UL 1004-3

STANDARD FOR SAFETY

Thermally Protected Motors

UL Standard for Safety for Thermally Protected Motors, UL 1004-3

Second Edition, Dated February 27, 2015

Summary of Topics

This revision of ANSI/UL 1004-3 dated January 12, 2023 is being issued to update the title page to reflect the most recent designation as a Reaffirmed American National Standard (ANS). No technical changes have been made.

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

The requirements are substantially in accordance with Proposal(s) on this subject dated October 21, 2022.

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FEBRUARY 27, 2015
(Title Page Reprinted: January 12, 2023)

ANSI/UL 1004-3-2018 (R2023)

UL 1004-3

Standard for Thermally Protected Motors

First Edition – September, 2008

Second Edition

February 27, 2015

This ANSI/UL Standard for Safety consists of the Second Edition including revisions through January 12, 2023.

The most recent designation of ANSI/UL 1004-3 as a Reaffirmed American National Standard (ANS) occurred on January 12, 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 UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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INTRODUCTION

1 Scope

1.1 This Standard is intended to be read together with the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1. The requirements in this Standard supplement or amend the requirements in UL 1004-1. The requirements of UL 1004-1 apply unless modified by this Standard.

1.2 This Standard applies to motors that rely upon a device (thermal motor protector) to prevent overheating under at least one operating condition. These motors shall be identified as thermally protected motors.

1.3 This Standard applies to motors protected either by electromechanical thermal motor protectors or solid-state thermal motor protectors.

1.4 This Standard applies to impedance protected motors where the manufacturer has provided a supplementary thermal motor protector.

1.5 The requirements in this Standard are intended to evaluate a specific motor/protector combination. When the motor, the protector, or the motor/protector combination is changed, the combination shall be reevaluated.

1.6 This Standard applies to motors provided with coordinated protection where Locked Rotor protection is provided by one means and Running Heating protection is provided by another as required by 7.11.

2 Glossary

2.1 For the purpose of this standard, the following definitions apply.

2.2 AUTOMATICALLY RESET PROTECTOR – A device that is calibrated to open the motor circuit upon reaching a certain temperature and automatically closes the circuit once the device has cooled to a lower temperature.

2.3 INTENTIONALLY WEAK TRACE (IWT) – A trace or conductive path provided on a printed-wiring board that is specifically designed to open under overcurrent conditions in order to provide a protective function for circuitry and components.

2.4 MANUALLY RESET PROTECTOR – A device that is calibrated to open the motor circuit upon reaching a certain temperature and requires a manual action to reclose the motor circuit.

2.5 PRIMARY PROTECTOR – A protector that is expected to operate during the abnormal testing of a motor sample.

2.6 SELF-HOLDING PROTECTOR – A device that is calibrated to open the motor circuit upon reaching a certain temperature but requires both cool down below the calibration point and removal of power for resetting of the protector.

2.7 SINGLE-OPERATION DEVICE – A device that is calibrated to open a motor circuit upon being exposed to a defined temperature and which is reset only upon cooling to -35°C (-31°F) or lower.

2.8 THERMAL CUTOFF – A device that is calibrated to open a motor circuit upon being exposed to a defined temperature.

2.9 THERMAL MOTOR PROTECTOR, THERMAL PROTECTOR, OR PROTECTOR – A device installed integrally within a motor that is responsive to motor current and temperature or temperature only and that, when applied as intended, prevents motor overheating. Types are: thermal cutoff, automatically reset, manually reset, self-holding and single-operation.

2.10 THERMALLY PROTECTED MOTOR – A motor that relies upon a device (protector) to prevent overheating.

CONSTRUCTION

3 Spacings

3.1 Spacings at a protector terminal intended to be used as a field-wiring terminal shall not be less than those specified in the Table for “Minimum acceptable spacings at field wiring terminals for voltages up to 750” or the Table for “Minimum acceptable spacings at field wiring terminals for voltages over 750” of UL 1004-1, as appropriate.

4 Thermal Protection Systems

4.1 Motors where the motor current is so great as to preclude the use of a thermal motor protector may use a combination of thermal motor protector or a temperature sensor and relay or contactor to achieve the functionality of a thermally protected motor provided that all the following are met:

a) The normally closed thermal motor protector is wired in series with the relay/contactor coil so that, in normal operation, the relay is electrically latched and thus any opening of the relay/contactor coil circuit would disable the motor.

b) The relay/contactor has been evaluated and found to comply with the Standard for Industrial Control Equipment, UL 508. Specifically:

1) The relay shall undergo 50 cycles of overload testing in accordance with UL 508;

2) The relay shall undergo 6,000 cycles of endurance testing in accordance with UL 508; and

3) The relay shall undergo the Short Circuit Test of UL 508.

c) The thermal motor protector used to control the relay has a pilot duty rating suitable for the relay to be controlled.

d) The combination (temperature sensing device, relay, wiring, and motor) have been evaluated to the requirements of this Standard.

4.2 Because a solid-state relay is considered a potential single-point of failure (i.e., the relay “contacts” may fail in the shorted condition thus obviating the protective functionality), solid-state relays may only be used in this capacity if either redundancy is provided or the solid-state relay complies with the Standard for Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements, UL 60730-1.

5 Intentionally Weak Trace (IWT)

5.1 A motor, as described in 7.10, shall comply with the requirements of this Section and Section 11, Intentionally Weak Trace (IWT) Tests

5.2 IWTs shall:

a) Not be used in lieu of branch circuit overcurrent protection;

b) Be designed as single use; and

c) Not be designed or considered to be a user-serviceable part.

5.3 If the IWT opens, the printed-wiring board (PWB) or the entire control shall be replaced or discarded. Bridging of an opened IWT with a fuse or other overcurrent protective device shall not be permitted.

5.4 It shall be established whether reliable performance of the IWT is required to provide a required safety function, i.e., motor overtemperature protection, 11.2.

5.5 It shall be established whether the IWT is designed as a full range device, 11.4, or is intended to protect against catastrophic, short-circuit, conditions only.

5.6 If the IWT is determined to be designed to function as a full range device, the rating of the IWT shall be established in accordance with 11.3.

PERFORMANCE

6 General

6.1 A motor that uses alternate major insulation system component materials shall have each material subjected to the Locked Rotor Endurance Test, Section 9. Following the tests, the motor shall not exhibit an increased risk of fire or electric shock.

Exception: It shall not be necessary to repeat the Locked Rotor Endurance Test, Section 9, to evaluate the suitability of the alternate material when all the following are met:

a) The alternate major insulation system component is of the same geometry, the same polymeric class (thermoplastic/thermoset), and is other than the magnet wire;

b) The Electrical and Mechanical Tensile Strength RTIs of the alternate material are, at a minimum, equal to the rating of the insulation system; and

c) The heat deflection temperature for the alternate material is either as high as or higher than:

1) The highest temperature plus 10°C recorded during the Locked Rotor Temperature Test, Section 8, conducted on the motor originally; or

2) The heat deflection temperature for the original material.

6.2 It shall not be necessary to repeat the Locked Rotor Endurance Test, Section 9, for alternate minor insulation system components.

6.3 The performance tests are to be conducted on representative samples of motor / protector combinations. The number of samples required to be tested are to be consistent with the range of motors to be protected.

6.4 A protector calibrated to have a tolerance in excess of ±5°C (±9°F) of the nominal opening temperature or ±15°C (±27°F) of the closing temperature, shall be tested in accordance with 6.5 to determine that the wider tolerance protector has an intended locked-rotor cycling life.

6.5 As required by 6.4, the following motor/protector combinations are to be tested to all temperature and endurance requirements as follows:

a) One sample protector calibrated to open at the maximum temperature shall be subjected to all tests required in this Standard; and

b) One sample calibrated to open at the minimum temperature and close at the maximum temperature shall be subjected to the Locked Rotor Endurance Test, Section 9, except the duration is to be 18 days.

6.6 When a secondary or back-up protector is provided, it shall not operate under any conditions of test.

6.7 Polyphase motors shall be provided with protectors so that each phase winding is protected from overheating.

6.8 A single-operation device shall not reset itself at a temperature higher than minus 35°C (minus 31°F).

6.9 During the tests, the current is to be monitored and recorded at key events such as when the load is increased during the Running Heating Temperature Test, Section 10, or when the protector trips during the Locked Rotor Temperature Test, Section 8.

Exception: The current is not required to be monitored during the Locked Rotor Endurance Test, Section 9.

6.10 The primary protector shall operate during the Locked Rotor Temperature Test, Section 8, and during the Locked Rotor Endurance Test, Section 9.

6.11 The primary protector shall not operate during the Rating or Temperature Test of UL 1004-1.

6.12 Manufacturers that choose to provide a thermal motor protector in their impedance protected motor may, at their option, elect to have the motor evaluated to the requirements of this Standard as a thermally protected motor. If so, at the manufacturer's option, the motor will be either tested at an elevated ambient or be tested at an elevated voltage in either case sufficient to cause the thermal protector to operate under locked rotor conditions and thus the motor to behave as a thermally protected motor.

6.13 A motor that employs an insulation system greater than Class A shall not be prohibited from being protected to the temperature limits for one insulation class lower than the insulation class marked on the motor for the locked-rotor tests. The running heating test would still comply with the temperature limit of the insulation class marked on the motor. [For example, during the running overload test, a motor with a Class B insulation system would be allowed to trip at or below 165°C (a Class B limit). For the locked-rotor test, the maximum temperature limit will be 200°C (a Class A limit) during the first hour and 175°C (a Class A limit) after the first hour.]

7 Motors Additionally Provided with Electronic Protection

7.1 Motors, provided with an electronic circuit designed to prevent overheating of the motor that are additionally provided with an electromechanical thermal motor protector, may be evaluated to the requirements of this Standard with the electronic circuit protection functions disabled.

7.2 These motors shall be considered thermally protected motors if the protector is subjected to motor winding current or a motor thermal protection system if the protector is not subjected to motor winding current. Electronic protection circuits for such motors shall be considered operating controls.

7.3 For these motors, the test compliance criteria of 8.1.3 and 9.1.3 shall apply to the control, as well as to the motor.

7.4 The dielectric test for motors described in 9.1.4 shall consist of one dielectric test for the control and one for the motor:

a) For the motor, the voltage shall be as described in 9.1.4 and the voltage is to be applied as directed in the Dielectric Voltage-Withstand Test of UL 1004-1. If a DC dielectric is used, the voltage is to be twice the normal peak voltage to the motor coils.

b) For the control, the voltage is to be as described in the Dielectric Voltage-Withstand Test of UL 1004-1.

7.5 If a test results in control board component failures, the test is to be repeated 3 times with essentially the same results (same components affected to the same extent).

7.6 If a test terminates as a result of an overcurrent protective device (OCP) opening, and that device:

a) Is not user accessible, the test shall be considered acceptable.

b) Is user accessible, the test is to be continued with the fuse replaced as many times as necessary to reach ultimate results. The test shall be considered acceptable if the motor/control does not exhibit a risk of fire or shock as defined in 8.1.3 and 9.1.3.

Exception: The test is to be terminated after the fuse is replaced 3 times, if there is no evidence of further circuit damage beyond the initial OCP operation. The test shall be considered acceptable.

A marking that specifies the manufacturer, model, type, and electrical values of the device shall be provided in accordance with 12.5.

7.7 A test that terminates due to failure of a component (faulty component), is to be repeated using a new component and if the component opens again, 7.8 shall apply.

7.8 A test that terminates due to failure of a component or components that are not designed, intended, and found suitable as an overcurrent protective device(s) shall be considered unacceptable.

7.9 A test that terminates due to opening of a printed-wiring board trace (not designed as a weak trace), the gap is to be electrically shorted and the test continued until ultimate results occur.

7.10 A test that terminates due to opening of an IWT shall comply with the requirements of Section 5, Intentionally Weak Trace (IWT), and Section 11, Intentionally Weak Trace (IWT) Tests.

7.11 In every case where a Locked Rotor Test terminates as a result of the operation of an overcurrent protective device, the Running Heating Test shall be performed and, under Running Heating Test conditions, the thermal motor protector must operate before the overcurrent protective device.

8 Locked Rotor Temperature Test

8.1 General

8.1.1 The rotor is to be locked in a stationary position using a means of low thermal conductivity.

8.1.2 Temperatures are to be measured:

a) By the change-in-resistance method; or

b) With a thermocouple applied directly to the actual conductor material, integrally applied conductor insulation, or coil wrap, as applicable.

8.1.3 As a result of this test, the motor shall comply with all of the following:

a) The coil temperature shall not exceed the temperature limits specified in Table 8.1.

b) The fuse in the grounding conductor shall not open.

c) There shall be no electrical or mechanical malfunction of any associated component parts such as capacitors.

d) A secondary protector shall not have operated.

e) A branch circuit fuse shall not have operated.

When examination of the motor windings requires disassembly of the motor, the examination shall be conducted after the Locked Rotor Endurance Test, Section 9.

Table 8.1
Maximum temperatures – Locked rotor temperature test

Protector type	Motor insulation class													
	A		E		B		F		H		N		R	
	°C	(°F)	°C	(°F)	°C	(°F)	°C	(°F)	°C	(°F)	°C	(°F)	°C	(°F)
1. Automatically reset:														
a) During 1st hour	200	(392)	215	(419)	225	(437)	250	(482)	275	(527)	295	(563)	315	(599)
b) After 1st hour[a]	175	(347)	190	(374)	200	(392)	225	(437)	250	(482)	270	(518)	290	(554)
c) Average[b]	150	(302)	165	(329)	175	(347)	200	(392)	225	(437)	245	(473)	265	(509)
2. Manually reset, single operation, Self-holding;	200	(392)	215	(419)	225	(437)	250	(482)	275	(527)	295	(563)	315	(599)
3. Thermal cutoff:														
a) During 1st hour	200	(392)	215	(419)	225	(437)	250	(482)	275	(527)	295	(563)	315	(599)
b) After 1st hour	150	(302)	165	(329)	175	(347)	200	(392)	225	(437)	245	(473)	265	(509)

[a] The temperatures are to be recorded for:

a) The second hour of operation or until the temperatures stabilize, whichever is longer; and

b) The seventy-second hour of the test.

Stabilized temperatures are obtained when the maximum temperatures readings of three successive cycles are within 2°C (3.6°F) of each other and are not showing a successive increase or a successive decrease in temperature.

[b] Refer to 8.1.4.

8.1.4 The average temperature referenced in Table 8.1 is to be determined for both the second and seventy-second hours. For each of these periods, the average temperature is to be determined by taking the arithmetic mean of the trip temperature and reset temperature. The temperatures of the hottest thermocouple are to be used.

8.1.5 When a "worst case" condition, i.e., speed of a multi-speed motor, frequency, etc. is not evident, a motor shall be tested at each condition until thermal stabilization. The condition resulting in the highest operating current is then to be subjected to the full Locked Rotor Temperature Test, Section 8, and the Locked Rotor Endurance Test, Section 9. When the currents are similar, the condition with the fastest protector cycling rate is to be tested. (It is not necessary that the protector cycle under all conditions.) When the cycling rates are also similar, the condition with the highest temperature is to be tested.

8.1.6 A motor shall comply with the requirements of this Standard in each condition that results in a protector opening. For each condition that does not result in the protector opening, the tests in the Standard for Impedance Protected Motors, UL 1004-2, are to be performed.

8.1.7 At the conclusion of the Locked Rotor Temperature Test, and while still in a heated condition, the motor shall be subjected to and comply with the Dielectric Voltage-Withstand Test of UL 1004-1.

8.2 Automatically reset protectors

8.2.1 Starting at room temperature, a motor provided with an automatically reset protector is to be energized continuously for 72 hours in the locked rotor condition, during which the winding temperatures are to be monitored:

a) Until temperatures stabilize, if monitored by thermocouple; or

b) Once a day, if monitored by the change of resistance method.

8.2.2 The protector shall open the circuit.

8.2.3 A polyphase motor that is not provided with a 3-phase protector that opens all phases on operation shall additionally be tested under single phasing conditions. The motor is to be energized in the locked rotor condition, with one supply conductor (the worst case) open circuited. For asymmetrical motor windings, the test is to be repeated until all phases have been singly opened. The test duration shall be such that the first and second hour winding temperatures are recorded or until temperatures stabilize, whichever is longer.

8.2.4 A polyphase motor that is provided with a 3-phase protector that opens all phases on operation shall additionally be tested under single phasing conditions. The motor is to be energized in the locked rotor condition, with one supply conductor open circuited. The test duration shall be such that the first and second hour winding temperatures are recorded or until temperatures stabilize, whichever is longer.

8.3 Manually reset protectors

8.3.1 Starting at room temperature, a motor provided with a manually reset protector is to be energized for 10 cycles of protector operation in the locked rotor condition, with the protector being reset as quickly as possible after it has opened the circuit.

8.3.2 A polyphase motor shall additionally be tested under single phasing conditions. The motor is to be energized in the locked rotor condition, with one supply conductor open circuited.

8.4 Thermal cutoffs

8.4.1 Starting at room temperature, three samples of a motor provided with a thermal cutoff are to be energized continuously in the locked rotor condition, until the thermal cutoff opens the circuit.

8.4.2 A polyphase motor shall additionally be tested under single phasing conditions. The motor is to be energized in the locked rotor condition, with one supply conductor (the worst case) open circuited. For asymmetrical motor windings, the test is to be repeated until all phases have been singly opened.

8.5 Self-holding protectors

8.5.1 Each combination of Positive Temperature Coefficient (PTC) and protector shall be considered a separate device and shall be subjected to the tests in 8.5.

8.5.2 Starting at room temperature, a motor provided with a self-holding protector is to be energized in the locked rotor condition. The protector shall open the circuit.

8.5.3 Once the self-holding protector opens the circuit, the motor shall be deenergized until the protector resets. Once the protector resets, the motor is to be immediately reenergized. This is to be repeated for a total of ten such cycles.

8.5.4 A polyphase motor shall additionally be tested under single phasing conditions. The motor is to be energized in the locked rotor condition, with one supply conductor (the worst case) open circuited. Once the protector resets, the motor is to be immediately reenergized. This is to be repeated for a total of ten such cycles. For asymmetrical motor windings, the test is to be repeated until all phases have been singly opened.

8.6 Single-operation devices

8.6.1 Starting at room temperature, three samples of a motor provided with a single-operation device are to be energized continuously in the locked rotor condition until the protector opens the circuit.

8.6.2 A polyphase motor shall additionally be tested under single phasing conditions. The motor is to be energized in the locked rotor condition, with one supply conductor (the worst case) open circuited. For asymmetrical motor windings, the test is to be repeated until all phases have been singly opened.

9 Locked Rotor Endurance Test

9.1 General

9.1.1 Immediately following the Locked Rotor Temperature Test, Section 8, the motor is to be re-energized in the locked rotor condition, and under the conditions of that test as appropriate for the type of protector.

9.1.2 If the Locked Rotor Endurance Test is interrupted prior to its completion, the manufacturer is to be given the option of restarting the test from the beginning with a new sample or continuing the test, with the original motor, at the point where it was interrupted, until the test has been completed. If the test is restarted and the motor complies with the acceptance criteria specified in 9.2 – 9.4, then the results are considered acceptable. If the motor fails to meet one or more of the criteria, then, at the manufacturer's discretion, the test may be repeated with a new sample.

9.1.3 At the conclusion of the test, the motor shall comply with the following:

a) The fuse in the grounding conductor shall not open.

b) The motor shall still electrically operate. For example, a bearing failure is considered in compliance.

c) There shall be no electrical or mechanical malfunction of any associated component parts such as capacitors or starting relays.

d) A secondary protector shall not have operated.

e) A branch circuit fuse shall not have operated.

9.1.4 Immediately following the conclusion of the Locked Rotor Endurance Test, and while still in a heated state, a motor shall withstand application of a potential of twice the marked rated voltage of the motor between the windings and the frame.

9.1.5 Polyphase motors are to be tested only under polyphase conditions.

9.1.6 For multiple voltage motors, the Locked Rotor Endurance Test is to be conducted at each voltage. A different sample may be used for each test.

9.2 Automatically reset protectors

9.2.1 A motor with an automatically reset protector is to be tested for an additional 15 days.

9.2.2 The automatically reset protector shall not open the circuit permanently prior to the completion of 15 days unless:

a) It is specifically intended to do so; and

b) Testing of three samples shows that it is capable of doing so consistently and reliably without permanent damage to the motor.

9.3 Manually reset protectors

9.3.1 A motor with a manually reset protector is to be tested for an additional 50 cycles being reset as quickly as possible.

9.3.2 The manually reset protector shall not open the circuit permanently prior to the completion of the 50 cycles.

9.3.3 For dual rotation and multi-speed motors, the Locked Rotor Endurance Test is to be conducted only at the condition resulting in the highest current. When the currents are similar, the condition with the fastest protector cycling rate is to be tested. When the cycling rates are also similar, the condition with the highest temperature is to be tested.

9.4 Self-holding protectors

9.4.1 A motor with a self-holding protector is to be tested for an additional 50 cycles being reset as quickly as possible.

9.4.2 The self-holding protector shall not open the circuit permanently prior to the completion of the 50 cycles.

9.4.3 For dual rotation and multi-speed motors, the Locked Rotor Endurance Test is to be conducted only at the condition resulting in the highest current. When the currents are similar, the condition with the fastest protector cycling rate is to be tested. When the cycling rates are also similar, the condition with the highest temperature is to be tested.

9.5 Self-holding protector cold reset

9.5.1 Starting at room temperature, a motor provided with a self-holding protector is to be energized in the locked rotor condition. The self-holding protector shall open the circuit. Once the self-holding protector opens the circuit, and while still energized, the assembly is to be placed inside a freezer maintained at 0°C for 8 hours.

9.5.2 During the 8 hours, the self-holding protector shall not reset.

10 Running Heating Temperature Test

10.1 General

10.1.1 At the manufacturer's option, the motor shall be subjected to and comply with the Running Heating Temperature Test described in this Section.

10.2 Continuous duty motors

10.2.1 A continuous-duty motor is to be operated under load at its nameplate current as a minimum and at the applicable test voltage until the motor winding temperatures stabilize. The protector shall not open when operating at the initial load point. The load is then to be increased to the maximum load that does not result in the protector opening. Other methods that result in the same objective may be deemed equivalent but in all cases, the protector trip must occur under conditions of increasing loading, not decreasing.

Figure 10.1

Air-Over Motors

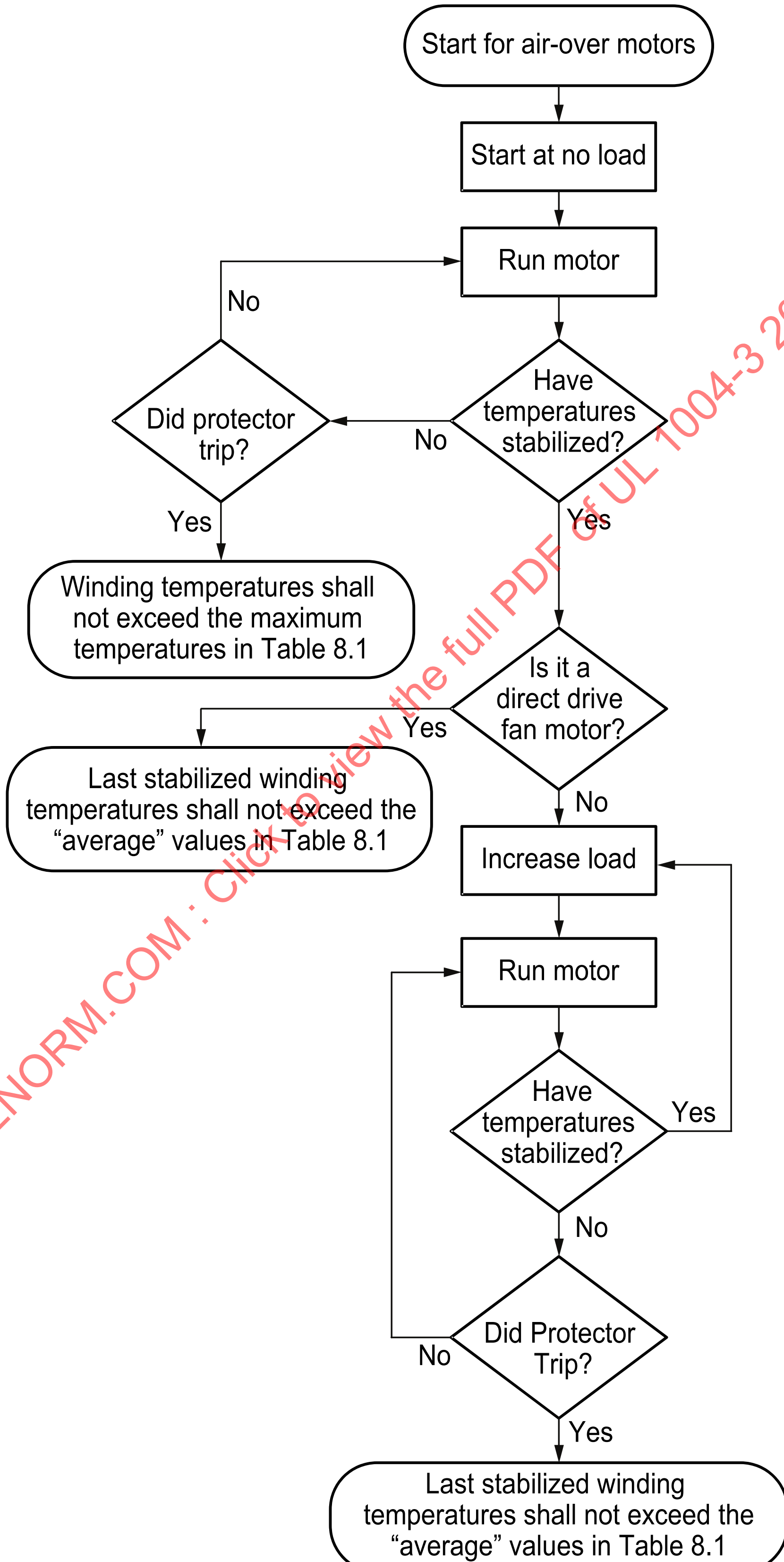

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Figure 10.2

Continuous Duty Motors

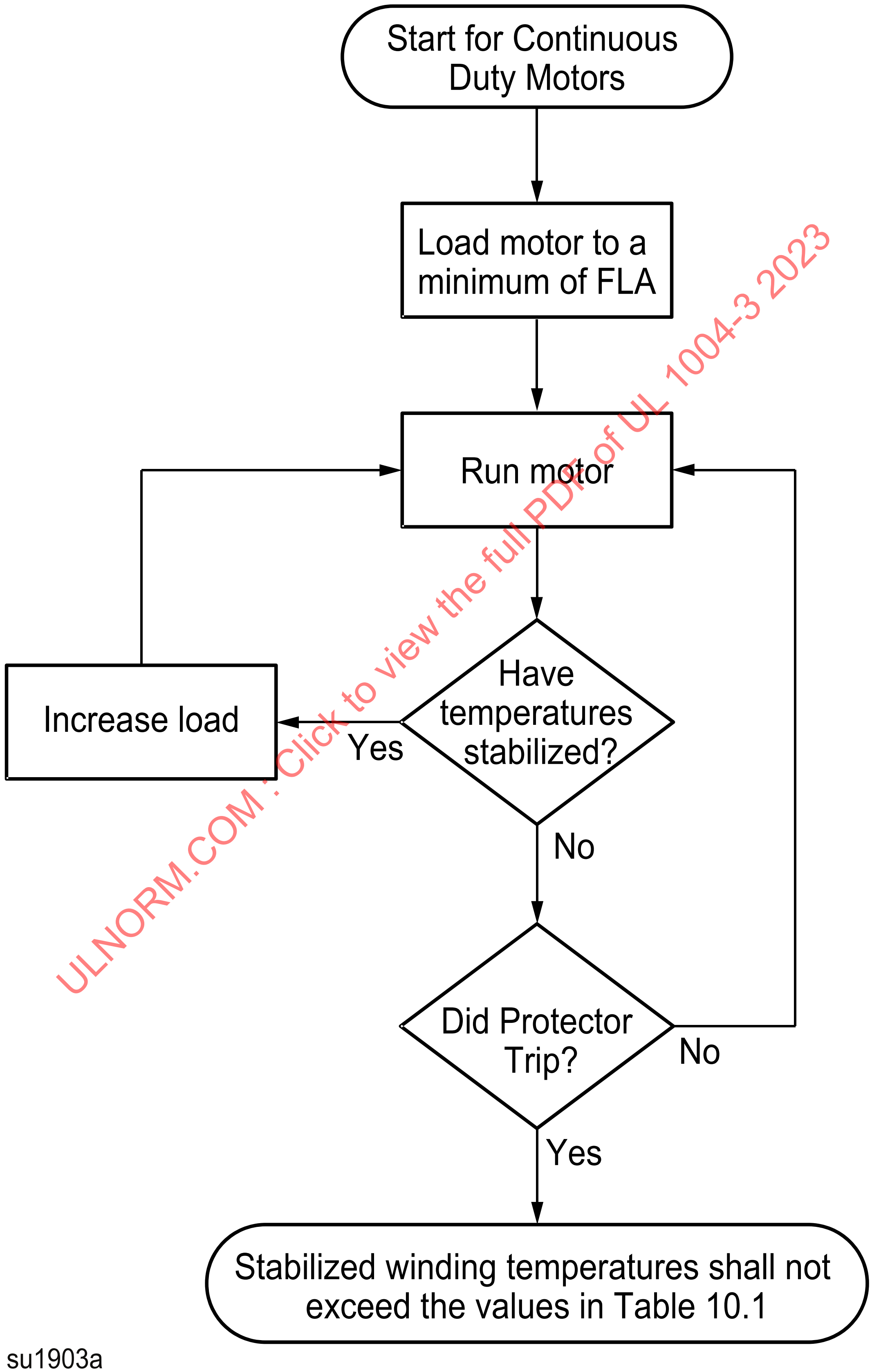
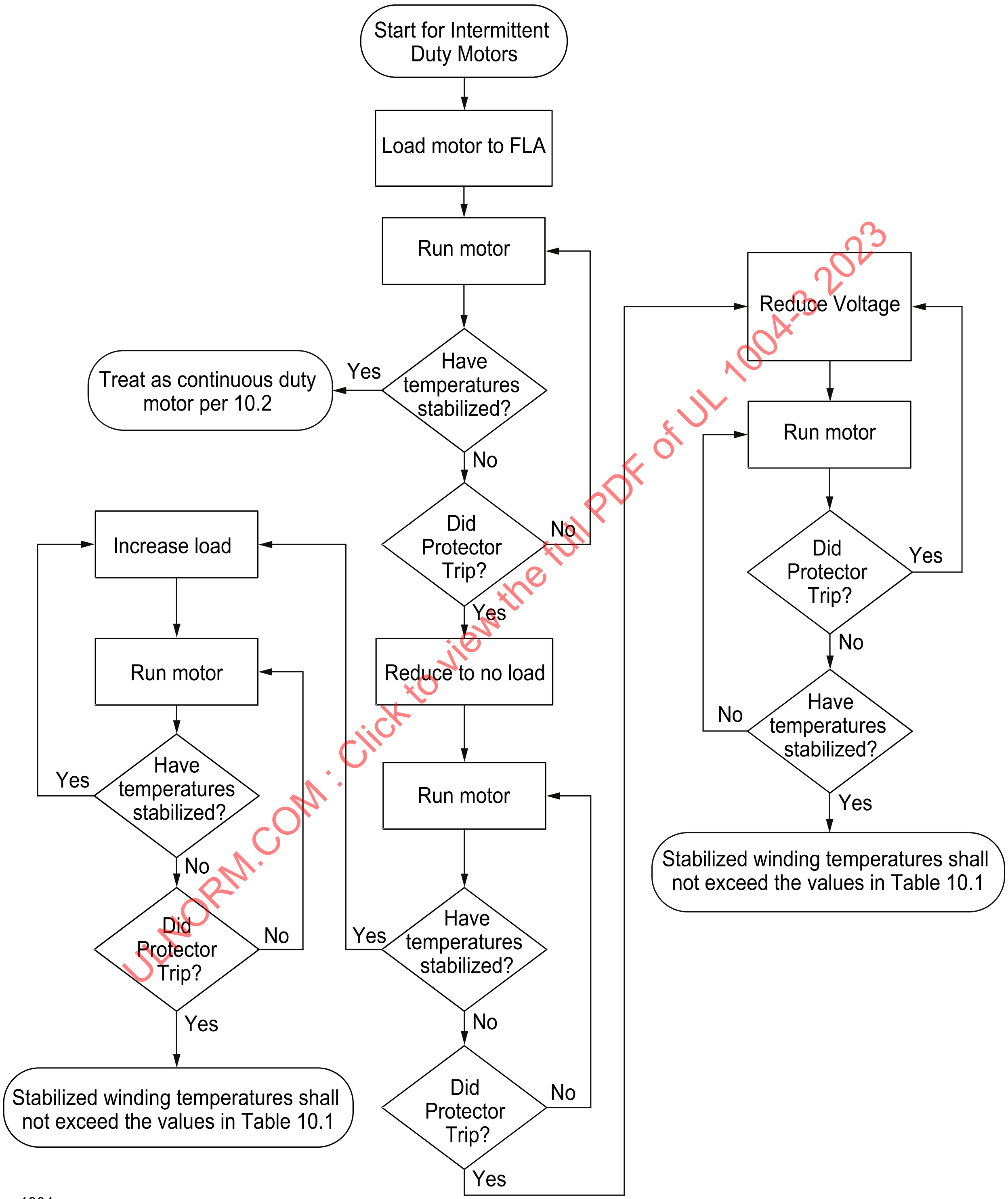


Figure 10.3

Intermittant Duty Motors



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10.2.2 When a motor-protector combination is running with the maximum load it is capable of carrying without resulting in the protector opening the circuit, the stabilized winding temperature shall not exceed the values specified in Table 10.1.

Table 10.1
Running heating temperature test – maximum winding temperatures

Motor insulation system	Maximum winding temperature	
	°C	(°F)
A	140	(284)
E	155	(311)
B	165	(329)
F	190	(374)
H	215	(419)
N	235	(455)
R	255	(491)

10.3 Polyphase motors

10.3.1 A continuous-duty polyphase motor is to be tested under both the normal polyphase operation and under single-phasing conditions.

10.3.2 For the single-phase test, the motor is to be energized and the load adjusted so that the motor operates at rated current. One motor supply conductor (the worst case) is to be opened. The motor winding temperature is to stabilize before beginning to load the motor. After opening the supply conductor, the motor may stall or continue to operate for a short time before the protector opens. This meets the intent of the requirement provided the winding temperatures do not exceed the locked rotor limits specified in Table 8.1. For asymmetrically wound motors not provided with a 3-phase protector that opens all phases on operation, this test is to be repeated until all phases have been singly opened.

10.4 Ultimate trip current

10.4.1 The ultimate trip current of a protector in a motor rated more than 1 horsepower (746 W) shall not exceed the percentage of motor full-load current specified in Table 10.2. The full-load current used for this determination shall be the marked nameplate value.

Table 10.2
Maximum ultimate trip current

Motor full load current amperes[a]	Ultimate trip current as a percentage of full load current
9.0 or less	170%
9.1 – 20.0	156%
20.1 or more	140%

[a] See 10.4.1.

NOTE – This table does not apply to polyphase motors operating under single-phase conditions

10.4.2 When requested by the manufacturer, the ultimate trip current shall be determined at a 40°C (104°F) referee ambient.

10.4.3 A motor shall comply with 10.4.1 at each voltage and speed connection.