: No-load current
SC: Short-circuit

[a] For 433 V, multiply by 0,878. For 525 V, multiply by 0,724.

Table B.1 *(concluded)*

1	2	3	4	5	6	7	8	9	10	11	12	13
Rated output kW	**Rated r/min**	**Full-load current at 380 V**[a]	**Full-load torque N·m**	**Efficiency**			**Power factor**					**NLA at 380 V**
				FL	**¾**	**½**	**FL**	**¾**	**½**	**NL**	**SC**	
90	2 965	163	290	93,5	92,5	90,5	0,90	0,88	0,84	0,12	0,35	40,5
	1 480	177	581	94	93,5	92	0,82	0,79	0,73	0,06	0,32	66,0
	985	174	872	93,5	93,5	92,5	0,84	0,82	0,76	0,06	0,32	56,0
	735	186	1 169	93	92,5	92	0,79	0,76	0,69	0,05	0,31	74,0
110	2 970	197	354	94	93	92	0,90	0,88	0,83	0,10	0,35	45,5
	1 480	217	710	94	94	93	0,82	0,78	0,68	0,05	0,33	94,5
	985	290	1 066	94	94	93	0,85	0,83	0,77	0,08	0,34	66,0
	738	230	1 423	93	93	92	0,78	0,75	0,64	0,05	0,32	102,0
132	2 978	238	423	94,5	94	92,5	0,89	0,87	0,83	0,11	0,31	52,0
	1 485	244	849	94,5	94	93,5	0,87	0,85	0,79	0,08	0,30	64,5
	990	257	1 273	94	93,5	92,5	0,83	0,80	0,70	0,07	0,33	109,0
	743	267	1 697	94	94	92	0,80	0,78	0,69	0,06	0,29	91,0
160	2 979	281	513	95	94,5	93	0,91	0,90	0,84	0,10	0,32	66,0
	1 485	292	1 029	94,5	94	92,5	0,88	0,85	0,78	0,08	0,31	80,5
	989	308	1 545	94	93,5	92	0,84	0,81	0,73	0,07	0,25	97,0
	742	323	2 059	94	94	93	0,80	0,78	0,69	0,06	0,28	108,0
185	2 978	332	539	95	94,5	93	0,89	0,87	0,84	0,10	0,30	72,0
	1 485	344	1 190	95	94,5	93	0,86	0,83	0,74	0,07	0,31	111,0
	990	356	1 784	94	93,5	92	0,84	0,81	0,73	0,08	0,25	114,0
	742	369	2 381	94	93	92,5	0,81	0,77	0,68	0,06	0,28	137,0
200	2 975	359	642	95	94,5	93	0,89	0,87	0,81	0,09	0,23	110,0
	1 486	374	1 285	94,5	94,0	93	0,86	0,84	0,80	0,09	0,29	98,0
	991	383	1 927	94,5	94,0	93	0,84	0,81	0,71	0,07	0,26	113,0
	743	412	2 570	94,5	94,0	93	0,78	0,74	0,66	0,06	0,28	116,0
220	2 980	395	705	95,0	94,3	93	0,89	0,87	0,81	0,08	0,23	98,0
	1 485	402	1 415	94,5	94	93	0,88	0,85	0,80	0,09	0,24	103,0
	991	416	2 120	94,5	94,0	93	0,85	0,82	0,74	0,07	0,25	137,0
	743	453	2 828	94,5	94,0	93	0,78	0,74	0,68	0,06	0,28	166,0
250	2 983	499	800	95,0	94,5	93	0,89	0,87	0,81	0,08	0,23	122,0
	1 485	457	1 608	94,5	94	93	0,88	0,85	0,80	0,09	0,24	125,0
	991	476	2 409	95,0	94,5	93,5	0,84	0,81	0,75	0,06	0,25	157,0
	744	515	3 209	94,5	94,0	93,0	0,78	0,74	0,68	0,06	0,26	201,0
275	2 983	494	880	95,0	94,5	93	0,89	0,87	0,81	0,08	0,23	141,0
	1 486	497	1 767	94,5	94	93	0,89	0,87	0,81	0,09	0,24	131,0
	991	517	2 650	95,0	94,5	93,5	0,85	0,82	0,75	0,06	0,26	182,0
300	2 981	539	961	95	94,2	93	0,89	0,86	0,81	0,08	0,20	149,0
	1 486	533	1 928	95	94,5	93	0,90	0,86	0,81	0,09	0,23	146,0
	991	564	2 891	95	94,5	93,5	0,85	0,82	0,75	0,06	0,26	205,0

NOTE The abbreviations have the following meanings:

FL: Full load
NL: No load
NLA: No-load current
SC: Short-circuit

[a] For 433 V, multiply by 0,878. For 525 V, multiply by 0,724.

Annex C
(informative)

Methods of determining losses

C.1 Losses independent of current

C.1.1 The losses independent of current are as follows:

a) core losses:
   – magnetic losses.
b) frictional losses:
   1) bearing friction;
   2) total windage losses; and
   3) brush friction.

C.1.2 The sum of the losses, independent of current, is determined by running the motor on no load, with the motor supplied at its rated voltage and frequency. The power absorbed, decreased by the I^2R losses in the stator, gives the total of the independent losses. (The I^2R losses in the rotor may be disregarded.)

C.1.3 The frictional losses C.1.1(b) can be determined by driving the motor (disconnected from the supply network) at its rated speed by means of a calibrated motor.

With the brushes (if any) in place, the power absorbed at the shaft of the motor (that might be deduced from the electrical power absorbed by the calibrated motor) gives the sum of the losses C.1.1(b)(1), (2) and, when relevant, (3). In the case of a motor fitted with brushes, the sum of the losses C.1.1(b)(1) and (2) is obtained by driving the motor as above but with the brushes lifted or removed. The loss C.1.1(b)(3) is then obtained by subtraction.

C.1.4 The losses may also be separated by running the motor on no load at rated frequency, but at different supply voltages. The power absorbed, decreased by the I^2R losses in the stator, is plotted against the square of the supply voltage. This, at low saturation, will give a straight line which can be extrapolated to zero voltage. However, at very low voltages, losses plotted on the diagram might be too high because rotor losses increase with increased slip. When the straight line is being extrapolated, this part of the diagram should be ignored. The sum of the losses C.1.1(b)(1), (2) and, when relevant, (3), is obtained in the above manner. The losses C.1.1(a) are obtained by subtraction. If the motor is started with a short-circuited rotor and the brushes are lifted, the sum of the losses C.1.1 (b)(1) and (2) is obtained at zero voltage.

NOTE It is usually not necessary to separate the losses C.1.1(b)(1), (2) and (3), since this makes a small difference to the calculation of efficiency.

C.2 Direct-load losses

C.2.1 Direct-load losses are as follows:

a) I^2R losses in stator windings;

b) I^2R losses in rotor windings; and

c) electrical losses in brushes.

C.2.2 The losses C.2.1(a) are calculated from the resistances of the stator windings (measured by direct current and at the steady state operating temperature) and from the current (measured during an on-load test) corresponding to the load under which the motor is tested.

C.2.3 The losses C.2.1(b) are determined during an on-load test, taking these losses to be equal to the product of the slip and the total power transmitted to the rotor, i.e. the power absorbed by the motor, decreased by the core losses (see C.1) and the I^2R losses in the stator. This method gives directly the losses C.2.1(b) in the case of cage motors, and the sum of the losses C.2.1(b) and C.2.1(c) in the case of slip-ring motors. The slip can be calculated by accurate measurement of the rotor speed. This is the only method applicable to cage motors since it is not possible to measure the rotor resistance of these motors accurately.

C.2.4 Unless it is possible to do an on-load test, the losses C.2.1(c) in the brushes cannot be directly measured but should be taken as the product of the current flowing in the brushes and a fixed voltage drop. The voltage drop in all brushes of the same phase should be taken as 1,0 V for carbon or graphite brushes, and 0,3 V for metal-carbon brushes.

C.3 Stray-load losses

Stray-load losses are as follows:

a) stray-load losses in iron; and

b) stray-load losses in conductors.

It is assumed that these losses vary as the square of the primary current and that their total value at full load is equal to 0,5 % of the rated output.

NOTE The stray-load losses can be measured from an input-output test or from a pump-back test by subtracting the total measured losses from all other known losses.

Annex D
(informative)

Guidance on a method of extrapolation for the determination of final temperatures of machines

When extrapolation is carried out, the measured temperatures should be plotted on a logarithmic scale against a linear time scale. The form of the resulting plots will normally be one of the following three:

a) the plot is a straight line (see figure D.1(a)). Extrapolation to T at the appropriate time interval is linear;

b) the initial part of the plot is not straight, but its gradient does not change sign (see figure D.1(b)). The straight part is first extrapolated linearly back to T. The differences between the extrapolated straight line and the measured temperatures are then plotted and extrapolated linearly to T_2 which is at the same point on the time axis T;

c) the initial part of the plot is not straight, but rises first, then falls, i.e. its gradient changes sign (see figure D.1(c)). The procedure is similar to that of (b) above but in this case, the required extrapolated temperature is given by ($T_1 - T_2$).

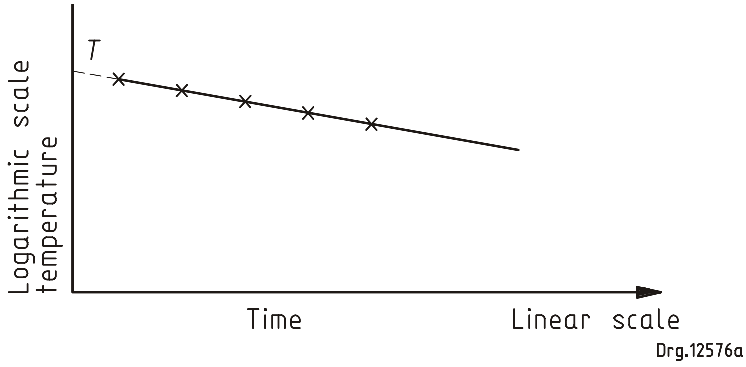

Figure D.1(a)

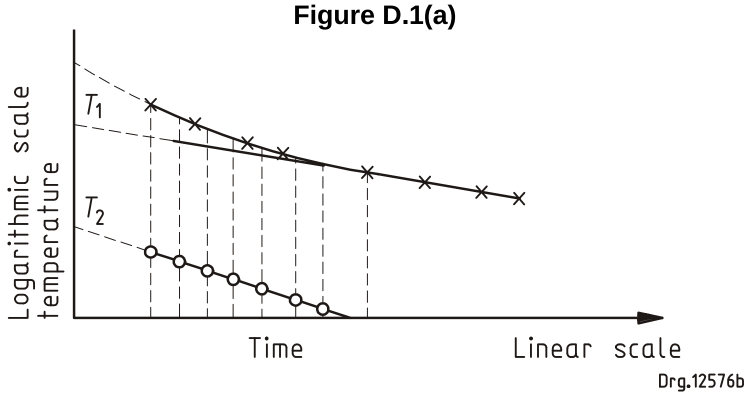

Figure D.1(b)

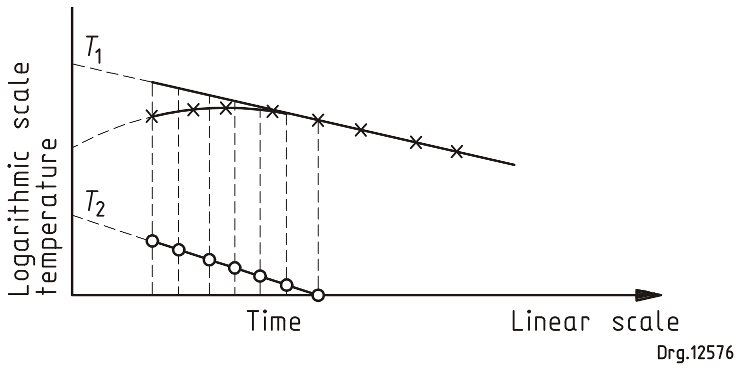

Figure D.1(c)

Figure D.1 — Measurement of final temperature of motor — Method of extrapolation

Bibliography

SANS 60034-8/IEC 60034-8, *Rotating electrical machines – Part 8: Terminal markings and direction of rotation.*

SANS 60034-23/IEC 60034-23, *Rotating electrical machines – Part 23: Specification for the refurbishing of rotating electrical machines.*