AUGUST 2023
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THE MAGAZINE OF ELECTRICAL DESIGN, CONSTRUCTION AND MAINTENANCE

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Assessing Circuit Breaker Condition and Arc Flash Safety

Best practices for identifying and reducing arc flash incident risk in the field. Read more *on pg. 36*

IN THIS ISSUE

Don’t Take Safety Lightly...

get reliable signal towers and audible devices for all of your machines, systems, and processes.

WERMA SIGNALTECHNIK

NEW!

NEW! WERMA eSIGN Series LED Signal Towers

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WERMA eSIGN series signal towers provide full-surface signaling with a variety of programmable signal modes. The electronic modularity of these towers provides various colors, brightness levels, and light effects, from the classic signal tower to completely customized settings. The eSIGN signal towers can also switch with ease between variable filling level indications and full-surface signaling.

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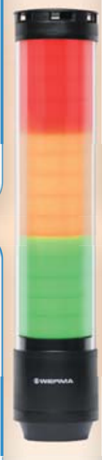

Autoscale Mode

In autoscale mode, the eSIGN segments are divided equally by the number of active status warnings. If only one status warning is active, the entire signal tower is illuminated in one color for maximum visibility.

Signal Tower Mode

In signal tower mode, eSIGN segments are combined to create a classic signal tower. Individual tiers are assigned fixed positions that are turned ON when their corresponding status bit is active.

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Patlite® LS7 series 70mm signal towers offer an attractive smooth body design with no screws or metal parts exposed, excellent for harsh environments and areas where high pressure/temperature washdowns are required.

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- Models with buzzer available
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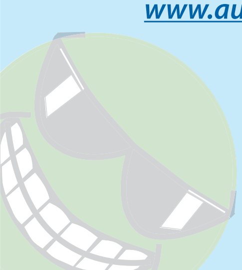

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COVER STORY

Courtesy of Shermco Industries

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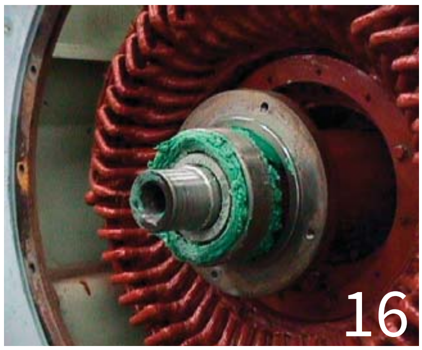

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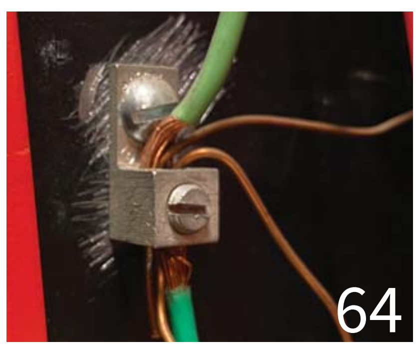
DEPARTMENTS



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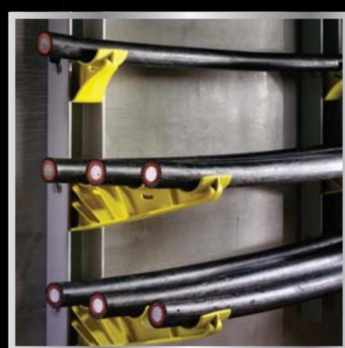

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EC&M TECH TALK VIDEO — TRANSFORMER REQUIREMENTS IN THE NEC AND BEYOND

Video ▶ In this episode, Electrical Safety Expert Randy Barnett covers various code requirements for transformers.

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WHAT TO DO WHEN A COWORKER IS CARELESS

Safety ▶ Electrical Consultant Mark Lamendola discusses what to do when a coworker is acting in unsafe ways.

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CODE CATASTROPHES: LIGHTING EDITION — PART 1

Gallery ▶ Take a look at some of the craziest Code violations showcasing lighting installations gone wrong.

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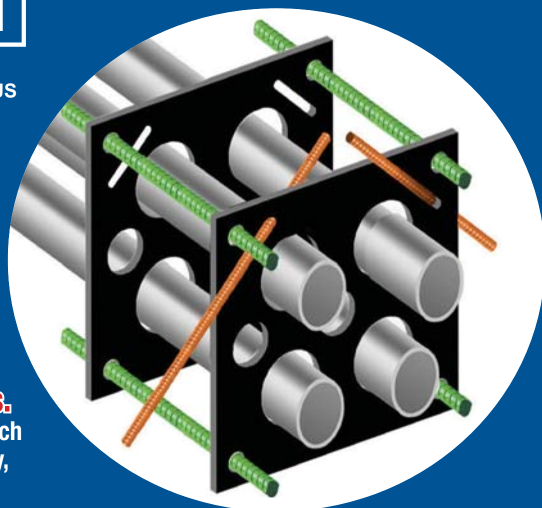

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Making Sure You Stay on the Safe Side of Electrical Maintenance

By Ellen Parson, Editor-in-Chief

This month's issue focuses on one of *EC&M*'s bread and butter topics — one that is consistently in high demand among our online audience (right up there with the National Electrical Code, electrical testing, safety, and training). One of our most sought-after subjects, "operations & maintenance" (O&M) topics commonly deliver practical maintenance, repair, and operations material in a hands-on manner, challenging electrical professionals to improve their skill sets and maximize best practices in an effort to streamline maintenance practices in the safest way possible. In addition to our regular coverage of O&M in our monthly MRO Insider e-newsletter, this August print issue highlights some of the most important aspects of electrical maintenance, including preventive maintenance best practices and checklists, safety considerations for various types of electrical equipment, and proper testing methods and techniques.

Our cover story is a perfect example of the type of technical content *EC&M* readers can't get enough of. Previously offered as a wildly popular companion webinar on the same topic (how circuit breaker conditions affect arc flash safety), more than 1,000 people registered for this live event, which took place on July 31. Presented by Denise Green, Midwest regional sales manager and national breaker specialist for Group CBS, a NETA Alliance partner, this webinar and article package addresses the most common issues typically found with circuit breaker condition and how those specifically relate to arc flash hazards. This webinar is available on-demand at https://tinyurl.com/yeyjj638. If you already registered for the live event (and are logged into the website), you can simply click on "Log In Now." If not, you can still register and view on-demand.

"The tell-tale sound, flash of light, flames, and resulting smoke — all indications that an arc flash incident has taken place. It's the ultimate workplace nightmare of every electrical professional — something has gone wrong, and now people (and equipment) are directly in harm's way," writes Green in the cover story. We all know arc flash events are often caused by human error — whether that stems from using uninsulated tools during energized work, coming in contact accidentally with exposed live parts, or working with damaged equipment. However, as Green explains, some incidents are a direct result of the condition of the equipment, such as a loose connection, water intrusion, or worn/damaged insulation. Read the cover story on page 36 to learn how you can identify and troubleshoot these hazards during normal inspections before they wreak havoc on your equipment and put the lives of maintenance personnel in danger.

Speaking of safety resources, *EC&M* recently unveiled its fourth-annual Workplace Safety Academy (https://workplacesafetyacademy.com/). Running through October 31, this free online learning event pulls together everything you need to know about workplace safety into one location, aggregating videos, white papers, articles, and sponsored content on all things safety related. Presented in cooperation with *EC&M* partner publications *CONTRACTOR*, *Contracting Business*, and *EHS Today*, the Workplace Safety Academy is designed to show safety managers, electricians, plumbers, HVAC technicians, engineers, and company leadership the latest tools, techniques, and technologies to support their company's safety agenda. Learn about emerging trends, and connect with manufacturers to answer your questions on tools, equipment, and PPE; software and technology; and codes/standards. Register for this free portal today at https://workplacesafetyacademy.com/register/.

Ellen Parson

2023's Largest Electrical Distributors

Despite concerns over a recession, most of 2023's Top 150 distributors expect to power through the uncertain economic climate and log increased revenues this year.

By Jim Lucy, *Electrical Wholesaling*

Facility Solutions, Austin, Texas (#64 on *EW*'s ranking), expects Netflix's plans to redevelop the Fort Monmouth, NJ, campus into a major film studio to provide business in the coming years. According to a Netflix press release, the first phase of the project will include the construction of 12 soundstages that will range in size from 15,000 sq ft to 40,000 sq ft each with a maximum build out of 480,000 sq ft.

While they live in different parts of the electrical market, electrical contractors and their suppliers have dealt with similar challenges over the past few years.

Electrical distributors and contractors both had to adapt to hybrid officing strategies during the COVID-19 era; endure the waiting game with product shortages; wrestle with head-spinning price increases; decide how much time and personnel to invest in new products like electric vehicle charging stations and the new generation of LED luminaires and controls; and, for some companies, decide if the time was right to sell the family business in the latest wave of mergers and acquisitions.

Despite it all, the largest electrical distributors proved once again that they, like electrical contractors, are a resilient bunch. For some companies ranked in the 2023 Top 150 Distributors listing published by *Electrical Wholesaling*, *EC&M*"s sister publication, 2022 was a banner sales year, and many saw their annual revenues blow past the 4% to 8% annual revenue increase range in the electrical market (**Table 1** on page 10).

Mike Pratt, CEO of American Electric Supply, Corona, Calif., said supplier support and the strong Southern California economy contributed to his company's sales increase in 2022. He applauded the suppliers that allowed the company to have stock for its customers when they needed it. Pratt sees an 8% sales increase in 2023 and says the continuing construction projects at Los Angeles' LAX airport and anticipated revenues from work related to the 2028 Los Angeles Olympics will support good future growth.

At OmniCable, West Chester, Pa., Greg Lampert, the company's recently retired president & CEO, said the company's 2022 sales increase was due to the new products, new markets, and investment in inventory to serve customers when supplies are tight. Lampert is

2023 Top 150 Electrical Distributors							
Rank	**Company Name**	**Town/City**	**State**	**2022 Sales**	**Employees**	**Locations**	**Senior Executive**
1	Wesco International Inc.	Pittsburgh	PA	18,849,600,000*	13,000	621*	John Engel
2	Sonepar North America	Charleston	SC	14,047,000,000*	NA	566*	Rob Taylor
3	Graybar	St. Louis	MO	10,500,000,000	9,400	325	Kathleen Mazzarella
4	Rexel Holdings (Rexel USA)	Dallas	TX	8,466,568,100*	9,223*	645*	Brad Paulsen
5	Consolidated Electrical Distributors (CED)	Irving	TX	NA	6000	700	Kurt Lasher
6	Border States	Fargo	ND	3,600,000,000	2,725	104	David White
7	City Electric Supply	Dallas	TX	NA	4,707*	668*	Thomas Hartland Mackie
8	Elliott Electric Supply Inc.	Nacogdoches	TX	2,067,000,000	2,650	171	Bill Elliott
9	U.S. Electrical Services	Middletown	CT	NA	2,000	150	Randy Eddy
10	McNaughton-McKay Electric Co.	Madison Heights	MI	NA	NA	65	Mark Borin
11	Crescent Electric Supply	East Dubuque	IL	NA	2,000	155	Scott Teerlinck
12	OmniCable	West Chester	PA	NA	712*	21*	Jeff Siegfried
13	Kendall Electric Inc. (The Kendall Group)	Portage	MI	NA	1,250	72	John Harman
14	W.W. Grainger Inc.	Lake Forest	IL	1,109,250,000	26,000*	246	Donald Macpherson
15	Van Meter Inc.	Cedar Rapids	IA	NA	810	25	Lura McBride
16	Main Electric Supply Co.	Santa Ana	CA	NA	641	15	R. Scott Germann
17	Gresco Utility Supply Inc.	Forsyth	GA	774,000,000	244	7	Steve Gramling
18	Wholesale Electric Supply	Texarkana	TX	698,753,248	736	69	Buddy McCulloch
19	Dakota Supply Group	Plymouth	MN	NA	966	53	Paul Kennedy
20	State Electric Supply	Huntington	WV	NA	680	41	John Spoor
21	Summit Electric Supply	Albuquerque	NM	NA	620	25**	Ed Gerber
22	Turtle	Linden	NJ	NA	905**	16**	Jayne Millard
23	Dealers Electrical Supply	Waco	TX	NA	632	55	Scott Bracey
24	IEWC	New Berlin	WI	NA	69**	24**	Mike Veum
25	Scott Electric	Greensburg	PA	NA	610	15	Larry Shirey
26	LoneStar Electric Supply	Houston	TX	559,000,000	390	7	Jeff Metzler
27	Franklin Empire	Mount-Royal	QU	NA	545	23	B. Backman & C. Backman
28	Kirby Risk Electrical Supply	Lafayette	IN	NA	552	40	James K. Risk, III
29	Motion Industries	Birmingham	AL	NA	9,100**	549*	Randy Breaux
30	Wholesale Electric Supply of Houston	Houston	TX	NA	479	12	Greg Hall
31	TEC Manufacturing and Distribution Services	Georgetown	TX	445,000,000	89	40	Johnny Andrews
32	Winsupply Inc.	Dayton	OH	NA	NA	75	Richard Schwartz
33	Echo Group Inc. (Echo Electric Supply)	Council Bluffs	IA	NA	500	21	Mitch Lane
34	Shepherd Electric Supply #	Baltimore	MD	429,320,832	332	5	Stuart Vogel
35	Werner Electric Supply Co.	Appleton	WI	NA	470	11	Craig Wiedemeier
36	Colonial Electric Supply	King of Prussia	PA	NA	NA	17	Steve Bellwoar
37	Villa Lighting Supply Inc.	St. Louis	MO	387,569,000	133	2	Jack Villa
38	Gerrie Electric Wholesale	Burlington	ON	NA	400	24	Elaine Gerrie
39	Green Mountain Electric Supply	Colchester	VT	NA	400	26	Nate Laber
40	Dominion Electric	Arlington	VA	374,000,000	320	11	Stephen Krooth
41	Edges Electrical Group	San Jose	CA	360,000,000	336	12	Chester C. Lehmann III
42	Rural Electric Supply Cooperative (RESCO)	Middleton	WI	302,542,000	75	7	Matt Brandrup
43	Ferguson plc	Newport News	VA	NA	33,000	1509	Kevin Murphy
44	Fastenal	Winona	MN	297,066,000	22,386	1,538*	Daniel Florness
45	Granite City Electric	Quincy	MA	NA	314	30	Steve Helle
46	Inline Electric Supply Co.	Huntsville	Al	295,000,000	350	20	Bruce Summerville
47	Schaedler Yesco Distribution Inc.	Harrisburg	PA	293,517,742	409	22	Greg Schaedler
48	United Electric Supply	Wilmington	DE	290,000,000	326	14	George Vorwick
49	Loeb Electric	Columbus	OH	NA	325	4	Charles Loeb
50	Agilix Solutions	St. Louis	MO	NA	375	13	Mike Stanfill
* North America **Global # Acquired in 2023 ## Acquired in 2022							

Table 1. The 50 largest electrical distributors had combined revenues of $88.3 billion in 2022, according to *Electrical Wholesaling* magazine estimates. That's 63% of 2022's total estimated industry sales of $140 billion. "NA" refers to companies where revenue was reported privately or estimated based on *EW*'s sales-per-employee average calculations.

optimistic about 2023 and is forecasting a 51% increase in revenues.

For some companies, price increases due to inflation accounted for a major portion of revenue increase. In the utility market, Matt Brandup, CEO of Rural Electrical Supply Cooperative (RESCO), Middleton, Wis., says inflation accounted for two-thirds of his company's 2022 sales growth and that real growth accounted for 33%. Brandup noted that RESCO's transformer sales increased considerably in 2022. He's expecting a 30% increase in 2023 revenues.

TEC Manufacturing and Distribution Services, Georgetown, Texas, is another utility specialist expecting a double-digit increase in 2023 sales. Johnny Andrews, the company's COO, is forecasting an 11% increase in revenues. He said that in 2022, the biggest driver for the company's sales increase was adding new sole-source alliances for electric cooperatives and municipal electric systems. "TEC manages the total supply chain for those organizations (demand planning, procurement, warehouse operations, inventory management, job kitting, and freight logistics)," he said in his response.

A prosperous Canadian economy and growth in the greater Toronto market and in the province of Ontario supported a 2022 revenue increase for O'Neil Electric Supply, Woodbridge, Ontario. Stephen Kleynhans, the company's president, said in his response that other contributing factors included immigration, an increase in construction spending, and the development of enhanced customer service programs. Kleynhans is forecasting a 15% increase in 2023 revenues.

At Jo-Kell Inc., Chesapeake, Va., a tightly defined OEM niche is producing solid growth. "The largest projects we have seen (and see in the immediate future) are in the automatic car wash OEM sector," said John Kelly, the company's chief corporate officer. "Our business in that market tripled in the past year, and we expect even more growth over the next year."

ACQUISITION ACTIVITY

While the national chains (WESCO, Sonepar, Graybar, Rexel, and CED) were once again the most active acquirers over two years, some large regional independents including Green Mountain Electric Supply, Colchester, Vt.; Elliott Electric Supply, Nacogdoches, Texas; Schaedler YESCO Distribution, Harrisburg, Pa.; and Inline Electric Supply, Huntsville, Ala., also made significant acquisitions. Bruce Summerville, president, Inline Electric Supply, said although his company's acquisition of Williams Electric Supply in the Nashville, Tenn., area last year was a big factor in the company's growth, Inline Electric Supply's revenues were up 30% across its existing footprint.

2023'S BIGGEST CHALLENGES

Although the majority of the Top 150 respondents believe a recession either has already started or will start before year-end, they were still bullish on their business prospects for 2023. Despite

Major Electrical Distributor Acquisitions: 2022-2023						
Company	**City/Town**	**State**	**Acquirer**	**City/Town**	**State**	**Year**
Shepherd Electric Supply	Baltimore	MD	Graybar Electric Co.	St. Louis	MO	2023
Billows Electric Supply #	Delran	NJ	Sonepar North America	North Charleston	SC	2023
Teche Electric #	Lafayette	LA	Rexel	Dallas	TX	2023
Buckles-Smith #	Santa Clara	CA	Rexel	Dallas	TX	2023
Advance Electric Supply Co. #	Chicago	IL	Border States	Fargo	ND	2022
Amperage Electrical Supply #	Roselle	IL	Consolidated Electrical Distributors (CED)	Irving	TX	2022
Lowe Electric Supply #	Macon	GA	Crescent Electric Supply	East Dubuque	IL	2022
Kansas City Electrical Supply #	Kansas City	MO	Elliott Electric Supply	Nacogdoches	TX	2022
West-Lite Supply	Cerritos	CA	Facility Solution Group (FSG)	Austin	TX	2022
CX Connexion #	Buffalo Grove	IL	Graybar Electric Co.	St. Louis	MO	2022
Walker Industrial Products	Newtown	CT	Graybar Electric Co.	St. Louis	MO	2022
New England Drives & Controls	Southington	CT	Graybar Electric Co.	St. Louis	MO	2022
Scott Electric Supply NY locations	Fredonia & Depew	NY	Green Mountain Electric Supply	Colchester	VT	2022
Davis Electric Supply	Buffalo	NY	Green Mountain Electric Supply	Colchester	VT	2022
Generation Electric Supply & Lighting	Liverpool	NY	Green Mountain Electric Supply	Colchester	VT	2022
Falcone Electric Supply	Batavia	NY	Green Mountain Electric Supply	Colchester	VT	2022
Williams Electric Supply	Nashville	TN	Inline Electric Supply	Huntsville	AL	2022
Horizon Solutions #	Rochester	NY	Rexel USA	Dallas	TX	2022
YESCO Electrical Supply #	Columbiana	OH	Schaedler YESCO Distribution Inc.	Harrisburg	PA	2022
Rockingham Electrical Supply Co. #	Newington	NH	Sonepar North America	North Charleston	SC	2022
Professional Electrical Products Co. (PEPCO) #	Eastlake	OH	Sonepar North America	North Charleston	SC	2022
Advance Electrical & Industrial	Norcross	GA	Sonepar North America	North Charleston	SC	2022
NEDCO Supply #	Las Vegas	NV	Sonepar North America/Codale	North Charleston	SC	2022
HOLT Electrical Supply	St. Louis	MO	Sonepar North America/ Springfield Electric Supply	North Charleston	SC	2022
Rahi Systems Holdings	Fremont	CA	WESCO International Inc.	Pittsburgh	PA	2022
First SOURCE Electrical #	Houston	TX	Winsupply Inc.	Dayton	OH	2022
Note: # *EW* Top 150 Electrical Distributors						

Table 2. Over the last three years, at least 14 distributors listed on *Electrical Wholesaling*'s 2020-2023 Top 150 rankings were acquired.

their optimism, they also see some challenges ahead. Concerns over longer lead times persist, and 60% of respondents ranked longer lead times as the top challenge in 2023. American Electric's Mike Pratt said his top concern in 2023 is the switchgear industry's slow recovery to improve lead time and lack of availability for common SKUs.

GROWTH EXPECTATIONS

Larry Swink, president, Jackson Electric Supply, Jacksonville, Fla., said that while his company had its second-best year in 2022, it was a decrease from 2021. "The largest impact was the delays in the switchgear market, resulting in 52 week-plus lead-times. The backlog carried over from these orders would have been another +35% in revenue with typical 12-week to 16-week lead times." Swink expects sales to increase by 20% in 2023.

Lead times were a challenge for K/E Electric Supply, Mount Clemens, Mich., said Rock Kuchenmeister, CEO and president. "Vendor improvements in fulfillment during the second half of 2022 allowed K/E Electric to begin the process of shrinking our customer backlog. However, customer expectations quickly recovered (from COVID levels), and the company backlog has actually grown to unprecedented levels." He is forecasting a 14% increase in K/E Electric's 2023 sales.

Other major concerns included the impact of remote officing on demand for new office construction and/or office retrofit work; price increases; the impact of the regional banking instability on the commercial real estate market; and rising interest rates.

ACQUISITION MANIA

Mergers and acquisitions have always been a huge part of the electrical wholesaling industry, but over the past few years, the pace of M&As has quickened. Since 2020, about 30 distributors formerly ranked on the Top 150 listing have been acquired (**Table 2**). Over the past 12 months, the largest acquisitions of electrical distributors included Sonepar's purchase of Billow Electric Supply in the Philadelphia market; Rexel's purchase of Buckles-Smith in Santa Clara, Calif.; and Teche Electric in Lafayette, La.; and Graybar's acquisition of Baltimore's Shepherd Electric Supply.

While several thousand independent electrical distributors still thrive, the larger national and regional wholesalers have steadily grabbed more market share through dozens of acquisitions and geographic expansion. In fact, *Electrical Wholesaling* estimates that the 10 largest distributors (Wesco, Pittsburgh; Sonepar USA, Charleston, S.C.; Graybar Electric Co., St. Louis; Rexel, Dallas; Consolidated Electrical Distributors, Irving, Texas; City Electric Supply, Dallas; Border State Electric, Fargo, N.D.; Elliott Electric Supply, Nacogdoches, Texas; U.S. Electrical Services, Middletown, Conn; and McNaughton-McKay, Electric, Madison Heights, Mich.) account for $65 billion in total sales — at least 40% of the market's $140 billion in total sales. These companies employ at least 51,000 employees and operate more than 4,000 locations. EC&M


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PRODUCT OF THE YEAR

UPS Produces More Power in a Compact Footprint

ABB's MegaFlex UL wins the Platinum award in the 2023 *EC&M* Product of the Year competition.

By Amy Fischbach, Freelance Writer

Within the last few years, the data center market has shifted, driving the demand for fewer but larger UPS modules and optimized switchboards/switchgear.

"Years ago, a customer would have to deploy two 800kW UPS in parallel to achieve 1,600kW," John Goosseff, MegaFlex UL global product manager says. "This required additional parallel switchboards, more valuable space in electrical rooms, additional cost of external conduit, and wiring of multiple electrical components."

ABB's customers were looking to deploy fewer UPS modules in their electrical one-line diagrams to achieve power ratings of 1,200kW or 1,600kW in small footprints. To meet this need, the company launched the MegaFlex UL, *EC&M's* Platinum-award-winning product in the 2023 Product of the Year competition.

The 3-phase, 480V double conversion UPS is flexible system architecture ready and features a monolithic-based topology. It uses 400kW power modules with power availability from 1,200 to 1,600 in one UPS cabinet configuration — offering up to 40% footprint savings, 25% reduced energy consumption kWh over the product lifespan, and a design life of 15 years, according to the company. It also provides easy front and top access, modular sub-assemblies, fast replacement of consumable components, and remote monitoring.

Before ABB launched MegaFlex UL, the company's largest UPS was rated at 1MW with a footprint of 144 in. wide, using 250kW internal power blocks. ABB's product management worked with the global R&D engineering teams to develop an even higher-power UPS system in a smaller footprint.

Through an accelerated development cycle, the company introduced the new MegaFlex UL at 1,200kW and 1,600kW ratings in a smaller 130-in.-wide footprint using 400kW internal power blocks. The UPS is designed for critical high-density computing environments.

"The target segment is data center customers including cloud and co-location end-users and system integrators especially critical power container applications where footprint and high-power density is highly valued," Goosseff says.

TESTING AND DESIGNING

ABB began commissioning MegaFlex UL units to the U.S. market in early 2022 after conducting extensive testing in its UPS Customer Test Center in Richmond, Va.

ABB Swiss and the United States R&D engineering teams collaborated on the design of the product with input from key data center end-users, consultants, and integrators.

"The ultimate goal was to have more power in a smaller enclosure," Goosseff says. "There is a delicate balance between simplification and still meeting the demands for higher power mission-critical systems with various N+1 redundant system architectures."

The most significant technical challenges were meeting high-density power and heat rejection in a small footprint, Goosseff says. To overcome these challenges, ABB did extensive CFD modeling internal to the UPS to optimize cooling and airflow.

Beyond the optimized footprint and high-power density, the MegaFlex UL has been designed with consumable parts with longer life expectancy and maintenance access to be easily serviced. This design for serviceability extends the consumable parts replacement intervals and reduces time during scheduled maintenance intervals.

"All internal 400kW power blocks have been designed to be fully front-accessible with sliding/removable drawers — reducing mean time to repair," Goosseff says. "In addition, all consumable life components have been placed at the front section of the UPS with no special tooling to remove or replace."

REDUCING INSTALLATION TIME

ABB offers integrated parallel inductors as a standard to help balance bypass currents when paralleling UPS modules for redundancy. These inductors allow design consultants and contractors the flexibility to have cable length variances of up to 25% compared to 10% cable length variances for UPS without the inductors.

The single split shipping cabinet reduces installation time compared to other UPS in this product category. MegaFlex UL yields lower installed costs, faster startups, and commissioning schedules. The MegaFlex design also allows for better heat rejection and simpler cooling, especially when deployed inside critical power containers.

"We have received incredibly positive feedback on the small footprint and high-power density with ease of installation of the MegaFlex UL," Goosseff says.

For more information, visit electrification.us.abb.com.

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GOLD AWARD

DIGITAL TOOLS & SOFTWARE

The National Fire Protection Association won the Gold Award for its NFPA LiNK software. The NFPA LiNK is an application-based platform containing real-time code information and situational content. It offers NFPA codes and standards, expert commentary, and supporting content to practitioners working in electrical, fire, and life safety.

Subscribers can add personalized notes, in addition to bookmarking and sharing specific sections of code. They can also quickly search all NFPA codes and standards by keyword or phrase. Users have the flexibility to use the platform online or offline via mobile, tablet, laptop, or desktop devices.

SILVER AWARD

TOOLS (POWER)

The 2023 Silver Award goes to Milwaukee Tool for its M12 cable stapler. The battery-powered M12 cable stapler features a compact, lightweight design to give users access to tight stud bays and increase efficiency during the rough-in process. It also offers improved ergonomics when stapling overhead or during difficult-to-reach situations. Moveable cable guides ensure proper alignment, and the coil-spring mechanism consistently sinks the staples to the appropriate depth when fastening NM-B sheathed cable (14, 12, 10 AWG) and low-voltage cables. The product, which is only compatible with 1-in. insulated staples (sold separately), gives the user the run-time needed to sink up to 1,200 staples on a fully charged M12 CP2.0ah battery.

THE *EC&M* TRADITION ENDURES

Established in 2000, the *EC&M* Product of the Year competition recognizes excellence in new product development for the electrical industry. Honoring inventiveness in product design, as well as improvements in safety and efficiency, the competition's two-fold judging and voting process determines the most groundbreaking products of the past year that allow electrical design professionals, installers, and maintenance personnel to perform their jobs more efficiently and effectively.

Products eligible for this year's competition were those introduced to the market between Jan. 1, 2022, and Dec. 31, 2022. A hand-picked panel of judges ranked the 110 products entered into this year's contest based on a uniform list of scoring criteria, ultimately selecting 34 category winners for the first phase of the competition. These category winners were then narrowed down to just three finalists through an online poll available to our readers on the *EC&M* website. *EC&M* subscribers determined the platinum, gold, and silver award-winning products of the year by casting their votes.

Best Practices for Electric Motor Bearing Relubrication

Optimize the lifetime and performance of machines through proper relubrication frequency and quantity.

By Tom Bishop, P.E., EASA, Inc.

Bearing failures are the most common cause of electric motor and generator failure. Maintenance professionals can optimize the life of these machines by following industry best practices for bearing relubrication frequency and quantity. Some considerations include:

- Is the lubricant grease or oil?
- Is it a ball, roller, or sleeve bearing?
- If it is a ball bearing, is the enclosure open, shielded, or sealed?

This article addresses grease relubrication frequency and quantity for ball and roller (rolling element) bearings separately from oil relubrication, viscosity and level (quantity) for ball, roller and sleeve bearings. It does not cover grease lubrication of sleeve bearings (rarely used) or sealed rolling element bearings, which do not require relubrication. A note of caution: Do not mix different lubricants because additives in them may not be compatible and could result in premature bearing failure.

GREASE RELUBRICATION FREQUENCY AND QUANTITY FOR BALL AND ROLLER (ROLLING ELEMENT) BEARINGS

Relubrication intervals

The frequency of relubrication is application and product specific, depending on parameters such as:

- Operating temperature
- Motor shaft speed
- Bearing size
- Bearing load
- Hours of operation
- Environmental conditions/contaminants

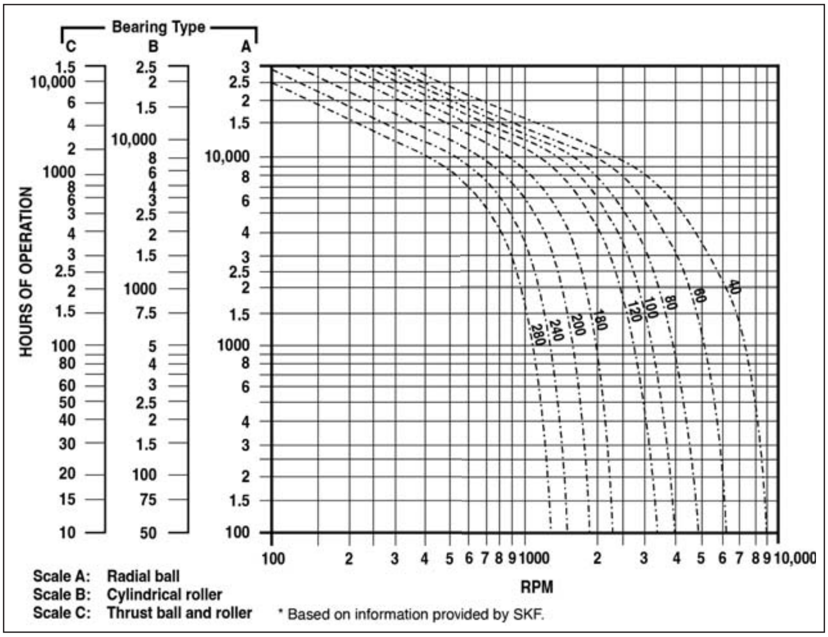


Fig. 1. Relubrication intervals for rolling element bearings.

- Vibration levels

Figure 1 provides a simple chart for determining appropriate grease relubrication intervals for motors operating under normal conditions. To use it:

- Find the motor rpm on the horizontal axis.
- Draw a vertical line from the motor rpm to the curve for the bearing inside diameter (in millimeters) or the next smaller diameter.*
- From there, draw a horizontal line to intersect the hours of operation (relubrication interval) for bearing type A, B, or C.
- For motors operating in other conditions (e.g., vertical mounting, belt load, or hostile environments), reduce the relubrication interval from **Fig. 1** by 50%.

Photo 1. This bearing was relubricated with an excessive quantity of grease.

* Note: The bearing inside diameter (D) in millimeters is five times the last

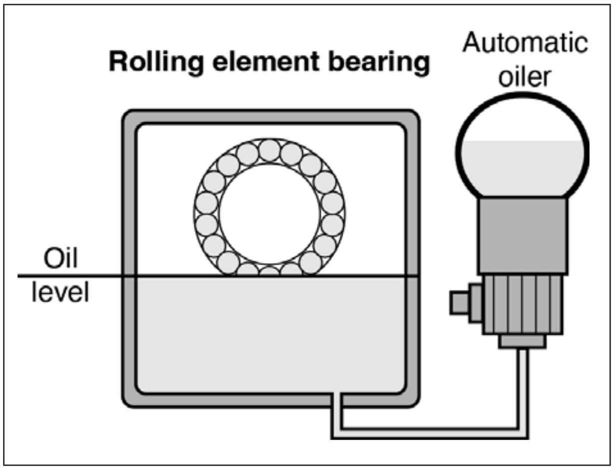


Fig. 2. This image shows the proper oil level for a horizontal motor.

two digits of the bearing number (e.g., for a 6211 bearing, D = 5 × 11 = 55 mm).

Example. Determine the relubrication frequency for a 6314 bearing operating at 1,750 rpm under normal conditions.

The inside diameter for a 6314 radial ball bearing is 5 x 14 = 70 mm. Since **Fig. 1** has no 70 mm curve, draw a vertical line from 1,750 rpm to intersect the 60 mm curve (the next smaller diameter). Drawing a horizontal line from there to the column for radial ball bearings (Type A) indicates that the motor should be relubricated after about 11,000 hr of operation.

If the motor operates in a hostile environment, the relubrication interval would be reduced by 50% (0.5 × 11,000 = 5,500 hours). The relubrication interval for a cylindrical roller bearing (Type B) with the same bore size, such as an NU214, would be about 9,000 hr under normal operating conditions.

Note: Some bearing manufacturers suggest that the relubrication interval for hybrid ceramic bearings can be at least double that of steel bearings.

Relubrication quantities

When it is time to relubricate a motor, be sure to add the correct quantity of grease. Excess lubricant is especially harmful because it can increase friction and retain heat. It can also contaminate and deteriorate the motor winding insulation (see **Photo 1**). **Table 1** provides guidelines for grease relubrication quantities and intervals for listed bearings. It also provides formulas for calculating grease quantities for other bearings.

Example. Using the formulas from **Table 1**, calculate the grease relubrication quantity (G) for a 6324 ball bearing with an outside diameter (D) of 10.24 in. (260 mm) and a width (B) of 2.17 in. (55 mm):

G = 0.11 × 10.24 in. × 2.17 in. = 2.4 fl oz (Imperial)

G = 0.005 × 260 mm × 55 mm = 72 ml (metric)

Relubrication procedure

The following relubrication procedure for ball and roller bearings works best with the motor warm and the shaft stationary. If the motor is running, observe all safety precautions.

1. Locate and clean the grease inlet area. If necessary, remove the pipe plug, and install a grease fitting.
2. Before removing the relief plug, clean off any caked grease with a wooden stick or suitable tool. If the plug is severely caked with grease, run the motor until the bearing housing is warm enough that grease flows through it freely.
3. Add the recommended volume of the recommended lubricant using a hand-operated grease gun.
4. Run the motor for 30 minutes with the relief plug removed.
5. Replace the relief plug and wipe off any excess grease.

Shielded bearings allow for a "small" amount of relubrication but with little effect, depending on the clearance between the inner race and the shield, which varies from 0.003 in. to 0.015 in. (0.08 mm to 0.38 mm) among manufacturers. Empirical evidence shows some oil from the lubricant will "find its way" into the ball area, but the shield will limit the amount of foreign material that can enter and cause damage. Applying

Recommended Grease Replenishment Quantities and Intervals for General-Purpose Motors

Bearing Number	Grease Fluid Ounces (milliliters)	Lubrication intervals (for units in service)		
		3,600 rpm	1,800 rpm	1,200 rpm
6203 through 6208	0.2 (6)	2 years	3 years	3 years
6209 through 6309	0.4 (12)	1 year	2 years	2 years
6310 through 6311	0.6 (18)	1 year	2 years	2 years
6312 through 6317	0.8 (24)	1 year	1 year	1 year
6218 through 6220	1.0 (30)	6 months	1 year	2 years

For motors mounted vertically or in hostile environments, reduce intervals shown by 50%.
Refer to motor nameplate for bearings provided on a specific motor.
For bearings not listed in the table above, calculate the amount of grease required by these formulas:

G Imperial = 0.11 x D x B
Where:
G = Quantity of grease in fluid ounces
D = Outside diameter of bearing in inches
B = Width of bearing in inches

G Imperial = 0.05 x D x B
Where:
G = Quantity of grease in milliliters
D = Outside diameter of bearing in millimeters
B = Width of bearing in millimeters

Table 1 provides guidelines for grease relubrication quantities and intervals for listed bearings.

grease externally to the gap enhances the shield's sealing efficiency.

OIL RELUBRICATION FREQUENCY, VISCOSITY, AND LEVEL (QUANTITY) FOR BALL AND ROLLER BEARINGS

Relubrication interval

The interval for changing lubricating oils will vary depending on operating conditions, oil quantity, and oil type. In general, replace oil-bath lubricants once a year if the operating temperature is 50°C (120°F) or less. When the operating temperature is 80°C to 100°C (175°F to 210°F), replace the oil at least every three months. For critical equipment, have lubricating oil analyzed at least every three months to determine when replacement is necessary.

Photo 2. This is the oil sight glass for a vertical motor bearing.

Oil level

For horizontal shaft applications, maintain the "standstill" oil level on the gauge at approximately the center of the lowest rolling element (see **Fig. 2** on page 17). With vertical shaft applications, about 50% of the rolling elements should be submerged at the "standstill" oil level (see **Photo 2** and **Fig. 3**).

Oil viscosity for horizontal motors

Table 2 provides guidelines for selecting the correct oil viscosity for rolling element bearings in horizontal motors, based on:

- Bearing operating temperature (°C or °F).
- Bearing pitch diameter (d_m = [(ID + OD) ÷ 2] in mm.
- Operating speed (n) in rpm

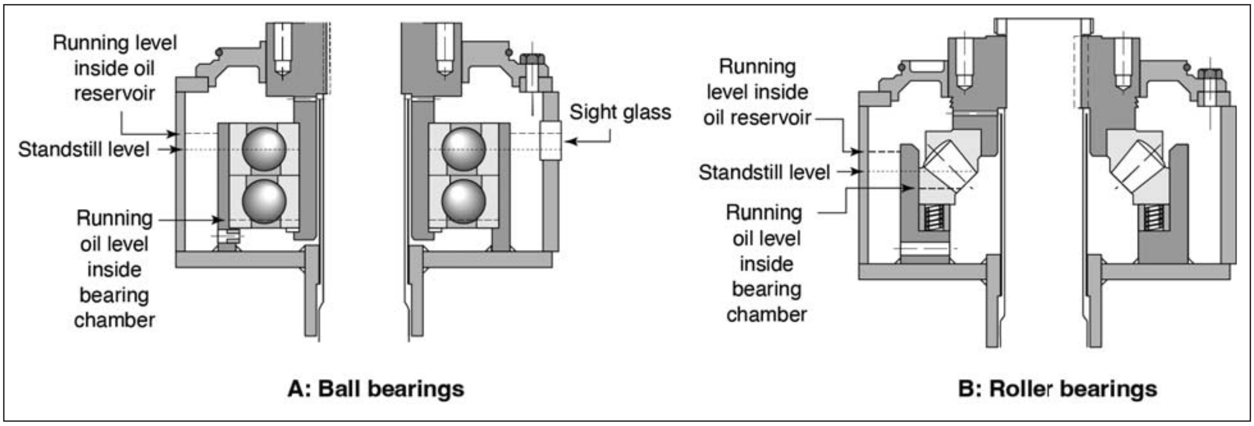


Fig. 3. This drawing shows the proper oil level for a vertical motor.

ISO Viscosity Grades for Light/Normal Load or [Heavy/Impact Load]

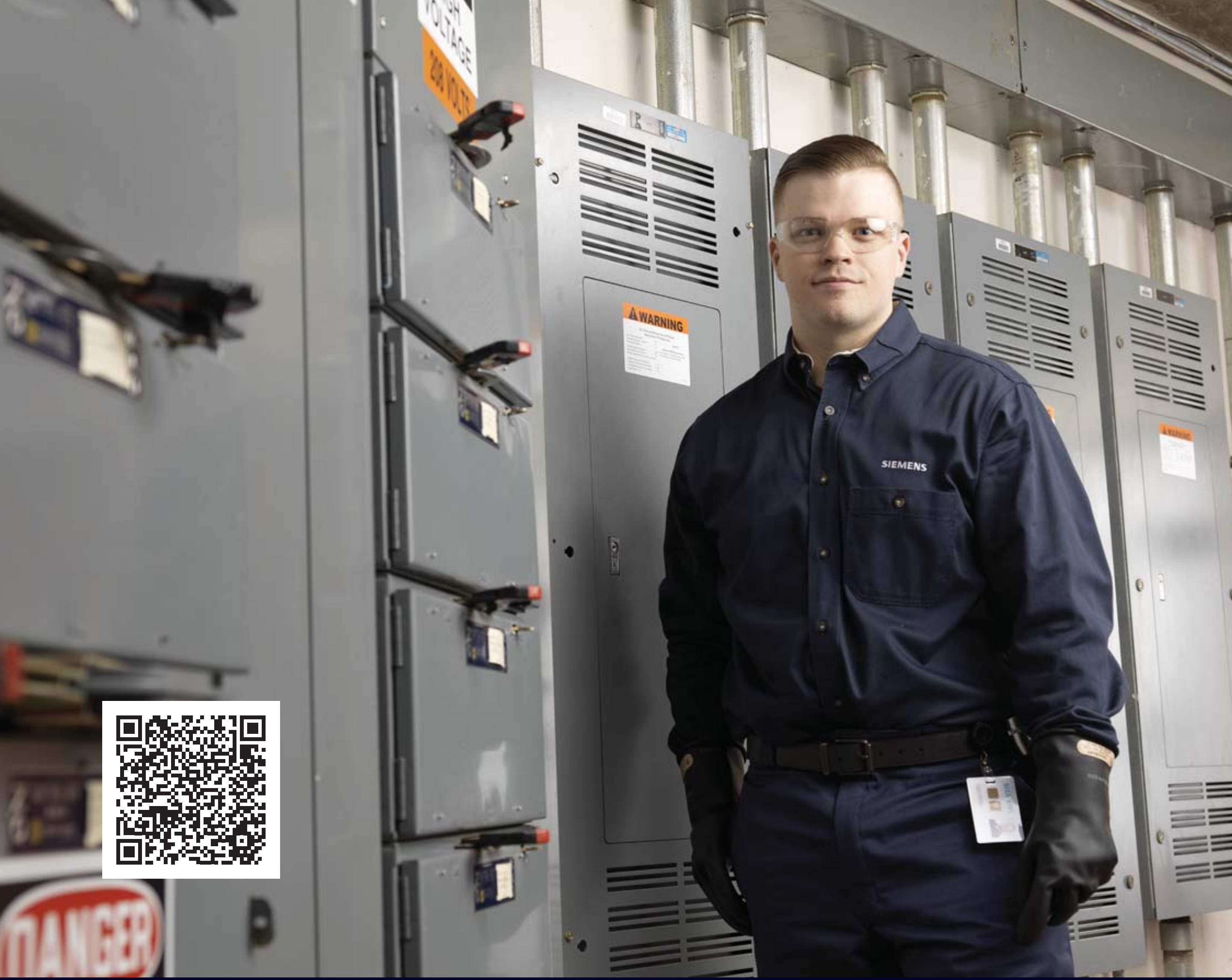
Operating Temperature °C (°F)	$d_m n$ value		
	600,000 or higher	300,000 to 600,000	300,000 or lower
-30 to 0 (-22 to 32)	15, 22, or 46 (all loads)	15, 22, or 46 (all loads)	15, 22, or 46 (all loads)
0 to 60 (32 to 140)	7, 10, or 22 [N/A]	32 [56 or 68]	56 [68]
60 to 100 (140 to 212)	22, 32, or 56 [N/A]	32 or 56 [56 or 68]	56 or 68 [68 or 100]
100 to 150 (212 to 302)	N/A (all loads)	56 or 68 [68 or 100]	56 or 68 [100 to 460]

Table 2. Use this table to select the appropriate viscosity.

Vertical Motor Rolling Element Bearing Oil Viscosity

Parameter	Angular Contact Ball Thrust		Spherical Roller Thrust	
Ambient temperature range	Up to 38°C (100°F)	Above 38°C to 60°C (100°F to 140°F)	Up to 4°C (40°F)	Above 4°C to 60°C (40°F to 140°F)
ISO VG	32	68	68	150

Table 3. For vertical motors, this is a guide for selecting the correct oil viscosity, regardless of bearing size or speed.


WARNING
SIEMENS

• Bearing loading level (light/normal or heavy/impact)

Example. Determine the correct oil viscosity for a 6210 ball bearing operating at 3,600 rpm at 90°C (194°F) under normal loading conditions [i.e., the ratio of the bearing's dynamic capacity (Cr) to the applied load (Pr) is between 0.06 and 0.12 (0.06 < Cr/Pr < 0.12)].

First, calculate the bearing pitch diameter:

$[(ID + OD) \div 2] = d_m$ (mm)

$[(50 + 90) \div 2] = 70$ mm

Now determine the $d_m n$ value by multiplying the bearing pitch diameter by the operating speed:

d_m (mm) × n (rpm) = $d_m n$

$70 \times 3{,}600 = 252{,}000\ d_m n$

The last step is to select the appropriate viscosity from **Table 2**. In this case, it is ISO VG 56 or VG 68 turbine oil.

Oil viscosity for vertical motors

For vertical motors, use **Table 3** on page 18 as a guide for selecting the correct oil viscosity, regardless of bearing size and speed. Note: If the motor lubrication plate specifies synthetic oil, DON'T substitute other oil.

OIL RELUBRICATION FREQUENCY FOR SLEEVE BEARINGS

Bearing clearance and oil viscosity

The clearance between the shaft journal and the bearing bore is critical with sleeve bearings such as the one depicted in **Photo 3**. Any short-term, metal-to-metal contact can increase the bearing temperature, and the associated "wiping" can quickly degrade the bearing, possibly causing catastrophic failure. To maintain sleeve bearing clearances, follow the viscosity guidelines in **Table 4.**

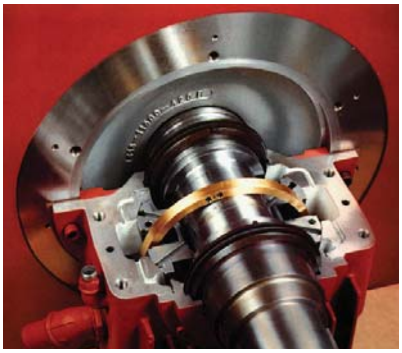


Photo 3. Typical sleeve bearing arrangement with the top half of the bearing removed for inspection.

Relubrication interval

Select relubrication intervals based on the manufacturer's instructions (if available). Otherwise, use the intervals in **Table 4**. Frequent starting and stopping, damp or dusty environments, extreme temperatures and other severe service conditions warrant more frequent oil changes than shown in **Table 4**. Contact the manufacturer regarding oil change intervals for specific situations, or regularly check the oil for contaminants or discoloration and replace it as needed. Another way to determine oil replacement intervals is to have a laboratory analyze oil samples periodically.

Tip: Take oil samples with the motor shut down to avoid removing too much. When replacing the oil, fill the reservoir to the "standstill" level that's normally shown on the sight glass.

Sleeve bearing oil level

If oil level information is available from the manufacturer, follow it. If not, as a general guideline, the oil rings should be immersed to approximately one-quarter of their circumference or about one-fifth of their diameter (**Fig. 4**).

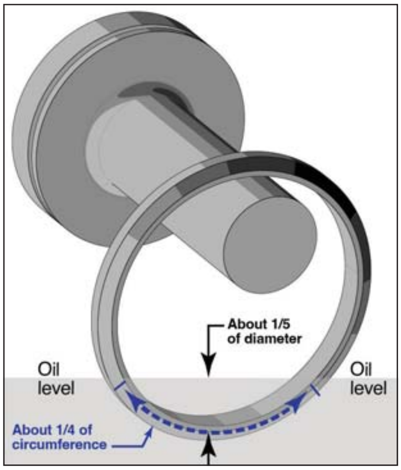


Fig. 4. This drawing shows the proper oil level in a horizontal motor.

If the stationary oil level is too low, it will be dangerously low when some oil is in play (in the bearing, dripping down the inside of the chamber, etc.). If it is too high, the friction between the oil and the rings will increase, so the rings will turn slower and supply less oil to the bearing. Adding oil with the machine at rest is preferable to when it is operating. Overfilling with the machine running can initiate oil siphoning through the labyrinth passages and cause chronic oil leakage.

Finally, note that the recommended temperature limit for all bearings is 80°C (176°F) for normal operation, with the alarm set at 90°C (194°F) and trip at 100°C (212°F). EC&M

Thomas H. Bishop, P.E. is a senior technical support specialist at EASA, Inc., St. Louis; (314) 993-2220; www.easa.com. EASA is an international trade association of more than 1,700 firms in nearly 70 countries that sell and service electromechanical apparatus.

Sleeve Bearing Oil Viscosity and Lubrication Intervals

Ambient Starting and Operating Temperature Range °C (°F)	Shaft Speeds (rpm)	ISO Viscosity Range	Lubrication Interval
Below 10°C (50°F)	All	Consult Manufacturer	—
10 °C to 32°C (50°F to 90°F)	Above 1,800	32 to 68	5,000 Operating Hours or 1 Year, whichever comes first
	Up to 1,800		1 Year
Above 32°C (90°F)	All	Consult Manufacturer	—

Table 4. To maintain sleeve bearing clearances, follow this table's viscosity guidelines.

Preventive Measures for UPS Systems

This case study reveals how to prevent costly shutdowns and lost production.

By Mark Varisco, P.E., Engineering and Inspection Services

Instrumentation and control systems in petrochemical facilities require an extremely reliable source of power. The backup power supply should be available for an adequate period in the event of an electric utility power outage or until an emergency generator is started (if available).

The design criteria for critical power equipment can be defined as follows:

1. Ability to provide emergency power during interruptions or loss of normal power, up to a designated time (usually determined by the time necessary to safely shut down a facility during a power outage)
2. Unaffected by outside events (transients, surges, etc.).
3. Robust performance (low risk of failure).
4. Robust internal system design — rapid isolation of internal failures, with means to supply alternate power (if supplied and available) without interruption.

Uninterruptible power supply systems (UPSs) are typically installed to provide power that meets these requirements. A typical industrial system may be comprised of a UPS unit and associated battery bank.

In many instances, much emphasis is placed purchasing exceptional (and expensive) UPS equipment while minimal or no attention is placed on the other components of the critical power system. Inattention to these items can compromise the reliability of this equipment, even rendering the reliability of the most expensive and reliable UPS unit marginal.

As discovered in the case of one industrial facility, the lack of attention to these peripheral details resulted in costly shutdowns and lost production, that could have been prevented with a few minimal changes. Ultimately, the cost to correct the overlooked details was a fraction of the lost production cost.

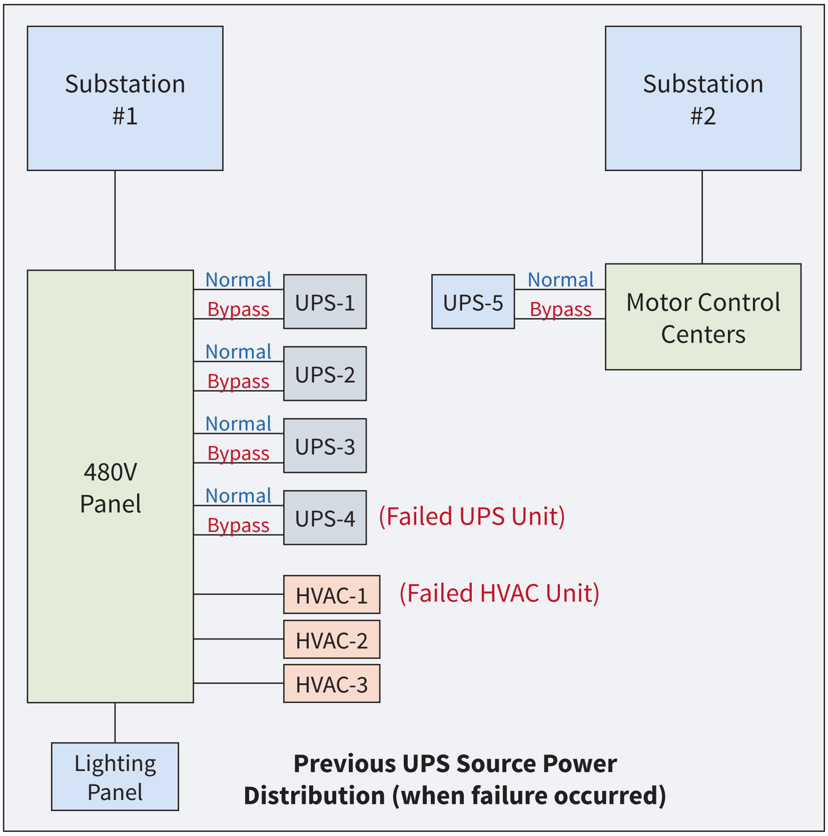


Fig. 1. Diagram of existing UPS power distribution setup for CHEM1.

INITIATING EVENT (2001)

In 2001, a chemical processing unit (CHEM1) at a major industrial petrochemical facility suffered a complete unit shutdown when one of five UPS units servicing that facility lost output power. The shutdown occurred after a loss of input power from a 480V distribution panel that supplied normal input power to four of the five units for this facility.

Normally, each UPS would have continued to supply power from its batteries. However, one of the UPS units lost

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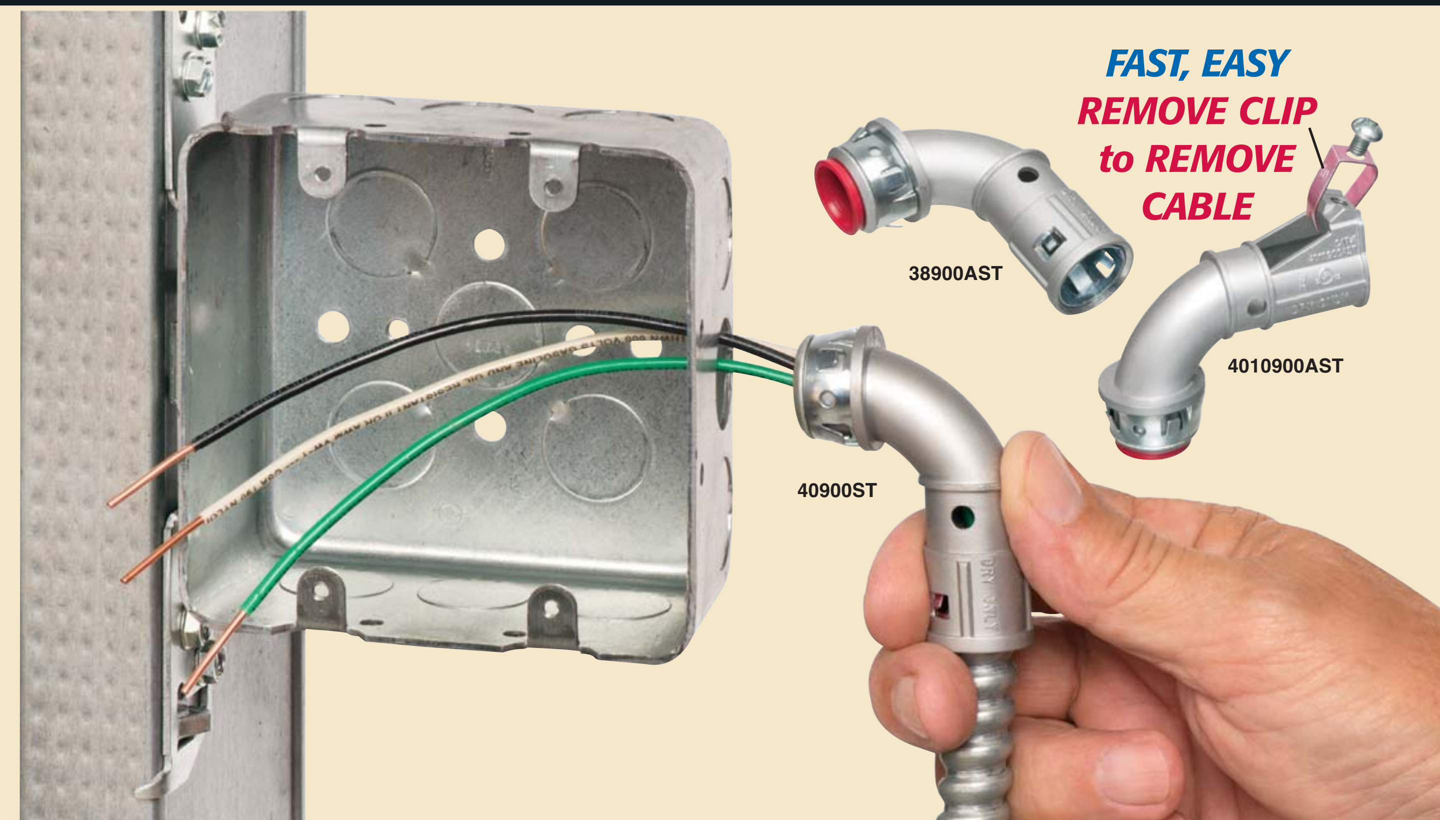

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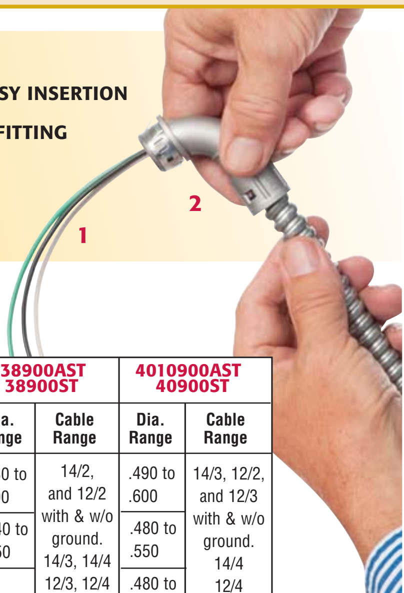

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MCI-A Steel & Aluminum	.440 to .550		.480 to .550	
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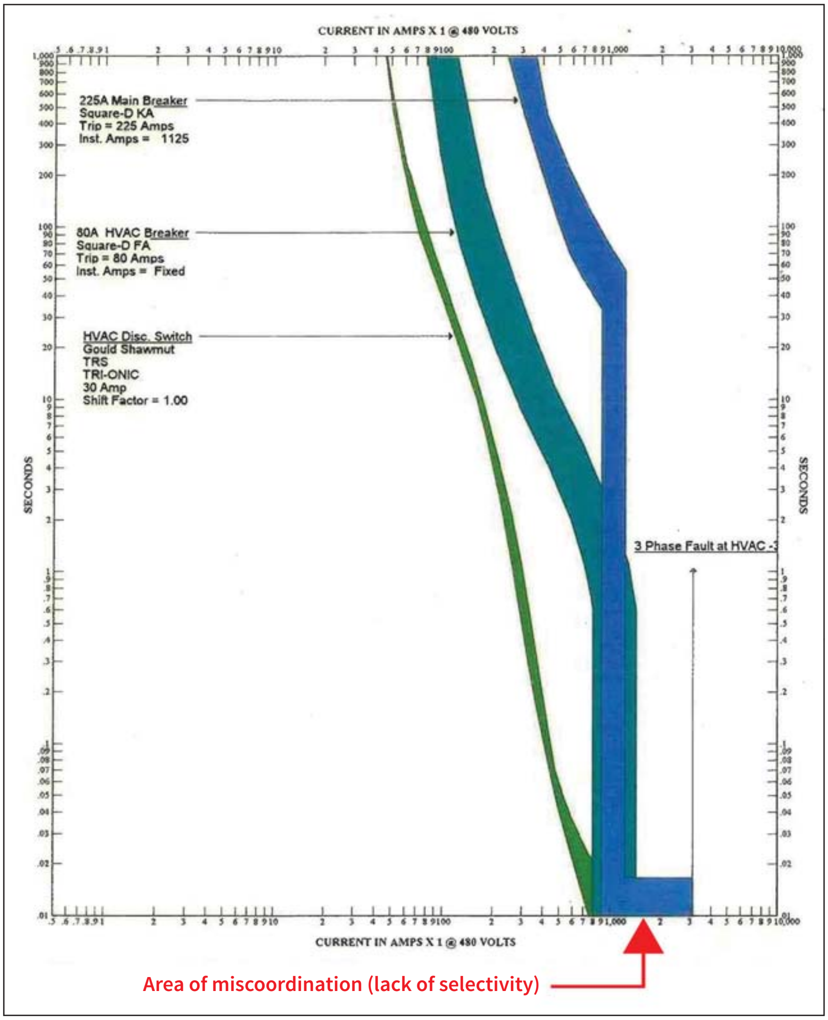

Fig. 2. Time current coordination curve of panel main breaker, HVAC breaker, and HVAC fuse.

output power after one of the cells failed in the unit's DC battery bank during the subsequent discharge.

INITIAL FAILURE INVESTIGATION

An investigation was performed to determine what caused the initial loss of the power supply to the 480V distribution panel and UPS equipment. The 480V panel supplied several non-critical loads in addition to the UPS equipment (e.g., HVAC units and lighting/convenience receptacles for the adjacent computer room). See **Fig. 1** on page 22 for the existing power distribution layout. Four of the five UPS units were supplied from one 480V distribution panel, including the failed unit.

The investigation revealed that one of the HVAC units sustained a failure (i.e., shorted heater strip). The fuses were blown in the HVAC disconnect switch to this unit. The failure also caused the main breaker in the 480V distribution panel to trip (the branch circuit breaker remained closed). What appeared to be an apparent miscoordination of the panel breakers and the HVAC fuses warranted further investigation.

CLASSIC CASE OF MISCOORDINATION

Why did the distribution panel main breaker trip instead of the branch breaker for the HVAC unit? Upon further analysis, the answer for this sequence of events was obvious and is a textbook case of a lack of selectivity for circuit breaker protection in a panel where the available fault current is high — and there is not enough separation of overcurrent device ratings to provide selectivity and coordination.

The available fault current at the 480V distribution panel was fairly high. Since the main breaker and the HVAC feeder breaker were close in size (rating), there was no coordination for a significant fault; the magnitude of fault current fell into the instantaneous region of both breakers and the fuse in the HVAC circuit (see TCC curve in **Fig. 2**).

While this issue is not easily corrected [it would probably require a major redesign of the panel (i.e., a new panel with a main breaker, and possibly an adjustable solid state trip unit)], a more affordable solution was to reconfigure the panel by moving the non-critical loads to other nearby electrical distribution centers, reducing the risk of exposure.

The loss of 480V power was the initiating failure; as mentioned earlier, though, the unit should have supplied power via battery discharge. This did not happen. Two additional issues ultimately caused the UPS to fail:

- **Battery failure itself** — The unit that failed was connected to a VRLA battery bank that failed. These banks are generally recognized as less reliable than flooded lead-acid stationary batteries. This bank had recently been maintained (i.e., tested) with no indications of underlying issues. The bank was approximately five years old.
- **Separate power for normal and alternate (bypass) input sources** — there was no redundancy for normal and alternate power; both sources were fed from the same 480V panel, which was also supplied by the same motor control center (MCC) and distribution transformer. In this case, the UPS output power may have been maintained if the alternate source was fed from a separate source than the normal input. The high-speed switching characteristics of the internal static switch would have switched sources without a loss of power.

As part of the event investigation, a review was performed of the other four UPS systems in this production unit

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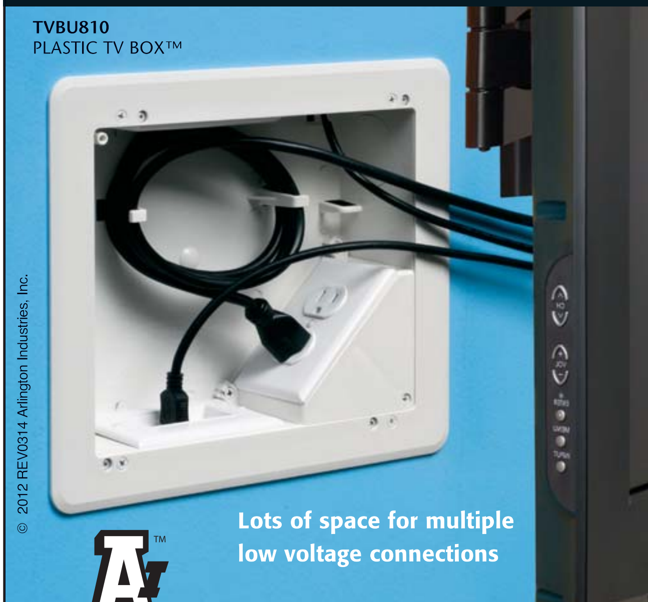

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Product info aifittings.com/landing/zinc-combination-couplings to identify similar risks. The following items were discovered as potential risks, which could affect the future reliability of the emergency power for the CHEM1 UPS equipment:

- Four of the five units were supplied by VRLA battery banks.
- Lack of redundancy for normal and alternate power for all five units (i.e., normal and alternate power were fed from the same upstream source).
- Comingling of loads in the 480V primary distribution panel to the UPS (i.e., critical vs. non-critical loads, such as lighting and HVAC in the same panel as the UPS supply).
- Several of the UPS output power panels were standard commercial power panels with standard molded-case circuit breakers (MCCBs). They were not the type recommended by most UPS manufacturers (e.g., a panel with fused disconnects utilizing high-speed semiconductor fuses).
- Two of the UPS units had no remote maintenance bypass switches (also known as "wraparound" maintenance bypass switches) to allow complete isolation of the unit. They had an internal bypass mode only. Internal repairs to these units could only be made during a plant outage.
- The five units were made by multiple manufacturers of UPS equipment — no standardization.
- Three of the UPS units were obsolete.

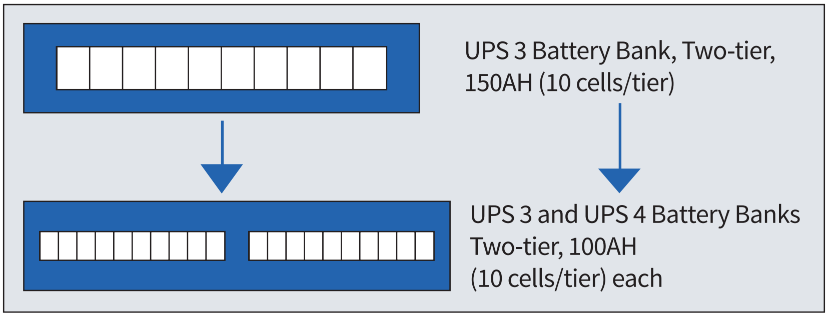

Fig. 3a. Battery bank reconfiguration.

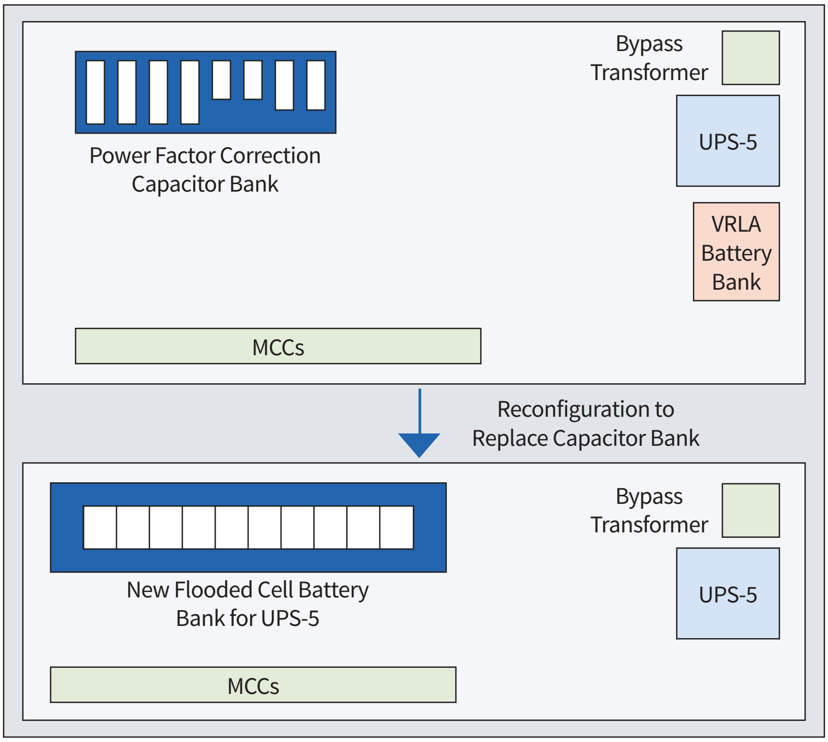

Fig. 3b. Motor control center room reconfiguration.

IMMEDIATE CORRECTIVE ACTIONS FOR CHEM1 UPS SYSTEMS

Immediate steps were taken on CHEM1 units to address three of the above issues:

1. All non-critical loads were removed from the main 480V UPS power distribution panel. Three HVAC units and a building service receptacle/lighting panel were relocated to other nearby 480V power sources (i.e., panelboards located in an adjacent substation building, fed from a different transformer).

2. Two of the units' VRLA battery banks were converted to flooded lead acid. These conversions involved several steps:

   a. A simple reconfiguration of the battery banks, including right-sizing the existing batteries, provides more real estate in the existing UPS equipment room. One of the larger banks was reconfigured into two smaller banks. The battery size of the two new battery banks, although slightly decreased in capacity, was adequate (CHEM1 requirements for battery backup durations were met), as shown in **Fig. 3a**.

   b. In the adjacent MCC building where one of the UPS units was located, a large and bulky power factor correction (PFC) capacitor bank rack was removed to provide space to install a flooded lead acid battery bank. There were only a few power factor correction capacitors installed for a 1,000kVA substation. In this case, the financial impact of a loss of critical power (partial or complete CHEM1 shutdown) far outweighed the savings of PFC at the utility billing point. Also, other PFC installations at the site provided adequate PFC. It was also discovered that several of the capacitors were either non-functional or not connected (the motors were previously removed). A flooded lead acid battery bank was installed in the location where the PFC bank was previously located (see **Fig. 3b**).

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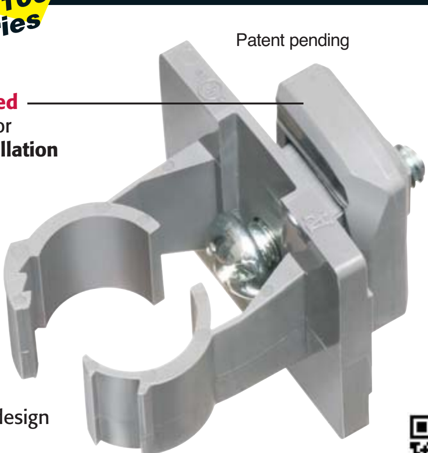

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3. Since all UPS units were installed near another substation, the input supply for each unit was separated so that the bypass input was supplied by a different substation (i.e., transformer) from the normal input for all five units.

Figure 4 shows the new power distribution arrangement incorporating items 1 and 3.

LONG-TERM STRATEGY FOR SITE-WIDE EVALUATION

The shutdown, while unwanted, allowed extending the review to a site-wide evaluation. The findings from the initial study were then evaluated for each chemical processing facility at the site. This review led to further changes across the entire facility. The following is an in-depth analysis of these issues and the corrective plans to address them.

First, each processing unit site-wide was evaluated to determine where gaps were compared to a "best practice." Once these concerns were identified, a site-wide capital plan was implemented to standardize all systems.

The following is a list that describes categories to be evaluated for each system (stated as a "best practice") and whether each unit met that category:

1. UPS manufacturer selection (for standardization).
2. UPS architecture — review of pulse-width modulated (PWM) versus ferroresonant architecture.
3. Panel coordination — the type of panel for output power was evaluated. UPS manufacturers recommend utilizing a fused disconnect panel with high-speed semiconductor-type fuses to quickly clear output faults and minimize system disturbances for the UPS output power.
4. Normal and Alternate source segregation — for each unit, each source is supplied by a separate transformer/substation.
5. Battery type — note the type of battery used, and is there an opportunity to upgrade?

A survey was conducted to benchmark the status of each system in several of the processing facilities, highlighting obvious gaps where improvements could be made. The representative survey results are shown in **Table 1** on page 30. Colors represent either "gaps" or "satisfactory" conditions against the criteria.

CORRECTIVE ACTIONS

For seven years (after the initial incident), most of the recommendations for the site-wide upgrade were implemented. Perhaps the most important upgrade was the selection of one manufacturer for standardization purposes. In some cases, the gap was recognized, but no change was made (i.e., the risk was accepted and the component marked as "satisfactory"), which is highlighted by the "yellow" score in **Table 1**.

Some highlights of the upgrade program to four processing units (CHEM1, CHEM5, CHEM4, and CHEM3) are as follows:

CHEM1 PROCESSING UNIT

The improvements (e.g., load separation, separate normal and bypass supply segregation and battery upgrades) had already been implemented for CHEM1 as previously explained.

UPS panel replacement — three of the existing eight UPS output panels were standard commercial/residential type distribution panels with MCCBs. These panels were replaced with fused disconnect switch panels to provide high-speed clearing of faults. Two of the existing panels had to be replaced with hybrid-type enclosures with custom-fabricated equipment due to the close clearances of the existing installation.

Standardization — three obsolete units were upgraded to the standardized manufacturer. Standardization provided the following benefits:

1. The manufacturer selected had a history of high reliability.
2. Spare parts were reduced since most of the digital control boards were common to the units, regardless of the power rating.
3. One manufacturer to provide support, streamlining maintenance of the units.
4. Common utilizations of one knowledge base for maintenance support.
5. Operating procedures were simplified (i.e., same for all units).

CHEM5 PROCESSING UNIT

The UPS unit for the CHEM5 facility was faced with imminent

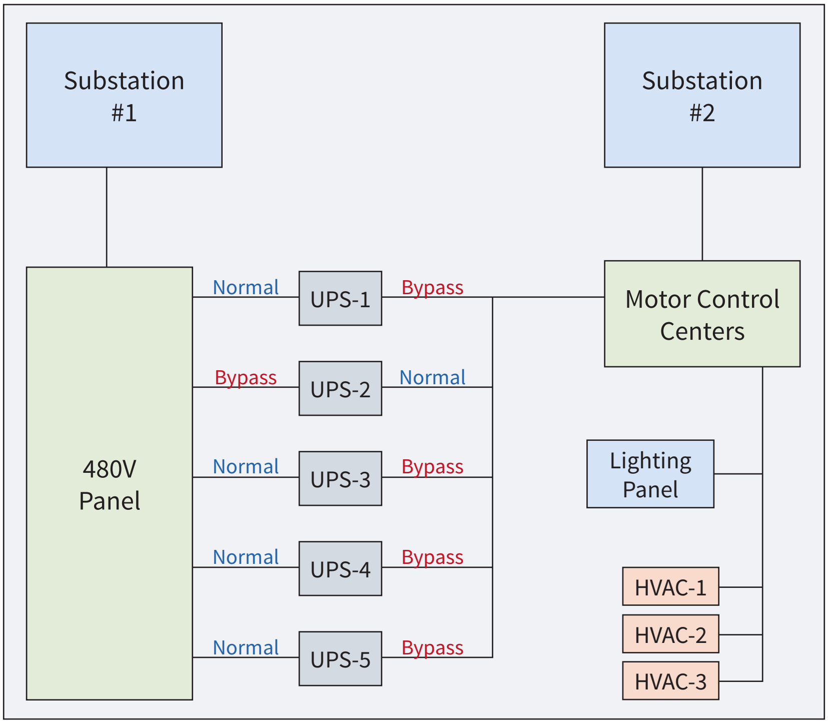

Fig. 4. Re-configured power distribution arrangement for UPS systems – CHEM1 facility.

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Plant	UPS |Tag #	Manufacturer	Architecture	Output	Battery Type	Parts Available	Separate Source for Bypass	Fused Distribution Output Panel	Fused Replacement Planned	Comments
CHEM1	UPS-1	Mfr#1	PWM Line Interactive	1-Ph	Internal to UPS-Sealed	N	N	N	Y	Obsolete
CHEM1	UPS-2	Mfr#1	PWM Line Interactive	1-Ph	Internal to UPS-Sealed	N	N	N	Y	Obsolete
CHEM1	UPS-3	Mfr#2	Analog Ferro	1-Ph	Flooded Lead Acid	N	N	N	Y	2 major component failures in last 5 years
CHEM1	UPS-4	Mfr#3	Digital Ferro	1-Ph	VRLA-AGM	Y	N	Y	—	
CHEM1	UPS-5	Mfr#3	Digital Ferro	1-Ph	VRLA-AGM	Y	N	Y	—	
CHEM2	UPS-1	Mfr#3	Digital Ferro	1-Ph	Flooded Lead Acid	Y	Y	Y	—	Batteries upgraded prior to improvements - from VRLA to Flooded Cell
CHEM3	UPS-1	Mfr#1	Analog PWM	3-Ph	Maintenance Free-Sealed	N	Y	Y	Y	
CHEM4	UPS-1	Mfr#1	Analog PWM	3-Ph	VRLA-AGM	N	Y	N	N	
CHEM4	UPS-2	Mfr#1	Analog PWM	3-Ph	VRLA-AGM	N	Y	N	N	
CHEM5	UPS	Mfr#4	Analog PWM	1-Ph	Flooded Lead Acid	Y	Y	Y	N	Unit no longer made, imminent obsolescence - still supported by Mfr#3

Blue	*Denotes entire UPS system that meets all criteria of "Best Design"*
Green	*Denotes best available technology or best option*
Yellow	*Denotes component is satisfactory (upgrade not practical or would only provide marginal improvement)*
Pink	*Denotes significant deficiencies or obsolete system*

Table 1. A site survey was performed to identify the status of all UPS equipment. The results of that survey are presented in this table.

obsolescence. The decision was made to replace the unit before it became a legacy system. Also, this unit would have required significant investment to replace spare warehouse parts where the shelf life of the boards was expired.

There were significant real estate issues involved with replacing this unit. A solution was reached by evaluating the size rating of the unit. It was discovered that the unit could be downsized (from a 15kVA to a 10kVA rating) and still meet CHEM5 backup power requirements. This allowed the installation of a smaller physical cabinet (½ size), which expedited and facilitated the replacement.

CHEM4 PROCESSING UNIT

Two older, obsolete analog PWM units with 3-phase outputs were replaced with new UPS units. The new units were single-phase output ferroresonant units, standardized with the other units made by the selected manufacturer.

CHEM3 PROCESSING UNIT

An older, obsolete analog PWM unit with 3-phase output was replaced with a new digital microprocessor-controlled PWM unit from the same selected manufacturer as the above units. It was decided that the use of a new PWM unit (as opposed to ferroresonant) was acceptable in this unit, as the risks offered very minor exposure. The batteries were also upgraded to a higher quality, more robust VRLA from the standard maintenance-free sealed type.

Table 2 on page 32 reflects the sitewide status after the upgrades.

RESULTS AND FUTURE PLANS

Since the implementation of all the sitewide changes, the affected processing units (CHEM1, CHEM3, CHEM4, and CHEM5) have sustained zero production outages due to UPS issues. This performance can also be attributed to rigorous PMs performed on the systems, both UPS, and batteries. All maintenance has been performed per industry standards, best-recognized practices and, for the most part, following the manufacturer's recommendations for maintenance.

The following examples are specific incidents that occurred after the upgrades to attest to the resiliency due to the upgrades:

- A UPS output power panel (for UPS4, CHEM1) sustained a fault on one of the branch circuits due to a computer system power supply failure. The fuse in the UPS4 output panel operated to clear the fault. No other loads were lost from that panel. This can be credited to the installation of the high-speed fault-clearing fuses that were installed as part of the panel upgrade.
- One of the primary 13.8kV utility power supply feeders coming into the CHEM1 plant was lost due to a fault, resulting in a complete loss of power to one of the substations providing normal power to some of the UPS units. The UPS units fed from this substation immediately went to battery. However,

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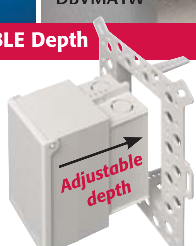

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IN BOX MEETS 2020 NEC Section 406.9 *for protection of exterior outlets which require the use of extra-duty weatherproof-in-use cover for all outdoor 15 or 20 AMP receptacles.*

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Plant	UPS |Tag #	Manufacturer	Architecture	Output	Battery Type	Parts Available	Separate Source for Bypass	Fused Distribution Output Panel	Comments
CHEM1	UPS-1	Mfr#3	Digital Ferro	1-Ph	VRLA-AGM	Y	Y	Y	
CHEM1	UPS-2	Mfr#3	Digital Ferro	1-Ph	VRLA-AGM	Y	Y	Y	
CHEM1	UPS-3	Mfr#3	Digital Ferro	1-Ph	Flooded Lead Acid	Y	N	Y	
CHEM1	UPS-4	Mfr#3	Digital Ferro	1-Ph	Flooded Lead Acid	Y	Y	Y	
CHEM1	UPS-5	Mfr#3	Digital Ferro	1-Ph	Flooded Lead Acid	Y	N	Y	
CHEM2	UPS-1	Mfr#3	Digital Ferro	1-Ph	Flooded Lead Acid	Y	Y	Y	Batteries upgraded prior to improvements - from VRLA to Flooded Cell
CHEM3	UPS-1	Mfr#3	Digital PWM	3-Ph	VRLA-AGM	Y	Y	Y	
CHEM4	UPS-1	Mfr#3	Digital Ferro	1-Ph	VRLA-AGM	Y	Y	N	Left computer panel as-is
CHEM4	UPS-2	Mfr#3	Digital Ferro	1-Ph	VRLA-AGM	Y	Y	Y	Changed field I-O panel to fused distribution
CHEM5	UPS	Mfr#3	Digital Ferro	1-Ph	Flooded Lead Acid	Y	Y	Y	Normal power can be fed from Emer. Generator

Blue	*Denotes UPS system that meets all criteria of "Best Design"*
Green	*Denotes best available technology*
Yellow	*Denotes component is satisfactory (upgrade not practical or would only provide marginal improvement)*
Pink	*Denotes significant deficiencies or obsolete system*

Table 2. After upgrades were completed at the facility, the tabulated data was updated to reflect the new equipment type, size and architecture.

one cell in the unit's DC battery subsequently failed. The unit switched to the bypass source upon DC bus failure (by design). The substation supplying the bypass source was not affected by the utility loss. While this is not the intended sequence for emergency backup, the ability to switch to an available Alternate source saved the processing unit. Before the implemented changes, this failure could have resulted in a plant shutdown or extensive rate reductions because both of the power supplies (NORMAL and BYPASS) were on the failed feeder. Note: The loss of the 13.8kV feeder only affected some of the process equipment in CHEM1, which allowed the plant to keep running but at reduced rates.

- The UPS in the CHEM5 processing plant sustained a major failure (i.e., failed ferroresonant transformer). The unit switched to the alternate source (via the internal static switch) and continued to supply outpower power to the facility, resulting in no lost production. Because the unit had a wrap-around remote maintenance bypass switch, the unit was replaced with a new unit without requiring a facility outage.

Plans are being implemented to replace two of the older units in CHEM1 due to imminent obsolescence. Performance and reliability remain high, even with the older units.

GENERAL OBSERVATIONS

While this facility chose to standardize on certain types of UPS architecture and one manufacturer as "best practices," each end-user should decide which options best fit their manufacturing strategy. Recent advances in equipment have or could change previously adopted design strategies, even those presented in this article.

For example:

1. The industry is trending away from ferroresonant-based UPS equipment to PWM units, and ferroresonant units are becoming less readily available. Several manufacturers offer PWM units that provide robust performance and reliability. Choices have to be made for the "best fit" for each user. For example, an equivalent rating PWM unit may have a smaller footprint and be more suitable for a particular installation than an equivalent ferroresonant unit.

2. Although the discussion of the selection of PWM versus ferroresonant technology is outside of the scope of this paper, a couple of significant considerations are:

   a. For a 3-phase output PWM unit, the conductors and components will be smaller as compared to a single-phase output of equivalent rating.

   b. The number of components in the 3-phase PWM unit is increased as compared to a ferroresonant unit (i.e., fewer components to fail). Since newer PWM units are more robust, this concern is not as relevant as in prior years.

3. VRLA batteries – the intent of this paper is not to discredit VRLA, just to recognize as with any design selection, there will be trade-offs. The end-user will ultimately have to make the final choice. If real estate is limited, VRLA

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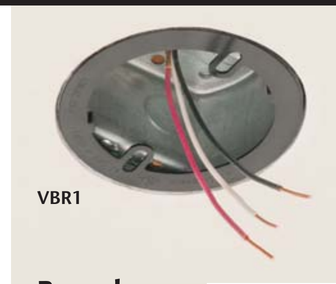

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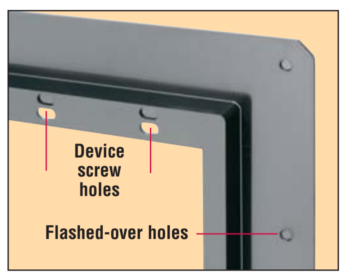

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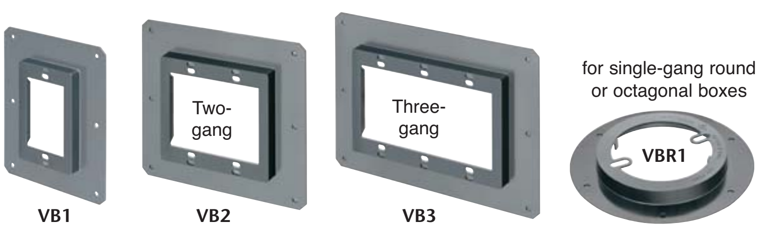

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Product Info aifittings.com/landing/vb1 may be the best choice. Adequate service from these units can be obtained if VRLA is selected but typically the maintenance requirements will increase, and the maintenance intervals can be more frequent.

Several battery manufacturers offer quality VRLA battery systems. With proper maintenance, they can provide many years of service. The reliability concerns with these units in the late '90s/early '00s have been addressed. As with any equipment, observe the manufacturer's recommendations for installation and maintenance to achieve the longest service life.

One of the fallacies that the author made (at the beginning of my career, with this facility) was that each UPS unit and supplemental equipment was optimally installed — there was no "gap" or "best practice" ignored or not followed. This was, of course, an extremely false assumption. After all, the systems in each production unit had been in service for many years. They certainly would not be inadequate. They would have been periodically reviewed.

No assessment was performed to determine the state of the systems and obvious opportunities to improve them. Of course, due to organizational changes, layoffs, and retirements, a lack of continuity provided no history of previous events and failures. Unfortunately, this is a common theme in today's manufacturing environment.

Incorrect or inadequate designs, instead of being corrected, are perpetuated over and over. Some entities — both in-house and outside consulting firms — have no operational experience and are provided no feedback or history of what they install, which leads to them continue installing inadequate designs and repeating the same mistakes. Manufacturers' recommendations are ignored. In some cases, engineers resort to copying existing designs with no scrutiny to ensure that the existing design is not correct or flawed.

Some excellent resources (papers) are available that discuss the application and issues of UPS equipment (e.g., search IEEE by authors Cosse/Spiewak/Dunn/Bowen/Nichols). A design guide is re-printed from one of these articles, which can be found online at https://ecmweb.com/21269816. Several items in this design guide were addressed in the upgrades presented in this piece.

Periodic reviews of all emergency power systems should be made during the life of a facility, where gaps/deficiencies can be highlighted and addressed.

While not covered in the scope of this article, enough emphasis cannot be placed on preventive maintenance (PMs). While the corrective actions discovered during PMs, at times can appear to be over-conservative, each user will have to decide whether the cost of the consequences is worth ignoring the recommendations.

CONCLUSION

The assumption that plant emergency electrical power systems are installed properly with optimal configuration can be a fallacy. As was demonstrated in this case study, one chemical facility's unwanted events allowed that facility to review each critical power system. A systematic approach was presented to evaluate all existing critical power systems for suitability. Similar to re-occurring process safety reviews, each system should be periodically re-evaluated for various parameters to determine if it is adequate or whether improvements can be made.

Several UPS systems at a petrochemical facility were discussed, including upgrades and changes to the system components that significantly improved the reliability of the systems. These aspects of system design can be overlooked.

Examples have been provided that demonstrate economic benefits (no outages) received after improvements were made in an existing chemical processing unit's critical power system.

AUTHOR'S ACKNOWLEDGMENT

As with most successful projects, the achievements discussed in this article would not be possible without the help and collaboration of these two co-workers: Robert Schindler (retired), senior electrical engineer for implementing several of the processing unit UPS upgrades at this facility, and David Lucio, principal electrical engineer, for guidance on achieving excellence in critical power systems and implementing some of the first generations of upgrades at this facility to modernize UPS equipment. EC&M

Mark Varisco, P.E., is the lead electrical engineer for Engineering and Inspection Services. He can be reached at mvarisco@eisllc.net.

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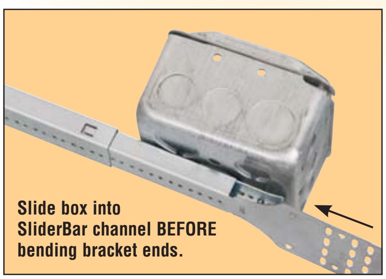

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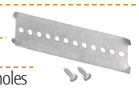

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By Denise Green, Group CBS

Assessing Circuit Breaker Condition and Arc Flash Safety

Best practices for identifying and reducing arc flash incident risk in the field

Photo 1. An arc flash can generate an electric arc with a temperature of 35,000°F.

The tell-tale sound, flash of light, flames, and resulting smoke is the ultimate workplace nightmare: an arc flash incident. Something has gone wrong, and people and equipment are in danger. In simplest terms, an arc flash or arc fault occurs when electricity leaves its intended path and travels from one conductor to another or to ground (**Photo 1**). An arc flash can generate an electric arc with a temperature of 35,000°F, approximately four times the temperature of the sun's surface. Equipment can start breaking up when an event exceeds 15 cal/cm^2. The severity of an arc flash event is directly related to the available incident energy and the duration of the event.

There are many causes of arc flash events. Often, they are driven by human error: the use of uninsulated tools during energized work, accidental contact with exposed live parts, and using damaged equipment. Some arc flash incidents are a direct result of the condition of the equipment, such as a loose connection, water intrusion, or worn/damaged insulation (**Photo 3** on page 37 and **Photo 4** on page 38). These items can often be identified during normal inspections — when, and if, they are performed.

MAINTENANCE, INSPECTIONS, AND TESTING

Environmental factors are another issue that can plague mechanical devices (**Photo 5** on page 38). Contaminants, moisture, extreme temperatures (both hot and cold), and the atmosphere that

Photo 2. When reviewing arc flash labels, it is important to remember that the accuracy of the values shown hinges on completely secured hardware.

the breaker operates in can all add to operational issues for a circuit breaker. Sometimes, these are obvious during an inspection, like a breaker covered in coal dust or current-carrying components that are blackened and damaged by hydrogen sulfide in a wastewater treatment plant. Environmental damage might be harder to spot, however. Rusted bearings deep within a mechanism or damaged contacts inside switches or relays may not be visible but can hinder the correct tripping of a breaker. Operational cycles on a circuit breaker are another consideration. A breaker that is used as a motor starter may have incurred enough operations to have worn mechanism components, internal parts, contacts, or weakened springs, making the device less effective at doing its job.

INCIDENT ENERGY CONSIDERATIONS

What happens when a breaker doesn't trip as expected, only partially opens, or doesn't trip at all? In all scenarios, available incident energy increases as the clearing time increases. This increase in available incident energy results in hazards to both personnel and equipment. Partial tripping can be extremely hazardous, especially in medium-voltage applications; the partial contact gap may not be sufficient to break the circuit and may generate conductive ionized air. In addition to a fault, delayed or nonexistent tripping can cause that fault to

Photo 3. An example of damaged insulation.

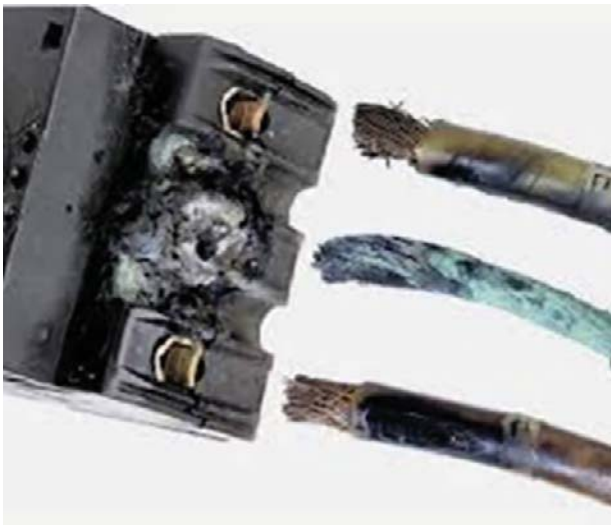

Photo 4. This is the type of damage that can occur from a loose connection.

be cleared by an upstream device, resulting in an outage that affects multiple circuits instead of just one.

Qualified personnel are trained to use all information available to assess the risk when racking or operating a circuit breaker. The first step is often to review the arc flash label for that particular device. An arc flash label indicating the potential hazard doesn't necessarily keep people completely safe from electrical dangers. However, the label provides a calculated arc flash hazard as well as arc flash boundary distance. These values are based on the premises that the equipment was properly installed/maintained, all doors and covers are closed and secured, and there are no signs of impending failure (**Photo 2**).

Let's look at the same breaker under two different scenarios. **Table 1** on page 40 shows the arc flash label calculations for a breaker that meets all of the requirements above. This particular breaker has a short-circuit function that is set so that an 8.11kA fault is interrupted in 0.143 seconds. Under these conditions, this breaker has an incident energy of 2.13 cal/cm^2 and an arc flash boundary of 22 inches. These values should allow for operation of the equipment with basic personal protective equipment (PPE) and a relatively low hazard to operators.

If the same breaker is in poor condition, has not been maintained, or the maintenance information is not known, the assumption of correct operation cannot be made. This same breaker that has the trip time increased to just 2 seconds from 0.143 seconds now has arc flash boundary and incident energy numbers that increase dramatically (see **Table 2** on page 40). The increase in fault clearing time extends the arc flash boundary to 112 inches and increases the incident energy to 29.70 cal/cm^2.

In the first scenario, since the incident energy displayed on the arc flash label is calculated at 2.13 cal/cm^2, an operator would likely select Category 1 or Category 2 PPE with a minimum arc rating of 4 cal/cm^2 or 8 cal/cm^2. When that same breaker fails to trip as expected — and there is an arc flash event — the operator is now in an extremely dangerous situation and is not equipped with the proper PPE to avoid injury. The resulting increase in incident energy would now require the operator to wear Category 4 PPE, which is designed for use up to 40 cal/cm^2. It is important to remember no matter what the Category rating, that PPE is designed to protect workers from non-recoverable injuries — not from walking away unscathed. The calculated ratings of PPE are set to prevent anything worse than a 2nd degree burn and to provide some shielding from flying debris. In the second scenario, the operator is woefully underdressed and could be exposed to life-threatening hazards. When racking or operating electrical equipment, it is usually not assumed that a fault will occur, but approaching these tasks in a proactive manner will go a long way toward protecting personnel.

2018 IEEE 1584 CALCULATIONS

There is additional information to consider when evaluating values listed on arc flash labels. In 2018, the IEEE 1584 formulas for calculating arc flash hazards were revised. The NFPA evaluated data collected over several years and determined that the formulas should be revised and enhanced to better reflect the actual hazards to personnel. Prior to 2018, one formulaic constant was used to represent the size of all cabinets. In addition, neither the orientation of conductors nor the location of the circuit — in an enclosure or in open air — were considered.The new formulas now take all of these parameters into account.

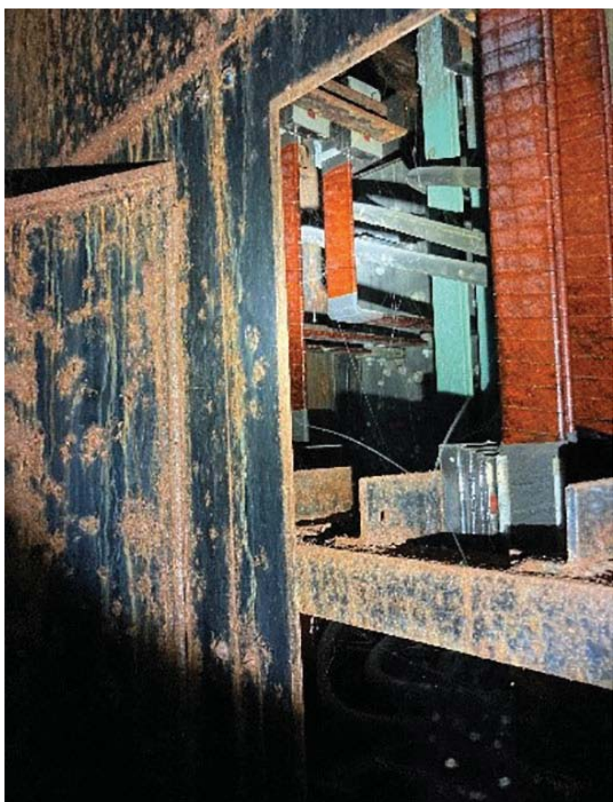

Photo 5. Environmental factors can have serious impacts on mechanical devices, resulting in increased risk of arc flash incidents.

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  ANY Snap2It Connectors LISTED for MC cable are also LISTED for MC-PCS cable! *These products offer the greatest time-savings.*
- **Fast, secure snap-on installation**
- **Easy to remove, reusable connector**

  From cable Loosen screw on top. Remove connector from cable.

  From box Slip screwdriver under notch in Snap-Tite® ring. Twist. Remove connector.

Easy to Snap into Box!

CATALOG NUMBER	**DESCRIPTION** Snap2It® connectors	**CABLE OUTSIDE DIA (OD)**
4010AST	Snap in, 1/2" KO w insulated throat	.405 to .610
5010AST	Snap in, 1/2" KO w insulated throat	.580 to .780
505010AST	Duplex Snap in, 3/4" KO w insulated throat	(2) .590 to .820
4110ST	Snap in, 1/2" KO	.525 to .705
414110ST	Duplex Snap in, 1/2" KO	(2) .525 to .640
NEW! **4141107ST**	Duplex Snap in, 3/4" KO	(2) .525 to .690

4141107ST

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AC Arc-Flash Evaluation Report — Well-Maintained Scenario

Bus Name	Bus ID	Protective Device Name	Bus kV	Bus Bolted Fault (kA)	Protective Device Bolted Fault (kA)	Protective Device Arcing Fault (kA)	Trip/Delay Time (sec)	% Arcing Fault Variation	Method	Electrode Configuration	Conductor Gap (mm)	Arc Flash Boundary	Working Distance (in.)	Incident Energy (cal/cm^2)	(Worst-Case Scenario) Notes
B-1536 MAIN	0008	52-MV SWGR-3	0.48	9.865	0.343	8.11	0.143		IEEE 1584-2018	VCB	13	2'2"	18	2.13	(R0)

Table 1. An example of an arc flash evaluation report.

AC Arc-Flash Evaluation Report — Poor Maintenance and/or Poor Environment Scenario

Bus Name	Bus ID	Protective Device Name	Bus kV	Bus Bolted Fault (kA)	Protective Device Bolted Fault (kA)	Protective Device Arcing Fault (kA)	Trip/Delay Time (sec)	% Arcing Fault Variation	Method	Electrode Configuration	Conductor Gap (mm)	Arc Flash Boundary	Working Distance (in.)	Incident Energy (cal/cm^2)	(Worst-Case Scenario) Notes
B-1536 MAIN	0008	52-MV SWGR-3	0.48	9.865	0.343	8.11	2		IEEE 1584-2018	VCB	13	11'2"	18	29.70	(SO) > Max FCT

Table 2. This table shows that the arc flash boundary and incident energy numbers increase dramatically when the trip time is increased to 2 seconds.

While NFPA 70E Sec. 130.5(G) requires any existing study to be reviewed for changes every five years and updated accordingly, the standard does not require recalculation if no changes have been made. There is not a requirement to replace labels because of the 2018 formulaic changes. There are many labels in use that were generated prior to 2018 that do not utilize these new formulas. This poses additional hazards for qualified workers. The original cubicle size calculation constant was based on a 20-inch × 20-inch × 20-inch compartment. The calculation change has the most impact on devices in shallow cabinets. With less volume available, any incident in a shallow cabinet — often only 8 inches or 12 inches deep in a motor control center bucket or panel — will most likely have a higher incident energy hazard than indicated on an older label. It is important to carefully evaluate the equipment that is scheduled for operation with this added factor in mind.

HAZARD RISK ASSESSMENT

It is important to recognize that there are many factors that must be considered when planning for electrical racking and switching tasks. Evaluating the information on an arc flash & shock hazard label is just the beginning. The need for regular operation, inspection, and maintenance of equipment greatly impacts the accuracy of that information. Careful evaluation of these components is a crucial part of the pre-task hazard risk assessment. This was recognized as an essential component to electrical workplace safety by the NFPA and is now a requirement in the 2023 NFPA 70B instead of a suggested practice. This change in language, along with refinements to the engineering calculations for arc flash hazard labels, is a positive step to increased worker safety and to the reduction in equipment damage because of arc flash incidents. **EC&M**

Denise Green is the Midwest regional sales manager and national breaker specialist for Group CBS and has been in the electrical distribution industry for 33 years. She can be reached at DGreen@CBSales.com.

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Pipe Sleeve
for 4" hole

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CPS40

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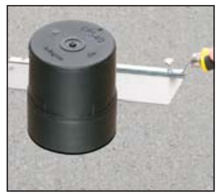
- Attaches to form with nails or screws
- Stackable up to 23" h for extra deep pours
- Vents keep wet pipe sleeves from sticking together
- Multiple hole sizes: 1-1/2" • 2" • 3" • 4" • 5" • 6"

Nail sleeve to form.



After concrete sets, cut sleeve flush with surface.

Insert conduit into sleeve.

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Changing end stop bushings is fast and easy. *No need to remove the strap.* Insert the bushing that works the best with the cables you're installing.

Reduce inventory – Costs much less than steel and **malleable iron fittings**

Built-in end stop

Patented

3-1/2"
8418

8418 for **1000 Mcm wire** and **TECK90**

Catalog Number	Trade Size	Cable O.D. Min	Cable O.D. Max	Wire Bundle O.D. Min	Wire Bundle O.D. Max	Conductor size # of Conductors* (AWG/KCMIL)
8412	1"	.780	1.120	.660	1.000	6/3, 6/4, 4-3, 4-4, 2-3, 2-4, 1-3
8413	1-1/4"	1.000	1.460	.870	1.370	2-3, 2-4, 1-3, 1-4, 1/0-3, 1/0-4, 2/0-3, 2/0-4, 3/0-3
8414	1-1/2"	1.360	1.770	1.250	1.590	2/0-4, 3/0-3, 3/0-4, 4/0-3, 4/0-4, 250-3, 250-4
8415	2"	1.700	2.200	1.550	2.050	250-4, 300-4, 350-3, 350-4, 500-3
8416	2-1/2"	2.100	2.700	1.950	2.400	500-3, 500-4, 600-3, 600-4, 750-3
8417	3"	2.500	3.300	2.350	3.000	600-4, 750-3, 750-4
8418	**3-1/2"**	**3.300**	**3.600**	**3.031**	**3.500**	**750-3, 750-4, 1000-4**

NEW

* Examples of 3- and 4-conductor cables accommodated.

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Measuring Insulation Resistance the Right Way

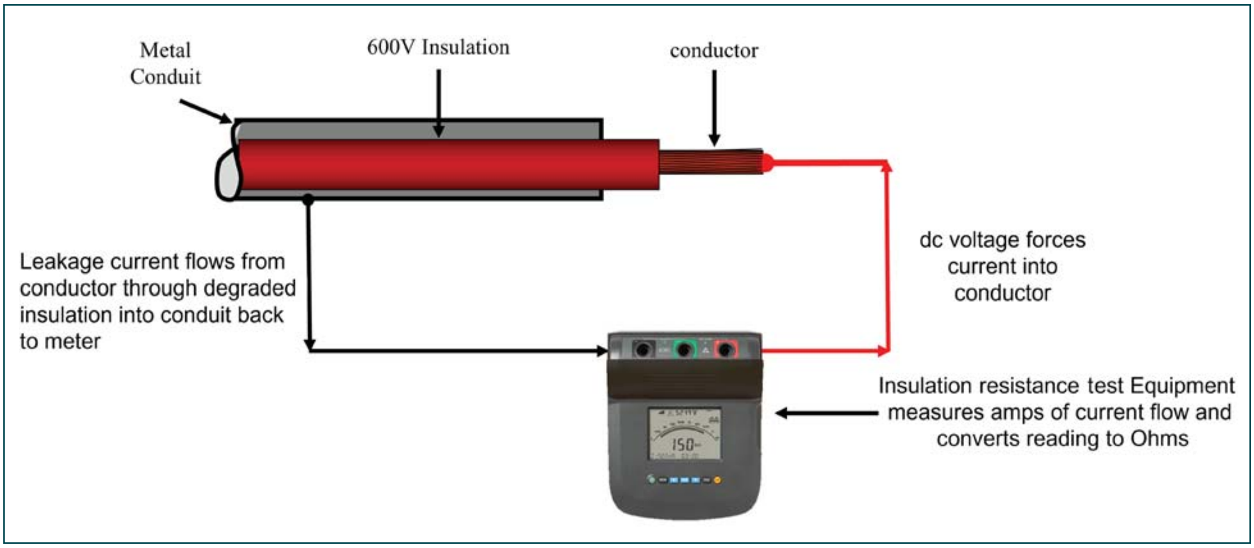

Fig. 1. Test voltage is applied by the insulation resistance tester typically at or above the insulation rating through the red lead attached to the conductor. Any current flow through the insulation and into the metal conduit will flow back to the meter through the black test lead attached to the conduit. The meter applies Ohm's law to provide a resistance reading.

How this maintenance practice can reduce costs/ downtime and create an electrically safe work condition

By Randy Barnett, NTT Training

Insulation failure is the root cause of many electrical conductors and equipment failures. When insulation fails, not only can equipment be damaged, but fire and shock can also result. Ideally, when the current leaves its normal path through a conductor, proper bonding will result in the overcurrent device clearing the fault. Being able to predict insulation failure is a great advantage of preventive maintenance technologies. In addition to safety, every maintenance contractor and organization must have goals to reduce replacement/repair costs and downtime. Measuring insulation resistance properly and correct interpretation of those measurements plays a large part in meeting these goals.

UNDERSTANDING INSULATION RESISTANCE MEASUREMENTS

The analogy of equating water flow through a piping system to measuring the quality of electrical insulation works well. For example, upon completion of installing a new piping system, it would only make sense to perform a leak test — and do so at a higher pressure than the normal operating pressure. Routine maintenance may also require testing as the system ages. Electrical insulation breaks down over time. The heating and cooling of the insulation, equipment vibration, and contaminants that enter the equipment all combine to degrade the insulation quality over time. The result is that electrical current unintentionally leaks into non-current-carrying conductors,

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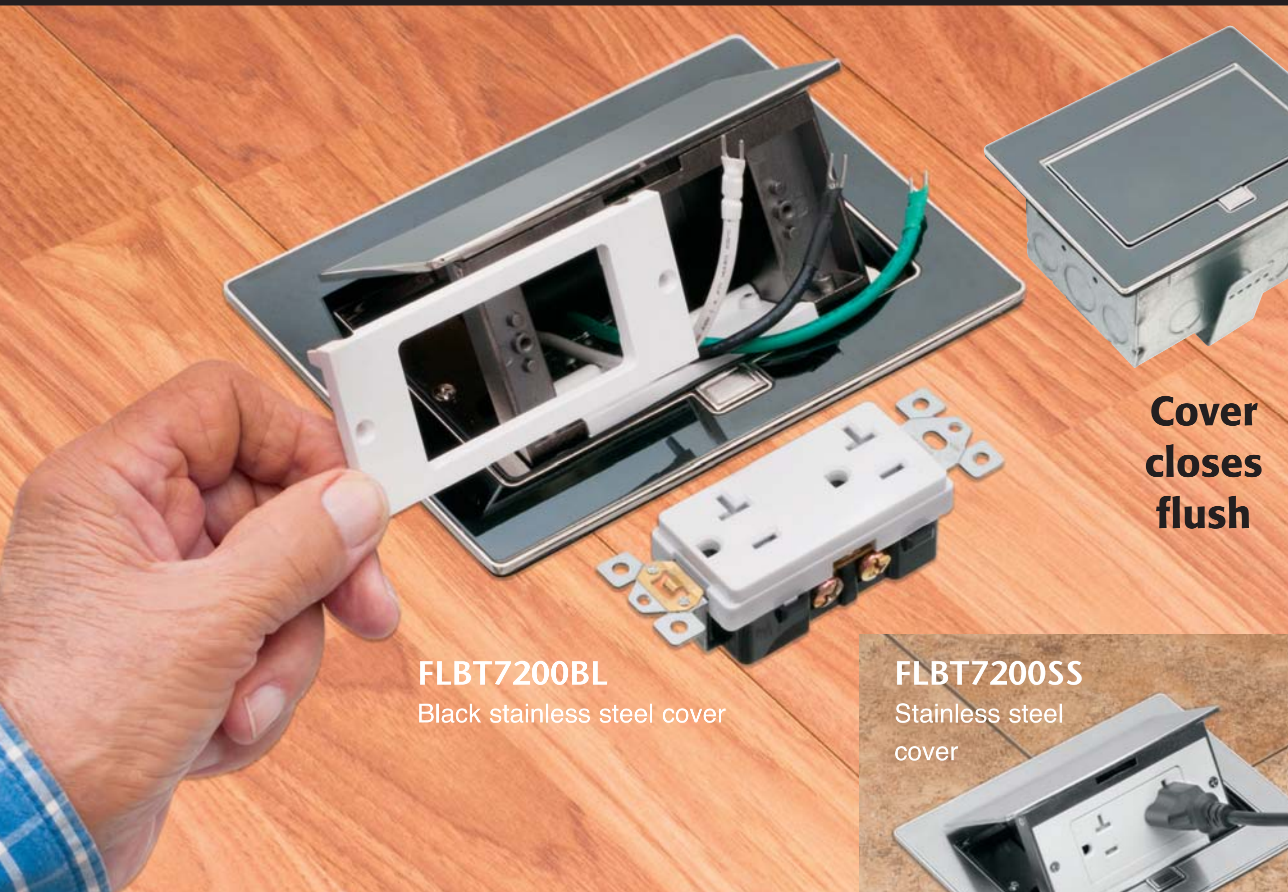

Arlington's **Pop-up COVER/BOX KITS** provide options for installing a device in a floor – or a countertop!

The kits include a 20A receptacle OR you can install one of your own. It's *easy.*

The device installs from the front. There's no need to dismantle the hinge mechanism. Just remove the white cover plate, install the receptacle and replace the cover plate.

Gasketed stainless steel or black stainless trapdoor covers close flush with the surface, preventing damage to the device and minimizing trip hazards in a floor installation.

- Easy **'No Glue'** installation – the spring steel clip holds box securely against the surface when screws are tightened
- Fits surfaces up to 1-1/2" thick
- Uses standard rectangular receptacle, and GFCI, and GFCI/combination receptacles

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Listed as floor box

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Ingress protection

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Product Info aifittings.com/landing/flbt7200-floorbox-kits metal enclosures, metal raceways, metal equipment, or earth (see **Fig. 1** on page 42). This is the National Electrical Code's definition of a "ground fault."

Ground faults are undesirable. Not only is insulation degradation over time a culprit, but ground faults can also occur during installation work. Insulation can be scraped from a conductor as it is pulled through a conduit. A conductor can be pinched between a cover and its enclosure. Always verify a system is clear of ground faults prior to initially energizing the system. Insulation quality testing during acceptance and commissioning can identify problems that would prevent the proper functioning of equipment and systems. Measuring and evaluating the quality of electrical insulation increases safety and reduces unexpected downtime — a win-win situation.

When applying DC voltage to a conductor, three separate currents flow. Just like charging a capacitor, some current flows to create a capacitive charge between the conductor under test and nearby conductors and from the conductor to ground. These are known as capacitive charging currents. Current flows also polarize any moisture or contamination molecules in the insulation. This is called absorption current. Finally, some current that is flowing is leaking from the conductor through the insulation into either the non-current carrying metal components of the system or into another conductor with poor-quality insulation. This is called leakage current. Fortunately, by applying the DC test voltage, the capacitive and the absorption currents will tend to read zero after a short time, and the remaining current flowing out of the conductor through the insulation is primarily leakage current.

These current values are indicated on the insulation resistance test equipment in ohms (see **Fig. 2**). Typically, the actual values will be in millions of ohms (Ω). 1MΩ = 1,000,000 ohms. Modern

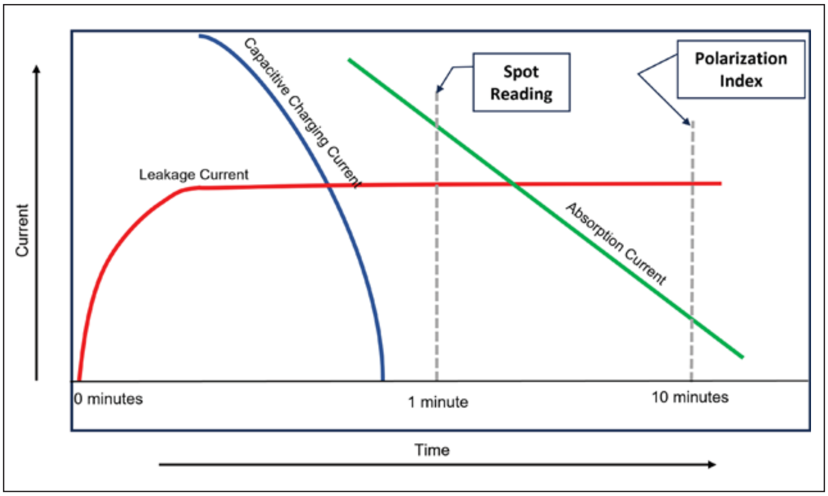

Fig. 2. In this simplified logarithmic chart, DC test voltage is applied at "0 minutes," and leakage current begins to flow through the insulation, quickly reaching a constant value. The capacitive charging current reaches zero in less than one minute. A spot reading test is the most common test method with the measured resistance value recorded after one minute. Any contamination in the insulation will be polarized by the absorption current. Recording the 10-minute reading and dividing it by the one-minute reading is the polarization index (PI).

Use Ohm's Law to Understand Insulation Resistance Testing

Ohm's Law explains how insulation resistance is measured. Understanding this simple formula helps to interpret readings.

From Ohm's Law:

R = E ÷ I, where (R) is resistance in ohms, (E) is voltage in volts, and (I) is current in amperes.

If the current increases, the resistance will decrease:

- Low leakage current would result in a higher resistance value (desired).
- Increased leakage current results in a lower resistance value (undesirable).

Motor insulation resistance example:

1,000VDC is applied to a motor winding. Using R = E ÷ I and given the below leakage currents through the winding insulation into the frame of the motor, what is the insulation resistance reading?

If 0.00004A flows through the winding insulation into the frame of the motor, the megohmmeter would read 25 megohm (MΩ), a satisfactory reading to safely operate the motor.

25 MΩ = 1,000VDC ÷ 0.00004A

If 0.001A flows through the winding insulation into the frame of the motor, the megohmmeter would read 1 MΩ, which is generally an unsatisfactory value. Running this motor may result in total motor failure requiring rewinding or replacement.

1 MΩ = 1,000VDC ÷ 0.001A

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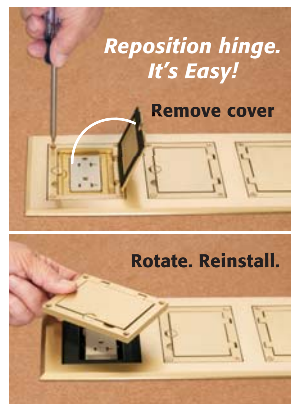
NOW IN PLASTIC, FIVE Colors!

FLBC8510BR

Build a two- or three-gang concrete floor box by simply locking *single gang* boxes together!

Then buy the UL LISTED single, two- or three-gang cover/frame kit, *with devices included*, in **PLASTIC, FIVE COLORS** – ***or in economical diecast zinc with a brass or nickel finish***.
Fast, easy installation.

Cover installs with hinge on either side.



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FLBC8510BL Black
FLBC8510GY Gray
FLBC8510CA Caramel
FLBC8510LA Lt Almond

Two-gang
FLBC8520BR Brown
FLBC8520BL Black
FLBC8520GY Gray
FLBC8520CA Caramel
FLBC8520LA Lt Almond

Three-gang
FLBC8530BR Brown
FLBC8530BL Black
FLBC8530GY Gray
FLBC8530CA Caramel
FLBC8530LA Lt Almond

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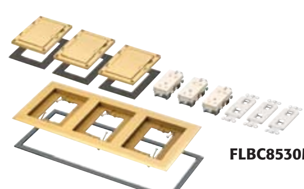
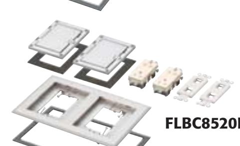
Metal Cover/frame Kit

Brass finish
Single gang **FLBC8510MB**
Two-gang **FLBC8520MB**
Three-gang **FLBC8530MB**

Nickel finish
Single gang **FLBC8510NL**
Two-gang **FLBC8520NL**
Three-gang **FLBC8530NL**



FLBC8530MB



FLBC8520NL

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testers can measure gigaohms of resistance. 1 GΩ = 1,000,000,000 ohms. A reading in kilohms (1 kΩ = 1,000 ohms) is generally an indication of a severe insulation problem.

An insulation resistance tester or megohmmeter is the most common type of test equipment used to measure insulation resistance (see **Fig. 3a** and **3b**). Like the pump for a leak test on a piping system providing high pressure, the megohmmeter forces current flow through a conductor using a voltage greater than for what the insulation is rated. For example, 600V-rated insulation may be tested at 1,000VDC. A common error in the field is to use a digital multimeter (DMM) to attempt to measure insulation resistance. The DMM only produces a very small voltage; it is not enough to detect a breakdown in insulation. More sophisticated tests (especially for medium- and high-voltage cables/equipment) may use AC or a very low frequency (VLF) AC for testing.

For the type of test to be conducted and the interpretation of results, always use the manufacturer's instructions. IEEE 43, *Recommended Practice for Testing Insulation Resistance of Rotating Machinery*, provides widely used industry values for test voltages and satisfactory test results.

PERFORMING THE INSULATION RESISTANCE TEST

Rule No. 1: "De-energize all equipment and conductors under test prior to beginning any test." In other words, use an electrical lockout/tagout procedure to create an electrically safe work condition. Part of that procedure requires removing any stored energy as well. Longer cable runs and motors can store significant amounts of electrical energy. Many insulation resistance testers are designed to discharge these currents before and after testing. If this function is not available on the tester used for measurements, a static discharge stick with built-in resistance should be used for discharging circuits before and after tests.

Once this safe condition is properly verified, the test process can begin. Follow the manufacturer's instructions to set up the test set. Insulation quality is measured from each ungrounded

Fig. 3a. This megohmmeter requires hand cranking of an internal generator for the duration of the test to provide the test voltage. An analog scale on the face provides the resistance in megohms.

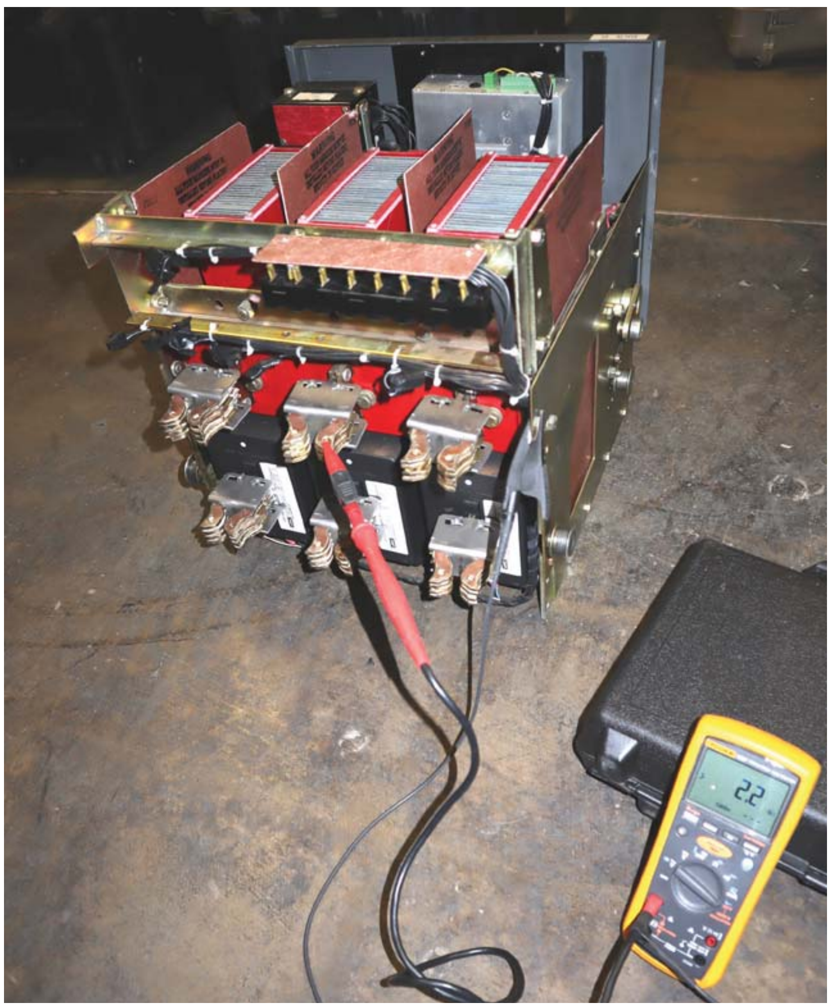

Fig. 3b. The megohmmeter has given way to more sophisticated test equipment, such as this insulation resistance tester being used for insulation resistance testing of a low-voltage power circuit breaker.

STEEL BOX WITH BRASS COVER

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- Brass covers hide miscut flooring; gaskets prevent water intrusion; flip lids protect the box when it's not in use.
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Fig. 4. The NEC Sec. 110.7 [Wiring Integrity] requires "completed wiring installations shall be free from short circuits, ground faults, or any connections to ground other than as required or permitted elsewhere in this Code." Before installation of load side conductors into this 200A disconnect, the line side conductors are tested to ensure no ground faults exist. Load side conductors will be tested after installation.

conductor to ground and between individual ungrounded conductors. The part of the system under test must also be disconnected from other parts to ensure no parallel paths to ground exist, which would give an erroneous reading.

The area under test is barricaded to prevent electric shock to an unqualified person. Follow the rules of shock protection found in NFPA 70E, *Standard for Electrical Safety in the Workplace*. The black test lead connects to ground — bare metal or the ground connection on the equipment. The red test lead connects to the bare ungrounded conductor. Insulation resistance will change with temperature changes. For consistency of readings over time, insulation temperature is measured, and charts are used to correct readings to a standard 40°C.

The appropriate test voltage is applied, and current begins to flow into the conductor material. Almost immediately, leakage current flows and will remain constant throughout the test. Just as current is used to charge a capacitor, some current is also flowing into the conductor to create the capacitive charge between the conductor and ground and between adjacent conductors. Any readings taken during the charging time of this capacitive charging process will result in an inaccurate leakage current reading. The capacitive current should be at or near zero after one minute. Taking a reading at one minute is referred to as a "spot-reading" test. It is the typical value used for determining insulation quality for many types of equipment.

In addition to leakage current, the absorption current continues to flow beyond the one-minute mark. As the impurities in the insulation are polarized, the absorption current drops to or at near zero. An increasing resistance value as the test proceeds toward 10 minutes is an indication of contamination on or in the insulation. The polarization index (PI) is the ratio obtained when dividing the 10-minute reading by the one-minute reading. A low ratio indicates questionable insulation quality.

Another method to determine insulation resistance quality is to divide the one-minute reading by a 30-second reading. This test is the dielectric absorption ratio (DAR). Follow the manufacturer's instructions, or refer to the IEEE 43 standard for specific values.

APPLICATIONS

Insulation resistance quality should be verified when electrical systems and equipment are installed as part of acceptance testing and commissioning of facilities. For example, nicked insulation in a conduit or pinched wires in an enclosure covering can be found. Identifying ground faults or short circuits between conductors is critical to startup. Section 110.7 of the NEC prohibits ground faults (see **Fig. 4**). Measuring electrical insulation quality can be used during troubleshooting to identify faulty insulation as the cause for blowing fuses or tripping circuit breakers. NFPA 70E requires the cause of a blown fuse or tripped circuit breaker to be determined prior to replacing the fuse or resetting/closing the circuit breaker.

A major advantage of periodically measuring insulation resistance is that the degradation of the insulation can be plotted over time — typically in months and years. Plotting out resistance values as they decrease can be used to help predict the failure of electrical systems and equipment. Repairs can be scheduled and made prior to more costly unscheduled downtime. By performing a polarization index test, damp or contaminated insulation can be corrected. Procedures exist to dry out windings in motors and generators. Windings can be cleaned using different methods, often significantly raising insulation resistance values.

Increasing personnel safety, preventing fires, and reducing downtime are goals of all organizations and electrical workers. Part of reaching those goals requires measuring the insulation quality of electrical systems and their components as part of installation, troubleshooting, and routine maintenance. Understanding the basics, following manufacturer instructions and industry standards for proper test methods, and interpreting measurements correctly to determine insulation quality provides for a safe and efficient work environment. **EC&M**

Randy Barnett is the electrical codes and safety program manager for NTT Training in Centennial, Colo. A certified electrical safety compliance professional (CESCP), he can be reached at electricrb@yahoo.com.

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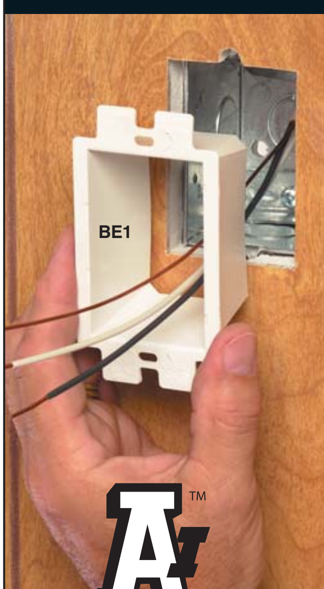

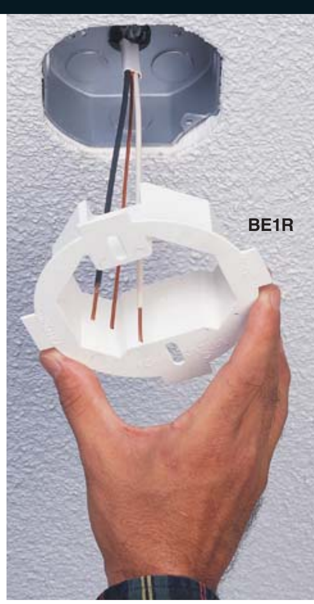

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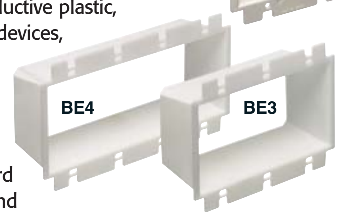

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NEC Requirements for Motors — Part 2 of 2

Do you know how to protect motors and related equipment from overcurrent and ground faults?

By Mike Holt, NEC Consultant

Overload devices protect motors, motor control equipment, and motor branch-circuit conductors against excessive heating due to motor overloads and failure to start, but not against overcurrent (e.g., short circuits or ground faults). We covered overloads in Part 1.

Motor branch-circuit short-circuit and ground-fault protective devices protect the motor, the motor control equipment, and the conductors against overcurrent, but not against overload. They are generally called overcurrent protective devices (OCPDs), and we'll look at them next.

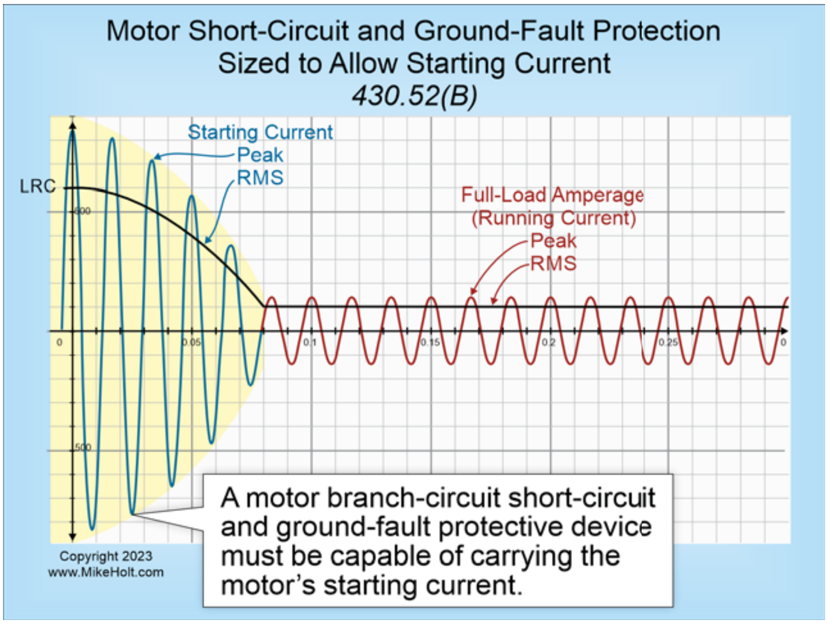

Fig. 1. A motor branch-circuit OCPD must be able to carry the motor's starting current.

BRANCH-CIRCUIT SHORT-CIRCUIT AND GROUND-FAULT PROTECTION

The motor branch-circuit OCPD must comply with Sec. 430.52(B), (C), and (if torque motors) (D) [Sec. 430.52(A)]. Section 430.52(B) is straightforward: A motor branch-circuit OCPD must be able to carry the motor's starting current (**Fig. 1**).

But Sec. 430.52(C) has changed extensively with the 2023 revision — or at least it looks that way at first glance. To determine the size of the OCPD that will protect the motor branch circuit against short circuits and ground faults, you now use Table 430.52(C)(1) instead of Table 430.52.

Another change is Exception No. 1 and Exception No. 2 in the 2020 NEC are now Sec. 430.52(C)(1)(a) and (b) in the 2023 NEC. The actual requirements are the same as in the 2020 NEC. If the value from the table doesn't correspond to the standard ampere ratings and settings provided in Sec. 240.6, you can use the next higher standard rating or setting [Sec. 430.52(C)(1)(a)]. If the OCPD doesn't have a high enough ampere rating to permit starting the motor, you have four options [Sec. 430.52(C)(1)(b)].

COMBINED OCPD

A motor can be protected against overload, short circuit, and ground fault by a single OCPD sized to the overload requirements in Sec. 430.32 [Sec. 430.55]. The "next size up protection" rule for branch circuits [Sec. 430.52(C)(1)(a)] does not apply to motor feeder OCPDs.

In some cases where there are 3-phase and single-phase motors on the same feeder, the current on L1, L2, and L3 (or Phase 1, Phase 2, and Phase 3) will be different. The "group" is determined by balancing out the motor currents between different phases (lines) of the motor feeder.

OVERCURRENT PROTECTION FOR CONTROL CIRCUITS

Motor control conductors that are not tapped from the motor branch-circuit conductors are classified as a Class 1 remote-control circuit and must have overcurrent protection per Sec. 724.43 [430.72(A)]. In previous Code revisions, this was Sec. 725.43. However, with the 2023 revision, Class 1 circuit requirements were moved from Art. 725 to the new Art. 724.

Overcurrent protection for conductors 14 AWG and larger must comply with the conductor ampacity from Table 310.16. Overcurrent protection for 18 AWG cannot exceed 7A; for 16 AWG conductors, the limit is 10A.

Motor control circuit conductors that are tapped from the motor

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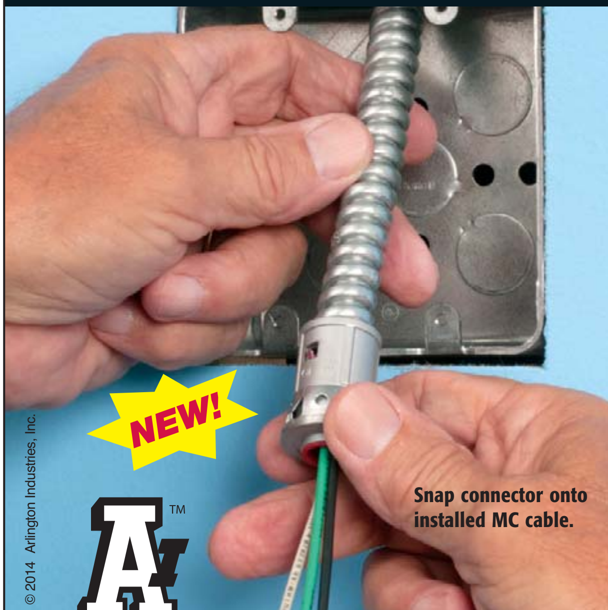

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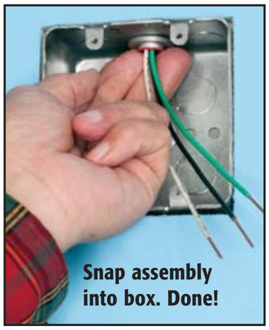

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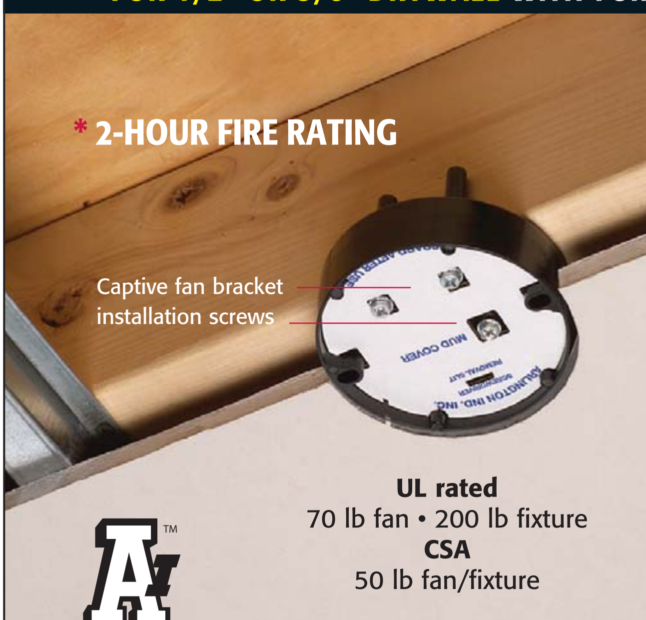

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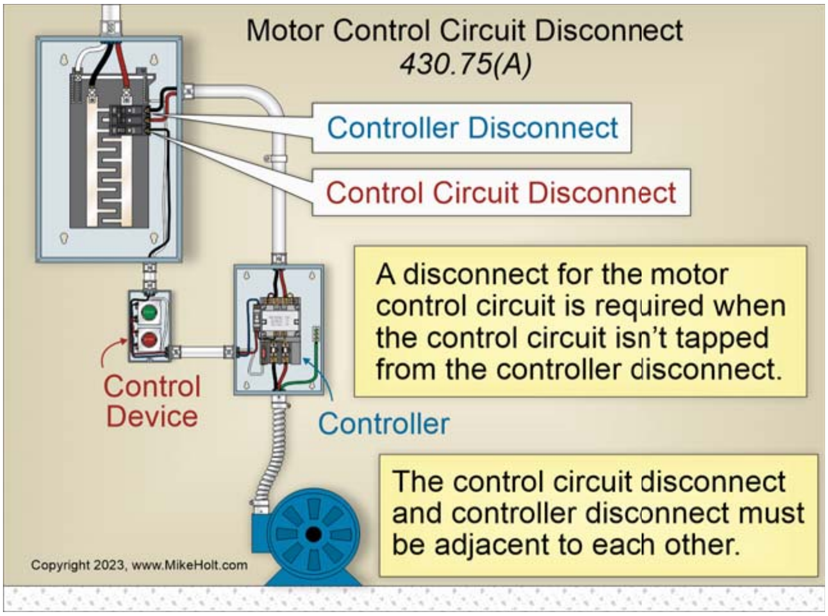

Fig. 2. Where control circuit conductors are not tapped from the controller disconnect (supplied by a Class 1 control circuit), a disconnect located adjacent to the controller disconnect is required.

branch-circuit OCPD and extend beyond the tap enclosure must have overcurrent protection that complies with Sec. 430.72(B)(1) (separate OCPD) or (2) (branch-circuit OCPD). Essentially, you are going to use Table 430.72(B)(2).

CONTROL CIRCUIT DISCONNECTS

Motor control circuit conductors must have a disconnect [Sec. 430.75(A)]. Where these conductors are tapped from the controller disconnect, the controller disconnect can serve as the disconnect for the control circuit conductors [Sec. 430.102(A)]. Where control circuit conductors are not tapped from the controller disconnect (supplied by a Class 1 control circuit), a disconnect located adjacent to the controller disconnect is required (**Fig. 2**).

CONTROLLERS

Circuit breakers and molded-case switches can serve as motor controllers [Sec. 480.83(A)]. Anything else you use to do that job must have a horsepower rating of at least that of the motor.

The motor controller can be a general-use snap switch for motors rated 2 hp or less where the motor FLC is not more than 80% of the ampere rating of the switch [Sec. 480.83(C)(2)].

MOTOR DISCONNECTS

Each motor controller must have a disconnect within sight from the controller, and each motor must have a disconnect within sight from the motor. The controller disconnect (if within sight from the motor) can also serve as the disconnect for the motor [Sec. 430.102(B)]. Either the controller disconnect or the motor disconnect required by Sec. 430.102 must be readily accessible [Sec. 430.107].

TYPE OF DISCONNECTING MEANS

The disconnect for the motor controller and/or the motor must be one of the seven types listed in Sec. 430.109(A)(1) through (7). For example, a listed horsepower-rated motor circuit switch or a listed molded-case circuit breaker.

For stationary motors of $\frac{1}{8}$ hp or less, the branch-circuit OCPD can serve as the disconnect [Sec. 430.109(B)]. For stationary motors rated 2 hp or less and 300V or less, the disconnect can be a general-use AC snap switch (not a general-use AC-DC snap switch) where the motor's full-load current (FLC) as listed in Tables 430.247 through 250 is not more than 80% of the ampere rating of the switch [Sec. 430.109(C)].

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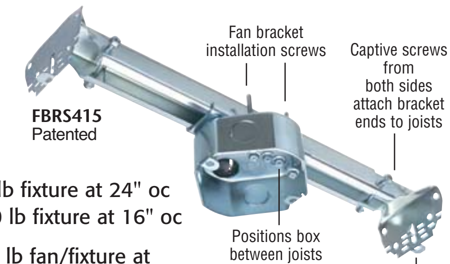

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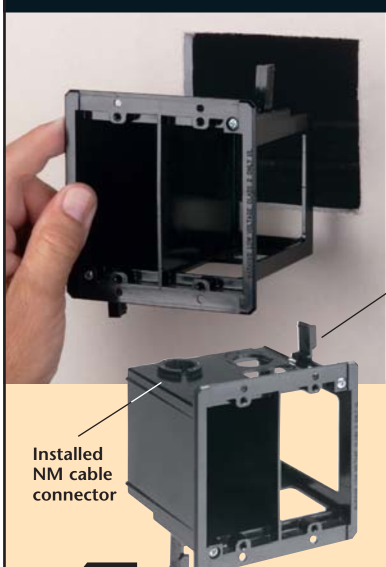

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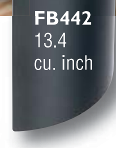

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ADJUSTABLE-SPEED DRIVES

The installation provisions of Part I through Part IX apply to adjustable-speed drives (ASDs) unless modified or supplemented by Part X [Sec. 430.120].

Circuit conductors for an ASD must have an ampacity of at least 125% of the rated input current of the ASD [Sec. 430.122(A)]. ASDs can have multiple power ratings and corresponding input currents [Sec. 430.122(A) Note].

The conductors between the power conversion equipment and the motor must have an ampacity equal to or greater than 125% of the motor's full-load current (FLC) as listed in Tables 430.247 through 250 [Sec. 430.122(B)], as shown in **Fig. 3**.

Exception: If the power conversion equipment is listed and marked as "Suitable for Output Motor Conductor Protection," the conductor between the power conversion equipment and the motor must have an ampacity equal to or greater than the larger of:

(1) 125% of the motor's full-load current (FLC) as determined by Sec. 430.6(A) or (B).

(2) The ampacity of the minimum conductor size marked on the power conversion equipment.

Informational Note No. 1: The minimum ampacity required of output conductors is often different from that of the conductors supplying the power conversion equipment. See Sec. 430.130 and Sec. 430.131 for branch-circuit protection requirements.

Informational Note No. 2: Circuit conductors on the output of an ASD are susceptible to breakdown under certain conditions due to the characteristics of the output waveform of the drive. Factors affecting the conductors include (but are not limited to) the output voltage, frequency and current, the length of the conductors, the spacing between the conductors, and the dielectric strength of the conductor insulation. Methods to mitigate breakdown include consideration of one or more of these factors.

Conductors supplying several motors or a motor and other loads (including power conversion equipment) must have ampacity per Sec. 430.24, using the rated input current of the power conversion equipment for purposes of calculating ampacity [Sec. 430.122(D)].

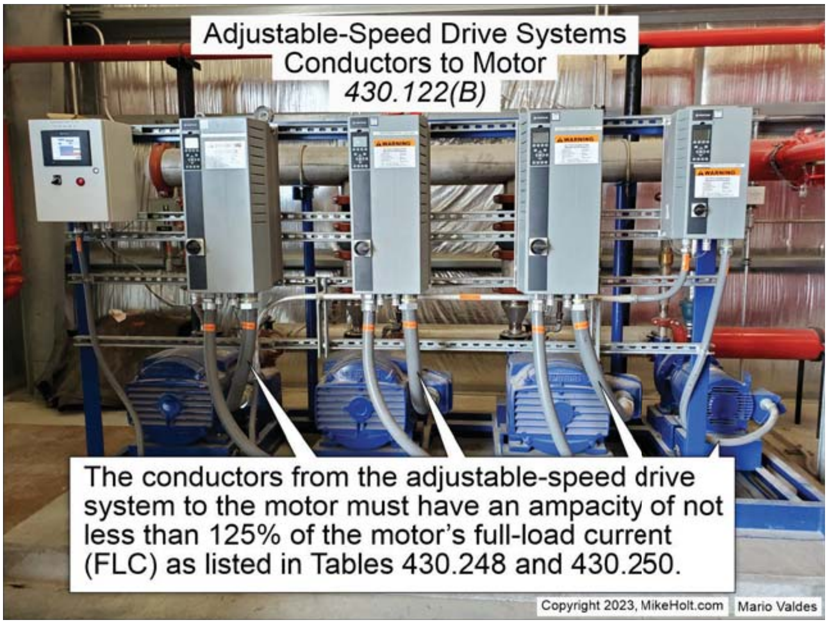

Fig. 3. The conductors between the power conversion equipment and the motor must have an ampacity equal to or greater than 125% of the motor's full-load current (FLC) as listed in Tables 430.247 through 250.

Where the ASD is marked to indicate that motor overload protection is included, additional overload protection is not required [Sec. 430.124(A)].

The disconnect for an ASD must have a rating of at least 115% of the rated input current of the conversion unit [Sec. 430.128].

Circuits containing power conversion equipment must be protected by a branch-circuit OCPD [Sec. 430.130(A)]. The rating and type of protection must be determined by Sec. 430.52(C)(1), (3), (5), or (6) using the motor's full-load current (FLC) rating as determined by Sec. 430.6(A) or (B). This differs from the previous Code revision, where you used the FLC ratings listed in Tables 430.248 and 430.250 [Sec. 430.130(A)(1)].

Exception: You are allowed to determine the rating and type of protection using Table 430.52(C)(1) with the power conversion equipment's rated input current where the power conversion equipment is listed and marked "Suitable for Output Motor Conductor Protection."

Informational Note 1: Motor conductor branch-circuit short-circuit and ground-fault protection from the power conversion equipment to the motor is provided by power conversion equipment that is listed and marked "Suitable for Output Motor Conductor Protection."

Informational Note 2: A motor branch circuit using power conversion equipment, including equipment listed and marked "Suitable for Output Motor Conductor Protection," includes the input circuit to the power conversion equipment.

Where maximum branch-circuit OCPD ratings are stipulated for specific device types in the manufacturer's instruction for the power conversion equipment (or otherwise marked on the equipment), you can't exceed them even if Sec. 430.130(A)(1) permits higher values [Sec. 430.130(A)(2)].

IT WILL NEVER BE SIMPLE

Article 430 in the 2023 Code has a fair number of changes from the 2020 Code. Many of these are editorial in nature, with the goal of making Art. 430 easier to understand and apply — but it will never be easy to understand or apply.

To avoid mistakes, mentally separate overload protection from overcurrent (and ground-fault) protection. **EC&M**

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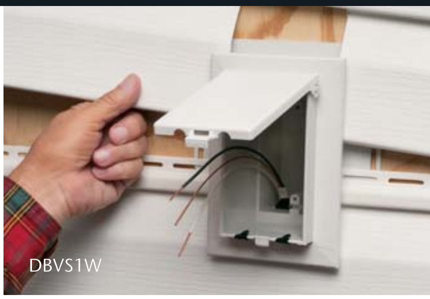

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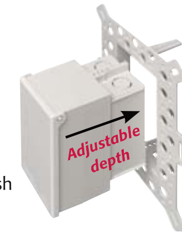

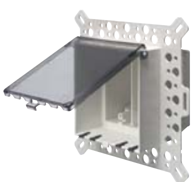

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Stumped by the Code?

By Mike Holt, NEC Consultant

All questions and answers are based on the 2023 NEC.

Q. Under what conditions can electrical metallic tubing (EMT) not be used and installed?

A. According to Sec. 358.12, EMT is not permitted to be used under the following conditions:

(1) Where subject to severe physical damage.

(2) For the support of luminaires or other equipment (**Fig. 1**).

Q. What are the requirements for securing and supporting EMT?

A. Section 358.30 gives the requirements for securing and supporting EMT.

EMT must be securely fastened in place and supported in accordance with (A) and (B).

(A) Securely Fastened. EMT must be securely fastened within 3 ft of every box, cabinet, or termination fitting, and at intervals not exceeding 10 ft.

Author's Comment: Fastening is required within 3 ft of termination, not within 3 ft of a coupling.

Exception No. 1: When structural members do not permit the raceway to be secured within 3 ft of a box or termination fitting, an unbroken raceway can be secured within 5 ft of a box or termination fitting.

(B) Horizontal Runs. EMT installed horizontally in bored or punched holes in wood or metal framing members, or notches in wooden members at intervals not greater than 3 ft, is considered supported, but the raceway must be secured within 3 ft of termination (**Fig. 2**).

Q. What is the minimum and maximum EMT trade size permitted?

A. The minimum and maximum EMT trade size permitted is stated in Sec. 358.20.

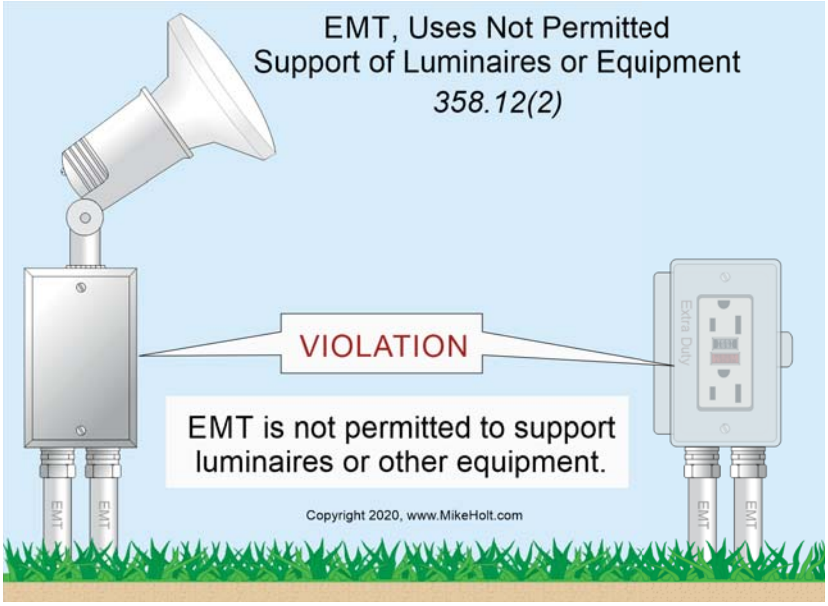

Fig. 1. Examples of EMT uses not permitted by the NEC.

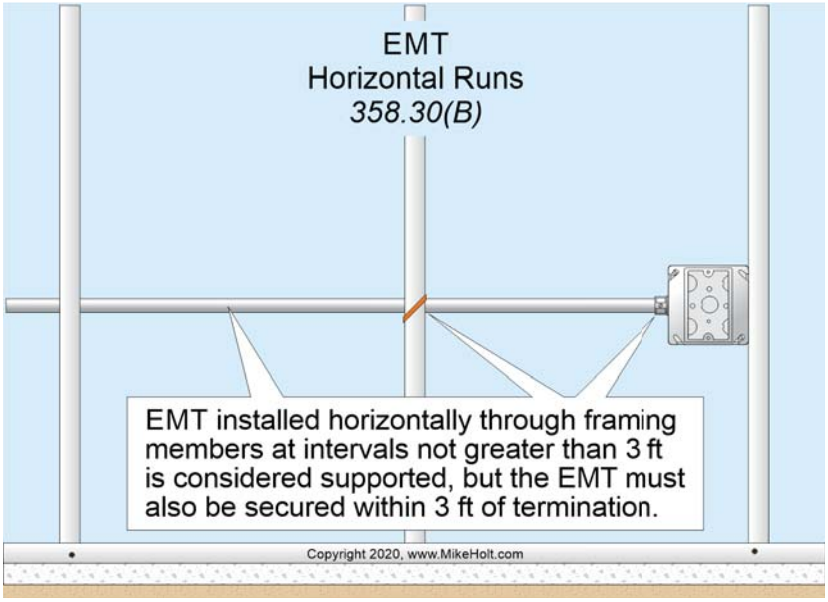

Fig. 2. Section 356.30)B) requirements for horizontal EMT runs.

(A) Minimum. EMT smaller than trade size ½ is not permitted.

(B) Maximum. EMT larger than trade size 4 is not permitted. **EC&M**

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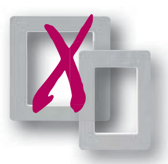
Designed for devices, Arlington's *economical* single and two-gang **Vapor Boxes** offer easy nail-on installation in new construction.



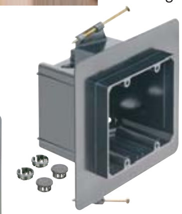
These cost-saving boxes don't include gaskets, but when caulked around the NM cable during installation, they **meet the requirements of NEMA 0S-4**. And help meet International Energy Conservation Codes (IECC), and other codes *where required.*

FN102FX
Two gang

- Nails ship captive. Plugs and NM cable connectors supplied.

2-hour Fire Rating

Patented



FN101FX
Single gang

Captive nails

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Product info
aifittings.com/landing/fn101fx-fn102fx/

UL LISTED

Illustrated Catastrophes

By Russ LeBlanc, NEC Consultant

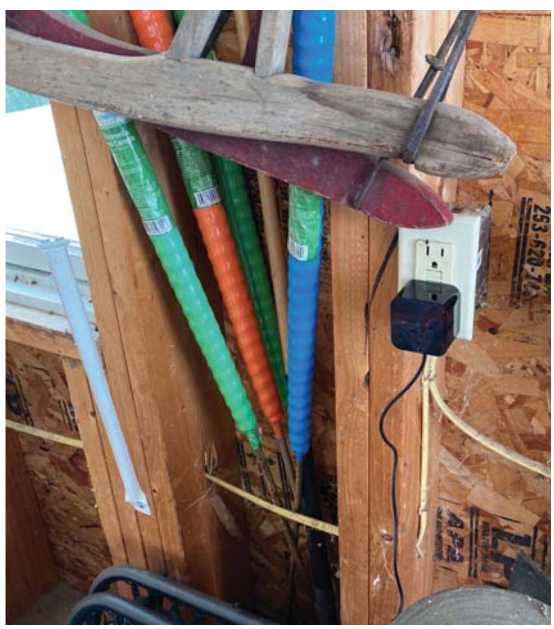
All references are based on the 2023 edition of the NEC.

A CREATIVE WIRING SOLUTION

While this installation does show some creativity and imagination, using what appears to be gas piping or gas pipe fittings as a wiring method is not recognized by the Code. Section 110.8 informs us that only suitable wiring methods are included in the Code. There is no Article in Chapter 3 covering gas piping as a wiring method. The box installed for the luminaire is not suitable for this outdoor wet location and does not comply with the requirements of Sec. 314.15. Boxes installed in wet locations such as this must be listed for use in wet locations. The manner in which this box is supported does not comply with any of the provisions specified in Sec. 314.23(A) through (H). Section 314.23(F) Exception No. 2 provides very specific requirements for using one threaded intermediate metal conduit (IMC) or rigid metal conduit (RMC) for the support of a box, but this installation does not comply with those requirements. The cover on the lower box where the photocell is mounted is only secured to the box with one screw, does not provide a weatherproof enclosure, and allows moisture to enter the box. This loose cover does not comply with Sec. 314.15 either.

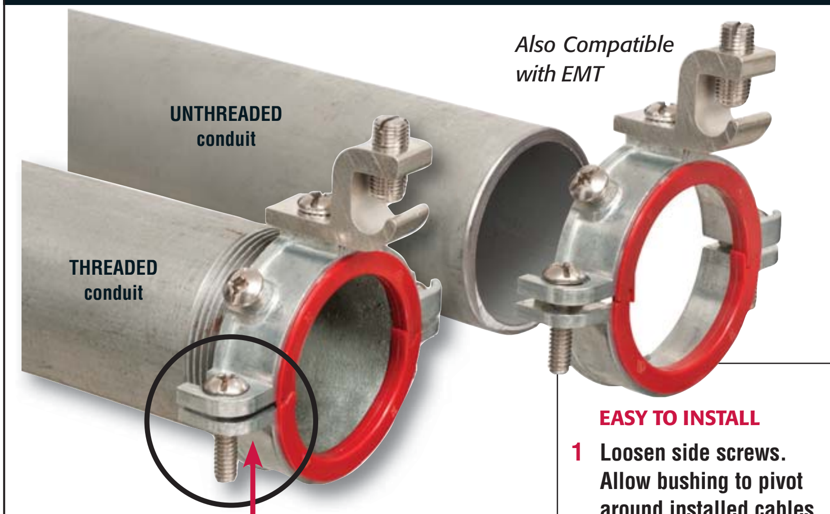
A COMMON SITE IN GARAGES

Section 334.10(1) permits NM cable to be installed in attached and detached garages of one- and two-family dwellings. This installation shows the inside of an attached garage for a dwelling unit. It's quite common for me to see installations very similar to this one where NM cable is exposed in the open walls, and storage items or tools get placed against the walls or in contact with the NM cable. In this case, large citronella candles were stuffed behind the cables running horizontally through the studs of the exterior walls. Some Code users would argue that NM cable should not be installed here, as it is exposed to physical damage, but there is no wording in Sec. 334.12 that specifically prohibits this installation. For exposed work, Sec. 334.14(C) requires the cable to be protected from physical damage by being installed in RMC, IMC, electrical metallic tubing (EMT), Schedule 80 PVC conduit, RTRC-XW, or other approved means where necessary. Is that type of protection necessary here? This question is often a topic of debate between electricians and inspectors who think that it's best to err on the side of caution when it comes to electrical installations.



SPLIT GROUNDING BUSHINGS for THREADED and UNTHREADED RIGID and IMC

EC&M Product of the Year
2023 Category Winner

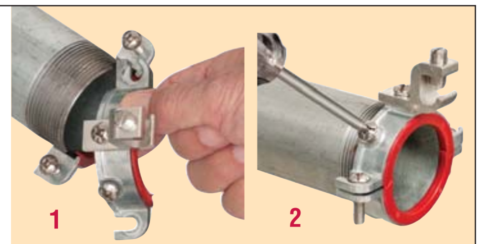


Get convenience and time-savings with Arlington's 550 series **SPLIT grounding bushings**. The split allows the addition of a bushing AFTER conductors are installed in threaded or unthreaded Rigid/IMC conduit. Great for tight spaces!

- In 1/2" to 4" trade sizes – Ships Assembled
- Compatible with EMT, 2-1/2" to 4" trade sizes, and threaded electrical fittings

EASY TO INSTALL

1. Loosen side screws. Allow bushing to pivot around installed cables
2. Tighten set screw to seat bushing on conduit



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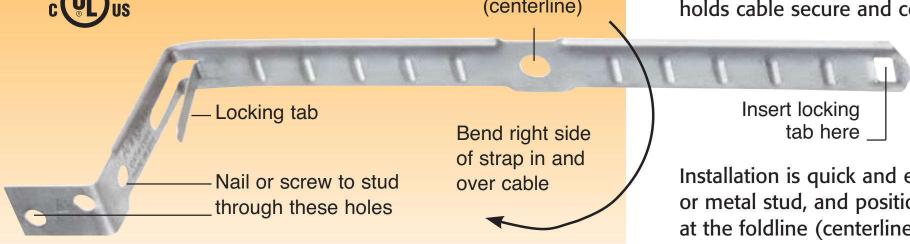


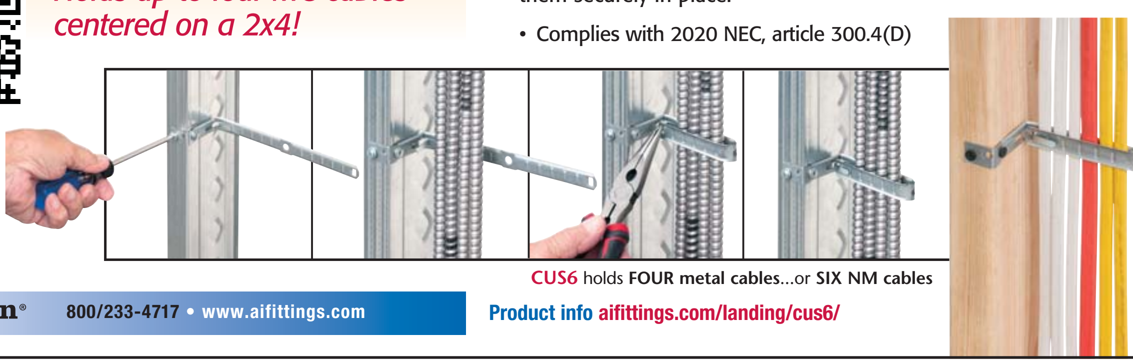
Holds up to four MC cables centered on a 2x4!

Arlington's economical CUS6 galvanized steel Cable Support holds cable secure and centered on a metal or wood stud.

It's perfect for fastening and positioning *up to four* individual metal clad cables – or six NM cables on a 2x4.

Installation is quick and easy. Nail or screw ***CUS6*** to a wood or metal stud, and position the cables. Next bend the strap at the foldline (centerline). Fold the strap over the cables and insert the locking tab in the opening as shown to hold them securely in place.

- Complies with 2020 NEC, article 300.4(D)



CUS6 holds **FOUR** metal cables...or **SIX** NM cables

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Panelboard Versus Panelboard Enclosure

Should labels really be installed on the panelboard itself?

By Russ LeBlanc, NEC Consultant

For electric space-heating cable installations such as the type shown in the **Photo**, Sec. 424.47 requires manufacturers to provide marking labels indicating that the installation incorporates space-heating cables. These marking labels are required to be affixed to the panelboards to identify which branch circuits supply the space-heating cables. This is where the Code wording gets a little fuzzy. Should these labels really be installed on the panelboard itself? Or perhaps it would be better to install them on the cover of the enclosure for the panelboard?

Article 100 defines a panelboard as "a single panel or group of panel units designed for assembly in the form of a single panel, including buses and automatic overcurrent devices, and equipped with or without switches for the control of light, heat, or power circuits; designed to be placed in a cabinet, enclosure, or cutout box placed in or against a wall, partition, or other support; and accessible only from the front." I really don't think the intent of Sec. 424.47 is for the labels to be installed on the busbar assembly.

I believe the intent of Sec. 424.47 is to have the labels installed on the cover of the cabinet or enclosure for the panelboard. Using the term "panelboard" as a generic catch-all term to include the busbar assembly, overcurrent protective devices, enclosure, cabinet, and cover is a very common occurrence in the electrical industry. I'm guilty of it myself. But the reality is that definitions matter, and panelboard, enclosure, cabinet, and cutout box each have their own definition in Art. 100.

There are many other instances in the Code where the literal term "panelboard" is used but the intent of wording is probably referring to the "enclosure" or "cabinet" for the panelboard instead of the panelboard itself. For example, Sec. 250.32(D)(3) states "the connection between the equipment grounding conductor and the grounding electrode at a separate building or structure shall be made in a junction box, panelboard, or similar enclosure located immediately inside or outside the separate building or structure." I'm pretty sure the use of the term "panelboard" here is really meant for the "cabinet" or "enclosure" for the panelboard.

When you have a moment, check out any rules where the term "panelboard" is used, and see if you think the Code is referring to the enclosure for the panelboard or the panelboard itself. If you are unsure, I suggest having a conversation with your AHJ to try and figure out these sometimes confusing rules. EC&M

PRODUCT NEWS

Arc Flash Protective Clothing

The Feature series of arc flash protective clothing PPE is made with Indura Ultra Soft FR-treated cotton. According to the company, meets current ASTM F1506 and F1959/1959M-99 standards. FR Velcro front closures provide a secure closure, easy access, and rapid removal in the event of arc flash exposure. FR Velcro calf/ankle closures allow for easy access and fit adjustment during donning and removal and adjustment while wearing boots. Clothing options include coats, parkas, bib/pants, coveralls, and leggings, available in sizes S-5X with a standard inseam of 32 in. Coveralls include elastic backs for ease of movement, and all coats and coveralls have Nomex knit wrist cuffs. Bib/pants have easily adjustable "quick disconnect" shoulder straps to ensure user safety. Kits are available in a duffle bag, backpack, or hard-sided storage canister, and include hard hats, safety glasses, and ear canal inserts.

Cementex

Energy Management System

EcoStruxure Energy Hub is a scalable self-service IoT software as a service (SaaS) solution, which simplifies the management of digitalized electrical and energy systems. With EcoStruxure Energy Hub, building owners and operators can comply with emerging energy codes and standards, more effectively managing essential energy systems and ensuring they're on track to meet larger sustainability goals. According to the company, EcoStruxure Energy Hub is designed to be simple to implement and use, connecting devices to collect and visualize data in minutes. Its graphical configuration customizes to the environment, while dashboards and reports are automatically populated. As a web-based application, there is no software to install or maintain, which eliminates shutdowns for software upgrades and maintenance as new features are released and updated automatically. EcoStruxure Energy Hub is a native IoT solution that is IT-friendly and designed with cybersecurity in mind.

Schneider Electric

Construction Technology Solutions

The company's new suite of construction technology solutions consists of a variety of connected tools, software, and mobile applications that incorporate artificial intelligence (AI) and the Internet of Things (IoT). MSUITE is a cloud-based suite of management software that connects BIM, fab, and field construction teams for off-site and modular construction. It helps contractors track, manage, and share data throughout the entire life cycle of a construction project with easy-to-use, scalable, and industry-focused software that provides real-time status updates and valuable progress tracking and estimating information. In addition, TOOL CONNECT Site Manager is a cloud-based platform allowing contractors to manage their tools and equipment remotely using a smartphone or tablet. It enables users to locate tools, check their inventory levels, and monitor usage and performance.

DEWALT

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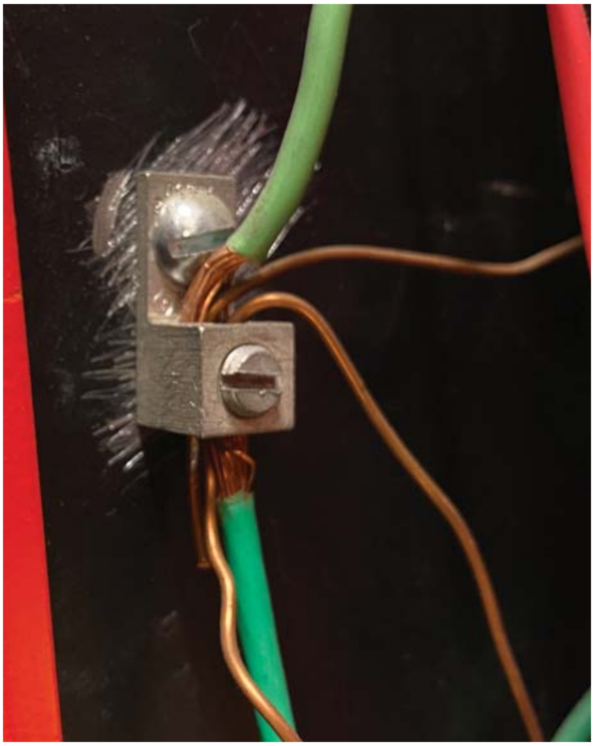
ENDEAVOR BUSINESS MEDIA

What's Wrong Here?

By Russ LeBlanc, NEC Consultant

How well do you know the Code? Think you can spot violations the original installer either ignored or couldn't identify? Here's your chance to moonlight as an electrical inspector and second-guess someone else's work from the safety of your living room or office. Can you identify the specific Code violation(s) in this photo? Note: Submitted comments must include specific references from the 2023 NEC.

Hint: A five-for-one special!



'TELL THEM WHAT THEY'VE WON...'

Using the 2023 NEC, correctly identify the Code violation(s) in this month's photo — in 200 words or less — and you could win an Arlington Industries 18-in. Slider Bar and plastic box for mounting between studs with non-standard spacing. E-mail your response, including your name and mailing address, to russ@russleblanc.net, and Russ will select three winners (excluding manufacturers and prior winners) at random from the correct submissions. Note that submissions without an address will not be eligible to win.

JUNE WINNERS

Unfortunately, we had no winners this month. Perhaps our readers were out enjoying their summer vacations.

It seems as though the electrical metallic tubing (EMT) was installed as the original installation here, then at some later point, the orange communication raceway was installed and secured to the original EMT. Later, several CATV cables and Class 2 and Class 3 cables were also secured to the original EMT. That poor EMT is now supporting a raceway and several cables! Section 358.12(2) prohibits using EMT to support luminaires or other equipment except for conduit bodies. Section 300.11(C) permits raceways to be used as a means of support for other raceways or cables only where raceways are identified as a means of support or where the raceway contains power conductors for electrically controlled equipment and is used to support Class 2 or Class 3 cables used for the equipment control circuits. Section 722.24(B) prohibits these cables from being secured by any means to the exterior of any raceway as a means of support.

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