

An Investigation of the Use of 16 and 18 AWG Conductors for Branch Circuits in Industrial Machinery Built to NFPA79 2002

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Abstract – It has been a long-standing requirement that conductors smaller than 14 AWG shall not be used in branch circuits. The industrial machinery industry has expressed a need to use smaller conductors, similar to those allowed by the International Electrotechnical Commission (IEC). This paper presents the engineering analysis and the experimental results of testing performed to verify the acceptability of 16 and 18 AWG conductors for branch circuits in industrial machinery built to NFPA 79 2002.

Index terms – conductor protection, overcurrent protection, insulation damage, industrial machinery, NFPA 79.

I. INTRODUCTION

In order to remain competitive within the global marketplace, United States industrial machinery manufacturers on the committee for NFPA79 (*Electrical Standard for Industrial Machinery*) expressed the need to be able to utilize circuit conductors that are smaller than 14 AWG, the existing minimum allowed for branch circuits in the United States. Several proposals were written and submitted for NFPA79 adoption. However, a study was requested to confirm the theoretical engineering analysis utilized for the substantiation of the proposals.

The existing requirements, 2002 edition of the National Electrical Code® (NEC®) [1] and the 1997 edition of NFPA79 [2], do not allow conductors smaller than 14 AWG to be utilized for branch circuits (per NEC® 210.19(A)(4) and 310.5, and NFPA 79 subclause 15.3).

The industrial machinery industry has recognized the need to utilize 16 and 18 AWG conductors for both motor and non-motor loads to remain competitive in the global market. Wire sizes of 0.75 mm² and 1 mm² are commonly applied where the load currents are very small in applications based upon IEC 60204-1 [3] (Safety of Machinery – Electrical Equipment of Machines). Wire sizes of 0.75 mm² and 1 mm² have an ampacity similar to 18 AWG and 16 AWG wire respectively.

An engineering-based analysis was completed on the properties of 16 and 18 AWG conductors. This analysis, developed by the NFPA 79 Small Wire Working Group was designed to cover typical “worst case” overcurrent conditions that could occur in various types of electrical distribution systems, and will be discussed in this paper. A Special Service Investigation was performed by UL to verify the premise and the testing results. This investigation was

submitted to the full NFPA 79 committee to substantiate the inclusion of 16 and 18 AWG conductors for branch circuits in the 2002 edition.

II. ENGINEERING ANALYSIS

A. Withstand Capabilities

The first step was to determine the withstand capabilities of the 16 and 18 AWG conductors. Withstand capabilities of insulated cable pertains to the level of short-circuit current an insulated conductor can handle for a certain amount of time before there is damage to the insulation, or the conductor itself. Insulated conductors are considered to be components of an electrical system and are therefore required to be protected against “excessive damage” per the NEC® in Section 110.10 and NFPA 79 subclause 8.1.2.

Research of available literature was conducted on the effects of short-circuit currents on insulated conductors. The findings of four different methods were analyzed to determine the most appropriate method to use for this analysis. The four different methods included:

- Insulated Cable Engineers Association Standard P-32-382 [4]
- Research conducted by William H. Middendorf [5] –[7]
- “Grounding Electrical Systems for Safety,” Eustice Soares [8]
- Onderdonk melting point.

The Insulated Cable Engineers Association (ICEA) standard P-32-382 provides a standard physics formula for determining the short-circuit withstand of insulated copper conductors. The formula is as follows:

PHYSICS EQUATION I ICEA CONDUCTOR WITHSTAND FORMULA

$$\left[\frac{I}{A} \right]^2 t = 0.0297 \log \left[\frac{T_2 + 234}{T_1 + 234} \right]$$

I = Short-circuit Current – Amperes
A = Conductor Area – Circular Mils
t = Time of Short-circuit - Seconds
T₁ = Maximum Operating Temperature
T₂ = Maximum Short-circuit Temperature

This physics formula for determining the heat rise for a specific cross sectional area of copper was used to create a worst-case condition for the wire. The formula utilized by ICEA was based upon an adiabatic process where all the heat is contained within the wire. ICEA then determined maximum short-circuit temperatures for conductors with various types of insulation as shown:

- Thermoplastic (150 °C)
- rubber, paper, varnished cloth (200 °C)
- Crosslinked Polyethylene & Ethylene Propylene Rubber (250 °C)

The temperatures specified above designate the start of insulation damage. Thermoplastic insulation (150°C) has the lowest temperature to reach its damage point, therefore was used to simulate a worst-case situation. Inserting 150 °C for T_2 into physics equation 1, would generate I^2t values as shown in Table I.

TABLE I

ICEA I^2t Withstand Limits for Copper Conductor, Thermoplastic Insulation (75°C) (No Insulation Damage)	
Wire Size	Short-circuit Withstand I^2t
14 AWG	47,000 A ² s
12 AWG	120,000 A ² s

Studies conducted by William H. Middendorf of the University of Cincinnati explored the effects of short-circuit currents on insulated conductors. The studies were conducted to evaluate the damage levels referenced in the ICEA standard P-32-382. The purpose was to evaluate the accuracy of the ICEA damage levels. As a result, Middendorf derived withstand limits different from the levels achieved by ICEA. The withstand levels derived from this research were based upon the amount of I^2t that would cause the dielectric strength of the insulation to be decreased to half that of its original value. As expected, the I^2t levels required to reduce the dielectric strength of the wire were greater than those for which there was no insulation damage allowed (ICEA). The I^2t values resulting from this research are shown in Table II.

TABLE II

Middendorf I^2t Withstand Limits for Copper Conductor, Thermoplastic (THW-75°C) Insulation (Insulation Damage to ½ of Original Dielectric)	
Wire Size	Short-circuit Withstand I^2t
14 AWG	150,000 A ² s
12 AWG	450,000 A ² s

Eustice Soares wrote, “Grounding Electrical Systems for Safety.” Soares provides another reference level for conductor withstand. Soares states that the validity rating for conductors corresponds to the amount of energy required to cause the copper to become loose under a lug after the conductor cools down. This “validity” rating is based on raising the copper temperature from 75°C to 250°C. Using physics equation 1, the I^2t withstand levels of conductors that will become loose under a lug are shown in Table III.

TABLE III

Soares I^2t Withstand Limits for Copper Conductor, (Conductor Becomes Loose Under Lug)	
Wire Size	Short-circuit Withstand I^2t
14 AWG	94,000 A ² s
12 AWG	238,000 A ² s

The final method, by Onderdonk, provides the withstand level that represents the amount of current and time required to cause copper conductors to melt. Onderdonk determined the temperature required to melt the conductors during a short-circuit to be 1083°C. Inserting this temperature into physics equation 1, the I^2t withstand levels required to melt copper are as shown in Table IV.

TABLE IV

Onderdonk I^2t Withstand Limits for Copper Conductor, (Melted Copper)	
Wire Size	Short-circuit Withstand I^2t
14 AWG	320,000 A ² s
12 AWG	804,000 A ² s

After thoroughly reviewing these four methods it was decided that the most conservative approach would be utilized to represent the worst-case scenario. The ICEA formula in physics equation I had the lowest withstand ratings as can be seen by the data in Tables I-IV. It is also the most common method used to determine conductor withstand ratings in the industry recommended by IEEE in the following standards:

- ANSI/IEEE 141-1993 (Red Book) [9] sections 5.6.2 and 12.4.6
- ANSI/IEEE 241-1990 (Gray Book) [10] sections 8.5.6 and 9.8.7.1
- ANSI/IEEE 242-1986 (Buff Book) [11] section 8.4.2
- ANSI/IEEE 1015-1997 (Blue Book) [12] section 4.11.1.2

It is also referenced in the Canadian Electrical Code, C22.1-98 [13] Appendix B. Therefore this was the method chosen to evaluate the 16 and 18 AWG conductors. Physics

equation 1 was used to calculate the withstand I^2t values for 16 and 18 AWG conductors in Table V.

TABLE V

ICEA I^2t Short-Circuit Withstand Limits Copper Conductor, Thermoplastic Insulation (75°C)	
Wire Size	Short-circuit Withstand I^2t
18 AWG	7,355 A ² s
16 AWG	18,657 A ² s

These values reflect the short-circuit withstand ratings of the conductor, but the overload capabilities of the conductors must be explored as well. Again using physics equation I, we determined specific over current damage points for a given period of time. These are shown in Table VI.

TABLE VI

Withstand Overload Conditions (75°C)		
Duration	16 AWG Withstand Current	18 AWG Withstand Current
1 sec	137	86
5 sec	61	38
10sec	43	27

B. Overcurrent Protective Devices

Once the withstand limits were determined it was necessary to select the proper overcurrent protective devices to prevent damage to the 16 and 18 AWG conductors. Devices must be selected based on their ability to carry the rated current and protect the conductor against overcurrents.

In order to provide protection against short-circuit currents, the protective device must be able to limit the energy let-through. The I^2t let-through of the device must be lower than the short-circuit withstand levels determined in Table V. The NFPA 79 small wire group chose to investigate the use of current limiting fuses listed to UL/CSA/ANCE 248 [14] to provide short-circuit protection. These devices were chosen because they have published standards with maximum clearing I^2t let-through limits. It was not the intention of this investigation to exclude other types of devices. Other devices may be suitable for use, but standards with published let-through values were not readily available. These devices must be individually evaluated for their suitability for use with 16 and 18 AWG conductors.

Any fuse that is listed to the UL/CSA/ANCE 248 standard must have a clearing I^2t let-through lower than the umbrella limit that is set by the standard. These umbrella limits can be found in the UL White Book [15], General Information for Electrical Equipment Directory. These limits were evaluated, and the fuses that had umbrella limits lower than the determined withstand levels were selected for this study. The overcurrent protective devices that met these criteria were Class CC, J and T fuses. The umbrella limits for these devices are shown in Table VII.

The overcurrent protective device must also interrupt low level overloads before overheating causes insulation damage. The two major types of branch circuit loads considered in this analysis were motor loads, and non-motor loads. The circuits with non-motor loads will only have one overcurrent protective device; therefore this device must protect the conductors from both overloads and short-circuits. The Class CC, J and T fuses are designed to provide overload and short-circuit protection when sized to match conductor ampacity. For circuits with motor loads, the fuses are only intended to provide short-circuit protection when sized per NEC[®] and NFPA 79 requirements. These circuits have an overload relay as part of a motor starter to provide protection against overload currents. UL508 [16] is the standard pertaining to motor starters. The overload relays are classified according to their opening time at 600% of their current rating per UL508. A Class 10 overload relay will open a 600% overcurrent in ten seconds, and a Class 20 relay will open a 600% overcurrent in twenty seconds. The Class 10 and 20 overload relays were investigated in this testing due to the popularity of these types of devices in the industry.

III. METHODS

A testing program was developed to provide data to support the engineering analysis. Tests were set up with three major principles in mind:

1. Create tests using a conservative approach to represent the worst case.
 - “Bus bar” testing from UL489 [17]
 - UL248 Umbrella fuses for short-circuit testing
 - 1’, 4’, 100’ lengths of wire
2. Create tests to simulate the various types of electrical systems and grounding schemes
 - Full voltage, high current testing on each phase
3. Check validity of wire insulation using dielectric testing
 - UL 83 [18], *Thermoplastic Insulated Wire and Cable*, section 27

TABLE VII

UL Class of Fuse	Current Rating	Between Threshold and 50KA		At 100 KA		At 200KA	
		Ip (A)	I^2t (A ² s)	Ip (A)	I^2t (A ² s)	Ip (A)	I^2t (A ² s)
Class CC	30	6,000	7,000	7,500	7,000	12,000	7,000
Class J	30	6,000	7,000	7,500	7,000	12,000	7,000
Class T (600V)	30	6,000	7,000	7,500	7,000	12,000	7,000

The test setups were created around these principles and used for the investigation. UL standards 248, 489, and 508 were used as the basis for testing. The test program to determine the suitability of the use of 16 and 18 AWG conductors for branch circuits was divided into two major categories: verification of overload protection, and verification of short-circuit protection. Following each test, the conductor was visually inspected, then subjected to dielectric testing per UL83, section 27.

A. Verification of Short-Circuit Protection

Testing was performed to investigate the short-circuit protection of 16 and 18 AWG conductors. Development of the test setups was based upon creating tests that would cover the majority of the applications for which the wire would be installed. A conservative approach using “worst case” test situations was used for this development.

The first step was to determine the test configuration for the short-circuit testing. In order to cover the variety of installations that could exist, it was determined that, initially, 1 foot, 4 feet and 100 feet lengths of conductor would be used in the testing, see Figs 1 through 3. The 1 foot and 4 feet lengths would investigate the thermal and magnetic withstands of short runs of conductor inside a cabinet. The 100 feet test setup investigated the thermal and magnetic withstands of long runs of conductor.

Three phase bolted fault conditions were used following testing configurations in UL248, UL489, and UL508 to simulate the worst case three phase short-circuit condition. The fault was created at the end of the conductor run. The circuit was connected to the test lab terminals following UL489 “bus bar” high fault circuit test configuration. This configuration calls for 4 feet of 1 AWG feeding the line lugs of the overcurrent protective device and 10 inches of rated wire for the load side. The tests were conducted with 1 foot of conductor on the load side for simplicity. For all of the short-circuit testing, special “umbrella” fuses were used that had clearing I^2t let-through values above the UL published limits. This insures that all commercially available Class CC, J and T fuses will have clearing I^2t values less than the “umbrella” fuses used in the test program.

Three short-circuit current levels, 50,000 amps, 10,000 amps and 5,000 amps were used to cover a variance in installations and available fault current levels in the industry. The 50kA level was chosen based on the UL248 fuse testing. The Class CC, J, and T each have the same I^2t limit for 50kA, 100kA, and 200kA. The 50kA level was determined to represent the high short-circuit current testing. The 10kA level was chosen because of its commonality in various UL standards for low level short-circuit current testing. And finally the 5kA level was chosen to represent the lower end of short-circuit currents. The 5kA testing was only used on the 1 foot, three phase bolted fault test setups.

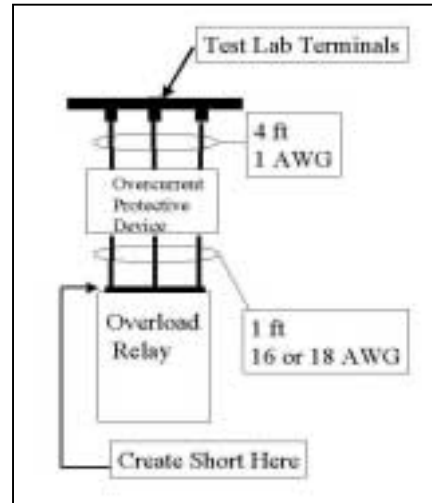


Fig. 1. 1 Foot Test Setup

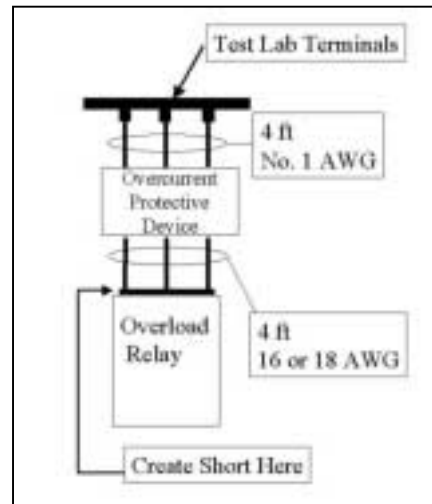


Fig. 2. 4 Feet Test Setup

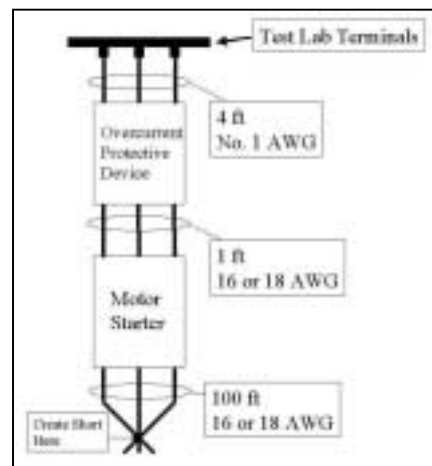


Fig. 3. 100 Feet Test Setup

All of these tests were performed at 480V, three phase. Conditional tests at a full 600V were performed on only the 18 AWG with the branch-circuit, short-circuit devices that passed all the 480V 1 foot testing, see Fig. 1 for setup. This test sequence was conducted for the 5, 10, and 50kA tests.

Additional test configurations were utilized to investigate various commonly used grounding schemes. The test configurations were used to verify the suitability of the conductors where the maximum possible I^2t , instantaneous peak current, and voltage would be imposed on the conductor pertaining to the various systems. The four types of systems investigated are shown in Fig.4 through Fig. 7.

The three phase bolted fault test configuration described previously covered the solidly grounded wye system. Additional test configurations were used to investigate the remainder of the systems. A fault was created across one pole of the branch-circuit, short-circuit devices using line-to-line voltage. This would simulate a

situation that could exist in these grounding schemes where single or multiple line to ground faults could impose full rated line-to-line voltage across one pole of the device (test setup is shown in Fig. 8). Consequently, a single pole of the three phase branch circuit overcurrent protection (set of three fuses, or a single three pole circuit breaker) would be required to interrupt the fault current at the full rated line-to-line voltage [19].

The single pole test setup used to simulate fault conditions for corner grounded delta, resistance grounded wye and ungrounded systems was performed with 1 foot of rated wire. These tests were conducted at 480V at the 50kA and 10kA fault levels.

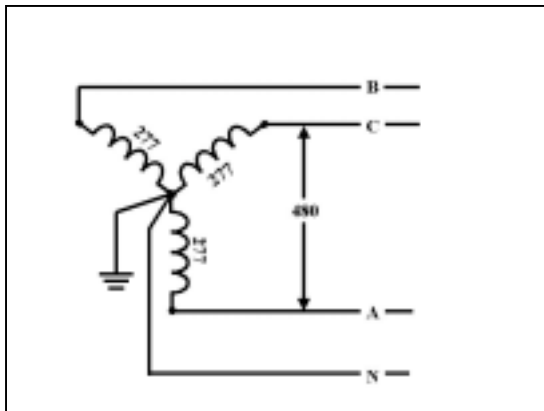


Fig. 4 Solidly Grounded Wye

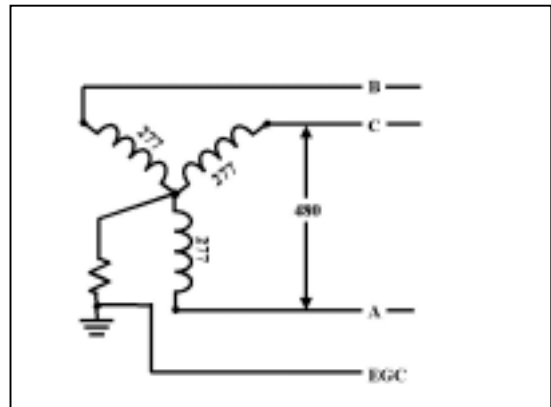


Fig. 6 Resistance Grounded Wye

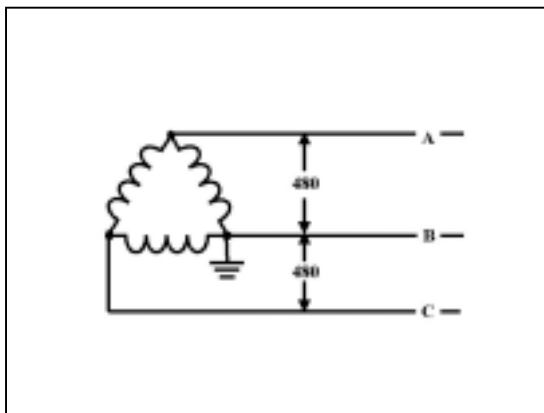


Fig. 5 Corner Grounded Delta

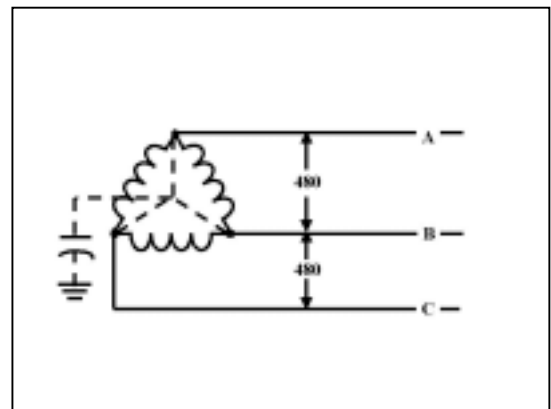


Fig. 7 Ungrounded Systems

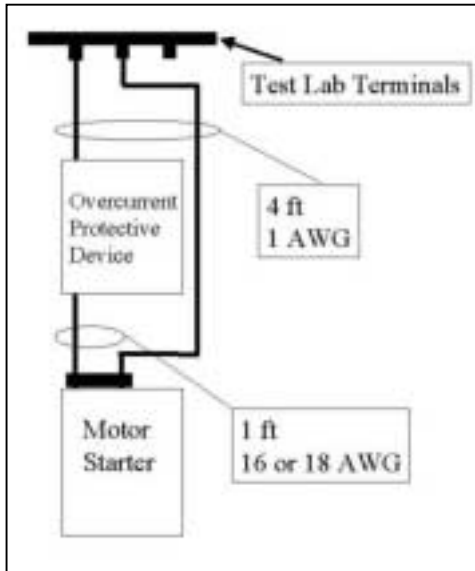


Fig. 8 Single Pole Test Setup

B. Verification of Overload Protection

To investigate overload protection of 16 and 18 AWG conductors, testing was performed to explore overcurrent protection for two different types of loads: motor loads and non-motor loads.

To investigate motor branch circuits, motor starters were used in conjunction with branch-circuit short-circuit protective devices that they were listed with. The motor controller characteristics had to be explored. Based upon the information proved in UL508, test points were compared to the time current curve to evaluate the performance of the overload device under long term heating conditions. The criteria for determining the full load ampacity was based on the maximum current value the conductor can handle for the set amount of time using physics equation 1 (10 sec for Class 10, 20 sec for Class 20, etc.). Both Class 10 and Class 20 overload relays were used in the test program. Class 20 overload relays are more common, but as shown below, the use of Class 10 overloads could lead to a larger permissible load current because it will operate faster during overload conditions. Limitations were placed on the load current for 16 and 18 AWG conductors depending on the class of overload relay used. These current levels are shown in Table VIII.

Two current levels were investigated on each test setup:

- 15 Amps
- 600% Maximum Full Load Ampacity

The first level was selected to link the overload testing with a common branch circuit current level recognized in the industry. The second level was selected to coincide with UL508 testing for the overload relays and to simulate a locked rotor condition on a motor. The overload relay was sized according to the maximum permissible load current during the overload testing. Opening time was

TABLE VIII

Maximum Full Load Currents for Motor Loads		
Overload Relay	16 AWG Maximum FLA	18 AWG Maximum FLA
Class 10	8	5
Class 20	5.5	3.5

recorded for each test. Visual inspection and dielectric testing of the wire was conducted.

Testing for non-motor loads consisted of a single branch circuit overcurrent protective device sized at the ampacity of the conductor. Two current levels were investigated on each test setup:

- 135% of the Overcurrent Protective Device Rating
- 600% of Maximum Full Load Ampacity

The first level was selected based upon a common overload test level conducted on branch circuit overcurrent protective devices. The second was selected to simulate a higher-level overload condition that might exist.

C. Acceptability of Results

To verify if a conductor passes the overload and short-circuit testing, a two-step investigation was implemented. Immediately following the tests, a visual inspection was performed on the conductor and observations were noted. Visual damage to the insulated wire including insulation damage, wire pulled out of terminal, or vaporization of the wire would result in a failure for the test. If a failure of the visual test resulted, the dielectric test was not conducted. The second step in the wire acceptance testing was a dielectric withstand test. It was determined that the dielectric withstand test in UL83, *Thermoplastic Insulated Wire and Cable*, section 27 would be used.

Dielectric Voltage-Withstand Test as specified in UL83 section 27.

- Immerse as much of the insulation of the wire as possible in room temperature tap water for a period of not less than 6 hours.
- With wire still immersed in the tap water, attach one lead of a dielectric voltage tester to the bare ends of the wire. Attach the other lead to a conducting material that is immersed in the water.
- Apply 2000V to the wire under test for 60 seconds. If the wire were not able to withstand the applied voltage without breakdown for the specified amount of time it would result in a failure.

IV. RESULTS

The maximum I^2t let-through was measured for each short-circuit test. The opening time was recorded for each overload test. Tables IX and X summarize the testing

sequences for the overload and short-circuit testing respectively. The resulting data is also found in these tables.

TABLE IX

Overload Test	Volts	Phase	Current (Amps)	Overcurrent Protective Device(s)	Wire Size	Conductor Withstand (Amps ² sec)	Opening Time	Visual Inspection Observation	Dielectric Testing Results (Pass/Fail)
Motor Overload	LV	1	15	20A Class CC Fuse & Class 10 Relay	16	18,657	Relay opened, 5 sec.	No Visible Damage	Pass
Motor Overload	LV	1	48	20A Class CC Fuse & Class 10 Relay	16	18,657	Relay opened, 2 sec.	No Visible Damage	Pass
Motor Overload	LV	1	15	20A Class CC Fuse & Class 20 Relay	16	18,657	Relay opened, 4.9 sec.	No Visible Damage	Pass
Motor Overload	LV	1	33	20A Class CC Fuse & Class 20 Relay	16	18,657	Relay opened, 3.1 sec.	No Visible Damage	Pass
Non-Motor Overload	LV	1	11	10A Class CC Fuse	16	18,657	5 min. 48 sec.	No Visible Damage	Pass
Non-Motor Overload	LV	1	48	10A Class CC Fuse	16	18,657	4.6 sec.	No Visible Damage	Pass
Motor Overload	LV	1	15	15A Class CC Fuse & Class 10 Relay	18	7,355	Relay opened, 6 sec.	No Visible Damage	Pass
Motor Overload	LV	1	30	15A Class CC Fuse & Class 10 Relay	18	7,355	Relay opened, 3 sec.	No Visible Damage	Pass
Motor Overload	LV	1	15	15A Class CC Fuse & Class 10 Relay	18	7,355	Relay opened, 5.8 sec.	No Visible Damage	Pass
Motor Overload	LV	1	21	15A Class CC Fuse & Class 10 Relay	18	7,355	Relay opened, 3.8 sec.	No Visible Damage	Pass
Non-Motor Overload	LV	1	8	7A Class CC Fuse & Class 10 Relay	18	7,355	35 sec.	No Visible Damage	Pass
Non-Motor Overload	LV	1	34	7A Class CC Fuse & Class 10 Relay	18	7,355	5.4 sec.	No Visible Damage	Pass

TABLE X

Short-Circuit Test	Volts	Phase	Current (Amps)	Overcurrent Protective Device(s)	Wire Size	Conductor Withstand (Amps ² sec)	Maximum I ² t Let Through (Amps ² sec)	Visual Inspection Observation	Dielectric Testing Results (Pass/Fail)
1 foot	480	3	5000	20A Umbrella Fuse	16	18,657	1,690	No Visible Damage	Pass
1 foot	480	3	10,000	20A Umbrella Fuse	16	18,657	1,980	No Visible Damage	Pass
1 foot	480	3	50,000	20A Umbrella Fuse	16	18,657	1,420	No Visible Damage	Pass
1 foot	480	3	5000	20A Umbrella Fuse	18	7,355	1,420	No Visible Damage	Pass
1 foot	480	3	10,000	20A Umbrella Fuse	18	7,355	1,440	No Visible Damage	Pass
1 foot	480	3	50,000	20A Umbrella Fuse	18	7,355	1,450	No Visible Damage	Pass
4 feet	480	3	10,000	20A Umbrella Fuse	18	7,355	7,010	No Visible Damage	Pass
4 feet	480	3	50,000	20A Umbrella Fuse	18	7,355	5,140	No Visible Damage	Pass
100 feet	480	3	10,000	20A Umbrella Fuse	16	18,657	820	No Visible Damage	Pass
100 feet	480	3	50,000	20A Umbrella Fuse	16	18,657	1,230	No Visible Damage	Pass
100 feet	480	3	10,000	20A Umbrella Fuse	18	7,355	1,000	No Visible Damage	Pass
100 feet	480	3	50,000	20A Umbrella Fuse	18	7,355	1,280	No Visible Damage	Pass
1 foot	600	3	5000	20A Umbrella Fuse	18	7,355	8,290	No Visible Damage	Pass
1 foot	600	3	10,000	20A Umbrella Fuse	18	7,355	10,400	No Visible Damage	Pass
1 foot	600	3	50,000	20A Umbrella Fuse	18	7,355	6,330	No Visible Damage	Pass
1 foot	480	3	5000	30A Umbrella Fuse	18	7,355	7,070	No Visible Damage	Pass
1 foot	480	3	10,000	30A Umbrella Fuse	18	7,355	8,120	No Visible Damage	Pass
1 foot	480	3	50,000	30A Umbrella Fuse	18	7,355	7,900	No Visible Damage	Pass
1 foot	480	1	10,000	30A Umbrella Fuse	18	7,355	6,690	No Visible Damage	Pass
1 foot	480	1	50,000	30A Umbrella Fuse	18	7,355	6,130	No Visible Damage	Pass

V. CONCLUSION

The tests performed support the engineering analysis. The devices that were used for the testing had lower I²t let-through values than the withstand ratings of the 16 and 18 AWG conductors. As expected all of the conductors passed both a visual inspection and the dielectric withstand test. These results were witnessed by UL and the Special Service Investigation, *An Investigation of the use of 16 and 18 AWG Conductors for Power Branch Circuits in Industrial Machinery Applications*, file number E4273 [20] was issued. Based on these findings, the following comment was sent to the NFPA 79 for the ROC meeting for inclusion in the 2002 edition of the standard:

13.6.1 Conductors shall not be smaller than 14 AWG for power circuits unless otherwise permitted in (a) or (b).

(a) 16 AWG shall be permitted, if part of a jacketed multiconductor cable assembly or flexible cord, or individual conductors used in a cabinet or enclosure, under the following conditions:

- (1) Non-motor power circuits of 8 amperes or less provided all the following conditions are met:
 - (a) Circuit is protected in accordance with Clause 7
 - (b) Overcurrent protection does not exceed 10 amperes
 - (c) Overcurrent protection is provided by one of the following:

- (1) A branch circuit rated circuit breakers listed and marked for use with 16 AWG wire
- (2) Branch circuit rated fuses listed and marked for use with 16 AWG wire
 - (3) Class CC, Class J, or Class T fuses
- (2) Motor power circuits with a full load ampacity of 8 amperes or less provided all the following are met:
 - (a) Circuit is protected in accordance with Clause 7
 - (b) Circuit is provided with Class 10 overload protection
 - (c) Overcurrent protection is provided by:
 - (1) A branch circuit rated circuit breakers listed and marked for use with 16 AWG wire
 - (2) Branch circuit rated fuses listed and marked for use with 16 AWG wire
 - (3) Class CC, Class J, or Class T fuses
- (3) Motor power circuits with a full load ampacity of 5.5 amperes or less provided all the following are met:
 - (a) Circuit is protected in accordance with Clause 7
 - (b) Circuit is provided with Class 20 overload protection
 - (c) Overcurrent protection is provided by:
 - (1) A branch circuit rated circuit breakers listed and marked for use with 16 AWG wire
 - (2) Branch circuit rated fuses listed and marked for use with 16 AWG wire
 - (3) Class CC, Class J, or Class T fuses
- (b) 18 AWG, shall be permitted if part of a jacketed multiconductor cable assembly or flexible cord, or

- individual conductors used in a cabinet or enclosure, under the following conditions:
- (1) Non-motor power circuits of 5.6 amperes or less provided all the following conditions are met:
 - (a) Circuit is protected in accordance with Clause 7
 - (b) Overcurrent protection does not exceed 7 amperes
 - (c) Overcurrent protection is provided by one of the following:
 - (1) A branch circuit rated circuit breakers listed and marked for use with 18 AWG wire
 - (2) Branch circuit rated fuses listed and marked for use with 18 AWG wire
 - (3) Class CC, Class J, or Class T fuses
 - (2) Motor power circuits with a full load ampacity of 5 amperes or less provided all the following conditions are met:
 - (a) Circuit is protected in accordance with Clause 7
 - (b) Circuit is provided with Class 10 overload protection
 - (c) Overcurrent protection is provided by:
 - (1) A branch circuit rated circuit breakers listed and marked for use with 18 AWG wire
 - (2) Branch circuit rated fuses listed and marked for use with 18 AWG wire
 - (3) Class CC, Class J, or Class T fuses
 - (3) Motor power circuits with a full load ampacity of 5.5 amperes or less provided all the following are met:
 - (a) Circuit is protected in accordance with Clause 7
 - (b) Circuit is provided with Class 20 overload protection
 - (c) Overcurrent protection is provided by:
 - (1) A branch circuit rated circuit breakers listed and marked for use with 18 AWG wire
 - (2) Branch circuit rated fuses listed and marked for use with 18 AWG wire
 - (3) Class CC, Class J, or Class T fuses

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