BS EN 60947-4-1:2010+A1:2012

BSI Standards Publication

Low-voltage switchgear and controlgear

Part 4-1: Contactors and motor-starters — Electromechanical contactors and motor-starters

National foreword

This British Standard is the UK implementation of EN 60947-4-1:2010+A1:2012. It is identical to IEC 60947-4-1:2009, incorporating amendment 1:2012. It supersedes BS EN 60947-4-1:2010, which will be withdrawn on 24 August 2015.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to IEC text carry the number of the IEC amendment. For example, text altered by IEC amendment 1 is indicated by A1) (A1.

The UK participation in its preparation was entrusted by Technical Committee PEL/17, Switchgear, controlgear, and HV-LV co-ordination, to Subcommittee PEL/17/2, Low voltage switchgear and controlgear.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

ISBN 978 0 580 73588 2

ICS 29.120.99; 29.130.20

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 May 2010

Amendments/corrigenda issued since publication

Date	Text affected
31 January 2013	Implementation of IEC amendment 1:2012 with CENELEC endorsement A1:2012

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 60947-4-1:2010+A1

October 2012

ICS 29.120.99; 29.130.20

English version

Low-voltage switchgear and controlgear - Part 4-1: Contactors and motor-starters - Electromechanical contactors and motor-starters

(IEC 60947-4-1:2009)

Appareillage à basse tension -
Partie 4-1: Contacteurs et démarreurs de moteurs -
Contacteurs et démarreurs électromécaniques
(CEI 60947-4-1:2009)

Niederspannungsschaltgeräte -
Teil 4-1: Schütze und Motorstarter -
Elektromechanische Schütze und Motorstarter
(IEC 60947-4-1:2009)

This European Standard was approved by CENELEC on 2010-04-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: Avenue Marnix 17, B - 1000 Brussels

Ref. No. EN 60947-4-1:2010 E

Foreword

The text of document 17B/1674/FDIS, future edition 3 of IEC 60947-4-1, prepared by SC 17B, Low-voltage switchgear and controlgear, of IEC TC 17, Switchgear and controlgear, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60947-4-1 on 2010-04-01.

This standard is to be used in conjunction with EN 60947-1.

This European Standard supersedes EN 60947-4-1:2001 + A1:2002 + A2:2005.

This EN 60947-4-1 includes the following significant technical changes with respect to the EN 60947-4-1:2001 + A1:2002 + A2:2005:

- deletion of the test at –5 °C and +20 °C for thermal overload relays that are not compensated for ambient air temperature;
- addition of conditions of the tests according to Annex Q of EN 60947-1;
- EMC tests: clarification of acceptance criteria and alignment with EN 60947-1 for fast transient severity level;
- Annex B, test for Icd: modification of the duration of the dielectric test voltage from 5 s to 60 s;
- Annex B, electrical durability: improvement of the statistical aspects;
- Annex H: clarification and introduction of new extended functions within electronic overload relays;
- Annex K, procedure to determine data for electromechanical contactors used in functional safety applications: creation of this new annex.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN and CENELEC shall not be held responsible for identifying any or all such patent rights.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2011-01-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2013-04-01

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association and covers essential requirements of EC Directive 2004/108/EC. See Annex ZZ.

Annexes ZA and ZZ have been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60947-4-1:2009 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60068-2-2:2007	NOTE	Harmonized as EN 60068-2-2:2007 (not modified).
IEC 60076-1:1993	NOTE	Harmonized as EN 60076-1:1997 (modified).
IEC 60269-1:2006	NOTE	Harmonized as EN 60269-1:2007 (not modified).
IEC 60269-2:2006	NOTE	Harmonized as EN 60269-2:2007 (modified).
IEC 60664-1:2007	NOTE	Harmonized as EN 60664-1:2007 (not modified).
IEC 61095:2009	NOTE	Harmonized as EN 61095:2009 (not modified).

Foreword to amendment A1

The text of document 17B/1769/FDIS, future edition 1 of IEC 60947-4-1:2009/A1, prepared by SC 17B, "Low-voltage switchgear and controlgear", of IEC TC 17, "Switchgear and controlgear" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60947-4-1:2010/A1:2012.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2013-05-24
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2015-08-24

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 60947-4-1:2009/A1:2012 was approved by CENELEC as a European Standard without any modification.

Add to the Bibliography of EN 60947-4-1:2010, the following note for the standard indicated:

IEC 61915-2:2011 NOTE Harmonized as EN 61915-2:2012 (not modified).

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60034-1	2004	Rotating electrical machines - Part 1: Rating and performance	EN 60034-1	2004
IEC 60085	2007	Electrical insulation - Thermal evaluation and designation	EN 60085	2008
IEC 60300-3-5	2001	Dependability management - Part 3-5: Application guide - Reliability test conditions and statistical test principles	-	-
IEC 60410	1973	Sampling plans and procedures for inspection by attributes	-	-
IEC 60947-1	2007	Low-voltage switchgear and controlgear - Part 1: General rules	EN 60947-1	2007
IEC 60947-2	2006	Low-voltage switchgear and controlgear - Part 2: Circuit-breakers	EN 60947-2	2006
IEC 60947-3	2008	Low-voltage switchgear and controlgear - Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units	EN 60947-3	2009
IEC 60947-5-1	2003	Low-voltage switchgear and controlgear - Part 5-1: Control circuit devices and switching elements - Electromechanical control circuit devices	EN 60947-5-1 + corr. July	2004 2005
IEC 61000-4-2	2008	Electromagnetic compatibility (EMC) - Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test	EN 61000-4-2	2009
IEC 61000-4-3	2006	Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test	EN 61000-4-3	2006
IEC 61000-4-4	2004	Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test	EN 61000-4-4	2004
IEC 61000-4-5	2005	Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test	EN 61000-4-5	2006

Publication	Year	Title	EN/HD	Year
IEC 61000-4-6	2008	Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields	EN 61000-4-6	2009
IEC 61051-2	1991	Varistors for use in electronic equipment - Part 2: Sectional specification for surge suppression varistors	-	-
IEC 61439-1 (mod)	2009	Low-voltage switchgear and controlgear assemblies - Part 1: General rules	EN 61439-1	2009
IEC 61508	Series	Functional safety of electrical/electronic/programmable electronic safety-related systems	EN 61508	Series
IEC 61511	Series	Functional safety - Safety instrumented systems for the process industry sector	EN 61511	Series
IEC 61513	2001	Nuclear power plants - Instrumentation and control for systems important to safety - General requirements for systems	-	-
IEC 61649	2008	Weibull analysis	EN 61649	2008
IEC 61810-1	2008	Electromechanical elementary relays - Part 1: General requirements	EN 61810-1	2008
IEC 62061	2005	Safety of machinery - Functional safety of safety-related electrical, electronic and programmable electronic control systems	EN 62061	2005
CISPR 11 (mod) + A1 + A2	2003 2004 2006	Industrial scientific and medical (ISM) radio-frequency equipment - Electromagnetic disturbance characteristics - Limits and methods of measurement	EN 55011 - + A2[1) 2)]	2007 - 2007
ISO 13849-1	2006	Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design	-	-

1) EN 55011 includes A1 to CISPR 11 (mod).

2) EN 55011 is superseded by prEN 55011(fragment 1), which is based on CISPR 11:200X (fragment 1)(CISPR/B/440/CDV).

Annex ZZ
(informative)

Coverage of Essential Requirements of EC Directives

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association and within its scope the standard covers all relevant essential requirements as given in Article 1 of Annex I of the Directive 2004/108/EC.

Compliance with this standard provides one means of conformity with the specified essential requirements of the Directives concerned.

WARNING: Other requirements and other EC Directives may be applicable to the products falling within the scope of this standard.

CONTENTS

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters

1 Scope and object

1.1 Scope

This part of IEC 60947 applies to the types of equipment listed in 1.1.1 and 1.1.2 whose main contacts are intended to be connected to circuits the rated voltage of which does not exceed 1 000 V a.c. or 1 500 V d.c.

Starters and/or contactors dealt with in this standard are not normally designed to interrupt short-circuit currents. Therefore, suitable short-circuit protection (see 9.3.4) forms part of the installation but not necessarily of the contactor or the starter.

In this context, this standard gives requirements for:

– contactors associated with overload and/or short-circuit protective devices;

– starters associated with separate short-circuit protective devices and/or with separate short-circuit and integrated overload protective devices;

– contactors or starters combined, under specified conditions, with their own short-circuit protective devices. Such combinations, e.g. combination starters or protected starters are rated as units.

For circuit-breakers and fuse-combination units used as short-circuit protective devices in combination starters and in protected starters, the requirements of IEC 60947-2 and IEC 60947-3 respectively apply.

Equipment covered by this standard is as follows.

1.1.1 AC and DC contactors

AC and DC contactors intended for closing and opening electric circuits and, if combined with suitable relays (see 1.1.2), for protecting these circuits against operating overloads which may occur therein.

NOTE For contactors combined with suitable relays and which are intended to provide short-circuit protection, the relevant conditions specified for circuit-breakers (IEC 60947-2) additionally apply.

This standard applies also to the actuators of contactor relays and to the contacts dedicated exclusively to the coil circuit of a contactor.

Contactors or starters with an electronically controlled electromagnet are also covered by this standard.

1.1.2 AC motor-starters

AC motor-starters A1⟩ (including motor management starter) ⟨A1 intended to start and accelerate motors to normal speed, to ensure continuous operation of motors, to switch off the supply from the motor and to provide means for the protection of motors and associated circuits against operating overloads.

For overload relays for starters, including those based on electronic technology with or without extended functions according to Annex H, the requirements of this standard apply.

1.1.2.1 Direct-on-line (full voltage) a.c. starters

Direct-on-line starters intended to start and accelerate a motor to normal speed, to provide means for the protection of the motor and its associated circuits against operating overloads, and to switch off the supply from the motor.

This standard applies also to reversing starters.

1.1.2.2 Reduced voltage a.c. starters

Reduced voltage a.c. starters intended to start and accelerate a motor to normal speed by connecting the line voltage across the motor terminals in more than one step or by gradually increasing the voltage applied to the terminals, to provide means for the protection of the motor and its associated circuits against operating overloads, and to switch off the supply from the motor.

Automatic change-over devices may be used to control the successive switching operations from one step to the others. Such automatic change-over devices are, for example, time-delay contactor relays or specified time all-or-nothing relays, under-current devices and automatic acceleration control devices (see 5.10).

1.1.2.2.1 Star-delta starters

Star-delta starters intended to start a three-phase motor in the star connection, to ensure continuous operation in the delta connection, to provide means for the protection of the motor and its associated circuits against operating overloads, and to switch off the supply from the motor.

The star-delta starters dealt with in this standard are not intended for reversing motors rapidly and, therefore, utilization category AC-4 does not apply.

NOTE In the star connection, A1 the starting current A1 in the line and the torque of the motor are about one-third of the corresponding values for delta connection. Therefore, star-delta starters are used when the inrush current due to the starting is to be limited, or when the driven machine requires a limited torque for starting. Figure 1 indicates typical curves of starting current, of starting torque of the motor and of torque of the driven machine.

1.1.2.2.2 Two-step auto-transformer starters

Two-step auto-transformer starters, intended to start and accelerate an a.c. induction motor from rest with reduced torque to normal speed and to provide means for the protection of the motor and its associated circuits against operating overloads, and to switch off the supply from the motor.

This standard applies to auto-transformers which are part of the starter or which constitute a unit specially designed to be associated with the starter.

Auto-transformer starters with more than two steps are not covered by this standard.

The auto-transformer starters dealt with in this standard are not intended for inching duty or reversing motors rapidly and, therefore, utilization category AC-4 does not apply.

NOTE In the starting position, the current in the line and the torque of the motor related to the motor starting with rated voltage are reduced approximately as the square of the ratio (starting voltage):(rated voltage). Therefore, auto-transformer starters are used when the inrush current due to the starting is to be limited or when the driven machine requires a limited torque for starting. Figure 2 indicates typical curves of starting current, of starting torque of the motor and of torque of the driven machine.

1.1.2.3 Rheostatic rotor starters

Starters intended to start an a.c. induction motor having a wound rotor by cutting out resistors previously inserted in the rotor circuit, to provide means for the protection of the motor against operating overloads and to switch off the supply from the motor.

[A1⟩ *Text deleted* ⟨A1]

This standard applies also to starters for two directions of rotation when reversal of connections is made with the motor stopped (see 5.3.5.5). Operations including inching and plugging necessitate additional requirements and are subject to agreement between manufacturer and user.

This standard applies to resistors which are part of the starter or constitute a unit specially designed to be associated with the starter.

1.2 Exclusions

This standard does not apply to:

– d.c. starters;
– star-delta starters, rheostatic rotor starters, two-step auto-transformer starters intended for special applications and designed for continuous operation in the starting position;
– unbalanced rheostatic rotor starters, i.e. where the resistances do not have the same value in all phases;
– equipment designed not only for starting, but also for adjustment of speed;
– liquid starters and those of the "liquid-vapour" type;
– semiconductor contactors and starters making use of semiconductor contactors in the main circuit;
– rheostatic stator starters;
– contactors or starters designed for special applications;
– auxiliary contacts of contactors and contacts of contactor relays. These are dealt with in IEC 60947-5-1.

1.3 Object

The object of this standard is to state:

a) the characteristics of contactors and starters and associated equipment;
b) the conditions applicable to contactors and starters with reference to:
   1) their operation and behaviour,
   2) their dielectric properties,
   3) the degrees of protection provided by their enclosures, where applicable,
   4) their construction;
c) the tests intended for confirming that these conditions have been met, and the methods to be adopted for these tests;
d) the information to be given with the equipment or in the manufacturer's literature.

2 Normative references

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

IEC 60034-1:2004, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60085:2007, *Electrical insulation – Thermal evaluation and designation*

IEC 60300-3-5:2001, *Dependability management – Part 3-5: Application guide – Reliability test conditions and statistical test principles*

IEC 60410:1973, *Sampling plans and procedures for inspection by attributes*

IEC 60947-1:2007, *Low-voltage switchgear and controlgear – Part 1: General rules*

IEC 60947-2:2006, *Low-voltage switchgear and controlgear – Part 2: Circuit-breakers*

IEC 60947-3:2008, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*

IEC 60947-5-1:2003, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*

IEC 61000-4-2:2008, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3:2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*
Amendment 1 (2007)

IEC 61000-4-4:2004, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5:2005, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6:2008, *Electromagnetic compatibility (EMC) – Part 4-6:Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

[A1] IEC 61051-2:1991, *Varistors for use in electronic equipment – Part 2: Sectional specification for surge suppression varistors* [A1]

IEC 61439-1:2009, *Low-voltage switchgear and controlgear assemblies – Part 1: General rules*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 61511 (all parts), *Functional safety – Safety instrumented systems for the process industry sector*

IEC 61513:2001, *Nuclear power plants –Instrumentation and control for systems important to safety – General requirements for systems*

IEC 61649:2008, *Weibull analysis*

IEC 61810-1:2008, *Electromechanical elementary relays – Part 1: General requirements* (available in English only)

IEC 62061:2005, *Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems*

CISPR 11:2003, *Industrial, scientific and medical (ISM) radio-frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement*
Amendment 1 (2004)
Amendment 2 (2006)

ISO 13849-1:2006, *Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design*

3 Terms, definitions, symbols and abbreviations

3.1 General

For the purposes of this document, the terms and definitions of Clause 2 of IEC 60947-1, as well as the following terms, definitions, symbol and abbreviations apply.

3.2 Alphabetical index of terms

Reference

3.3 Terms and definitions concerning contactors

3.3.1
(mechanical) contactor
mechanical switching device having only one position of rest, operated otherwise than by hand, capable of making, carrying and breaking currents under normal circuit conditions including operating overload conditions

NOTE 1 Contactors may be designated according to the method by which the force for closing the main contacts is provided.

[IEV 441-14-33]

NOTE 2 The term "operated otherwise than by hand" means that the device is intended to be controlled and kept in working position from one or more external supplies.

NOTE 3 In French, a contactor the main contacts of which are closed in the position of rest is usually called a "rupteur". The word "rupteur" has no equivalent in the English language.

NOTE 4 A contactor is usually intended to operate frequently.

3.3.2
electromagnetic contactor
contactor in which the force for closing the normally open main contacts or opening the normally closed main contacts is provided by an electromagnet

NOTE The electromagnet may be electronically controlled.

3.3.3
pneumatic contactor
contactor in which the force for closing the normally open main contacts or opening the normally closed main contacts is provided by a device using compressed air, without the use of electrical means

3.3.4
electro-pneumatic contactor
contactor in which the force for closing the normally open main contacts or opening the normally closed main contacts is provided by a device using compressed air under the control of electrically operated valves

3.3.5
latched contactor
contactor, the moving elements of which are prevented by means of a latching arrangement from returning to the position of rest when the operating means are de-energized

NOTE 1 The latching, and the release of the latching, may be mechanical, electromagnetic, pneumatic, etc.

NOTE 2 Because of the latching, the latched contactor actually acquires a second position of rest and, according to the definition of a contactor, it is not, strictly speaking, a contactor. However, since the latched contactor in both its utilization and its design is more closely related to contactors in general than to any other classification of switching device, it is considered proper to require that it complies with the specifications for contactors wherever they are appropriate.

[IEV 441-14-34]

3.3.6
vacuum contactor (or starter)
contactor (or starter) in which the main contacts open and close within a highly evacuated envelope

3.3.7
position of rest (of a contactor)
position which the moving elements of the contactor take up when its electromagnet or its compressed-air device is not energized

[IEV 441-16-24]

A1) **3.3.8.**
electronically controlled electromagnet
electromagnet in which the coil is controlled by a circuit with active electronic elements

3.3.9
holding power (of a contactor)
power needed to maintain the operation of the electromagnet

3.3.10
pick-up power (of a contactor)
power needed to operate the contactor from the de-energized state to the energized state (A1

3.4 Terms and definitions concerning starters

3.4.1
starter
combination of all the switching means necessary to start and stop a motor in combination with suitable overload protection

[IEV 441-14-38, modified]

3.4.2
direct-on-line starter
starter which connects the line voltage across the motor terminals in one step

[IEV 441-14-40]

3.4.3
reversing starter
starter intended to cause the motor to reverse the direction of rotation by reversing the motor primary connections while the motor may be running

3.4.4
two-direction starter
starter intended to cause the motor to reverse the direction of rotation by reversing the motor primary connections only when the motor is not running

3.4.5
reduced voltage starter
starter which connects the line voltage across the motor terminals in more than one step or by gradually increasing the voltage applied to the terminals

3.4.5.1
star-delta starter
starter for a three-phase induction motor such that in the starting position the stator windings are connected in star and in the final running position they are connected in delta

[IEV 441-14-44]

3.4.5.2
auto-transformer starter
starter for an induction motor which uses for starting one or more reduced voltages derived from an auto-transformer

[IEV 441-14-45]

NOTE An auto-transformer is defined as follows in 3.1.2 of IEC 60076-1: “A transformer in which at least two windings have a common part."

3.4.6
rheostatic starter
starter utilizing one or several resistors for obtaining, during starting, stated motor torque characteristics and for limiting the current

[IEV 441-14-42]

NOTE A rheostatic starter generally consists of three basic parts which may be supplied either as a composite unit or as separate units to be connected at the place of utilization:

– the mechanical switching devices for supplying the stator (generally associated with an overload protective device);
– the resistor(s) inserted in the stator or rotor circuit;
– the mechanical switching devices for cutting out the resistor(s) successively.

3.4.6.1
rheostatic stator starter
rheostatic starter for a squirrel cage motor which, during the starting period, cuts out successively one or several resistors previously provided in the stator circuit

3.4.6.2
rheostatic rotor starter
rheostatic starter for an asynchronous wound-rotor motor which, during the starting period, cuts out successively one or several resistors previously provided in the rotor circuit

[IEV 441-14-43]

3.4.7
protected starter
equipment consisting of a starter, a manually-operated switching device and a short-circuit protective device, rated as a unit by the manufacturer

NOTE 1 The protected starter may or may not be enclosed.

NOTE 2 In the context of this standard, the term "manufacturer" means any person, company or organization with ultimate responsibility as follows:

– to verify compliance with the appropriate standard;
– to provide the product information according to Clause 6.

NOTE 3 The manually operated switching device and the short-circuit protective device may be just one device and may also incorporate the starter overload protection.

3.4.8
combination starter (see Figure 3)
equipment consisting of a protected starter incorporating an isolating function

NOTE Also called "combination motor controller".

3.4.9
manual starter
starter in which the force for closing the main contacts is provided exclusively by manual energy

[IEV 441-14-39]

3.4.10
electromagnetic starter
starter in which the force for closing the main contacts is provided by an electromagnet

3.4.11
motor-operated starter
starter in which the force for closing the main contacts is provided by an electric motor

3.4.12
pneumatic starter
starter in which the force for closing the main contacts is provided by using compressed air, without the use of electrical means

3.4.13
electro-pneumatic starter
starter in which the force for closing the main contacts is provided by using compressed air under the control of electrically operated valves

3.4.14
single-step starter
starter in which there is no intermediate accelerating position between the OFF and ON positions

NOTE This starter is a direct-on-line starter.

3.4.15
two-step starter
starter in which there is only one intermediate accelerating position between the OFF and ON positions

EXAMPLE A star-delta starter is a two-step starter.

3.4.16
***n*-step starter** (see Figure 4)
starter in which there are n-1 intermediate accelerating positions between the OFF and ON positions

[IEV 441-14-41]

EXAMPLE A three-step rheostatic starter has two sections of resistors used for starting.

3.4.17
phase loss sensitive thermal overload relay or release
multipole thermal overload relay or release which operates in the case of overload and also in case of loss of phase in accordance with specified requirements

3.4.18
under-current relay or release
measuring relay or release which operates automatically when the current through it is reduced below a predetermined value

3.4.19
under-voltage relay or release
measuring relay or release which operates automatically when the voltage applied to it is reduced below a predetermined value

3.4.20
starting time (of a rheostatic starter)
period of time during which the starting resistors or parts of them carry current

NOTE The starting time of a starter is shorter than the total starting time of the motor which also takes into account the last period of acceleration following the switching operation to the ON position.

3.4.21
starting time (of an auto-transformer starter)
period of time during which the auto-transformer carries current

NOTE The starting time of a starter is shorter than the total starting time of the motor which also takes into account the last period of acceleration following the switching operation to the ON position.

3.4.22
open transition (with an auto-transformer starter or star-delta starter)
circuit arrangement such that the supply to the motor is interrupted and reconnected when changing over from one step to another

NOTE The transition stage is not considered as an additional step.

3.4.23
closed transition (with an auto-transformer starter or star-delta starter)
circuit arrangement such that the supply to the motor is not interrupted (even momentarily) when changing over from one step to another

NOTE The transition stage is not considered as an additional step.

3.4.24
inching (jogging)
energizing a motor or solenoid repeatedly for short periods to obtain small movements of the driven mechanism

3.4.25
plugging
stopping or reversing a motor rapidly by reversing the motor primary connections while the motor is running

3.4.26
protected switching device
equipment (for non motor loads) consisting of a contactor or a semiconductor controller, overload protection, a manually operated switching device and a short-circuit protective device, rated as a unit by the manufacturer

NOTE 1 The protected switching device may or may not be enclosed.

NOTE 2 In the context of this standard, the term "manufacturer" means any person, company or organization with ultimate responsibility as follows:

– to verify compliance with the appropriate standard;

– to provide the product information according to Clause 6.

NOTE 3 The manually operated switching device and the short-circuit protective device may be just one device and may incorporate the overload protection as well.

3.4.27
combination switching device
equipment consisting of a protected switching device incorporating an isolating function

3.4.28
stall sensitive (electronic overload) relay
electronic overload relay which operates when the current has not decreased below a predetermined value for a specific period of time during start-up or when the relay receives the input indicating there is no rotation of the motor after a predetermined time in accordance with specified requirements

NOTE 1 Explanation of stall: rotor locked during start.

NOTE 2 With appropriate adjustment of the current and starting time settings, such relay can be used to detect overtime starts.

3.4.29
jam sensitive (electronic overload) relay
electronic overload relay which operates in the case of overload and also when the current has increased above a predetermined value for a specific period of time during operation, in accordance with specified requirements

NOTE Explanation of jam: high overload occurring after the completion of starting which causes the current to reach the locked rotor current value of the motor being controlled.

3.4.30
inhibit time
time-delay period during which the tripping function of the relay is inhibited (may be adjustable)

[A1⟩ **3.4.31**
motor management starter
starter including extended functions with communication ability

NOTE Interoperable device profiles for motor management starter are defined by IEC 61915-2.⟨A1]

3.5 Terms and definitions concerning characteristic quantities

3.5.1
transient recovery voltage
TRV
recovery voltage during the time in which it has a significant transient character

NOTE In a vacuum contactor or starter, the highest transient recovery voltage may occur on another pole than the first pole to clear.

[IEC 60947-1, 2.5.34, modified]

3.5.2
CO operation
breaking of the circuit by the SCPD resulting from closing the circuit by the equipment under test

3.5.3
O operation
breaking of the circuit by the SCPD resulting from closing the circuit on the equipment under test which is in the closed position

NOTE The SCPD is normally in the closed position prior closing the circuit; in some cases the SCPD has to close the circuit (see 9.3.4.2.2, item b).

3.6 Symbols and abbreviations

AQL	Acceptable quality level
EMC	Electromagnetic compatibility
SCPD	Short-circuit protective device
I_c	Current made and broken (Table 7)
I_e	Rated operational current (5.3.2.5)
I_{er}	Rated rotor operational current (5.3.2.7)
I_{es}	Rated stator operational current (5.3.2.6)
A1⟩ I_q	Maximum conditional short-circuit test current ⟨A1
I_{th}	Conventional free air thermal current (5.3.2.1)
I_{the}	Conventional enclosed thermal current (5.3.2.2)
I_{thr}	Conventional rotor thermal current (5.3.2.4)
I_{ths}	Conventional stator thermal current (5.3.2.3)
I_u	Rated uninterrupted current (5.3.2.8)
A1⟩ P_c	Nominal holding power of a d.c. controlled contactor
P_p	Pick-up power of a d.c. controlled contactor with separate pick-up and hold-on windings
S_h	Holding power of an a.c. controlled contactor
S_p	Pick-up power of an a.c. controlled contactor ⟨A1
T_p	Tripping time (Table 2)
U_c	Rated control circuit voltage (5.5)
A1⟩ U_d	Voltage drop of a contactor pole ⟨A1
U_e	Rated operational voltage (5.3.1.1)
U_{er}	Rated rotor operational voltage (5.3.1.1.2)
U_{es}	Rated stator operational voltage (5.3.1.1.1)
U_i	Rated insulation voltage (5.3.1.2)
U_{imp}	Rated impulse withstand voltage (5.3.1.3)
U_{ir}	Rated rotor insulation voltage (5.3.1.2.2)
U_{is}	Rated stator insulation voltage (5.3.1.2.1)
U_r	Power frequency or d.c. recovery voltage (Table 7)
U_s	Rated control supply voltage (5.5)
A1⟩ Z	Pole impedance of a contactor (5.3.7)
"r"	Minimum short-circuit test current ⟨A1

4 Classification

Subclause 5.2 gives all the data which may be used as criteria for classification.

5 Characteristics of contactors and starters

5.1 Summary of characteristics

The characteristics of a contactor or starter shall be stated in the following terms, where such terms are applicable:

- type of equipment (5.2);
- rated and limiting values for main circuits (5.3);
- utilization category (5.4);
- control circuits (5.5);
- auxiliary circuits (5.6);
- types and characteristics of relays and releases (5.7);
- co-ordination with short-circuit protective devices (5.8);
- types and characteristics of automatic change-over devices and automatic acceleration control devices (5.10);
- types and characteristics of auto-transformers for two-step auto-transformer starters (5.11);
- types and characteristics of starting resistors for rheostatic rotor starters (5.12).

5.2 Type of equipment

The following shall be stated (see also Clause 6).

5.2.1 Kind of equipment

- contactor;
- direct-on-line a.c. starter;
- star-delta starter;
- two-step auto-transformer starter;
- rheostatic rotor starter;
- combination or protected starter.

5.2.2 Number of poles

5.2.3 Kind of current (a.c. or d.c.)

5.2.4 Interrupting medium (air, oil, gas, vacuum, etc.)

5.2.5 Operating conditions of the equipment

5.2.5.1 Method of operation

For example: manual, electromagnetic, motor-operated, pneumatic, electro-pneumatic.

5.2.5.2 Method of control

For example:

- automatic (by pilot switch or sequence control);
- non-automatic (such as by hand operation or by push-buttons);

– semi-automatic (i.e. partly automatic, partly non-automatic).

5.2.5.3 Method of change-over for particular types of starters

The change-over for star-delta starters, rheostatic rotor starters or auto-transformer starters may be automatic, non-automatic or semi-automatic (see Figures 4 and 5).

5.2.5.4 Method of connecting for particular types of starters

For example: open transition starter, closed transition starter (see Figure 5).

5.3 Rated and limiting values for main circuits

The rated values established for a contactor or starter shall be stated in accordance with 5.3.1 to 5.4, and 5.8 and 5.9, but it may not be necessary to specify all the values listed.

NOTE The rated values established for a rheostatic rotor starter are stated in accordance with 5.3.1.2, 5.3.2.3, 5.3.2.4, 5.3.2.6, 5.3.2.7 and 5.3.5.5 but it is not necessary to specify all the values listed.

5.3.1 Rated voltages

A contactor or starter is defined by the following rated voltages.

5.3.1.1 Rated operational voltage (U_e)

Subclause 4.3.1.1 of IEC 60947-1 applies.

5.3.1.1.1 Rated stator operational voltage (U_{es})

For rheostatic rotor starters, a rated stator operational voltage is a value of voltage which, when combined with a rated stator operational current, determines the application of the stator circuit including its mechanical switching devices and to which are referred the making and breaking capacities, the type of duty and the starting characteristics. In no case shall the maximum rated operational voltage exceed the corresponding rated insulation voltage.

NOTE The rated stator operational voltage is expressed as the voltage between phases.

5.3.1.1.2 Rated rotor operational voltage (U_{er})

For rheostatic rotor starters, the value of rated rotor operational voltage is that of the voltage which, when combined with a rated rotor operational current, determines the application of the rotor circuit including its mechanical switching devices and to which are referred the making and breaking capacities, the type of duty and the starting characteristics.

This voltage is taken as equal to the voltage measured between slip-rings, with the motor stopped and the rotor open-circuited, when the stator is supplied at its rated voltage.

[A1) The rated insulation voltage of the switching devices inserted in the rotor circuit shall be at least 50 % the highest voltage between open slip-rings.

NOTE Electrical stresses are lower and shorter in the rotor than in the stator. (A1]

The rated rotor operational voltage is only applied for a short duration during the starting period. For this reason, it is permissible that the rated rotor operational voltage exceed the rated rotor insulation voltage by 100 %.

The maximum voltage between the different live parts (e.g. switching devices, resistors, connecting parts, etc.) of the rotor circuit of the starter will vary and account may be taken of this fact in choosing the equipment and its disposition.

5.3.1.2 Rated insulation voltage (U_i)

Subclause 4.3.1.2 of IEC 60947-1 applies.

5.3.1.2.1 Rated stator insulation voltage (U_{is})

For rheostatic rotor starters, the rated stator insulation voltage is the value of voltage which is designated for the devices inserted in the stator supply, as well as the unit they are part of, and to which dielectric tests and creepage distances are referred.

Unless otherwise stated, the rated stator insulation voltage is the value of the maximum rated stator operational voltage of the starter.

5.3.1.2.2 Rated rotor insulation voltage (U_{ir})

For rheostatic rotor starters, the rated rotor insulation voltage is the value of voltage which is designated to the devices inserted in the rotor circuit, as well as the unit they are part of (connecting links, resistors, enclosure), and to which dielectric tests and creepage distances are referred.

5.3.1.3 Rated impulse withstand voltage (U_{imp})

Subclause 4.3.1.3 of IEC 60947-1 applies.

5.3.1.4 Rated starting voltage of an auto-transformer starter

The rated starting voltage of an auto-transformer starter is the reduced voltage derived from the transformer.

Preferred values of rated starting voltage are 50 %, 65 % or 80 % of the rated operational voltage.

5.3.2 Currents or powers

A contactor or a starter is defined by the following currents.

NOTE In the case of a star-delta starter, these currents relate to the delta connection and, in the case of a two-step auto-transformer or rheostatic rotor starter, to the ON position.

5.3.2.1 Conventional free air thermal current (I_{th})

Subclause 4.3.2.1 of IEC 60947-1 applies.

5.3.2.2 Conventional enclosed thermal current (I_{the})

Subclause 4.3.2.2 of IEC 60947-1 applies.

5.3.2.3 Conventional stator thermal current (I_{ths})

The conventional stator thermal current of a starter may be either free air current I_{ths} or enclosed current I_{thes}, in line with 5.3.2.1 and 5.3.2.2.

For a rheostatic rotor starter, the stator thermal current is the maximum current it can carry on eight-hour duty (see 5.3.4.1) without the temperature rise of its several parts exceeding the limits specified in 8.2.2 when tested in accordance with 9.3.3.3.

5.3.2.4 Conventional rotor thermal current (I_{thr})

The conventional rotor thermal current of a starter may be either free air current I_{thr} or enclosed current I_{ther}, in line with 5.3.2.1 and 5.3.2.2.

For rheostatic rotor starters, the rotor thermal current is the maximum current that those parts of the starter through which the rotor current flows in the ON position, precisely after cutting out resistors, can carry on eight-hour duty (see 5.3.4.1) without their temperature rise exceeding the limits specified in 8.2.2 when tested in accordance with 9.3.3.3.

NOTE 1 For those elements (switching devices, connecting links, resistors) through which a current of practically no value flows in the ON position, it should be verified that, for the rated duties (see 5.3.4) stated by the manufacturer, the value of integral

$$\int_0^t i^2 \, dt$$

does not lead to temperature rises higher than those appearing in 8.2.2.

NOTE 2 When resistors are built-in into the starter, the temperature rise should be taken into account.

5.3.2.5 Rated operational currents (I_e) or rated operational powers

A rated operational current of a contactor or a starter is stated by the manufacturer and takes into account the rated operational voltage (see 5.3.1.1), the conventional free air or enclosed thermal current, the rated current of the overload relay, the rated frequency (see 5.3.3), the rated duty (see 5.3.4), the utilization category (see 5.4) and the type of protective enclosure, if any.

In the case of equipment for direct switching of individual motors, the indication of a rated operational current may be replaced or supplemented by an indication of the maximum rated power output, at the rated operational voltage considered, of the motor for which the equipment is intended. The manufacturer shall be prepared to state the relationship assumed between the current and the power.

NOTE Annex G gives values concerning the relationship between rated operational currents and rated operational powers.

For starters, the rated operational current (I_e) is the current in the ON position of the starter.

5.3.2.6 Rated stator operational current (I_{es}) or rated stator operational power

For rheostatic rotor starters, a rated stator operational current is stated by the manufacturer and takes into account the rated current of the overload relay installed in this starter, the rated stator operational voltage (see 5.3.1.1.1), the conventional free air or enclosed thermal current, the rated frequency (see 5.3.3), the rated duty (see 5.3.4), the starting characteristics (see 5.3.5.5) and the type of protective enclosure.

The indication of a rated stator operational current may be replaced by the indication of the maximum rated power output, at the rated stator operational voltage considered, of the motor for which the stator elements of the starter are intended. The manufacturer shall be prepared to state the relationship assumed between the motor power and the stator current.

5.3.2.7 Rated rotor operational current (I_{er})

For rheostatic rotor starters, a rated rotor operational current is stated by the manufacturer and takes into account the rated rotor operational voltage (see 5.3.1.1.2), the conventional free air or enclosed rotor thermal current, the rated frequency (see 5.3.3), the rated duty (see 5.3.4), the starting characteristics (see 5.3.5.5) and the type of protective enclosure.

It is taken as equal to the current flowing in the connections to the rotor when the latter is short-circuited and the motor is running at full load and the stator is supplied at its rated voltage and rated frequency.

When the rotor part of a rheostatic rotor starter is rated separately, the indication of a rated rotor operational current may be supplemented by the maximum rated power output, for motors having the rated rotor operational voltage considered, of the motor for which that part of the starter (switching devices, connecting links, relays, resistors) is intended. This power varies in particular with the breakaway torque foreseen and consequently takes into account the starting characteristics (see 5.3.5.5).

5.3.2.8 Rated uninterrupted current (I_u)

Subclause 4.3.2.4 of IEC 60947-1 applies.

5.3.3 Rated frequency

Subclause 4.3.3 of IEC 60947-1 applies.

5.3.4 Rated duties

Subclause 4.3.4 of IEC 60947-1 applies.

5.3.4.1 Eight-hour duty (continuous duty)

Subclause 4.3.4.1 of IEC 60947-1 applies with the following addition.

For a star-delta starter, a two-step auto-transformer starter or a rheostatic rotor-starter, the continuous duty is the duty in which the starter is in the ON position and the main contacts of the switching devices which constitute it, which are closed in this position, remain closed while each of them carries a steady current long enough for the starter to reach thermal equilibrium, but not for more than 8 h without interruption.

5.3.4.2 Uninterrupted duty

Subclause 4.3.4.2 of IEC 60947-1 applies with the following addition.

For a star-delta starter, a two-step auto-transformer starter or a rheostatic rotor starter, the uninterrupted duty is the duty in which the starter is in the ON position and the main contacts of the switching devices which constitute it, which are closed in this position, remain closed without interruption while each of them carries a steady current for periods of more than 8 h (weeks, months or even years).

5.3.4.3 Intermittent periodic duty or intermittent duty

Subclause 4.3.4.3 of IEC 60947-1 applies with the following addition.

For a reduced voltage starter, the intermittent duty is the duty in which the starter is in the ON position and the main contacts of the switching devices which constitute it remain closed for periods bearing a definite relation to the no-load periods, both periods being too short to allow the starter to reach thermal equilibrium.

Preferred classes of intermittent duty are:

– for contactors: 1, 3, 12, 30, 120, 300 and 1 200 (operating cycles per hour);
– for starters: 1, 3, 12 and 30 (operating cycles per hour).

It is recalled that an operating cycle is a complete working cycle comprising one closing operation and one opening operation.

For starters, an operating cycle comprises starting, running to full speed and switching off the supply from the motor.

NOTE In the case of starters for intermittent duty, the difference between the thermal time-constant of the overload relay and that of the motor may render a thermal relay unsuited for overload protection. It is recommended that, for installations intended for intermittent duty, the question of overload protection be subject to agreement between manufacturer and user.

5.3.4.4 Temporary duty

Subclause 4.3.4.4 of IEC 60947-1 applies.

5.3.4.5 Periodic duty

Subclause 4.3.4.5 of IEC 60947-1 applies.

5.3.5 Normal load and overload characteristics

Subclause 4.3.5 of IEC 60947-1 applies with the following additions.

5.3.5.1 Ability to withstand motor switching overload currents

Requirements to meet these conditions are given for contactors in 8.2.4.4.

5.3.5.2 Rated making capacity

Requirements for the various utilization categories (see 5.4) are given in 8.2.4.1. The rated making and breaking capacities are only valid when the contactor or the starter is operated in accordance with the requirements of 8.2.1.1 and 8.2.1.2.

5.3.5.3 Rated breaking capacity

Requirements for the various utilization categories (see 5.4) are given in 8.2.4.1. The rated making and breaking capacities are only valid when the contactor or the starter is operated in accordance with the requirements of 8.2.1.1 and 8.2.1.2.

5.3.5.4 Conventional operational performance

This performance is specified as a series of making and breaking operations in 8.2.4.2.

5.3.5.5 Starting and stopping characteristics of starters (see Figure 6)

Typical service conditions for starters are:

a) one direction of rotation with the motor being switched off during running in normal service conditions (utilization categories AC-2 and AC-3);
b) two directions of rotation, but the running in the second direction is realized after the starter has been switched off and the motor has completely stopped (utilization categories AC-2 and AC-3);
c) one direction of rotation, or two directions of rotation as in item b), but with the possibility of infrequent inching (jogging). For this service condition, direct-on-line starters are usually employed (utilization category AC-3);
d) one direction of rotation with frequent inching (jogging). Usually direct-on-line starters (utilization category AC-4) are used for this duty;
e) one or two directions of rotation, but with the possibility of infrequent plugging for stopping the motor, plugging being associated, if so provided, with rotor resistor braking (reversing starter with braking). Usually a rheostatic rotor starter is used for this duty condition (utilization category AC-2);
f) two directions of rotation, but with the possibility of reversing the supply connections to the motor while it is running in the first direction (plugging), in order to obtain its rotation in the other direction, with switching off the motor running in normal service conditions. Usually a direct-on-line reversing starter is used for this duty condition (utilization category AC-4).

Unless otherwise stated, starters are designed on the basis of the starting characteristics of the motors compatible with the making capacities of Table 7. These making capacities cover both the transient and steady-state starting currents of the great majority of standard motors. However, the starting currents for some large motors may attain peak values corresponding to power factors considerably lower than those specified for the test circuit in Table 7. In these cases, the operational current of the contactor or starter should be decreased to a value lower than its rated value such that the making capacity of the contactor or starter is not exceeded.

5.3.5.5.1 Starting characteristics of rheostatic rotor starters

A distinction shall be drawn between the currents and voltages in the stator and rotor circuits of slip-ring motors. However, the changes of the current values in stator and rotor circuits, caused by the various steps of the starting process, are nearly proportional under normal operating conditions.

The following definitions deal mainly with the characteristics of the rotor circuit:

U_{er} is the rated rotor operational voltage;

I_{er} is the rated rotor operational current;

Z_r is the characteristic impedance of the rotor of an a.c. slip-ring induction motor;

where

$$Z_r = \frac{U_{er}}{\sqrt{3} \times I_{er}};$$

I_1 is the current in the rotor circuit immediately before shorting out a resistor section;

I_2 is the current in the rotor circuit immediately after shorting out a resistor section;

I_m = 1/2 (I_1 + I_2);

T_e is the rated motor operational torque;

t_s is the starting time;

k is the severity of start = $\frac{I_m}{I_{er}}$.

It is recognized that many rheostatic rotor starter applications have very specific starting requirements which may result not only in a different number of starting steps and different values of I_1 and I_2, but also in the values of I_1 and I_2 being different for individual resistor sections. Therefore, no attempt has been made to lay down standard parameters, but the following factors should be taken into consideration:

– for most applications, between two and six starting steps are adequate depending upon load torque, inertia and the severity of start required;

– the resistor sections should be designed to have adequate thermal ratings bearing in mind the starting time of the drive, which will be dependent upon load torque and load inertia.

5.3.5.5.2 Standard conditions for making and breaking corresponding to the starting characteristics for rheostatic rotor starters

These conditions are given in Table 7 and apply to starting with high torque. (For the designation of the mechanical switching devices, see Figure 4.)

A1 *Text deleted* A1

The conditions for making and breaking as given in Table 7 for AC-2 utilization category are considered as standard.

The starter circuit shall be designed to open all rotor resistor switching devices before or approximately simultaneously with the opening of the stator switching device. Otherwise, the stator switching device shall comply with AC-3 requirements.

5.3.5.5.3 Starting characteristics for two-step auto-transformer starters

Unless otherwise stated, the auto-transformer starters and specifically the auto-transformers are designed on the condition that the starting time for all classes of duty (see 5.3.4) shall not exceed 15 s. The number of starting cycles per hour assumes equal periods between starts except that, in the event of two operating cycles being made in rapid succession, the starter and the auto-transformer shall be allowed to cool to ambient air temperature before a further start is made.

When a starting time in excess of 15 s is required, this shall be the subject of agreement between manufacturer and user.

5.3.6 Rated conditional short-circuit current

Subclause 4.3.6.4 of IEC 60947-1 applies.

A1 5.3.7 Pole impedance of a contactor (*Z*)

The pole impedance may be stated by the manufacturer and is determined by measuring the voltage drop resulting of the current flowing through the pole. A1

5.4 Utilization category

5.4.1 General

Subclause 4.4 of IEC 60947-1 applies with the following additions.

For contactors and starters, the utilization categories as given in Table 1 are considered standard. Any other type of utilization shall be based on agreement between manufacturer and user, but information given in the manufacturer's catalogue or tender may constitute such an agreement.

Each utilization category is characterized by the values of the currents, voltages, power-factors or time-constants and other data of Table 7 and Table 10, and by the test conditions specified in this standard.

For contactors or starters defined by their utilization category, it is therefore unnecessary to specify separately the rated making and breaking capacities as these values depend directly on the utilization category as shown in Table 7.

The voltage for all utilization categories is the rated operational voltage of a contactor or a starter other than a rheostatic rotor starter, and the rated stator operational voltage for a rheostatic rotor starter.

All direct-on-line starters belong to one or more of the following utilization categories: AC-3, AC-4, AC-7b, AC-8a and AC-8b.

All star-delta and two-step auto-transformer starters belong to utilization category AC-3.

Rheostatic rotor starters belong to utilization category AC-2.

5.4.2 Assignment of utilization categories based on the results of tests

a) A contactor or starter which has been tested for one utilization category or at any combination of parameters (such as highest operational voltage and current, etc.) can be assigned other utilization categories without testing, provided that the test currents, voltages, power-factors or time-constants, number of operating cycles, on and off times given in Table 7 and Table 10, and the test circuit for the assigned utilization categories are not more severe than those at which the contactor or starter has been tested and the temperature rise has been verified at a current not less than the highest assigned rated operational current in continuous duty.

For example, when tested for utilization category AC-4, a contactor may be assigned utilization category AC-3 provided I_e for AC-3 is not higher than 1,2 I_e for AC-4 at the same rated operational voltage.

b) DC-3 and DC-5 contactors are assumed to be capable of opening and closing loads other than those on which they have been tested provided that:
   - the voltage and current do not exceed the specified values of U_e and I_e;
   - the energy J stored in the actual load is equal to or less than the energy J_c stored in the load with which they were tested.

The values of the energy stored in the test circuit are as follows:

Utilization category	Stored energy J_c
DC-3	0,005 25 × U_e × I_e
DC-5	0,031 5 × U_e × I_e

The values of the constants 0,005 25 and 0,031 5 are derived from:

$$J_c = 1/2\ LI^2$$

where the time-constant has been replaced by:

$2,5 \times 10^{-3}$ s (DC-3) and:

15×10^{-3} s (DC-5)

and where U = 1,05 U_e, I = 4 I_e and L is the inductance of the test circuit.

(See Table 7 of this standard.)

Table 1 – Utilization categories

Kind of current	Utilization categories	Additional category designation	Typical applications
AC	AC-1	General use	Non-inductive or slightly inductive loads, resistance furnaces
	AC-2		Slip-ring motors: starting, switching off
	AC-3		Squirrel-cage motors: starting, switching off motors during running[a]
	AC-4		Squirrel-cage motors: starting, plugging, inching
	AC-5a	Ballast	Switching of electric discharge lamp controls
	AC-5b	Incandescent	Switching of incandescent lamps
	AC-6a		Switching of transformers
	AC-6b		Switching of capacitor banks
	AC-7a[c]		Slightly inductive loads in household appliances and similar applications
	AC-7b[c]		Motor-loads for household applications
	AC-8a		Hermetic refrigerant compressor motor[b] control with manual resetting of overload releases
	AC-8b		Hermetic refrigerant compressor motor[b] control with automatic resetting of overload releases
DC	DC-1		Non-inductive or slightly inductive loads, resistance furnaces
	DC-3		Shunt-motors: starting, plugging, inching
			Dynamic breaking of d.c. motors
	DC-5		Series-motors: starting, plugging, inching
			Dynamic breaking of d.c. motors
	DC-6	Incandescent	Switching of incandescent lamps

a AC-3 category may be used for occasional inching (jogging) or plugging for limited time periods such as machine set-up; during such limited time periods, the number of such operations should not exceed five per minute or more than ten in a 10-min period.

b A hermetic refrigerant compressor motor is a combination consisting of a compressor and a motor, both of which are enclosed in the same housing, with no external shaft or shaft seals, the motor operating in the refrigerant.

c For AC-7a and AC-7b, see IEC 61095.

5.5 Control circuits

A1⟩ Subclause 4.5 of IEC 60947-1:2007 applies. ⟨A1

5.6 Auxiliary circuits

Subclause 4.6 of IEC 60947-1 applies.

Digital inputs and/or digital outputs contained in contactors and motor-starters, and intended to be compatible with PLCs shall fulfil the requirements of Annex S of IEC 60947-1.

5.7 Characteristics of relays and releases (overload relays)

NOTE In the remainder of this standard, the words "overload relay" will be taken to apply equally to an overload relay or an overload release, as appropriate.

5.7.1 Summary of characteristics

The characteristics of relays and releases shall be stated in the following terms, whenever applicable:

- types of relay or release (see 5.7.2);
- characteristic values (see 5.7.3);
- designation and current settings of overload relays (see 5.7.4);
- time-current characteristics of overload relays (see 5.7.5);
- influence of ambient air temperature (see 5.7.6).

5.7.2 Types of relay or release

a) Release with shunt coil (shunt trip).

b) Under-voltage and under-current opening relay or release.

c) Overload time-delay relay the time-lag of which is:

   1) substantially independent of previous load;
   2) dependent on previous load;
   3) dependent on previous load and also sensitive to phase loss.

d) Instantaneous over-current relay or release (e.g. jam sensitive).

e) Other relays or releases (e.g. control relay associated with devices for the thermal protection of the motor).

f) Stall relay or release.

5.7.3 Characteristic values

a) Release with shunt coil, under-voltage (under-current), over-voltage (instantaneous over current), current or voltage imbalance and phase reversal opening relay or release:

   - rated voltage (current);
   - rated frequency;
   - operating voltage (current);
   - operating time (when applicable);
   - inhibit time (when applicable).

b) Overload relay:

   - designation and current settings (see 5.7.4);
   - rated frequency, when necessary (for example in the case of a current transformer operated overload relay);
   - time-current characteristics (or range of characteristics), when necessary;
   - trip class according to classification in Table 2, or the value of the maximum tripping time, in seconds, under the conditions specified in 8.2.1.5.1, Table 3, column D, when this time exceeds 40 s;
   - nature of the relay: thermal, magnetic, electronic or electronic without thermal memory (electronic relay not fulfilling the thermal memory test verification according 8.2.1.5.1.2 shall be marked ~~Thm~~);
   - nature of the reset: manual and/or automatic; in case of combination manual or automatic-reset, the set position shall be indicated;
   - tripping time of overload relays class 10A if longer than 2 min at –5 °C or below (see 8.2.1.5.1.1, item c).

[A1⟩ c) Release with residual current sensing relay:
- rated current;
- operating current;
- operating time or time-current characteristic according to Table T.1 of IEC 60947-1:2007, Amendment 1;
- inhibit time (when applicable);
- type designation (see Annex T of IEC 60947-1: 2007, Amendment 1). ⟨A1]

Table 2 – Trip classes of overload relays

Trip class	Tripping time T_p under the conditions specified in 8.2.1.5.1, Table 3, column D s	Tripping time T_p under the conditions specified in 8.2.1.5.1, Table 3, column D for tighter tolerances (tolerance band E) [a] s
2	–	$T_p \leq 2$
3	–	$2 < T_p \leq 3$
5	$0,5 < T_p \leq 5$	$3 < T_p \leq 5$
10 A	$2 < T_p \leq 10$	–
10	$4 < T_p \leq 10$	$5 < T_p \leq 10$
20	$6 < T_p \leq 20$	$10 < T_p \leq 20$
30	$9 < T_p \leq 30$	$20 < T_p \leq 30$
40	–	$30 < T_p \leq 40$

[a] The manufacturer shall add the letter E to trip classes to indicate compliance with the band E.

NOTE 1 Depending on the nature of the relay, the tripping conditions are given in 8.2.1.5.

NOTE 2 In the case of a rheostatic rotor starter, the overload relay is commonly inserted in the stator circuit. As a result, it cannot efficiently protect the rotor circuit and more particularly the resistors (generally more easily damageable than the rotor itself or the switching devices in case of a faulty start); protection of the rotor circuit should be the subject of a specific agreement between manufacturer and user (see, inter alia, 8.2.1.1.3).

NOTE 3 In the case of a two-step auto-transformer starter, the starting auto-transformer is normally designed for use during the starting period only: as a result, it cannot be efficiently protected by the overload relay in the event of faulty starting. Protection of the auto-transformer should be the subject of specific agreement between manufacturer and user (see 8.2.1.1.4).

NOTE 4 The lower limiting values of T_p are selected to allow for differing heater characteristics and manufacturing tolerances.

5.7.4 Designation and current settings of overload relays

Overload relays are designated by their current setting (or the upper and lower limits of the current setting range, if adjustable) and their trip class.

The current setting (or current setting range) shall be marked on the relays.

However, if the current setting is influenced by the conditions of use or other factors which cannot readily be marked on the relay, then the relay or any interchangeable parts thereof (e.g. heaters, operating coils or current transformers) shall carry a number or an identifying mark which makes it possible to obtain the relevant information from the manufacturer or his catalogue or, preferably, from data furnished with the starter.

In the case of current transformer operated overload relays, the marking may refer either to the primary current of the current transformer through which they are supplied or to the current setting of the overload relays. In either case, the ratio of the current transformer shall be stated.

5.7.5 Time-current characteristics of overload relays

Typical time-current characteristics shall be given in the form of curves supplied by the manufacturer. These curves shall indicate how the tripping time, starting from the cold state (see 5.7.6), varies with the current up to a value of at least eight times the full-load current of the motor with which it is intended that the relay be used. The manufacturer shall be prepared to indicate, by suitable means, the general tolerances applicable to these curves and the conductor cross-sections used for establishing these curves (see 9.3.3.2.2, item c)).

NOTE It is recommended that the current be plotted as abscissa and the time as ordinates, using logarithmic scales. It is recommended that the current be plotted as multiples of the setting current and the time in seconds on the standard graph sheet detailed in 5.6.1 and Figure 1 of IEC 60269-1 and in Figure 104, Figure 504 and Figure 505 of IEC 60269-2.

5.7.6 Influence of ambient air temperature

The time-current characteristics (see 5.7.5) refer to a stated value of ambient air temperature, and are based on no previous loading of the overload relay (i.e from an initial cold state). This value of the ambient air temperature shall be clearly given on the time curves; the preferred values are +20 °C or +40 °C.

The overload relays shall be able to operate within the ambient air temperature range of –5 °C to +40 °C, and the manufacturer shall be prepared to state the effect of variation in ambient air temperature on the characteristics of overload relays.

5.8 Co-ordination with short-circuit protective devices

The co-ordination of contactors and starters is characterized by the type, ratings and characteristics of the short-circuit protective devices (SCPD) that provide protection of the contactor and starter against short-circuit currents. Requirements are given in 8.2.5.1 and 8.2.5.2 of this standard, and in 4.8 of IEC 60947-1.

5.9 Void

5.10 Types and characteristics of automatic change-over devices and automatic acceleration control devices

5.10.1 Types

a) Time-delay devices, e.g. time-delay contactor relays (see IEC 60947-5-1) applicable to control-circuit devices or specified-time all-or-nothing relays (see IEC 61810-1).
b) Undercurrent devices (undercurrent relays).
c) Other devices for automatic acceleration control:
   - devices dependent on voltage;
   - devices dependent on power;
   - devices dependent on speed.

5.10.2 Characteristics

a) The characteristics of time-delay devices are:
   - the rated time-delay or its range, if adjustable;
   - for time-delay devices fitted with a coil, the rated voltage, when it differs from the starter line voltage.
b) The characteristics of the undercurrent devices are:
   - the rated current (thermal current and/or rated short-time withstand current, according to the indications given by the manufacturer);
   - the current setting or its range, if adjustable.
c) The characteristics of the other devices shall be determined by agreement between manufacturer and user.

5.11 Types and characteristics of auto-transformers for two-step auto-transformer starters

Account being taken of the starting characteristics (see 5.3.5.5.3), starting auto-transformers shall be characterized by:

- the rated voltage of the auto-transformer;
- the number of taps available for adjusting the starting torque and current;
- the starting voltage, i.e. the voltage at the tapping terminals, as a percentage of the rated voltage of the auto-transformer;
- the current they can carry for a specified duration;
- the rated duty (see 5.3.4);
- the method of cooling { air-cooling; oil-cooling.

The auto-transformer can be:

- either built-in into the starter, in which case the resulting temperature rise has to be taken into account in determining the ratings of the starter;
- or provided separately, in which case the nature and dimensions of the connecting links have to be specified by agreement between the manufacturer of the transformer and the manufacturer of the starter.

5.12 Types and characteristics of starting resistors for rheostatic rotor starters

Account being taken of the starting characteristics (see 5.3.5.5.1), the starting resistors shall be characterized by:

- the rated rotor insulation voltage (U_{ir});
- their resistance value;
- the mean thermal current, defined by the value of steady current they can carry for a specified duration;
- the rated duty (see 5.3.4);
- the method of cooling { free air; forced air; oil-immersion.

They can be:

- either built-in into the starter, in which case the resulting temperature rise has to be limited in order not to cause any damage to the other parts of the starter;
- or provided separately, in which case the nature and dimensions of the connecting links have to be specified by agreement between the manufacturer of the resistors and the manufacturer of the starter.

6 Product information

6.1 Nature of information

The following information shall be given by the manufacturer.

6.1.1 Identification

a) manufacturer's name or trade mark;

b) type designation or serial number;

c) number of this standard, if the manufacturer claims compliance.

6.1.2 Characteristics, basic rated values and utilization

Characteristics:

d) rated operational voltages (see 5.3.1.1);

A1⟩ aa) polarity of terminals, if applicable; ⟨A1

e) utilization category and rated operational currents (or rated powers), at the rated operational voltages of the equipment (see 5.3.2.5 and 5.4);

f) either the value of the rated frequency 50/60 Hz or the symbol ⎓, or other rated frequencies e.g. 16 2/3 Hz, 400 Hz;

g) rated duty with the indication of the class of intermittent duty, if any (see 5.3.4), and the off time as specified in footnote d) of Table 10, if necessary.

Associated values:

h) rated making and breaking capacities. These indications may be replaced, where applicable, by the indication of the utilization category (see Table 7).

A1⟩ NOTE 1 Other information such as the pole impedance could be given e.g. in the product literature. ⟨A1

Safety and installation:

i) rated insulation voltage (see 5.3.1.2);

j) rated impulse withstand voltage (see 5.3.1.3);

k) IP code, in case of an enclosed equipment (see 8.1.11);

l) pollution degree (see Clause 7);

m) – for contactor or starter: rated conditional short-circuit current (see 5.3.6) and type of co-ordination (see 8.2.5.1) and type, current rating and characteristics of the associated SCPD;

– for combination starter, combination switching device, protected starter or protected switching device: rated conditional short-circuit current (see 5.3.6) and type of co-ordination (see 8.2.5.1);

n) void.

Control circuits:

The following information concerning control circuits shall be placed either on the coil or on the equipment:

o) rated control circuit voltage (U_c), nature of current and rated frequency;

A1⟩ NOTE 2 Other information such as the holding or pick-up power could be given e.g. in the product literature. ⟨A1

p) if necessary, nature of current, rated frequency and rated control supply voltage (U_s).

Air supply systems for starters or contactors operated by compressed air:

q) rated supply pressure of the compressed air and limits of variation of this pressure, if they are different from those specified in 8.2.1.2.

Auxiliary circuits:

r) ratings of auxiliary circuits (see 5.6).

Overload relays and releases:

s1) characteristics according to 5.7.2, 5.7.5 and 5.7.6;

s2) characteristics according to 5.7.3 and 5.7.4.

Additional information for certain types of contactor and starter:

Rheostatic rotor starters:

t) circuit diagram;

u) severity of start (see 5.3.5.5.1);

v) starting time (see 5.3.5.5.1).

Auto-transformer starters:

w) rated starting voltage(s), i.e. voltage(s) at the tapping terminals.

[A1) NOTE 3 (A1] This value may be expressed as a percentage of the rated operational voltage of the starter.

Vacuum contactors and starters:

x) maximum permissible altitude of the site of installation, if less than 2 000 m.

EMC:

y) environment A or B: see 7.3.1 of IEC 60947-1;

z) special requirements, if applicable, for example shielded or twisted conductors.

[A1) NOTE 4 (A1] Unshielded or untwisted conductors are considered as normal installation conditions.

6.2 Marking

Subclause 5.2 of IEC 60947-1 applies to contactors, starters and overload relays with the following additions.

Data under items d) to x) in 6.1.2 shall be included on the nameplate or on the equipment or in the manufacturer's published literature.

Data under [A1) items c) in 6.1.1, aa), k) and s2) in 6.1.2 (A1] shall be marked on the equipment; time-current characteristics (or range of characteristics) may be provided in the manufacturer's published literature.

In the case of electronically controlled electromagnets, information other than that given in o) and p) of 6.1.2 may also be necessary; see also 5.5 [A1) and Annex U of IEC 60947-1:2007, Amendment 1.(A1]

NOTE In the USA and Canada, on multiple equipment, the additional category designation given in Table 1 is marked on the product.

6.3 Instructions for installation, operation and maintenance

Subclause 5.3 of IEC 60947-1 applies with the following addition.

Information shall be provided by the manufacturer to advise the user on the measures to be taken with regard to the equipment in the event of a short-circuit and the measures to be taken with regard to the equipment, if any, concerning EMC.

In the case of protected starters, the manufacturer shall also provide the necessary mounting and wiring instructions.

The manufacturer of a starter incorporating an automatic reset overload relay capable of being connected to enable automatic restarting, shall provide, with the starter, that information necessary to alert the user to the possibility of automatic restarting.

7 Normal service, mounting and transport conditions

Clause 6 of IEC 60947-1 applies with the following addition.

Unless otherwise stated by the manufacturer, a contactor or a starter is for use in pollution degree 3 environmental conditions, as defined in 6.1.3.2 of IEC 60947-1. However, other pollution degrees may be considered to apply, depending upon the micro-environment.

8 Constructional and performance requirements

8.1 Constructional requirements

8.1.1 General

Subclause 7.1.1 of IEC 60947-1 applies.

8.1.2 Materials

8.1.2.1 General materials requirements

Subclause 7.1.2.1 of IEC 60947-1 applies

8.1.2.2 Glow wire testing

Subclause 7.1.2.2 of IEC 60947-1 applies with the following addition.

When tests on the equipment or on sections taken from the equipment are used, parts of insulating materials necessary to retain current-carrying parts in position shall conform to the glow-wire tests of 8.2.1.1.1 of IEC 60947-1 at a test temperature of 850 °C.

8.1.2.3 Test based on flammability category

Subclause 7.1.2.3 of IEC 60947-1 applies.

8.1.3 Current-carrying parts and their connections

Subclause 7.1.3 of IEC 60947-1 applies.

8.1.4 Clearances and creepage distances

Subclause 7.1.4 of IEC 60947-1 applies.

8.1.5 Actuator

Subclause 7.1.5 of IEC 60947-1 applies with the following addition.

Means for padlocking the operating handle of the manually operated switching device of a combination starter may be provided.

8.1.5.1 Insulation

Subclause 7.1.5.1 of IEC 60947-1 applies.

8.1.5.2 Direction of movement

Subclause 7.1.5.2 of IEC 60947-1 applies.

8.1.5.3 Mounting

Actuators mounted on removable panels or opening doors shall be so designed that, when the panels are replaced or the doors closed, the actuator will engage correctly with the associated mechanism.

8.1.6 Indication of the contact position

8.1.6.1 Indicating means

Subclause 7.1.6.1 of IEC 60947-1 applies to manually operated starters.

8.1.6.2 Indication by the actuator

Subclause 7.1.6.2 of IEC 60947-1 applies.

8.1.7 Additional requirements for equipment suitable for isolation

Subclause 7.1.7 of IEC 60947-1 applies.

8.1.8 Terminals

Subclause 7.1.8 of IEC 60947-1 applies with, however, the following additional requirements.

8.1.8.1 Terminal identification and marking

Subclause 7.1.8.4 of IEC 60947-1 applies with additional requirements as given in Annex A.

8.1.9 Additional requirements for equipment provided with a neutral pole

Subclause 7.1.9 of IEC 60947-1 applies.

8.1.10 Provisions for protective earthing

Subclause 7.1.10 of IEC 60947-1 applies.

8.1.11 Enclosures for equipment

8.1.11.1 Design

Subclause 7.1.11.1 of IEC 60947-1 applies with the following additions.

Starting resistors mounted within an enclosure shall be so located or guarded that issuing heat is not detrimental to other apparatus and materials within the enclosure.

For the specific case of combination starters, the cover or door shall be interlocked so that it cannot be opened without the manually operated switching device being in the open position.

However, provision may be made to open the door or cover with the manually operated switching device in the ON position by the use of a tool.

8.1.11.2 Insulation

Subclause 7.1.11.2 of IEC 60947-1 applies.

8.1.12 Degrees of protection of enclosed equipment

Subclause 7.1.12 of IEC 60947-1 applies.

8.1.13 Conduit pull-out, torque and bending with metallic conduits

Subclause 7.1.13 of IEC 60947-1 applies.

8.2 Performance requirements

8.2.1 Operating conditions

8.2.1.1 General

Subclause 7.2.1.1 of IEC 60947-1 applies with the following additions.

8.2.1.1.1 General conditions A

Starters shall be so constructed that they:

a) are trip free;
b) can be caused to open their contacts by the means provided when running and at any time during the starting sequence;
c) will not function in other than the correct starting sequence.

8.2.1.1.2 General conditions B

Starters employing contactors shall not trip due to the shocks caused by operation of the contactors when tested according to 9.3.3.1, after the starter has carried its rated full load current at the reference ambient temperature (i.e. +20 °C) and has reached thermal equilibrium at both minimum and maximum settings of the overload relay, if adjustable.

8.2.1.1.3 General conditions C

For rheostatic starters, the overload relay shall be connected in the stator circuit. Special arrangements may be made to protect the rotor contactors and resistors against overheating, if requested by the user.

8.2.1.1.4 General conditions D

When starters are used in conditions in which the overheating of the starting resistors or transformers would represent an exceptional hazard, it is recommended that a suitable device be fitted to switch off the starter automatically before a dangerous temperature is reached.

8.2.1.1.5 General conditions E

The moving contacts of multipole equipment intended to make and break together shall be so coupled that all poles make and break substantially together, whether operated manually or automatically.

8.2.1.2 Limits of operation of contactors and power-operated starters

[A1⟩ Subclause 7.2.1.2 of IEC 60947-1:2007 applies with following additions:

For latched contactors, the device shall drop out and open fully when a de-latching voltage between 85 % and 110 % of the rated de-latching voltage is applied. ⟨A1]

8.2.1.3 Limits of operation of under-voltage relays and releases

Subclause 7.2.1.3 of IEC 60947-1 applies with the following addition: tests are specified in 9.3.3.2.2 of this standard.

8.2.1.4 Limits of operation of shunt-coil operated releases (shunt trip)

Subclause 7.2.1.4 of IEC 60947-1 applies with the following addition: tests are specified in 9.3.3.2.2 of this standard.

8.2.1.5 Limits of operation of current sensing relays and releases

8.2.1.5.1 Limits of operation of time-delay overload relays when all poles are energized

8.2.1.5.1.1 General tripping requirements of overload relays

NOTE 1 The thermal protection of motors in the presence of harmonics in the supply voltage is under consideration.

The relays shall comply with the requirements of Table 3 when tested as follows:

a) with the overload relay or starter in its enclosure, if normally fitted, and at *A* times the current setting, tripping shall not occur in less than 2 h starting from the cold state, at the value of reference ambient air temperature stated in Table 3. However, when the overload relay terminals have reached thermal equilibrium at the test current in less than 2 h, the test duration can be the time needed to reach such thermal equilibrium;

b) when the current is subsequently raised to *B* times the current setting, tripping shall occur in less than 2 h;

c) for class 2, 3, 5 and 10A overload relays energized at *C* times the current setting, tripping shall occur in less than 2 min starting from thermal equilibrium, at the current setting, in accordance with 9.3.3 of IEC 60034-1; for class 10 A overload relays, for ambient air temperature –5 °C or below, the manufacturer may declare a longer tripping time but not longer than 2 times the values required for 20 °C;

NOTE 2 Subclause 9.3.3 of IEC 60034-1 states: “Polyphase motors having rated outputs not exceeding 315 kW and rated voltages not exceeding 1 kV shall be capable of withstanding a current equal to 1,5 times the rated current for not less than 2 min”.

d) for class 10, 20, 30 and 40 overload relays energized at *C* times the current setting, tripping shall occur in less than 4, 8, 12 or 16 min respectively, starting from thermal equilibrium, at the current setting;

e) at *D* times the current setting, tripping shall occur within the limits given in Table 2 for the appropriate trip class and tolerance band, starting from the cold state.

In the case of overload relays having a current setting range, the limits of operation shall apply when the relay is carrying the current associated with the maximum setting and also when the relay is carrying the current associated with the minimum setting.

For non-compensated overload relays, the current multiple/ambient temperature characteristic shall not be greater than 1,2 %/K.

NOTE 3 1,2 %/K is the derating characteristic of PVC-insulated conductors.

An overload relay is regarded as compensated if it complies with the relevant requirements of Table 3 at +20 °C and is within the limits shown in Table 3 at other temperatures.

Table 3 – Limits of operation of time-delay overload relays when energized on all poles

Type of overload relay	Multiples of current setting				Ambient air temperature values
	A	B	C	D	
Thermal type not compensated for ambient air temperature variations	1,0	1,2[b]	1,5	7,2	+40 °C
Thermal type compensated for ambient air temperature variations	(A1) c (A1)	(A1) c (A1)	–	–	less than - 5 °C (A1) d (A1)
	1,05	1,3	1,5	–	- 5 °C
	1,05	1,2[b]	1,5	7,2	+20 °C
	1,0	1,2[b]	1,5	–	+40 °C
	d	d	–	–	more than +40 °C (A1) d (A1)
Electronic type (A1) a (A1)	1,05	1,2[b]	1,5	7,2	0 °C, +20 °C and +40 °C

a (A1) This test shall only be done at 20 °C for A, B and D multiples of current setting. (A1)

b If specified by the manufacturer, the tripping current could be different from 120 % but shall not exceed 125 %. In this case the test current value shall be equal to this tripping current value. In this case, the tripping current value shall be marked on the device.

(A1) *Text deleted* (A1)

(A1) c (A1) Multiples of current setting should be declared by the manufacturer.

(A1) d (A1) See 9.3.3.2.2 for tests outside the -5 °C +40 °C range.

8.2.1.5.1.2 Thermal memory test verification

Unless the manufacturer has specified that the device does not contain thermal memory, electronic overload relays shall fulfil the following requirements (see Figure 8):

– apply a current equal to I_e until the device has reached the thermal equilibrium;

– interrupt the current for a duration of $2 \times T_p$ (see Table 2) with a relative tolerance of ±10 % (where T_p is the time measured at the *D* current according to Table 3);

– apply a current equal to $7{,}2 \times I_e$;

– the relay shall trip within 50 % of the time T_p.

8.2.1.5.2 Limits of operation of three-pole time-delay overload relays energized on two poles

With reference to Table 4:

The overload relay or starter shall be tested in its enclosure if normally fitted. With the relay energized on three poles, at A times the current setting, tripping shall not occur in less than 2 h, starting from the cold state, at the value of the ambient air temperature stated in Table 4.

Moreover, when the value of the current flowing in two poles (in phase loss sensitive relays, those carrying the higher current) is increased to *B* times the current setting, and the third pole de-energized, tripping shall occur in less than 2 h.

The values shall apply to all combinations of poles.

In the case of overload relays having an adjustable current setting, the characteristics shall apply both when the relay is carrying the current associated with the maximum setting and when the relay is carrying the current associated with the minimum setting.

Table 4 – Limits of operation of three-pole time-delay overload relays when energized on two poles only

Type of overload relay	Multiples of current setting		Reference ambient air temperature
	A	B	
Thermal, compensated for ambient air temperature variations or electronic Not phase loss sensitive	3 poles 1,0	2 poles 1,32 1 pole 0	+20 °C
Thermal, not compensated for ambient air temperature variations Not phase loss sensitive	3 poles 1,0	2 poles 1,25 1 pole 0	+40 °C
Thermal, compensated for ambient air temperature variations or electronic Phase loss sensitive	2 poles 1,0 1 pole 0,9	2 poles 1,15 1 pole 0	+20 °C

8.2.1.5.3 Limits of operation of instantaneous magnetic overload relays

For all values of the current setting, instantaneous magnetic overload relays shall trip with an accuracy of ±10 % of the value of the published current value corresponding to the current setting.

NOTE Magnetic instantaneous overload relays covered by this standard are not intended for short-circuit protection.

8.2.1.5.4 Limits of operation of under-current relays and releases for automatic change over

8.2.1.5.4.1 Limits of operation of under-current relays

An under-current relay or release, when associated with a switching device, shall operate to open the switching device within 80 % to 120 % of the set time, when the current during operation is below 0,9 times the under current setting in all poles. When the operating time is below 1 s, a different tolerance may be given by the manufacturer but the upper limit shall not exceed 1,2 s.

NOTE The tolerance depends on the sensing technology.

8.2.1.5.4.2 Limits of operation of automatic change over by under-current relays

This subclause applies to:

– star-delta starters from star to delta, and

– auto-transformer starters from the starting to the ON position.

The lowest drop-out current of an under-current relay shall be not greater than 1,5 times the actual current setting of the overload relay which is active in the starting or star connection. The under-current relay shall be able to carry any value of current, from its lowest current setting to the stalled current in the starting position or the star connection, for the tripping times determined by the overload relay at its highest current setting.

8.2.1.5.5 Limits of operation of stall relays

A stall relay, when associated with a switching device, shall operate to open the switching device within 80 % to 120 % of the set time (stall inhibit time) or within the accuracy specified by the manufacturer, when:

a) current sensing relays: the current is 20 % higher than the set stall current value;

   EXAMPLE Set current of the stall relay: 100 A; set time: 6 s; accuracy: ±10 %, the relay shall trip within 5,4 s and 6,6 s when the current is equal to or greater than 100 A × 1,2 = 120 A.

b) rotation sensing relays: an input signal indicating no motor rotation exists.

8.2.1.5.6 Limits of operation of jam relays and releases

A jam relay or release, when associated with a switching device, shall operate to open the switching device within 80 % to 120 % of the set time (jam inhibit time) or within the accuracy specified by the manufacturer, when the current is above 1,2 times the set current value of the jam relay, during running after completion of the starting.

8.2.2 Temperature rise

8.2.2.1 General

The requirements of 7.2.2 of IEC 60947-1 apply to contactors and starters in a clean, new condition.

NOTE 1 Contact resistance due to oxidation may impact the temperature rise test at test voltages below 100 V. In the case of conducting the test at a voltage below 100 V, such devices may have the contacts cleaned either by any nonabrasive method or by carrying out 10 operating cycles under the conditions of Table 10 for any applicable utilization category at any voltage.

The temperature rises of the several parts of the contactor or starter measured during a test carried out under the conditions specified in 9.3.3.3 shall not exceed the limiting values stated in Table 5 of this standard and in 7.2.2.1 and 7.2.2.2 of IEC 60947-1.

In the case of an electronically controlled electromagnet, coil temperature measuring by variation of resistance may be impracticable; in such a case, other methods are permitted, e.g. thermocouples or other suitable methods.

Table 5 – Temperature rise limits for insulated coils in air and in oil

Class of insulating material (according to IEC 60085)	**Temperature rise limit (measured by resistance variation)** K	
	Coils in air	**Coils in oil**
A	85	60
E	100	60
B	110	60
F	135	–
H	160	–

Because, in an auto-transformer starter, the auto-transformer is energized only intermittently, a maximum temperature rise of 15 K greater than the figures in Table 5 is permissible for the windings of the transformer when the starter is operated according to the requirements of 5.3.4 and 5.3.5.5.3.

NOTE 2 The temperature rise limits given in Table 5 of this standard and in 7.2.2.2 of IEC 60947-1 are applicable only if the ambient air temperature remains within the limits –5 °C, +40 °C.

8.2.2.2 Terminals

Subclause 7.2.2.1 of IEC 60947-1 applies.

8.2.2.3 Accessible parts

Subclause 7.2.2.2 of IEC 60947-1 applies.

8.2.2.4 Ambient air temperature

Subclause 7.2.2.3 of IEC 60947-1 applies.

8.2.2.5 Main circuit

The main circuit of a contactor or a starter which carries current in the ON position, including the over-current releases which may be associated with it, shall be capable of carrying, without the temperature rises exceeding the limits specified in 7.2.2.1 of IEC 60947-1 when tested in accordance with 9.3.3.3.4:

– for a contactor or starter intended for continuous duty: its conventional thermal current (see 5.3.2.1 and/or 5.3.2.2);
– for a contactor or starter intended for uninterrupted duty, intermittent duty or temporary duty: its relevant rated operational current (see 5.3.2.5).

8.2.2.6 Control circuits

Subclause 7.2.2.5 of IEC 60947-1 applies.

8.2.2.7 Windings of coils and electromagnets

8.2.2.7.1 Uninterrupted and eight-hour duty windings

With the maximum value of current according to 8.2.2.5 flowing through the main circuit, the windings of the coils, including those of electrically operated valves of electro-pneumatic contactors or starters, shall withstand, under continuous load and at the rated frequency, if applicable, their maximum rated control supply voltage without the temperature rise exceeding the limits specified in Table 5 of this standard and in [A1]7.2.2.6[A1] of IEC 60947-1.

NOTE Depending on the technology, e.g. for some kinds of electronically controlled electromagnets, the control supply voltage may not be directly applied on the coil winding when connected as in normal service.

8.2.2.7.2 Intermittent duty windings

With no current flowing through the main circuit, the windings of the coils shall withstand, at the rated frequency, if applicable, their maximum rated control supply voltage applied as detailed in Table 6 according to their intermittent duty class, without the temperature rise exceeding the limits specified in Table 5 of this standard and in 7.2.2.2 of IEC 60947-1.

NOTE Depending on the technology, e.g. for some kind of electronically controlled electromagnet, the control supply voltage may not be directly applied on the coil winding when connected as in normal service.

Table 6 – Intermittent duty test cycle data

Intermittent duty class		One close-open operating cycle every	Interval of time during which the supply to the control coil is maintained
Contactors	Starters		
1	1	3 600 s	"ON" time should correspond to the on-load factor specified by the manufacturer
3	3	1 200 s	
12	12	300 s	
30	30	120 s	
120		30 s	
300		12 s	
1 200		3 s	

8.2.2.7.3 Specially rated (temporary or periodic duty) windings

Specially rated windings shall be tested under operating conditions corresponding to the most severe duty for which they are intended and their ratings shall be stated by the manufacturer.

NOTE Specially rated windings may include coils of starters which are energized during the starting period only, trip coils of latched contactors and certain magnetic valve coils for interlocking pneumatic contactors or starters.

8.2.2.8 Auxiliary circuits

Subclause 7.2.2.7 of IEC 60947-1 applies.

8.2.2.9 Other parts

Subclause 7.2.2.8 of IEC 60947-1 applies, replacing words "plastics and insulating materials" with "insulating parts".

8.2.3 Dielectric properties

A1) Subclause 7.2.3 of IEC 60947-1:2007 applies with the following additions:

General requirements for device including voltage limiting components inserted between circuits not connected to the ground/earth to be tested according to the dielectric test are described as follows.

These voltage limiting components called varistors used in order to protect electronic parts from surges within the device shall comply with IEC 61051-2. In this clause, the intent is not to reduce the clearances. For the type test of the device the voltage limiting components may be disconnected.

IEC 61051-2 applies as follows:

a) Preferred climatic categories of the varistor:
   - maximum lower temperature: -10 °C
   - minimum upper temperature: +85 °C

The device manufacturer has to verify that the varistor is suitable for use in the extended ambient temperature if any.

b) The minimum rated voltage of the varistor shall be 1,2 times the maximum peak voltage where the varistor is connected.

c) When connected to the mains, varistors shall withstand the surge test according to 9.4.2.5.

NOTE 1 With the verification of the varistors above it is assumed that a fuse protecting the varistor is not necessary.

NOTE 2 The possibility given in 8.3.3.4.1 item 1) of IEC 60947-1:2007 of disconnecting circuits between poles may be not appropriate in the routine test, because the products are completed and it is not appropriate to reopen and manipulate them. The main purpose of this test is to identify the proper operation of the voltage limiting component. (A1

8.2.4 Normal load and overload performance requirements

Requirements concerning normal load and overload characteristics according to 5.3.5 are given in 8.2.4.1, 8.2.4.2 and 8.2.4.4.

8.2.4.1 Making and breaking capacities

Contactors or starters shall be capable of making and breaking currents without failure under the conditions stated in Table 7 for the required utilization categories and the number of operations indicated, as specified in 9.3.3.5.

The off-time and on-time values given in Table 7 and Table 8 shall not be exceeded.

**Table 7 – Making and breaking capacities –
Making and breaking conditions according to utilization category**

A1

Utilization category	Make and break conditions					
	I_c / I_e	U_r / U_e	Cos ϕ	On-time [b] s	Off-time s	Number of operating cycles
AC-1	1,5	1,05	0,8	0,05	[f]	50
AC-2	4,0 [h]	1,05	0,65 [h]	0,05	[f]	50
AC-3 [i]	8,0	1,05	[a]	0,05	[f]	50
AC-4 [i]	10,0	1,05	[a]	0,05	[f]	50
AC-5a	3,0	1,05	0,45	0,05	[f]	50
AC-5b	1,5 [c]	1,05	[c]	0,05	60	50
AC-6a	[j]					
AC-6b	1,5	1,05		[l]	[m]	50
AC-8a [k]	6,0	1,05	[a]	0,05	[f]	50
AC-8b [k]	6,0	1,05	[a]	0,05	[f]	50
Utilization category	I_c / I_e	U_r / U_e	L / R ms	On-time [b] s	Off-time s	Number of operating cycles
DC-1	1,5	1,05	1,0	0,05	[f]	50 [d]
DC-3	4,0	1,05	2,5	0,05	[f]	50 [d]
DC-5	4,0	1,05	15,0	0,05	[f]	50 [d]
DC-6	1,5 [c]	1,05	[c]	0,05	60	50 [d]
Utilization category	Make conditions [i]					
	I / I_e	U / U_e	Cos ϕ	On-time [b] s	Off-time s	Number of operating cycles
AC-3	10	1,05[g]	[a]	0,05	10	50
AC-4	12	1,05[g]	[a]	0,05	10	50

I = current made. The making current is expressed in d.c. or a.c. r.m.s. symmetrical values but it is understood that, for a.c., the actual peak value during the making operation may assume a higher value than the symmetrical peak value.

I_c = current made and broken, expressed in d.c. or a.c. r.m.s. symmetrical values

I_e = rated operational current

U = applied voltage

U_r = power frequency or d.c. recovery voltage

U_e = rated operational voltage

Cos ϕ = power factor of test circuit

L / R = time-constant of test circuit

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A1) **Table 7** *(continued)*

a	Cos ϕ = 0,45 for $I_e \leq 100$ A; 0,35 for $I_e > 100$ A.
b	The time may be less than 0,05 s, provided that contacts are allowed to become properly seated before re-opening.
c	Tests to be carried out with an incandescent light load.
d	If polarity not marked on the device, 25 operating cycles with one polarity and 25 operating cycles with reverse polarity.
e	The load shall consist of commercially available capacitor combinations to obtain a steady-state reactive current I_e calculated according to 9.3.3.3.4. Alternatively capacitive ratings may be derived by capacitor switching tests or assigned on the basis of established practice and experience. As a guide, reference may be made to the formula given in Table 9 which does not take into account the thermal effects due to harmonic currents. The available current capacity at the test terminals shall not be less than the prospective current "*r*". It can be determined by analytical evaluation.
f	See Table 8.
g	For U / U_e, a tolerance of ±20 % is accepted.
h	The values shown are for stator contactors. For rotor contactors, the test shall be made with a current of four times the rated rotor operational current and a power factor of 0,95.
i	The make conditions for utilization categories AC-3 and AC-4 shall also be verified. The verification may be made during the make and break test, but only with the manufacturer's agreement. In this case, the making current multiples shall be as shown for I / I_e and the breaking current as shown for I_c / I_e. 25 operating cycles shall be made at a control supply voltage equal to 110 % of the rated control supply voltage U_s and 25 operating cycles at 85 % of U_s. The off-times are to be determined from Table 8.
j	The manufacturer shall verify the AC-6a rating by testing with a transformer or may derive the rating from the values for AC-3 according to Table 9.
k	A lower ratio of I_c / I_e (locked rotor to full load current) may be used if specified by the manufacturer.
l	The on time shall be long enough in order to reach the stabilized current.
m	Off-time according to Table 8. The value of a discharge resistor shall be determined to reach less than 50 V at the end of off-time.

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Table 8 – Relationship between current broken I_c and off-time for the verification of rated making and breaking capacities

Current broken I_c A	Off-time s
$I_c \leq$ 100	10
100 < $I_c \leq$ 200	20
200 < $I_c \leq$ 300	30
300 < $I_c \leq$ 400	40
400 < $I_c \leq$ 600	60
600 < $I_c \leq$ 800	80
800 < $I_c \leq$ 1 000	100
1 000 < $I_c \leq$ 1 300	140
1 300 < $I_c \leq$ 1 600	180
1 600 < I_c	240

The off-time values may be reduced if agreed by the manufacturer.

Table 9 – Operational current determination for utilization categories AC-6a and AC-6b when derived from AC-3 ratings

Rated operational current	Determination from making current for utilization category AC-3
I_e (AC-6a) for switching of transformers having inrush current peaks of not more than 30 times peak of rated current	0,45 I_e (AC-3)
I_e (AC-6b) for switching of single capacitor banks in circuits having a prospective short-circuit current i_k at the location of the capacitor bank	$i_k \frac{x^2}{(x-1)^2}$ with $x = 13{,}3 \times \frac{I_e \text{ (AC - 3)}}{i_k}$ and for $i_k > 205\ I_e$ (AC-3)

The expression for the operational current I_e (AC-6b) emanates from the formula for the highest inrush current peak:

$$I_{pmax} = \frac{U_e \times \sqrt{2}}{\sqrt{3}} \times \frac{1 + \sqrt{\frac{X_c}{X_L}}}{X_L - X_c}$$

where

U_e is the rated operational voltage;

X_L is the short-circuit impedance of the circuit;

X_c is the reactance of the capacitor bank.

This formula is valid on condition that capacitance on the supply side of the contactor or starter can be neglected and that there is no initial charge on the capacitor.

8.2.4.2 Conventional operational performance

Subclause 7.2.4.2 of IEC 60947-1 applies with the following addition.

Contactors or starters shall be capable of making and breaking currents without failure under the conventional conditions stated in Table 10 for the required utilization categories and the number of operating cycles indicated as specified in 9.3.3.6.

**Table 10 – Conventional operational performance –
Making and breaking conditions according to utilization category**

A1

Utilization category	Make and break test conditions					
	I_c / I_e	U_r / U_e	Cos ϕ	On-time s	Off-time s	Number of operating cycles
AC-1	1,0	1,05	0,80	0,05 [b]	c	6 000 [i]
AC-2	2,0	1,05	0,65	0,05 [b]	c	6 000 [i]
AC-3	2,0	1,05	a	0,05 [b]	c	6 000 [i]
AC-4	6,0	1,05	a	0,05 [b]	c	6 000 [i]
AC-5a	2,0	1,05	0,45	0,05 [b]	c	6 000 [i]
AC-5b	1,0 [e]	1,05	e	0,05 [b]	60	6 000 [i]
AC-6a	g	g	g	g	g	g
AC-6b	1 [k]	1,05		l	m	6 000
AC-8a	1,0	1,05	0,80	0,05 [b]	c	30 000
AC-8b [h, j]	6,0	1,05	a	1	9	5 900
				10	90 [d]	100
Utilization category	I_c / I_e	U_r / U_e	*L* / *R* ms	On-time s	Off-time s	Number of operating cycles
DC-1	1,0	1,05	1,0	0,05 [b]	c	6 000 [f]
DC-3	2,5	1,05	2,0	0,05 [b]	c	6 000 [f]
DC-5	2,5	1,05	7,5	0,05 [b]	c	6 000 [f]
DC-6	1,0 [e]	1,05	e	0,05 [b]	60	6 000 [f]

I_c = current made or broken. Except for AC-5b, AC-6 or DC-6 categories, the making current is expressed in d.c. or a.c. r.m.s. symmetrical values but it is understood that for a.c. the actual peak value during the making operation may assume a higher value than the symmetrical peak value.

I_e = rated operational current

U_r = power frequency or d.c. recovery voltage

U_e = rated operational voltage

Cos ϕ = power factor of test circuit

L / *R* = time-constant of test circuit

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A1 **Table 10** *(continued)*

[a] Cos ϕ = 0,45 for $I_e \leq 100$ A; 0,35 for $I_e > 100$ A.

[b] The time may be less than 0,05 s, provided that contacts are allowed to become properly seated before re-opening.

[c] These off-times shall be not greater than the values specified in Table 8.

[d] The manufacturer may choose any value for the Off-time up to 200 s.

[e] Tests to be carried out with an incandescent light load.

[f] If polarity not marked on the device, 3 000 operating cycles with one polarity and 3 000 operating cycles with reverse polarity.

[g] The manufacturer shall verify the AC-6a rating by testing with a transformer or may derive the rating from the values for AC-3 according to Table 9.

[h] Tests for category AC-8b shall be accompanied by tests for category AC-8a. The tests may be made on different samples.

[i] For manually operated switching devices, the number of operating cycles shall be 1 000 on-load, followed by 5 000 off-load.

[j] A lower ratio of I_c / I_e (locked rotor to full load current) may be used if specified by the manufacturer.

[k] The load shall consist of commercially available capacitor combinations to obtain a steady-state reactive current I_e calculated according to 9.3.3.3.4. Alternatively capacitive ratings may be derived by capacitor switching tests or assigned on the basis of established practice and experience. As a guide, reference may be made to the formula given in Table 9 which does not take into account the thermal effects due to harmonic currents. The available current capacity at the test terminals shall not be less than the prospective current "*r*". It can be determined by analytical evaluation.

[l] The on time shall be long enough in order to reach the stabilized current.

[m] Off-time according to Table 8. The value of a discharge resistor shall be determined to reach less than 50 V at the end of off-time.

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8.2.4.3 Durability

Subclause 7.2.4.3 of IEC 60947-1 applies with the following additions.

8.2.4.3.1 Mechanical durability

The mechanical durability of a contactor or starter is verified by a special test conducted at the discretion of the manufacturer. Recommendations for conducting this test are given in Annex B.

8.2.4.3.2 Electrical durability

Electrical durability of a contactor or starter is verified by a special test conducted at the discretion of the manufacturer. Recommendations for conducting this test are given in Annex B.

8.2.4.4 Overload current withstand capability of contactors

Contactors with utilization categories AC-3 or AC-4 shall withstand the overload currents given in Table 11, as specified in 9.3.5.

Table 11 – Overload current withstand requirements

Rated operational current	Test current	Duration of test
≤630 A	8 × I_e max/AC-3	10 s
>630 A	6 × I_e max/AC-3*	10 s
* With a minimum value of 5 040 A.		

NOTE This test also covers duties where the current is less than shown in Table 11 and the test duration is longer than 10 s, provided that the tested value of I^2t is not exceeded.

A1) 8.2.4.5 Coil power consumption

Where the power consumption of the coil is given, it shall be tested according to 9.3.3.2.1.2.

8.2.4.6 Pole impedance

Where the pole impedance is given, it shall be tested according to 9.3.3.2.2.2 (A1

8.2.5 Co-ordination with short-circuit protective devices

8.2.5.1 Performance under short-circuit conditions (rated conditional short-circuit current)

The rated conditional short-circuit current of contactors and starters backed up by short-circuit protective device(s) (SCPD(s)), combination starters, combination switching devices, protected starters and protected switching devices shall be verified by short-circuit tests as specified in 9.3.4. These tests are mandatory:

a) at the appropriate value of prospective current shown in Table 13 (test current "*r*"), and
b) at the rated conditional short-circuit current I_q, if higher than test current "*r*".

The rating of the SCPD shall be adequate for any given rated operational current, rated operational voltage and the corresponding utilization category.

Two types of co-ordination are permissible, "1" or "2". The test conditions for both are given in 9.3.4.2.1 and 9.3.4.2.2.

Type "1" co-ordination requires that, under short-circuit conditions, the contactor or starter shall cause no danger to persons or installation and may not be suitable for further service without repair and replacement of parts.

Type "2" co-ordination requires that, under short-circuit conditions, the contactor or starter shall cause no danger to persons or installation and shall be suitable for further use. The risk of contact welding is recognized, in which case the manufacturer shall indicate the measures to be taken as regards the maintenance of the equipment.

NOTE Use of an SCPD not in compliance with the manufacturer's recommendations may invalidate the co-ordination.

A1 These tests are applicable to AC motor ratings only. A1

8.2.5.2 Co-ordination at the crossover current between starter and associated SCPD

Co-ordination at the crossover current between the starter and the SCPD is a special test. The way to verify it is described in B.4.

A1 *Text deleted* A1

8.3 Electromagnetic compatibility (EMC)

8.3.1 General

Subclause 7.3.1 of IEC 60947-1 applies with the following addition.

Power frequency magnetic field tests are not required because the devices are naturally submitted to such fields. Immunity is demonstrated by the successful completion of the operational performance capability tests (see 9.3.3.5 and 9.3.3.6).

This equipment is inherently sensitive to voltage dips and short time interruptions on the control supply; it shall react within the limits of 8.2.1.2 and this is verified by the operating limits tests given in 9.3.3.2.

8.3.2 Immunity

8.3.2.1 Equipment not incorporating electronic circuits

Subclause 7.3.2.1 of IEC 60947-1 applies.

8.3.2.2 Equipment incorporating electronic circuits

Subclause 7.3.2.2 of IEC 60947-1 applies with the following addition.

The test results are specified using the performance criteria given in Table 12.

Table 12 – Specific acceptance criteria for immunity tests

Item	Acceptance criteria		
	A	B	C
General	Normal performance within the specified limits	Temporary degradation or loss of function or performance which is self-recoverable	Temporary degradation or loss of function or performance which requires operator's intervention or system reset. There shall not be any damaged component
Operation of power and control circuits	No unwanted operation - the contactor shall remain in the expected position - the overload relay shall not trip	Temporary unwanted operation which cannot cause tripping Unintentional opening or closing of contacts is not accepted Self-recoverable	Tripping of overload relay Unintentional opening or closing of contacts Not self-recoverable
Operation of displays and auxiliary circuits	No changes to visible display information Only slight light intensity fluctuations of LEDs or movement of characters No unwanted operation of auxiliary contacts	Temporary visible changes, for example unwanted LED illumination Unintentional opening or closing of auxiliary contacts is not accepted.	Permanent loss of display information Unintentional opening or closing of auxiliary contacts is not accepted.
Information processing and sensing functions	Communication and data interchange to external devices without unwanted action or erroneous information	Temporarily disturbed communication with possible external impacts, but self-recoverable	Erroneous processing of information Loss of data and/or information Not self-recoverable

8.3.3 Emission

The level of severity required for environment B covers those required for environment A.

The devices covered by this standard do not generate significant levels of harmonics and therefore no harmonic tests are required.

8.3.3.1 Equipment not incorporating electronic circuits

Subclause 7.3.3.1 of IEC 60947-1 applies with the following addition.

Equipment incorporating only components such as diodes, varistors, resistors or capacitors is not required to be tested (e.g. in surge suppressors).

8.3.3.2 Equipment incorporating electronic circuits

Subclause 7.3.3.2 of part 1 applies.

9 Tests

9.1 Kinds of test

9.1.1 General

Subclause 8.1.1 of IEC 60947-1 applies.

9.1.2 Type tests

Type tests are intended to verify compliance of the design of contactors and starters of all types with this standard. They comprise the verification of:

a) temperature rise limits (see 9.3.3.3);

b) dielectric properties (see 9.3.3.4);

c) rated making and breaking capacities (see 9.3.3.5);

d) change-over ability and reversibility, where applicable (see 9.3.3.5);

e) conventional operational performance (see 9.3.3.6);

f) operation and operating limits (see 9.3.3.1 and 9.3.3.2);

g) ability of contactors to withstand overload current (see 9.3.5);

h) performance under short-circuit conditions (see 9.3.4);

i) mechanical properties of terminals (see 8.2.4 of IEC 60947-1);

j) degrees of protection of enclosed contactors and starters (see Annex C of IEC 60947-1);

k) EMC tests, where applicable (see 9.4).

9.1.3 Routine tests

Subclause 8.1.3 of IEC 60947-1 applies where sampling tests (see 9.1.4) are not made.

Routine tests for contactors and starters comprise:

– operation and operating limits (see 9.3.6.2);
– dielectric tests (see 9.3.6.3).

9.1.4 Sampling tests

Sampling tests for contactors and starters comprise:

– operation and operating limits (see 9.3.6.2)
– dielectric tests (see 9.3.6.3).

Subclause 8.1.4 of IEC 60947-1 applies with the following additions.

A manufacturer may use sampling tests instead of routine tests at his own discretion. Sampling shall meet or exceed the following requirements as specified in IEC 60410 (see Table II-A: Single sampling plans for normal inspection):

– sampling based on AQL ≤ 1;
– acceptance number Ac = 0 (no defect accepted);
– rejection number Re = 1 (if 1 defect, the entire lot shall be tested).

Sampling shall be made at regular intervals for each specific lot.

Alternative statistical methods that ensure compliance with the above IEC 60410 requirements can be used, e.g. statistical methods controlling continuous manufacturing or process control with capability index.

Sampling tests for clearance verification shall be performed according to 8.3.3.4.3 of IEC 60947-1.

9.1.5 Special tests

9.1.5.1 General

Special tests are mechanical and electrical durability tests and verification of co-ordination at the crossover current between the starter and the SCPD (see Annex B). The test results can be used to obtain data needed for functional safety applications (see Annex K).

9.1.5.2 Special tests – damp heat, salt mist, vibration and shock

For these special tests, Annex Q of IEC 60947-1 applies with the following additions.

Where Table Q.1 of IEC 60947-1 calls for verification of operational capability, this shall be done according to 9.3.6.2 of this standard.

The vibration tests shall be done on the equipment in the open and closed positions. The overload relay shall not trip during the test. To check the behavior of main and auxiliary contacts, tests can be done under any current /voltage value.

The shock test on the equipment shall be done in the open position.

For the dry heat test, the equipment shall be in the close position during the conditioning period (see 5.3.3 of IEC 60068-2-2). For categories A, B and C, the test may be done without current in the poles and for categories D, E and F, the test shall be done under the maximum rated AC-3 current, but may be limited to 100 A for practical reasons. During the last hour, the contactor shall be operated 5 times. During the whole test the overload relay may trip.

For the low temperature test, the test Ad is to be chosen instead of the test Ab and the equipment shall be in the open position during the cooling period. It shall then be energized for the last hour. For categories A, B and C, the test may be done without current in the poles and for categories D, E and F, the test is done under the maximum rated AC-3 current which may be limited to 100 A for practical reasons. During this last hour the contactor shall be operated 5 times. During the whole test the overload relay shall not trip.

For the damp heat test, for categories A, B and C, the test may be done without current in the poles. For categories D, E and F the equipment shall be energized under the maximum rated AC-3 current for the first cycle and de-energized for the second cycle. The current may be limited to 100 A for practical reasons. After stabilization of the temperature, during the first 2 h of the first cycle and during the last 2 h of the second cycle, the contactor shall be operated 5 times. The overload relay may trip only if it is permitted according to its temperature characteristic.

With the agreement of the manufacturer, the duration of the recovery periods may be reduced.

After the salt mist test, the product may be washed where agreed by the manufacturer.

9.2 Compliance with constructional requirements

(A1) 9.2.2 Electrical performance of screwless-type clamping units

Subclause 8.2.4.7 of IEC 60947-1:2007, Amendment 1 applies with the following changes:

The number of specimens shall be at least 4.

The insertion and disconnection of the conductors shall be made in accordance with the manufacturer's instructions. (A1)

[A1] A suitable test arrangement is shown in Figure 10. If the measurement points cannot be positioned within the 10 mm to the point of contact, the voltage difference between the ideal and the actual measuring points shall be deducted from the voltage drop measured. This voltage difference within the part of the conductor shall be determined with a suitable measurement method on one specimen at a stabilised temperature. The measurement methods and the results shall be documented in the test report. The test current is I_{th}.

NOTE 1 Usually it is possible to equip a IEC 60947-4-1 product with many different types of wires (stranded, solid, flexible…) which results in a sufficient number of tests for the same terminal.

NOTE 2 Particular testing method with conductor cross sections larger than 16 mm² is under consideration.

NOTE 3 The device sample may be provided with holes or equivalent arrangements which provide measurement access points for the voltage drop on the terminal.

9.2.3 Ageing test for screwless-type clamping units

Subclause 8.2.4.8 of IEC 60947-1:2007, Amendment 1 applies with the following change:

The test shall be done on the device equipped with the clamping units.

The test current is I_{th}.

NOTE The device sample may be provided with holes or equivalent arrangements which provide measurement access points for the voltage drop on the terminal. [A1]

9.3 Compliance with performance requirements

9.3.1 Test sequences

Each test sequence is made on a new sample.

NOTE 1 With the agreement of the manufacturer, more than one test sequence or all test sequences may be conducted on one sample. However, the tests are conducted in the sequence given for each sample.

NOTE 2 Some tests are included in the sequences solely to reduce the number of samples required, the results have no significance for the preceding or following tests in the sequence. Therefore, for convenience of testing and by agreement with the manufacturer, these tests may be conducted on separate new samples and omitted from the relevant sequence. This only applies to the following tests when called for:

Subclause 8.3.3.4.1, item 7) of IEC 60947-1 : Verification of creepage distances.

Subclause 8.2.4 of IEC 60947-1: Mechanical properties of terminals.

Annex C of IEC 60947-1 : Degrees of protection of enclosed equipment.

The test sequence shall be as follows.

a) Test sequence 1
   1) verification of temperature rise (see 9.3.3.3)
   2) verification of operation and operating limits (see 9.3.3.1 and 9.3.3.2)
   3) verification of dielectric properties (see 9.3.3.4)
b) Test sequence 2
   1) verification of rated making and breaking capacities, change-over ability and reversibility, where applicable (see 9.3.3.5)
   2) verification of conventional operational performance (see 9.3.3.6)

c) Test sequence 3
performance under short-circuit conditions (see 9.3.4);

d) Test sequence 4 (applicable to contactors only)
verification of ability to withstand overload currents (see 9.3.5);

e) Test sequence 5
   1) [A1] verification of mechanical properties of terminals (see 8.2.4 of IEC 60947-1:2007, 9.2.1 and 9.2.2); [A1]
   2) verification of degrees of protection of enclosed contactors and starters (see Annex C of IEC 60947-1).

There shall be no failure in any of the tests.

9.3.2 General test conditions

Subclause 8.3.2 of IEC 60947-1 applies with the following addition.

The selection of samples to be tested for a series of devices with same fundamental design and without significant difference in construction shall be based on engineering judgement.

Except for devices specifically rated for only one frequency, tests performed at 50 Hz are deemed to cover 60 Hz applications and vice-versa.

Unless otherwise specified in the relevant test subclause, the clamping torque for connections shall be that specified by the manufacturer or, if not specified, the torque given in Table 4 of IEC 60947-1.

9.3.3 Performance under no load, normal load and overload conditions

9.3.3.1 Operation

It shall be verified that contactors and starters operate according to the requirements of 8.2.1.1.2.

To verify the insensitivity of the starter to contactor operation, the starter shall be loaded to attain a steady state temperature as stated in 8.2.2 and the contactor operated in the normal switching sequence three times without intentional delay between operations. The starter shall not trip due to the contactor operation.

When the overload relay has a combined stop and reset actuating mechanism, with the contactor closed, the resetting mechanism shall be operated and this shall cause the contactor to drop out. When the overload relay has either a reset only or separate stop and reset actuating mechanisms, with the contactor closed and the resetting mechanism in the reset position, the tripping mechanism shall be operated and the contactor shall have been caused to drop out. These tests are to verify that the overload tripping action cannot be defeated by holding the resetting mechanism in the reset position.

In the case of rheostatic rotor starters, tests shall be performed to verify that the time setting of time-delay relays and the calibration of any other devices used for controlling the rate of starting are within the limits stated by the manufacturer.

The value of the starting resistors shall be verified for each section to be within ±10 % of the stated figures.

It shall also be verified that the rotor switching devices cut out the steps of resistors in the correct sequence.

It shall also be verified that the open-circuit voltages on the tapping terminals of the auto-transformer are in accordance with the designed figures and that the phase sequence at the motor terminals of the two-step auto-transformer starter is correct in both the starting and ON positions of the starter.

9.3.3.2 Operating limits

9.3.3.2.1 Power-operated equipment

A1⟩ 9.3.3.2.1.1 General

Contactors and starters shall be tested to verify their performance according to the requirements given in 8.2.1.2.

The drop out test requirements of 8.3.3.2.1 of IEC 60947-1:2007, Amendment 1 applies.

9.3.3.2.1.2 Coil power consumption

9.3.3.2.1.2.1 General

A contactor coil is evaluated for both holding power and pick-up power.

In the case where different coils cover a range of voltages, 5 coils shall be tested as follows:

The coil with the lowest rated control supply voltage U_s, the coil with the highest rated control supply voltage U_s, plus 3 coils deemed to be representative of the coils with the highest calculated hold power at the discretion of the manufacturer.

The test shall be performed at ambient temperature +23 °C ± 3 °C. The test shall be made without any load in the main and auxiliary circuits. The coil shall be supplied with the rated control supply voltage U_s and at the rated frequency. For a given coil, where a voltage range is declared, the test shall be made at the highest voltage at the respective frequency.

The measured values shall be obtained with a r.m.s. measurement method covering at least a bandwidth from 0 Hz to 10 kHz and the resulting power values shall be given within a measurement uncertainty better than 5 %.

9.3.3.2.1.2.2 Holding power for conventional and electronically controlled electromagnet

The current measurement $I_{(i)}$ of the coil shall be performed after the coil has been energized and has reached a stable temperature.

The holding power consumption is defined as follows:

$S_{h(i)} = U_{s(i)} \times I_{(i)}$ [VA] for a.c. controlled contactor;

$P_{c(i)} = U_{s(i)} \times I_{(i)}$ [W] for d.c. controlled contactor. ⟨A1

A1⟩ The published value shall be equal to the average value of the 5 tested coils.

$S_h = \sum (U_{s(i)} \times I_{(i)}) / 5$ [VA] respectively $P_c = \sum (U_{s(i)} \times I_{(i)}) / 5$ [W]

NOTE The power dissipation for an a.c. controlled contactor can also be expressed in [W], taking into account the power factor.

9.3.3.2.1.2.3 Pick-up power for a.c. controlled contactor or d.c. controlled contactor with separate pick-up and hold-on windings

The pick-up measurement shall be performed directly after the measurement of the hold current (see 9.3.3.2.1.2.2).

The current measurement $I_{(i)}$ of the coil shall be performed immediately after the coil has been de-energized, the contactor has been held in the Off position and re-energized.

The pick-up power consumption is defined as follows:

$S_{p(i)} = U_s \times I_{(i)}$ [VA] for a.c. controlled contactor;

$P_{p(i)} = U_s \times I_{(i)}$ [W] for d.c. controlled contactor with separate pick-up and hold windings.

The published value shall be equal to the average value of the 5 tested coils.

$S_p = \sum (U_{s(i)} \times I_{(i)}) / 5$ [VA] respectively $P_p = \sum (U_{s(i)} \times I_{(i)}) / 5$ [W]

NOTE Unless otherwise stated in the manufacturer literature, for d.c. conventional controlled contactor, the pick-up power is equal to the holding power.

9.3.3.2.1.2.4 Pick-up power for electronically controlled electromagnet

Under consideration.

9.3.3.2.1.3 Pole impedance

The pole impedance shall be determined during the test and with the conditions given in 9.3.3.3.4. The test in an enclosure is not deemed necessary even if the contactor can be used in an individual enclosure.

The voltage drop U_d shall be measured between the line and load terminals (terminals included) of the contactor preferably at the same time the temperature rise is measured.

The impedance per pole is defined as follows:

$Z = U_d / I_{th}$ [Ω]

Care should be taken that voltage drop measurement does not significantly affect the temperature rise nor affect significantly the impedance.

NOTE The method is the same irrespective of the number of poles of the contactor. ⟨A1

9.3.3.2.2 Relays and releases

A1⟩ a) Operation of under-voltage relays and releases

Under-voltage relays or releases shall be tested for compliance with the requirements of 8.2.1.3. When associated with a switching device, the release shall be fitted to the switching device having the maximum current rating for which the release is suitable.

1) Drop-out voltage

   The voltage shall be reduced from rated control supply voltage at a rate to reach 0 V in approximately 30 s.

   The test for the lower limit is made without previous heating of the release coil. In the case of a release with a range of rated control supply voltage, this test applies to the maximum voltage of the range. When associated with a switching device, the test for the lower limit is made without current in the main circuit.

   The test for the upper limit is made starting from a constant temperature corresponding to the application of rated control supply voltage to the release and rated current in the main poles. This test may be combined with the temperature-rise test of 9.3.3.3. In the case of a release with a range of rated control supply voltage, this test is made at the minimum rated control supply voltage.

2) Test for limits of operation when associated with a switching device

   Starting with the main circuit open, at the temperature of the test room, and with the supply voltage at 35 % rated maximum control supply voltage, it shall be verified that the switching device cannot be closed by the operation of its actuator. When the supply voltage is raised to 85 % of the minimum control supply voltage, it shall be verified that the switching device can be closed by the operation of its actuator.

3) Performance under over-voltage conditions

   When associated with a switching device, the test is made without current in the main circuit. The test at 110 % of the rated supply voltage shall be made for 30 min or until the temperature has reached thermal equilibrium and without impairing its functions. Verification shall be made according 2) above.

b) Shunt-coil operated release

Shunt releases shall be tested for compliance with the requirements of 8.2.1.4 at the ambient temperature. When associated with a switching device, the release shall be fitted to the switching device having the maximum rated current for which the release is suitable.

In the case of a release having a range of rated control supply voltages, the test voltages shall be 70 % of the minimum rated control supply voltage and 110 % of the maximum rated control voltage. ⟨A1

c) Thermal, electronic and time-delay magnetic overload relays

Overload relays and starters shall be connected using conductors in accordance with Table 9, Table 10 and Table 11 of IEC 60947-1 for test currents corresponding to:

– 100 % of the current setting of the overload relay for overload relays of trip classes 2, 3, 5 and 10 A for all overload relay types (see Table 2) and 10, 20, 30 and 40 for electronic overload relay types;

– 125 % of the current setting of the overload relay for thermal overload relays of trip classes 10, 20, 30 and 40 (see Table 2) and for overload relays for which a maximum tripping time greater than 40 s is specified (see 5.7.3).

It shall be verified that relays and releases operate according to the requirements of 8.2.1.5.1 with all poles energized.

The characteristics defined in 8.2.1.5.1 shall be verified at −5 °C, +20 °C, +40 °C. In addition any declared time-current characteristics outside the –5 °C, +40 °C range shall be verified at minimum and maximum temperatures. However, for relays or releases declared compensated for ambient temperature, in case of temperature range declared by the manufacturer is outside the range given in Table 3, the characteristics at –5 °C and/or +40 °C need not be verified if, when tested at the declared minimum and maximum temperatures, the corresponding tripping current values are in compliance with the limits specified for –5 °C and/or +40 °C in that Table 3.

For electronic overload relays, the thermal memory test verification of 8.2.1.5.1.2 shall be carried out at +20 °C.

Three-pole thermal or electronic overload relays energized on two poles only shall be tested as stated in 8.2.1.5.2 on all combinations of poles and at the maximum and minimum current settings for relays with adjustable settings.

d) Instantaneous magnetic overload relays

Each relay shall be tested separately. The current through the relay shall be increased at a rate suitable for an accurate reading to be made. The values shall be as stated in 8.2.1.5.3.

e) Under-current relays

The limits of operation shall be verified in accordance with 8.2.1.5.4.1.

f) Under-current relays in automatic change-over

The limits of operation shall be verified in accordance with 8.2.1.5.4.2.

g) Stall relays

The limits of operation shall be verified in accordance with 8.2.1.5.5.

For current sensing stall relays, the verification shall be made for the minimum and for the maximum set current values and for the minimum and maximum stall inhibit time (four settings).

For stall relays operating in conjunction with a rotation sensing mean, the verification shall be made for the minimum and maximum stall inhibit time. The sensor can be simulated by an appropriate signal on the sensor input of the stall relay.

h) Jam relays

The limits of operation shall be verified in accordance with 8.2.1.5.6.

The verification shall be made for the minimum and for the maximum set current values and for the minimum and maximum jam inhibit time (four settings).

For each of the four settings, the test shall be made under the following conditions:

- apply a test current of 95 % of the set current value. The jam relay shall not trip;
- increase the test current to 120 % of the set current value. The jam relay shall trip according to the requirements given in 8.2.1.5.6.

9.3.3.3 Temperature rise

9.3.3.3.1 Ambient air temperature

Subclause 8.3.3.3.1 of IEC 60947-1 applies.

9.3.3.3.2 Measurement of the temperature of parts

Subclause 8.3.3.3.2 of IEC 60947-1 applies.

9.3.3.3.3 Temperature rise of a part

Subclause 8.3.3.3.3 of IEC 60947-1 applies.

9.3.3.3.4 Temperature rise of the main circuit

Subclause 8.3.3.3.4 of IEC 60947-1 applies with the following additions. The main circuit shall be loaded as stated in 8.2.2.4.

All auxiliary circuits which normally carry current shall be loaded at their maximum rated operational current (see 5.6) and the control circuits shall be energized at their rated voltages.

The starter shall be fitted with an overload relay complying with 5.7.4 and selected as follows:

– Non-adjustable relay

  The current setting shall be equal to the maximum operational current of the starter and the test shall be made at this current;

– Adjustable relay

  The maximum current setting shall be that which is nearest to but not greater than the maximum operational current of the starter.

  The test shall be made with that overload relay for which the current setting is nearest to the maximum of its scale.

A1) NOTE 1 (A1 The selection method described above is designed to ensure that the temperature rise of the field wiring terminals of the overload relay and the power dissipated by the starter are not less than those that will occur under any combination of relay and contactor. In cases where the effect of the overload relay on these values is insignificant (i.e. electronic overload relays), the test current shall always be the maximum operational current of the starter.

A1) For equipment intended for utilization category AC-6b, the test current for the temperature rise test shall be equal to 1,35 times I_e (the rated capacitive current). I_e shall be calculated as follow:

- $I_e = Q$ (var) / U_e for single-phase rating, where U_e is the minimum rated voltage;
- $I_e = Q$ (var) / ($U_e \times \sqrt{3}$) for three-phases rating, where U_e is the minimum rated voltage.

NOTE 2 This calculation follows the requirements of IEC 60381-1.

The test shall be done with cross section of conductor based on 1,35 times I_e (the rated capacitive current). (A1

9.3.3.3.5 Temperature rise of control circuits

Subclause 8.3.3.3.5 of IEC 60947-1 applies with the following addition.

The temperature rise shall be measured during the test of 9.3.3.3.4.

9.3.3.3.6 Temperature rise of coils and electromagnets

Subclause 8.3.3.3.6 of IEC 60947-1 applies with the following additions.

a) Electromagnets of contactors or starters intended for uninterrupted or 8 h duty are subjected only to the conditions prescribed in 8.2.2.7.1, with the corresponding rated current flowing through the main circuit for the duration of the test. The temperature rise shall be measured during the test of 9.3.3.3.4.

b) Electromagnets of contactors or starters intended for intermittent duty shall be subjected to the test as stated above, and also to the test prescribed in 8.2.2.7.2 dealing with their duty class, with no current flowing through the main circuit.

c) Specially rated (temporary and periodic duty) windings shall be tested as stated in 8.2.2.7.3, without the current in the main circuit.

A1) The coil with the highest power consumption, for a given frequency a.c. or d.c., according to 9.3.3.2.1.2.2 is deemed to be representative for all coils, for the same contactor, and shall be used for the temperature rise test. (A1

9.3.3.3.7 Temperature rise of auxiliary circuits

Subclause 8.3.3.3.7 of IEC 60947-1 applies with the following addition.

The temperature rise shall be measured during the test of 9.3.3.3.4.

9.3.3.3.8 Temperature rise of starting resistors for rheostatic rotor starters

The temperature rise of resistors shall not exceed the limits specified in Table 3 of IEC 60947-1, when the starter is operated at its rated duty (see 5.3.4) and according to its starting characteristics (see 5.3.5.5.1).

The current through each section of the resistors shall be thermally equivalent to the current during the starting time when the controlled motor is operating with the maximum starting torque and the starting time for which the starter is rated (see 5.3.4 and 5.3.5.5.1); in practice, the current value I_m can be used.

Starting operations shall be evenly spaced in time according to the number of starts per hour.

The temperature rise of the enclosures and of the issuing air shall not exceed the limits specified in Table 3 of IEC 60947-1.

NOTE It is not practical to test the performance of starting resistors of every combination of motor output and rotor voltage and current; it is recommended only that a sufficient number of tests be made to prove, by interpolation or deduction, compliance with this standard.

9.3.3.3.9 Temperature rise of the auto-transformer for two-step auto-transformer starters

A1) The temperature rise of the auto-transformer shall not exceed the limits specified in Table 5 increased by 15 K (see 8.2.2) and those specified in Table 3 of IEC 60947-1:2007, when the starter is operated at its rated duty (see 5.3.4). (A1

The current through each winding of the auto-transformer shall be thermally equivalent to the current carried when the controlled motor is operating with the maximum starting current and starting time for which the starter is rated (see 5.3.5.5.3); this condition is assumed to be reached when the current drawn from the auto-transformer during the starting time is equal to the maximum starting current specified in 5.3.5.5.3 multiplied by:

$$0{,}8 \times \frac{\text{starting voltage}}{U_e} \quad \text{(see 5.3.1.4)}$$

The operating cycles shall be evenly spaced in time according to the number of starts per hour (see 5.3.4.3).

In the event of two successive operating cycles (see 5.3.4.3), the temperature rise of the auto-transformer may exceed the maximum value given in 8.2.2 but no damage shall result to the auto-transformer.

In the case of an auto-transformer with several sets of taps, the test shall be made with the taps giving the highest power loss in the transformer; it shall be made over a period of time sufficient for the temperature rise to reach a constant value.

In order to facilitate this test, star-connected impedances may be used in place of a motor.

9.3.3.4 Dielectric properties

Subclause 8.3.3.4 of IEC 60947-1 applies with the following modifications.

9.3.3.4.1 Type tests

Subclause 8.3.3.4.1 of IEC 60947-1 applies with the addition of

– the following sentences, at the end of item 1):

  The metal foil shall be applied to all surfaces where these are likely to be touched by people during normal operation or adjustment of the equipment and where such surfaces can also be touched by the standard test finger.

  The metal foil shall not be applied for power frequency withstand verification after switching and short-circuit tests.

– the following sentence, after the second paragraph of item 2) b):

Circuits of a contactor or starter including devices which have been subjected to U_{imp} test voltages lower than those specified in 7.2.3.1 of IEC 60947-1 and 8.3.3.4.2 of IEC 60947-1 may be disconnected for the test, according to the manufacturer's instructions.

– the following sentence, after the paragraph of item 2) c) ii):

Where the control circuit normally connected to the main circuit is disconnected (according to 8.3.3.4.1 of IEC 60947-1, item 2) b)), the method used to maintain the main contacts closed shall be indicated in the test report.

– the following sentence at the end of 8.3.3.4.1 of IEC 60947-1, item 8):

For equipment suitable for isolation, the leakage current shall be measured through each pole with the contacts in the open position at a test voltage of 1,1 U_e and shall not exceed 0,5 mA.

Verification of impulse withstand voltage across open contacts is not required for equipment not suitable for isolation (see 8.3.3.4.1, item 2) c) iv) of IEC 60947-1).

9.3.3.5 Making and breaking capacities

Subclause 8.3.3.5 of IEC 60947-1 applies with the following additions.

9.3.3.5.1 General test conditions

The tests shall be made, under the operating conditions stated in Table 7, without failure, see 9.3.3.5.5 f).

The control supply voltage shall be 100 % of U_s, except that, for the make only test of utilization categories AC-3 and AC-4, the control supply voltage shall be 110 % of U_s for half the number of operating cycles and 85 % of U_s for the other half.

A1 NOTE If there is no distinction between U_s and U_c, then the test has to be done with U_c accordingly. A1

Connections to the main circuit shall be similar to those intended to be used when the contactor or starter is in service. If necessary, or for convenience, the control and auxiliary circuits, and in particular the magnet coil of the contactor or starter, may be supplied by an independent source. Such a source shall deliver the same kind of current and the same voltage as specified for service conditions.

The overload relay and the SCPD of the starter may be short-circuited for the purpose of carrying out the rated making and breaking capacity tests.

9.3.3.5.2 Test circuit

Subclause 8.3.3.5.2 of IEC 60947-1 applies.

9.3.3.5.3 Characteristics of transient recovery voltage

Subclause 8.3.3.5.3 of IEC 60947-1 applies to utilization categories AC-2, AC-3, AC-4, AC-8a and AC-8b (see Table 1).

It is not necessary to adjust factor γ or the oscillatory frequency for testing making capacity only (in AC-3 and AC-4).

9.3.3.5.4 Void

A1 *Text deleted* A1

9.3.3.5.5 Rated making and breaking capacities

If the contactor in a starter has separately satisfied the requirements of item a) hereafter for the utilization category of the starter, the starter need not be tested.

a) Rated making and breaking capacities of contactors

The contactor shall make and break the current corresponding to its utilization category and for the number of operating cycles given in Table 7. See also item d) hereafter for reversing contactors.

Contactors of utilization categories AC-3 and AC-4 shall be subjected to 50 making only operations followed by 50 making and breaking operations.

b) Rated making and breaking capacity of direct-on-line and two direction starters (AC-3) and stator switching devices of rheostatic rotor starters (AC-2)

The starter shall make and break the current corresponding to its utilization category for the number of operating cycles given in Table 7.

Starters of utilization category AC-3 shall be subjected to 50 making only operations followed by 50 making and breaking operations.

c) Rated making and breaking capacities and change-over ability of star-delta starters (AC-3) and two-step auto-transformer starters (AC-3)

The starter shall make and break the currents corresponding to its utilization category given in Table 7.

Both the starting and the ON or delta position of the starters shall first be subjected to 50 making only operations, the current being broken by a separate switching device.

The starter shall then be subjected to the 50 making and breaking operations. Each operating cycle shall consist of the following sequences:

– make the current in the starting or star position;
– break the current in the starting or star position;
– make the current in the ON or delta position;
– break the current in the ON or delta position;
– off period.

The load circuit shall be connected to the starter as would be the windings of a motor. The rated operational current of the starter (I_e) is the current in the ON or delta position.

NOTE In the case of star-delta starters, it is important that the test currents be measured in star and delta since the supply impedance has a significant effect on the transformation ratio.

When a transformer has more than one output voltage, it shall be connected to give the highest starting voltage.

The on-time in the starting and ON positions and the off-time shall be as stated in Table 7.

d) Rated making and breaking capacities of direct-on-line and reversing starters (AC-4)

The starters shall make and break the currents given in Table 7.

The 50 making only operations shall be done first, the current being broken by a separate switching device, followed by the 50 making and breaking operations.

The load circuit shall be connected to the starter as would be the windings of a motor.

For starters incorporating two contactors, two contactors A and B shall be used and wired as in normal application. Each sequence of the 50 operations shall be:

close A – open A – close B –
open B – off period

The change-over from "open A" to "close B" shall be made as fast as the normal control system will allow.

Mechanical or electrical interlocking means provided in the starter or available for associating contactors as reversing devices shall be used.

If the reversing circuit arrangement is such that both contactors can be energized simultaneously, ten additional sequences shall be conducted with both contactors energized simultaneously.

e) Rated making and breaking capacities of the rotor switching devices of a rheostatic rotor starter

Verification of the making and breaking capacities of the rotor switching devices shall be performed as in 9.3.3.5.5 b) for AC-2 category where $I_e = I_{er}$, the maximum rated rotor current for which the starter is designed. $U_e = U_{er}$ (rated rotor operational voltage) and U/U_e shall be 0,8. The power factor shall be 0,95. The starting resistors may be disconnected for these tests and, for starters having more than two steps, the test shall be performed on each switching device in turn. Since the rotor switching devices in starters having more than two steps do not break and make at the full rotor voltage, the voltage for these tests may be reduced in the ratio:

$$\frac{\text{Starting resistance switched}}{\text{Total starting resistance}}$$

When a starter is so connected that the circuit is opened by the stator switch before the rotor switching devices open, no verification of the breaking capacity is necessary.

For rotor switching devices which have previously satisfied the requirements corresponding to those specified above, no further tests are needed.

f) Behaviour and condition of the contactor or starter during and after the making and breaking capacity, change-over and reversing tests

During the tests within the limits of the specified making and breaking capacities of 9.3.3.5 and the verification of conventional operational performance of 9.3.3.6.1 to 9.3.3.6.6, there shall be no permanent arcing, no flash-over between poles, no blowing of the fusible element in the earth circuit (see 9.3.3.5.2) and no welding of the contacts.

The contacts shall operate when the contactor or starter is switched by the applicable method of control.

9.3.3.6 Operational performance capability

Subclause 8.3.3.6 of IEC 60947-1 applies with the following additions.

Tests concerning the verification of conventional operational performance are intended to verify that a contactor or starter is capable of fulfilling the requirements given in Table 10.

Connections to the main circuit shall be similar to those intended to be used when the contactor or starter is in service.

The overload relay and the SCPD of the starter may be short-circuited for the purpose of carrying out the tests.

The test circuit given in 9.3.3.5.2 is applicable and the load is to be tuned according to 9.3.3.5.3.

The control voltage shall be 100 % of the rated control supply voltage.

If the contactor in a starter has separately satisfied the requirements of 9.3.3.6.1 for the utilization category of the starter, the starter need not be tested.

9.3.3.6.1 Conventional operational performance of contactors

The contactor shall make and break the current corresponding to its utilization category and for the number of operating cycles given in Table 10. See also 9.3.3.6.4.

9.3.3.6.2 Conventional operational performance of direct-on-line and two direction starters (AC-3) and stator switching devices of rheostatic rotor starters (AC-2)

The starter shall make and break the current corresponding to its utilization category and for the number of operating cycles given in Table 10.

9.3.3.6.3 Conventional operational performance of star-delta starters (AC-3) and two-step auto-transformer starters (AC-3)

The starter shall make and break the current corresponding to its utilization category for the number of operating cycles given in Table 10.

The test procedure shall be as stated in 9.3.3.5.5, item c), except that the 50 making only operations are not done.

9.3.3.6.4 Conventional operational performance of direct-on-line and reversing starters (AC-4)

The starter shall make and break the current corresponding to its utilization category for the number of operating cycles given in Table 10.

The test procedure shall be as stated in 9.3.3.5.5, item d), except that the 50 making only operations and the 10 additional sequences of simultaneous energizing are not done.

9.3.3.6.5 Conventional operational performance of the rotor switching devices of a rheostatic rotor starter

Verification of conventional operational performance of the rotor switching devices shall be performed as in 9.3.3.6.1 for the AC-2 category given in Table 10.

The test procedure shall be as stated in 9.3.3.5.5, item e).

9.3.3.6.6 Behaviour of the contactor or starter during, and its condition after, the conventional operational performance tests

The requirements of 9.3.3.5.5, item f), shall be fulfilled and then the verification of power frequency withstand according to 8.3.3.4.1, item 4), of IEC 60947-1 shall be made.

For equipment suitable for isolation, the leakage current shall be measured through each pole, with the contacts in the open position, at a test voltage of 1,1 U_e and shall not exceed 2 mA.

For equipment provided with mirror contacts, the additional test of F.7.3 shall be carried out.

9.3.4 Performance under short-circuit conditions

This subclause specifies test conditions for verification of compliance with the requirements of 8.2.5.1. Specific requirements regarding test procedure, test sequences, condition of equipment after the test and types of co-ordination are given in 9.3.4.1 and 9.3.4.2.

9.3.4.1 General conditions for short-circuit tests

9.3.4.1.1 General requirements for short-circuit tests

Subclause 8.3.4.1.1 of IEC 60947-1 applies with the following modification.

A1) If devices tested in free air may also be used in an individual enclosure, they shall be additionally tested in the smallest of such enclosures stated by the manufacturer. For devices tested only in free air, information shall be provided to indicate that the device has not been evaluated for use in an individual enclosure.

NOTE An individual enclosure is an enclosure designed and dimensioned to contain one device (starter, etc) only. (A1

The individual enclosure shall be in accordance with the manufacturer specifications. In case of multiple enclosure options are provided, the individual enclosure with the smallest volume shall be taken.

Enclosed stationary and moveable assemblies are tested according to IEC 61439-1.

9.3.4.1.2 Test circuit for the verification of short-circuit ratings

Subclause 8.3.4.1.2 of IEC 60947-1 applies except that, for type "1" co-ordination, the fusible element F and the resistor R_L are replaced by a solid 6 mm² wire of 1,2 m to 1,8 m in length, connected to the neutral, or with the agreement of the manufacturer, to one of the phases.

NOTE This larger size of wire is not used as a detector but to establish an "earth" condition allowing the damage to be evaluated.

9.3.4.1.3 Power-factor of the test circuit

Subclause 8.3.4.1.3 of IEC 60947-1 applies.

[A1] If Table 17 is used, the power factor is given in this Table 17. [A1]

9.3.4.1.4 Time-constant of the test circuit

Subclause 8.3.4.1.4 of IEC 60947-1 applies.

9.3.4.1.5 Calibration of the test circuit

Subclause 8.3.4.1.5 of IEC 60947-1 applies.

9.3.4.1.6 Test procedure

Subclause 8.3.4.1.6 of IEC 60947-1 applies with the following additions.

The contactor or the starter and its associated SCPD, or the combination starter, the combination switching device, the protected starter or the protected switching device, shall be mounted and connected as in normal use. They shall be connected in the test circuit using a maximum of 2,4 m of cable (corresponding to the operational current of the starter) for each main circuit.

If the SCPD is separate from the starter, it shall be connected to the starter using the cable specified above. (The total length of cable shall not exceed 2,4 m.)

Three-phase tests are considered to cover single-phase applications.

9.3.4.1.7 Void

9.3.4.1.8 Interpretation of records

Subclause 8.3.4.1.8 of IEC 60947-1 applies.

9.3.4.2 Conditional short-circuit current of contactors, starters, combination starters, combination switching devices, protected starters and protected switching devices

The contactor or starter and the associated SCPD, or the combination starter, the combination switching device, the protected starter or the protected switching device, shall be subjected to the tests given in 9.3.4.2.1 and 9.3.4.2.2. The tests shall be so conducted that conditions of maximum I_e and of maximum U_e for utilization category AC-3 are covered.

For a magnetically operated contactor or starter, the magnet shall be held closed by a separate electrical supply at the rated control supply voltage U_s. The SCPD used shall be as stated in 8.2.5.1. If the SCPD is a circuit-breaker with an adjustable current setting, the test shall be done with the circuit-breaker adjusted to the maximum setting for the declared type of co-ordination and discrimination.

During the test, all openings of the enclosure shall be closed as in normal service and the door or cover secured by the means provided.

A starter covering a range of motor ratings and equipped with interchangeable overload relays shall be tested with the overload relay with the highest impedance and the overload relay with the lowest impedance together with the corresponding SCPDs.

For type "1" co-ordination, a new test sample may be used for each operation stated in 9.3.4.2.1 and 9.3.4.2.2.

For type "2" co-ordination, one sample shall be used for the tests at the prospective current "*r*" (see 9.3.4.2.1) and one sample for the tests at current I_q (see 9.3.4.2.2).

By agreement of the manufacturer, the tests at *r* and I_q may be carried out on the same sample.

9.3.4.2.1 Test at the prospective current "*r*"

The circuit shall be adjusted to the prospective test current corresponding to the rated operational current I_e A1⟩ according to Table 13 or preferably Table 17 at the discretion of the manufacturer. Both tables are considered equivalent for the product to comply with this standard.⟨A1

The contactor or starter and the associated SCPD, or the combination starter, the combination switching device, the protected starter or the protected switching device, shall then be connected in the circuit. The following sequence of operations shall be performed:

a) one breaking operation of the SCPD shall be performed with all the switching devices closed prior to the test (“O” operation);
b) one breaking operation of the SCPD shall be performed by closing the contactor or starter on to the short-circuit (“CO” operation).

Table 13 – Value of the prospective test current according to the rated operational current

Rated operational current I_e (AC-3)a A	Prospective current “*r*” kA
A1⟩ $I_e \le 16$ ⟨A1	1
$16 < I_e \le 63$	3
$63 < I_e \le 125$	5
$125 < I_e \le 315$	10
$315 < I_e \le 630$	18
$630 < I_e \le 1\,000$	30
$1\,000 < I_e \le 1\,600$	42
$1\,600 < I_e$	Subject to agreement between manufacturer and user

A1⟩ [a] If the contactor or starter is not specified according to utilization category AC-3, the prospective current “*r*” shall be subject of agreement between manufacturer and user.⟨A1

A1 Table 17 – Value of the prospective test current according to the rated operational current (harmonized table)

Rated operational current I_e (AC-3) [a, e] A	Prospective current "*r*" kA [f]	Power factor
$I_e \leq 12$	1	0,7 - 0,8
$12 < I_e \leq 50$ [b]	3	0,7 - 0,8
$50 < I_e \leq 100$ [c]	5	0,7 - 0,8
$100 < I_e \leq 250$ [d]	10	0,5 - 0,7
$250 < I_e \leq 500$	18	0,2 - 0,3
$500 < I_e \leq 800$	30	0,2 - 0,3
$800 < I_e \leq 1\,300$	42	0,2 - 0,3
$1\,300 < I_e$	Subject to agreement between manufacturer and user.	0,2 - 0,3

[a] If the contactor or starter is not specified according to utilization category AC-3, the prospective current "*r*" shall be subject of agreement between manufacturer and user.

[b] at 690 V and above: $12 < I_e \leq 63$

[c] at 690 V and above: $63 < I_e \leq 125$

[d] at 690 V and above: $125 < I_e \leq 250$

[e] Rated operational current may be marked “motor full load current” in North America.

[f] Prospective current "*r*" may be called “standard fault current” in North America.

NOTE Table 17 has been introduced for harmonization purpose with UL 60947-4-1 and is equivalent to UL 60947-4-1. A1

9.3.4.2.2 Test at the rated conditional short-circuit current I_q

NOTE This test is done if the current I_q is higher than the current "*r*".

The circuit shall be adjusted to the prospective short-circuit current I_q equal to the rated conditional short-circuit current.

If the SCPD is a fuse and the test current is within the current-limiting range of the fuse, then, if possible, the fuse shall be selected to permit the maximum peak let-through current (I_p) and the maximum let-through energy (I^2t).

The contactor or starter and the associated SCPD, or the combination starter, the combination switching device, the protected starter or the protected switching device, shall then be connected to the circuit.

The following sequence of operations shall be performed:

a) one breaking operation of the SCPD shall be performed with all the switching devices closed (“O” operation) prior to the test.

b) one breaking operation of the SCPD shall be performed by closing (“CO” operation) the contactor or starter on to the short-circuit.

c) in the case of a combination starter or a protected starter, with the switching device of the SCPD having a short-circuit breaking capacity or rated conditional short-circuit current less than the rated conditional short circuit current of the combination starter or protected starter the following additional test shall be made. One breaking operation of the SCPD shall be performed by closing ("CO" operation) the switching device (switch or circuit-breaker) on to the short-circuit, the contactor or starter already being closed. This operation may be performed either on a new sample (starter and SCPD) or on the first sample with the agreement of the manufacturer. After this operation only conditions a) to g) of 9.3.4.2.3 shall be verified.

9.3.4.2.3 Results to be obtained

The contactor, starter, or the combination starter, the combination switching device, the protected starter or the protected switching device, shall be considered to have passed the tests at the prospective current "r" and, where applicable, the prospective current I_q, if the following conditions are met for the claimed type of co-ordination.

Both types of co-ordination (all devices):

a) The fault current has been successfully interrupted by the SCPD, the combination starter or the combination switching device and the fuse or fusible element or solid connection between the enclosure and supply shall not have melted.

b) The door or cover of the enclosure has not been blown open and it is possible to open the door or cover. Deformation of the enclosure is considered acceptable provided that the degree of protection by the enclosure is not less than IP2X.

c) There is no damage to the conductors or terminals and the conductors have not been separated from the terminals.

d) There is no cracking or breaking of an insulating base to the extent that the integrity of mounting of a live part is impaired.

Both types of co-ordination (combination starters, combination switching devices, protected starters and protected switching devices only):

e) The circuit-breaker or the switch is capable of being opened manually by its operating means.

f) Neither end of the SCPD is completely separated from its mounting means to an exposed conductive part.

g) If a circuit-breaker with rated ultimate short-circuit breaking capacity less than the rated conditional short-circuit current assigned to the combination starter, the combination switching device, the protected starter or the protected switching device is employed, the circuit-breaker shall be tested to trip as follows:

   1) circuit-breakers with instantaneous trip relays or releases: at 120 % of the trip current.

   2) circuit-breakers with overload relays or releases: at 250 % of the rated current of the circuit-breaker.

Type "1" co-ordination (all devices):

h) There has been no discharge of parts beyond the enclosure. Damage to the contactor and the overload relay is acceptable. The starter may be inoperative after each operation. The starter shall therefore be inspected and the contactor and/or the overload relay and the release of the circuit-breaker shall be reset if necessary and, in the case of fuse protection, all fuse-links shall be replaced.

Type "1" co-ordination (combination and protected starters only):

i) The adequacy of insulation in accordance with 8.3.3.4.1, item 4), of IEC 60947-1 is verified after each operation (at currents “*r*” and “I_q”) by a dielectric test on the complete unit under test (SCPD plus contactor/starter but before replacement of parts) using a power frequency withstand voltage of twice the rated operational voltage U_e but not less than 1 000 V. The test voltage shall be applied to the incoming supply terminals, with the switch or the circuit-breaker in the open position, as follows:
   - between each pole and all other poles connected to the frame of the starter;
   - between all live parts of all poles connected together and the frame of the starter;
   - between the terminals of the line side connected together and terminals of the other side connected together.

   For equipment suitable for isolation, the leakage current shall be measured through each pole, with the contacts in the open position, at a test voltage of 1,1 U_e and shall not exceed 6 mA.

Type "2" co-ordination (all devices):

j) No damage to the overload relay or other parts has occurred, except that welding of contactor or starter contacts is permitted, if they are easily separated (e.g. by a screwdriver) without significant deformation, but no replacement of parts is permitted during the test, except that, in the case of fuse protection, all fuse-links shall be replaced.

   In the case of welded contacts as described above, the functionality of the device shall be verified by carrying out 10 operating cycles under the conditions of Table 10 for the applicable utilization category.

k) The tripping of the overload relay shall be verified at a multiple of the current setting and shall conform to the published tripping characteristics, according to 5.7.5, both before and after the short circuit test.

l) The adequacy of the insulation in accordance with 8.3.3.4.1, item 4), of IEC 60947-1 shall be verified by a dielectric test on the contactor, the starter, the combination starter, the combination switching device, the protected starter or the protected switching device, using a power frequency withstand voltage of twice the rated operational voltage U_e but not less than 1 000 V.

   In the case of combination starters, combination switching devices, protected starters and protected switching devices, additional tests according to 8.3.3.4.1, item 3), of IEC 60947-1 shall be made across the main poles of the device with the contacts of the switch or of the circuit-breaker open and the contacts of the starter closed.

   For equipment suitable for isolation, the leakage current shall be measured through each pole, with the contacts in the open position, at a test voltage of 1,1 U_e and shall not exceed 2 mA.

   Fuse-links, if any, are shorted.

9.3.5 Overload current withstand capability of contactors

For the test, the contactor shall be mounted, wired and operated as specified in 9.3.2.

All poles of the contactors are simultaneously subjected to one test with the overload current and duration values stated in 8.2.4.4. The test is performed at any convenient voltage and it starts with the contactor at room temperature.

After the test, the contactor shall be substantially in the same condition as before the test. This is verified by visual inspection.

NOTE The I^2t value (Joule integral) calculated from this test cannot be used to estimate the performance of the contactor under short-circuit conditions.

9.3.6 Routine tests and sampling tests

9.3.6.1 General

The tests shall be carried out under the same conditions as those specified for type tests in the relevant parts of 9.1.2 or under equivalent conditions. However, the limits of operation in 9.3.3.2 may be verified at the prevailing ambient air temperature and on the overload relay alone, but a correction may be necessary to allow for normal ambient conditions.

[A1] If devices are tested separately, their combination shall be tested with the dielectric test and other relevant operational tests. However, if the combination is built up with already tested connection systems or auxiliaries, an additional dielectric test is not necessary. [A1]

9.3.6.2 Operation and operating limits

For electromagnetic, pneumatic and electro-pneumatic contactors or starters, tests are carried out to verify operation within the limits specified in 8.2.1.2.

For manual starters, tests are carried out to verify the proper operation of the starter (see 8.2.1.2, 8.2.1.3 and 8.2.1.4).

NOTE 1 In these tests it is not necessary to reach thermal equilibrium. The lack of thermal equilibrium may be compensated by using a series resistor or by appropriately decreasing the voltage limit.

Tests shall be made to verify the calibration of relays. In the case of a time delay overload relay, this may be a single test with all poles equally energized at a multiple of the current setting, to check that the tripping time conforms (within tolerances) to the curves supplied by the manufacturer; in the case of an instantaneous magnetic overload relay, the test shall be carried out at 1,1 times the current setting. For under-current relays, stall relays and jam relays, tests shall be carried out to verify the proper operation of these relays (see 8.2.1.5.4, 8.2.1.5.5 and 8.2.1.5.6).

NOTE 2 In the case of a time-delay magnetic overload relay comprising a time-delay device working with a fluid dashpot, calibration may be carried out with the dashpot empty, at a percentage of the current setting indicated by the manufacturer and capable of being justified by a special test.

9.3.6.3 Dielectric tests

[A1] 9.3.6.3.1 General [A1]

Subclause 8.3.3.4.2 of IEC 60947-1 applies with the following addition.

In the case of a rheostatic rotor starter, all the poles of the rotor switching devices will normally be connected through the starting resistors; the dielectric test is therefore confined to the application of the test voltage between the rotor circuit and the frame of the starter.

The use of the metal foil is not necessary.

NOTE The combined test of 8.3.3.4.2 of IEC 60947-1 is permitted.

[A1] 9.3.6.3.2 Routine power frequency test for devices incorporating voltage limiting components

At the discretion of the manufacturer, the device incorporating voltage limiting components are to be tested with the following sequence a) to b):

a) Application of the test voltage

The test shall be performed in accordance with 8.3.3.4.2 2) of IEC 60947-1:2007. The value of the test voltage shall be the U_V r.m.s. value (max. operational voltage of the voltage limiting components) or the maximum U_V d.c. value of the voltage limiting components with a tolerance of -10 %.

Acceptance criteria: The over-current relay of the test apparatus shall not trip (lower tripping limit).

b) Verification of the proper function of the voltage limiting components

The test shall be performed in accordance with 8.3.3.4.2 2) of IEC 60947-1:2007. The value of the test voltage shall be chosen by the manufacturer so that a current is generated between the upper tripping limit and the lower tripping limit of the test apparatus.

Acceptance criteria: The current shall be between a) and b) and the voltage limiting component shall not be damaged.

NOTE The main purpose of this test is to check the proper operation of the voltage limiting component. [A1]

9.4 EMC tests

9.4.1 General

Subclauses 8.3.2.1, 8.3.2.3 and 8.3.2.4 of IEC 60947-1 apply with the following additions.

With the agreement of the manufacturer, more than one EMC test or all EMC tests may be conducted on one and the same sample, which may initially be new or may have passed test sequences according to 9.3.1. The sequence of the EMC tests may be any convenient sequence.

The test report shall include any special measures that have been taken to achieve compliance, for example the use of shielded or special cables. If auxiliary equipment is used with the contactor or starter in order to comply with immunity or emission requirements, it shall be included in the report.

The test sample shall be in the open or closed position, whichever is the worse, and shall be operated with the rated control supply.

9.4.2 Immunity

The tests of Table 14 are required. Special requirements are specified in 9.4.2.1 to 9.4.2.7.

If, during the EMC-tests, conductors are to be connected to the test sample, the cross-section and the type of the conductors are optional but shall be in accordance with the manufacturer's literature.

Table 14 – EMC immunity tests

Type of test	Test level required
Electrostatic discharge immunity test IEC 61000-4-2	Corresponding test level of Table 23 of IEC 60947-1 applies.
Radiated radio-frequency electromagnetic field immunity test (80 MHz to 1 GHz and 1,4 GHz to 2 GHz) IEC 61000-4-3	Corresponding test level of Table 23 of IEC 60947-1 applies.
Electrical fast transient/burst immunity test IEC 61000-4-4 [a]	Corresponding test level of Table 23 of IEC 60947-1 applies.
1,2/50 µs – 8/20 µs surge immunity test IEC 61000-4-5	Corresponding test level of Table 23 of IEC 60947-1 applies.
Conducted disturbances induced by radio-frequency fields immunity test [b c] (150 kHz to 80 MHz) IEC 61000-4-6	Corresponding test level [d] of Table 23 of IEC 60947-1 applies.

[a] The contactor shall be operated at least one time during the test and the overload relay is loaded at 0,9 times the current setting with a maximum of 100 A.
[b] Applicable to ports only interfacing with cables whose total length according to the manufacturer’s functional specification may exceed 3 m.
[c] The test level can also be defined as the equivalent current into a 150 Ω load.
[d] Except for the ITU broadcast frequency band 47 MHz to 68 MHz, where the level shall be 3 V.

9.4.2.1 Performance of the test sample during and after the test

Unless otherwise specified, performance criterion B applies, see 8.3.2.2.

No loss of performance shall be permitted during or after the tests. After the tests the operating limits of 9.3.6.2 shall be verified at ambient temperature.

9.4.2.2 Electrostatic discharge

The test shall be conducted using the methods of IEC 61000-4-2.

Except for metallic parts for which contact discharge is made, only air discharge is required.

Ten positive and ten negative pulses shall be applied to each selected point, the time interval after each successive single discharge being 1 s.

Tests are not required on power terminals. The application of conductors is not required, except for energizing the coil.

9.4.2.3 Electromagnetic field

The tests shall be conducted using the methods of IEC 61000-4-3. The test procedure of IEC 61000-4-3 shall apply.

The device shall comply with performance criterion A.

9.4.2.4 Fast transient bursts

The tests shall be conducted using the methods of IEC 61000-4-4 with a repetition rate of 5 kHz.

The bursts shall be applied to all main, control or auxiliary terminals, whether they comprise electronic or conventional contacts.

The test voltage shall be applied for the duration of 1 min.

9.4.2.5 Surges (1,2/50 μs – 8/20 μs)

The test shall be conducted using the methods of IEC 61000-4-5. Capacitive coupling shall be preferred. The surges shall be applied to all main, control or auxiliary terminals, whether they comprise electronic or conventional contacts.

The test voltage values are those of Table 14 but shall not exceed the corresponding U_{imp} value(s) given by the manufacturer following 7.2.3 of IEC 60947-1.

The repetition rate shall be one surge per minute, with the number of pulses being five positive and five negative.

9.4.2.6 Harmonics

Under consideration.

9.4.2.7 Conducted disturbances induced by radio-frequency fields

Subclause 8.4.1.2.6 of IEC 60947-1 applies with the following addition.

The device shall comply with performance criterion A under the test conditions given in Table 14.

9.4.3 Emission

For equipment designed for environment A, a suitable warning shall be given to the user (for example in the instruction manual) stipulating that the use of this equipment in environment B may cause radio interference in which case the user may be required to employ additional mitigation methods.

9.4.3.1 Conducted radio-frequency emission tests

A description of the test, the test method and the test set-up are given in CISPR 11.

To pass, the equipment shall not exceed the levels given in Table 15.

Table 15 – Conducted radio-frequency emission test limits

Frequency band MHz	**Environment A** dB(μV)	**Environment B** dB(μV)
0,15 – 0,5	79 quasi-peak 66 average	66 – 56 quasi-peak 56 – 46 average (decrease with log of frequency)
0,5 – 5,0	73 quasi-peak 60 average	56 quasi-peak 46 average
5 – 30	73 quasi-peak 60 average	60 quasi-peak 50 average

9.4.3.2 Radiated radio-frequency emission tests

A description of the test, the test method and the test set-up are given in CISPR 11.

Tests are required where the control and auxiliary circuits contain components with fundamental switching frequencies greater than 9 kHz, for example switch-mode power supplies, etc.

To pass, the equipment shall not emit at higher levels than those given in Table 16.

Table 16 – Radiated emission test limits

Frequency band MHz	**Environment A** [a] dB(μV/m)	**Environment B** dB(μV/m)
30 – 230	30 quasi-peak at 30 m	30 quasi-peak at 10 m
230 – 1 000	37 quasi-peak at 30 m	37 quasi-peak at 10 m

[a] These tests may be carried at 10 m distance with the limits raised by 10 dB.

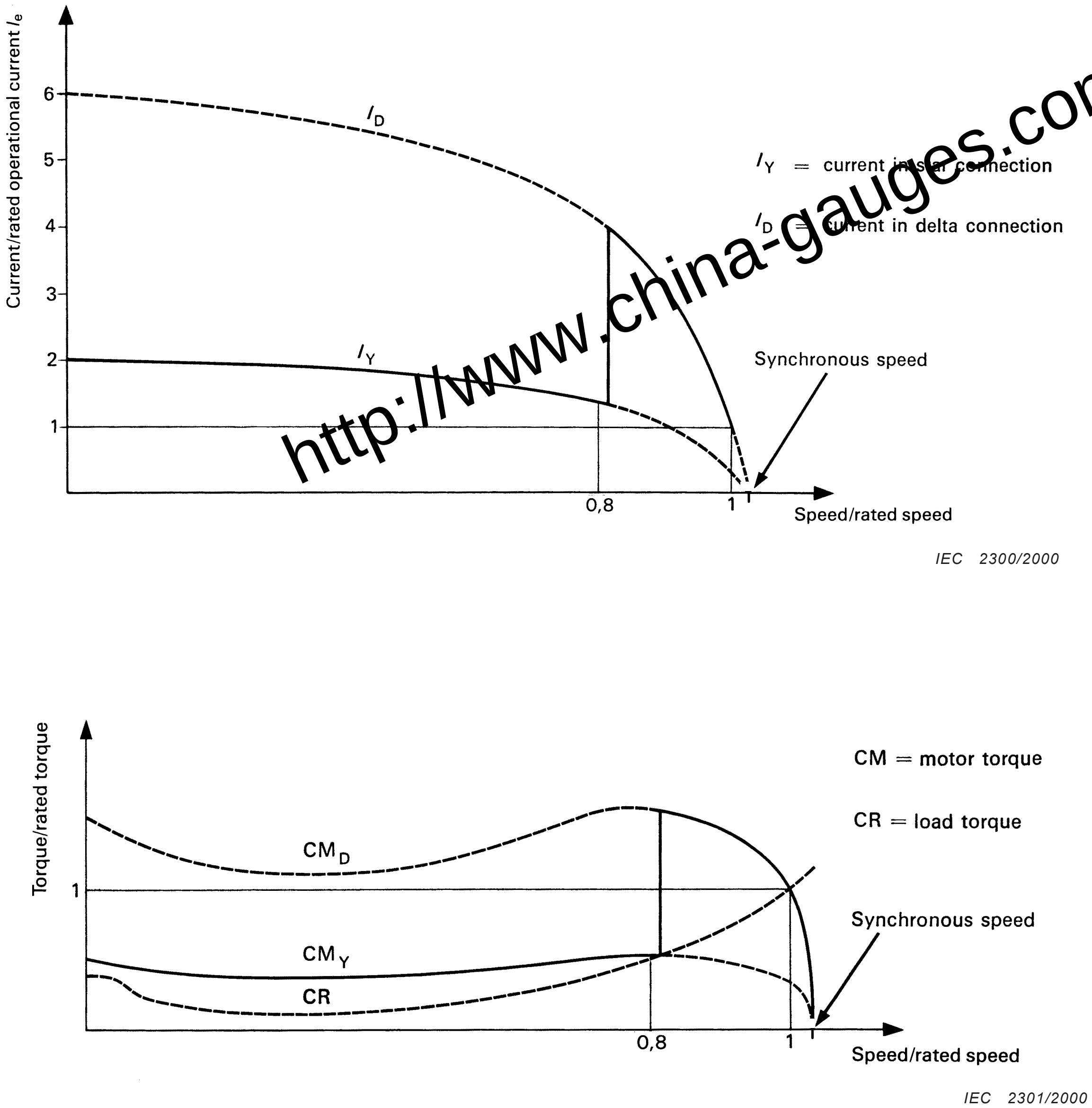
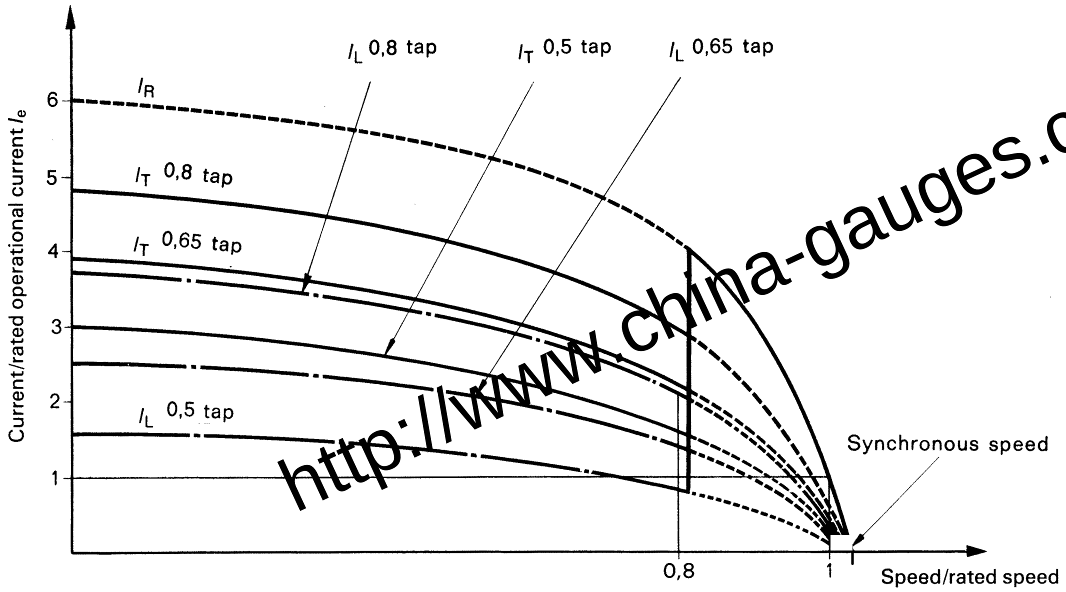


Figure 1 – Typical curves of currents and torques during a star-delta start (see 1.1.2.2.1)

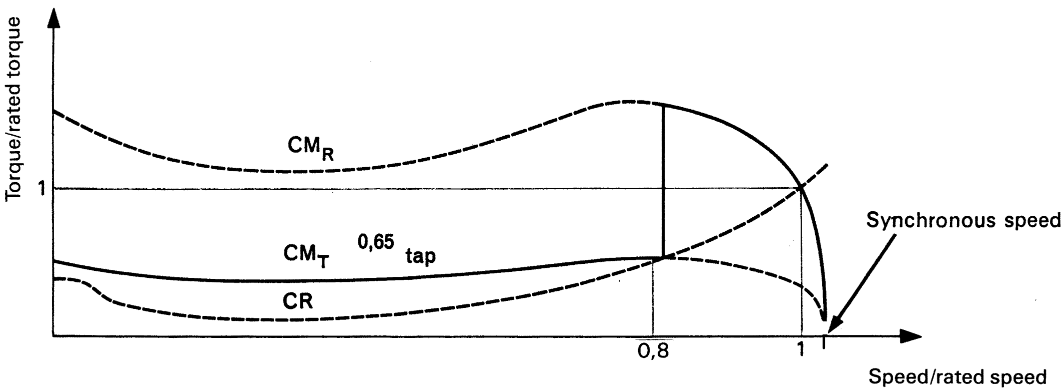


IEC 2302/2000

I_R = motor current at rated voltage

I_T = motor current at reduced voltage

I_L = line current at reduced voltage



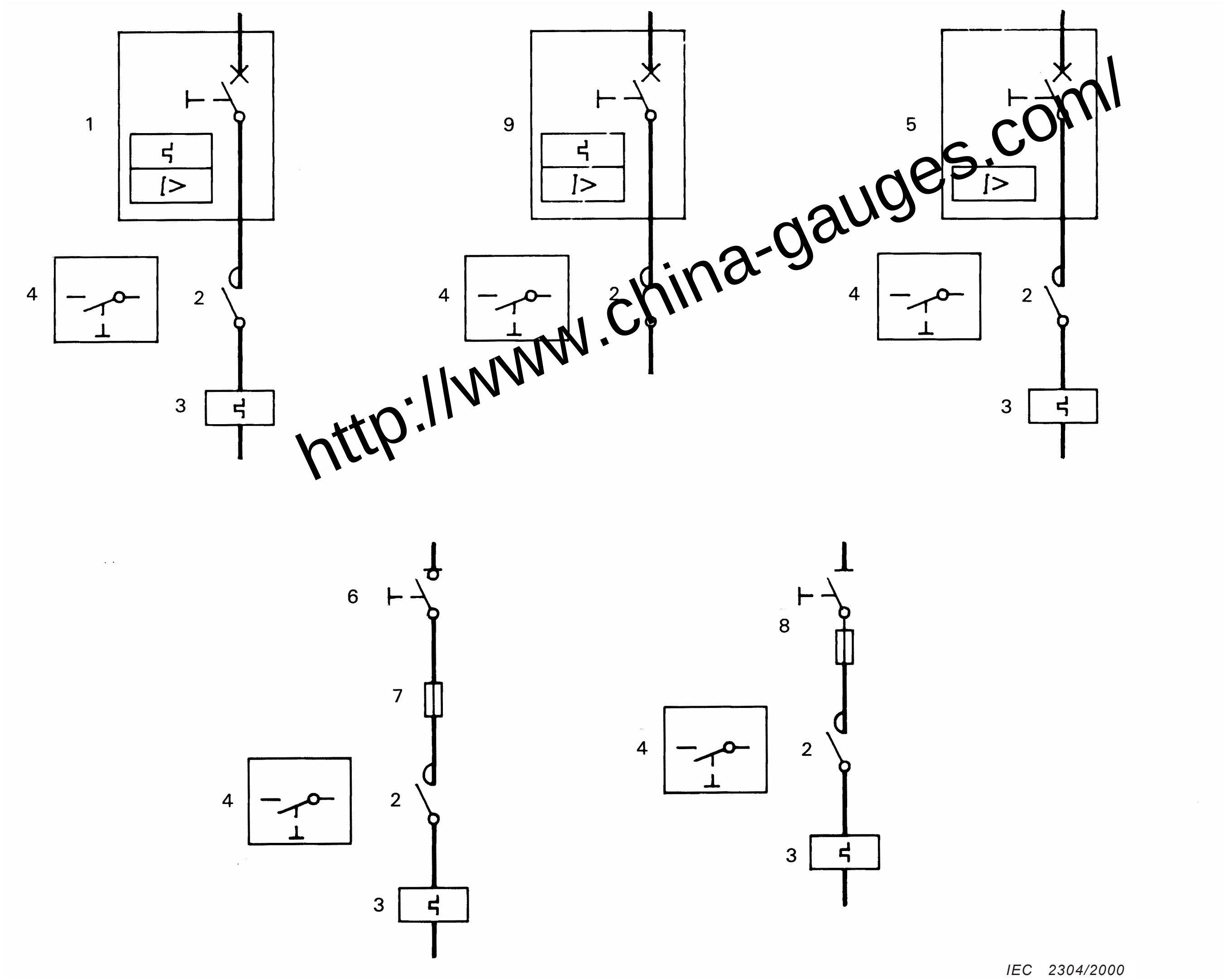
IEC 2303/2000

CR = load torque

CM_R = motor torque at rated voltage

CM_T = motor torque at reduced voltage

Figure 2 – Typical curves of currents and torques during an auto-transformer start (see 1.1.2.2.2)



A1 1 circuit-breaker according to IEC 60947-2 A1

2 contactor

3 overload relay

4 control switch

5 circuit-breaker magnetic trip only

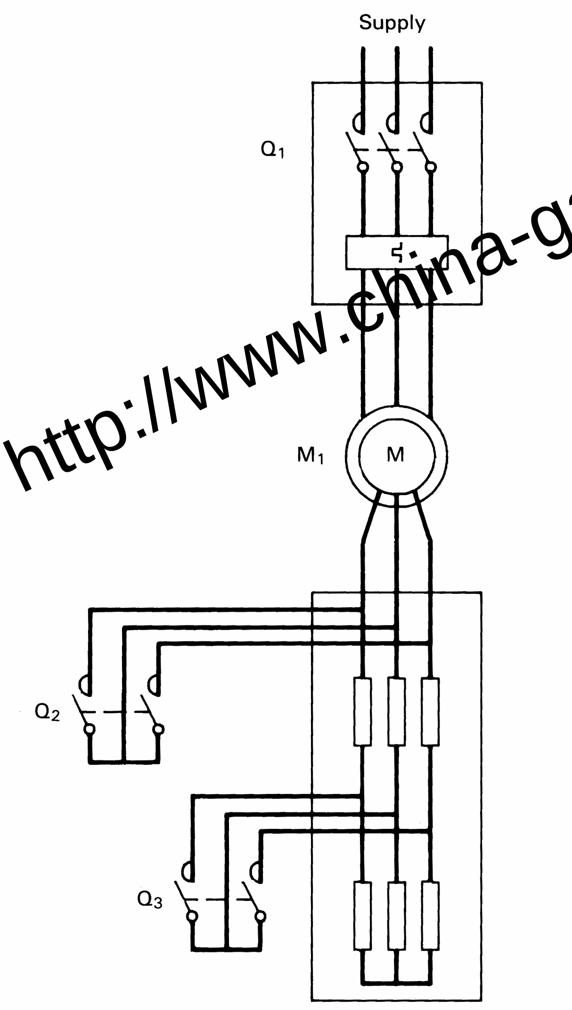
6 switch-disconnector

7 fuse

8 disconnector fuse

A1 9 motor protection circuit-breaker according to this standard A1

Figure 3 – Typical variants of protected starters, combination starters, protected switching devices and combination switching devices



IEC 2305/2000

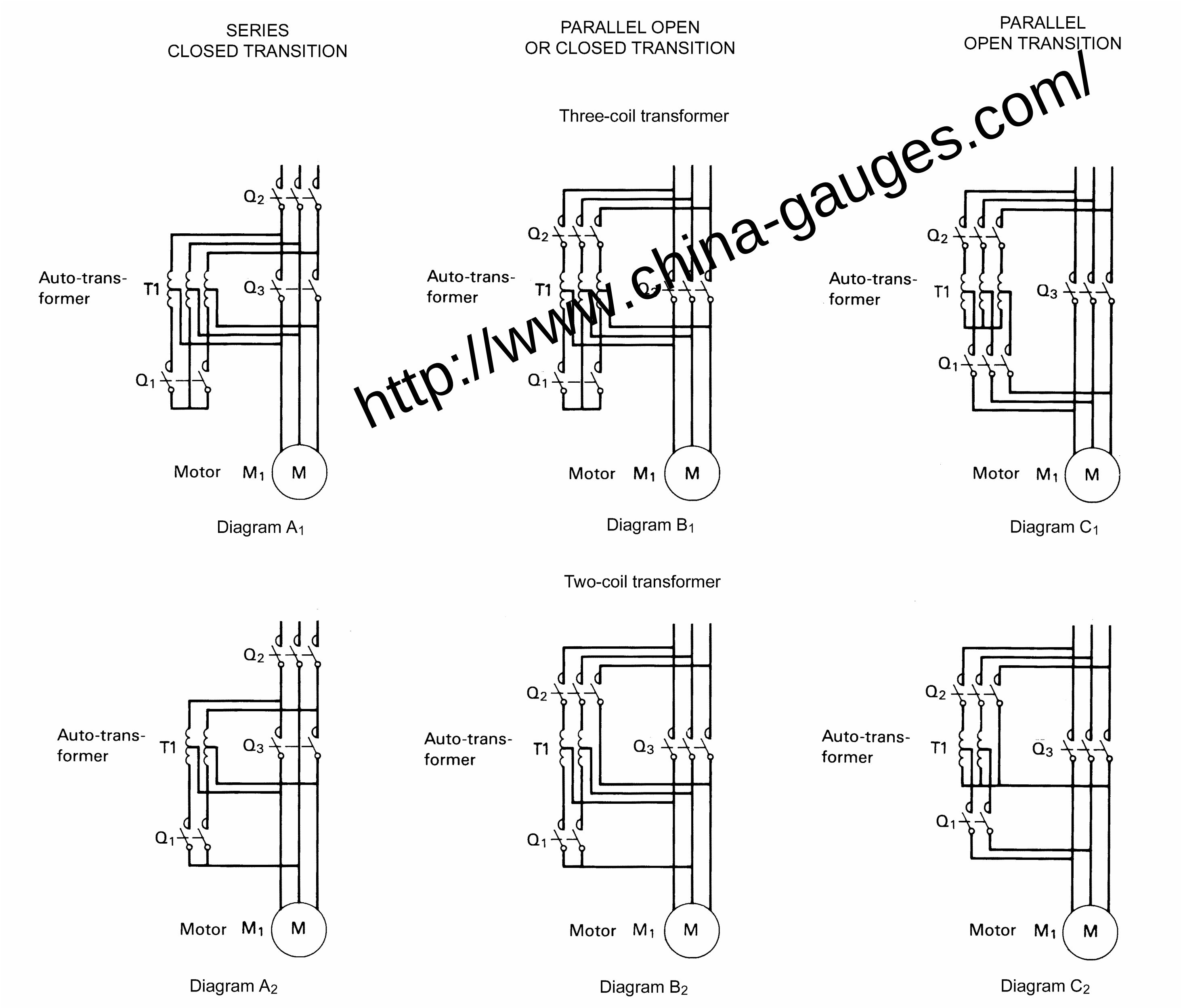
Position of the mechanical switching devices

Position of the starter / Mechanical switching device	Stop	Starting			ON		
		1st step	2nd step	3rd step			
Q_1	O	C	C	C			
Q_2	O	O	O	C			
Q_3	O	O	C	C			

O mechanical switching device open Q contactor

C mechanical switching device closed M motor

Figure 4 – Example of three-phase diagram of a rheostatic rotor starter with three starting steps and one direction of rotation (in the case when all the mechanical switching devices are contactors)



IEC 2306/2000

Contact sequence			
Contacts	Start	Transition	On
Q_1	C	O	O
Q_2	C	C	C
Q_3	O	O	C

C = contact closed

O = contact open

Contact sequence					
Contacts	Start	Transition			On
		Open	Close		
			1	2	
Q_1	C	O	O	O	O
Q_2	C	O	C	C	O
Q_3	O	O	O	C	C

For open transition, Q_1 and Q_2 may be contacts of the same mechanical switching device

Contact sequence			
Contacts	Start	Transition	On
Q_1	C	O	O
Q_2	C	O	O
Q_3	O	O	C

Q_1 and Q_2 may be contacts of the same mechanical switching device.

NOTE The graphical symbols utilized above correspond to the case where all the mechanical switching devices are contactors.

Figure 5 – Typical methods and diagrams of starting alternating-current induction motors by means of auto-transformers

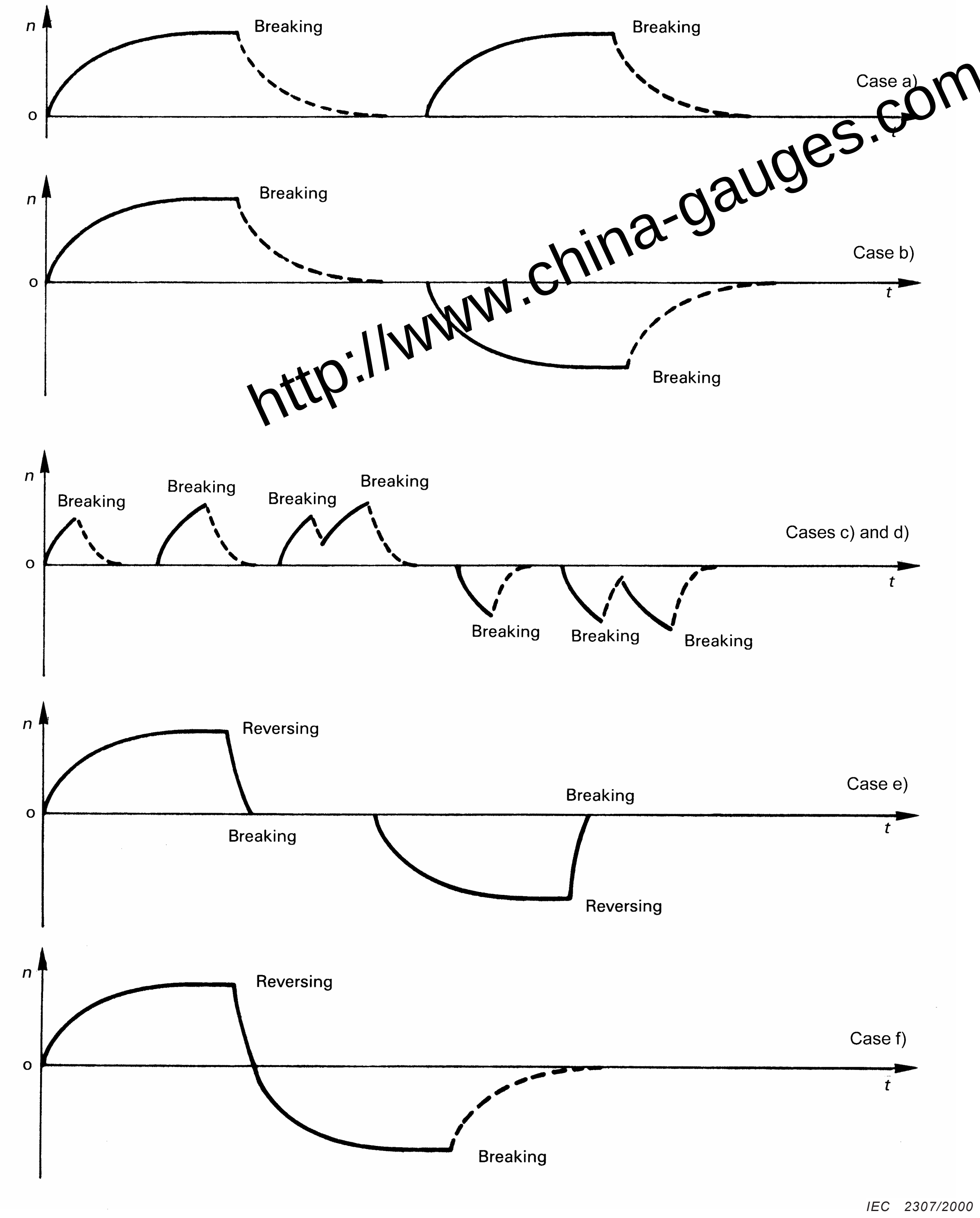


Figure 6 – Examples of speed/time curves corresponding to cases a), b), c), d), e) and f) of 5.3.5.5 (the dotted parts of the curves correspond to the periods when no current flows through the motor)

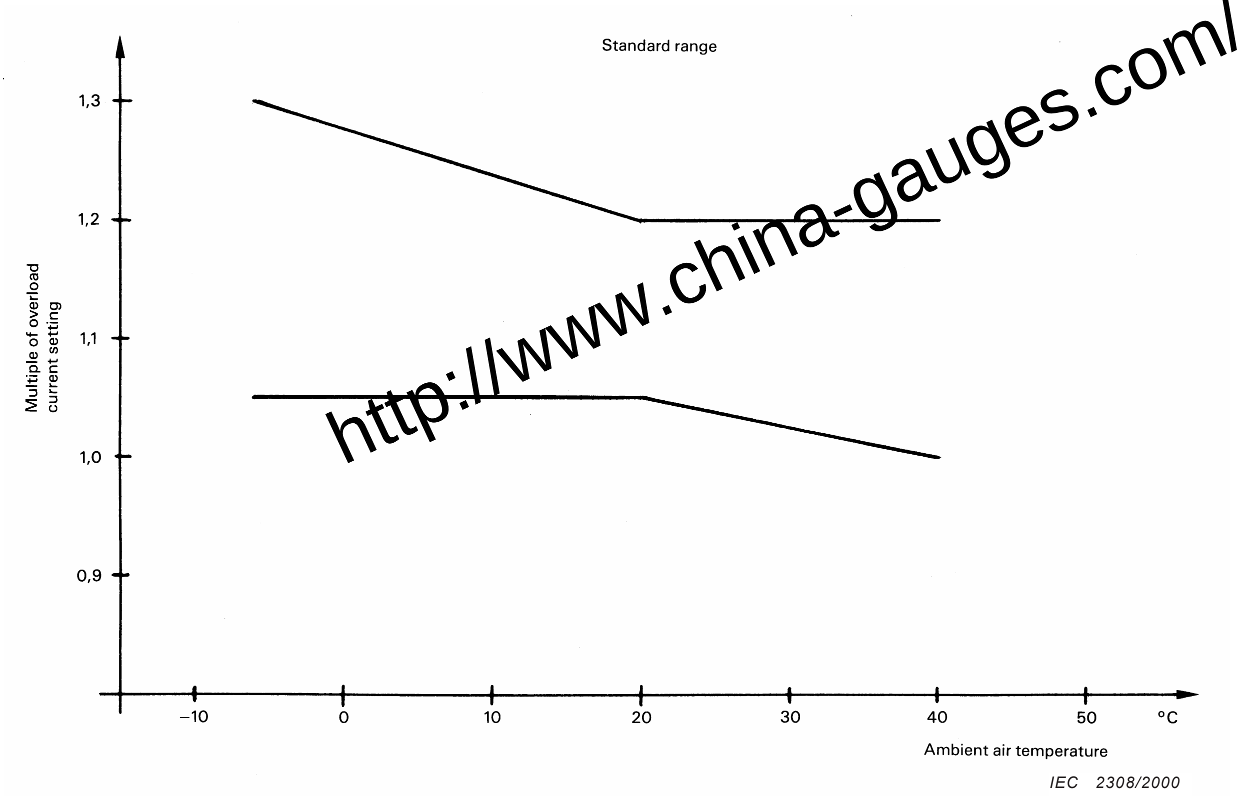


Figure 7 – Multiple of current setting limits for ambient air temperature compensated time-delay overload relays (see 8.2.1.5.1)

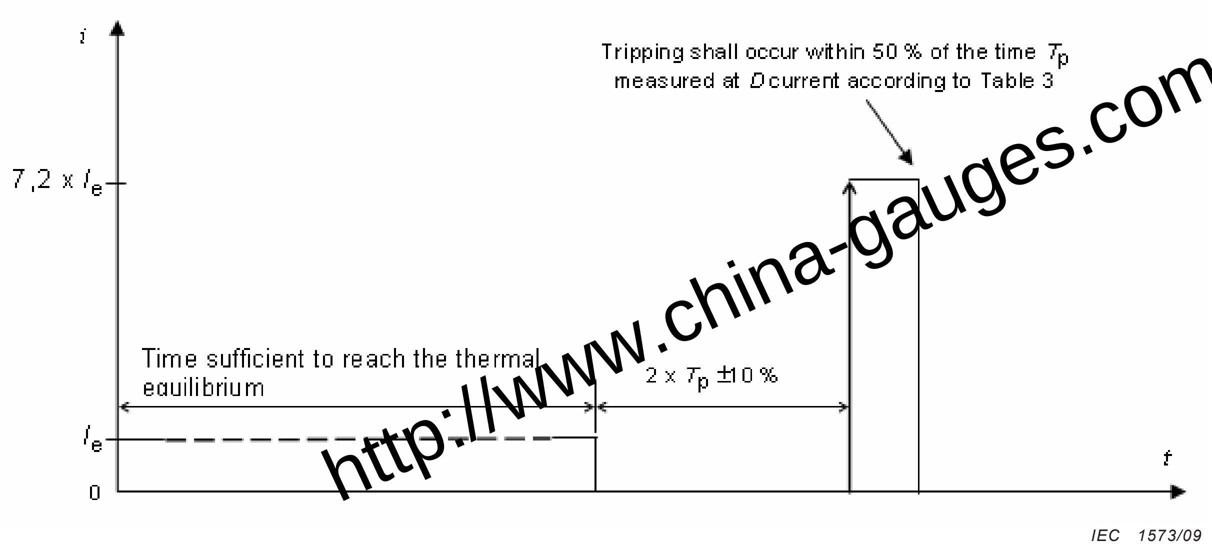


Figure 8 – Thermal memory test

A1

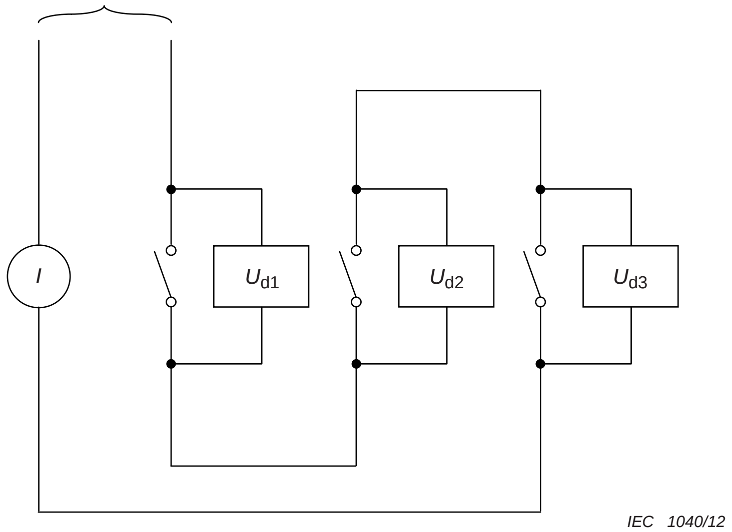


Figure 9 – Example of a pole impedance measurement for a 3 pole contactor

Dimmensions in millimetres

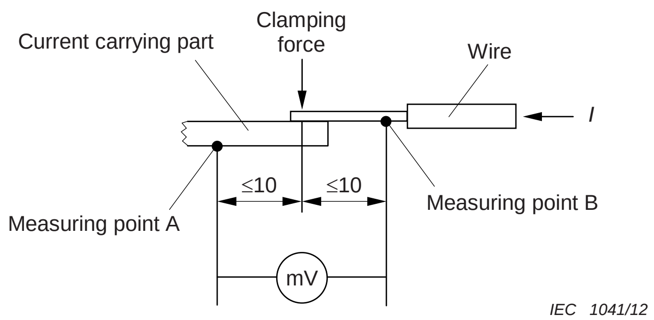


Figure 10 – Voltage drop measurement at contact point of the clamping terminal A1

Annex A
(normative)

Marking and identification of terminals of contactors and associated overload relays

A.1 General

The purpose of identifying terminals of contactors and associated overload relays is to provide information regarding the function of each terminal or its location with respect to other terminals or for other use.

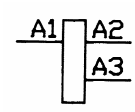
A.2 Marking and identification of terminals of contactors

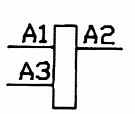
A.2.1 Marking and identification of terminals of coils

In the case of identification by alphanumeric markings, the terminals of a coil for an electromagnetic contactor shall be marked A1 and A2.

For a coil with tappings, the terminals of the tappings shall be marked in sequential order A3, A4, etc.

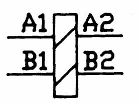
EXAMPLE





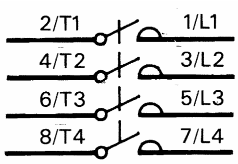
NOTE As a consequence of this, both incoming and outgoing terminals may have even or odd numbers.

For a coil having two windings, the terminals of the first winding will be marked A1, A2 and those of the second winding B1, B2.



A.2.2 Marking and identification of terminals of main circuits

The terminals of the main circuits shall be marked by single figure numbers and an alphanumeric system.



NOTE The present alternative methods of marking, i.e. 1-2 and L1-T1, will be progressively superseded by the new method above.

Alternatively, terminals may be identified on the wiring diagram supplied with the device.

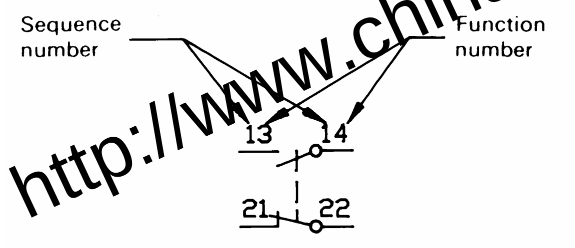
A.2.3 Marking and identification of terminals of auxiliary circuits

The terminals of auxiliary circuits shall be marked or identified on the diagrams by two figure numbers:

– the unit number is a function number;

– the figure of the tens is a sequence number.

The following examples illustrate such a marking system:

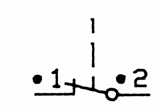


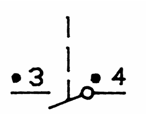
A.2.3.1 Function number

Function numbers 1, 2 are allocated to circuits with break contacts and function numbers 3, 4 to circuits with make contacts.

NOTE 1 The definitions for make contacts and break contacts are given in 2.3.12 and 2.3.13 of IEC 60947-1.

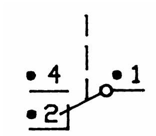
EXAMPLES





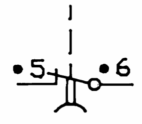
NOTE 2 The dots in the above examples take the place of the sequence numbers which should be added appropriately to the application.

The terminals of circuits with change-over contact elements shall be marked by the function numbers 1, 2 and 4.

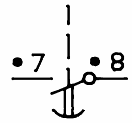


Function numbers 5 and 6 (for break contacts) and 7 and 8 (for make contacts) are allocated to terminals of auxiliary circuits containing auxiliary contacts with special functions.

EXAMPLES



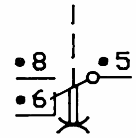
Break contact delayed on closing



Make contact delayed on closing

The terminals of circuits with change-over contact elements with special functions shall be marked by function numbers 5, 6 and 8.

EXAMPLE



Change-over contact
delayed in both directions

A.2.3.2 Sequence number

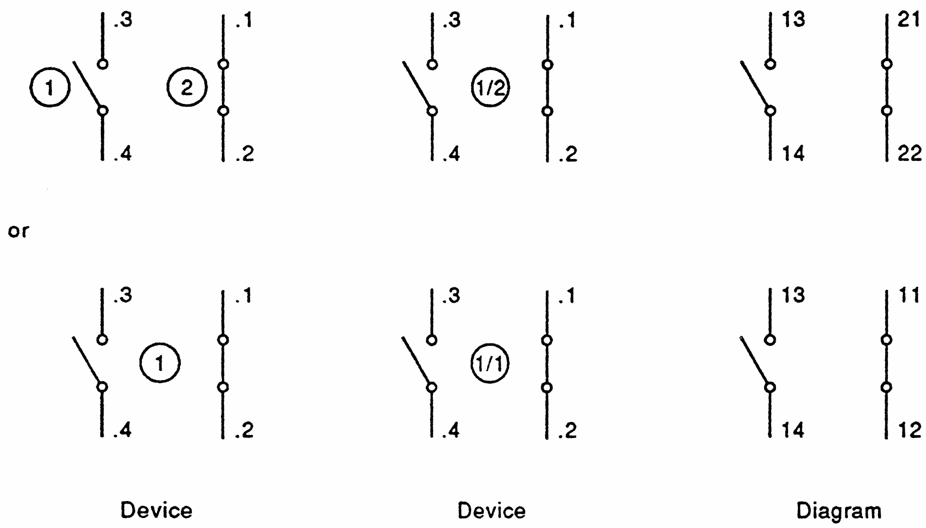
Terminals belonging to the same contact element shall be marked by the same sequence number.

All contact elements having the same function shall have different sequence numbers.

EXAMPLES

Four contact elements   Three contact elements

The sequence number may be omitted from the terminals only if additional information provided by the manufacturer or the user clearly gives such a number.



NOTE The dots shown in the above examples are merely used to show the relationship and do not need to be used in practice.

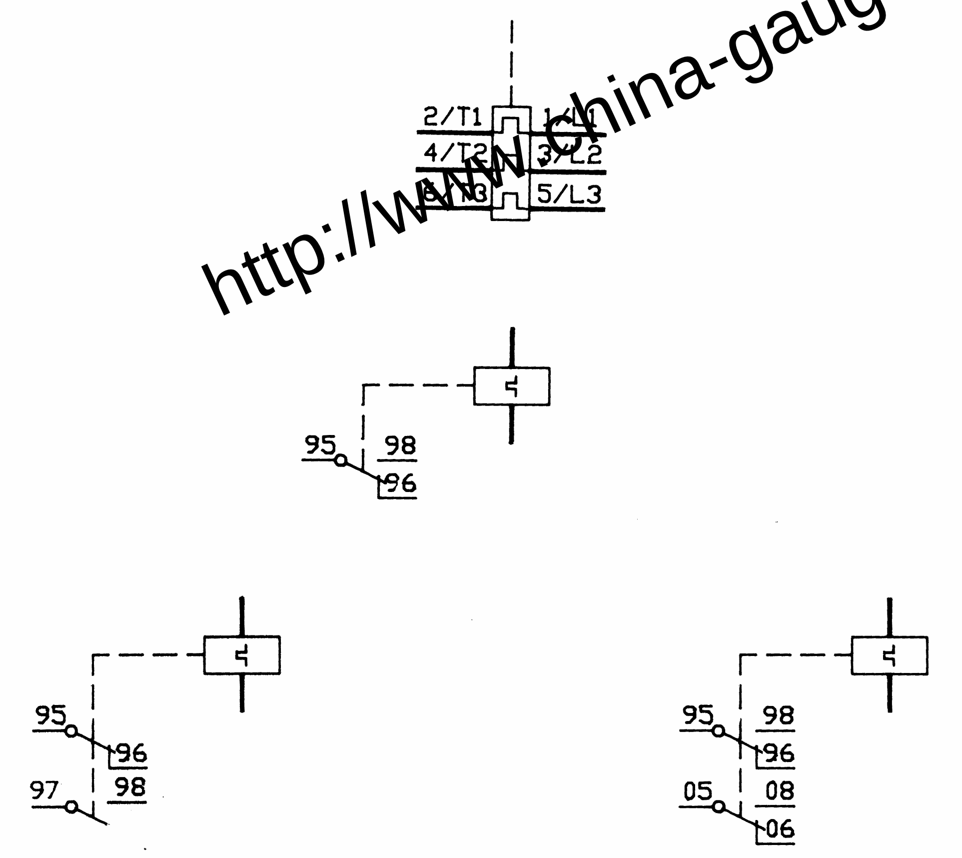
A.3 Marking and identification of terminals of overload relays

The terminals of the main circuits of overload relays shall be marked in the same manner as the terminals of the main circuits of contactors (see A.2.2).

The terminals of the auxiliary circuits of overload relays shall be marked in the same manner as the terminals of the auxiliary circuits of contactors with specified functions (see A.2.3).

The sequence number shall be 9; if a second sequence number is required, it shall be 0.

EXAMPLES



Alternatively, terminals may be identified on the wiring diagram supplied with the device.

Annex B
(normative)

Special tests

B.1 General

Special tests are done at the discretion of the manufacturer.

B.2 Mechanical durability

B.2.1 General

By convention, the mechanical durability of a design of contactor or starter is defined as the number of no-load operating cycles which would be attained or exceeded by 90 % of all the apparatus of this design before it becomes necessary to service or replace any mechanical parts; however, normal maintenance including replacement of contacts as specified in B.2.2.1 and B.2.2.3 is permitted.

The preferred numbers of no-load operating cycles, expressed in millions, are:

0,001 – 0,003 – 0,01 – 0,03 – 0,1 – 0,3 – 1 – 3 and 10.

B.2.2 Verification of mechanical durability

B.2.2.1 Condition of the contactor or starter for tests

The contactor or starter shall be installed as for normal service; in particular, the conductors shall be connected in the same manner as for normal use.

During the test, there shall be no voltage or current in the main circuit. The contactor or starter may be lubricated before the test if lubrication is prescribed in normal service.

B.2.2.2 Operating conditions

The coils of the control electromagnets shall be supplied at their rated voltage and, if applicable, at their rated frequency.

If a resistance or an impedance is provided in series with the coils, whether short-circuited during the operation or not, the tests shall be carried out with these elements connected as in normal operation.

Pneumatic and electro-pneumatic contactors or starters shall be supplied with compressed air at the rated pressure.

Manual starters shall be operated as in normal service.

B.2.2.3 Test procedure

a) The tests are carried out at the frequency of operations corresponding to the class of intermittent duty. However, if the manufacturer considers that the contactor or starter can satisfy the required conditions when using a higher frequency of operations, he may do so.
b) In the case of electromagnetic and electro-pneumatic contactors or starters, the duration of energization of the control coil shall be greater than the time of operation of the

contactor or starter and the time for which the coil is not energized shall be of such a duration that the contactor or starter can come to rest at both extreme positions.

The number of operating cycles to be carried out shall be not less than the number of no-load operating cycles stated by the manufacturer.

The verification of mechanical durability may be made separately on the various components of the starter which are not mechanically linked together, unless a mechanical interlock not previously tested with its contactor is involved.

c) For contactors or starters fitted with releases with shunt coils or undervoltage releases, at least 10 % of the total number of opening operations shall be performed by these releases.

d) After each tenth of the total number of operating cycles given in B.2.1 has been carried out, it is permissible before carrying on with the test:

– to clean the whole contactor or starter without dismantling;

– to lubricate parts for which lubrication is prescribed by the manufacturer for normal service;

– to adjust the travel and the pressure of the contacts if the design of the contactor or starter enables this to be done.

e) This maintenance work shall not include any replacement of parts.

f) In the case of star-delta starters, the built-in device causing time-delay between closing on star connection and closing on delta connection, if adjustable, may be set at its lowest value.

g) In the case of rheostatic starters, the built-in device causing time-delay between closing of the rotor switching devices, if adjustable, may be set at its lowest value.

h) In the case of auto-transformer starters, the built-in device causing time-delay between closing on the starting position and closing on the ON position, if adjustable, may be set at its lowest value.

B.2.2.4 Results to be obtained

A1⟩ Following the tests of mechanical durability, the contactor or starter shall still be capable of complying with the operating conditions specified in 9.3.6.2 and 9.3.6.3 at room temperature. ⟨A1

Any timing relays or other devices for the automatic control shall still be operating.

B.2.2.5 Statistical analysis of test results for contactors or starters

The mechanical durability of a design of a contactor or starter is assigned by the manufacturer and verified by a statistical analysis of the results of the tests.

For contactors or starters which are produced in small quantities, the tests described in B.2.2.6 and B.2.2.7 do not apply.

However, for contactors or starters which are produced in small quantities and which also differ from a basic design only by minor variations without notable influence on characteristics, the manufacturer may assign mechanical durability on the basis of experience with similar designs, analysis, properties of materials, etc., and on the basis of the analysis of test results on large quantity production of the same basic design.

After this assignment, one of the two tests described below shall be performed. It should be selected by the manufacturer as being the most suitable in each case, for example according to the quantities of planned production or according to the conventional thermal current.

NOTE This test is not intended to be a lot-by-lot or production acceptance test for application by the user.

B.2.2.6 Single 8 test

Eight contactors or starters shall be tested to the assigned mechanical durability.

If the number of failures does not exceed two, the test is considered passed.

B.2.2.7 Double 3 test

Three contactors or starters shall be tested to the assigned mechanical durability.

The test is considered passed if there is no failure, and failed if there is more than one failure. Should there be one failure, then three additional contactors or starters are tested up to assigned mechanical durability and, providing there is no additional failure, the test is considered passed. The test is failed if at any time there is a total of two or more failures.

B.2.2.8 Other methods

Other methods given in IEC 60410 can also be used. The maximum acceptance quality level shall be 10 %. The chosen method shall be indicated in the test report.

NOTE The single 8 test and the double 3 test are both given in IEC 60410 (see Table X-C-2 and Table X-D-2). These two tests have been chosen with the objective of basing them on testing a limited number of contactors or starters on essentially the same statistical characteristics (acceptance quality level: 10 %).

B.3 Electrical durability

B.3.1 General

With respect to its resistance to electrical wear, a contactor or starter is by convention characterized by the number of on-load operating cycles corresponding to the different utilization categories given in Table B.1 which can be made without repair or replacement.

Since, for star-delta, two-step auto-transformer and rheostatic rotor starters, the operation is subjected to large variations in the service conditions, it is deemed convenient not to give standard values for the test conditions. However, it is recommended that the manufacturer indicate the electrical durability of the starter for stated service conditions; this electrical durability may be estimated from the results of tests on the component parts of the starter.

For categories AC-3 and AC-4, the test circuit shall comprise inductors and resistors so arranged as to give the appropriate values of current, voltage and power factor given in Table B.1; moreover, for AC-4, the test circuit testing the making and breaking capacity shall be used, see 9.3.3.5.2.

In all cases, the speed of operation shall be chosen by the manufacturer.

The tests shall be taken as valid if the values recorded in the test report differ from the values specified only within the following tolerances:

– current: ±5 %;
– voltage: ±5 %.

Tests shall be carried out with the contactor or the starter under the appropriate conditions of B.2.2.1 and B.2.2.2 using the test procedure, where applicable, of B.2.2.3, except that replacement of contacts is not permitted.

In the case of starters, if the associated contactor has already satisfied an equivalent test, the test need not be repeated on the starter.

Table B.1 – Verification of the number of on-load operating cycles – Conditions for making and breaking corresponding to the several utilization categories

Utilization category	Value of the rated operational current	Make			Break		
		I/I_e	U/U_e	Cos ϕ [a]	I_c/I_e	U_r/U_e	Cos ϕ [a]
AC-1	All values	1	1	0,95	1	1	0,95
AC-2	All values	2,5	1	0,65	2,5	1	0,65
AC-3	$I_e \le 17$ A	6	1	0,65	1	0,17	0,65
	$I_e > 17$ A	6	1	0,35	1	0,17	0,35
AC-4	$I_e \le 17$ A	6	1	0,65	6	1	0,65
	$I_e > 17$ A	6	1	0,35	6	1	0,35
		I/I_e	U/U_e	L/R [b] ms	I_c/I_e	U_r/U_e	L/R [b] ms
DC-1	All values	1	1	1	1	1	1
DC-3	All values	2,5	1	2	2,5	1	2
DC-5	All values	2,5	1	7,5	2,5	1	7,5

I_e = rated operational current

U_e = rated operational voltage

I = current made

In a.c. the conditions for making are expressed in r.m.s. values but it is understood that the peak value of symmetrical current corresponding to the power factor of the circuit may assume a higher value.

U = applied voltage

U_r = power-frequency or d.c. recovery voltage

I_c = current broken

[a] Tolerance for cos ϕ: ±0,05.

[b] Tolerance for L/R: ±15 %.

B.3.2 Results to be obtained

After the test, the contactor or the starter shall fulfil the operating conditions as specified in 9.3.6.2 of this standard at ambient temperature and withstand a dielectric test voltage as given in 8.3.3.4.1, item 4) b), of IEC 60947-1, and applied as in 8.3.3.4.1, item 4), of IEC 60947-1, the test voltage being applied only:

- between all poles connected together and the frame of the contactor or starter, and
- between each pole and all the other poles connected to the frame of the contactor or starter.

B.3.3 Statistical analysis of test results for contactors or starters

The electrical durability of a design of a contactor or starter is assigned by the manufacturer and verified by a statistical analysis of the results of the tests. One of the three test methods shall be selected by the manufacturer between B.3.3.1, B.3.3.2 and B.3.3.3 as being the most suitable for example according to the quantities of planned production or according to the conventional thermal current.

For contactors or starters which are produced in small quantities, the tests described in B.3.3.1 and B.3.3.2 do not apply. However, for contactors or starters which are produced in small quantities and which also differ from a basic design only by minor variations without notable influence on characteristics, the manufacturer may assign electrical durability on the basis of experience with similar designs, analysis, properties of materials, etc., and on the basis of the analysis of test results on large quantity production of the same basic design.

NOTE This test is not intended to be a lot-by-lot or production acceptance test for application by the user.

B.3.3.1 Single 8 test

Eight contactors or starters shall be tested to the assigned electrical durability. If the number of failures does not exceed two, the test is considered passed.

B.3.3.2 Double 3 test

Three contactors or starters shall be tested to the assigned electrical durability. The test is considered passed if there is no failure, and failed if there is more than one failure. Should there be one failure, then three additional contactors or starters are tested up to assigned electrical durability and, providing there is no additional failure, the test is considered passed. The test is failed if at any time there is a total of two or more failures.

B.3.3.3 Other methods

Other methods given in IEC 60410 can also be used. The maximum acceptance quality level shall be 10 %. The chosen method shall be indicated in the test report.

NOTE The single 8 test and the double 3 test are both given in IEC 60410 (see Table X-C-2 and Table X-D-2). These two tests have been chosen with the objective of basing them on testing a limited number of contactors or starters on essentially the same statistical characteristics (acceptance quality level: 10 %).

B.4 Co-ordination at the crossover current between the starter and associated SCPD

B.4.1 General and definitions

B.4.1.1 General

This annex states different methods of verifying the performance of starters and the associated SCPD(s) at currents below and above the intersection I_{co} of their respective time-current characteristics, provided by the starter and SCPD manufacturer(s), and the corresponding types of co-ordination described in 8.2.5.1.

Co-ordination at the crossover current between the starter and the SCPD can be verified either by the direct method with the special test of B.4.2 or, for type "2" co-ordination, by the indirect method as in B.4.5.

B.4.1.2 Terms and definitions

B.4.1.2.1
crossover current I_{co}
current corresponding to the crossover point of the mean or published curves representing the time-current characteristics of the overload relay and the SCPD respectively

NOTE The mean curves are the curves corresponding to the average values calculated from the tolerances on the time-current characteristics given by the manufacturer.

B.4.1.2.2
test current I_{cd}
test current greater than I_{co}, tolerances included, designated by the manufacturer and verified by the requirements given in Table B.2

B.4.1.2.3
time-current withstand characteristic capability of contactors/starters
locus of the currents a contactor/starter can withstand as a function of time

B.4.2 Condition for the test for the verification of co-ordination at the crossover current by a direct method

The starter and its associated SCPD shall be mounted and connected as in normal use. All the tests shall be performed starting from the cold state.

B.4.3 Test currents and test circuits

The test circuit shall be according to 8.3.3.5.2 of IEC 60947-1 except that the oscillatory transient voltage need not be adjusted. The currents for the tests shall be:

(i) $0{,}75\ I_{co}\ {}^{\ 0}_{-5}$ % and

(ii) $1{,}25\ I_{co}\ {}^{+5}_{\ 0}$ %.

The power factor of the test circuit shall be in accordance with Table 7. In the case of small relays having a high resistance, inductors should be mainly used in order to have a value of power factor as low as possible. The recovery voltage shall be 1,05 times the rated operational voltage.

The SCPD shall be as stated in 8.2.5.1 and of the same rating and characteristics as used in the tests of 9.3.4.2.

If the switching device is a contactor, its coil shall be energized from a separate source at the rated control supply voltage of the contactor coil and connected so that the contactor opens when the overload relay operates.

B.4.4 Test procedure and results to be obtained

B.4.4.1 Test procedure

With the starter and the SCPD closed, the test currents stated in B.4.3 shall be applied by a separate closing device. In each case, the device tested shall be at room temperature.

[A1] Co-ordination at the crossover current between the starter and the SCPD can be verified either by the direct method with the special test of B.4.2 or, for type "2" co-ordination only, by the indirect method as in B.4.5. [A1]

B.4.4.2 Results to be obtained

After the test at the lower current (i) in B.4.3, the SCPD shall not have operated and the overload relay or release shall have operated to open the starter. There shall be no damage to the starter.

After the test at the higher current (ii) in B.4.3, the SCPD shall have operated before the starter. The starter shall meet the conditions of 9.3.4.2.3 for the type of co-ordination stated by the manufacturer.

B.4.5 Verification of co-ordination at the crossover current by an indirect method

[A1] *NOTE deleted* [A1]

The indirect method consists in verifying on a diagram (see Figure B.1) that the following conditions for the verification of co-ordination at the crossover current are met:

– the time-current characteristic of the overload relay/release, starting from cold state, supplied by the manufacturer, shall indicate how the tripping time varies with the current up to a value of at least I_{co}; this curve has to lie below the time-current characteristic of the SCPD up to I_{co};

– I_{cd} of the starter, tested as in B.4.5.1, shall be higher than I_{co};

– the time-current withstand characteristic of the contactor, tested as in B.4.5.2, shall be above the time-current characteristic (starting from cold state) of the overload relay up to I_{co}.

B.4.5.1 Test for I_{cd}

Subclause 9.3.4.1 applies with the following addition.

– Test procedure: the contactor or starter shall make and break the test current (I_{cd}) for the number of operating cycles given in Table B.2 below. This is made without the SCPD in the circuit.

Table B.2 – Test conditions

	U_r/U_e	Cos ϕ	On-time (see Note 2) s	Off-time s	Number of operations
I_{cd}	1,05	See Note 1	0,05	See Note 3	3

NOTE 1 Power factor to be selected according to Table 16 of IEC 60947-1.

NOTE 2 Time may be less than 0,05 s provided that contacts are allowed to become properly seated before re-opening.

NOTE 3 See Table 8.

– Behaviour of contactors or starters during and after the I_{cd} test:

a) during the test, there shall be no permanent arcing, no flash-over between poles, no blowing of the fusible element in the earth circuit (see 9.3.4.1.2) and no welding of contacts;

b) after the test,

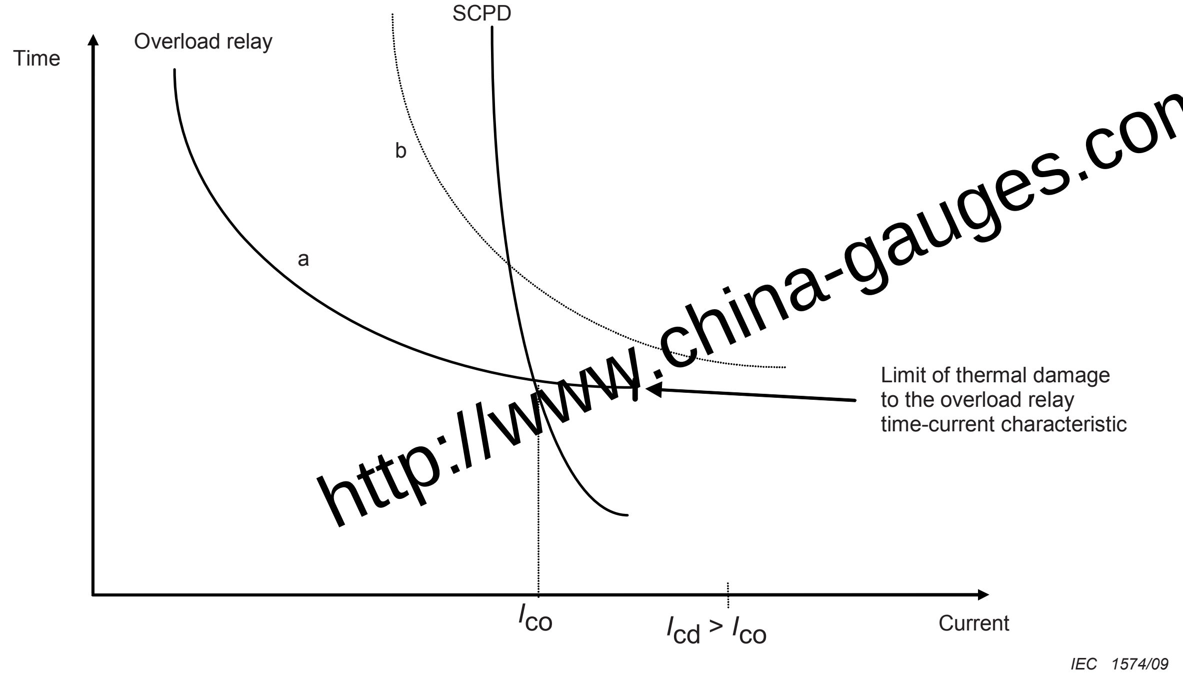
1) the contacts shall operate correctly when the contactor or starter is switched by the applicable method of control;

2) the dielectric properties of the contactors and starters shall be verified by a dielectric test on the contactor or starter using an essentially sinusoidal test voltage of twice the rated operational voltage U_e used for the I_{cd} test, with a minimum of 1 000 V. The test voltage shall be applied for [A1) 5s (A1] , as specified in 8.3.3.4.1 of IEC 60947-1, items 2) c) i) and 2) c) ii).

B.4.5.2 Time-current characteristic withstand capability of contactors/starters

This characteristic is issued by the manufacturer and the values are obtained according to the test procedure specified in 9.3.5 but with combinations of overload currents and durations to establish the characteristic at least up to I_{co}, in addition to those stated in 8.2.4.4.

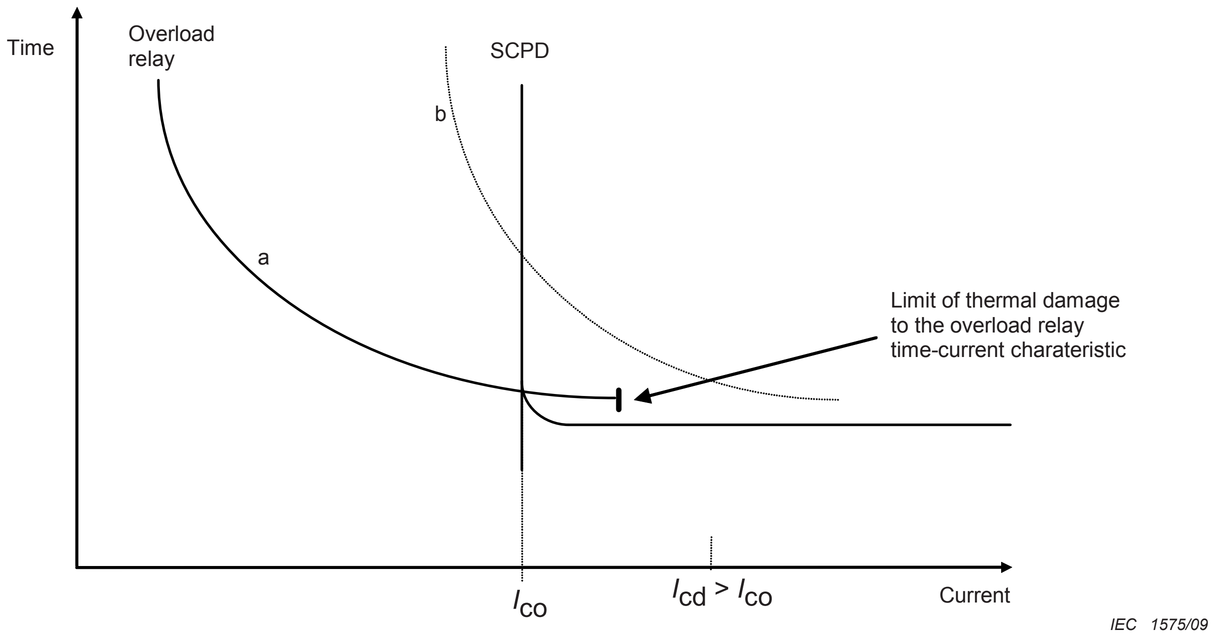
This characteristic is valid for overload currents, starting with the contactor at room temperature. The minimum cooling duration required by the contactor between two such overload tests should be stated by the manufacturer.



a mean overload relay time-current characteristic from cold state

b time-current characteristic withstand capability of contactor

Figure B.1a – Co-ordination with fuse



a mean overload relay time-current characteristic from cold state

b time-current characteristic withstand capability of contactor

Figure B.1b – Co-ordination with circuit-breaker

Figure B.1 – Examples of time-current withstand characteristic

Annex C

Void

Annex D
(informative)

Items subject to agreement between manufacturer and user

NOTE For the purpose of this annex:

– *agreement* is used in a very wide sense;

– *user* includes testing stations.

Annex J of IEC 60947-1 applies, as far as covered by clauses and subclauses of this standard, with the following additions.

Clause or subclause number of this standard	Item
1.1.2.3	Additional requirements concerning two-direction starters and inching and plugging
5.3.4.3 – Note	Overload protection of starters for intermittent duty
5.3.5.5.3	Time interval between two successive starts of auto-transformer starters having a starting time exceeding 15 s
5.4	Types of utilization other than the utilization categories defined in Table 1
5.7.2	Specific applications of instantaneous over-current relays or releases and of relays or releases listed in 5.7.2 e)
5.7.3	Protection of the rotor circuit for a rheostatic rotor starter
5.7.3	Protection of the auto-transformer for an auto-transformer starter
5.7.5	Tolerances on time-current characteristics of overload relays (to be indicated by the manufacturer)
5.10.2	Characteristics of devices for automatic acceleration control
5.11; 5.12	Nature and dimensions of the connecting links: a) between an auto-transformer starter and the auto-transformer, if this is provided separately b) between a rheostatic rotor starter and the resistors, if these are provided separately Agreement for items a) and b) is to be concluded between the starter manufacturer and the manufacturer of the transformer, or of the resistors, as the case may be
8.2.2.7.3	Ratings of specially rated windings (to be stated by the manufacturer)
Table 7	Verification of the make conditions when this verification is carried out during the make and break test (manufacturer's agreement)
Table 13	Value of the prospective current "*r*" for the conditional short-circuit current test of devices of I_e > 1 600 A

Annex E
A1 Void A1

A1 *Text deleted* A1

Annex F
(normative)

Requirements for auxiliary contact linked with power contact (mirror contact)

F.1 Scope and object

F.1.1 Scope

This annex applies to auxiliary contacts mechanically linked with power contacts of a contactor and designated as mirror contacts in order to avoid any confusion with mechanically linked contact elements dealt within Annex L of IEC 60947-5-1. However, that does not prevent a given auxiliary contact to comply with both requirements for mirror contact of this annex and for mechanically linked contact of Annex L of IEC 60947-5-1.

NOTE 1 A typical application of mirror contacts is to have, in the machine control circuit, a highly reliable monitoring of the status of the contactor. However, mirror contact should not be relied upon exclusively as a means to ensure safety.

NOTE 2 Mirror contacts have previously been referred to as positively safety contacts, forced contacts, linked contacts or positively driven contacts.

[A1) NOTE 3 The meaning of “mechanically linked” is also applicable to additional contact blocks which can be mounted by the user. (A1]

F.1.2 Object

This annex provides additional specifications (definition, requirements and tests) which shall be used for stating the required design characteristics, marking and performance of mirror contact.

F.2 Terms and definitions

For the purposes of this annex, the following term and definition applies.

F.2.1
mirror contact
normally closed auxiliary contact which cannot be in closed position simultaneously with the normally open main contact under conditions defined in Clause F.7

NOTE One contactor may have more than one mirror contact.

F.3 Characteristics

All mirror contacts shall also comply with the relevant requirements given in this standard.

F.4 Product information

Clause 6 applies with the following addition.

Mirror contacts shall be clearly identified:

– on the contactor itself, or
– in the manufacturer documentation, or
– both.

Where a symbol is used to identify a mirror contact, it shall be as shown in Figure F.1.

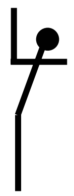


Figure F.1 – Mirror contact

F.5 Normal service, mounting and transport conditions

There are no supplementary requirements.

F.6 Constructional and performance requirements

Clause 8 applies with the following addition.

When any of the main contacts is closed, no mirror contact shall be closed.

NOTE Self-checking of the mirror contact circuit is recommended.

F.7 Tests

F.7.1 General

Clause 9 applies with the following addition.

Tests according to both F.7.2 and F.7.3 shall be carried out.

F.7.2 Tests on products in a new condition

For each mirror contact, the test shall be carried out on *m* products, where *m* is the number of main contacts.

A new product is used for testing each mirror contact with each of the main contacts.

The tests shall be carried out on products in a new and clean condition. The test procedure shall be as follows:

a) To simulate the occurrence of welding on one main pole, one main contact shall be maintained in the closed position, e.g. by welding or gluing each point of contact (e.g. for double breaking contact, welding is carried out at the two contact points). The thickness of welding or gluing shall be such that the distance between contacts is not modified significantly and the method used shall be described in the test report.

b1) With the operating coil de-energized, an impulse test voltage of 2,5 kV at sea level (correction should be made according to Table F.1 given below, calculated from Table 12 of IEC 60947-1) shall be applied across the mirror contact. There shall be no disruptive discharge.

Table F.1 – Test voltage according to altitude

Sea level	200 m	500 m	1 000 m	2 000 m
2,5 kV	2,37 kV	2,37 kV	2,29 kV	2,12 kV
NOTE This test ensures a minimum gap of 0,5 mm in accordance with Figures A.1, Figure A.2 and Figure A.3 of IEC 60664-1 from which Table 13 of IEC 60947-1 is issued.				

b2) As an alternative to item 1) above, with the operating coil de-energized, the gap of the contact shall be measured with direct means; it shall be more than 0,5 mm. In case of two or more contact gaps in series, the sum of contact gaps shall be more than 0,5 mm.

The sequences a) and b) (1) or 2)) are repeated on new samples for each main contact welded successively.

F.7.3 Test after conventional operational performance (defined under Table 10)

At the end of the conventional operational performance tests according to 9.3.3.6, it shall be verified that, when the coil is energized, the mirror contact shall withstand its rated insulation voltage U_i.

Annex G
(informative)

Rated operational currents and rated operational powers of switching devices for electrical motors

G.1 General

The given values in Table G.1 are guide values for the relationship between rated operational currents and rated operational powers. They should be considered for use when information concerning products has to be given to the customers.

The statements of this annex are applicable to all kind of switching devices for electrical motors.

The figures are harmonized within the IEC and therefore state the basis for all the product information given by the manufacturer.

The values given in the Table G.1 are typical rated operational currents of motors for the corresponding rated operational powers.

If the devices are in compliance with these values, they are able to switch on and off most of the existing electrical motors.

These values state a harmonized guideline for design of switching devices.

G.2 Rated operational powers and rated operational currents

Rated operational power is linked with individual rated operational currents at different voltages according to Table G.1.

The guide values for rated operational currents are determined on the basis of a four-pole squirrel-cage motor at 400 V, 1 500 min^{-1} and 50 Hz. The rated operational currents for the other voltages are calculated on the basis of values at 400 V.

Table G.1 – Rated operational powers and rated operational currents of motors

Rated operational power		Guide values of rated operational currents at										
kW [a]	hp [b]	110-120 V A	200 V A	208 V A	230 V A	220-240 V A	380-415 V A	400 V A	440-480 V A	500 V A	550-600 V A	690 V A
0,06 0,09 0,12	– – –	– – –	– – –	– – –	0,35 0,52 0,70	– – –	– – –	0,20 0,30 0,44	– – –	0,16 0,24 0,32	– – –	0,12 0,17 0,23
0,18 0,25 0,37	– – –	– – –	– – –	– – –	1,0 1,5 1,9	– – –	– – –	0,60 0,85 1,10	– – –	0,48 0,68 0,88	– – –	0,35 0,49 0,64
– 0,55 –	1/2 – 3/4	4,4 – 6,4	2,5 – 3,7	2,4 – 3,5	– 2,6 –	2,2 – 3,2	1,3 – 1,8	– 1,5 –	1,1 – 1,6	– 1,2 –	0,9 – 1,3	– 0,87 –
– 0,75 1,1	1 – –	8,4 – –	4,8 – –	4,6 – –	– 3,3 4,7	4,2 – –	2,3 – –	– 1,9 2,7	2,1 – –	– 1,5 2,2	1,7 – –	– 1,1 1,6
– – 1,5	1-1/2 2 –	12,0 13,6 –	6,9 7,8 –	6,6 7,5 –	– – 6,3	6,0 6,8 –	3,3 4,3 –	– – 3,6	3,0 3,4 –	– – 2,9	2,4 2,7 –	– – 2,1
2,2 – 3,0	– 3 –	– 19,2 –	– 11,0 –	– 10,6 –	8,5 – 11,3	– 9,6 –	– 6,1 –	4,9 – 6,5	– 4,8 –	3,9 – 5,2	– 3,9 –	2,8 – 3,8
4 – 5,5	– 5 –	– 30,4 –	– 17,5 –	– 16,7 –	15 – 20	– 15,2 –	– 9,7 –	8,5 – 11,5	– 7,6 –	6,8 – 9,2	– 6,1 –	4,9 – 6,7
– – 7,5	7-1/2 10 –	44,0 56,0 –	25,3 32,2 –	24,2 30,8 –	– – 27	22,0 28,0 –	14,0 18,0 –	– – 15,5	11,0 14,0 –	– – 12,4	9,0 11,0 –	– – 8,9
11 – –	– 15 20	– 84 108	– 48,3 62,1	– 46,2 59,4	38,0 – –	– 42,0 54,0	– 27,0 34,0	22,0 – –	– 21,0 27,0	17,6 – –	– 17,0 22,0	12,8 – –
15 18,5 –	– – 25	– – 136	– – 78,2	– – 74,8	51 61 –	– – 68	– – 44	29 35 –	– – 34	23 28 –	– – 27	17 21 –

Table G.1 *(continued)*

Rated operational power		Guide values of rated operational currents at										
kW [a]	hp [b]	110-120 V A	200 V A	208 V A	230 V A	220-240 V A	380-415 V A	400 V A	440-480 V A	500 V A	550-600 V A	690 V A
22 – –	– 30 40	– 160 208	– 92 120	– 88 114	72 – –	– 80 104	– 51 66	41 – –	– 40 52	33 – –	– 32 41	24 – –
30 37 –	– – 50	– – 260	– – 150	– – 143	96 115 –	– – 130	– – 83	55 66 –	– – 65	44 53 –	– – 52	32 39 –
– 45 55	60 – –	– – –	177 – –	169 – –	– 140 169	154 – –	103 – –	– 80 97	77 – –	– 64 78	62 – –	– 47 57
– – 75	75 100 –	– – –	221 285 –	211 273 –	– – 230	192 248 –	128 165 –	– – 132	96 124 –	– – 106	77 99 –	– – 77
90 – 110	– 125 –	– – –	– 359 –	– 343 –	278 – 340	– 312 –	– 208 –	160 – 195	– 156 –	128 – 156	– 125 –	93 – 113
– 132 –	150 – 200	– – –	414 – 552	396 – 528	– 400 –	360 – 480	240 – 320	– 230 –	180 – 240	– 184 –	144 – 192	– 134 –
150 160 185	– – –	– – –	– – –	– – –	– 487 –	– – –	– – –	– 280 –	– – –	– 224 –	– – –	– 162 –
– 200 220	250 – –	– – –	– – –	– – –	– 609 –	604 – –	403 – –	– 350 –	302 – –	– 280 –	242 – –	– 203 –
– 250 280	300 – –	– – –	– – –	– – –	– 748 –	722 – –	482 – –	– 430 –	361 – –	– 344 –	289 – –	– 250 –
– – 300	350 400 –	– – –	– – –	– – –	– – –	828 954 –	560 636 –	– – –	414 477 –	– – –	336 382 –	– – –

Table G.1 *(continued)*

Rated operational power		Guide values of rated operational currents at										
kW [a]	hp [b]	110-120 V A	200 V A	208 V A	230 V A	220-240 V A	380-415 V A	400 V A	440-480 V A	500 V A	550-600 V A	690 V A
315 – 335	– 450 –	– – –	– – –	– – –	940 – –	– 1 030 –	– – –	540 – –	– 515 –	432 – –	– 412 –	313 – –
355 – 375	– 500 –	– – –	– – –	– – –	1 061 – –	– 1 180 –	– 786 –	610 – –	– 590 –	488 – –	– 472 –	354 – –
400 425 450	– – –	– – –	– – –	– – –	1 200 – –	– – –	– – –	690 – –	– – –	552 – –	– – –	400 – –
475 500 530	– – –	– – –	– – –	– – –	– 1 478 –	– – –	– – –	– 850 –	– – –	– 680 –	– – –	– 493 –
560 600 630	– – –	– – –	– – –	– – –	1 652 – 1 844	– – –	– – –	950 – 1 060	– – –	760 – 848	– – –	551 – 615
670 710 750	– – –	– – –	– – –	– – –	– 2 070 –	– – –	– – –	– 1 190 –	– – –	– 952 –	– – –	– 690 –
800 850 900	– – –	– – –	– – –	– – –	2 340 – 2 640	– – –	– – –	1 346 – 1 518	– – –	1 076 – 1 214	– – –	780 – 880
950 1 000	– –	– –	– –	– –	– 2 910	– –	– –	– 1 673	– –	– 1 339	– –	– 970

[a] Preferred rated values according to IEC 60072-1 (primary series).

[b] Horsepower and currents values according to UL 508 (60 Hz).

A1 Annex H
(normative)

Extended functions to electronic overload relays

H.1 General

Annex T of IEC 60947-1:2007, Amendment 1 applies with the following additions.

H.2 Terms and definitions

H.2.1
electronic overload relay with control functions
multipole electronic relay with motor control operations through its inputs and outputs

NOTE Example of control functions: reversing control, two speed control, star-delta control, etc.

H.2.2
electronic overload relay with under-voltage restarting function
electronic relay which operates when the voltage applied to the main circuit or control circuit is reduced below a predetermined value and automatically resets (with or without time delay) when the voltage is recovered

H.2.3
electronic overload relay with main circuit under-voltage restarting function
electronic overload relay with under-voltage restarting function monitoring only the main circuit

H.2.4
electronic overload relay with control circuit under-voltage restarting function
electronic overload relay with under-voltage restarting function monitoring only the control circuit

NOTE The automatic restarting function may be de-activated.

H.3 Limits of operation of control functions

H.3.1 General

The operation time sequences, the interactions with the inputs and outputs and the limits of operation shall be described in the manufacturer literature.

For motor restart functions, the ranges and tolerances of time and voltage dip detection and of the delay of restarting after voltage restoration shall be given in the manufacturer literature.

H.3.2 Limits of electronic overload relay with main circuit under-voltage restarting function

When under-voltage or loss of voltage occurs in the main circuit, the relay will operate. The following applies: A1

A1) a) if the voltage resumes within T1 (off-time for immediate reset), the overload relay shall control the starter circuit to immediately restore the running condition;

b) if the voltage resumes between T1 and T2 (off-time for reset), the relay shall reset to the starting sequence;

c) if the voltage resumes after T2, the relay shall not reset automatically.

T1 and T2 are adjustable, and the value of T2 is greater than T1.

The tolerance of the threshold voltage and of the time settings shall be specified by the manufacturer but no more than ±10 %. If the time setting value is lower than 1 s, the manufacturer shall state the tolerances.

H.4 Test of the control functions

The test of the control functions shall be verified according to H.3, and each control function should be verified at least 3 times.

For restart functions, the detection time for a voltage dip and the delay of restarting shall be verified according to H.3. (A1

Annex I
(informative)

AC1 contactors for use with semiconductor controlled motor loads

Contactors are often used with semiconductor controllers, starters or drives. Contactors for such applications are not intended to make or break motor load currents at the stated system voltage.

The intended use is to carry motor currents either on the line or load side of such controllers, and allow the controller to be removed from the line and/or load in the off condition. A further use is to by-pass controllers, usually for the purpose of reducing thermal losses, in the up-to speed condition. In such applications the contactors should be so controlled and interlocked so as to prevent them being opened or closed when the load current is present.

When the above conditions are met, the contactors may be chosen according to category AC1.

Annex J

Void

Annex K
(normative)

Procedure to determine data for electromechanical contactors used in functional safety applications

K.1 General

K.1.1 Introduction

Provision of these data is optional, at the discretion of the manufacturer.

K.1.2 Scope and object

This annex specifies procedures for the provision of specific data characterising the performance of electromechanical contactors in functional safety applications.

These data are required by functional safety standards including IEC 61508 series, IEC 62061, IEC 61511 series, IEC 61513, ISO 13849-1.

Specific data for functional safety applications are for example: failure rate per operation, useful life, confidence level and overall life time.

This annex addresses only the main function of an electromechanical contactor.

K.1.3 General requirements

The specific data for functional safety shall be obtained with this procedure.

The procedure is based on statistical analysis of test results in order to generate reliability data.

The confidence level related to failure rate calculation during the useful life of the device shall be 60 % unless otherwise specified by the manufacturer.

NOTE The parameters associated with the reliability data are chosen for being consistent with those of other products also used in functional safety applications.

The statistical data obtained according to this annex are valid only during the useful life of the contactor.

In this annex, to keep statistical consistency, the term "time" may refer to the number of operation cycles.

This annex does not consider replacement of parts of the contactors during test and application.

K.2 Terms, definitions and symbols

For the purposes of this annex, the following terms, definitions and symbols apply.

K.2.1 Terms and definitions

K.2.1.1
reliability
performance
ability of an item to perform a required function under given conditions for a given time interval

[IEV 191-02-06, modified]

K.2.1.2
useful life
under given conditions, the time interval beginning at a given instant of time, and ending when the failure rate becomes unacceptable

NOTE For contactors, the useful life is expressed in number of operations.

K.2.1.3
constant failure rate period
that period, if any, in the life of a non-repaired item during which the failure rate is approximately constant

[IEV 191-10-09]

K.2.1.4
overall lifetime
lifetime of the device which should not be exceeded in order to maintain the validity of the estimated failure rates due to random hardware failures

NOTE 1 Overall lifetime covers also periods of non-use e.g. storage. The overall lifetime is expressed in number of years

NOTE 2 It corresponds to T_1 according to IEC 62061 and to T_M according to ISO 13849-1.

K.2.1.5
censoring
termination of the test after either a certain number of failures or a certain time at which there are still items functioning

K.2.1.6
suspension
situation in which an item that either has not failed or has not failed in the manner under investigation, i.e. failed due to some other cause, is removed from test

K.2.1.7
no-make-break-current utilization
conditions in which the switching device makes and breaks without load

K.2.1.8
time to failure
operating time accumulated from the first use, or from restoration, until failure

NOTE For contactors, the time to failure is expressed in number of operations.

K.2.2 Symbols

- n number of samples tested
- r number of failures
- t number of operating cycles
- η Weibull characteristic life or scale parameter
- β Weibull shape parameter
- c number of operations per hour
- λ_u assessed failure rate (upper limit) at confidence level of 60 % expressed in per operation
- λ failure rate expressed in per hour
- λ_D dangerous failure rate expressed in per hour

K.3 Method based on durability test results

K.3.1 General method

As the failures of such products are of a random nature, the method is based on results given by a continuous appropriate monitoring of the contactors under the appropriate durability test.

K.3.2 Test requirements

Mechanical durability shall be determined in accordance with B.2.1 to B.2.2.4. For the no-make-break-current utilisation the mechanical durability is applicable.

Electrical durability shall be determined in accordance with B.3.1 to B.3.2 using utilization category AC-3 unless otherwise stated by the manufacturer.

The test environment shall be in accordance with Clause 7.

Product modifications which do not impact the data listed in K.5 do not require retesting of the product.

K.3.3 Characterization of a failure mode

The occurrence of one or more of the failure modes listed in Table K.1 or the attainment of the specified number of operating cycles given by the manufacturer shall lead to the conclusion of the test for that device.

Table K.1 – Failure mode of contactors

Failure modes	Characteristics for a normally open contactor
Failure to open	– current remaining after the coil is de-energised
Failure to close	– no current in one or more poles after the coil is energised
Short-circuit between poles	– insulation failure between poles
Short-circuit between pole and any adjacent part	– insulation failure with any adjacent part

K.3.4 Weibull modelling

K.3.4.1 Modelling method

The reliability data are obtained by modelling the test result data with the Weibull distribution according to IEC 61649.

A1⟩ The median rank regression (MRR) shall be used if the number of failures is equal or less than 20. If the number of failures is greater than 10, the maximum likelihood estimation (MLE) method should be used to get the point estimates of the distribution parameters β and η after checking the Kolmogorov-Smirnov goodness-of-fit test (H) with the Fisher distribution ($F\gamma$) at γ = 60 %. ⟨A1

NOTE 1 IEC 61649 provides details and examples of calculation.

NOTE 2 Small number of samples will increase the uncertainty of estimating the life parameters, which will result in a lower value of the lower limit of the failure rate per operation.

If a test is terminated at a specified time, T, before all items have failed, then the data are said to be time censored. An item on test that has not failed by the failure mode in question is a suspension. Normally, suspensions are included in the analysis by adjustment of the ranking. However, this annex provides a method for the estimation of Weibull parameters that is simplified by the omission of suspensions. Further discussion of censoring and suspension is covered in IEC 60300-3-5 and associated computations are covered by IEC 61649.

K.3.4.2 Median rank regression

Median Rank Regression (MRR) is a method for estimating the parameters of the distribution using linear regression techniques with the variables being the median rank and operation cycle.

If a table of median ranks and a means to calculate median ranks using the Beta distribution is not available, Bernard’s approximation, Equation (K.1), may be used where:

$$F_{\mathrm{i}} = \frac{(i - 0{,}3)}{(N + 0{,}4)} \times 100 \ \% \qquad \text{(K.1)}$$

where

N is the sample size, and

i is the ranked position of the data item of interest.

NOTE This equation is mostly used for N ≤ 30; for N > 30 the correction of the cumulative frequency can be neglected: Fi = (i/N) × 100 %.

Small sample size makes it difficult to gauge the goodness-of-fit. The coefficient of determination is the most commonly used for checking the Weibull distribution. This can be calculated using Equation (K.2):

$$r^2 = \frac{\left(\sum_{i=1}^{n} x_i y_i - \frac{\sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{n} \right)^2}{\left(\sum_{i=1}^{n} x_i^2 - n\left(\overline{x}\right)^2 \right)\left(\sum_{i=1}^{n} y_i^2 - n\left(\overline{y}\right)^2 \right)} \qquad \text{(K.2)}$$

where (x_i) and (y_i), i=[1..n] are the median ranks and the failure time respectively.

r^2 is the proportion of variation in the data that can be explained by the Weibull hypothesis. The closer this is to 1, the better the data are fitted to a Weibull distribution; the closer to 0 indicates a poor fit.

The following are the steps to plot data sets.

a) First, rank the times in operation cycle from earliest to latest;
b) Use Bernard's approximation (K.1) to calculate the median ranks;
c) Plot the failure times (x) versus the median ranks F_i *(y)* on 1 x 1 Weibull paper or log-log paper to derive x_{ln} and y_{ln};
d) Calculate $\hat{\beta}$ by a straight regression function to get the equation for the line $y_{ln}=\hat{\beta}\ x_{ln}+b$;
e) Calculate $\hat{\eta} = e^{\left(\frac{b}{\hat{\beta}}\right)}$;
f) Plot the regression line on the graph to verify the fit.

Normally for an electromechanical contactor, $\hat{\beta}$ is greater or equal to 1.

K.3.5 Useful life and upper limit of failure rate

K.3.5.1 Numerical method

Assuming a constant failure rate, the useful life is determined as the lower confidence level of the number of cycles by which 10 % of the device population will have failed ($B_{10|\text{lower limit}}$).

For 20 or fewer data points, with or without censoring times, the Weibull parameters $\hat{\beta}$ and $\hat{\eta}$ obtained with Median Rank Regression (MRR) in K.3.4.2 shall be used.

K.3.5.2 Point estimate of the fractile (10 %) of the time to failure

Compute $\hat{B}_{10}$ using Equation (K.3), the point estimate of B_{10}, the time by which 10 % of the population will have failed:

$$\hat{B}_{10} = \hat{\eta}\left[\ln\left(\frac{1}{0{,}9}\right)\right]^{1/\hat{\beta}} \qquad \text{(K.3)}$$

K.3.5.3 Useful life

Compute the lower (1 – y)100 % confidence level of B_{10} using Equations (K.4), (K.5), (K.6) and (K.7):

$$h_1 = \ln\left[-\ln(0{,}9)\right] \qquad \text{(K.4)}$$

$$\delta_1 = \frac{-A_6x^2 - rh_1 + x\sqrt{\left(A_6^2 - A_4A_5\right)x^2 + rA_4 + 2rh_1A_6 + rA_5h_1^2}}{r - x^2A_5} \qquad \text{(K.5)}$$

where:

$x = u_\gamma$
is the *y* fractile of the normal distribution. Unless otherwise specified by the manufacturer, a 60 % lower confidence level shall be used (hence $y = 0{,}4$ and $u_\gamma = 0{,}253\ 3$).

A_4, A_5 and A_6
are computed as follows, using the ratio $q = r/n$:
$A_4 = 0{,}49q - 0{,}134 + 0{,}622q^{-1}$;
$A_5 = 0{,}244\ 5\ (1{,}78 - q)\ (2{,}25 + q)$;
$A_6 = 0{,}029 - 1{,}083\ \ln(1{,}325q)$.

$$Q_1 = e^{\left(-\frac{\delta_1 + h_1}{\hat{\beta}}\right)} \qquad \text{(K.6)}$$

$$B_{10|lowerlimit} = Q_1 \hat{B}_{10} \qquad \text{(K.7)}$$

This value of $B_{10|lowerlimit}$ is considered as the useful life.

K.3.5.4 Upper limit of failure rate

The upper limit of failure rate per operation is given by the following Equation (K.8):

$$\lambda_u = \frac{-\ln(0{,}9)}{B_{10|lowerlimit}} \approx \frac{1}{10 \times B_{10|lowerlimit}} \qquad \text{(K.8)}$$

K.3.5.5 Test conditions

Normal conditions are given in Clause 7.

Other conditions are subject to agreement between user and manufacturer. In such cases, the given values shall be obtained under these conditions.

K.3.6 Reliability data

The resulting reliability data are:

– Failure rate per operation: λ_u.
– Useful life value = $B_{10|lower\ limit}$.

K.4 Method based on experience of returns from the field

This method can use the same statistical calculations but failure data collected from the field can be related to a very wide range of environments and utilization categories.

This method is under consideration.

K.5 Data to be provided

A set of reliability data of the product shall include a combination of the following relevant characteristics:

– failure rate per operation λ_u (see K.3.6);
– useful life (see K.3.6);
– confidence level if different from 60 %;

– no-make-break-current or utilization category if different from AC-3 utilization;
– maximum switching rate;
– maximum operational voltage, if different from U_e;
– maximum operational current for the specified utilization category, if different from I_e;
– overall life time = 20 years unless otherwise specified by the manufacturer;
– environment conditions if different from the normal conditions.

NOTE 1 The failure rate λ, expressed in “per hour”, is given by the failure rate, expressed in “per operation”, λu, multiplied by the number of operations per hour c:

$$\lambda = \lambda u \times c$$

NOTE 2 The overall life time of 20 years is generally used as a statistical reference for reliability analysis.

The hardware fault tolerance for one contactor is generally zero.

NOTE 3 In IEC 62061, a hardware fault tolerance of N means that N+1 faults could cause a loss of the function.

The Table K.2 gives the typical failure ratio used to calculate the rate of dangerous failure λ_D ; this dangerous failure rate is calculated with the following equation:

$$\lambda_D = \lambda \times F$$

Table K.2 – Typical failure ratios for normally open contactors

Failure modes	Typical failure ratios *F* associated with AC3 electrical durability test results for normally open contactors [a]	Typical failure ratios *F* associated with mechanical durability test results for normally open contactors [a]
Failure to open [b]	73 %	50 %
Failure to close	25 %	50 %
Short-circuit between poles	1 %	0 %
Short-circuit between poles and any adjacent part (e.g. auxiliary, earth plate, coil)	1 %	0 %
NOTE If a contactor is used in such a way that a hazardous situation can be caused by a failure mode for which the failure ratio is above 40%, the system may need a diagnostic function and appropriate fault reaction function(s).		
[a] The typical values result from tests performed on different contactors [b] The diagnostic coverage of the subsystem incorporating a contactor with mirror contacts can be 99 % if an appropriate fault reaction function(s) is provided.		

K.6 Example

K.6.1 Test results

A total of 15 contactors (n = 15) have been tested at the same time until all have failed. The 15 times to failure (r =15) are ordered with i in the Table K.3.

Table K.3 – Example of 15 sorted ascending times to failure of contactors

i	Cycles t_i
1	1 000 000
2	1 250 000
3	1 400 000
4	1 550 000
5	1 650 000
6	1 750 000
7	1 850 000
8	1 950 000
9	2 050 000
10	2 150 000
11	2 280 000
12	2 420 000
13	2 500 000
14	2 700 000
15	2 800 000

K.6.2 Weibull distribution and median rank regression

The calculation of median ranks gives the following results:

i	Cycles t_i	Median ranks		*i*	Cycles t_i	Median ranks
1	1 000 000	4,5 %		9	2 050 000	56,5 %
2	1 250 000	11,0 %		10	2 150 000	63,0 %
3	1 400 000	17,5 %		11	2 280 000	69,5 %
4	1 550 000	24,0 %		12	2 420 000	76,0 %
5	1 650 000	30,5 %		13	2 500 000	82,5 %
6	1 750 000	37,0 %		14	2 700 000	89,0 %
7	1 850 000	43,5 %		15	2 800 000	95,5 %
8	1 950 000	50,0 %				

The coefficient of determination r^2 = 0,998. This value, close to 1, indicates a good fit to a Weibull distribution.

The linear regression with two natural logarithm scales gives: $y = 3{,}908x - 57$.

From this equation, the distribution parameters can be derived: $\hat{\beta} = 3{,}908$ and $\hat{\eta} = 2\ 149\ 131$.

The fitting result obtained by MRR gives the assurance of a good Weibull distribution (see Figure K.1).

K.6.3 Useful life and failure rate

To calculate the lower confidence level of the number of cycles by which 10 % of the contactors will have failed, this example follows the subclause K.3.5.

The point estimate $\hat{B}_{10} = 1\ 212\ 879$

The factor $Q_1 = 0{,}960\ 1$ and $B_{10|\text{lower limit}} = 1\ 164\ 541$

Finally, the upper limit of the failure rate $\lambda_u = 9{,}05 \times 10^{-8}$

The result of this numerical method is illustrated by the Figure K.1.

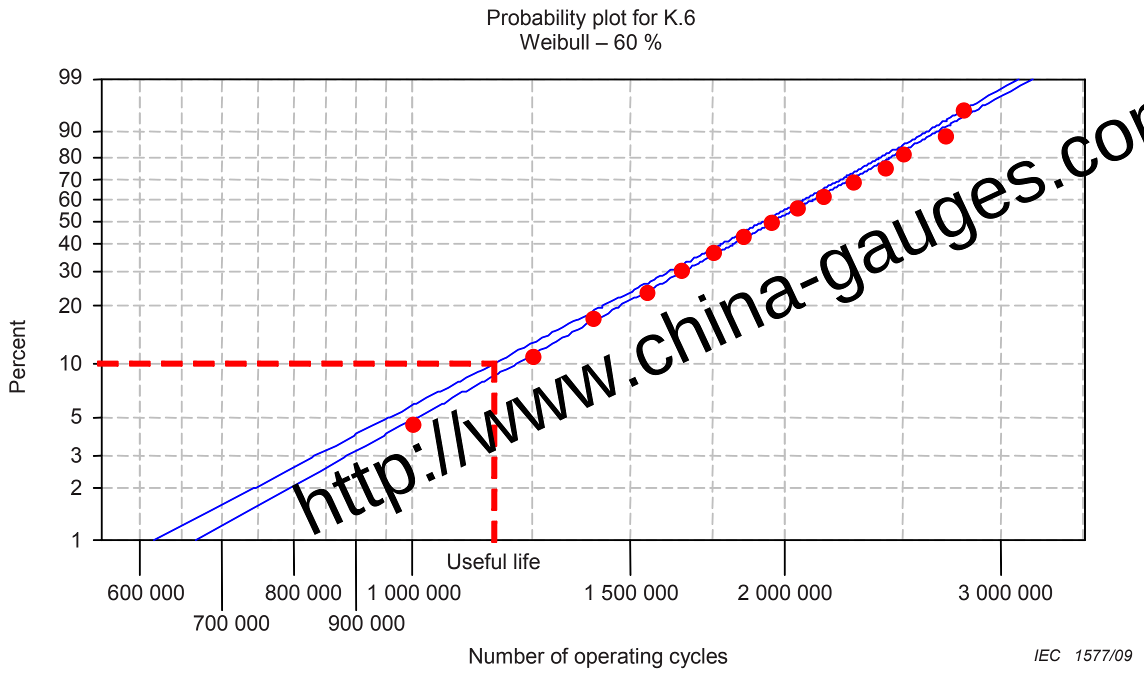


Figure K.1 – Plot of Weibull median rank regression

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