A terminal plate formed from stock having the minimum required thickness specified above may have the metal extruded at the tapped hole for the binding screw to provide two full threads.

5.207 Bus bar connections

Field connections for control centers may be made with bus bars as follows:

a) The control center enclosures shall be provided with a covered access opening allowing sufficient room to make the connections.

b) The bus bars shall be plated with silver, tin, or the like over the intended area of connection between bus bars and splices. Splice conductors shall be sized based upon power bus ampacity and short-circuit requirements.

c) Necessary hardware to perform field splicing and directions for the intended means of connection shall be provided in accordance with Clause 5.102.203.

5.208 Connector and grounding kits

The wire connector kits, bus connector kits, and grounding kits (in the form of either individual terminals or an assembly) shall be constructed so that:

a) installation can be easily accomplished without the use of special tools;

b) live parts are suitably supported after being assembled;

c) reliable connections to terminal pads will be afforded;

d) the grounding terminal means are readily accessible when the controller is mounted as in service, and are not connected directly to a neutral (when provided);

e) each kit can be installed without disassembly of factory-assembled parts (other than those parts normally disassembled for installation and wiring);

f) with the kit installed, spacings will be maintained; and

g) it is marked in accordance with Clause 5.10.204(v).

5.209 Insulating material

Material for the support of an uninsulated live part shall be porcelain, glass polyester, or other material found acceptable for the support of an uninsulated live part. These materials shall withstand the most severe conditions likely to be met in service.

Insulating material, including barriers between parts of opposite polarity and material that may be subject to the influence of the arc formed by the opening of a switch, shall be suitable for the particular application.

Insulating material for above applications, may be substituted as permitted by Annex A, Item 26, Appendix A, without performing a complete series of conformance tests on the equipment.

5.210 Wire-bending space for field-installed conductors

Wire bending space shall be such that, during installation, field-installed conductors need not be bent to a radius less than:

a) 8 times the overall diameter for non-shielded conductors; or

b) 12 times the overall diameter for shielded or lead-covered conductors.

Construction shall take into account the type and maximum size of wire, optional use of stress cones for field terminations, and other instructions provided in accordance with Clause 5.10.206.

5.211 Field-installed accessories (kits)

This clause applies to accessories (kits) designed for field installation in medium-voltage control equipment and also applies, as appropriate, to field installation of accessories (kits) in medium-voltage control equipment. The following requirements shall apply:

a) Medium-voltage control equipment shall be suitable for use with or without such kits installed.

b) Each kit shall be acceptable for the intended use and shall comply with all applicable requirements of this standard when installed in the intended manner.

c) Each kit shall be capable of being installed without the use of a special tool, unless such a tool and instructions for its use are furnished with each kit.

d) A barrier that is necessary because spacings would otherwise be less than required or for any other reason shall be securely attached to either the kit or the medium-voltage control equipment.

5.212 Blank spaces, provision for future controllers, and spare controllers

5.212.1 Blank space

Blank space (s) (see Clause 3.1.215), when provided, shall include a cover or hinged door over the provided space. The door or cover shall require the use of a tool to open or have provision for locking.

5.212.2 Space for future controller

5.212.2.1 Space for future controller(s) (see Clause 3.1.216), when provided, shall include a cover or hinged door over the compartment. The door or cover shall require the use of a tool to open or have provision for locking. Any energized bus or other electrical component(s) within the compartment shall be fully insulated or isolated.

5.212.2.2 Spaces for future controllers shall be marked with the type or catalog designation of the controller kits that have been investigated or approved for use in this space in accordance with this standard. See Clause 5.10.204(w) for marking details and Clause 5.211 for kit requirements.

5.212.3 Factory-prepared space for future controller

Factory-prepared space for future controller(s) (see Clause 3.1.217), when provided, shall include a cover or hinged door over the compartment. The door or cover shall require the use of a tool to open or have provision for locking. If the factory-prepared space includes a controller isolating switch, the door shall be interlocked with the switch operating handle to prevent opening the door with the isolating switch in the closed position. Any conductive parts on the line side of the disconnect device within the compartment shall be fully insulated or isolated. Spaces for factory-prepared controllers shall be marked with the type or catalog designation of the controller(s) and associated kits that have been investigated or approved for use in this space. See Clause 5.10.204(w) for marking details and Clause 5.211 for kit requirements.

5.212.4 Partially-completed controller compartment

Compartments with partially completed controller(s), when provided, shall comply with all requirements for controllers, except that certain components may be omitted, as indicated in Clause 3.1.218. Compartments with partially completed controllers shall be marked with the type or catalog designation of the kits that have been investigated or approved to complete the controller. See Clause 5.10.204(w) for marking details and Clause 5.211 for kit requirements.

5.212.5 Spare controller

Spare controller(s) (see Clause 3.1.219), when provided, shall comply with all requirements for controllers.

5.213 Insulated bus (optional)

5.213.1 General

An optional system for insulating bus bars and bus joints may be supplied. An insulated bus shall meet the requirements of Clause 5.213.2.

5.213.2 Insulated bus requirements

The following requirements shall apply:

a) Bus joints, other than at shipping joints, shall be completely covered by insulating materials at the factory. For interconnecting bus joints that must be made in the field, insulating material shall be supplied for application in accordance with the manufacturer's instructions.

b) A representative sample of insulated bus shall withstand without breakdown the test for bus bar insulation described in Clause 6.2.202.5. This test is required on one insulated bus bar test sample for each rated voltage.

NOTE: Purpose of insulation - Insulated bus is provided to minimize the possibility of communicating faults and prevent the development of bus faults that would result if foreign objects momentarily contacted bare bus. This insulating covering is usually only a part of the primary insulation system, and in such cases the outer surface of this insulating covering will not be at ground potential. It should not be assumed, therefore, that personnel can contact this insulating covering safely.

5.214 Controllers – general requirements

Controllers shall be wired and assembled as complete, totally enclosed, and self-supporting units.

6 Type Tests

6.1 General

The performance of medium-voltage industrial control equipment shall be investigated by subjecting a representative sample or samples in commercial form to the tests listed in Table 6 as applicable. When selecting the sample, consideration shall be given to optional features, such as bus structures in multi-unit assemblies and the like, and the effects of such features on performance during the tests. A contactor or controller shall be tested in the smallest enclosure in which it is intended to be used, unless otherwise specified.

The sequence in which these tests shall be conducted is indicated in Table 6. Unless otherwise indicated, these tests shall be conducted at rated frequency.

In some cases (e.g., temperature rise, impulse withstand) it will be necessary to repeat tests previously conducted on individual controllers when controllers are configured together in control center construction. This standard defines the additional tests required on control centers.

Type tests are intended to prove the performance of a given controller design and are not to be considered production tests.

Type tests for ratings other than preferred ratings shall use the same test methods, sequences and acceptance criteria mandated for preferred ratings.

6.2 Dielectric tests

Dielectric tests shall be made on a completely assembled controller. The outside surfaces of insulating parts shall be in clean condition.

If the controller contains wiring assemblies or other electronic circuit components that would be affected adversely by application of the test voltage, or that are specifically designed to protect the equipment from voltage, they shall be removed, disconnected, or otherwise rendered inoperable before the dielectric tests are made. A representative subassembly may be tested instead of an entire unit. The insulation and spacings of circuits using these devices shall then be tested separately for dielectric strength.

If a controller includes a meter or meters in other than the main circuit, such devices shall be disconnected from the circuit and the complete device subjected to a power-frequency voltage withstand test as indicated in Clause 6.2.202. The meter or meters shall be tested separately for power-frequency voltage withstand, with an applied potential of 1 000 V in the case of an ammeter, and 1 000 V plus twice rated voltage in the case of any other device having a voltage circuit. The test potential shall be applied between live parts and the mounting panel, including the meter face, zero adjuster, etc.

For devices incorporating static switching elements, a shorting jumper may be placed across the static switching elements and a shorting jumper across their control terminals during the dielectric tests.

6.2.201 Impulse withstand tests

6.2.201.1 General

Dielectric tests shall be made under the temperature and humidity conditions normally obtained in commercial testing. Appropriate correction factors applied shall be used in accordance with Annex A, Item 16.

Test voltage levels shall be equal to or greater than those in Table 1.

The impulse withstand test is a design test intended to prove the rated insulation level (impulse voltage withstand, or basic insulation level [BIL]) rating of a given controller design. The medium-voltage circuits of a previously untested controller shall be capable of withstanding voltage impulses using a full-wave 1.2 microsecond rise time and a 50 microsecond to half voltage having a peak value in accordance with Table 1.

6.2.201.2 Impulse voltage withstand test methods

Method 1 (3×3 test procedure): This is the historic test method that is no longer valid.

Method 2 (3×9 test procedure): This method is preferred for new tests. This method is procedure (or method) “C” in Annex A, Item 16, in the U.S.A. column. The test voltage shall be as specified in Table 1. In each of these tests, three positive and three negative impulses shall be applied to each phase individually without causing a disruptive discharge, except as noted in Clause 6.2.201.4.

Method 3 (15/2 test procedure): This method is an alternate preferred test method for new tests. This method is procedure (or method) “B” in Annex A, Item 16, in the U.S.A. column. The test voltage shall be as specified in Table 1. In each of these tests, fifteen positive and fifteen negative impulses shall be applied to each phase individually without causing a disruptive discharge, except as noted in Clause 6.2.201.4.

NOTE: Some insulating materials retain a charge after an impulse test, and for these cases care should be taken when reversing the polarity. To allow the discharge of insulating materials, the use of appropriate methods, such as the application of 3 impulses at about 80% of the test voltage in the reverse polarity before the test, is recommended.

6.2.201.3 Impulse voltage withstand test sequence

The test samples shall be subjected to the following sequence of tests. Control and auxiliary circuits shall be grounded in these tests, and the medium-voltage motor circuit fuses (in the case of Class E2 controllers) and control circuit fuses shall be in place:

a) Test 1: With the controller bus installed, the isolating means closed, and the contactor in the open position, the “Common value” of impulse test voltage shown in Table 1 shall be applied between each phase and ground, and between phases, except that the impulse voltage need not be applied across the open gap of the contactor. Load side of contactor need not be grounded.

b) Test 2: Test 1 shall be repeated, except that the contactor shall be closed.

c) Test 3: With the isolating means open, the “Across the isolating distance” impulse test voltage shown in Table 1 shall be applied in each phase individually between the contacts of the isolating means across the isolating gap. Where the isolating means has provision for automatically grounding its load side when in the fully opened position, the test voltage shall be the “Common value” test voltage specified for Tests 1 and 2.

The test shall be conducted using at least one of the test voltage levels from Table 1 without any surge arresters connected. Additional tests may be performed with or without surge arresters. Dry-type core and coil assemblies, such as reduced-voltage-starting reactors, autotransformers, CPTs, and voltage transformers, may also be disconnected at the transformer terminals for this test. Cable and bus connections to the transformer shall be in locations representative of when connected to the transformer, but may be insulated from the terminals.

If a higher impulse level is desired, based on the inclusion of surge arresters, the clamping voltage of the arresters shall be below the impulse levels verified by the initial impulse test. Testing shall demonstrate that no disruptive discharges will occur within the controller at the higher impulse level.

6.2.201.4 Evaluation

The controller shall be considered to have passed the test under the following conditions:

Test method 1, 3×3 test procedure: This method is no longer valid.

Test method 2, 3×9 test procedure: If a disruptive discharge occurs on only one test during any group of three consecutive tests, nine more tests shall be made. If the equipment successfully withstands all nine of the second group of tests, the flashover in the first group shall be considered a random flashover, and the controller shall be considered as having successfully completed the test.

Test method 3, 15/2 test procedure: The controller shall be considered as having successfully completed the test if the following conditions are fulfilled:

a) Each group has at least 15 tests.

b) The number of disruptive discharges does not exceed two for each complete group.

c) No disruptive discharges on non-self-restoring insulation occur. This is confirmed by 5 consecutive impulse withstands without a disruptive discharge following the last disruptive discharge.

NOTE: This procedure leads to a maximum possible number of 25 impulses per group.

6.2.202 Power-frequency voltage withstand test

6.2.202.1 General

Equipment shall be capable of withstanding for 1 min without breakdown the application of a 48 to 62 Hz essentially sinusoidal test voltage, as indicated in Table 1, in the cases described in Clauses 6.2.202.2 to 6.2.202.5.

A transformer, a coil, or a similar device normally connected between lines of opposite polarity shall be disconnected from one side of the line during test between terminals of opposite polarity.

The controller shall be tested by means of a 500 VA or larger capacity transformer, whose output is essentially sinusoidal and can be varied. The applied voltage can be determined by measuring the input to the test transformer. A test transformer of less than 500 VA capacity may be used if the applied potential is measured at the output of the test transformer, either directly or through a voltage transformer.

6.2.202.2 Tested at the “Common value” test voltage in Table 1

The test voltage shall be applied:

a) between each phase of the power circuit and ground with the other phases grounded and the controller contacts both open and closed. The control circuit shall be grounded for this test;

b) between the control circuit and ground with the control circuit ungrounded; and

c) for a controller with a vacuum-type interrupter, across the open contacts of the vacuum interrupter. Care shall be taken not to apply a test voltage across the open contacts of a vacuum interrupter that exceeds the manufacturer's recommendation, to avoid generating harmful X-rays.

6.2.202.3 Tested at the “Across the isolating distance” voltage in Table 1

The test voltage shall be applied:

a) across the open contacts of the isolating distance; and

b) if the controller has a test position obtained by means of a drawout element, across the open contacts of the isolating distance, with the drawout element in the test position, both with the contactor contacts open and closed.

6.2.202.4 Power-frequency voltage withstand (repeated) test

Where required by other parts of this standard, the controller shall comply with the requirements of Clauses 6.2.202.2 and 6.2.202.3, except that the test potential shall be as shown for “Power-frequency withstand-voltage test (repeated)” as shown in Table 1.

6.2.202.5 Test for bus bar insulation

If insulation is provided for bus bars, it shall be tested for dielectric strength.

The insulated bus bar sample shall have the rated maximum voltage U_r at rated power-frequency applied from the conductor to an electrode effectively covering the outer surface of the insulation, but sufficiently far from the ends of the sample to be able to withstand the test voltage. The insulated bus bar sample shall have a construction that is typical of bus bars, elbows, splices, and joints as used in the manufacturer's design. The test voltage shall be applied for 1 min.

NOTE: Suggested external electrodes are conductive paint or metallic foil or the equivalent. Care should be taken to prevent the external insulation media from penetrating the test area between the sample insulation and the electrodes.

6.2.203 Partial discharge test

6.2.203.1 General

Controllers with rated maximum voltages (Ur) greater than 7.2 kV shall be subjected to a partial discharge test. Testing shall conform to Annex A, Item 24 and as noted below.

6.2.203.2 Partial discharge test method

The controller used for the partial discharge test shall have been previously subjected to the power frequency voltage withstand test described in Clause 6.2.202. The partial discharge test may be combined with the power frequency voltage withstand test if all the parameters for both tests are met.

With the controller bus installed, the isolating means closed, and the contactor in the open position, the test voltage shall be applied between each phase and ground with the other phases grounded. The test voltage shall first be raised to the rated short-duration power-frequency common value shown in Table 1 and held for no less than 10 s. The voltage shall then be reduced to the minimum CEV (corona extinction voltage) shown in Table 1 and held for one minute.

The test shall be repeated as in the preceding paragraph, except with the contactor in the closed position.

6.2.203.3 Evaluation

At the end of the one minute period, if the measured partial discharge level is 100 pC (picocoulombs) or less, the equipment is considered to have passed the test.

6.3 Radio interference voltage (RIV) test

[Vacant]

6.4 Resistance measurement

6.4.1 Measurement of the resistance of the contactor

A measurement of the resistance of each phase of the contactor shall be made before and after the fault interruption test (see Clause 6.104) to determine that the contactor is capable of carrying its rated continuous current after the test. The following requirements shall apply:

a) Not more than 5 no-load operations of the contactor shall be permitted between the fault interruption test and measurement of resistance.

b) The measurement shall be made with dc by measuring the voltage drop or resistance from the line side terminals of the contactor to the load terminals of the contactor.

c) The current during the measurement shall have any convenient value between 50 A and the continuous current rating.

d) The measurement of the dc voltage drop or the resistance shall be made before the tests, with the contactor at the ambient air temperature, and after the test when the contactor has cooled to a temperature equal to the ambient air temperature. The resistance after the test shall not exceed 200% of the resistance determined before the test.

e) The measured value of the dc voltage drop or the resistance shall be given in the type-test report, as well as the general conditions during the test (current, ambient air temperature, points of measurement, etc.).

6.4.2 Measurement of the resistance of the controller

A measurement of the resistance of each phase of the controller shall be made before and after the fault interruption test (see Clause 6.104) to determine that the controller is capable of carrying its rated continuous current after the test. The following requirements shall apply:

a) Not more than 5 no-load operations of the contactor shall be permitted between the fault interruption test and measurement of resistance.

b) The measurement shall be made with dc by measuring the voltage drop or resistance from the line side terminals of the controller to the load terminals of the controller.

c) The current during the measurement shall have any convenient value between 50 A and the continuous current rating.

d) The measurement of the dc voltage drop or the resistance shall be made before the tests, with the contactor at the ambient air temperature, and after the test when the contactor has cooled to a temperature equal to the ambient air temperature. The resistance after the test shall not exceed 200% of the resistance determined before the test.

e) The measured value of the dc voltage drop or the resistance shall be given in the type-test report, as well as the general conditions during the test (current, ambient air temperature, points of measurement, etc.).

f) Fuses and solid state switching elements if provided shall be shunted or replaced by solid links of negligible resistance during this test.

6.5 Temperature-rise tests

6.5.1 Conditions of the controller to be tested

The temperature-rise test of the main circuits shall be made on a new switching device with clean contacts, and, if applicable, filled with the appropriate liquid or gas at the minimum functional pressure (or density) for insulation prior to the test. A contactor or controller shall be tested in the smallest enclosure in which it is intended to be used.

6.5.2 Arrangement of the equipment

Anti-condensation heaters, representative of the maximum wattage rating to be provided, shall be installed and energized at their rated voltage during the temperature test, unless the anti-condensation heaters are automatically de-energized.

The CPT need not be energized, provided the transformer heat loss is simulated by an equivalent heat source representing the largest transformer available.

Controller and control center sections shall be tested at rated continuous current with 1.2 m (4 ft) of copper wire attached to each field-wiring terminal. The wire shall be of the smallest size having an ampacity of at least 125% of the test current for motor loads and at least 100% for other loads. Wire size shall be determined in accordance with Table 7. The type of insulation is not specified, but the color shall be black. The temperature test may be conducted with conductors having other than black insulation, but reference temperature measurements shall be conducted with black insulated conductors. If the terminal will not receive the size of wire required for testing at rated continuous current, the maximum allowable wire size shall be used.

In a device employing high-voltage motor circuit fuses, live fuses shall be used during the temperature test. If a range of fuse types or ratings is applicable, the fuse type or rating having the highest power loss shall be used. These fuses shall not open during the temperature test.

Conductors supplying two or more motor controllers shall have an ampacity equal to the sum of the full load current rating of all the motor controllers plus 25% of the highest rated motor controller in the group.

Temperature rise tests shall be performed on at least one vertical section containing the maximum number of controllers permitted by the design.

Each controller shall carry maximum rated continuous current for that particular controller and mounting location. Temperature rises shall be recorded for the controllers, non-extendable power bus, and (if provided) on the extendable power bus and splices. If the controllers have been previously tested in accordance with Clause 6.5, temperature rises for the controllers in control centers need only be recorded at the points of highest temperature rise as determined in the individual controller temperature rise tests.

For control center vertical sections designed with extendable power bus, the temperature rise test shall be conducted using representative extendable bus configurations.

If a range of extendable power buses is available, both the highest current density bus configuration and the highest ampacity configuration shall be tested to represent the range of available buses.

The rated continuous current for a controller mounted in a vertical section with more than one controller may be less than the rated continuous current for an individual controller.

Extendable power bus ratings shall be tested using a representative length of bus long enough to pass through at least one complete vertical section and shall include one or more bus connecting splice joints. Tests shall include incoming line power bus configuration(s) that connect to the extendable power bus.

For the temperature rise test, the extendable power bus shall be loaded as follows:

a) A current equal to the extendable power bus rated continuous current shall be passed through the bus of one complete vertical section and one or more splice joint assemblies. Conductors supplying the power bus shall be sized based upon the ampacity of the power bus. Table 7 may be used for determining conductor sizing.

b) The controllers mounted in the vertical section shall be simultaneously loaded as described in this clause.

c) The remainder of the current shall be passed through the outgoing section of the extendable power bus. Conductors shall be sized based on this remaining current. The extendable and non-extendable bus structures may be energized from two separate sources.

Equipment incorporating solid state switching elements shall also comply with Clause 6.5.5.201.

6.5.3 Measurement of the temperature and the temperature rise

6.5.3.201 General

The tests on all parts shall be made simultaneously, as the heating of one part may affect the heating of another part.

6.5.3.202 Measurement of coil temperature by resistance method

The preferred method of measuring the temperature of a coil shall be the resistance method, but temperature measurements by either the thermocouple or resistance method are acceptable. The thermocouple method shall not be employed for a temperature measurement at any point at which supplementary insulation is employed.

The resistance method consists of the determination of the temperature of a copper or aluminum winding by comparing the resistance of the winding at the temperature to be determined with the resistance at a known temperature, according to the following formula:

$$\Delta t = \frac{R}{r}\ times\ (k + t_1) - (k + t_2)$$

where:

Δt = temperature rise,

R = the resistance of the coil at the end of the test, ohms

r = the resistance of the coil at the beginning of the test, ohms

k = 234.5 for copper and 225.0 for electrical conductor grade (EC) aluminum. Values of the constant for other grades must be determined.

t_1 = the ambient temperature at the beginning of the test, °C

t_2 = the ambient temperature at the end of the test, °C

As it is generally necessary to de-energize the winding before measuring resistance, the value of resistance at shutdown may be determined by taking several resistance measurements at short intervals, beginning as quickly as possible after the instant of shutdown. A curve of the resistance values and the time shall be plotted and extrapolated to give the value of resistance at shutdown.

6.5.3.203 Measurement of temperature by thermocouple method

The thermocouple method shall consist of the determination of temperature by the application of thermocouples to the hottest accessible parts.

Temperatures shall be measured using thermocouples and related instruments that are accurate and calibrated. Thermocouples shall consist of wires not larger than 30 AWG (0.0509 mm^2). If the thermal mass of the materials whose temperature is being measured is significantly larger than that of the thermocouple wire, larger-size wires may be used, but in no event larger than 24 AWG (0.205 mm^2).

A thermocouple junction and adjacent thermocouple lead wire shall be securely held in good thermal contact with the surface of the material on which the temperature is being measured.

NOTE 1: In most cases, adequate thermal contact will result from securely taping or cementing the thermocouple in place, but if a metal surface is involved, brazing or soldering the thermocouple to the metal will in some cases be necessary.

NOTE 2: Care should be used to keep the bare thermocouple wire from being twisted together ahead of the point of contact with the part, as this will result in the effective junction being some distance from the part and will in some cases result in errors.

The thermocouple wire shall conform with the requirements for special thermocouples as listed in the table of limits of error of thermocouples in Annex A, Item 19.

6.5.3.204 Measurement of temperatures for solid state equipment

Measurement of temperatures for solid-state equipment shall be in accordance with Clauses 6.5.3.202 and 6.5.3.203 when monitoring non-conductive parts or conductive parts that are not energized.

When one or more thermocouples are connected directly to energized parts, care shall be taken for safety and to prevent damage due to voltage differences and grounds.

Measurement of energized parts operating at line voltage can require the use of methods other than the thermocouple method, such as temperature indicating labels. These methods may be used when agreeable to all concerned, and when it can be demonstrated that these methods have accuracy comparable to that of the thermocouple method.

During the temperature test, the temperatures of all heat sinks for solid state devices in the power assembly shall be monitored to determine which heat sink(s) in each phase shall be provided with thermal sensors in accordance with 5.203(k).

6.5.3.205 Test conditions

To determine whether industrial control equipment complies with the temperature test requirements, the device shall be operated under normal conditions and shall carry its rated current until temperatures are constant. An overload relay shall not trip during the test. A source of supply of any convenient voltage may be used for temperature tests on parts other than coils.