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SOUTH AFRICAN STANDARD

Code of practice

SABS 0242-1

The rewinding and refurbishing of rotating electrical machines

Part 1: Low-voltage three-phase induction motors

Consolidated edition incorporating	amendment No. 1: 6 September 1993 amendment No. 2: 17 February 1997 amendment No. 3: 9 February 1998 amendment No. 4: 12 November 1999

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SOUTH AFRICAN BUREAU OF STANDARDS

CODE OF PRACTICE

THE REWINDING AND REFURBISHING OF ROTATING ELECTRICAL MACHINES

PART 1: LOW-VOLTAGE THREE-PHASE INDUCTION MOTORS

Obtainable from the

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Notice

This part of SABS 0242 was approved in accordance with SABS procedures on 13 August 1992. Amendment 4 was approved in accordance with SABS procedures on 12 November 1999.

NOTES

1 In terms of the Standards Act 1993 (Act 29 of 1993), no person shall claim or declare that he or any other person complied with an SABS standard unless

a) such claim or declaration is true and accurate in all material respects, and

b) the identity of the person on whose authority such claim or declaration is made, is clear.

2 It is recommended that authorities who wish to incorporate any part of this standard into any legislation in the manner intended by section 31 of the Act consult the SABS regarding the implications.

This part of SABS 0242 will be revised when necessary in order to keep abreast of progress. Comment will be welcome and will be considered when this part of SABS 0242 is revised.

Foreword

Edition 1.4 cancels and replaces the first edition (SABS 0242-1:1992).

Annex A (Notes to users) forms an integral part of this part of SABS 0242. Annex B (AC motor flow chart and stator/rotor rewind flow chart) and annex C (Bibliography) are for information only.

A vertical line in the margin shows where the test has been modified by amendment Nos. 1, 2, 3 and 4.

Attention is drawn to the normative references given in clause 2 of this standard. These references are indispensable for the application of this standard.

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Contents

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The rewinding and refurbishing of rotating electrical machines

Part 1:
Low-voltage three-phase induction motors

1 Scope

1.1 This part of SABS 0242 establishes general principles for the rewinding and refurbishing of low-voltage three-phase alternating current induction motors of the cage and wound rotor (slip-ring) types, with rated output not exceeding 800 kW, for rated voltages not exceeding 1 100 V between phases, at a service frequency of 50 Hz.

1.2 This part of SABS 0242 covers motors with random-wound (mush) coils and form-wound coils.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of SABS 0242. 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 SABS 0242 are encouraged to take steps to ensure the use of the most recent editions of the standards indicated below. Information on currently valid national and international standards may be obtained from the South African Bureau of Standards.

BS 3953, *Synthetic resin bonded woven glass fabric laminated sheet.*

IEC 85, *Thermal evaluation and classification of electrical insulation.*

IEC 317-0-2, *Specifications for particular types of winding wires − Part 0: General requirements − Section 2: Enamelled rectangular copper wire.*

IEC 778, *Brush-holders for slip-rings group R – type RA* **Amdt 2, Feb. 1997**

IEC 1015, *Brush-holders for electrical machines. Guide to the measurement of static thrust applied to brushes.* **Amdt 2, Feb. 1997**

ISO 15, *Rolling bearings − Radial bearings − Boundary dimensions − General plan.*

ISO 1940-1, *Mechanical vibration − Balance quality requirements of rigid rotors − Part 1: Determination of permissible residual unbalance.*

ISO 5343, *Criteria for evaluating flexible rotor balance.*

ISO 5406, *The mechanical balancing of flexible rotors.*

ISO 850-1, *Preparation of steel substrates before application of paints and related products − Visual assessment of surface cleanliness − Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings.*

SABS 136, *ISO metric precision hexagon-head bolts and screws, and hexagon nuts (coarse thread medium fit series).*

SABS 314-1, *Flameproof enclosures for electrical apparatus − Part 1: International requirements.* **Amdt 2, Feb. 1997**

SABS 314-2, *Flameproof enclosures for electrical apparatus − Part 2: National requirements.* **Amdt 2, Feb. 1997**

SABS 416, *Chemical resistant gloves.*

SABS 434, *Boiler suits and workwear suits.*

SABS 492-2, *Protective and safety gum boots − Part 2: Moulded rubber gum boots.*

SABS 630, *Decorative high gloss enamel paint for interior and exterior use.*

SABS 681, *Undercoats for paints.*

SABS 804, *Electrolytic tough pitch high conductivity copper.*

SABS 970, *Ex N (non-sparking) electrical equipment for use in potentially flammable atmospheres (Class 1, Division 2 locations).*

SABS 1091, *National colour standards for paint.*

SABS 1404-1, *Eye and face protectors for general industrial use − Part 1: Face shields.*

SABS 1561-1, *Rewinding and refurbishing of rotating electrical machines − Part 1: Low-voltage three-phase induction motors.*

SABS 1804-2, *Induction motors − Part 2: Low-voltage three-phase standard motors.* **Amdt 4, Nov. 1999**

SABS 064, *Preparation of steel surfaces for coating.*

SABS 0220, *The selection, use and maintenance of respiratory protective equipment.*

SABS IEC 6034-8, *Rotating electrical machines − Part 8: Terminal markings and direction of rotation of rotating machines.* **Amdt 2, Feb. 1997**

SABS IEC 60317-8, *Specifications for particular types of winding wires − Part 8: Polyesterimide enamelled round copper wire, class 180.* **Amdt 4, Nov. 1999**

SABS ISO 286-1, *ISO system of limits and fits − Part 1: Bases of tolerances, deviations and fits.* **Amdt 2, Feb. 1997**

SABS ISO 286-2, *ISO system of limits and fits − Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts* **Amdt 2, Feb. 1997**

3 Definitions

For the purposes of this part of SABS 0242, the following definitions apply:

3.1 acceptable: Acceptable to the parties concluding the rewinding and refurbishing agreement, but in relation to inspections carried out by the Bureau, acceptable to the South African Bureau of Standards.

3.2 air gap: A gap in the ferromagnetic portion of a magnetic circuit.

3.3 coil side: Either of the two normally straight parts of a coil that lie in the axial direction of a motor.

3.4 conductor: The current-carrying metal without any insulation.

3.5 core: The parts of a magnetic circuit in a motor, excluding the air gap, that are intended to carry the flux.

3.6 dipping: The process of immersing an otherwise complete winding into a dipping varnish for the purpose of providing a solid sealing coat around the outside of the winding, with limited penetration of the varnish into the interstices and pores between or within the solid insulation materials in the winding.

3.7 dipping varnish: A viscous liquid insulation material used in the dipping process, the material being a resinous solution (i.e. it contains solvents).

3.8 end winding: Either of the two parts of a coil that connect the coil sides.

3.9 heat-cleaning oven: An oven for removing organic binder materials from motor windings by means of combustion. The oven has a heat source and an air flow control to maintain the oven temperature to within 15 °C of the set point and incorporates an active overtemperature suppression facility to limit the temperature to 30 °C above the set point when materials that have exothermic degradation characteristics are being processed.

WARNING To attain adequate emission safety standards, the oven byproducts (which may be toxic) first have to pass through an afterburner operating at a temperature of 800 °C or more before they are vented to atmosphere.

3.10 impregnant: The liquid insulation material used in the impregnating process, that is of sufficiently low viscosity and is so applied as to completely penetrate the interstices and pores between the conductors and solid insulation materials in a winding.

NOTES

1 Impregnant has low drain-off characteristics, i.e. it does not drain out of the winding after impregnation and before heat is applied (low primary drain-off characteristic) and it does not drain out of the winding when heat is applied (low secondary drain-off characteristic).

2 Impregnants used for low-voltage motors have distinctly different requirements and properties from impregnants used for high-voltage motors.

3.11 impregnating: The process of using an impregnant to fill the interstices between the elements of insulated conductors and solid insulation materials in a winding, including the filling of the interstices and the pores within fibrous and porous solid insulation materials. The process includes the filling of the interstices between the windings and the core, and the complete coating and sealing of the outer surface of the windings.

3.12 impregnating resin: An impregnant that is a solvent-free resinous compound. After having been cured, the impregnant in the solid state is almost totally free of voids.

3.13 impregnating varnish: An impregnant that is a resinous solution (i.e. it contains solvents). After having been cured, the impregnant in the solid state is not free of voids because of the evaporation of the solvent from the solution.

3.14 interturn insulation: The insulation between adjacent turns.

3.15 journal (of a shaft): That part of a shaft that is intended to rotate in a sleeve bearing or on which the inner race of a ball/roller bearing is mounted.

3.16 liquid insulation material: A winding insulation material (see 3.25) that is in a liquid state when it is introduced into or applied to the winding but that solidifies within and around the winding during the winding process. The liquid insulation material (so solidified) remains permanently in the solid state and provides the necessary electrical insulation.

NOTE A liquid insulation material is distinctly different from an insulating liquid. The latter remains permanently in the liquid state, e.g. transformer and switchgear oil is an insulating liquid.

3.17 rotor, flexible: A rotor that, owing to its elastic deflection, cannot be termed a rigid rotor.

3.18 rotor, rigid: A rotor is considered rigid if it can be corrected in any two (arbitrarily selected) planes and, after it has been corrected, its unbalance does not significantly exceed the balancing tolerances (relative to the shaft axis) at any speed up to maximum service speed and when running under conditions that approximate closely to those of the final supporting system.

3.19 size (of wire): The nominal dimensions of the conductor.

3.20 solid insulation material: A winding insulation material (see 3.25) that is in a solid state when it is introduced into or applied to a winding, and that remains permanently solid during and after completion of the winding.

NOTE A solid insulation material may, in whole or in part, be in the liquid state during the course of its manufacture, but is in the solid state before its introduction into the winding.

3.21 temperature index (TI): The number that corresponds to the temperature, in degrees Celsius, that is derived from the thermal endurance relationship at a given time, normally 20 000 h.

3.22 vacuum-pressure impregnation (VPI): An insulation process in which the impregnant is introduced into the winding under vacuum and pressure after complete assembly and connection of the winding.

3.23 varnish: A liquid that may contain solvent, pigments or dyes, that solidifies after curing and that provides protection or improves appearance.

3.24 winding (of a motor): An assembly of turns or coils that have a defined function in a motor, e.g. a stator winding or a rotor winding.

3.25 winding insulation material: A material that provides the necessary insulation for the winding of a motor and that is applied during or after the course of rewinding or refurbishing (or both) of a motor.

3.26 winding overhang: Either of the two portions of a winding that extend beyond the ends of the core.

3.27 wire: An insulated conductor.

4 Requirements for rewinding and refurbishing

4.1 Flow chart diagram for rewinding and refurbishing

The flow chart diagram given in annex B may be used as a guide to the procedures to be followed during the rewinding and refurbishing of electric motors.

4.2 Cleaning and inspection before dismantling

4.2.1 Protective equipment

The general safety regulations given in the Machinery and Occupational Safety Act, 1983 (Act 6 of 1983), require that, during the cleaning process, operators wear protective equipment for protection against hazards associated with certain industrial activities. Many of the procedures described in this part of SABS 0242 require the use of such protective equipment. The equipment used shall preferably comply with the requirements of the following SABS standards, as relevant:

a) SABS 434 (protective clothing, e.g. overalls);

b) SABS 492-2 (rubber gum boots);

c) SABS 1404-1 (face shields);

d) SABS 416 (gloves); and

e) SABS 0220 (respirators or filtering masks).

4.2.2 Cleaning

On receiving a motor for rewinding and refurbishing, thoroughly clean the external surfaces of the motor to remove grease, oil, dirt and any other contaminants, in accordance with 4.5.2. During the cleaning process use, as necessary, the protective equipment described in 4.2.1.

4.2.3 Inspection

After cleaning the motor and allowing it to dry, visually inspect it for any signs of external damage to the frame, feet, shaft, terminal box and the like. Check the shaft to see if it can be rotated easily.

4.2.4 Record sheet

For each motor, use a suitable record sheet to record all the results of inspection and also record all the necessary information marked on the nameplate of the motor. Use the same sheet to record all other necessary details throughout the process of rewinding and refurbishing of the motor.

4.3 Dismantling of motor

4.3.1 Marking of end shields

Before dismantling the motor, punch or stamp suitable identifying markings on the end shield and the stator, on both the driving end (DE) and the non-driving end (NDE) of the motor, thus ensuring correct location of each end shield with respect to the stator.

4.3.2 Dismantling

4.3.2.1 Dismantle the motor carefully, ensuring that the end shields are evenly separated from the stator, using stud removal facilities (if available) or using crowbars. Take extreme care to prevent damage when mating flanges are being separated.

4.3.2.2 Apply acceptable identifying markings to the stator, the rotor and all the other mechanical components. Keep all the components in a bin or container that is so marked that it can be positively distinguished from other bins or containers in which components of other motors are being kept.

4.4 Inspection of winding before cleaning

4.4.1 Visually inspect the winding and check for the following:

a) any visible electrical/mechanical defects (see 4.6);

b) moisture in the stator;

c) grease or oil or both; and

d) excessive dirt and other contaminants (e.g. carbon black, metallic dust and chips) that make it difficult to assess the condition of the winding.

4.4.2 If, during the inspection, there are

a) any visible electrical defects, rewinding may be necessary. In this case, proceed in accordance with clause 5 and submit components (other than the winding) for cleaning in accordance with 4.5; and

b) any visible mechanical defects, submit the winding and components for cleaning in accordance with 4.5.

4.4.3 If, during the inspection, there are no visible electrical or mechanical defects, use the apparatus described in 4.8.2.1.1 to check whether the winding is earthed. If the measured insulation resistance is found to

a) be very low, e.g. less than 0,05 MΩ, rewinding may be necessary. Proceed in accordance with clause 5 and submit components (other than the winding) for cleaning in accordance with 4.5;

b) exceed 0,05 MΩ, consider the winding not to be earthed. In this case, submit the winding and components for cleaning in accordance with 4.5.

4.5 Cleaning of all components of motor

4.5.1 Cleaning shall be carried out by an experienced operator wearing properly designed, modern and effective protective equipment as described in 4.2.1.

4.5.2 Use one or more of the following acceptable methods of cleaning, as required:

a) steam cleaning;

b) water blasting with or without solvent degreaser (detergent), applied under low pressure at a moderate temperature (about 40 °C). If a solvent degreaser is found to be necessary, the recommendations of the varnish manufacturer and the wire manufacturer shall be followed;

c) vacuum suction; and

d) clean dry compressed air.

4.5.3 Consider the points in 4.5.3.1 to 4.5.3.4 when cleaning.

4.5.3.1 It is important that, during cleaning, grease, oil, dirt and other contaminants be removed from the winding surfaces and also from mechanical components.

4.5.3.2 Dry dust and other contaminants (e.g. carbon black, metallic dust and chips) can be removed from a winding by vacuum suction. After the initial cleaning with vacuum, the remaining dust and dirt can be removed with dry compressed air. Care should be taken that the winding is not damaged due to the force of the compressed air jet. For this method of cleaning, at least a face shield and a respirator or a filter mask should be worn.

4.5.3.3 A winding that is saturated with oil, dirt and grease can be effectively cleaned by means of a steam cleaning method (which sprays a high-velocity jet of steam and water that may contain a mild detergent). If the detergent is found to be necessary, the recommendations of the varnish manufacturer and the wire manufacturer shall be followed. Alternatively, the winding may be cleaned by means of the water-blast method described in 4.5.2(b).

4.5.3.4 A winding that has been cleaned with the help of a solvent shall be thoroughly rinsed with steam or shall be water blasted to remove all traces of solvent. During either of these methods of cleaning, the necessary protective equipment described in 4.2.1 should be worn. Care should be taken that the winding is not damaged due to the force of the water-blast jet.

NOTE An ideal solvent degreaser for the cleaning of windings is non-toxic, non-flammable, acts quickly on oil and grease but is slow acting with respect to varnishes.

4.5.3.5 All the air vent ducts of the motor should be cleaned by means of either water blasting or compressed dry air, care being taken that the winding is not damaged due to the force of the compressed-air jet. For this method of cleaning, at least a face shield and a respirator or a filter mask should be worn.

4.5.3.6 In the case of a water cooled motor, test the cooling system for leaks and, after repairing any leaks, clean the water passages (usually pipes). Test the cooling system by closing one end and allowing water to enter at the other end. Initially allow the water to enter the cooling system at a low pressure in order to eliminate air that might be trapped inside, and then gradually increase the pressure of the water to a steady value as recommended by the motor manufacturer. Normally this pressure is between 4 MPa and 5 MPa. Check for visible leaks and monitor the water pressure. A pressure drop after a short time indicates the presence of leaks. Repair the leaks.

Clean the cooling system by circulating appropriate chemical solution through it for the appropriate time. For best results, follow the recommendations of the motor manufacturer. If such recommendations are not readily available, follow the recommendations of a chemical manufacturing company for the correct choice of chemicals and the procedure to be followed.
Amdt 2, Feb. 1997

4.5.4 After cleaning the winding and components, dry the winding by heating it in an oven to a temperature not exceeding 150 °C (and, in the case of winding with class B insulation, to a temperature not exceeding 120 °C) for at least 6 h, ensuring that the insulation is not damaged during the drying period. The heating oven should have means of continuously monitoring the internal temperature of the oven, using a suitable temperature chart recorder or other equivalent means. After drying, visually inspect the winding for the typical types of failure described in 4.6, examine the mechanical components for wear and damage in accordance with 4.7, and submit the winding to the electrical tests described in 4.8. **Amdt 2, Feb. 1997**

4.6 Inspection of stator and rotor windings for typical types of failure

4.6.1 Stator

Visually examine the stator for typical types of failure such as:

a) winding single-phased (star or delta connected);

b) winding shorted phase-to-phase;

c) winding with interturn insulation failure;

d) winding open-circuited;

e) winding earthed (grounded) at end of slot;

f) winding earthed (grounded) in the slot;

g) shorted connection;

h) phase damaged due to unbalanced voltage;

i) winding damaged due to overload;

j) winding damaged due to locked rotor;

k) winding damaged due to high-voltage surges;

l) stator core laminations damaged due to rubbing by the rotor;

m) defective welded joints in the stator casing; and

n) damaged or missing e.g. bolts. **Amdt 2, Feb. 1997**

4.6.2 Rotor

Visually examine the rotor for typical types of failure such as:

a) cracks in rotor bars;

b) cracks in rotor end rings;

c) evidence of overheating due to overload or locked rotor as indicated by any discoloration of rotor bars, laminations or both;

d) loose laminations or missing teeth in the rotor;

e) in the case of a wound rotor, rotor winding excessively distorted or damaged as in 4.6.1, or excessively worn or damaged slip-rings;

f) worn or damaged rotor core pack; and

g) loose fit or rotor core on the shaft. **Amdt 2, Feb. 1997**

4.6.3 Record sheet

After the visual inspection, record (on the individual record sheet of the motor) the types of failure (if any) found, and

a) if one or more of the typical types of failure are found in the winding, and rewinding is necessary, proceed in accordance with clause 5; and

b) if no failures are found in the winding, proceed in accordance with clause 6.

4.7 Inspection of mechanical components for wear and damage

All measuring instruments such as micrometers, vernier callipers, straight-edges and feeler gauges shall be calibrated regularly (at least once a year) against certified instruments that have a known valid relationship to nationally recognized standards.

4.7.1 General

In addition to the inspections carried out in 4.2.3, 4.6.1 and 4.6.2, carry out the inspection as in 4.7.1.1 to 4.7.1.4 and record the findings.

4.7.1.1 Visually inspect the mechanical components for typical damage such as:

a) cracked or distorted end shields, damaged spigots and securing holes;

b) damaged bearing housing covers;

c) damaged flange of flange mounted motor;

d) bent or damaged extension shaft;

e) damaged keyways of extension shaft;

f) damaged shaft of rotor;

g) broken or missing fan blades;

h) fan loose on the shaft;

i) damaged fan cowl;

j) damaged securing bolts/studs, nuts and washers of end shields and grease covers;

k) in the case of a slip-ring motor, excessively worn brushes and damaged brush boxes;

l) damaged terminals, terminal blocks, terminal box, terminal box cover and gaskets; and

m) loose feet. **Amdt 2, Feb. 1997**

4.7.1.2 Measure the inside diameter of each bearing housing. Take at least three measurements approximately equally spaced from one another. Check whether each bearing housing is still within the bearing manufacturer's specified tolerances.

4.7.1.3 After carefully removing the bearings from the rotor shaft, measure the outside diameter of each shaft journal. Take at least three measurements approximately equally spaced from one another. Check whether the diameter of each journal is still within the bearing manufacturer's specified tolerances.

4.7.1.4 Measure the inside diameter of the stator core and measure the outside diameter of the rotor. In each case take at least three measurements approximately equally spaced from one another. Determine the air gap by halving the difference between the diameter of the stator and the diameter of the rotor. Check for compliance with design data, if available.

4.7.2 Ventilation fans

Visually inspect mechanical components of a ventilation fan for typical wear and damage such as:

a) cracked or damaged fan casing;

b) damaged inlet and outlet screens;

c) damaged supporting/mounting bolts of the fan motor;

d) damaged impeller blades; and

e) incorrect clearance between the tips of the impeller blades and the fan casing; check the clearance by means of a suitable feeler gauge and ensure that the measured clearance is within the manufacturer's specified limits.

4.7.3 Flameproof and Ex N motors

In addition to the inspection carried out in accordance with 4.7.1, carry out those inspections that are required in terms of SABS approved quality systems for flameproof motors, in accordance with SABS 314-1 and SABS 314-2, and for Ex N motors, in accordance with SABS 970.

Amdt 2, Feb. 1997

4.8 Electrical tests on windings

4.8.1 General

All electrical measuring instruments shall be calibrated regularly (at least once a year) against certified instruments that have a known valid relationship to nationally recognized standards.

For the electrical tests both ends of each phase winding should preferably be individually accessible. In the case of a motor that is internally connected in star or in delta, the measurements are taken between the lines connected together and the frame (for insulation resistance and high-voltage withstand tests), or between the lines (for the line resistance comparison test).

The electrical tests on a winding shall only be carried out by experienced operators.

4.8.2 Insulation resistance test

4.8.2.1 Apparatus

4.8.2.1.1 Insulation tester, capable of measuring insulation resistance at d.c. voltages of 500 V (for motors rated up to and including 550 V) and 1 000 V (for motors rated above 550 V up to and including 1 100 V), with limits of error not exceeding 5 %.

4.8.2.1.2 Thermometer, or other equivalent means capable of measuring the temperature of a winding within a range of 0 °C to 50 °C, and accurate to within 0,5 °C.

4.8.2.2 Procedure

4.8.2.2.1 Before measuring insulation resistance, earth the winding and the frame for a few seconds in order to ensure that any residual electric charges that may 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.

4.8.2.2.2 Measure the insulation resistance (before and after the high-voltage withstand test) 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, see 4.8.1.

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

4.8.2.2.4 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 expression:

$$R_c = K_t \times R_t$$

where

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

R_t is the measured insulation resistance at a temperature of *t* °C, in mega-ohms; and

K_t is the appropriate insulation resistance temperature coefficient at a temperature of *t* °C obtained from figure 1.

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

$$R_m = (1 + k)\ \text{M}\Omega$$

where

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

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 For 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.

4.8.2.2.6 If the winding passes this insulation resistance test, proceed in accordance with 4.8.3. If the winding fails this test, and if rewinding is necessary, proceed in accordance with clause 5.

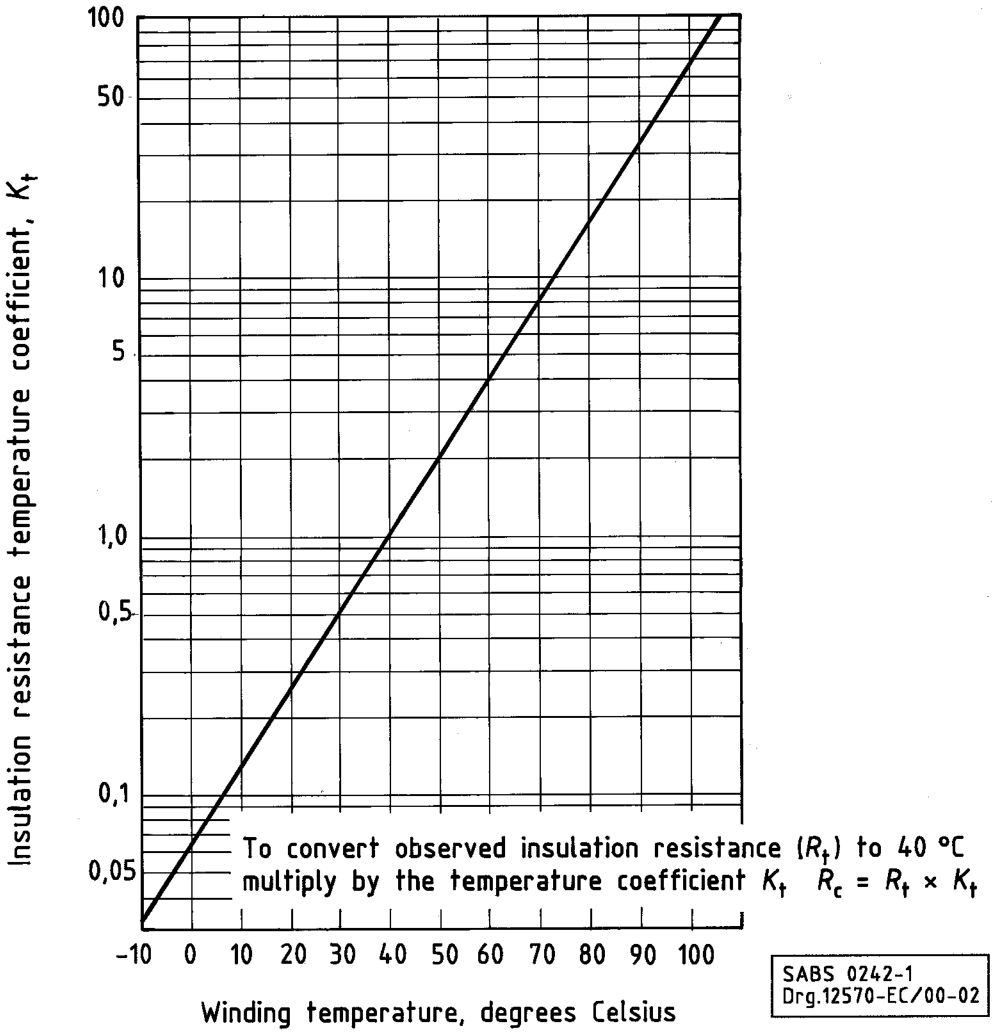


Figure 1 — Approximate insulation resistance variation with temperature for rotating machines

4.8.3 High-voltage withstand test

4.8.3.1 Apparatus

High-voltage test transformer that

a) has a rating of at least 500 VA;

b) operates at a frequency of 50 Hz;

c) is capable of supplying a waveform as nearly sinusoidal as is practicable;

d) has an output current of at least 40 mA at the appropriate of the test voltages given in column 2 of table 1; and

e) has limits of error of the high-voltage indicating voltmeter that do not exceed 3 %.

4.8.3.2 Procedure

4.8.3.2.1 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. Thus the test voltage is also effectively applied between all three-phase windings.

In the case of a winding that is internally connected in star or in delta, see 4.8.1.

4.8.3.2.2 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.

4.8.3.2.3 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.

4.8.3.2.4 Check whether the winding withstands the test voltage for 1 min without flashover or breakdown of insulation.

4.8.3.2.5 If the winding passes this high-voltage withstand test, again measure the insulation resistance in accordance with 4.8.2 and if the winding passes this insulation resistance test, proceed in accordance with 4.8.4. If the winding fails this test and if rewinding is necessary, proceed in accordance with clause 5.

Table 1 — Test voltages

1	2
Components to which the voltage is applied	**r.m.s. test voltage *)** V
Insulated stator winding	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
*) Motors with the original windings (i.e. of category IW1 of SABS 1561-1) shall be subjected to a test at a voltage equal to 1,5 times the rated voltage, with a minimum of 1 000 V if the rated voltage is equal to or exceeds 100 V and a minimum of 500 V if the rated voltage is less than 100 V. **Amdt 1, Sept. 1993**	

4.8.4 Phase resistance or line resistance comparison test

Use a resistance bridge or other equivalent means to measure the resistance of each phase winding separately. The three resistance readings so measured shall not differ from one another by more than 5 % of the highest reading. In the case of a winding that is permanently connected in star or in delta, see 4.8.1.

If the resistance readings are within 5 % of one another, proceed in accordance with 4.8.5. If the resistance readings are not within 5 % of one another, and if rewinding is necessary, proceed in accordance with clause 5.

4.8.5 Interturn test

NOTE This is a test for applying or inducing a voltage of predetermined amplitude between adjacent turns of an insulated winding, for the purpose of checking the integrity of interturn insulation of the winding.

4.8.5.1 Apparatus

4.8.5.1.1 Induction test set up, that comprises

a) a three-phase a.c. power supply of frequency 50 Hz, with either a variable voltage or with a suitable number of fixed voltage tappings, that is capable of supplying at least the rated full load current of the motor for at least 60 s;

b) a.c. r.m.s. measuring ammeter(s) of accuracy at least class 1;

c) a.c. r.m.s. measuring voltmeter(s) of accuracy at least class 1; and

d) measuring current transformer(s) with suitable rated transformation ratio(s) and of accuracy at least class 1 at the rated burden of at least 5 VA. The rated secondary current is 5 A.

4.8.5.1.2 "Growler", that may range from a basic electromagnet of a horse-shoe pattern with an ammeter in its circuit and connected through an isolating transformer to a 50 Hz variable source a.c. supply, to a more modern type that may consist of an electromagnetic voltage inducing test probe operating at 1 000 Hz or more, and provided with a detection means that senses the magnetic field set up by the circulating current in the shorted turns of a coil or shorts between phases.

4.8.5.1.3 Surge test generator (as an alternative to a "growler"), that generates voltage between turns of a coil by discharging a capacitor (charged to a predetermined level) into a winding. The discharge generates a surge followed by a damped sine waveform as the current oscillates between the winding and the capacitor. The surge test voltage is indicated on an oscilloscope screen. Figure 2 shows a typical surge comparison test circuit. Two matched capacitors C1 and C2 are charged by the rectified high-voltage supply. When the thyristor is switched on, the capacitors discharge into the phase windings L1 and L2 under test, generating damped oscillations in the two LC circuits. If the phase windings match and have no shorts between turns or no other faults at the test voltage, their waveforms will match on the oscilloscope screen (see figure 3(a)). If the phase windings are faulty at the test voltage, their waveforms will not match and will be distorted (see figure 3(b) for shorts between phases, and figure 6 for shorts between turns). The nature of the mismatch is often a clue to the type of fault.

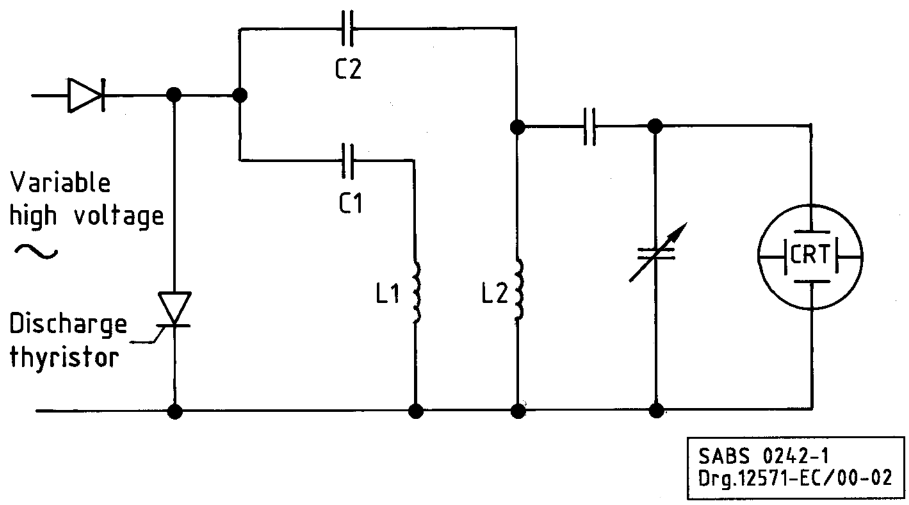
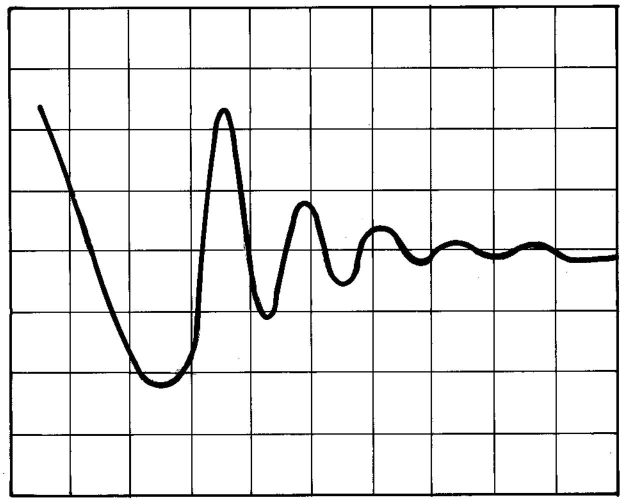


Figure 2 — Typical surge comparison test circuit



SABS 0242-1
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Figure 3(a) — Typical surge waveform of two phase windings without shorts between turns

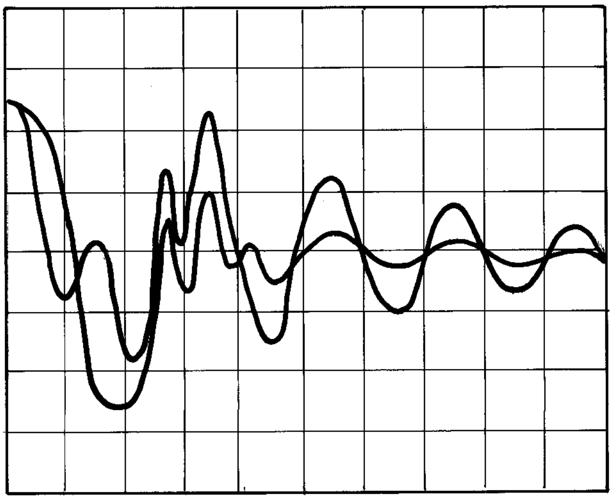

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Figure 3(b) — Typical surge waveform of two phase windings shorting between phases

Figure 3 — Typical surge waveforms

4.8.5.2 Procedure

NOTE A winding that is internally connected in delta is tested using the induction method or the surge test generator method (see below), since other test methods such as the "growler" or the surge test generator are not suitable. On the other hand, a winding that is either internally connected in star, or that has each phase winding individually accessible, is tested using any one of the methods given below. **Amdt 3, Feb. 1998**

4.8.5.2.1 Induction method

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

Switch the winding on to the power supply and note the current in each line. So adjust the voltage of the power supply (by either varying the voltage or selecting a suitable tapping) that the current in each line is at least equal to the rated full load current of the motor.

Record the current in each line and the voltage between phases after allowing the winding to be energized for not longer than 60 s.

Calculate the average current in the three lines and check whether the current in each line differs from the average current by more than 5 %, after taking into consideration the voltage unbalance (if any) between the phases.

Consider the winding to be free of shorts between turns if the current in each line does not differ from the average current by more than 5 %.

4.8.5.2.2 "Growler" method

Use the "growler" to test the winding for possible shorts between turns, following the practice that is well established in the rewinding industry.

4.8.5.2.3 Surge test generator method

To test for possible shorts between turns (interturn faults), connect the surge test generator to the winding as shown schematically in figure 4 (phase winding B being compared with phase winding C while phase winding A forms a common path for charge/discharge currents of windings B and C).

Adjust the d.c. voltage of the surge generator to 1 000 V plus twice the rated voltage of the motor.

If both phase windings are in good condition and have no shorts between turns or no other faults, the oscilloscope screen of the surge generator will show typically a single trace of surge waveform as shown in figure 5.

If one of the phase windings has shorts between turns, the amplitude of the faulty phase winding will be lower and its frequency higher than that of the phase winding without shorts between turns. The oscilloscope screen of the surge generator will show typically a double trace of surge waveform as in figure 6. Other faults may also be detected.

Repeat the test twice (i.e. to a total of three times), comparing winding A with winding B and comparing winding C with winding A.

If no faults are found in the winding of each of the three phases, rewinding may not be necessary. In this case, proceed in accordance with clause 6. If a fault is found in the winding of one or more of the three phases and if rewinding is necessary, proceed in accordance with clause 5.

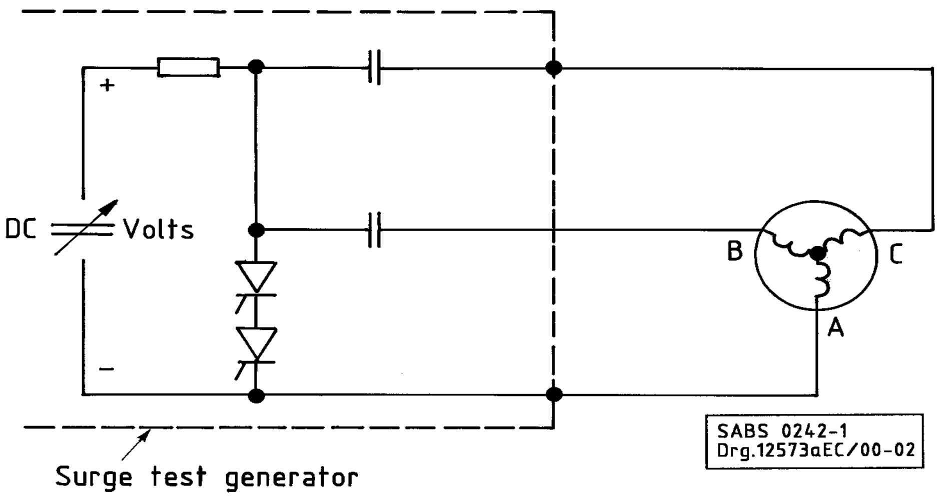

Figure 4 — Surge comparison test set up comparing phase B with C

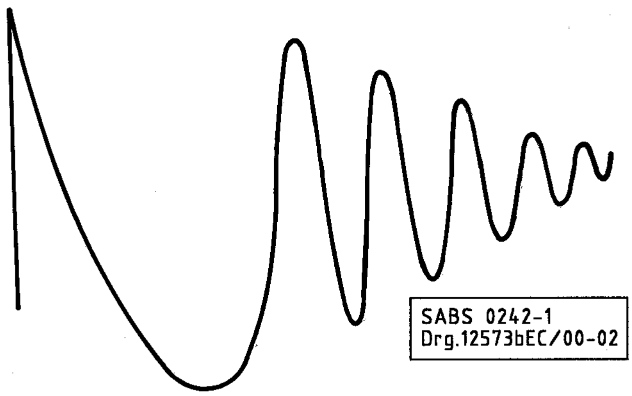

Figure 5 — Typical surge waveform of two phase windings without shorts between turns

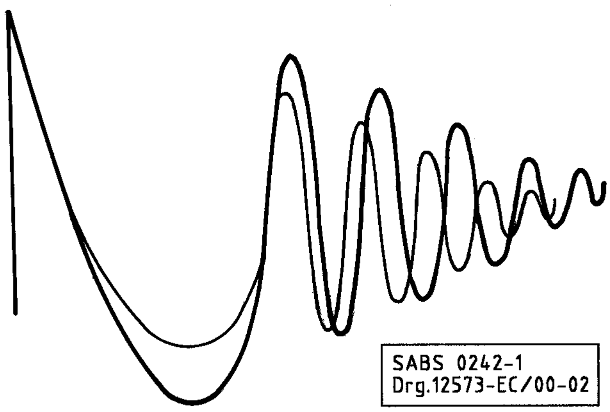

Figure 6 — Typical surge waveform of two phase windings where one phase has shorts between turns

4.8.6 Rotor-bar test (die-cast cage/fitted bar construction)

Use a "growler" as described in 4.8.5.1.2 or other equivalent means to test the cage rotor for cracked rotor bars or cracked end rings (or both). After the test, visually inspect the rotor for defects.

If no defects are found in the rotor, proceed in accordance with 4.9.1.9.5.

If the rotor has defects such as cracked rotor bars or cracked end rings (or both), proceed in accordance with 4.9.1.9.1 to 4.9.1.9.5.

4.8.7 Open circuit rotor voltage test (only motors with wound rotors)

Check for compliance with 5.9 of SABS 1561-1. If no defects are found, proceed in accordance with clause 6 and 4.9.1.9.5, respectively.

If the rotor has a defective winding, proceed in accordance with 5.6.

4.9 Replacement and repair of mechanical components

4.9.1 General

4.9.1.1 Bearings

Replace all bearings (irrespective of their condition) with new bearings of the same type. Only use bearings that have radial clearance as required, and that comply with ISO 15.

NOTE See 7.1 and 7.2 for the method of fitting the bearings on the shaft and of lubricating the bearings.

4.9.1.2 End shields

Replace all end shields that are cracked or distorted or that have damaged spigots or damaged securing holes, and that cannot be economically repaired to the original design.

4.9.1.3 Bearing housing

4.9.1.3.1 Ensure that each end shield is in good condition before repairing the bearing housing.

4.9.1.3.2 Repair all bearing housings that are damaged or worn beyond the bearing manufacturer's specified tolerances.

4.9.1.3.3 Use an acceptable engineering practice to fit a sleeve in position by a "heat shrink" or other method.

4.9.1.3.4 Machine the sleeve to the manufacturer's tolerances for the particular type of bearing being used. Machining shall be done true to the existing spigot.

4.9.1.3.5 Alternatively to fitting a sleeve, use other acceptable methods of repairing the bearing housing. Among the acceptable methods of repairing are plating the housing with nickel or chrome, or building up the housing by means of flame spraying, arc spraying, or microwelding, provided that all these methods are carried out in an acceptable manner.

4.9.1.3.6 Finally, machine the plated or built-up bearing housing to the manufacturer's specified tolerances for the particular type of bearing being used. Machining shall be done true to the existing spigot.

4.9.1.4 Shafts

4.9.1.4.1 Replace any shaft that is bent or has a damaged shaft extension, shaft journal, fan seating, keyway or spline or that has shaft journals worn beyond the manufacturer's specified tolerances, and that cannot be economically repaired to the original manufacturer's design specification or drawing. When a rotor shaft has to be replaced, ensure that the new shaft is manufactured to the original manufacturer's design specification or drawing, with reference to the material used, heat treatment, dimensions and surface finish.

4.9.1.4.2 A shaft that has been damaged or become worn at the shaft extension, shaft journal or fan seating may be repaired by building up the shaft at these areas by means of nickel or chrome plating or microwelding, provided that the process of plating or microwelding is carried out in an acceptable manner. Machine the built-up shaft at the shaft journals and fan seatings to the bearing manufacturer's specified tolerances and surface finish. Machining shall be done true to existing true landings or true to the rotor core. When repairing shaft journals and fan seatings, do not knurl or pop-mark the shaft or use any other unorthodox methods of building up the shaft in order to fit the bearings or the fans.

4.9.1.4.3 In cases where the manufacturer's specified tolerances on shaft journals, fan seatings (landings) and fan bores are not readily available, all the tolerances shall comply with the requirements of SABS ISO 286-1 and SABS ISO 286-2.

The dimensions of shaft extensions and keyways for standard motors shall be in accordance with the relevant requirements of SABS 948-1. **Amdt 2, Feb. 1997**

4.9.1.4.4 After replacing or after repairing the shaft, apply a suitable anti-rust coating to the shaft and to the rotor core. **Amdt 2, Feb. 1997**

4.9.1.5 Securing bolts/studs, nuts and washers

Replace all damaged or missing fasteners and eye bolts, and retap all damaged threaded holes.
Amdt 2, Feb. 1997

4.9.1.6 Terminal boxes

Replace all damaged components and retap all damaged threaded holes. If not already provided, fit on the terminal box an earthing terminal that complies with the relevant requirements of SABS 948-1. **Amdt 2, Feb. 1997**

4.9.1.7 Oil seals/O-rings

Replace all oil seals and O-rings (irrespective of their condition) after ensuring by visual inspection that the seal seating (landing) is in an acceptable condition. For the method of installation of oil seals, see 7.3.

4.9.1.8 Stator

Conduct a core test for hot spots in accordance with 5.4 on all stators, irrespective of whether the stator winding has to be rewound or not (see 4.8). For recommended methods of repairing a damaged core, see 5.4.5.

4.9.1.9 Cage rotor

4.9.1.9.1 Rotor core pack

Replace or repair any mechanically damaged or worn rotor core pack.

4.9.1.9.2 Rotor with fitted bars

Replace all cracked rotor bars and cracked rotor end rings with bars and end rings of identical materials and dimensions.

4.9.1.9.3 End connections

Securely braze all rotor bars to the end rings and, in order to ensure low electrical resistance between each bar and the end rings, braze each bar.

4.9.1.9.4 Cooling fins

Ensure that all cooling fins are in position and are effective.

4.9.1.9.5 Balancing

NOTES

1 In the case of a rigid rotor (see 3.18), balancing of the rotor should be carried out in accordance with ISO 1940-1, using a balance quality grade (e.g. G6, 3) that is suitable for the particular application of the motor. The choice of the balance quality grade should be as agreed upon between the rewinding contractor and the user.

2 In the case of a flexible rotor (see 3.17), balancing of the rotor should be carried out in accordance with ISO 5406 and ISO 5343, using a rotor classification (e.g. class 2) that is suitable for the particular application of the motor. The choice of the classification of the rotor should be as agreed upon between the rewinding contractor and the user.

Dynamically balance the complete rotor and shaft assembly, including cooling fans and coupling, irrespective of whether the rotor was repaired or not. Balance masspieces (which should be made from steel) shall be fixed and locked into position, using high-tensile steel nuts and bolts of strength grade 8,8 of SABS 136.

Balance masspieces should be shaped to conform to the shape of the area where they are fitted and they should be fitted to the main hub of fan assemblies, balance discs or core press-plates and not to blades of fans.

4.9.1.10 Other components

Replace or repair, as necessary or as required by the user, all other defective components such as fan blades, fan cowls, slip-rings, brushes and brush boxes that are not explicitly listed above.

4.9.1.11 Measurement of static thrust applied to brushes

4.9.1.11.1 The static spring pressure exerted on the brushes by the brush-holding mechanism shall be as follows:

a) as stated by the brush-holder manufacturer, or

b) in the absence of such information, in accordance with the specific spring pressure or the colour code marking applied to the spring (as in IEC 778) as follows:

1	2	3	4	5	6
Static spring pressure kPa	15	17,5	**20**	22,5	25
Colour	Green	Red	White	Blue	Black
NOTE The preferred value is in bold print.					

NOTE If, for specific reasons, the spring pressure is adjusted to less than 15 kPa or to more than 25 kPa, the marking colour should be yellow, regardless of the special value demanded by the user.

4.9.1.11.2 The measurement of the static force applied to the brush in a brush-holder consists of measuring the static force applied to the brush in its direction of travel and is based upon the application of the following principles (based on IEC 1015):

a) the force applied to the brush (mounted in its holder) is measured in the direction of travel;

b) the measurement of the force is carried out using a suitable measuring device. The measuring device shall be calibrated regularly (at least once a year) against certified instruments that have a known valid relationship (i.e. are traceable) to nationally recognized standards; and

c) the measurement to be obtained is the static value of the force F to be applied to a brush, to just lift off the brush.

The resulting specific pressure p, in kilopascals, is calculated as follows:

$$p = \frac{F}{A}$$

where

F is the static force, in newtons; and

A is the true cross-sectional area of the brush, in millimetres squared.

The calculated pressure shall be within 10 % of the value given in 4.9.1.11.1 above.

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4.9.2 Ventilation fans

Replace or repair, as necessary or as required by the user, all defective components of the ventilation fan.

4.9.3 Flameproof and Ex N motors

In addition to the replacement and repair of the mechanical components as carried out in 4.9.1, replace or repair, as necessary, those components that are required to be replaced or repaired in terms of SABS approved quality systems for flameproof motors in accordance with SABS 314, and for Ex N motors in accordance with SABS 970.

5 Procedure for rewinding

After positively establishing in accordance with 4.4, 4.6.3(a) and 4.8 that rewinding is necessary, proceed in accordance with 5.1 to 5.6.

5.1 Procedure for removal of stator winding

NOTE Although specifically dealing with the stator winding, this procedure is equally applicable to a rotor winding in the case of motors with wound rotors.

5.1.1 Inspection for temperature indicating devices

5.1.1.1 Before removing the winding, check whether temperature protection devices (e.g. thermo-couples, thermistors) are fitted in the winding.

5.1.1.2 If one or more temperature protection devices are fitted, carefully record the type of each device used, the location of each device in the winding and whether the devices are connected in series or in parallel or are individually terminated at the terminal block.

NOTE This information on the temperature protection devices is considered necessary since in most cases these devices will be damaged during removal of the winding. After rewinding, it will be necessary to replace these devices with new ones of the same type, to position the devices in the winding in the original location, and to connect the devices in the same way that they were originally connected.

5.1.2 Recording of winding data

Record the following winding details on the record sheet of the motor (see 4.2.4):

a) the number of poles;

b) the number of slots;

c) the number of turns per coil;

d) the number of wires in parallel per coil;

e) the size of wire;

f) the number of coils per phase group;

g) the number of phase groups;

h) the coil pitch;

i) the core length, core diameter (ID), the type of connections (e.g. internally star connected, externally delta connected);

j) the length of the overhang on each side of the core;

k) the resistance of the winding, in ohms per phase, calculated as follows:

$$R_p = \frac{0{,}0175 \times (½MLT) \times N_p \times N_s}{A \times (C_p)^2}$$

where

R_p is the resistance of winding per phase, in ohms;

MLT is the mean length per turn of coil, in metres;

N_p is the number of slots per phase;

N_s is the number of conductors per slot;

A is the cross-sectional area of conductor, in millimetres squared; and

C_p is the number of parallel circuits per phase.

NOTE C_p =1 when there is only one circuit. **Amdt 2, Feb. 1997**

l) obtain from the user the direction of rotation of the motor and the user's a.c. supply system phase voltage sequence. **Amdt 2, Feb. 1997**

Check, whenever possible, whether the recorded winding is identical with the motor manufacturer's original design data.

5.1.3 Cutting off the winding overhang

5.1.3.1 When necessary, firmly clamp the stator in position (vertically or horizontally), then cut off one end of the overhang as close to the core as possible, using a proper cut-off machine that is fitted with an acceptable metallic cutting disc or an abrasive wheel. Take care not to damage the laminations of the core.

5.1.3.2 Alternatively, use a cold chisel or a similar tool to cut off the overhang of the winding, taking extreme care not to damage the laminations.

5.1.3.3 Identify and retain the overhang until the winding data has been verified.

5.1.4 Carbonizing or softening of varnish on winding

After cutting off the overhang of the winding, carbonize or soften the varnish, using one of the procedures in 5.1.4.1 or 5.1.4.2, as required.

5.1.4.1 Carbonizing of varnish in a heat-cleaning oven

Proceed as follows:

a) use a specially equipped heat-cleaning oven (see 3.9) to burn off the old insulation. The heat-cleaning oven should have means of continuously monitoring the internal temperature of the oven, using a suitable temperature chart recorder or other equivalent means. **Amdt 2, Feb. 1997**

b) so adjust the temperature control of the heat-cleaning oven that the set point temperature does not exceed 380 °C;

c) place the stator in the heat-cleaning oven and allow the temperature of the oven to reach its predetermined value;

d) keep the stator at that temperature for at least 3 h before switching off the oven;

e) allow the stator to remain in the oven until it cools down to a convenient temperature, before removing the stator for stripping the winding from the core; and

f) if necessary, firmly clamp the stator onto a solid surface. Strip the winding away from the core, using acceptable mechanical means, e.g. hooks, clamps or other equivalent means. Take care not to damage the end laminations and ensure that the support fingers are straight and in place.

NOTE Health and safety hazards may develop as a result of toxic and explosive gases being given off during the "heat-cleaning" process. It is therefore necessary that preventive action be taken to ensure the safe release of such gases.

5.1.4.2 Softening the varnish by direct flame

In the case of aluminium-framed motors, the direct-flame method might be preferred to the heat-cleaning method, especially if it is feared that the heat-cleaning method might damage the aluminium frame. This procedure of softening the varnish by direct flame shall only be carried out by an experienced operator, as follows: **Amdt 2, Feb. 1997**

a) using a suitable gas torch or a blow lamp, carefully apply the flame (in a circular motion) directly to that side of the winding where the overhang has been cut off and also to the remaining overhang, so that the winding conducts the heat inside the slots and so softens the varnish; also apply indirect flame from the torch (in a circular motion) to the core to help soften the varnish further in the slots; avoid, as much as possible, applying direct flame to the core laminations, since this action may damage the insulation between the laminations through overheating; and

b) as soon as the varnish becomes soft through heating, strip the winding from the core in accordance with 5.1.4.1(f).

5.2 Cleaning of stator after removal of winding

The cleaning of a stator shall only be carried out by an experienced operator wearing properly designed, modern and effective protective equipment as described in 4.2.1.

Ensure that all air vent ducts are properly cleaned. The stator/rotor and other components after replacement and repair (see 4.9) and, when relevant, after being placed in the heat-cleaning oven (see 5.1.4.1(c)), shall be cleaned internally and externally, in accordance with one of the following:

a) high-pressure cleaning with steam or hot water;

b) heavy duty cleaning by water blasting; and

c) abrasive blast cleaning.

For recommendations on details of the use of equipment for the above cleaning methods, see SABS 064.

Blast clean all internal and external metal surfaces to grade Sa 2½ of ISO 8501-1.

Because of possible degradation of the magnetic properties of the stator/rotor core, exercise extreme care when carrying out abrasive blast cleaning.

Ensure that all machined surfaces, spigots and recesses are effectively protected, by suitably masking off, during the blast cleaning procedure.

NOTE Attention is drawn to the existence of legislation promulgated by the Department of National Health and Population Development, the Department of Mineral and Energy Affairs, and the Department of Manpower (e.g. in the Machinery and Occupational Safety Act, 1983 (Act 6 of 1983)). There are specific requirements in respect of the safety and health of operators and bystanders, in respect of the equipment and the blasting operation per se, and in respect of sandblasting in particular. In addition, there may be applicable Provincial ordinances and Local Authority by-laws governing this operation and the responsibilities attached to it.

5.3 Priming of external and internal surfaces

5.3.1 As soon as is practical, but not later than 4 h after cleaning in accordance with 5.2, apply (by spraying or brushing) one coat of chromate primer

a) to all accessible surfaces of the stator/rotor core that are intended to be painted, and

b) to all surfaces of all other components that are intended to be painted.

In the case of a user specifying protective coating system 2 (see clause 9) on the assembled motor, use an epoxy-resin-based primer as in 9.3.1.

5.3.2 After applying the primer, inspect all slots in the stator/rotor for the presence of foreign particles (e.g. bits of old insulation) and for high laminations or distorted laminations. Carefully remove any foreign particles and so repair the high or distorted laminations as to restore the core slots to an acceptable condition.

5.3.3 Touch up by applying the same primer as in 5.3.1 to any areas on the metal surfaces that may have become exposed through removal of obstructions from the slots.

5.3.4 Allow the primer to dry before subjecting the stator core to a core test for "hot spots" in accordance with 5.4.

5.4 Core test

5.4.1 General

A core test is a test to ensure that the insulation between core laminations is in a satisfactory condition. One of the most practical methods of determining whether there are shorts between laminations is to induce, by transformer action, magnetic flux in the stator core that is equal to the value of the flux as determined in 5.4.3 and 5.4.4. This is accomplished by winding one or more turns of flexible cable (e.g. welding cable) through the stator core as shown in figure 7.

Passing a suitable value of current through the cable wound around the core will cause an alternating magnetic flux to flow in the core. Any shorts between the laminations will cause a circulating current to flow between the shorted laminations, creating a "hot spot" at the point of damage. Thus such "hot spots" are an indication that the laminations are shorted. These short-circuits between the laminations have to be eliminated in order for the core to function satisfactorily.

5.4.2 Test circuit for producing and measuring of flux density

A schematic diagram of a typical test circuit is shown in figure 7. Essential elements are

a) a suitable single-phase power supply of 50 Hz,

b) an r.m.s. reading voltmeter of accuracy at least class 3, and connected to an insulated conductor that is looped once through the stator bore,

c) a suitably insulated flexible cable (e.g. a welding cable), adequately rated for the current and of sufficient length to be looped at least once through the stator bore (the excitation winding),

d) a temperature sensing device, e.g. an infra-red sensor, and

e) the core under test.

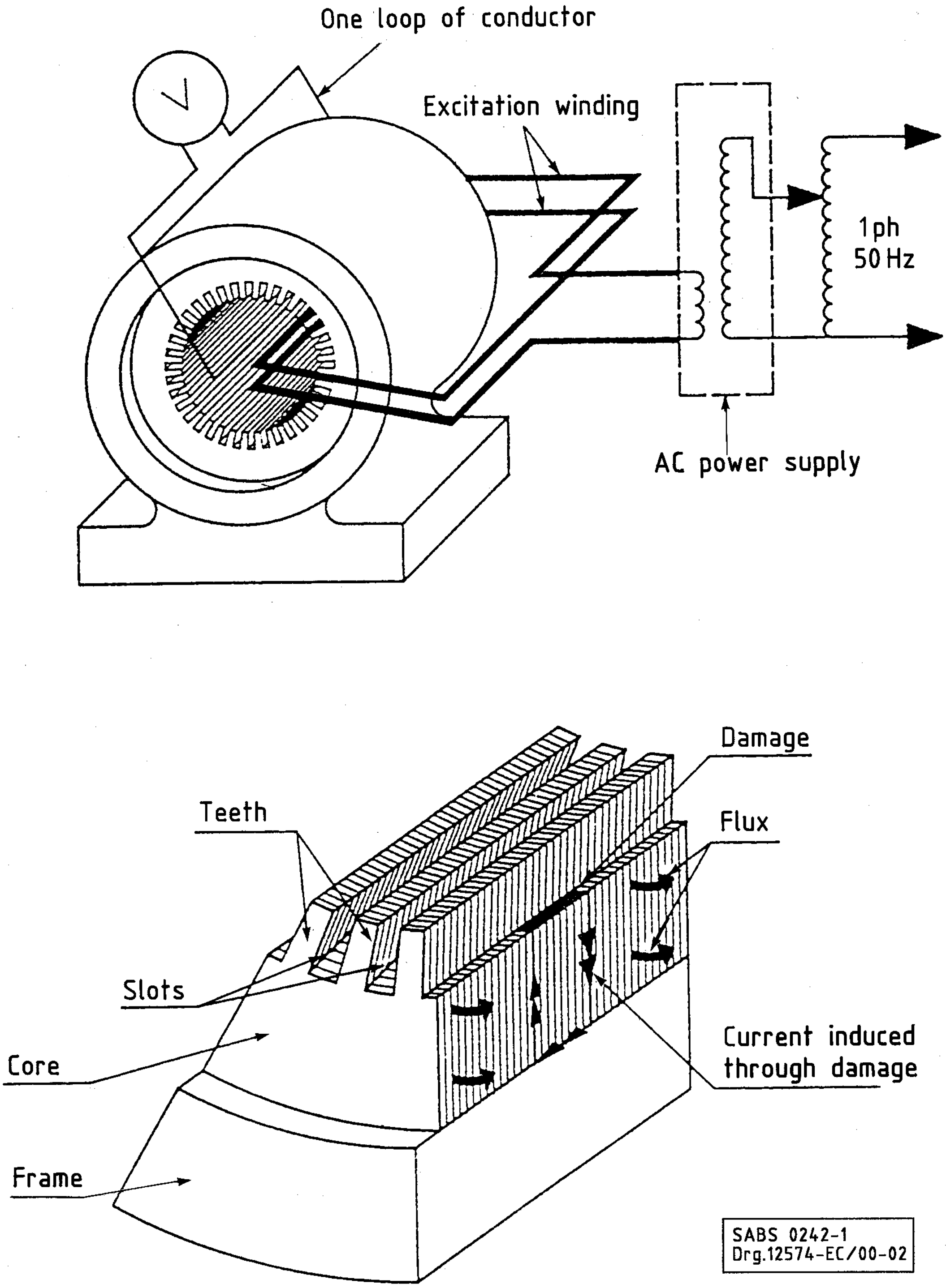

Figure 7 — Schematic diagram of a typical test circuit for a core test

5.4.3 Procedure when design value of flux density is known

5.4.3.1 Obtain the value of volts per turn at the design value of flux density, using the motor manufacturer's design data, or alternatively, calculate from the winding data the volts per turn at the rated flux density, using the following expression:

$$\mathrm{V_t} = \frac{3 \times V_\mathrm{p} \times P_\mathrm{n}}{2 \times N_\mathrm{c} \times C_\mathrm{n}}$$

where

V_t is the voltage per turn, in volts;

V_p is the voltage per phase, in volts;

P_n is the number of parallel circuits;

N_c is the number of turns per coil; and

C_n is the number of coils per phase.

5.4.3.2 Energize the excitation winding and gradually increase the value of current flowing through it until the voltmeter indicates the design value of volts per turn.

WARNING Do not probe the iron or enter the core (in case of large stators) while the excitation winding is energized, since voltage is generated between laminations, and also do not allow metallic objects (e.g. bolts or clamps) to come into contact with the laminations during the test.

5.4.3.3 Constantly watch for "hot spots" because they may show up very rapidly, causing further damage if testing is not stopped and repairs made before continuing with the test. If "hot spots" are not immediately present, continue the test for at least 15 min. Immediately thereafter, using the temperature sensor, check for the presence of "hot spots" and general overheating of the core, by measuring the temperature at the bottom of the slots and at the tip of the teeth at different positions, evenly distributed around the stator core. Also record the approximate average temperature of the core.

5.4.3.4 Consider a "hot spot" to be present where the temperature exceeds the approximate average temperature of the core by more than 10 °C.

5.4.3.5 Indicate the positions of "hot spots" on the core for later repairs to the core in accordance with 5.4.5.

5.4.3.6 If no "hot spots" are present, and if, after 15 min, the approximate average temperature rise of the core exceeds 20 °C, consider overheating of the core to be present.

5.4.3.7 If the core is found to be overheating, reject the core as not being suitable for rewinding, and repair or restack the core in accordance with 5.4.5 or replace the core with a new one, whichever way is considered to be more cost-effective.

5.4.4 Procedure when design value of flux density is unknown

5.4.4.1 When it is not possible to obtain the value of flux density from the manufacturer's design data or when the manufacturer is unknown, then calculate the value of volts per turn from the particulars of the winding data, obtained from the stator winding (see 5.1.2) and then proceed as in 5.4.3.2 to 5.4.3.7 or, alternatively, calculate the value of volts per turn at a flux density of 1,2, using the following empirical expression:

$$V_t = \frac{T \times A_c}{48,44}$$

where

V_t is the voltage per turn, in volts;

T is the flux density in back iron (yoke) of core, in tesla; and

A_c is the cross-sectional area in back iron (yoke) of core, in square centimetres.

$$A_c = \frac{A - B}{2} \times CL$$

where

A and B are as in figure 8, in centimetres; and

CL is the length of the core, in centimetres.

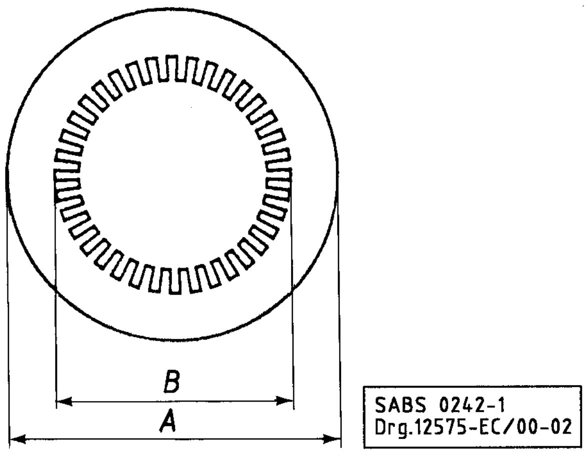

Figure 8 — Dimensions for calculation of core area

Example of calculation

CL = 41,3 cm

A = 48,0 cm

B = 41,7 cm

T = 1,2 T

$$V_1 = \frac{T \times A_c}{48,44}$$

$$= \frac{1,2}{48,44} \times \frac{48,0 - 41,7}{2} \times 41,3$$

$$= \frac{1,2}{48,44} \times 3,15 \times 41,3$$

= 3,22

5.4.4.2 Proceed as in 5.4.3.2 to 5.4.3.7.

5.4.4.3 As an additional method, a suitable core-loss tester can be used to measure the actual core losses, in watts, of the iron core. Typically, the value of the watt loss is dependent on the type of lamination steel in the core and the frame of the motor. The mass of the back iron (the yoke) is calculated in kilograms, and the final result is expressed as the core loss in watts per kilogram. With experience, typical values of the core loss per kilogram will be known, indicating whether a particular core is suitable or not suitable for rewinding.

5.4.5 Method of repairing core damage

5.4.5.1 The following are some methods of repairing core damage:

a) use a high-speed cutting tool to cut the surface of the laminations of the core at the location of the "hot spot"; or

b) cut the tooth-tip surface of the whole core by means of a very fine line bore, taking care not to increase the size of the air gap excessively; any cutting action shall be done in the same direction as the joints between adjacent laminations and not across the joints;

c) on small motors where excessive heat has burned the insulation between the laminations, causing them to short together, separate these laminations by inserting a knife in the laminations in order to force the teeth apart;

d) if possible, insert mica slivers between the laminations in the damaged portion of the core, then dip the core in varnish in such a position as to enable the varnish to fill the openings between the laminations, and then bake the core with the core still in the same position;

e) where the core has been damaged by the rotor rubbing or by the winding blowing up, so grind the area that the laminations are cut clean, and so remove any burrs from the edges that they do not short out the laminations or cut the insulation; or

f) restack the core, spreading the damaged parts throughout the core after re-insulating the laminations with a lamination varnish.

5.4.5.2 After repairing the core, repeat the test for "hot spots" in accordance with 5.4.1 to 5.4.4, as applicable.

5.5 Rewinding: insulation and impregnation systems

The insulation and the impregnation systems used in the rewinding of a motor shall be one of those given in 5.5.3.1, 5.5.4.1 or 5.5.5.1, as agreed upon.

5.5.1 Class of insulation of materials

The materials used in the rewinding of a motor shall be one of the following, as required:

a) class F, having a temperature index of 155 °C as defined in SABS 1804-2 and IEC 85; or
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b) class H, having temperature index of 180 °C as defined in SABS 1804-2 and IEC 85.
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NOTES

1 Basically, this part of SABS 0242 covers class F insulation systems and therefore gives explicit guidance on the use of materials that are suitable for this system; however, this part of SABS 0242 also makes provision for a class H insulation system, if so required.

2 For a class H insulation system, the recommendations of the manufacturer or the supplier of insulating materials should be followed as to the suitability of materials to be used for items specified in 5.5.3.1, 5.5.4.1 and 5.5.5.1.

3 Only electrical grade adhesive tapes should be used where they are applied to any part of the winding. (The adhesives in non-electrical grades usually contain chlorine and other substances that are corrosive and have been proven to attack insulation and conductors when they degrade at high temperatures.)

5.5.2 Coil conductor

The conductor used for coils shall

a) be of high conductivity copper that complies with the relevant requirements of SABS 804;

b) in the case of round conductor, comply with the requirements of SABS IEC 60317-8, and
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c) in the case of rectangular conductor, comply with the requirements for dimensions as specified in IEC 317-0-2.

5.5.3 Double-dip-and-bake method

5.5.3.1 Materials for rewinding

The materials and their applications for a double-dip-and-bake method using a class F insulation system, shall be as follows:

a) **slot liners, separators and caps:** a-three ply composite material of suitable dimensions and consisting of a polyethylene terephthalate (polyester) film that is sandwiched between two layers of acceptable calendered 75 µm aramid paper[1] shall be used, unless otherwise required.

b) **overhang phase insulation:** a three-ply composite material consisting of a polyester film that is sandwiched between two layers of acceptable uncalendered 125 µm aramid paper[2] shall be so installed that the ends of each phase group are effectively insulated.

NOTE Formwound windings do not use separate phase insulation. Coils are individually insulated.

c) **intercoil and end connections:** the intercoil and the end connections shall be brazed or silver-soldered and each joint shall be effectively insulated.

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1 NOMEX(R) 410/416 is an acceptable aramid paper.

2 NOMEX(R) 411 is an acceptable aramid paper.
[NOMEX] is the trade name of a product supplied by TM Du Pont. This information is given for the convenience of users of this part of SABS 0242 and does not constitute the SABS' endorsement of the product named. Equivalent products may be used if they can be shown to lead to the same result.

d) **slot wedges:** the slot wedges shall be of epoxy glass-reinforced composite material that complies with the requirements for grade EP-5 of BS 3953, or an equivalent grade that complies with the requirements of another acceptable standard, and of thickness at least 1 mm. The wedges shall be of adequate dimensions in order to secure the coils in the slots and shall extend at least beyond the ends of the core to the ends of the slot liners.

e) **coil end flexible leads:** the coils shall be connected to the motor terminals by means of flexible stranded copper cables, each of which is of cross-sectional area at least equal to the cross-sectional area of the winding to which it is connected. The cable insulation shall be of an acceptable temperature and voltage rating.

f) **bracing of end windings:** woven or braided polyester or glass tying cord shall be lashed around the end windings to provide adequate bracing.

g) **impregnating varnish:** the impregnating varnish shall be at least a class F varnish that is such as to be acceptable and to be compatible with the insulation system used for the winding.

h) terminal markings: the motor terminals to which the flexible leads of the stator windings are connected, shall be marked, preferably in accordance with SABS IEC 6034-8. In the case of slip-ring motors, the terminals of conductors connected to slip rings shall be marked, preferably R, S and T. **Amdt 2, Feb. 1997**

5.5.3.2 Testing of winding before varnishing

After completing of rewinding, carry out the following tests before subjecting the winding to a double-dip-and-bake method:

NOTE Because it is necessary to have access to both ends of each phase in order to carry out these tests successfully, in some cases making of permanent internal connections should be left till after the tests have been completed.

a) **coil reversal, polarity of winding and direction of rotation test**: with the winding energized from a three-phase low-voltage a.c. source of supply that has standard phase voltage sequence (red, white and blue), check for coil reversal and polarity of the winding, using a suitable instrument, e.g. a freely rotating brass cylinder fitted on a brass rod that, when inserted into the opening of the stator and moved around the core, will rotate in the same direction when there is no coil reversal and polarity of the winding, using a suitable instrument, e.g. a freely rotating brass cylinder fitted on a brass rod that, when inserted into the opening of the stator and moved around the core, will rotate in the same direction when there is no coil reversal and when polarity is normal. Using the same instrument inserted into the stator core (shaft end), ensure that the direction of rotation of the brass cylinder is in the desired direction of rotation of the motor. The relationship between terminal markings and direction of rotation shall be in accordance with SABS IEC 6034-8.

NOTE The standard phase voltage sequence of a source of supply (that is the red, white and blue phases) is found by determining the order in which the phase voltages reach their maximum value of the same polarity. Thus the white phase voltage lags the red phase voltage by 120 degrees, and the blue phase voltage lags the red phase voltage by 240 degrees. **Amdt 2, Feb. 1997**

b) **insulation resistance test:** use the procedure given in 4.8.2.

c) **high-voltage withstand test:** use the procedure given in 4.8.3.

d) **phase resistance test:** use the procedure given in 4.8.4; verify the results by calculating the resistance per phase from formula given in 5.1.2(k), and compare with the value of resistance calculated for the original winding as recorded in 5.1.2(k). **Amdt 2, Feb. 1997**

e) **interturn test:** use the procedure given in 4.8.5.

5.5.3.3 Procedure for varnishing

After the winding has successfully passed all the tests of 5.5.3.2, proceed as follows:

a) ensure that the stator and the winding are clean;

b) place the stator in a drying oven at a temperature in the range 115 °C to 150 °C for a period of time sufficient to drive out moisture that may be present in the winding and in the insulation;

c) after drying in the oven, remove the stator and allow the winding to cool down to within 10 °C above room temperature (or to a temperature as recommended by the varnish manufacturer, e.g. 30 °C to 40 °C) but never lower than 25 °C.

NOTE If the winding is cooled down below 25 °C and allowed to stand, it will absorb moisture quickly. If the winding is placed in the varnish at a temperature higher than that recommended by the varnish manufacturer, the varnish will tend to harden quickly and may not effectively impregnate the winding inside the slots.

d) ensure that the viscosity of the varnish in the storage tank is within the varnish manufacturer's recommended limits, e.g. by using a number 4 Ford cup and measuring the time for the varnish to fully drain from the cup. If necessary, adjust the viscosity of the varnish, either by adding solvent or by adding varnish. In both cases, ensure that the resulting mixture is uniformly distributed throughout the tank. Carry out this procedure (and record the details) at regular intervals of time, to ensure that the viscosity of the varnish is maintained within the original limits. Keep documented records of the frequency of cleaning the varnish and the varnish tank, and also document the procedure for checking the varnish for contamination; **Amdt 2, Feb. 1997**

e) use the varnish manufacturer's recommendations (if any) for the dipping process. Immersion shall be maintained until there are no air bubbles;

f) dip and part-bake the complete core and winding and then redip and fully cure it in a manner recommended by the varnish manufacturer.

g) after baking for the second time, remove the stator from the oven and, while the stator is still hot, remove varnish only from all machined surfaces, tapped holes and the top surfaces of the stator teeth, i.e. the surface of the stator core at the air gap. Finally, after removing varnish from the specified machined surfaces, submit the stator for the assembling of the motor in accordance with clause 7.

NOTE The varnish remaining on other surfaces of the stator forms an excellent undercoat for final painting of the motor.

5.5.4 Vacuum pressure impregnation (VPI)

5.5.4.1 Materials for rewinding

The materials specified below have been selected for optimum coil slot and winding overhang resin retention. The materials and their application for a vacuum pressure impregnation with resin, using a class F insulation system, shall be as follows:

a) **slot liners, separators and caps:** the material shall be one of the following, as required:

1) a three-ply composite material of suitable dimensions consisting of a polyethylene teraphthalate (polyester) film that is sandwiched between two layers of acceptable calendered 75 µm aramid paper[3] shall be used. An additional slot liner of acceptable uncalendered 125 µm aramid paper[4] shall be inserted inside the three-ply composite liner; or

3 NOMEX(R) 410/416 is an acceptable aramid paper.

4 NOMEX(R) 411 is an acceptable aramid paper.

2) alternatively, a three-ply composite material consisting of acceptable calendered 75 µm aramid paper[3], polyester film and acceptable uncalendered 125 µm aramid paper[4] may be used, provided that the calendered aramid paper side is fitted against the iron core.

Once all coil wires have been inserted, the slot liner shall be folded over and the stator slot wedges shall be fitted above the slot liners in order to seal the coil in position in the slot.

b) **overhang phase insulation:** the winding overhang phase insulation shall be one of the following, as required:

1) each coil shall be fully taped around the winding overhang with adequate layers (dependent upon voltage) of a woven polyester tape into and around the liner/wedge, to seal the slot. The tape shall allow the impregnating resin to penetrate the slot and the winding overhang under pressure, and shall retain the resin during the curing process. No additional phase insulation is necessary;

2) alternatively (in the case of random wound windings), if the overhang is not required to be fully taped, then a three-ply composite material, consisting of polyester film that is sandwiched between two layers of acceptable uncalendered 125 µm aramid paper[5]**,** shall be so installed that the ends of each phase group are effectively insulated.

c) **intercoil and end connections:** the intercoil and the end connections shall be brazed or silver-soldered and each joint shall be effectively insulated. If the overhang is required to be fully taped, then, in addition, each joint shall be taped from end to end with a woven polyester tape to fully seal the connection when impregnated.

d) **slot wedges:** the slot wedges shall be of epoxy glass-reinforced composite material that complies with the requirements for grade EP-5 of BS 3953, or an equivalent grade that complies with the requirements of another acceptable standard, and of thickness at least 1 mm. The wedges shall be of adequate dimensions in order to secure the coils in the slots and shall extend at least beyond the ends of the core to the ends of the slot liners.

e) **coil end flexible leads:** the coils shall be connected to the motor terminals by means of flexible stranded copper cables, each of which is of cross-sectional area at least equal to the cross-sectional area of the winding to which it is connected. The cable insulation shall be of an acceptable temperature and voltage rating.

f) **bracing of end windings:** woven or braided polyester or glass tying cord shall be lashed around the end windings to provide adequate bracing.

g) **impregnating resin:** the impregnating resin shall be at least a class F resin such as to be acceptable and to be compatible with the insulation system used for the winding.

h) **terminal markings**: the motor terminals to which the flexible leads of the stator windings are connected, shall be marked, preferably in accordance with SABS IEC 34-8. In the case of slip-ring motors, the terminals of conductors connected to slip rings shall be marked, preferably R, S and T.

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5.5.4.2 Testing of winding before vacuum pressure impregnation

Proceed as in 5.5.3.2.

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3 NOMEX(R) 410/416 is an acceptable aramid paper.

4 NOMEX(R) 411 is an acceptable aramid paper.

5 NOMEX(R) 411 is an acceptable aramid paper.

5.5.4.3 Procedure for vacuum pressure impregnation

After the winding has successfully passed all the tests of 5.5.3.2, proceed as follows:

a) as in 5.5.3.3(a);

b) as in 5.5.3.3(b);

c) ensure, at regular intervals of time as recommended by the resin manufacturer, that the viscosity of the resin in the storage tank is within the resin manufacturer's recommended limits. Keep documented records of the frequency of cleaning the resin tank, and also document the procedure for checking the resin for contamination. **Amdt 2, Feb. 1997**

d) subject the core and the winding to vacuum pressure impregnation in a manner recommended by the resin manufacturer; and

NOTE Useful guidelines to be followed during the process of vacuum pressure impregnation are given in a paper titled *TAKING THE MYTH OUT OF VPI* (see annex C). **Amdt 2, Feb. 1997**

e) after baking in the oven, proceed in accordance with 5.5.3.3(g).

5.5.5 Trickle method (random wound windings only)

5.5.5.1 Materials for rewinding

NOTES

1 Because the trickle method can be completed in under an hour compared to a much longer time required for the double-dip-and-bake and VPI methods of impregnation, this method of impregnation may be of interest to those users who wish to have their rewound motors returned for duty in the shortest possible time, e.g. where non-availability of the motor would lead to loss of production.

2 The trickle method of impregnation as given in 5.5.5.3 is considered satisfactory for length of core up to and including 750 mm. For length of core exceeding 750 mm, the resin manufacturer should be consulted for the optimum temperature of the winding at which resin impregnation should be carried out, in order to ensure complete resin penetration.

The materials and their applications for the trickle method using a class F insulation system shall be the same as those given in 5.5.3.1, except that impregnation shall be carried out using a class F resin that is compatible with the insulation system used for rewinding.

5.5.5.2 Testing of winding before trickle impregnation

Proceed as in 5.5.3.2.

5.5.5.3 Procedure for trickle method

After the winding has successfully passed all the tests of 5.5.3.2, proceed as follows:

a) as in 5.5.3.3(a);

b) as in 5.5.3.3(b);

c) as in 5.5.3.3(c);

d) subject the core and the winding to the trickle method in a manner recommended by the resin manufacturer; and

e) after removing excess resin from the stator teeth and allowing the resin to cure until dry enough to handle, submit the stator for assembling of the motor in accordance with clause 7.

5.6 Rewinding of rotor

5.6.1 Banding

Before removing the winding from the rotor of a slip-ring induction motor, record (on the record sheet of the motor (see 4.2.4)) the following banding details:

a) whether steel wire banding or resin-filled glass-fibre tape banding has been used;

b) in the case of wire banding, the number of turns per layer, the number of layers and the diameter of the wire; and

c) in the case of glass-fibre banding, the width and the overall thickness of the banding from which the number of turns can be estimated.

If the banding is so badly damaged that no reliable information can be obtained, the new banding specification can be calculated taking into consideration the mass of the copper winding overhang, the speed of the motor and the strength of the banding material, using a suitable factor of safety.

5.6.2 Rewinding

Rewind the rotor winding, using the same procedure as for a stator winding in accordance with 5.5, except that the slip-rings shall be removed from the shaft before the rotor is placed in the heat-cleaning oven, and the impregnation and baking shall be carried out after the rotor has been banded in accordance with 5.6.4.

5.6.3 Bracing

After rewinding, suitably brace and support the connections between the winding and the slip-rings in order to restrain the connections against radial movement.

5.6.4 Banding of rotor

5.6.4.1 Before applying the banding wire or banding tape around each overhang of the winding, pull down and evenly bed the coils against the winding supports, using a conventional temporary banding operation; if no winding supports are fitted, pull down and evenly bed the coils against temporary supports (which shall be removed after the banding operation has been completed).

5.6.4.2 Carry out the banding operation in accordance with the recommendations of the banding material supplier, taking into consideration particulars such as the correct tension required in the wire banding or glass-fibre tape banding and, in the case of the glass-fibre tape banding, the temperature to which the rotor is required to be preheated, the time limits within which the banding operation has to be completed and the temperature and duration of curing.

5.6.5 Impregnation of rotor

Impregnate the rotor in accordance with 5.5.3.3, 5.5.4.3 or 5.5.5.3.

5.6.6 Dynamic balancing of rotor

Balance the rotor in accordance with 4.9.1.9.5. After the balancing, submit the rotor for assembling of the motor in accordance with clause 7.

6 Refurbishing of winding

After positively establishing (in accordance with 4.8.1 to 4.8.5) that rewinding is not necessary, proceed as given in 6.1 and 6.2.

6.1 Procedure for cleaning of winding

Ensure that the stator, the rotor and the winding are still clean after the electrical tests have been carried out. In some cases it may be necessary to again clean the surfaces of the stator and the winding, by wiping these surfaces with clean cloth rags that have been soaked in a solvent that is recommended by the wire manufacturer, or to remove any other contaminants, such as dust, from the winding by blowing out with clean dry compressed air (see 4.5.3). After cleaning, place the winding in a drying oven at a temperature in the range 115 °C to 150 °C (in the case of class B insulation, in the range 115 °C to 120 °C) for a period of time sufficient to drive out moisture that may be present in the winding and in the insulation.

6.2 Procedure for dip-and-bake of winding

After removing the stator from the drying oven, subject the winding to a single-dip-and-bake procedure in accordance with 5.5.3.3(c) to (f). Alternatively, subject the winding to the VPI method in accordance with 5.5.4.3(c) to (e), or to the trickle method in accordance with 5.5.5.3(d) to (e).

7 Assembling of motor

7.1 Fitting of bearings on the shaft

7.1.1 Before fitting a bearing on the shaft, heat the bearing by means of a suitable electro-magnetic induction heater that is recommended by the bearing manufacturer. The electromagnetic induction heater shall also have a facility for demagnetizing the bearing after heating it.

7.1.2 Prevent overheating of the bearing by using temperature-sensitive crayons, or other equivalent means, and do not allow the maximum temperature of the inner ring of the bearing to exceed 110 °C.

7.1.3 Demagnetize the bearing after heating and, while it is still hot, fit the bearing with due skill and technique onto the shaft journal.

7.2 Lubrication of bearings and bearing cap covers

7.2.1 Fill the bearing with grease from both sides by thumbing the grease into the bearing spaces.

7.2.2 Use your hands if you wish, but wear protective gloves (e.g. plastics gloves) when handling the grease, since there is a risk of skin allergy if the skin is in regular direct contact with petroleum products.

7.2.3 Ensure that your hands are clean, otherwise dirt may be deposited in the grease and then get into the bearing and cause damage.

7.2.4 Unless otherwise required, or otherwise recommended by the bearing manufacturer, fill the bearing cap covers one-third full (in the case of motors with two poles) to two-thirds full (in the case of motors with four poles or more) with grease, leaving some space in the housing to allow for expansion of the grease.

NOTE Overgreasing can be just as harmful as undergreasing. Overgreasing causes churning and internal friction which may result in the bearings running hot, separation of the oil and soap, oxidation of the grease and possible leakage through retaining seals.

7.2.5 For lubrication of bearings and bearing cap covers, use only the type of grease as recommended or as required.

7.3 Installation of oil seals

The importance of installing an oil seal properly cannot be overemphasized. Failure to observe correct installation procedures probably accounts for more cases of improper functioning of the oil seal than any other cause. In order to secure optimum service, the following precautions should be observed:

a) ensure that the oil seal is of the correct size for the housing diameter, housing depth and shaft diameter;

b) assemble the seal with the toe or the wiping edge of the sealing element facing towards the oil;

c) check that the bore has adequate chamfer, and remove any scratches or sharp edges in the bore;

d) ensure that the shaft is uniform and free from burrs, nicks, scratches and grooves;

e) in all cases apply a lubricant to the shaft or to the sealing element of the oil seal. This aids installation and reduces heat generated during the first few minutes of motor run. Apply lubricant to the outer surface of a synthetic rubber-covered seal, since this will reduce the possibility of shearing or bruising; and

f) use the proper size pressing tool when pressing the seal into the bore, to localize the pressure on the face of the seal, and to be in direct line with the side walls of the seal to prevent damage and distortion to the seal cases during the installation.

7.4 Final assembly

7.4.1 In particular, pay attention to the cleanliness of flanges, spigots and all machined surfaces in order to ensure that the assembled components are not misaligned.

7.4.2 Take extreme care when fitting end shields to bearing housings and also when fitting shaft mounted assemblies (e.g. couplings), in order to prevent damage to the bearings.

7.4.3 Apply a suitable anti-seizing compound to all the threaded bolts and fitting surfaces of a coupling.

7.4.4 Measure, in accordance with SABS 948-1, and record the shaft extension run-out of the flange-mounted assembled motor. The measured shaft extension run-out shall be in accordance with table 2.
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Table 2 – Shaft extension run-out

1	2	3
Diameter of shaft *D* mm	**Shaft extension run-out**	
	Normal class µm	**Precision class (only on request)** µm
$D \leq 10$	30	15
$10 < D \leq 18$	35	18
$18 < D \leq 30$	40	21
$30 < D \leq 50$	50	25
$50 < D \leq 80$	60	30
$80 < D \leq 120$	70	35

7.4.5 Ensure that the assembled motor complies with the following additional requirements:

a) in the case of a foot-mounted motor, the feet of the motor shall be in the same plane;

b) the height of the motor shaft shall be within the height specified in the manufacturer's original design;

c) the axial play of the rotor shall be within the acceptable tolerance; and

d) no welding shall have been done on the motor frame, since welding could cause damage to the bearings.
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8 Testing of assembled motor

The assembled motor shall be tested in accordance with SABS 1561-1. After testing, submit the motor for protective coatings in accordance with clause 9.
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9 Protective coatings

9.1 General

Basically, two systems of protective coatings against corrosion are recommended for application to the external surfaces of the assembled motor. The coating applied to an assembled motor shall be one of the following, as required.

9.2 System 1 protective coating

NOTE This system is considered suitable for motors in normal industrial types of application. For best results, however, the recommendations of the paint manufacturer should be followed.

9.2.1 Primer coat

One coat of chromate primer, that has already been applied in accordance with 5.3.1 to the external and internal surfaces of the stator, and to the surfaces of all other components.

9.2.2 Undercoat

9.2.2.1 Apply (by brushing or spraying) one coat of undercoat that complies with the requirements for grade 1 or 2 of SABS 681, to all external surfaces of the assembled motor. **Amdt 3, Feb. 1998**

9.2.2.2 In the case of stators that were subjected to the dip-and-bake method of varnish impregnation or to the VPI method of impregnation with resin, it is not necessary to apply an undercoat to the external surfaces of the stator, since these surfaces are well covered with one or more layers of varnish or a layer of resin, and thus have an effective undercoat.

9.2.2.3 The undercoat shall have a distinctly different colour from the primer coat and also from the finishing coat, so that each stage of the process of the protective coatings being applied to the motor can be easily and positively identified.

9.2.2.4 Allow the undercoat to dry for a period of time as recommended by the paint manufacturer, and ensure that there is no contamination of the undercoat before the finishing coat is applied.

9.2.3 Finishing coat

9.2.3.1 Apply (by brushing or spraying) one coat of high-gloss alkyd base enamel paint that complies with the requirements of SABS 630, to all external surfaces of the undercoated motor.

9.2.3.2 The colour of the finishing coat shall be one of the colours given in SABS 1091, as required.

9.3 System 2 protective coating

NOTES

1 To ensure compatibility of the films that constitute a paint system (and thereby to ensure optimum performance of the system), both primer and finishing coat should be purchased from the same manufacturer.

2 This system is considered more suitable for motors in applications of exposure to severe corrosive conditions, e.g. freshwater and seawater immersion. For best results, however, the recommendations of the paint manufacturer should be followed.

9.3.1 Primer coat

9.3.1.1 Follow the paint manufacturer's recommendations closely with regard to the mixing of primer, the pot-life of the primer and the curing time required at different ambient air temperatures.

NOTE Compatibility with the top coat of the resin or varnish used for impregnation, should be confirmed by the paint manufacturer.

9.3.1.2 Apply (by brushing or spraying) one coat of epoxy-resin-based primer to all external surfaces of the assembled motor. **Amdt 3, Feb. 1998**

9.3.1.3 In the case of motors that were subjected to the dip-and-bake method of varnish impregnation or to the VPI method of impregnation with resin, it is not necessary to apply a primer coat to the external surfaces of the stator, since these surfaces are well covered with one or more layers of varnish or a layer of resin and thus have an effective primer coat.

9.3.1.4 The primer shall have a distinctly different colour from the finishing coat, so that each stage of the process of the protective coatings being applied to the motor can be easily and positively identified.

9.3.1.5 Ensure that, during the curing time, there is no contamination of the primer coat before the finishing coat is applied.

9.3.2 Finishing coat

9.3.2.1 Apply (by brushing or spraying) one coat of epoxy-resin-based finishing paint to all external surfaces of the primed motor. **Amdt 3, Feb. 1998**

9.3.2.2 The colour of the finishing coat shall be one of the colours given in SABS 1091, as required.

9.4 Alternative system

If so required, another suitable protective coating system may be used as an alternative to system 2 protective coatings.

10 Protection of motor during transit

During the transit of a motor between the rewinding contractor and the user, the motor shall be protected against damage in accordance with the user's instructions, if any. Extension shafts, flanges and roller bearings need particular protection. A suitable rotor locking device should be used to so lock the rotor to the frame of the motor as to prevent radial and axial movement of the rotor against the bearings, thus protecting the bearings against damage (hammer action).

Annex A
(normative)

Notes to users

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

a) the method of cleaning (see 4.5.2);

b) Deleted by amendment No. 1.

c) the radial clearance of bearings (see 4.9.1.1);

d) whether components are to be replaced or repaired (see 4.9.1.10 and 4.9.2);

e) the procedure to be followed during the carbonizing or softening of varnish (see 5.1.4);

f) whether class F or class H system of insulation of materials is required (see 5.5.1);

g) if the user has a particular requirement, the type of impregnation system (see 5.5.3, 5.5.4 or 5.5.5);

h) the depth of lubrication and the type of grease required for lubrication of bearings (see 7.2.4 and 7.2.5);

i) whether system 1 or system 2 protective coatings are to be used on the assembled motor and whether an alternative system to system 2 is to be used (see 9.2 or 9.3 and 9.4); and

j) the colour of the finishing coat (see 9.2.3.2 and 9.3.2.2).

A.2 The following requirements shall be as agreed upon between the user and the rewinding contractor:

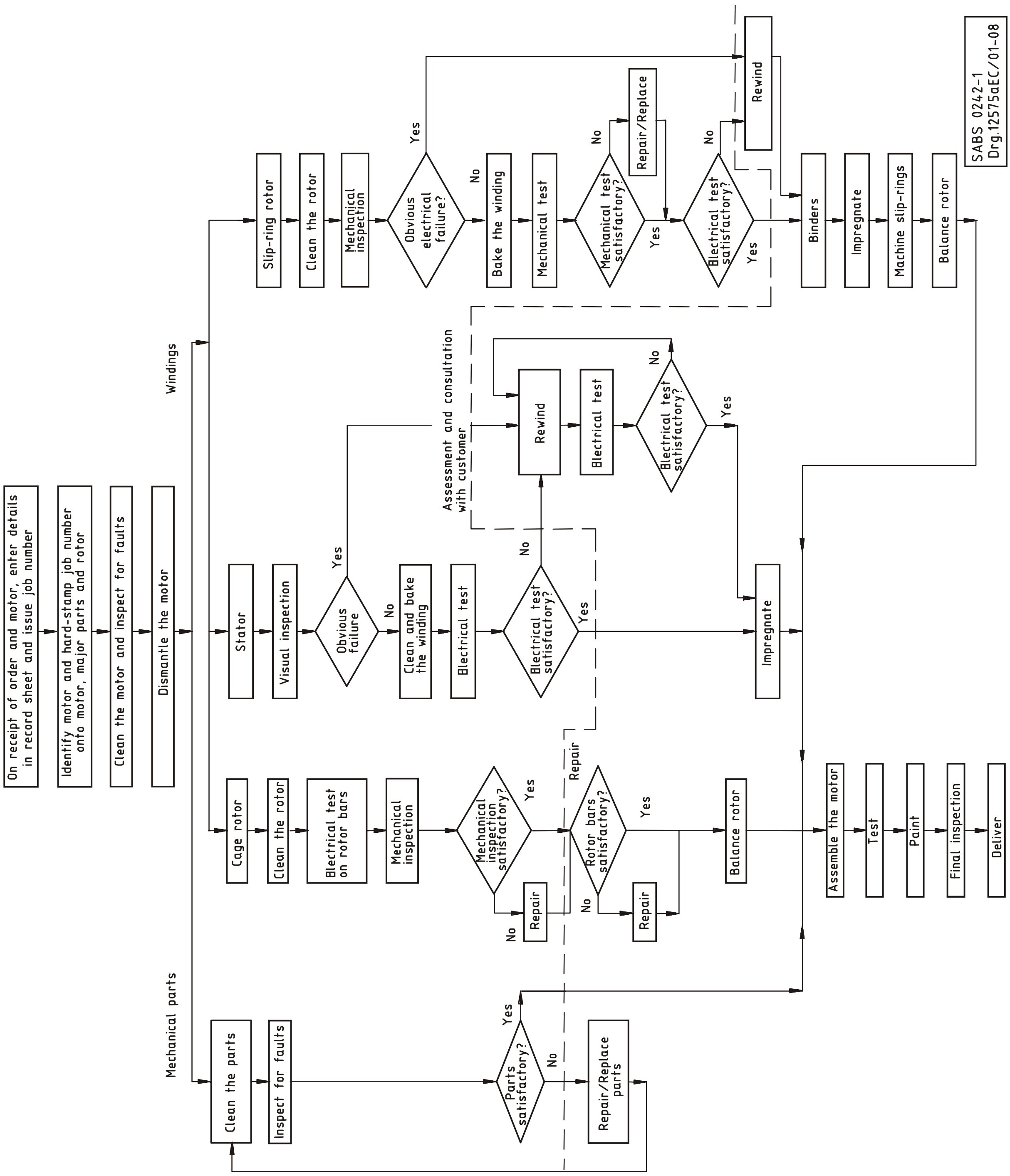
a) in the case of rigid rotors, the balance quality grade (see NOTE (1) to 4.9.1.9.5);

b) in the case of flexible rotors, the classification of the rotor (see NOTE (2) to 4.9.1.9.5); and

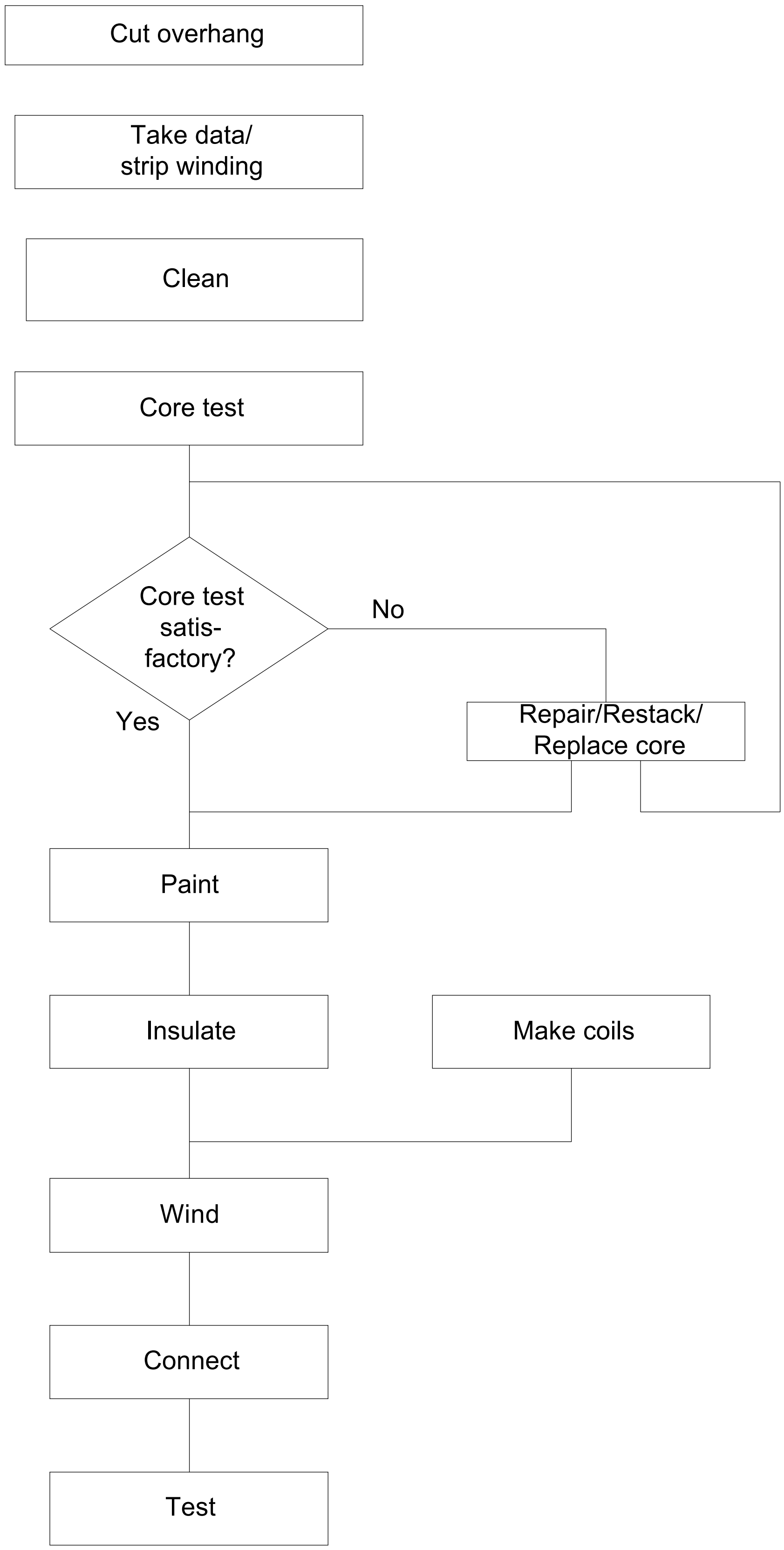
c) the insulation and impregnation systems to be used in the rewinding of a motor (see 5.5).

Annex B
(informative)

B.1 AC motor flow chart



B.2 Stator/rotor rewind flow chart



Annex C
(informative)

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