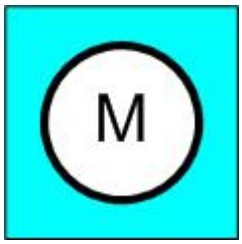

Electric Motor Connection Issues Part 2

Howard W Penrose, Ph.D., CMRP
President, SUCCESS by DESIGN Reliability Services
Executive Director, Institute of Electrical Motor Diagnostics, Inc.

Richard Borge
President, Performance Evaluation, LLC

Introduction

As mentioned in 'The Right Connections' article, as an industry we have drifted away from proper electric motor connection techniques. This becomes evident, as the number of issues related to taped connections has been increasing. In fact, the number of instances we have directly been involved with since the first article has been disturbing. While performing the necessary steps of confirming the materials we were to include in this article we did discover another issue: the information on making connections, or splicing the leads, is not readily available, including any changes or updates. We will use the terms splice and connection throughout this article interchangeably.

We are going to explore the proper techniques for making electric motor connections in AC motors under 600 Volts. First, we are going to discuss the NFPA 79-2007 and the NFPA 70-2007, or National Electrical Code, rules for splicing. Second, we will discuss splicing kits followed by the appropriate method of insulating connections if kits are not available.

NFPA 79-2007 and NFPA 70-2007

Over the past few years we have received a number of questions related to wire nut connections for electric motors. One of the statements made within the NFPA79, Section 13.5.9.2 was interesting: "Electrical connections at motor terminal boxes shall be made with an identified method of connection. Twist-on wire connections shall not be used for this purpose." However, we have found a number of instances where instructions are provided for the use of wire nuts for electric motor connections, let alone a very large number of cases where small electric motors

use wire nuts for making connections. Section 13 also discusses that the insulation material cannot be combustible and that soldered or insulation piercing connectors cannot be used.

The NEC does call for the minimum insulation requirements as: “conductors must be spliced or joined with splicing devices identified for the purpose and the splices must be covered with insulation equivalent to that of the conductor. The use of identified manufactured splice insulators to cover wire to wire connections is recommended.” This is easily defined as recommending the use of splice kits, which we will be discussing later, while allowing for alternate methods of insulating connections.

So far as the preparation requirements for motor connections, the connection box, lead and cable length, and openings are considered in the NEC Article 430.12 and 430.13. For the purpose of this article, we are going to focus on splice connections and not fixed terminals within connection boxes.

In order to properly meet the NEC, the motor connection box must be complete and is normally metallic with the exception of instances where grounding connections are made directly to the motor housing. The connection box must protect the conductors and splice insulation from direct exposure to moisture and other contaminants. Additionally, the volume of the connection box must meet minimum requirements for standard purpose machines (See Tables 1 and 2).

Table 1: Terminal Housings Motors 11 Inch Diameter or Less

	Cover Opening Minimum Dimension		**Useable Volume Minimum**	
Horsepower	**Millimeters**	**Inches**	**Centimeters^3**	**Inches^3**
1 and Smaller	41	1-5/8	170	10.5
1.5, 2, and 3	45	1-3/4	275	16.8
5 and 7.5	50	2	365	22.4
10 and 15	65	2-1/2	595	36.4

Table 2: Terminal Housings Motors Over 11 Inch Diameter

Maximum Full Load Current for 3-Phase Motors with Maximum of 12 Leads (In Amperes)	**Terminal Box Cover Opening Minimum Dimension**		**Useable Volume Minimum**		**Typical Maximum Horsepower 3-Phase**	
	mm	**in**	**cm^3**	**in^3**	**230 Volt**	**460 Volt**
45	65	2.5	595	36.4	15	30
70	84	3.3	1265	77	25	50
110	100	4.0	2295	140	40	75
160	125	5.0	4135	252	60	125
250	150	6.0	7830	450	100	200
400	175	7.0	13,775	840	150	300
600	200	8.0	25,255	1540	250	500

The lead wire from the motor and incoming power supply should be at least 6 inches in length and properly marked. This allows proper access to make and position connections within the motor housing. According to the NFPA 79, Articles 12.2.1 and 12.2.2, feeder conductors to the motor must be stranded soft-annealed copper.

An area of concern is where conductors enter the motor connection box. This is covered under the NEC Article 430.13: "Where wires pass through an opening in an enclosure, conduit box, or barrier, a bushing shall be used to protect the conductors from edges of openings having sharp edges. The bushing shall have smooth, well-rounded surfaces where it may be in contact with the conductors. If used where oils, greases, or other contaminants may be present, the bushing shall be made of material not deleteriously affected."

The common methods used to make the connections, themselves, are crimped lugs with appropriate sized one or multiple-bolt-hole connection points or split bolts. In both cases, the connections must be tightened to the requirement for the fastener, or at least 7 lb-in (0.8 N.m). Sharp edges must be removed and the fasteners should not extend far beyond the lugs so that they do not penetrate the splice insulation. The fastening system for lugs should also include washers and a lock washer to ensure that they do not come loose. Crimped connections should not be soldered or tinned, per the NEC, unless the fastening method requires it.

Splicing/Connection Kits

One of the reasons why many organizations do not use splicing kits is the cost. For electric motors, the common name for connection box splices is a 'pigtail splice.' These usually consist of sealing strips and slip-on rubber boots that are sized by the feeder and motor lead sizes. The key is the timesavings involved in the installation of the pre-fabricated splicing systems. While the kit may cost upwards of twenty times the cost of electrical tape, the time savings involved is substantial, ensuring a quick and reliable return to operation. The average time for all three pigtail splices is 5-10 minutes versus up to 30 minutes for the properly insulated standard taping system. In addition, should the motor require disconnection, these splicing systems are removed far more quickly than tape without the requirement of cutting the leads and feeder conductors. The difference in cost is quickly recovered in labor alone, not including the return of equipment to normal operation and the availability of that labor for other tasks.

Taping Splices

In the December/January Edition of Uptime, the failed splice insulation systems consisted of crimped insulated lugs and vinyl electrical tape-only insulation systems. This is of primary concern as we often see electricians carrying only the vinyl electrical tape in their kits. The other

issue is the size of the splice insulation system when taped. Some have almost no insulation on them while others will be a fist-sized ball of tape.

When pigtail-splicing kits are not available, taping systems can be used as a method for insulating your connections. However, the proper method of taping requires three types of tapes to be applied:

1. Varnished cambric – preferably non-adhesive. If there is adhesive, it should be faced outwards during taping;
2. Rubber insulating tape; and,
3. Vinyl electrical tape.

The first step is to apply two layers of varnished cambric tape. This provides a barrier to sharp edges of the connection in addition to electrical insulation. The next layer should be four half-lap layers of rubber tape. During application a constant tension should be applied so that the rubber tape bonds to itself, which is a moisture barrier. Over top of the rubber tape two half-lap layers of vinyl electrical tape is applied and should extend at least 1 inch below the rubber tape along the feeder conductor(s) and motor lead(s). The tape should also have tension applied as it is wrapped so that it conforms to the layers underneath and has a good seal against moisture and contaminants while also providing an armor jacket to the other layers.

Conclusion

Proper insulation of motor lead connections is important to ensure reliable and safe operation of an electric motor. Unfortunately, the tendency has been away from the proper application of both splicing and the insulation system, which has led to shorts to ground within connection boxes. The NFPA 70-2007 (NEC) and NFPA 79-2007 address a number of issues related to splicing and insulating connections including disallowing the use of twist-on connectors. The optimal method for timesavings and proper insulation includes the use of lugs or split bolts, proper torque, and commercially available splicing kits. Alternately, taping of the connections can be performed with a proper taping procedure that includes insulated cambric, rubber, and vinyl tapes.

Bibliography

NFPA, NFPA 70-2007 National Electrical Code, Article 430, 2007

NFPA, NFPA 79-2007 Electrical Standard for Industrial Machinery, 2007

Goodman and Brown, “Electrical Taping Skills: A Lost Art?” EC&M Magazine, January 1, 2006.

Penrose and Borge, “The Right Connections,” Uptime Magazine, December/January 2008.

About the Authors

Howard W Penrose, Ph.D., CMRP is the President of SUCCESS by DESIGN Reliability Services and a member of the National Writers Union (UAW Local 1981). SBD provides training and facilitation for the application of motor management programs for clients that include General Motors and US Steel. For more information, contact SUCCESS by DESIGN at 800 392-9025 ext 203 (USA Only) or 860 577-8537 ext 203, via email at info@motordoc.net or our website http://www.motordoc.net.

Performance Evaluation has been testing electrical equipment for the past 22 years with an assortment of test equipment. Performance has used both static and dynamic tests to help prevent unscheduled downtime. The testing includes AC/ DC motors of all sizes and transformers. Performance contact is Richard Borge, www.performancetdr.com, 888-484-7564, perfeval@aol.com and 973-661-4281 (fax).