UL 6420

STANDARD FOR SAFETY

Equipment Used for System Isolation and Rated as a Single Unit

UL Standard for Safety for Equipment Used for System Isolation and Rated as a Single Unit, UL 6420

First Edition, Dated October 19, 2012

Summary of Topics

This revision of ANSI/UL 6420 dated July 14, 2023 includes new requirements for Pneumatic Isolation; Annex C

Text that has been changed in any manner or impacted by ULSE's electronic publishing system is marked with a vertical line in the margin.

The new requirements are substantially in accordance with Proposal(s) on this subject dated December 30, 2022.

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OCTOBER 19, 2012
(Title Page Reprinted: July 14, 2023)

ANSI/UL 6420-2023

UL 6420

Standard for Equipment Used for System Isolation and Rated as a Single Unit

First Edition

October 19, 2012

This ANSI/UL Standard for Safety consists of the First Edition including revisions through July 14, 2023.

The most recent designation of ANSI/UL 6420 as an American National Standard (ANSI) occurred on July 14, 2023. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

Comments or proposals for revisions on any part of the Standard may be submitted to ULSE at any time. Proposals should be submitted via a Proposal Request in the Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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ANNEX C Pneumatic Isolation Module (Normative)

GENERAL

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1 Scope and Object

1.1 Scope

1.1.1 General

1.1.1.1 This standard applies to isolating equipment incorporating electromechanical contactors remotely controlled and monitored to provide remote isolation status indication with a defined integrity level. This equipment is intended for use as an additional isolating means on the load side of the required supply-disconnecting device and over current protection. This standard applies to isolating equipment that is to be used in circuits of which the rated voltage does not exceed 1000 Vac or 1500 Vdc.

1.1.1.2 The system isolation equipment is expected to be used both as a means for removal of power for prevention of unexpected start-up of a stopped machine and as an isolator to provide protection from electric shock by ensuring the removal of electrical energy.

1.1.1.3 This equipment is intended for installation in accordance with the National Electrical Code, NFPA 70 and the Electrical Standard for Industrial Machinery, NFPA 79:2012.

Note – Reference to System Isolation Equipment is found in Article 430.109(A)(7) of the National Electrical Code NFPA 70; in Clause 5.5.4(3), Devices for Disconnecting (Isolating) Electrical Equipment, of the Electrical Standard for Industrial Machinery, NFPA 79:2012; and in Clause 5.3.2(d) of the Standard for Safety of Machinery – Electrical Equipment of Machines – Part 1: General Requirements, IEC 60204-1.

1.1.1.4 The System Isolation Equipment is not intended to fulfill the function of a motor starter or other motion control device.

1.1.2 System isolation equipment

1.1.2.1 Typical application

1.1.2.1.1 The system isolation equipment is principally intended for industrial machine applications where, isolation of power is so frequently required that the mechanical life of a typical disconnecting means is unacceptably short or where there are multiple entry points on the machine where disconnection is required, or both.

Note – Multiple entry points are a function of access needs and the layout of the machine.

1.2 Object

1.2.1 The object of this standard is to state:

a) The characteristics of the system isolation equipment;

b) The conditions of operation and behavior for the system isolation equipment, its dielectric properties, and the degree of protection provided by its enclosure where applicable;

c) The information to be marked on or given with the system isolation equipment;

d) The normal service, mounting and transport conditions of the system isolation equipment;

e) The construction and performance of the system isolation equipment;

f) The tests intended to verify that these conditions have been met, and the methods to be adopted for these tests.

2 Normative References

2.1 The following normative documents contain provisions, which, through reference in this text, constitute provisions of this standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

UL 60947-1
Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules

UL 60947-4-1A
Standard for Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters

NFPA 79:2012
Electrical Standard for Industrial Machinery

3 Definitions

3.1 For the purpose of this standard, the definitions of Clause 2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, and the definitions of Clause 3 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, together with the following definitions apply.

3.2 CONNECTED EQUIPMENT – All circuits that are isolated by the system isolation equipment.

3.3 MIRROR CONTACT – Normally closed auxiliary contact, which cannot be in closed position simultaneously with the normally open main contact.

Note – For more information see the Requirements for Auxiliary Contact Linked with Power Contact (Mirror Contact), in the Standard for Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters, IEC 60947-4-1, Annex F. One contactor may have more than one mirror contact.

3.4 MONITORED CIRCUITS – Control circuits that are designed so that their function(s) are checked for failure continuously or at suitable intervals by the control system.

3.5 REDUNDANTLY MONITORED – Control circuits that are monitored through the use of multiple path systems.

3.6 STOP CATEGORY 1 – A controlled stop with power to the machine actuators available to achieve the stop then remove power when the stop is achieved. (Electrical Standard for Industrial Machinery, NFPA 79:2012, Clause 9.2.2, Stop functions.)

3.7 SUPPLY DISCONNECT – Disconnecting means to remove incoming power supplied to a machine.

3.8 SYSTEM ISOLATION EQUIPMENT – Equipment packaged to provide the disconnection/isolation function separate from the supply disconnect and capable of operation from multiple remote locations by means of lockout switches. Each lockout switch is capable of being padlocked in the OFF (open) position. Visual indication is provided to the operator at the respective lockout station that is in the OFF (open) position when the power bus is isolated.

4 Classification of the System Isolation Equipment

4.1 General

4.1.1 This clause lists the characteristics of system isolation equipment. Information about these listed characteristics may be given by the manufacturer but may not necessarily have to be verified by testing, unless such requirements are indicated here or elsewhere in this document.

4.2 According to the system design with single or multiple power isolation points

4.2.1 A single power isolation is accomplished by isolating the power to multiple motors.

4.2.2 A multiple power isolation is accomplished by isolating the power to individual motors, groups of motors or other loads.

4.3 According to the utilization category/load designation

4.3.1 Although the system isolation equipment is not intended to be used as a motor starter or any other form of motor control, the power components and power circuits shall be appropriate for on-load switching of motors or other inductive loads of the connected equipment. The system isolation equipment's rating and load designation shall be in accordance with the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, Table 5.4DV.1. The utilization category/load designation shall be based on the construction and performance requirements found in Clause 8 and testing requirements in Clause 9.

4.3.2 Clause 5.4 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies with the following additions:

a) AC−23A: Switching of alternating current motor loads or other highly inductive loads (A = frequent use)

b) DC−23A: Switching of highly inductive direct current loads (e.g. series motors) (A = frequent use)

4.3.3 Only references to contactors in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, apply to power control components of system isolation equipment.

4.4 According to the required safety performance

4.4.1 The system isolation equipment shall be designed to meet the requirements of Clause 5.1.2.4.

4.5 According to the normal load and overload characteristics

4.5.1 Although the system isolation equipment is not intended to be used as a motor starter or any other form of motor control, the power circuit components and power circuits shall be appropriate for carrying normal loads and over loads and for infrequent, occasional on-load switching of motors or other inductive loads. The classification shall reflect the limitations.

4.6 According to the method chosen to monitor the controlled load side power circuit

4.6.1 Methods:

a) Voltage sensing method refers to measurement of the power circuit voltage on the load side of the system isolation equipment contactor to determine whether the voltage is below a preset threshold, or

b) Voltage grounding method refers to placing a short circuit between all ungrounded conductors to the equipment grounding conductor on the load side of the system isolation equipment isolation contactor to insure that voltage is not present, or

c) Alternate monitoring methods meeting the performance requirements of Clause 4.4.1 may be used to verify that the removal of power has been achieved.

4.6.2 See Clause 5.4.

4.7 According to the configuration limits of the lockout station locations (See Annex A, Figure A.2 and Figure A.3)

4.7.1 The maximum number of lockout station locations and the circuit distance limitations or combinations there of.

4.7.2 See Clause 5.6.

4.8 According to the available machine control interface functions

4.8.1 The system isolation equipment may be configured to meet additional machine control interface applications such as the following:

a) Safety related interface including both signal and feedback channels:

1) Guard door locked status signals;

2) Release signal for guard locks;

3) Signal to / feedback from – safety pneumatic control valve;

4) Signal from / feedback to – E-stop system;

5) Signal collected from E-stop devices to / feedback from E-stop system;

6) Signal collected from E-stop devices rapid stop signal / to machine drive control system;

7) Run permissive signal to machine drive control system;

8) Zero speed signals from drive;

9) Zero voltage signals from drive;

10) Signal to machine stop.

b) Information related interface channels:

1) Lockout switch positions (open or closed);

2) System isolation equipment components status / trouble shooting aids;

3) System isolation equipment status.

4.9 According to the reset function following restoration of power to the power circuit line terminals

4.9.1 When power to the line side of the system isolation equipment is initiated or restored, the system isolation equipment requires a manual reset before power can be made available to the connected equipment.

5 Characteristics of the System Isolation Equipment (Including the Characteristics of the Self Contained Components that are Used in the Construction of the System Isolation Equipment)

5.1 General

Note – Some of the requirements for the various components of the system isolation equipment are defined in parts of the UL 60947 series of standards. In most cases these requirements are incorporated by reference rather than restated in this Clause.

5.1.1 Control components

5.1.1.1 The control circuit components shall be selected to meet the relevant construction and performance requirements in Clause 8, Construction and performance standards. The control circuit components shall be applied within the limits defined by their characteristics. See Clause 5.1.1.3.

Note – The requirements of control components selected to be used in system isolation equipment may be found in the Standard for Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices, IEC 60947-5-1 and the Standard for Industrial Control Equipment, UL 508.

5.1.1.2 Control circuit components shall be evaluated in order to determine their suitability in the system isolation equipment design. See Clauses 5.1.2.4 and 8.2.9.

5.1.1.3 The characteristics of control circuit devices and switching elements should be evaluated in the following terms, where applicable:

a) Type of equipment (e.g. kind of control circuit device: manual control switches, electromagnetically operated control switches, indicator lights and kind of switching elements: auxiliary contacts, interlocking contacts, control circuit contacts);

b) Rated and limiting values for switching elements (see Clause 5.1.1.4);

c) Utilization categories of switching elements (see Clause 5.1.1.10);

d) Normal and abnormal load characteristics (see Clause 5.1.1.9);

e) Switching over-voltages (see Clause 5.1.1.11);

f) Durability for the application (see Clause 8.3.4.3).

5.1.1.4 The rated and limiting values for switching elements of a control circuit device application in the system isolation equipment design shall be based on evaluations in accordance with Clauses 5.1.1.5 to 5.1.1.9 inclusive.

5.1.1.5 Rated voltage(s) of a switching element is defined by the following:

a) Rated operational voltage (U_e): Clause 4.3.1.1 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies;

Note 1 – A switching elements may be assigned a number of combinations of rated operational voltage and rated operational current.

Note 2 – Control switches dealt with in the Standard for Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices, IEC 60947-5-1, and the Standard for Industrial Control Equipment, UL 508, are often not intended to be used at very low voltages and they may not be suitable for such a service. It is therefore recommended to seek the advice of the manufacturer concerning any application with a low value of operational voltage, e.g. most applications below 100 V ac or dc.

b) Rated insulation voltage (U_i): Clause 4.3.1.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies.

Note – The selection of dielectric insulation rating should anticipate the levels appropriate to the electrical power components rated voltage of the system isolation equipment. For example if the machine where the system isolation equipment is employed has other systems with rated insulation voltages up to 690 Vac, then the dielectric test voltage to check for the proposed isolation would be 1890 V. See the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, Clause 4.3.1.2, and Table 12A.

5.1.1.6 A switching element is characterized by the following currents:

a) Conventional free air thermal current (I_{th}): Clause 4.3.2.1 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies.

b) Conventional enclosed thermal current (I_{the}): Clause 4.3.2.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies.

c) Rated operational current (I_e): The first paragraph of Clause 4.3.2.3 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies.

5.1.1.7 Rated frequency: Clause 4.3.3 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies.

5.1.1.8 Normal and abnormal load characteristics

5.1.1.8.1 Rated making and breaking capacities and behavior of switching elements under normal conditions shall comply with the requirements given in Clause 8.3.4.2.4 and Table 8.9 and Table 8.10 corresponding to the assigned utilization category and the requirements according to the rated operational voltage.

Note 1 – For a switching element to which a utilization category is assigned, it is not necessary to specify separately a making and breaking capacity.

Note 2 – A switching element used for the switching of small motors and tungsten filament lamp loads shall be assigned a utilization category given in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, and comply with the appropriate corresponding requirements in that publication.

5.1.1.8.2 Making and breaking capacities of switching elements under abnormal conditions shall comply with the requirements given in Clause 8.3.4.1.4 and Table 8.1 corresponding to the assigned utilization category.

Note – An example of an abnormal condition of use is one where the electromagnet does not operate and the switching elements have to interrupt the making current.

5.1.1.9 Rated conditional short-circuit current: Clause 4.3.6.4 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies.

5.1.1.10 Utilization categories for switching elements in the control circuits as given in Table 5.1 and Table 8.11 are for purposes of evaluating the characteristics of control circuit devices and switching elements when determining their suitability for a particular system isolation equipment design.

Table 5.1
Utilization categories for switching elements

Kind of current	Category	Typical applications
Alternating current	AC-12	Control of resistive loads and solid state loads with isolation by opto-couplers
	AC-13	Control of solid state loads with transformer isolation
	AC-14	Control of small electromagnetic loads (≤72 VA)
	AC-15	Control of electromagnetic loads (>72 VA)
Direct current	DC-12	Control of resistive loads and solid state loads with isolation by opto-couplers
	DC-13	Control of electromagnets
	DC-14	Control of electromagnetic loads having economy resistors in circuit

5.1.1.11 Switching over-voltages: Clause 4.9 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies.

5.1.2 Control component application architecture

5.1.2.1 In order to ascertain that the control component contacts are suitable for control circuit applications where the voltage used is below 100 V ac or dc, it is necessary to define the predicted behavior of control circuit component's contacts within an acceptable confidence level (see Note 1). If the system isolation equipment application control circuits will involve extended distances a similar analysis of the wire and control circuit component's contacts predictable behavior shall be done. The defined predictable behavior test data or similar information and other evaluation data (Clause 5.1.1.3) is to be used in addressing component failures (Clause 8.3.8) and the results of such failure on the overall design of the system isolation equipment (Clause 8.3.8.2).

Note 1 – Conventional methods to determine the predicted behavior of control circuit component's contacts within acceptable confidence levels may be done by using the precise conventional testing methods such as those found in IEC 60947-5-4, Low-Voltage Switchgear and Controlgear – Part 5: Control circuit devices and switching elements – Section 4: Methods of assessing the performance of low-energy contacts – Special tests, or using a similar methodology such as found in IEC 61810-1, Electromechanical Elementary Relays – Part 1 General requirements and IEC 61810-2, Part 2 Reliability.

Note 2 – Often the needed defined predictable behavior test data or other similar information will nominally be gathered during the development of a particular control circuit component, and verified by a third party; such test data in turn may be made available by that component manufacturer to the system isolation equipment manufacturer. Such data could be suitable for the analysis (Clause 8.3.8) of that particular control component application to the system isolation equipment design.

5.1.2.2 The effects of switching over-voltage and inrush current within the system isolation equipments' control circuits shall be addressed in the design to match the chosen components to the application.

5.1.2.3 The parts of the system isolation equipment internal control circuits or components shall, as a minimum, be designed, constructed, selected, assembled and combined, in accordance with the relevant standards, using basic safety principles.

5.1.2.4 The following requirements apply for the overall design to achieve the safety performance for the system isolation equipment.

a) In order for the system isolation equipment to achieve the required safety performance, the system isolation equipment shall be designed so that:

1) A single fault in any of the safety-related parts does not lead to a loss of the safety function; and

2) The single fault is detected at or before the next demand upon the safety functions, such as immediately, at switch-on, or at end of a machine operating cycle. If this detection is not possible, then an accumulation of faults shall not lead to a loss of the safety function.

b) If the detection of certain faults is not possible, for reasons of technology or circuit engineering, then the occurrence of further faults shall be assumed. In this situation the accumulation of faults shall not lead to loss of the safety function.

Note – For further clarification of the methods indicated herein to achieve the required safety performance, see Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design, ISO 13849-1, including Clauses 6 and 7. The term "well-tried component" refers to a component for a safety-related application, which has been widely used in the past with successful results in similar applications or made and verified using principles, which demonstrate its suitability and reliability for safety-related applications. In some well-tried components certain faults can also be excluded because the fault rate is known to be very low. Guidance on the Application of ISO 13849-1 and IEC 62061 in the Design of Safety-Related Control Systems for Machinery, IEC TR 62061-1:2010, provides guidance on the application of the Safety of Machinery – Safety-Related Parts of Control Systems – Part 1: General Principles for Design, ISO 13849-1:2006, and the Safety of Machinery – Functional Safety of Safety-Related Electrical, Electronic and Programmable Electronic Control Systems, IEC 62061:2005 in the design of safety related control systems for machinery.

5.1.3 Power components

5.1.3.1 The effects of over-voltage on the continued proper function of the system isolation equipment components and circuits must be addressed in the design. External surge over-voltage originating from the circuits before the supply disconnect is expected to be limited to the conditions described in the Electrical Standard for Industrial Machinery, NFPA 79:2012, Clause 4.3.2.5, Voltage Impulses.

Note – These over-voltage conditions are also described in the Standard for Safety of Machinery – Electrical Equipment of Machines – Part 1: General Requirements, IEC 60204-1, Clause 4.4.2, Electromagnetic compatibility (EMC), including Notes 1 and 2.

5.1.3.2 Rated voltage(s) of a power switching element is defined by the following:

a) Rated operational voltage (U_e): Clause 4.3.1.1 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies with the following additions. For three phase circuits, U_e is stated as rms voltage between phases;

b) Rated insulation voltage (U_i): Clause 4.3.1.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies. Power switching elements for which the manufacturer has not declared a value or U_{imp} (Clause 4.3.1.3 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1) the rated insulation voltage would be used to determine the minimum acceptable spacing to non arcing parts (Clause 8.1.3 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A).

c) For an isolation contactor, the spacing across the gap between the switch's separable contacts of the same pole when in the open position is evaluated according to Clause 8.2.6.1.

d) Rated impulse withstand voltage (U_{imp}): Clause 4.3.1.3 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies. A withstand value implies no damage to the switch and no change in its characteristics.

5.1.3.3 A power switching element is characterized by the following currents:

a) Conventional free air thermal current (I_{th}): Clause 4.3.2.1 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies.

b) Conventional enclosed thermal current (I_{the}): Clause 4.3.2.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies.

c) Rated operational current (I_e): The first paragraph of Clause 4.3.2.3 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies.

d) Maximum load rating of connected equipment motor current (I_{em}) (the full load ampere rating of all motors that can be operated simultaneously plus the full load ampere rating of non-motor loads).

5.1.3.4 Rated frequency: Clause 4.3.3 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies.

5.1.3.5 Normal load and overload characteristics – Making and breaking capacities of switching elements shall comply with the requirements given in Clauses 8.3.4.1.1 – 8.3.4.1.3 and Table 8.2, Table 8.3 and Table 8.4 corresponding to the assigned utilization category. See Clause 5.1.3.6.

Note 1 – For a switching element to which a utilization category is assigned, it is not necessary to specify separately a making and breaking capacity.

Note 2 – A switching element used for the switching of small motors and tungsten filament lamp loads shall be assigned a utilization category given in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, and comply with the appropriate corresponding requirements in that publication.

5.1.3.6 Conventional operational performance of switching elements for the rated operational current shall comply with the requirements given in Clauses 8.3.4.2.1 – 8.3.4.2.3 and Table 8.5, Table 8.6, Table 8.7, and Table 8.8 corresponding to the assigned utilization category and the requirements according to the rated operational voltage.

5.1.3.7 Rated conditional short-circuit current: Clause 4.3.6.4 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies.

5.1.3.8 Utilization categories for switching elements of auxiliary and mirror contacts in the control circuits as given in Table 5.1 and Table 8.11 are for purposes of evaluating the characteristics of control circuit devices and switching elements when determining their suitability for a particular system isolation equipment design.

5.1.3.9 Switching over-voltages: Clause 4.9 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies.

5.2 Electromechanical isolating contactor(s)

5.2.1 General

5.2.1.1 The electromechanical contactor(s) in the system isolation equipment that isolate the connected equipment shall meet the requirements in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, with the following supplements and additions:

a) The requirements for isolation shall be fulfilled. See Clause 8.2.6.1.

b) Indication of the main contacts open position shall be fulfilled by the system isolation equipment verification function. See Clause 5.2.2, Auxiliary and mirror contacts, and Clause 5.5.3, Verification light.

c) Contactors shall be capable of holding in (closed) while the related short circuit protection device opens the circuit to the fault location.

Note – This requirement may result in selecting a larger contactor than might be required based only on the nominal load that the system isolation equipment is intended to serve.

d) Immunity to reasonably anticipate seismic activity and vibration that would cause the reduction of the open contacts gap to fall below the value needed to meet isolation requirements shall be provided. Mechanical vibrations that are greater than 5 g/33 Hz during operation are to be avoided by external means, such as through application design considerations.

Note – The vibration issue in normal service may be addressed by the installation instructions and by the physical application of the contactors, e.g. in a redundant contactor application, the orientation of each contactor in quadrature (different plane 90° apart) or by using appropriate shock isolation/dampening mountings. Alternatively, contactors that are immune by design to the stated mechanical vibrations can be used. The appropriate values of mechanical shock, bump and vibration, to compare with the expected application of the system isolation equipment can nominally be found in contactor/component manufacturer's catalog data. In the absence of that data:

1) A method to prove a component's capability to function during and after non repetitive shocks encountered in service may be found in test Ea in the Standard for Environmental Testing – Part 2: Tests – Test Ea and guidance: Shock, IEC 60068-2-27.

2) A method to prove a component's capability to function during and after repetitive bumps encountered in service may be found in test Eb in the Standard for Environmental Testing – Part 2: Tests – Test Eb and Guidance: Bump, IEC 60068-2-29.

3) A method to prove a component's capability to withstand conditions of vibration may be found in test Fc in the Standard for Environmental Testing – Part 2: Tests – Test Fc: Vibration (sinusoidal), IEC 60068-2-6.

e) The contactors shall be rated to interrupt the full load current and overload (including locked rotor) current of the connected equipment.

5.2.2 Auxiliary and mirror contacts

5.2.2.1 Mirror contacts shall be used on each isolation contactor to indicate when the contactor's main contacts have reached the minimum parting distance to fulfill the isolation requirements in Clause 8.2.6.1. The mirror contacts relationship to the contactor main contacts must account for the failure modes of the contactor assembly in a way to prevent false positive indications by the mirror contacts.

Note – For more information, see the Standard for Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters, IEC 60947-4-1, Annex F, Requirements for auxiliary contact linked with power contact (mirror contact). One contactor may be required to have more than one mirror contact to detect proper operation of the contactor. The physical arrangement and number of auxiliary contacts required for verification of isolation is dependent on the construction of the isolation contactor and the mechanical connection to the mirror contacts. One example of a failure mode would be when the welding of only one power contact (phase A) would hold the contactor's mechanical connection to the mirror contact in a way that the faulted condition might not be detected by the mirror contact monitoring the phase C side.

5.3 Connections to internal control circuits

5.3.1 Internal control power sources

5.3.1.1 All control power used internally by the system isolation equipment shall be sourced from the line side of the electromechanical isolation contactor(s) and physically contained within the system isolation equipment's boundaries.

Note – Using the line side of the isolation contactor to obtain verification control power establishes one of the independent paths that verify the contactor has in fact opened when zero voltage is detected or confirmed on the load side of the isolation contactor.

5.3.1.2 With reference to Clause 5.3.1.1, communication modules that are electrically separated from the SIE and that receive only electrically isolated inputs from the SIE circuitry, in accordance with Clause 5.3.2.2, from the Safety Isolation Equipment and that are required to be powered for the maintenance of communication when power to the SIE is not present, are permitted to receive power from other than the line side of the Safety Isolation Equipment contactors.

5.3.1.3 With reference to Clause 5.3.1.1, multiplexer modules which are sufficiently remote from the SIE that it is not practicable to receive power there from, and where the multiplexer outputs are electrically isolated from SIE inputs, are permitted to receive power from other than the line side of the SIE contactors.

5.3.1.4 When a control power isolation transformer or an isolated control power supply is used it shall be constructed to relevant standards. Primary and secondary short circuit and overload protection is required in accordance with the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1. When selecting the size of the control power source and over current protective devices, primary consideration shall be given to the protection of the control switching components within the system isolation equipment. The control switching components shall be protected from damage due to over currents, including damage such as welding of the control switching component's contacts. Thus, the isolated control power source shall be so designed that the control circuit is protected from damaging over-currents by means which include the following:

a) Use of a control transformer(s) that does not deliver over-currents that can be damaging (this may require the use of separate control transformers for the logic control and the isolating contactor coils).

b) Use of protective devices in the control circuit that will limit the isolating control transformer fault current to levels that are not damaging.

c) Use of a current limiting isolating power supply.

Note – An appropriate way to meet the requirements in this Clause, if a control power isolation transformer is to be selected, is to use one that is built and protected in accordance with the Standard for Specialty Transformers, UL 506, or the Standard for Safety of power transformers, power supplies, reactors and similar products – Part 2-2 Particular requirements and tests for control transformers and power supplies incorporating control transformers, IEC 61558-2-2, or a transformer that is built to similar requirements.

5.3.1.5 All control power from the "internal control power source(s)", shall be electrically isolated within the system isolation equipment. See Clause 5.6.1.1.

5.3.1.6 When an external device is substituted in place of a lockout station and directly connected to the system isolation equipment's internal control circuit (such as a dual channel safety relay in the machine circuit), the device and its connections shall be provided with the same degree of isolation afforded to the system isolation equipment internal control circuits as in Clauses 5.6.1 and 6.3.5.

Note – An example would be a safety relay with other functions that is used in the machine's E-stop system to send the signal to remove motive voltage as part of a stop category 1 sequence. In order to maintain the physical isolation requirement of Clause 5.6.1.2, the connection to the safety relay output contacts remote from the system isolation equipment would be provided with a cover and a tamper indication seal.

5.3.2 Isolated control circuit output

5.3.2.1 When the system isolation equipment provides an interlock for the machine's control circuit, such as a means to inhibit the activation of the start control function for the machine control equipment, an isolated output circuit shall be provided. See Clauses 6.3.4 and A3.3.4.

5.3.2.2 The isolated outputs from the system isolation equipment shall consist of dry contacts or optically-isolated solid-state devices. Where the output is provided by an optically isolated solid state device, its power shall not be provided from the internal control power source in Clause 5.3.1.

5.3.3 Isolated control circuit input

5.3.3.1 External devices providing inputs to the system isolation equipment shall only interface the internal control circuit through isolating dry contacts or optically-isolated solid-state devices. The circuits

connections shall be protected from unintended access by the tamper indication sealing and isolation requirements that are used for the system isolation equipment's internal circuits and shall comply with Clause 5.1.1, Control components, Clause 5.3.1, Internal control power sources, and Clause 5.6.1, Isolation. See Clause A3.3.4.

5.3.3.2 The isolated inputs to the system isolation equipment shall consist of a relay coil or optically-isolated solid-state devices, and its power shall not be provided from the internal control power source in Clause 5.3.1.

5.4 Load side power circuit monitoring methods

5.4.1 Voltage sensing method

5.4.1.1 Voltage monitoring relay

5.4.1.1.1 The voltage monitoring safety relay component, or any other type of monitoring component determined to be suitable for the application, operates as a threshold switch. The switching thresholds are equal or less than 15 V for ac voltages and 12 V for dc voltages measured on the load side of the isolation contactor between each set of phase conductors and between phase conductors and neutral or grounded conductor.

Note 1 – The switching thresholds of 15 Vac and 12 Vdc are below the generally accepted lowest steady state touch voltage of 16 Vac or 35 Vdc ripple free in the Standard for Protection against Electric Shock – Common Aspects for Instillation and Equipment, IEC 61140: 2001, Clause 5.15, Limitations of voltage, and the Standard for Extra-low Voltage – Limit values, IEC 61201, Table 1, Limits for steady state voltage. For more information about touch voltage limits see various parts of the Standard for Electrical installation of buildings – Part 4-41: Protection for safety – Protection against electric shock, IEC 60364-4-41 or the Standard for Voltage Bands for Electrical Installations of Buildings, IEC 60449, about voltage bands.

Note 2 – Early conceptual proposals for some versions of devices similar to this system isolation equipment showed the use of sets of individual relays to perform the voltage sensing function (that particular solution potentially could work with general purpose industrial relays where the purpose of the device was used only for the prevention of unexpected start-up of a machine but it could not be used for the isolation function described in this document). While it may be possible to find a set or combination of relays that will function properly at both the operating power voltage and the acceptable touch voltage values needed for isolation applications, most general purpose industrial relays do not have that broad an operating range (pull-in, hold, drop-out values).

5.4.1.1.2 The voltage monitoring circuits are connected and self-checked in a manner to assure that the lack of voltage present, on the connected load bus, is not the result of other reasons such as an open measuring circuit.

Note – An example solution in a typical design, is the use of double circuiting with a wire-break monitoring function.

5.4.1.1.3 The voltage monitor with its associated circuitry shall provide a status indication of any inability to perform the voltage monitoring function.

5.4.2 Voltage grounding method

5.4.2.1 Shorting contactor

5.4.2.1.1 After the system isolation equipment’s isolation contactor component opens, the shorting contactor component operates to place a direct short to ground on all power conductors on the load side of the system isolation equipment’s isolation contactor. See Clause 5.2.

5.4.2.1.2 The manufacturer shall provide a means to test the continuity of the shorting contactor to ground.

5.4.2.2 Auxiliary contacts

5.4.2.2.1 Auxiliary contacts shall be provided to indicate when the shorting contactor's main contacts have reached the closed position, fulfilling the voltage grounding method.

5.5 Lockout station

5.5.1 The system isolation equipment lockout station includes lockout control switch(s) and a verification light as an assembly. Lockout stations are intended for installation on a machine near points of entry used by the machine operator for adjustment and maintenance.

Note – The number and placement of the lockout stations is a function of the operation of the machine where the system isolation equipment is to be employed, and is based on the risk assessment of that machines' particular application.

5.5.2 Lockout switch

5.5.2.1 The lockout switch contacts shall have a direct (positive) opening operation to ensure that all the normally open contacts are in the open position when the actuator is in the position corresponding to the open position of the device. See Clause 8.2.6.2.

5.5.2.2 The lockout switch contacts and circuit connections shall not be physically accessible when the lockout switch is in the open position and the lockout station is locked.

5.5.2.3 The lockout switch actuator shall be black and the locking collar or background shall be yellow. If the system isolation equipment is designed to be capable of use as an emergency stopping device the switch actuator shall be red with a yellow locking collar or background.

5.5.2.4 A red lockout switch actuator shall not be provided when the system isolation equipment is only fulfilling a part of an emergency stopping system, see Clause 5.3.3.2.

5.5.2.5 The lockout switch contact set which are used in the verification light circuit shall be mechanically connected with respect to the other lockout switch contact sets, at the farthest most position from the lockout switch actuator.

Note – This mechanical connection requirement is referring to the lockout switch's mechanical connection that is between the handle and the switch's various contacts. The above requirement is to ensure that the operator, who is using the system isolation equipment, is alerted should a failure to the lockout switch's mechanical connection occur. The operator is alerted to the failure by the indicating function from the verification light not occurring.

5.5.3 Verification light

5.5.3.1 The verification light, when illuminated, indicates that the system isolation equipment has verified the open position of the isolation contactor.

5.5.3.2 The verification light shall be of the low impedance type to reduce the risk of induced voltage from other circuits providing an induced false signal. The verification light circuit shall be protected to reduce the risk of voltage from other sources providing an undetected false signal.

Note – It is suggested that a high visibility LED array be used for the local verification light function.

5.5.3.3 The verification light circuit is configured so the verification light is lit at the respective lockout station only when:

a) The system isolation equipment isolation contactor is open;

b) The load side circuit voltage sensing or grounding methods indicate an isolated state; and

c) The local lockout switch is in the open position.

Note – When subsequent lockout stations are used, their verification lights will come on only when all the above criteria are met. The purpose of restricting the operating verification light to the location of the opened and locked lockout stations is so that, when another lockout switch is operated and locked at another entry point, the additional lockout operation is independently verified and acknowledged by the system isolation equipment.

5.5.3.4 The verification light shall be green.

Note – The color selected is based on the Standard for Safety of machinery – Indication, marking and actuation – Part 1: Requirements for visual, auditory and tactile signals, IEC 61310-1, Clause 5.2, Coding of visual signals, Clause 5.2.1, Use of colours, Table 2, Meaning of colours for coding – General principles, and the same Table 2 in the Standard for Basic and Safety Principles for Man-Machine Interface, Marking and Identification – Coding Principles for Indicators and Actuators, IEC 60073. The selection is also consistent with the Electrical Standard for Industrial Machinery, NFPA 79:2012, Table 10.3.2, Machine Indicator Lights and Icons, where the safety of persons or environment is indicated to be safe by using the color green.

5.6 Configuration requirements

5.6.1 Isolation

5.6.1.1 Electrical isolation of the system isolation equipment internal circuits

5.6.1.1.1 Except for the line and load side power connections of the system isolation equipment, the system isolation equipment is electrically isolated from all other power circuits. The system isolation equipment internal control circuits are electrically isolated from all external circuits. See Clauses 5.3.2, 5.3.3.1, and terminal X-03 in Clause A3.3.4 and Figure A.1, Figure A.2, and Figure A.3 in Annex A.

5.6.1.2 Physical isolation of the system isolation equipment internal circuits and components

5.6.1.2.1 Means shall be provided to discourage inadvertent/accidental access to the following:

a) The internal power and control circuit components inside of enclosures;

b) Power terminals (X1-in and X1-out, see Annex A) external to an enclosure;

c) Control circuit terminals – X01, X02, X1 – X8 (see Annex A) external to an enclosure and;

d) When used, pre-wired connectors used for interconnections external to an enclosure.

Electrically isolated input and output terminals – X03 (see Clauses 5.3.2, 5.3.3.1 and Annex A) are not required to comply with this requirement.

5.6.1.2.2 Each equipment enclosure and connection external to an enclosure shall be provided with a means to restrict undisclosed access, such as the provision for a tamper indication seal.

Note – The reason for restricting access to the referenced circuits and components is to prevent accidental compromising of the internal circuits by a technician working on another problem on the machine, it is not to prevent technically trained personnel from obtaining access to the unit to complete an installation or repair. Further requirements restricting access may be agreed to between the manufacturer and the customer.

5.6.1.2.3 In addition to inhibiting undisclosed access to the system isolation equipment components or cabled circuits, the system isolation equipment may also be provided with enclosures that provide various degrees of protection depending on the particular application.

5.6.2 Coordination with short circuit protective device(s)

5.6.2.1 The short-circuit protection, specified to coordinate with the system isolation equipment short circuit current ratings, shall form part of the installation but is not required to be provided as a part of the system isolation equipment. See Clause 8.3.5, Coordination with short-circuit protective devices. If not provided, the manufacturer of the system isolation equipment shall specify the required short-circuit protective device, the voltage rating and the short circuit current rating that is required in order to complete the installation of the system isolation equipment on the machine.

5.6.3 Status indication

5.6.3.1 The system isolation equipment shall include means to indicate it is functioning properly and also to indicate if a fault has occurred without requiring access to internal components and circuits.

Note – The system isolation equipment enclosures should have a means of providing status and functional state indication; e.g.: a HMI display or a window of transparent material where indicators on terminal strips and on the various devices indicate the current functional state of the system isolation equipment.

5.6.4 Troubleshooting and repair

5.6.4.1 The system isolation equipment shall be provided a means to determine which part of the system isolation equipment requires repair without having to open the unit with a tamper indication as indicated in Clause 5.6.1.2.2.

Note – The manufacturer may choose to have the system isolation equipment supplied in a modular form that, when faulted, can be replaced and the faulty unit returned to the manufacturer for repair. Alternately, the manufacture can establish a procedure for the owners technicians to facilitate repairs inside of modules with tamper indication seals and the subsequent re-sealing of the modules after repair and testing.

5.6.5 Enclosure construction

5.6.5.1 The system isolation equipment shall be constructed within one or more enclosures in accordance with Clauses 8.2.9 and 8.2.10.

6 Product Information

6.1 Nature of information

6.1.1 Clause 6.1 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies.

Note – Clause 6.1.2 (y) environments 1 or 2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A – environment 1 (environment B in the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, Clause 7.3.1): mainly relates to low-voltage public networks such as residential, commercial and light industrial locations/installations. This environment does not cover highly disturbing sources such as arc welders. Environment 2 (environment A in the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, Clause 7.3.1): mainly relates to low-voltage non-public or industrial networks/locations/installations including highly disturbing sources. In the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, Clause 7.3.1, environment B, in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, is referred to as environment 1 and corresponds to environment class B in the Standard for Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement, CISPR 11. In the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, Clause 7.3.1, environment A, in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, is referred to as environment 2 and corresponds to environment class A in the Standard for Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement, CISPR 11.

6.2 Marking

6.2.1 Clause 6.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies as appropriate with the following additions:

a) Maximum load rating of connected equipment motor current (I_{em}) (the full load ampere rating of all motors that can be operated simultaneously plus the full load ampere rating of non-motor loads).

b) The ratings of the short circuit protective devices specified in Clause 5.6.2 that are to be used on the line side of the system isolation equipment power circuits.

c) Rated impulse withstand voltage for isolation (see Table 9.2).

6.2.2 The complete markings in Clause 6.2.1 shall be placed on the chassis or the enclosure for the power circuit or the control circuit in an area visible when installed or when access covers or doors are opened. Other modules of the system isolation equipment as a minimum shall be marked with the data in Clause 6.1.1(a) and (b) in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, and a reference to the system isolation equipment or installation instructions that specifies its use.

6.2.3 If interconnection cables between the system isolation equipment respective enclosures are provided they shall have a unique identification that will set them apart from the machines' other cable systems. For example, cord/cable connections systems, and cable labels, would include indicating methods that identify they are only to be used to interconnect the system isolation equipment.

6.3 Instructions for installation, operation and maintenance

6.3.1 Clause 6.3 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies. The manufacturer shall also provide the necessary mounting and wiring instructions and include any special measures that need to be taken to achieve compliance with EMC immunity or emission requirements. See Clause 8.4.

6.3.2 If the inter-connection cables are not provided, the manufacturer of the system isolation equipment shall specify the necessary way of installing, identification and protection (see Clause 5.1.2.4) in order to complete the installation of the system isolation equipment.

6.3.3 When provided, an isolated output circuit is to be identified for use as an interlock to prohibit the activation of the start control function for the connected equipment where the system isolation equipment is employed. The interlocks used shall be explained in the application instructions. When an isolated output is not provided, the need for the machine control voltage to be sourced from the load side of the system isolation equipment shall be explained in the application instructions. In either case, compliance with the Standard for Electrical Standard for Industrial Machinery, NFPA 79:2012, Clause 7.5.3, Restarting, is required for the installation. See Clauses 1.1.1.3 and 5.3.2.1.

Note 1 – The use of the interlock is to provide machines, which have control circuits supplied from sources other than its motive voltage, the means to meet the requirements of Clause 7.5.3, Restarting of the Electrical Standard for Industrial Machinery, NFPA 79:2012 to prevent unexpected machine movement.

Note 2 – See the Electrical Standard for Industrial Machinery, NFPA 79:2012, Clause 7.5.3, Restarting. And similarly see the Standard for Safety of Machinery – Electrical Equipment of Machines – Part 1: General Requirements, IEC 60204-1, Clause 7.5, Protection against supply interruption or voltage reduction and subsequent restoration, third paragraph.

6.3.4 For a lockout station input to be used for connection to the machine control circuit as in Clause 5.3.1.4, the instructions shall indicate the means required to be provided at installation to maintain

electrical isolation and to prevent physical access to connections to the internal control circuit in accordance with Clause 5.6.1.

6.3.5 When the system isolation equipment is provided with voltage monitoring or grounding methods, the manufacturer's instructions shall include a procedure for testing and testing frequency.

7 Normal Service, Mounting and Transport Conditions

7.1 Clause 7 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies with the following addition in Clause 7.2.

7.2 The system isolation equipment shall be designed to operate correctly within the conditions found in the Electrical Standard for Industrial Machinery, NFPA 79:2012, Chapter 4, General Operating Conditions.

8 Construction and performance requirements

8.1 General

8.1.1 Clause 8 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies with the following additions.

8.2 Lockout switch actuator (see 8.1.4 of UL 60947-4-1A)

8.2.1 Insulation

8.2.1.1 The lockout switch actuator shall be insulated from the live parts for the rated insulation voltage.

8.2.1.2 A lockout switch actuator:

a) Made of metal shall be capable of being connected to a protective conductor unless it is provided with additional reliable insulation;

b) Made of or covered by insulating material, any internal metal part, which might become accessible in the event of insulation failure, shall also be insulated from live parts for the rated insulation voltage.

8.2.2 Direction of movement

8.2.2.1 The actuator of the lockout switch shall be provided with a means for padlocking it in the OFF position.

8.2.3 Actuating force (or moment)

8.2.3.1 The force (or moment) required to operate the actuator shall be compatible with the intended application, taking into account the size of the actuator, the type of enclosure or panel, the environment of the installation and the use for which it is intended.

8.2.3.2 The minimum starting force (or moment) of the lockout switch actuator shall prevent inadvertent operation of the switch due to environmental tests associated with the enclosure rating; e.g. push-buttons and rotary switches to be used with enclosures complying with degrees of protection IPX5 or IPX6 shall not become actuated when hit by the jet of water applied during the test of the enclosed equipment.

8.2.4 Limitation of rotation

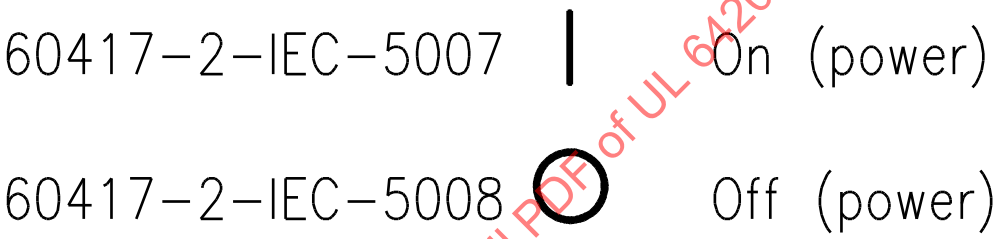
8.2.4.1 When actuators with limited or unidirectional movement are used, they shall be fitted with robust means of limitation, capable of withstanding five times the actual maximum actuating moment.

8.2.5 Indication of contact position (see 8.1.5 of UL 60947-4-1A)

8.2.5.1 Indication of the position of the lockout switch

8.2.5.1.1 The indication of the closed and open positions of the lockout switch shall be unambiguous and clearly indicated. This is done by means of position-indication on the lockout switch (position-indicating device is part of a mechanical switching device which indicates whether it is in the open or closed position).

8.2.5.1.2 If symbols are used, they shall indicate the closed and open positions.



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8.2.5.2 Indication by the lockout switch actuator

8.2.5.2.1 The actuator of the lockout switch shall stay, when released, in the position corresponding to that of the moving contacts of the lockout switch; in this case, the actuator shall have two distinct rest positions corresponding to those of the moving contacts.

8.2.5.3 Indication of open position of contacts of isolation contactor

8.2.5.3.1 The lockout switch actuator in the OFF position and the verification light lit shall provide indication that the main contacts of the isolation contactor are open in accordance with Clauses 8.3.3 and 8.3.6. Compliance with this requirement shall be verified in accordance with Clause 8.3.8.

8.2.6 Requirements for equipment with isolating function

Note – A single contactor by itself does not meet the functional requirements for isolation defined in this Standard. However, a contactor as the control element in addition to other safety-related parts of a control system can meet the requirements for isolation.

8.2.6.1 Constructional requirements for electromechanical isolation contactor

8.2.6.1.1 Electromechanical isolation contactor(s) shall provide, in the open position, (see the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, definition 2.4.21) an isolation distance in accordance with the requirements necessary to satisfy the isolating function, see Clauses 8.3.3 and 8.3.6. The additional requirements for equipment suitable for isolation functions for contactors shown in Clause 7.1.6 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, are included here but without Clause 7.1.6.1DV additional note and included as shown in Clause 8.1.6 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, along with the additional requirements contained within this standard, as requirements for contactors in this document.

8.2.6.2 Construction requirements for lockout switches

8.2.6.2.1 Locking of the lockout switch actuator in the open position shall only be possible when the lockout switch contacts are in the open position. Compliance with this requirement shall be verified while the test force "3F" is applied to the actuator as in Clause 9.2.2.2.1.

8.2.6.2.2 The lockout switch shall be designed so that the actuator, front plate or cover is fitted to the enclosure in a manner which ensures correct contact position indication and locking. Compliance with this requirement and Clause 8.2.5.1.1 shall be verified in accordance with Clause 9.2.2 and following the tests required by Clauses 8.2.6.2.1 and 8.2.6.2.5.

8.2.6.2.3 The locking means shall be designed in such a way that the switch contacts cannot change positions with the appropriate padlock(s) installed.

8.2.6.2.4 Alternatively, padlock able means may be provided to prevent access to the actuator.

8.2.6.2.5 Compliance with Clause 8.2.6.2.3 shall be verified using a padlock specified by the manufacturer or an equivalent gauge, giving the most adverse conditions, to simulate locking. The test force "3F" specified in Clause 9.2.2.2.1 shall be applied to the actuator in an attempt to operate the lockout switch from the open position to the closed position. At the same time as the test force "3F" is applied, the lockout switch shall be subjected to a test voltage across open contacts to ensure there is no continuity.

8.2.6.2.6 Depending on the design of the system isolation device, the lockout switch contacts shall comply with the 'A' designated AC-15 or the 'N' designated DC 13 ratings in Table 8.11, Examples of mirror contact rating designation based on utilization categories.

8.2.6.2.7 The lockout switch shall demonstrate resistance to mechanical and electrical wear verified to a minimum of 10,000 cycles of operations as in Clause 8.3.4.3.

8.2.7 Terminals

8.2.7.1 Clause 8.1.7 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies.

8.2.8 Provisions for earthing

8.2.8.1 Clause 8.1.9 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies with the following additions.

8.2.8.2 Control circuits shall be allowed to be grounded or ungrounded. Ungrounded control circuits shall be provided with an insulation monitoring device that either indicates a ground (earth) fault or interrupts the circuit automatically after a ground (earth) fault.

8.2.9 Enclosures for equipment

8.2.9.1 Clause 7.1.10 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies with the following additions.

8.2.9.2 The system isolation equipment shall be provided in an enclosure to restrict access. See Clause 5.6.1.2.1.

8.2.9.3 When the enclosed system isolation equipment additionally contains the supply disconnect, the operating means shall be interlocked with the cover or door as in Clause 8.1.10 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A.

8.2.10 Degrees of protection of enclosed equipment

8.2.10.1 Clause 7.1.11 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies.

Note – Conformance with Clause 7.1.10 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, restricts enclosures to a minimum IP rating of 2X.

8.3 Performance requirements (see 8.2 of UL 60947-4-1A)

8.3.1 Operating conditions and limits

8.3.1.1 Clause 8.2.1.1 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, with the following additions apply with regard to isolation and shorting contactors.

8.3.1.2 For isolation contactors and, where used, the shorting contactor applications, Clause 8.2.1.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies.

8.3.1.3 For control circuit component applications Clauses 7.2.1.1 and 7.2.1.2 (for control relays) of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, apply.

8.3.1.4 The verification indication occurs only if the voltage of the isolated circuit is less than 15 Vac rms between phases and between any phase to neutral or grounded conductor or 12 Vdc (ripple free) between circuit conductors or circuit conductors and common (or earth in a grounded system), after isolation has occurred. For the voltage grounding method, the verification indication occurs only when it has been verified that the grounding contactor has been pulled in (energized).

8.3.2 Temperature rise

8.3.2.1 Clause 8.2.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies with regard to isolation and shorting contactors.

8.3.3 Dielectric properties

8.3.3.1 The system isolation equipment power circuit shall be capable of withstanding the dielectric tests specified in Clause 9.3.3.4.

8.3.3.2 The system isolation equipment control circuit shall be capable of withstanding the power frequency withstand verification of solid insulation test specified in Clause 9.3.3.4.3.

8.3.4 Normal load and overload performance requirements

8.3.4.1 Making and breaking capacities

8.3.4.1.1 Making and breaking capacities of the isolation contactor(s) and (where used) the shorting contactor in Clause 8.2.4.1 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies with the following additions.

8.3.4.1.2 The main isolation contactor shall comply with AC-23A or DC-23A. The main isolation contactor shall additionally comply with contactor overload test in Table 8.1 and Table 8.2.

Table 8.1
Verification of rated making and breaking capacities – conditions for making and breaking corresponding to the various utilization categories

Utilization category	Rated operational current	Making[a]			Breaking			Number of operating cycles
		I / I_{em}	U / U_e	cos Φ	I_c / I_{em}	U_r / U_e	cos Φ	
AC-23A	$0 < I_e$ 100 A	10	1.05	0.45	8	1.05	0.45	5
AC-23A	100 A < I_e	10	1.05	0.35	8	1.05	0.35	3
				L/R ms			L/R ms	
DC-23A	All values	4	1.05	15	4	1.05	15	5

I = Making current

I_c = Breaking current

I_{em} = Rated operational motor current

U = Applied voltage

U_e = Rated operational voltage

U_r = Operational frequency or dc recovery voltage

[a] For ac the making current is expressed by the rms value of the periodic component of the current.

Table 8.2
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

Table 8.2 Continued on Next Page

Table 8.2 Continued

Current broken I_c, A	Off-time, s
$400 < I_c \leq 600$	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
$1{,}600 \leq I_c$	240

8.3.4.1.3 The shorting contactor shall comply with AC-1 or DC-1 (make only) as in Table 8.2 and Table 8.3.

Table 8.3
Verification of rated making and breaking capacities – Conditions for making and breaking corresponding to the various utilization categories

Utilization category	Making and breaking conditions					Number of operating cycles
	I_c / I_e	U_r / U_e	cos Φ	On-time[2] s	Off-time s	
AC-1	1.5	1.05	0.8	0.05	Table 8.2	50
DC-1	1.5	1.05	1.0	0.05	Table 8.2	50

I = current made. The making current is expressed in dc or ac rms symmetrical values but it is understood that, for ac, 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 dc or ac rms symmetrical values

I_e = rated operational current

U = applied voltage

U_r = power frequency or dc recovery voltage

U_e = rated operational voltage

cos Φ = power factor of test circuit

L/R = time-constant of test circuit

[1] 25 operating cycles with one polarity and 25 cycles with reverse polarity.

[2] The time may be less than 0.05 s, provided that contacts are allowed to become properly seated before re-opening.

8.3.4.1.4 Making and breaking capacities of control circuit components under abnormal conditions, Clause 8.2.4.1 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies in addition to Clause 8.3.4.1.5.

8.3.4.1.5 The control circuit components switching elements shall be capable of making and breaking currents without failure under the conditions stated in Table 8.4, for the required utilization categories and the number of operating cycles indicated, under the conditions specified in Clause 9.3.3.6.3.

Table 8.4
Verification of making and breaking capacities of switching elements under abnormal conditions corresponding to the utilization categories[1)]

Utilization Category	Make			Break			Minimum on-time	Making and breaking operation	
	I/I_e	U/U_e	–	I/I_e	U/U_e	–		Number	Rate per minute
AC	–	–	cos φ	–	–	cos φ	**Cycles (at 50 Hz or 60 Hz)**	–	–
AC-15	10	1.1	0.3	10	1.1	0.3	2	10	6
DC	–	–	$T_{0.95}$ ms			$T_{0.95}$ ms	**Time** ms	–	–
DC-13	1.1	1.1	$6 \times P^{5)}$	1.1	1.1	$6 \times P^{5)}$	$T_{0.95}$	10	6
DC-14	10	1.1	15	10	1.1	15	25[4)]	10	6

I_e Rated operational current

I Current to be made or broken

U_e Rated operational voltage

U Voltage before make

$P = U_e \times I_e$ Steady-state power consumption, in W

$T_{0.95}$ Time to reach 95% of the steady-state current

[1)] The abnormal condition is to simulate a blocked open electromagnet. See Clause 9.3.3.6.3.

[2)] For tolerances on test quantities, see Clause 8.3.2.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1.

[3)] For semiconductor switching devices an overload protective device specified by the manufacturer should be used to verify the abnormal conditions.

[4)] Both on-time values (for I_{make} and for I_{break}) shall be at least equal to 2 cycles (or 25 ms for DC-14).

[5)] The value "6 × P" results from an empirical relationship which is found to represent most dc magnetic loads to an upper limit of P = 50 W, i.e., 6 × P = 300 ms. Loads having power consumption greater than 50 W are assumed to consist of smaller loads in parallel. Therefore, 300 ms is to be an upper value, irrespective of the power consumption value.

For semiconductor switching devices the maximum time constant shall be 60 ms, i.e. T0.95 = 180 (3 × time constant).

8.3.4.2 Conventional operational performance

8.3.4.2.1 Clause 8.2.4.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies with the following additions.

8.3.4.2.2 Depending on the intended application of the system isolation device, the main isolation contactor shall comply with AC-23A or DC-23A. The main isolation contactor shall be subjected to operations indicated in Table 8.5 and Table 8.6.

Table 8.5
Verification of operational performance – conditions for making and breaking corresponding to the various utilization categories

Utilization category	Rated operational motor current	Making[a)]			Breaking			Number of operating cycles
		I / I_{em}	U / U_e	cos Φ	I_c / I_{em}	U_r / U_e	cos Φ	
AC-23A	All values	1	1	0.65	1	1	0.65	See Table 8.6
DC-23A	All values	1	1	L / R ms	1	1	L / R ms	See Table 8.6
				7.5			7.5	

I = Making current

I_c = Breaking current

I_{em} = Rated operational motor current

U = Applied voltage

U_e = Rated operational voltage

U_r = Operational frequency or dc recovery voltage

[a)] For ac the making current is expressed by the rms value of the periodic component of the current.

Table 8.6
Verification of operational performance – number of operating cycles corresponding to the rated operational current for AC-23A and DC-23A utilization categories

Rated operational current I_{em}	Numbering of operating cycles per hour	Number of operating cycles		
		AC and DC A categories		
		Without current	With current	Total
$0 < I_{em} \leq 100$	120	8,500	1,500	10,000
$100 < I_{em} \leq 315$	120	7,000	1,000	8,000
$315 < I_{em} \leq 630$	60	4,000	1,000	5,000
$630 < I_{em} \leq 2,500$	20	2,500	500	3,000
$2,500 < I_{em}$	10	1,500	500	2,000

Note – For information on mechanical durability testing and the results to be obtained see Clause 9.1.2, Special tests.

8.3.4.2.3 Depending on the intended application of the system isolation equipment, the shorting contactor shall comply with AC-1 or DC-1 (make only). For conventional operational performance the shorting contactor shall be subjected to the conventional conditions indicated in Table 8.7 and Table 8.8 without failure for 6,000 operating cycles.

Table 8.7
Verification of operational performance conditions for making and breaking corresponding to the various utilization categories

Utilization category	Making and breaking conditions					Number of operating cycles
	I_c / I_e	U_r / U_e	cos Φ	On-time[2] s	Off-time s	
AC-1	1.0	1.05	0.8	0.05	Table 8.8	6,000
DC-1	1.0	1.05	1.0	0.05	Table 8.8	6,000[1]

I = current made. The making current is expressed in dc or ac rms symmetrical values but it is understood that, for ac, 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 dc or ac rms symmetrical values

I_e = rated operational current

U = applied voltage

U_r = power frequency or dc recovery voltage

U_e = rated operational voltage

Cos Φ = power factor of test circuit

L/R = time-constant of test circuit

[1] 3,000 operating cycles with one polarity and 3,000 operating cycles with reverse polarity.

[2] The time may be less than 0.05 s, provided that contacts are allowed to become properly seated before re-opening.

Table 8.8
Relationship between current broken I_c and off-time for the verification operational performance

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
$1{,}600 \leq I_c$	240

8.3.4.2.4 Making and breaking capacities of switching elements of control circuit components under normal conditions, Clause 8.3.3.6 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies for the required utilization category and number of cycles indicated in Table 8.9 and Table 8.10.

Table 8.9
Verification of making and breaking capacities of switching elements of control circuit components under normal conditions corresponding to the utilization categories[1)]

Utilization Category	Make[2)]			Break[2)]			Minimum on-time
	I/I_e	U/U_e		I/I_e	U/U_e		
AC			cos φ			cos φ	Cycles (at 50 Hz or 60 Hz)
AC-15	10	1	0.3	1	1	0.3	3[3)]
DC			T0.95 ms			T0.95 ms	Time ms
DC-13	1	1	6 × P[4)]	1	1	6 × P[4)]	T0.95
DC-14	10	1	15	1	1	15	25[3)]

I_e Rated operational current

I Current to be made or broken

U_e Rated operational voltage

U Voltage before make

$P = U_e \times I_e$ Steady-state power consumption, in W

T0.95 Time to reach 95% of the steady-state current

[1)] See Clause 9.3.3.5.2.

[2)] For tolerances on test quantities, see Clause 8.3.2.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1.

[3)] Both on-time values (for I_{make} and for I_{break}) shall be at least equal to 2 cycles (or 25 ms for DC-14).

[4)] The value "6 × P" results from an empirical relationship which is found to represent most dc magnetic loads to an upper limit of P = 50 W, i.e. 6 × P = 300 ms. Loads having power consumption greater than 50 W are assumed to consist of smaller loads in parallel. Therefore, 300 ms is to be an upper value, irrespective of the power.

Table 8.10
Sequence, number and rate of operation for verification of making and breaking capacities of switching elements of control circuit components under normal conditions corresponding to the utilization categories[1)]

Sequence, number and rate of operations		
Order[1)]	Number	Rate per minute
1	50[2)]	6
2	10	Rapidly[3)]
3	990	60
4	5,000	6

[1)] For all utilization categories the test sequence shall be in the order given.

[2)] The first 50 operating cycles shall be made with the test voltage raised to $U_e \times 1.1$, the test current I_e having been first set with the voltage at U_e.

[3)] As rapidly as possible whilst ensuring complete closing and opening of contacts.

8.3.4.3 Durability of isolation contactor and lockout switch

8.3.4.3.1 Elements of minimum mechanical and electrical durability are demonstrated in meeting the performance requirements for the system isolation equipment components; however, additional levels of durability may be required in order to meet the safety performance category classification in Clause 4.4. Clause 7.2.4.3 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1 applies in addition to Clause 8.3.4.3.2.

8.3.4.3.2 The additional level of mechanical and electrical durability of the system isolation equipment components is verified, when needed, by special tests conducted at the discretion of the manufacturer. Instructions for conducting these tests are given in Clause 9.1.2.

8.3.5 Coordination with short-circuit protective devices (see Clause 8.2.5 of UL 60947-4-1A)

8.3.5.1 The rated conditional short-circuit current of the system isolation equipment (with short circuit protective device) specified by the manufacturer shall be verified by short-circuit tests as specified in Clause 9.

8.3.6 Leakage current when isolated (system isolation equipment isolation contactor)

8.3.6.1 The leakage current shall be measured through each pole of the isolation contactor with the contacts in the open position. The value of leakage current, with a test voltage equal to 1.1 times the rated operational voltage shall not:

a) Exceed 0.5 mA per pole for equipment in a new condition;

b) Exceed 2 mA per pole for equipment having been subjected to the making and breaking operations or short circuit test in accordance with the test requirements as specified herein.

8.3.6.2 A leakage current of 5 mA at 1.1 times the rated operational voltage is a limiting value for equipment suitable for isolation which value shall not be exceeded under any circumstances.

8.3.7 Mirror contacts

8.3.7.1 Depending on the design of the system isolation equipment, the auxiliary (mirror) contact shall comply with the A designated AC-15 or the N designated DC 13 ratings of Table 8.11.

Table 8.11
Examples of mirror contact rating designation based on utilization categories

Designation[1)]	Utilization category	Conventional enclosed thermal current I_{the}A	Rated operational current I_e (A) at rated operational voltage U_e						VA rating	
Alternating current			120 V	240 V	380 V	480 V	500 V	600 V	Make	Break
A150	AC – 15	10	6	–	–	–	–	–	7,200	720
A300	AC – 15	10	6	3	–	–	–	–	7,200	720
A600	AC – 15	10	6	3	1.9	1.5	1.4	1.2	7,200	720
B150	AC – 15	5	3	–	–	–	–	–	3,600	360
B300	AC – 15	5	3	1.5	–	–	–	–	3,600	360
B600	AC – 15	5	3	1.5	0.95	0.75	0.72	0.6	3,600	360
C150	AC – 15	2.5	1.5	–	–	–	–	–	1,800	180
C300	AC – 15	2.5	1.5	0.75	–	–	–	–	1,800	180
C600	AC – 15	2.5	1.5	0.75	0.47	0.375	0.35	0.3	1,800	180
D150	AC – 14	1.0	0.6	–	–	–	–	–	432	72
D300	AC – 14	1.0	0.6	0.3	–	–	–	–	432	72
E150	AC – 14	0.5	0.3	–	–	–	–	–	216	36
Direct current			125 V	250 V		400 V	500 V	600 V	Make	Break

Table 8.11 Continued on Next Page

Table 8.11 Continued

Designation[1)]	Utilization category	Conventional enclosed thermal current I_{the}A	Rated operational current I_e (A) at rated operational voltage U_e						VA rating	
N150	DC – 13	10	2.2	–		–	–	–	275	275
N300	DC – 13	10	2.2	1.1		–	–	–	275	275
N600	DC – 13	10	2.2	1.1		0.63	0.55	0.4	275	275
P150	DC – 13	5	1.1	–		–	–	–	138	138
P300	DC – 13	5	1.1	0.55		–	–	–	138	138
P600	DC – 13	5	1.1	0.55		0.31	0.27	0.2	138	138
Q150	DC – 13	2.5	0.55	–		–	–	–	69	69
Q300	DC – 13	2.5	0.55	0.27		–	–	–	69	69
Q600	DC – 13	2.5	0.55	0.27		0.15	0.13	0.1	69	69
R150	DC – 13	1.0	0.22	–		–	–	–	28	28
R300	DC – 13	1.0	0.22	0.1		–	–	–	28	28

[1)] The letter stands for the conventional enclosed thermal current and identifies (ac or dc): for example B means 5 A ac The rated insulation voltage U_i is at least equal to the number after the letter.

[2)] The rated operational current I_e (A), the rated operational voltage U_e (V) and the break apparent power B (VA) are correlated by the formula $B = U_e \times I_e$.

8.3.7.2 The auxiliary (mirror) contact component shall demonstrate resistance to mechanical and electrical wear verified to a minimum of 10,000 cycles of operations as in Clause 8.3.4.3.

8.3.7.3 As a result of the test in Clause 9.3.5 on each pole of the isolation contactor, the mirror contact gap(s) shall be greater than 0.5 mm or there shall be no disruptive discharge across the mirror contact.

8.3.7.4 At the end of the conventional operational performance tests of the respective contactor, according to Clause 9.3.3.6, it shall be verified that, when the coil is energized, the open mirror contact shall withstand its rated insulation voltage U_i.

8.3.8 Functional requirements

8.3.8.1 Normal operation

8.3.8.1.1 In normal operation the system isolation equipment shall meet the following functional criteria:

a) When a lockout switch is placed in the off (open) position the system isolation equipment:

1) Isolates the connected equipment from the source voltage; and

2) Verifies the isolation of the connected equipment by:

i) Checking the position of the isolating device(s) have been opened and

ii) Positively confirms that there is no motive voltage on the load side of the system isolation equipment; and

iii) No faults detected in the system isolation equipment.

3) Once verification is established by (a)(2),

i) The verification light is illuminated at the lockout station,

ii) The isolated condition remains as long as any lockout switch remains in the off (open) position; and

iii) It shall not be possible for the isolation contactor to be re-closed only by interruption and restoration of the mains power supply.

b) When any lockout switch is in the off (open) position:

1) All lockout stations which remain in the on (closed) position shall not have their verification lights illuminated; and

2) Any subsequent lockout switches which are placed into the off (open) position, the system isolation equipment fulfills the steps in (a).

c) Upon returning a lockout switch to the closed (ON) position, the verification light at that lockout station is de-energized, and the isolation contactor shall close only when:

1) All lockout switches are in the closed (ON) position; and

2) No internal faults are detected within the system isolation equipment. A fault that is not detectable until a system transition occurs, i.e. from on to off or from off to on, shall not result in an unsafe condition.

d) Upon restoration of power to the system isolation equipment, the isolation contactor shall not close:

1) Until a deliberate manual command or operation to the system isolation equipment control circuit has been executed; and

2) All lockout switches are in the closed (ON) position; and

3) No internal faults are detected within the system isolation equipment. A fault that is not detectable until a system transition occurs, i.e. from on to off or from off to on, shall not result in an unsafe condition.

8.3.8.2 Fault reaction requirements

8.3.8.2.1 The system isolation equipment shall respond to single faults listed in Clause 8.3.8.3, such that:

a) Under any operating condition, a false verification indication shall not be given at any lockout station;

b) At power on, prior to isolation contactor being closed, the control functions shall be monitored to verify the absence of internal faults within the system isolation equipment. If an internal fault is detected, the isolation contactor shall not close. A fault that is not detectable until a system transition occurs (i.e. from on to off or from off to on, shall not result in an unsafe condition).

c) If an internal fault is detected after verification is established, the isolated condition remains as long as the lockout switch remains in the off (open) position, including a failure of the verification light.

d) Re-closure of the isolation contactor is not possible as long as an internal fault in the system isolation equipment is present. A fault that is not detectable until a system transition occurs (i.e. from on to off or from off to on, shall not result in an unsafe condition).

e) A manual reset command or operation of the internal control circuit of the system isolation equipment is required following the repair of the failure to initiate the control fault monitoring process, and if no faults are detected, the normal operating condition is restored.

8.3.8.2.2 The effect of component failure upon the system isolation equipment performance shall be determined using an analysis method such as one of those mentioned in Clause 9.3.6.

8.3.8.3 Component failures to be addressed

8.3.8.3.1 The component/equipment failures to be addressed using the failure analysis method selected from Clause 9.3.6 in the design of the system isolation equipment include, but are not limited to:

a) Power contactor failures;

1) Power contact(s) broken or welded, won't open.

2) Auxiliary contact won't change state due to mechanical link failure.

3) Auxiliary contact(s) welded.

4) Auxiliary contact(s) not making circuit due to corrosion or other foreign material.

b) Connection from monitored circuits to voltage check component (e.g. relays) failures;

1) One wire open.

2) Multiple wires open.

c) Voltage check (e.g. relays) failures;

1) Open coil.

2) Contact won't change state due to mechanical link failure.

3) Contact(s) welded.

4) Contact(s) not making circuit due to corrosion or other foreign material.

d) Rated safety components used within the system isolation equipment failures;

1) Example failures to consider:

i) Open coil.

ii) Contact won't change state due to mechanical link failure.

iii) Contact(s) welded.

iv) Contact(s) not making circuit due to corrosion or other foreign material.

v) Other internal failure of the respective component.

2) Lockout switch failures;

i) Circuits to switch shorted.

ii) Circuits to switch open.

iii) N.O. contacts will not open.

iv) N.O. contacts will not close.

v) N.C. contacts will not open.

vi) N.C. contacts will not close.

vii) Contacts won't change state due to mechanical link failure.

viii) N.C. auxiliary contact will not open.

ix) N.C. auxiliary contact will not close.

3) Verification light at lockout station failure;

i) Light burn out.

8.3.8.3.2 Overall design of the system isolation equipment shall be such that any failure(s) will not prevent it from performing in accordance with Clause 4.4.

8.4 Electromagnetic compatibility (EMC) (see 8.3 of UL 60947-4-1A)

8.4.1 General

8.4.1.1 For products falling within the scope of this standard, two sets of environmental conditions are considered and are referred to as environment A and environment B. See Clause 8.4.3.

8.4.1.2 Power frequency magnetic field tests are not required when contactors are used. Immunity is demonstrated by the successful completion of the operational performance capability tests. See Clauses 9.3.3.5 and 9.3.3.6 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A.

8.4.1.3 This equipment is inherently sensitive to voltage dips and short time interruptions on the control supply. It shall react within the limits of Clause 8.2.1.2 and this is verified by the operating limits tests given in Clause 9.3.3.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A.

8.4.2 Immunity

8.4.2.1 Equipment not incorporating electronic circuits

8.4.2.1.1 For electro-mechanical contactors and relays which do not incorporate active electronic circuits, no immunity tests are required.

8.4.2.2 Equipment incorporating electronic circuits

8.4.2.2.1 Equipment incorporating electronic circuits shall have a satisfactory immunity to electromagnetic disturbances. The appropriate tests to verify the compliance with these requirements are in Clause 9.4. Equipment utilizing electronic circuits in which all components are passive (for example, diodes, resistors, varistors, capacitors, surge suppressors, inductors) are not required to be tested.

8.4.2.2.2 The performance criteria are quoted in Table 8.12 and described in more detail in Table 8.13. Normal performance is as defined under normal operation criteria, Clause 8.3.8.1 and fault reaction criteria, Clause 8.3.8.2.

Note – The test results are specified using the performance criteria of the Standard for Electromagnetic Compatibility (EMC) – Part 4-2: Testing and Measurement Techniques – Electrostatic Discharge Immunity Test, IEC 61000-4-2, Clause 9, Evaluation of test results.

Table 8.12
Performance criteria for immunity tests

Performance criteria	Test result
1	Normal performance within the specification limits
2	Temporary degradation, or loss of function or performance which is self-recoverable
3	Temporary degradation, or loss of function or performance, which requires operator's intervention or system reset. Normal functions shall be restorable by simple intervention, for example by manual reset or restart. There shall not be any damaged component.

Table 8.13
Specific acceptance criteria for immunity tests

Item	Acceptance criteria		
	1	2	3
Operation of power and control circuits	No mal-operation	Temporary mal-operation which cannot cause tripping	Tripping of overload relay
		Unintentional separation or closure of contacts is not accepted	Unintentional separation or closure of contacts
		Self-recoverable	Not self-recoverable
Operation of displays and auxiliary circuits	No changes to visible display information	Temporary visible changes, for example unwanted LED illumination	Permanent loss of display information
	Only slight light intensity fluctuations of LEDs or movement of characters	No mal-operation of auxiliary contacts	Mal-operation of auxiliary contacts

8.4.3 Emission

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

Note 1 – Environment 1 in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, and environment B in the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1: mainly relates to low-voltage public networks such as residential, commercial and light industrial locations/installations. This environment does not cover highly disturbing sources such as arc welders. In the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, Clause 7.3.1, environment B is referred to in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, Tables 14 & 15, as environment 1 and corresponds to environment class B in the Standard for Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement, CISPR 11.

Note 2 – Environment 2 in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, and environment A in the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1: mainly relates to low-voltage non-public or industrial networks/locations/installations including highly disturbing sources. In the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, Clause 7.3.1, environment A is referred to in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, Tables 14 & 15, as environment 2 and corresponds to environment class A in the Standard for Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement, CISPR 11.

8.4.3.2 Equipment not incorporating electronic circuits

8.4.3.2.1 For electro-mechanical contactors and relays which do not incorporate active electronic circuits, no emission tests are required.

8.4.3.3 Equipment incorporating electronic circuits

8.4.3.3.1 Limits for high-frequency emissions – Equipment incorporating electronic circuits, such as switched mode power supplies and circuits incorporating microprocessors with high-frequency clocks, may generate continuous electromagnetic disturbances. Radiated radio-frequency emission tests are required only for equipment incorporating circuits with fundamental switching frequency greater than 9,000 Hz. For such emissions, these shall not exceed the limits specified in the relevant product standard.

Note – Within this equipment assembly the components which are used generally have their own product standard. The product standard limits are based on the Standard for Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement, CISPR 11 for environment A and for environment B or based on limits contained in the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, and FCC regulations. If such components are used, it is recommended that the assembled equipment be also tested to ensure that the high frequency emissions are not enhanced by the assembly or normal connections effects.

8.4.3.3.2 Limits for low-frequency emissions – For equipment which generates low frequency harmonics, where applicable, the requirements of Table 8.14 apply.

Table 8.14
Limits for low frequency harmonics

Harmonic order	Maximum permissible harmonic current
Odd order harmonics	
3	2.3
5	1.14
7	0.77
9	0.40
11	0.33
13	0.21
15 ≤ n ≤ 39	0.15 15/n
Even order harmonics	
2	1.08
4	0.43
6	0.30
8 ≤ n ≤ 40	0.23 8/n
Note – Additional information may be found in the Standard for Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current Less than or equal to 16 A per phase), IEC 61000-3-2.	

8.4.3.3.3 For equipment which generates low frequency voltage fluctuations, a relative voltage fluctuation limit of 6% applies.

Note – Additional information may be found in the Standard for Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection, IEC 61000-3-3.

9 Tests

9.1 Kinds of test

9.1.1 General

9.1.1.1 Kinds of tests related to contactors in Clause 9.1 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A apply with the following additions.

9.1.1.2 Kinds of tests related to control circuit devices in Clause 8.1 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1 apply with the following additions.

9.1.2 Special tests (see Clause 9.1.5 of UL 60947-4-1A)

9.1.2.1 General

9.1.2.1.1 Special tests are durability tests.

9.1.2.2 Mechanical and electrical durability – general

9.1.2.2.1 By convention, the mechanical and electrical durability of a design of an isolation contactor or a lockout switch 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 Clauses 9.1.2.3.1 and 9.1.2.3.3 is allowed.

9.1.2.2.2 The preferred numbers of no-load operating cycles, expressed in millions, are: 0.01, 0.03, 0.1, 0.3, 1, 3, and 10.

9.1.2.3 Mechanical durability – verification of mechanical durability

9.1.2.3.1 Condition of the contactor for tests

9.1.2.3.1.1 The contactor shall be installed as for normal service; in particular, the conductors shall be connected in the same manner as for normal use.

9.1.2.3.1.2 During the test, there shall be no voltage or current in the main circuit. The contactor may be lubricated before the test if lubrication is prescribed in normal service.

9.1.2.3.2 Operating conditions

9.1.2.3.2.1 The coils of the control electromagnets shall be supplied at their rated voltage and, if applicable, at their rated frequency.

9.1.2.3.2.2 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.

9.1.2.3.2.3 Pneumatic and electro-pneumatic contactors shall be supplied with compressed air at the rated pressure.

9.1.2.3.3 Test procedure

9.1.2.3.3.1 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 can satisfy the required conditions when using a higher frequency of operations, he may do so.

9.1.2.3.3.2 In the case of electromagnetic and electro-pneumatic contactors, the duration of energization of the control coil shall be greater than the time of operation of the contactor and the time for which the coil is not energized shall be of such a duration that the contactor 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.

9.1.2.3.3.3 For contactors 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.

9.1.2.3.3.4 After each tenth of the total number of operating cycles given in Clause 9.1.2.2.2 has been carried out, it is allowable before carrying on with the test:

a) To clean the whole contactor without dismantling;

b) To lubricate parts for which lubrication is prescribed by the manufacturer for normal service;

c) To adjust the travel and the pressure of the contacts if the design of the contactor enables this to be done.

9.1.2.3.3.5 This maintenance work shall not include any replacement of parts.

9.1.2.3.4 Results to be obtained

9.1.2.3.4.1 Following the tests of mechanical durability, the contactor shall still be capable of complying with the operating conditions specified in Clause 8.3.1.2 and in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, Clause 9.3.3.2, at room temperature. There shall be no loosening of the parts used for connecting the conductors.

9.1.2.3.4.2 Any timing relays or other devices for the automatic control shall still be operating.

9.1.2.3.5 Statistical analysis of test results for contactors

9.1.2.3.5.1 The mechanical durability of a design of a contactor is assigned by the manufacturer and verified by a statistical analysis of the results of the tests.

9.1.2.3.5.2 For contactors which are produced in small quantities, the tests described in Clauses 9.1.2.3.6 and 9.1.2.3.7 do not apply.

9.1.2.3.5.3 For contactors which are produced in small quantities and which also differ from a basic design only by detailed variations, that is, without any significant variation 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.

9.1.2.3.5.4 After this assignment, one of the two tests described in Clause 9.1.2.3.6 or 9.1.2.3.7 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.

9.1.2.3.6 Single 8 test

9.1.2.3.6.1 Eight contactors shall be tested to the assigned mechanical durability.

9.1.2.3.6.2 If the number of failures does not exceed two, the test is considered passed.

9.1.2.3.7 Double 3 test

9.1.2.3.7.1 Three contactors shall be tested to the assigned mechanical durability.

9.1.2.3.7.2 The test is considered passed if there is no failure, and failed if there is more than one failure.

9.1.2.3.7.3 Should there be one failure, then three additional contactors are tested up to assigned mechanical durability and, providing there is no additional failure, the test is considered passed.

9.1.2.3.7.4 The test is failed if at any time there is a total of two or more failures.

Note – The single 8 test and the double 3 test are both given in the Standard for Sampling plans and procedures for inspection by attributes, IEC 60410 (see tables X-C-2 Sample size code letter C and X-D-2 Sample size code letter D). These two tests have been chosen with the objective of basing them on testing a limited number of contactors on essentially the same statistical characteristics (acceptance quality level: 10%).

9.1.2.4 Electrical durability – verification of electrical durability

9.1.2.4.1 Test procedure for contactors

9.1.2.4.1.1 With respect to its resistance to electrical wear, the contactor is by the number of on-load operating cycles corresponding to the different utilization categories given in Clause 8.3.4.2 which can be made without repair or replacement.

9.1.2.4.1.2 For categories AC the test circuit shall comprise inductors and resistors so arranged as to give the appropriate values of current, voltage and power factor given in Clause 8.3.4.2.

9.1.2.4.1.3 In all cases, the speed of operation shall be chosen by the manufacturer.

9.1.2.4.1.4 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:

a) Current: ±5%;

b) Voltage: ±5%.

9.1.2.4.1.5 Tests shall be carried out with the contactor under the appropriate conditions of Clauses 9.1.2.3.1 and 9.1.2.3.2 using the test procedure, where applicable, of Clause 9.1.2.3.3, except that replacement of contacts is not allowed.

9.1.2.4.1.6 After the test, the contactor shall fulfill the operating conditions specified in Clause 9.3.3.2 and withstand a dielectric test voltage as in Clause 9.3.3.4.2.

9.1.2.4.2 Electrical durability test procedures for control circuit devices (relays and lockout switches)

9.1.2.4.2.1 Electrical durability tests are carried out by operating the device under the conditions defined in Table 9.1, in accordance with Clause 9.1.2.4.2.5 for ac or with Clause 9.1.2.4.2.8 for dc.

Table 9.1
Making and breaking conditions for electrical durability

Kind of current	Utilization Category	Make			Break		
Alternating	AC – 15	I	U	cos φ	I	U	cos φ
		10 I_e	U_e	0.7[1)]	I_e	U_e	0.4[1)]
Direct[2)]	DC-13	I	U	$T_{0.95}$	I	U	$T_{0.95}$
		I_e	U_e	6 × P[3)]	I_e	U_e	6 × P[3)]

I_e Rated operational current

I Current to be made or broken

U_e Rated operational voltage

U Voltage

$P = U_e \times I_e$ Steady-state power consumption, in W

$T_{0.95}$ Time to reach 95% of the steady-state current in milliseconds

[1)] The power-factors indicated are conventional values and apply only to the test circuits which simulate the electrical characteristics of coil circuits. It should be noted that, for circuits with power-factor 0.4, shunt resistors are used in the test circuit to simulate the damping effect on the eddy current losses of the actual electromagnet.

[2)] For dc electromagnetic loads provided with switching devices introducing an economy resistor, the rated operational current shall be at least equal to the maximum value of the inrush current.

[3)] The value "6 × P" results from an empirical relationship which is found to represent most dc magnetic loads to an upper limit of P = 50 W, i.e., 6 × P = 300 ms. Loads having power consumption greater than 50 W are assumed to consist of smaller loads in parallel. Therefore, 300 ms is to be an upper value irrespective of the power.

9.1.2.4.2.2 Each mechanical operating cycle shall include an interruption of test current.

9.1.2.4.2.3 The ON-duration of current shall be not more than 50% and not less than 10% of an operating cycle. If the test circuit shown in Figure 9.1(a) is used, the ON-duration of current at ten times I_e shall not cause overheating. See Figure 9.2 for examples of contact element schematic sketches.

Figure 9.1

AC test circuits (see Clause 9.1.2.4.2.5)

(a) Normal circuit (see Clause 9.1.2.4.2.5) – (b) Simplified circuit (see Clause 9.1.2.4.2.6)

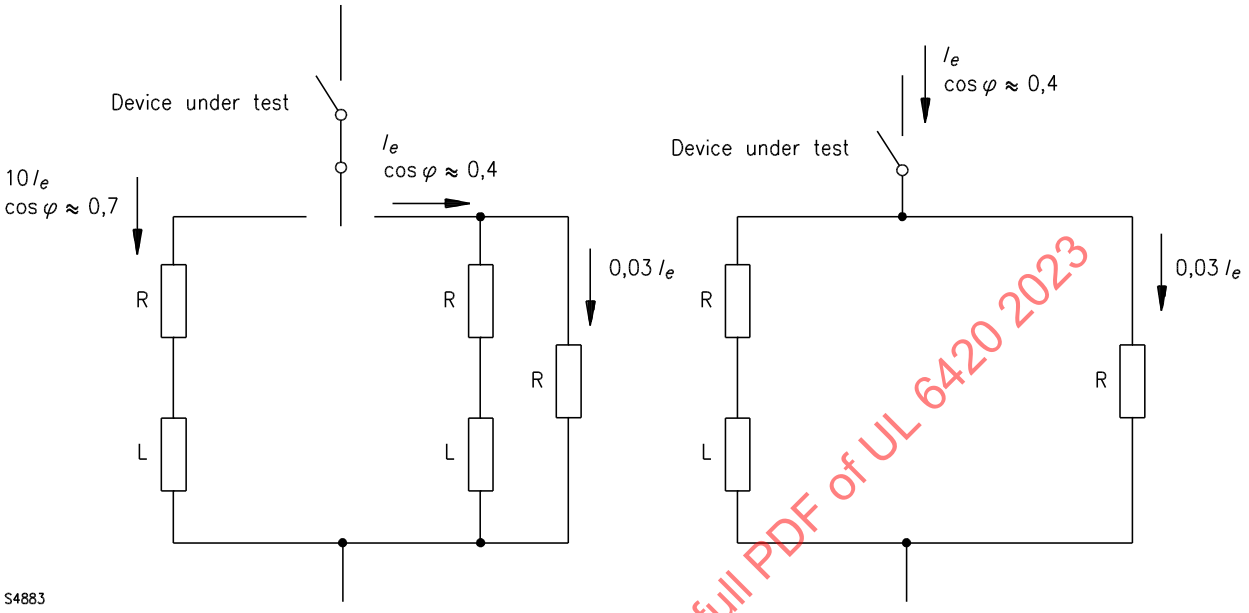
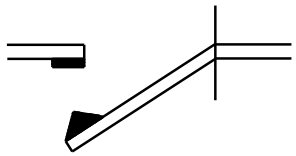
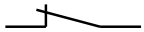
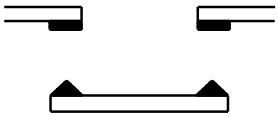
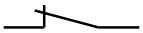
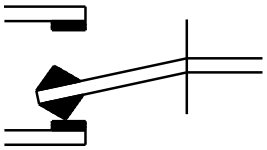
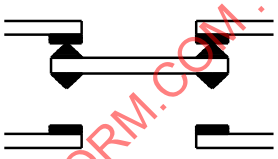
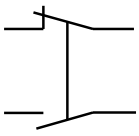
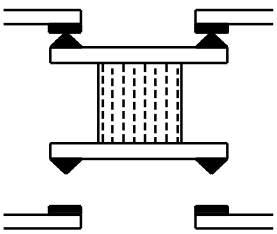
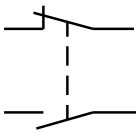


Figure 9.2

Examples of contact elements (schematic sketches)

Figure No.	Figure	Symbols	Forms	Description
4a)		 Note 1	A	Single gap contact element with two terminals
		 Note 1	B	
4b)		 Note 1	X	Double gap contact element with two terminals
		 Note 1	Y	
4c)		 Note 1	C	Change-over, single gap, contact element with three terminals
4d)			Za	Change-over, double gap, contact element with four terminals Note – The contacts are of the same polarity
4e)			Zb	Change-over, double gap, contact element with four terminals (The two moving contacts are electrically separated)

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9.1.2.4.2.4 Alternatively these tests may be performed on the actual load for which the control relay or lockout switch is intended.

9.1.2.4.2.5 In the AC tests the circuit to be used shall be as shown in Figure 9.1(a), comprising of:

a) A making circuit, consisting of an air-cored inductor, in series with a resistor, having a power factor of 0.7 and drawing a current of 10 I_e;

b) A breaking circuit, consisting of an air-cored inductor in series with a resistor, the whole being in parallel with a resistor in which flows about 3% of the breaking current I_e, so that the total power factor be of 0.4.

9.1.2.4.2.6 If in the AC tests the contact element has a bounce time less than 3 ms, the test may be made with the simplified circuit shown in Figure 9.1(b). See Figure 9.2 for examples of contact element schematic sketches.

9.1.2.4.2.7 The test report shall record which test circuit has been used.

9.1.2.4.2.8 The DC test circuits to be used shall consist of:

a) An air-cored inductor in series with a resistor. A resistor shall be connected across the complete test circuit to simulate the damping due to eddy currents; the resistance value shall be such that 1% of the test current will pass through this resistor; or

b) An iron-cored inductor, in series with a resistor, if required, to obtain a duration T0.95 as indicated in Table 9.1. It shall be verified, by oscillograms, that the time to reach 95% of the steady-state current is equal to the value given in Table 9.1 ±10%, and the time to reach 63% of the steady-state current is one-third of the value given in Table 9.1 ±20%.

9.2 Compliance with constructional requirements

9.2.1 Clause 8.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies except for Clauses 8.2.5 and 8.2.6 with the following additions.

9.2.2 Verification of direct (positive) operation of the lockout switch

9.2.2.1 General

9.2.2.1.1 To verify the direct (positive) operation of the lockout switch contacts as required by Clauses 8.2.5.1.1 and 8.2.6.2.2, the means of indication of contact position shall continue to function correctly after the operational performance type tests, the actuator strength tests required by Clauses 8.2.6.2.1 and 8.2.6.2.5.

9.2.2.2 Method of test – dependent and independent manual operation

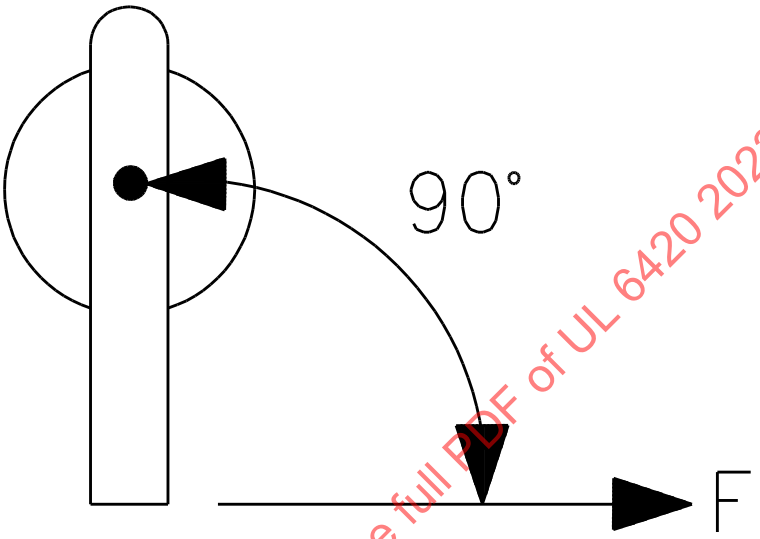
9.2.2.2.1 The normal operation force, F, required at the extremity of the actuator to operate the lockout switch into the open position shall first be determined. During the rotation testing process the test sample shall be mounted according to the manufacturer's instructions.

9.2.2.2.2 With the lockout switch in the closed position, the fixed and moving contacts of the pole for which the test is deemed to be the most severe shall be fixed together, for example, by welding.

9.2.2.2.3 The lockout switch actuator shall be submitted to a test force of 3F but which, however, shall not be less than the minimum value of 100 N or more than the maximum value of 200 N. For a rotary lockout switch, the test force shall be applied as indicated in Figure 9.3.

Figure 9.3

Rotary lockout switch actuator test force



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9.2.2.2.4 The test force shall be applied without shock to the extremity of the actuator of the lockout switch or a control circuit device rotary switch, for a period of 10 s, in the direction to open the contacts.

9.2.2.2.5 The direction of the test force with respect to the actuator shall be maintained throughout the test.

9.2.2.3 Condition of lockout switch after test

9.2.2.3.1 After the test, when the test force is no longer applied, the actuator being left free shall remain in the on (closed) position and the lockout switch shall not show any damage such as to impair its normal operation.

9.2.2.3.2 It shall not be possible to lock the lockout switch in the open position while the test force is applied.

9.2.2.4 Verification of limitation of rotation (of a rotary lockout switch based on Clause 8.2.4):

9.2.2.4.1 The operation moment shall be measured five times and the maximum value recorded. The maximum moment value, multiplied by five, shall be applied to the actuator by forcing it against each means of limitation. The moment shall be applied for 10 s.

9.2.2.4.2 The test is passed if each means of limitation has not moved, become loose or prevented the actuator's normal operation.

9.3 Performance

9.3.1 Test sequences

9.3.1.1 Clause 9.3.1 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies to tests conducted on isolating contactor and shorting contactor and the following addition, Clause 9.3.1.2, applies for control circuit devices.

9.3.1.2 Test sequences for control circuit devices; the type and sequence of tests to be performed on representative samples are as follows.

9.3.1.3 Test sequence I (sample No. 1)

9.3.1.3.1 Test No. 1 – Operating limits of contactors and relays (Clause 9.3.3.2), if applicable.

9.3.1.3.2 Test No. 2 – Temperature rise (Clause 9.3.3.3).

9.3.1.3.3 Test No. 3 – Dielectric properties (Clause 9.3.3.4).

9.3.1.3.4 Test No. 4 – Mechanical properties of terminals (Clause 8.2.4 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, and the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E).

9.3.1.4 Test sequence II (sample No. 2)

9.3.1.4.1 Test No. 1 – Making and breaking capacities of switching elements under normal conditions (Clause 9.3.3.6.2).

9.3.1.4.2 Test No. 2 – Dielectric verification (Clause 9.3.3.6.4).

9.3.1.5 Test sequence III (sample No. 3)

9.3.1.5.1 Test No. 1 – Making and breaking capacities of switching elements under abnormal conditions (Clause 9.3.3.6.3).

9.3.1.5.2 Test No. 2 – Dielectric verification (Clause 9.3.3.6.4).

9.3.1.6 Test sequence IV (sample No. 4)

9.3.1.6.1 Test No. 1 – Performance under conditional short-circuit current (Clauses 9.3.4.3 – 9.3.4.6).

9.3.1.6.2 Test No. 2 – Dielectric verification (Clause 9.3.3.6.4).

9.3.1.7 Test sequence V (sample No. 5)

9.3.1.7.1 Test No. 1 – Degree of protection of enclosed control circuit devices (Annex C of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1).

9.3.1.7.2 Test No. 2 – Verification of actuation force or moment (Clause 9.2.2.2).

9.3.1.8 Test sequence VI (sample No. 6)

9.3.1.8.1 Test No. 1 – Measurement of clearances and creepage distances, if applicable (Clause 7.1.3 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1).

9.3.1.8.2 Test No. 2 – Verification of limitation of rotation of a rotary switch (Clause 9.2.2.4).

9.3.1.9 There shall be no failure in any of the above tests.

9.3.1.10 More than one test sequence or all test sequences may be conducted on one sample at the request of the manufacturer. However, the tests shall be conducted in the sequence given for each sample above.

9.3.2 General test conditions

9.3.2.1 Clause 9.3.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies for tests conducted on isolating contactor and shorting contactor.

9.3.2.2 Clause 8.3.2.1 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies for tests conducted on control circuit devices in addition to Clauses 9.3.2.3 – 9.3.2.9.

9.3.2.3 General requirements; the tests shall be performed with the actuator operated by a machine complying with the requirements of Clause 9.3.2.4 or, for a rotary switch, in accordance with Clause 9.3.2.5.

9.3.2.4 For push-buttons and/or related control switches the operating machine shall apply the actuating force (or moment) to the actuator in the direction of its motion.

a) The force (or moment) or the travel of the operating machine shall comply with one of the following conditions according to the manufacturer's instructions:

1) The maximum force (or moment) exerted on the actuator shall not exceed 1.5 times the force (or moment) required for maximum over-travel of the contact element(s);

2) The over-travel of the contact elements shall be between 50% and 80% of the over-travel inherent in the design of the contact elements.

b) During the whole part of the operating cycle where the contacts move from the open to closed position (or vice versa) or at least at the moment when the switching operation occurs, the velocity of the operating machine, measured where it touches the actuator, shall be between 0.05 m/s and 0.15 m/s.

c) The mechanical connection between the operating machine and the actuator shall have a sufficient free play (lost motion) to avoid the operating machine impeding the free motion of the actuator away from it.

9.3.2.5 For switches fully rotary in both directions, one operating cycle comprises either one fully clockwise operation of the actuator or one fully anti-clockwise operation of the actuator. However, in this case approximately three-quarters of the total number of operating cycles shall be made in the clockwise direction, followed by the remainder in the anti-clockwise direction. The angular velocity shall be between 0.5 to 1 revolution per second.

9.3.2.6 Test quantities; Clause 8.3.2.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies except for Clause 8.3.2.2.3.

9.3.2.7 Evaluation of test results; Clause 8.3.2.3 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies in addition to Clauses 8.3.1 – 8.3.8 and Clauses 9.3.2.8 – 9.3.2.9.

9.3.2.8 The condition of the control circuit device after each test shall be checked by the verifications applicable to each test.

9.3.2.9 A control circuit device is deemed to have met the requirements of this standard if it meets the requirements of each test and/or test sequence as applicable.

9.3.3 Performance under no load, normal load, abnormal load and over load conditions

9.3.3.1 Operation

9.3.3.1.1 Clause 9.3.3.1 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies for tests conducted on isolating contactor and shorting contactor.

9.3.3.1.2 Clause 8.3.3.1 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies for tests conducted on control circuit devices.

9.3.3.2 Operating limits

9.3.3.2.1 Clause 9.3.3.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies for tests conducted on isolating contactor and shorting contactor.

9.3.3.2.2 Clause 8.3.3.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies for tests conducted on control circuit devices.

9.3.3.2.3 A voltage monitoring circuit associated with the system isolation equipment shall operate as in Clauses 8.3.1.4 and 8.3.8.1.1(a) even with a slowly falling voltage present on the load side of the system isolation equipment.

9.3.3.3 Temperature rise

9.3.3.3.1 Clause 9.3.3.3 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies for tests conducted on isolating contactor and shorting contactor.

9.3.3.3.2 Clause 8.3.3.3 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies for tests conducted on control circuit devices in addition to Clauses 9.3.3.3.3 – 9.3.3.3.4.

9.3.3.3.3 All switching elements of the control circuit device shall be tested. All switching elements that may be simultaneously closed shall be tested together. However, switching elements forming an integral part of an actuating system in such a manner that the elements cannot remain in the closed position, are exempt from this test.

Note – Several temperature-rise tests may be necessary if the control circuit device has several positions in which switching elements are in their closed position.

9.3.3.3.4 The minimum length of each temporary connection, from terminal to terminal, shall be 1 m.

9.3.3.4 Dielectric properties

9.3.3.4.1 Clause 8.3.3.4 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, with the addition of Clause 9.3.3.4.2 for the isolating contactor.

9.3.3.4.2 The isolation contactor shall additionally comply with the impulse withstand test for equipment suitable for isolation with a minimum value of impulse test voltage of 8000 V. See Table 9.2, Test voltages across the open contacts of equipment suitable for isolation.

Table 9.2
Test voltages across the open contacts of equipment suitable for isolation

Rated impulse withstand voltage U_{imp} kV	Test voltages and corresponding altitudes				
	$U_{1.2/50}$ kV				
	Sea level	200 m	500 m	1,000 m	2,000 m
8.0	12.3	12.1	11.7	11.1	10
12	18.5	18.1	17.5	16.7	15
Note – $U_{1.2/50}$ = 1.2/50 µs impulse test voltage, the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, Clause 8.3.3.4.1 U_{imp} = Rated impulse withstand voltage, the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, Clause 4.3.1.3					

9.3.3.4.3 Clause 8.3.3.4.1(3) of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, applies for tests conducted on system isolation equipment control circuit in accordance with Clause 9.3.3.4.4.

9.3.3.4.4 The system isolation equipment control circuit shall be capable of withstanding the test voltage applied as follows:

– Between live parts of the control circuit and grounded parts;

– Between live parts of the lockout station control circuit and surfaces of the lockout station likely to be touched in service, conductive or made conductive by a metal foil;

– Between live parts of the control circuit and isolated inputs and outputs.

9.3.3.5 Making and breaking capacities for contactors

9.3.3.5.1 Clause 9.3.3.5 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies for tests conducted on isolating contactor and shorting contactor.

9.3.3.5.2 Clause 9.3.3.6 applies only for tests conducted on control circuit devices.

9.3.3.6 Making and breaking capacities for control circuit switching elements

9.3.3.6.1 Test circuits and connections

9.3.3.6.1.1 Tests for verification of making and breaking capacities shall be made according to the general test requirements stated in Clause 9.3.2.2.

9.3.3.6.1.2 Tests shall be carried out on a single-pole element or on one pole of a multi-pole device provided that all pole elements are identical in construction and operation.

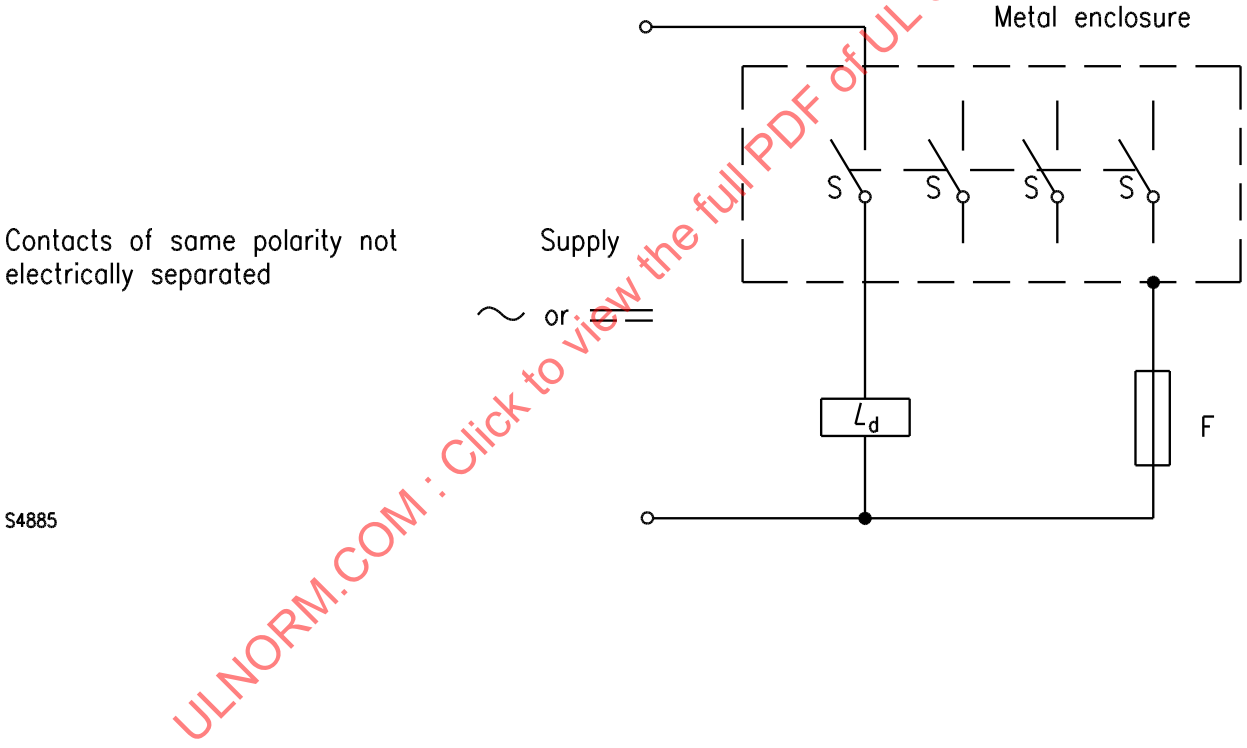
9.3.3.6.1.3 Adjacent contact elements are considered to be of the opposite polarity unless otherwise stated by the manufacturer.

9.3.3.6.1.4 Change-over contacts of forms C and Za are of the same polarity and change-over contacts of form Zb are of the opposite polarity.

9.3.3.6.1.5 Single-pole elements or contact elements in a multi-pole device stated as the same polarity shall be connected in accordance with the circuit shown in Figure 9.4. Any adjacent contact elements not being tested shall not be connected. See Figure 9.2 for examples of contact element schematic sketches.

Figure 9.4

Test circuits for multi-pole control switches – Contacts of same polarity, not electrically separated

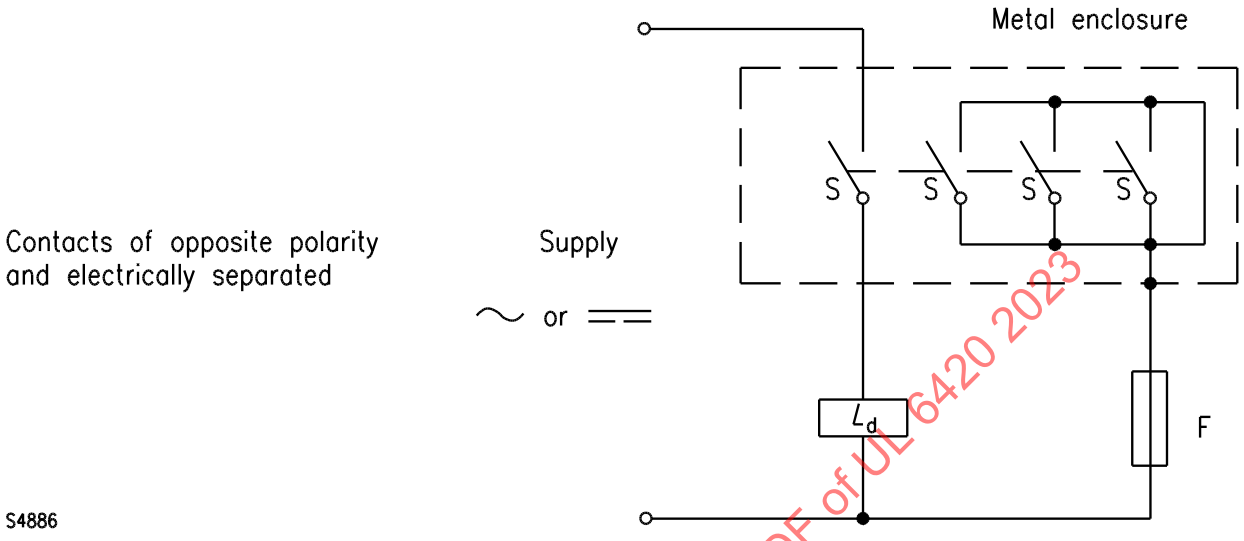


9.3.3.6.1.6 Change-over contacts of forms C and Za shall be subject to separate tests in the normally open and normally closed positions connected in accordance with Figure 9.4.

9.3.3.6.1.7 Contact elements of the opposite polarity shall be connected in accordance with the circuit shown in Figure 9.5. Adjacent contact elements of the opposite polarity not being tested shall be jointly connected to the supply, as shown. See Figure 9.2 for examples of contact element schematic sketches.

Figure 9.5

Test circuits or multi-pole control switches – contacts of opposite polarity, and not electrically separated

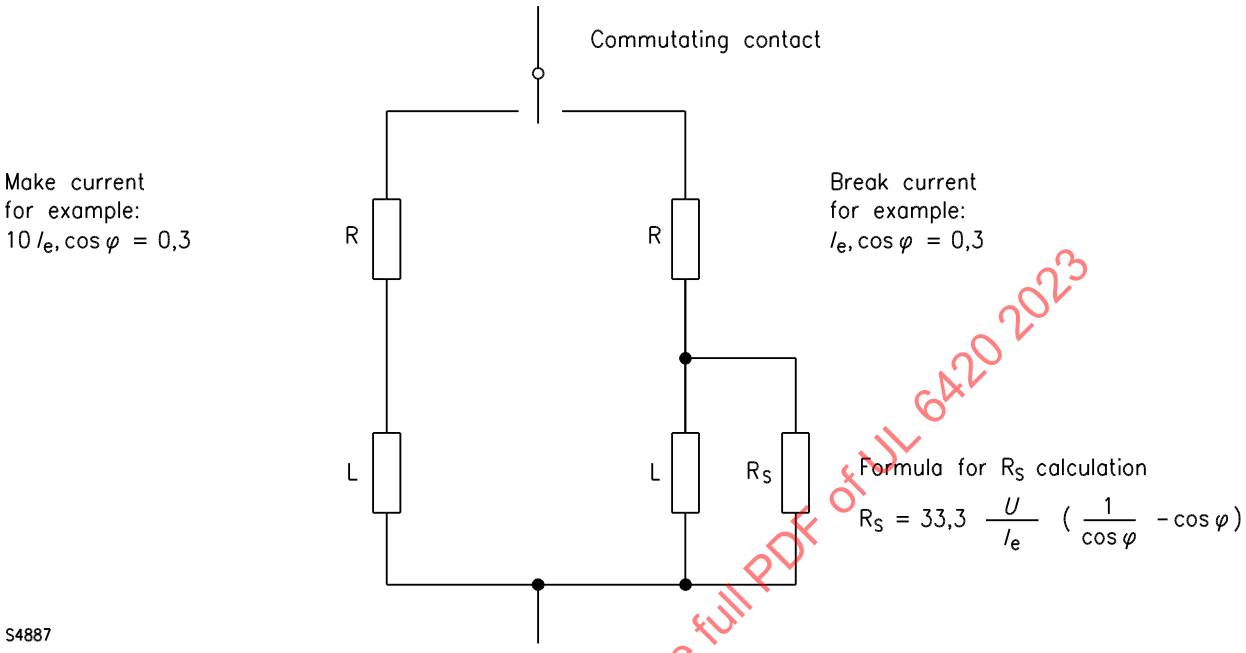


9.3.3.6.1.8 Change-over contacts of form Zb shall be subject to separate tests in the normally open and normally closed positions but with both terminals of the opposite position being connected to the supply, as shown in Figure 9.5, for an adjacent contact of opposite polarity.

9.3.3.6.1.9 If the make and break operations require different values, the circuit shown in Figure 9.6 shall represent load Ld in Figure 9.4 and Figure 9.5. See Figure 9.2 for examples of contact element schematic sketches.

Figure 9.6

Load Ld details for test conditions requiring different values of make and break current and/or power factor (time constants)



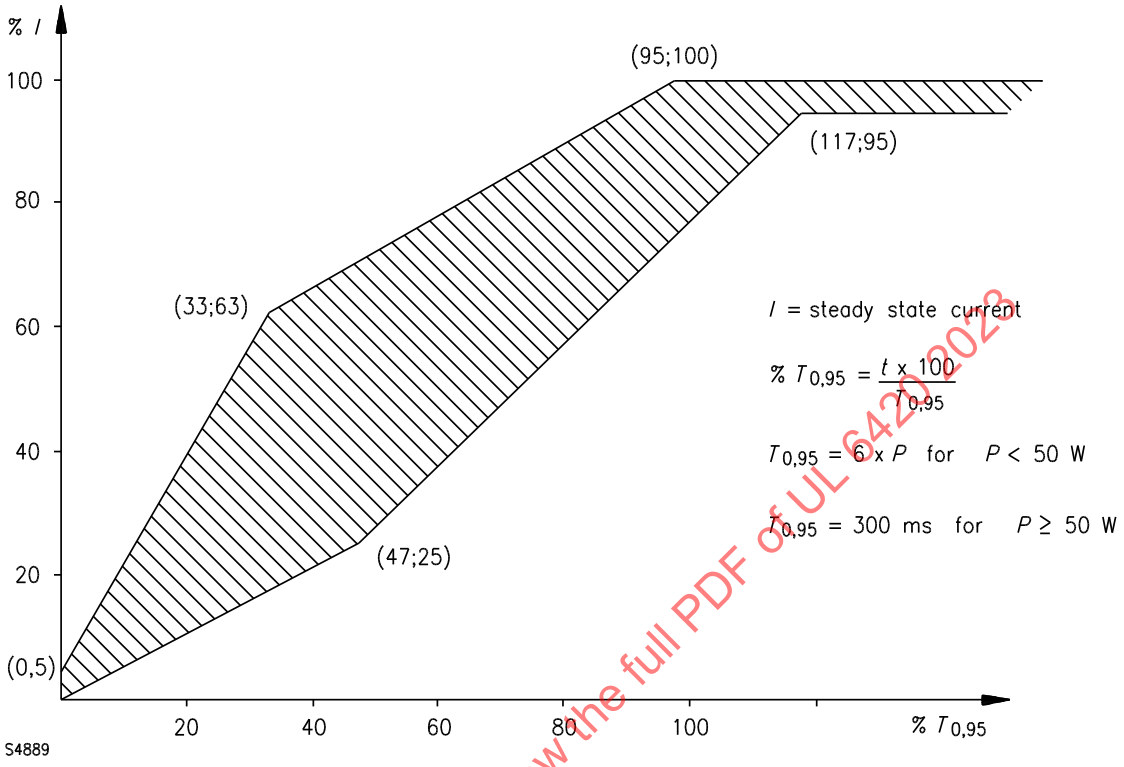
9.3.3.6.1.10 For ac tests, the load shall be an air-cored inductor in series with a resistor, if needed, to obtain the specified power factor. The inductor shall be shunted by a resistor taking 3% of the total power consumed (see Figure 9.6).

9.3.3.6.1.11 For dc tests, to obtain the specified steady-state current the test current shall increase from zero to the steady-state value within the limits shown in Figure 9.7.

Note – For guidance, an example of an iron cored load see Annex B, Examples of inductive test loads for dc contacts, of the Standard for Low-voltage switchgear and controlgear Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices, IEC 60947-5-1:2009.

Figure 9.7

Current/time limits for dc test loads



9.3.3.6.1.12 Test voltage and test current shall be in accordance with Table 8.1 and Table 8.9. The test circuit applied shall be stated in the test report.

9.3.3.6.2 Making and breaking capacities of control circuit switching elements under normal conditions

9.3.3.6.2.1 The tests are intended to verify that the control circuit device is capable of performing its intended duty according to the utilization category.

9.3.3.6.2.2 With the load set in accordance with Table 8.9, the 6,050 operating cycles shall be carried out in the following sequence:

a) 50 operations at 10-s intervals with the voltage set at 1.1 U_e;

b) 10 operations as rapidly as possible at the same time ensuring complete closing and opening of contacts;

c) 990 operations at 1-s intervals;

d) 5,000 operations at 10-s intervals.

9.3.3.6.2.3 When the construction of the device is such that rapid cycling is not possible, for example overload relay contacts, the operations shall be at 10-s intervals or as fast as the device will allow.

9.3.3.6.2.4 For auxiliary contacts of a switching device, for example contactor, circuit-breaker, the number of operating cycles shall be the same as that required for the verification of the conventional operational performance capability of the switching device (see appropriate product standard).

9.3.3.6.3 Making and breaking capacities of control circuit switching elements under abnormal conditions

9.3.3.6.3.1 The test is intended to verify that the control circuit device is capable of making and breaking currents associated with electromagnetic loads. Load values, together with the sequence of operations shall be in accordance with Table 8.1.

9.3.3.6.4 Results to be obtained

9.3.3.6.4.1 During the tests of Clauses 9.3.3.6.2 and 9.3.3.6.3 there shall be no electrical or mechanical failures, no contact welding or prolonged arcing, and the fuses shall not blow.

9.3.3.6.4.2 After the test of Clauses 9.3.3.6.2 and 9.3.3.6.3 the device shall withstand the power-frequency test voltage of 2 U_e, but not less than 1,000 V, applied as specified in Clause 9.3.3.4.3.

9.3.4 Performance under short-circuit conditions

9.3.4.1 General conditions for short-circuit tests

9.3.4.1.1 Clause 9.3.4.1 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies for tests conducted on isolating contactor and shorting contactor with the following addition.

9.3.4.1.2 Test circuit for the verification of short-circuit ratings

9.3.4.1.2.1 Clause 9.3.4.1.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies for tests performed on the isolation contactor with its associated line side short-circuit protective devices.

Note – The associated line side short-circuit protective device(s) could be the main machine short-circuit protective device(s) as in the cases of Figure A.2 and Figure A.3 but not in the case of Figure A.1.

9.3.4.1.3 Clauses 9.3.4.3, 9.3.4.4, 9.3.4.5, and 9.3.4.6 apply only for tests conducted on control circuit switching elements.

9.3.4.2 Conditional short-circuit current of contactors

9.3.4.2.1 Clause 9.3.4.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies with the following addition.

9.3.4.2.2 The rating or setting of the isolation contactor's associated line side short-circuit protective device(s) shall be equal to the rated current of the power circuit of the system isolation equipment.

9.3.4.2.3 Test at the prospective current "r"

9.3.4.2.3.1 Clause 9.3.4.2.1 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies with the following additions.

9.3.4.2.3.2 The minimum test current shall comply with Table 9.3 which replaces Table 9.3.4.2.1DV.1.1.1 in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A.

Table 9.3
Short circuit test values

Rated operational current I_e	Test Current, symmetrical rms	Power factor cos Φ
$0 < I_e \leq 315$	10,000	0.50
$315 < I_e \leq 630$	18,000	0.30
$630 < I_e \leq 1{,}000$	30,000	0.25
$1{,}000 < I_e \leq 1{,}600$	42,000	0.25

9.3.4.2.3.3 The isolation contactor(s) and its associated line side short-circuit protective device(s) shall be connected to the circuit and the following sequence of operations performed:

a) One closing (CO) operation of the isolation contactor(s); and

b) One withstand (O) operation with the isolation contactor(s) closed prior to the test.

Where a series connected pair of contactors is used, it shall be permitted that only the contactor designated for switching be closed for the (CO) operation while the contactor designated as non-switching is closed prior to the test. Further, where a series connected pair of contactors is used both contactors shall be closed prior to the withstand (O) operation.

9.3.4.2.4 Test at the rated conditional short-circuit current Iq

9.3.4.2.4.1 Clause 9.3.4.2.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, applies with the following addition.

9.3.4.2.4.2 The isolation contactor and its associated line side short-circuit protective device(s) shall be connected to the circuit and the following sequence of operations performed:

a) One closing (CO) operation of the isolation contactor; and

b) One withstand (O) operation with the isolation contactor closed prior to the test.

9.3.4.2.5 Results to be obtained

9.3.4.2.5.1 The system isolation equipment shall comply with the following:

a) The solid connection between the enclosure and supply shall not have melted or opened. See 9.3.4.1.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A.

b) The door or cover of the enclosure shall not be blown open and it is possible to open the door or cover. Deformation of the enclosure is considered acceptable when the degree of protection is not less than indicated in Clause 8.2.10.

c) There shall be no damage to the conductors or terminals and the conductors shall not be separated from the terminals.

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

e) The main circuit breaker or switch, if part of the system isolation equipment, is capable of being opened manually by its operating means.

f) Neither end of a short circuit protective device 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 system isolation equipment, the circuit-breaker shall be tested to trip as follows:

1) Circuit-breakers with instantaneous trip relays or releases at 130% of the trip current; and

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

h) There shall be no discharge of parts beyond the enclosure.

i) The adequacy of insulation is verified after each operation (at currents "r" and "Iq") by a dielectric test on the complete unit under test (short circuit protective device plus contactors but before replacement of parts) using an essentially sinusoidal test voltage of twice the rated operational voltage U_e but not less than 1000 V. The test voltage shall be applied for 1 min to the incoming supply terminals, with the switch or the circuit-breaker in the open position, as follows:

1) Between each pole and all other poles connected to the frame of the contactor(s);

2) Between all live parts of all poles connected together and the frame of the contactor(s);

3) Between the terminals of the line side connected together and the terminals of the other side connected together.

j) There shall be no damage to the isolating contactor, the contacts shall not be welded, and the contacts shall comply with impulse withstand and leakage current requirements for isolation.

9.3.4.3 General conditions for control circuit switching elements short-circuit tests

9.3.4.3.1 The switching element shall be in a new and clean condition, mounted as in service.

9.3.4.4 Test procedure for control circuit switching elements short-circuit tests

9.3.4.4.1 The switching element may be operated several times before the test, at no load or at any current not exceeding the rated current.

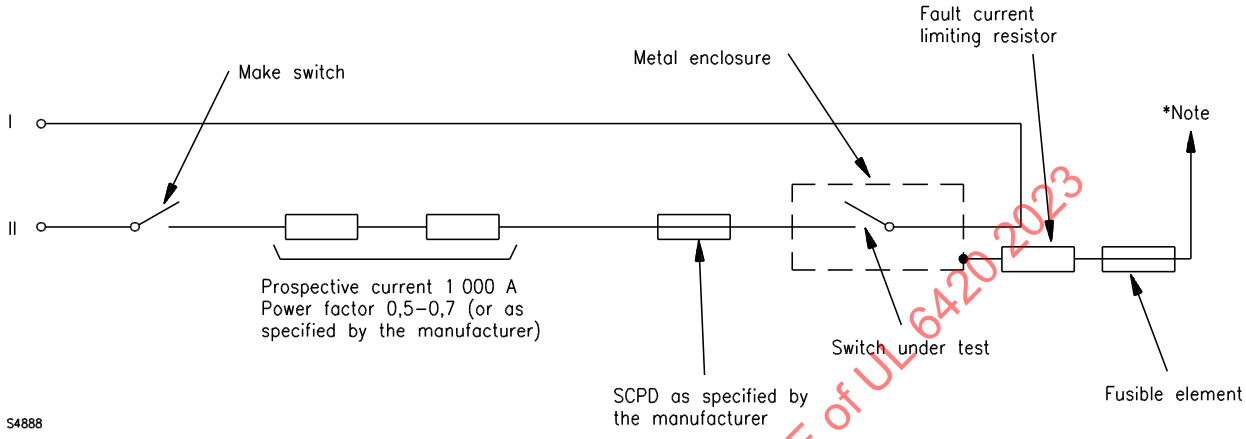
9.3.4.4.2 A contact element with two terminals shall be tested with the actuator in the position corresponding to the closed position of the switching element under test.

9.3.4.4.3 The contact element to be tested shall be in series with the Short-Circuit Protective Device (SCPD), the load impedance, and a separate switching device in a single-phase circuit as shown in Figure

9.8. See Figure 9.2 for examples of contact element schematic sketches. The test quantities shall be in accordance with Clause 9.3.4.5.

Figure 9.8

Test circuit, conditional short-circuit current



9.3.4.4.4 The test is performed by making the current with the separate making switch and the current shall be maintained until the SCPD operates.

9.3.4.4.5 The test shall be performed three times on the same contact element, the SCPD being reset or replaced after each test. The time interval between the tests shall be not less than 3 min. The actual time interval shall be stated in the test report.

9.3.4.4.6 For change-over contact elements, the above test shall be made separately on both the normally closed and normally open contacts.

Note – For control switches with both two terminals and change-over contact elements, both types should be tested.

9.3.4.4.7 A separate control circuit device may be used for each contact element.

9.3.4.5 Test circuit and test quantities for control circuit switching elements short-circuit tests

9.3.4.5.1 The switching element shall be connected in series with the short-circuit protective device of type and rating stated by the manufacturer; it shall also be in series with the switching device intended to close the circuit.

9.3.4.5.2 The test circuit load impedance shall be an air-cored inductor in series with a resistor, adjusted to a prospective current of 1,000 A, or a higher value, if stated by the manufacturer, at a power factor of between 0.5 and 0.7 and at the rated operational voltage. No parallel damping load shall be added. The open circuit voltage shall be 1.1 times the maximum rated operational voltage of the switching element.

9.3.4.5.3 The switching element shall be connected in the circuit using 1 m total length of cable corresponding to the operational current of the switching element.

9.3.4.6 Condition of the switching element after the control circuit switching elements short-circuit test

9.3.4.6.1 After the short-circuit test it shall be possible to open the switching elements by the normal actuating system.

9.3.4.6.2 After the test the device shall withstand the power-frequency voltage of 2 U_e but not less than 1,000 V applied as specified in Clause 9.3.3.4.3.

9.3.5 Evaluation of mirror contacts

9.3.5.1 The sequences (a) and (b), or (a) and (c), are repeated on new mirror contact samples for each main contact welded successively. 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.

b) With the operating coil de-energized, an impulse test voltage of 2.5 kV at sea level, correction should be made according to Table 9.4, calculated from Table 12 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, shall be applied across the mirror contact. There shall be no disruptive discharge.

c) As an alternative to (b), 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.

Table 9.4
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, A.2 and A.3 of the Standard for Insulation coordination for equipment with low-voltage systems – Part 1: Principles, requirements and tests, IEC 60664-1, from which Table 13 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, is based.				

9.3.5.2 The sequences (a) and (b) or (a) and (c) are repeated on new samples for each main contact welded successively.

9.3.6 Failure analysis techniques

9.3.6.1 The failure analysis techniques that can be used include but are not limited to:

a) Failure mode and effects analysis (FMEA for hardware and FMECA for the consequences) as appropriate to:

1) Evaluation of the effects and the sequences of events caused by each identified failure;

2) Determination of the significance or criticality of each failure to the system's correct function or performance;

3) Classification of identified failure according to their detect ability and any other relevant characteristic;

4) Estimate the significance and probability of failure.

Note 1 – The Failure Modes and Effects Analysis (FMEA) and Failure Modes, Effects and Criticality analysis (FMECA) are methods of reliability analysis intended to identify failures that have significant consequences affecting the system performance in the application considered.

Note 2 – For more information about FMEA methodology see the Standard for Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA), IEC 60812.

b) Fault tree analysis (FTA) as appropriate to:

1) Identification of the causes or combinations of causes leading to the hazard;

2) Determination of whether a particular reliability measure meets a stated requirement;

3) Demonstration that assumptions made in other analyses, regarding the independence of systems and non-relevance of failures, are not violated;

4) Identification of common events or common cause failures.

Note 1 – The fault tree is particularly suited to the analysis of complex systems comprising several functionally related or dependent subsystems with different performance objectives. The fault tree itself is an organized graphical representation of the conditions or other factors causing or contributing to the occurrence of a defined undesirable event, referred to as the "top event".

Note 2 – Fault tree analysis is basically a deductive (top-down) method of analysis aimed at pinpointing the causes or combinations of causes that can lead to the defined top event.

Note 3 – For more information about FTA methodology see the Standard for Fault Tree Analysis (FTA) IEC 61025.

9.4 EMC Tests

9.4.1 General

9.4.1.1 Clauses 8.3.2.1, 8.3.2.3, and 8.3.2.4 of the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, apply with the following additions.

9.4.1.2 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 Clause 9.3.1 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A. The sequence of the EMC tests may be any convenient sequence.

9.4.1.3 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 in order to comply with immunity or emission requirements, it shall be included in the report and in the information provided by the manufacturer.

9.4.1.4 The contactor 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

9.4.2.1 The test shall be conducted using the methods in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, Clause 9.4.2.

Note – The requirements that are specified in Clauses 9.4.2.1 – 9.4.2.7.

9.4.2.2 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.

9.4.2.3 Performance of the test sample during and after the test

9.4.2.3.1 Unless otherwise specified, performance criterion 2 applies, see Clause 8.4.2.2.

9.4.2.3.2 No loss of performance shall be allowed during or after the tests. After the test, the operating limits of Clause 9.3.3.2 of the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, shall be verified.

9.4.2.4 Electrostatic discharge

9.4.2.4.1 The test shall be conducted using the methods in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, Clause 9.4.2.2.

Note – A description of the test, the test methods are given in the Standard for Electromagnetic Compatibility (EMC) – Part 4-2: Testing and Measurement Techniques – Electrostatic Discharge Immunity Test, IEC 61000-4-2.

9.4.2.4.2 Except for metallic parts for which contact discharge is made, only air discharge is required.

9.4.2.4.3 Ten positive and ten negative pulses shall be applied to each selected point, the time interval after each successive single discharge being 1 s.

9.4.2.4.4 Tests are not required on power terminals. The application of conductors is not required, except for energizing the coil.

9.4.2.5 Electromagnetic field

9.4.2.5.1 The tests shall be conducted using the methods in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, Clause 9.4.2.3

Note – A description of the test, the test methods are given in the Standard for Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test, IEC 61000-4-3.

9.4.2.5.2 The device shall comply with performance criterion 1. See Clause 8.4.2.2.

9.4.2.5.3 Tests are not required if the equipment is to be fully enclosed in an EMC specific purpose metallic enclosure installed as specified by the manufacturer.

9.4.2.6 Fast transient bursts

9.4.2.6.1 The tests shall be conducted using the methods in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, Clause 9.4.2.4.

Note – A description of the test, the test methods are given in the Standard for Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test, IEC 61000-4-4.

9.4.2.6.2 The bursts shall be applied to all main, control or auxiliary terminals, whether they comprise electronic or conventional contacts.

9.4.2.6.3 The test voltage shall be applied for the duration of 1 min.

9.4.2.7 Surges (1.2/50 µs – 8/20 µs)

9.4.2.7.1 The test shall be conducted using the methods in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, Clause 9.4.2.5.

Note – A description of the test, the test methods are given in the Standard for Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test, IEC 61000-4-5.

9.4.2.7.2 The surges shall be applied to all main, control or auxiliary terminals, whether they comprise electronic or conventional contacts.

9.4.2.7.3 The repetition rate shall be one surge per minute, with the number of pulses being five positive and five negative.

9.4.3 Emission

9.4.3.1 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.

9.4.3.2 Conducted radio-frequency emission tests

9.4.3.2.1 The test shall be conducted using the methods in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, Clause 9.4.3.1

Note – A description of the test, the test method and the test set-up are given in the Standard for Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement, CISPR 11.

9.4.3.2.2 To pass, the equipment shall not exceed the levels given in Table 9.5.

Table 9.5
Conducted radio-frequency emission test limits

Frequency band MHz	Environment A (2)[a)]	Environment B (1)[a)]
0.15 – 0.5	79 dB (µV) quasi-peak 66 dB (µV) average	66 dB (µV) – 56 dB (µV) quasi-peak 56 dB (µV) – 46 dB (µV) average (decrease with log of frequency)
0.5 – 5.0	73 dB (µV) quasi-peak 60 dB (µV) average	56 dB (µV) quasi-peak 46 dB (µV) average
5 – 30	73 dB (µV) quasi-peak 60 dB (µV) average	60 dB (µV) quasi-peak 50 dB (µV) average

[a)] Environment A in the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, is referred to as environment 2 in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A. Environment B in the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, is referred to as environment 1 in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A. See notes in Clause 8.4.3.

9.4.3.3 Radiated radio-frequency emission tests

9.4.3.3.1 The test shall be conducted using the methods in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, Clause 9.4.3.2.

Note – A description of the test, the test method and the test set-up are given in the Standard for Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement, CISPR 11.

9.4.3.3.2 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.

9.4.3.3.3 To pass, the equipment shall not emit at higher levels than those given in Table 9.6.

Table 9.6
Radiated emission test limits

Frequency band MHz	Environment A (2)[a)]	Environment B (1)[a)]
30 – 230	30 dB (μV/m) quasi-peak at 30 m	30 dB (μV/m) quasi-peak at 10 m
230 – 1,000	37 dB (μV/m) quasi-peak at 30 m	37 dB (μV/m) quasi-peak at 10 m

[a)] These tests may be carried at a 10-m distance with the limits raised by 10 dB.

Environment A (2): mainly relates to low-voltage non-public or industrial networks/locations/ installations including highly disturbing sources. Environment A in Clause 7.3.1 in the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, is referred to as environment 2 in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, and corresponds to environment class A in the Standard for Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement, CISPR 11.

Environment B (1): mainly relates to low-voltage public networks such as residential, commercial and light industrial locations/installations. This environment does not cover highly disturbing sources such as arc welders. Environment B in Clause 7.3.1 in the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1, is referred to as environment 1 in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A, and corresponds to environment class B in the Standard for Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement, CISPR 11.

9.4.3.3.4 Tests are not required if the equipment is to be fully enclosed in an EMC specific purpose metallic enclosure installed as specified by the manufacturer.

Annex A
Intended Applications

(informative)

A1 General

A1.1 As with the opening of any other isolation device, safe work on associated machinery is predicated on knowing that correct operation of the device has occurred, and thus upon opening a typical disconnecting device, before work can be performed on the associated machinery, Standard for Electrical Safety in the Workplace, NFPA 70E, and the OSHA regulations requires verification to confirm that isolation has occurred. The system isolation equipment uses electromagnetic contactor(s) to provide isolation and, internal design features to provide verification that the isolation has been completed.

A2 Evaluating the application

A2.1 The system isolation equipment is designed to be an electrical power isolation component in an industrial machinery system whose function is to isolate and thereby prevent the unexpected start-up of that machinery.

Note – The Electrical Standard for Industrial Machinery, NFPA 79:2012, Clause 5.5, Clause 5.5.4(3), and the Standard for Safety of Machinery – Electrical Equipment of Machines – Part 1: General Requirements, IEC 60204-1, Clause 5.5.

A2.2 The isolating function of the System Isolating Equipment may or may not remove the potential energy from other sources of power, which are a part of that industrial machine. The system isolation equipment application needs to be evaluated by the user as to whether the appropriate safeguards are present on the particular industrial machine and are providing the intended risk reduction to the industrial machinery application.

Note – The Electrical Standard for Industrial Machinery, NFPA 79:2012, Clause 4.1, and the Standard for Safety of Machinery – Electrical Equipment of Machines – Part 1: General Requirements, IEC 60204-1, Clause 4.1.

A2.3 The risk assessment of the machine incorporating the system isolation equipment is a completely different process from that of qualifying the performance level of the system isolation equipment by the failure analysis required in Clause 9.3.6. The former is a risk assessment process while the latter is design verification process.

A2.4 For further information on risk assessment and risk reduction methods see the Technical Report: Risk Assessment and Risk Reduction – A Guide to Estimate, Evaluate and Reduce Risks Associated with Machine Tools, ANSI B11.TR3 and the Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design, ISO 13894-1 and the Guidance on the Application of ISO 13849-1 and IEC 62061 in the Design of Safety-Related Control Systems for Machinery, IEC TR 62061-1:2010 and the Safety of Machinery – Principles of Risk Assessment, ISO 14121 for guidance.

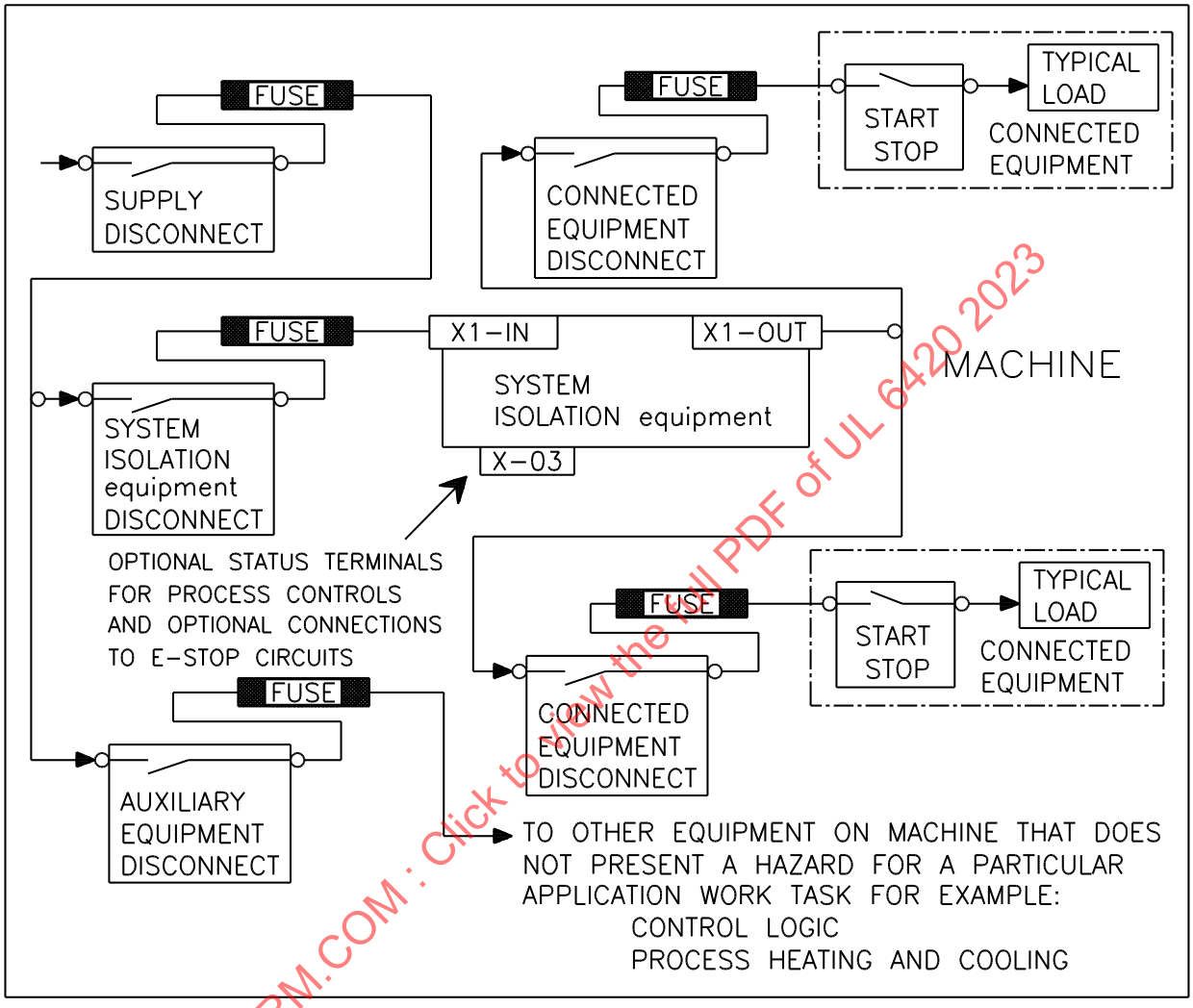
Note – The safety aspects of a design process involve one or more iterations of a "risk assessment" followed by a "risk reduction" followed by a "risk assessment" of the design with the "risk reduction" implemented. See the Technical Report: Risk Assessment and Risk Reduction – A Guide to Estimate, Evaluate and Reduce Risks Associated with Machine Tools, ANSI B11.TR3, Figure 1, Risk assessment and risk reduction process, and the Safety of Machinery – Principles of Risk Assessment, ISO 14121, Figure 1, The iterative process for reducing risk. A Risk assessment include activities such as: hazard identification, risk estimation, determining the limits of operation of the designed equipment and risk evaluation.

A3 Typical functions

A3.1 The system isolation equipment meets the short circuit and isolation requirements of a supply disconnecting device; however, it does not perform the function of the supply disconnect. The system isolation equipment is located in the power circuit on the load side of the supply disconnect as seen in Figure A.1.

Figure A.1

Example block diagram showing the possible application of a system isolation equipment employed on a machine



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