



## Change History

Date	Description of Change	Pages / Sections Modified	Change Approver Initials
3/26/13	Add two manufacturers to list	4 - 16120, E. #1 (Conductors and Cable; Manufacturers)	SO
3/26/13	Amend Materials paragraphs to avoid use of PVC thermoplastic jacketing and insulation compounds in favor of non PVC thermoset compounds.	5 - 16120, F. #1, #2, #3, #4 & #8 (Conductors and Cable; Materials)	SO
3/26/13	Add at end of text to paint Fire Alarm conduit red.	8 - 16120 H. #8 (Conductors and Cable; Installation Guidelines)	SO
3/26/13	Amend text to remove 'MV'.	13 - 16124 H. #2 (Medium Voltage Cables; Special Requirements)	SO
3/26/13	Add next item to address alternate power serve in shared Man hole with normal power service.	13 - 16124 H. #3 (Medium Voltage Cables; Special Requirements)	SO
3/26/13	Replace 'THHN/THWN' with 'XHHW-2' to avoid use of thermoplastic insulation compounds.	14 - 16124 K #7 (Medium Voltage Cables; Installation Guidelines)	SO
3/26/13	Amend item paragraph on acceptable fitting for EMT systems.	20 - 16130 E. #6 (Raceways and Boxes; Materials)	SO
3/26/13	Add next item defining data and security system runs.	25 - 16130 F #18 (Raceways and Boxes; Installation Guidelines)	SO
3/26/13	Amend text for cover plates on emergency power systems.	34 - 16140 G. #9 (Wiring Devices; Installation Guidelines)	SO
3/26/13	Add next item addressing separation of alternate and emergency power runs from normal power runs/	34 - 16140 G. #10 (Wiring Devices; Installation Guidelines)	SO
6/14/13	Amend manufacturer list for updated parent company name (BICC is now General Cable) and fix alpha order.	4 - 16120 E. #1 (Conductors and Cable; Manufacturers)	SO

## 16120

### **Conductors and Cables**

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## CONTENTS

- A. [Summary](#)
- B. [System Design and Performance Requirements](#)
- C. [Submittals](#)
- D. [Product Standards](#)
- E. [Manufacturers](#)
- F. [Materials](#)
- G. [Preparation](#)
- H. [Installation Guidelines](#)
- I. [Quality Control](#)



### A. Summary

This section contains design criteria for building wire and cable, flexible cords, connecting devices, and related materials for use on systems below 600 volts.

### B. System Design and Performance Requirements

1. For power and lighting systems, use single-conductor stranded wires installed in conduit, whenever possible. Use cables only if FMC is unsuitable due to size or other restrictions. However, cables may be specified in the tenant spaces of Yale University Investments Office properties when permitted by the Yale University Project Manager.
2. Except for special situations, such as excessive voltage drop or a high ambient environment, the minimum wire size for power and lighting branch circuits is #12 AWG. The minimum wire size for control circuits is #14 AWG. In instances where the length of the control circuit (measured from source to operating device) exceeds 250 feet, the minimum wire size is #12 AWG.
3. Where single conductors are used for fire alarm systems, the minimum wire sizes are #16 AWG for initiation circuits and #14 AWG for signal circuits.
4. Specify insulated equipment grounding conductors for all conduits containing circuits operating at over 50 volts to ground.
5. Base conductor ampacities on 75°C ratings, unless required connections are rated at 90°C. All conductors shall be copper.
6. For voltage drop calculations, assume a nominal system voltage at the building service entrance with all connected loads energized. Where certain loads cannot operate simultaneously, the smaller load may be omitted from the calculations. Minimum voltages with a full connected load energized are:
  - At all panelboards—98 percent of nominal voltage
  - At all utilization equipment—95 percent of nominal voltage or no more than 3 percent of nominal voltage from panelboard



7. Ensure that branch circuits supplying personal computers and other equipment generating harmonics in the grounded circuit conductor are run with individual neutral. Where individual neutrals cannot be provided due to raceway size restrictions, multiwire branch circuits may be provided with neutral conductor ampacity sized at 200 percent of the setting of the overcurrent protective device **or** with neutral conductor sized at 200 percent of the size of phase conductor whichever is higher. Where one-third or more of the connected load or anticipated future load on a feeder consists of such equipment, ensure that feeder neutrals are similarly oversized. Where the size of ungrounded conductors is increased due to voltage drop, increase neutral size accordingly.
8. Ensure that feeder schedules shown on construction documents are in accordance with [Section 01064: Electrical Regulatory and Directive Standards](#).
9. Ensure that EM&C system control wiring provided under Division 16 includes the following:
  - Wiring from the power source to the Direct Digital Control (DDC) panels
  - Wiring from remote input points to the DDC panels
  - Wiring from the DDC panels to controlled output devices
  - Wiring from DDC panels to the telephone system connection for communication with the central system
10. On the Central and Science Campuses, ensure that all EM&C control wiring is compatible with the Johnson Controls "Metasys" system.
11. On the Medical School Campus, ensure that all EM&C control wiring is compatible with the Robertshaw Controls "DMS350A" system.

### C. Submittals

Submit wiring diagrams showing point-to-point interconnections and terminations, cabling, identification schemes, logic diagrams, switch settings, and jumper positions.

### D. Product Standards

Ensure that all products conform to the following standards:

- ICEA S-19-81, Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
- ICEA S-61-402, Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy



- UL 62, Flexible Cord and Fixture Wire
- UL 83, Thermoplastic-Insulated Wires and Cables
- UL 310, Electric Quick-Connect Terminals
- UL 486A, Wire Connectors and Soldering Lugs for Use with Copper Conductors
- UL 486C, Splicing Wire Connectors
- UL 486E, Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors
- UL 510, Insulating Tape
- UL 1059, Electrical Terminal Blocks
- Johnson Controls, Metasys Design Manual
- Robertshaw Controls, Electronics Products Master Catalog

## E. Manufacturers

1. Subject to compliance with the design requirements, provide 600 V cables by one of the following manufacturers:
  - American Wire and Cable
  - Chromalox
  - Colonial Wire and Cable
  - General Cable
  - Nelson
  - Rockbestos
  - Southwire



### F. Materials

1. Use only single-conductor, insulated, stranded copper cables, cords, or building wire. Use flame-retardant, dual-rated, type XHHW-2, 600 volts conductor insulation rated at 75°C in wet locations and 90°C in dry locations. The insulation must be labeled as Gasoline and Oil Resistant II.
2. Use the following stranded copper wiring for control systems and fire alarm systems that use single conductors in conduit:
  - #14 AWG: Type XHHW-2, 600 volts, 19 strands
  - #16 AWG: Type SF-1, SFF-1 or SFF-2, 300 volts, 7 strands
  - #18 AWG: Type SF-1, SFF-1 or SFF-2, 300 volts, 7 strands
3. Where permitted, use type MC cables with type XHHW-2 copper conductors and an insulated grounding conductor contained within an interlocked steel sheath constructed with integral bonding wire so that sheath is also suitable for grounding.
4. Where specified use type STOO flexible cords with type XHHW-2 conductors and an insulated grounding conductor.
5. Make connections other than terminations at equipment lugs as follows. Connecting devices requiring solder are not acceptable.
  - Feeders—copper compression connectors or tin-plated copper power distribution blocks
  - Branch circuits—insulated spring wire connectors
  - Control circuits—tin-plated copper fork or ring terminals, quick-connect terminals, or terminal blocks
6. For instrument cables single or multi paired, use shielded, twisted pairs of #18 AWG stranded copper conductors, with 300 volt insulation, contained in blue teflon jackets. Unless completely installed in conduit, all cables must be plenum rated. Cables must be 2-, 3-, or 4-conductor, as required by specific design conditions.



7. Use Anixter #889315 pre-made cables to connect temperature sensors ("metastats") to the telephone system, including 25 feet of 8-conductor plenum cable and RJ45 connectors.
8. Use #14 AWG, type XHHW-2 wiring on 120 VAC systems to provide power for EM&C system control panels and control devices, such as actuators, freezestats, and starters. If circuits have 20 amp breakers then wiring shall be #12 AWG.
9. Wiring in the plenums shall be rated for the area. Type AC cable or other factory assembled multi-conductor cable of metallic wiring systems with no nonmetallic sheath shall not be used in plenum areas. Other types of cables and conductors have to be installed in electrical metallic tubing, metal conduit, metal wireway, or solid metal tray. All cables shall be listed as having adequate fire-resistant and low smoke-producing characteristics.
10. The use of MC cable shall only be from a branch junction box to single branch device. Branch circuits home runs with MC cable is not permitted.

### G. Preparation

1. Comply with the following color-coding requirements for power and lighting circuits:
  - Single phase systems—black for line 1, white for the grounded circuit conductor, green for the equipment grounding conductor.
  - Three phase systems, 208Y/120 volts—black for phase A, red for phase B, blue for phase C, white for neutral, green for ground.
  - Three phase systems, 480Y/277 volts—brown for phase A, orange for phase B, yellow for phase C, gray for neutral, green for the ground.
  - Three phase systems, 480 volts—same as 480Y/277 volts, except no gray for neutral.
  - Isolated ground systems shall be green with yellow tracer for isolated ground conductor.
2. On conductors #8 AWG and larger, black insulation may be used for all phases if colored, pressure-sensitive plastic tape is applied at all terminations in half-overlapping turns for three inches, with last two laps of tape applied with no tension to prevent unwinding.



### H. Installation Guidelines

1. With the following exceptions, run all wiring in conduit or other raceway.
  - Where flexibility is required and FMC is unsuitable due to size or other restrictions, type MC cable may be used. Type MC cable may be used only for device drops.
  - Final connections to exterior floodlights may be made with type STOO flexible cord.
  - Such items as pendent pushbutton stations and cord connectors may be made with type STOO flexible cord.
  - Cabling for fire alarm, intrusion detection, access control, public address, closed circuit television, HVAC control, energy management control, and similar systems, may be run without raceways where permitted by the Yale University Project Manager.
2. Run conductors of different systems in separate raceways. Do not run systems above 250 volts in raceways with systems below 250 volts. Each type of system below 50 volts (controls, public address, access control) is considered an individual system to be provided with dedicated raceways. Do not run conductors serving emergency systems, such as emergency lighting, with conductors of any other systems. Do not run circuits fed from the alternate service system with circuits fed from the normal service system.
3. Include the following requirement in specifications: Where #10 AWG and smaller conductors pass through boxes without termination or splice, loop the conductors once within the box to provide adequate slack should future connections become necessary.
4. Use wire basket grip strain relief devices for all flexible cord terminations.
5. Identify all junction boxes serving EM&C systems by painting the covers blue, as described in Division 9, Finishes.
6. Ensure that color-coding and numbering of individual wires is in accordance with Division 15 requirements.
7. Communication cables or coaxial cables shall be marked in accordance with the requirement of NEC 800.113 or NEC 820.113 respectively.
8. Fire alarm systems wiring shall be run in conduit. All fire alarm system conduit to be painted red.



## I. Quality Control

Perform insulation resistance testing for all #3/0 and larger feeders, and submit the results to Yale University.

**End of Section**





## 16124

### Medium-Voltage Cables

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## CONTENTS

- A. [Summary](#)
- B. [System Design and Performance Requirements](#)
- C. [Submittals](#)
- D. [Product Standards](#)
- E. [Manufacturers](#)
- F. [Materials](#)
- G. [Accessories or Special Features](#)
- H. [Special Requirements](#)
- I. [Quality Control Testing](#)
- J. [Preparation](#)
- K. [Installation Guidelines](#)
- L. [Field Quality Control](#)

### A. Summary

This section contains design criteria for cables, terminating devices, and related materials for use in the medium voltage systems.

### B. System Design and Performance Requirements

1. The Medium Voltage (MV) Cables shall be single conductor, shielded power cable for installations in conduits, underground ducts.
2. Conductor shall be uncoated copper, Type MV-105, Class B compact stranded with minimum of 98% conductivity at 20 degree C.
3. The conductor stress control layer shall be an extruded, black-colored, non-conducting thermoset material in accordance with Part 3 of ANSI/ICEA S-93-639-2004. The minimum point thickness for the 500 kcmil size is 16 mils. This material shall have a high dielectric constant in order to provide the desired stress control. This stress control layer shall be Kerite Permashield or similar material in order to achieve the same results.
4. The cable insulation shall be a thermosetting Ethylene-Propylene Rubber (EPR) material with a minimum of 30 years successful service. The material shall be discharge resistance as demonstrated by the ASTM D2275 test. Insulation thickness shall be 133% (220 mils) and rated 105 degree C for normal operation and 140 degree C for emergency operation.



5. The insulation shield shall be a thermoplastic extruded semi-conducting layer. The layer should be easily removable without the use of special tools or solvents.
6. The cable shield shall be a 5 mil copper tape helically applied with a 20% minimum overlap.
7. The overall jacket shall be low smoke, zero-halogen, black, sunlight resistant polyolefin. The jacket shall be free stripping from the insulation screen and shall be printed with the following legends:
  - a. Manufacturer's Name and Cable Type (Trade Name)
  - b. Conductor size
  - c. CU (Conductor Material –copper)
  - d. Voltage Rating- 15 kV
  - e. Insulation level of 133%
  - f. Insulation Thickness
  - g. Sequential Footage Number (as applicable)
  - h. Year of Manufacture

### C. Submittals

1. Submit the following manufacturer's technical product data:
  - a. Cable construction specifications, data and a sample of the exact design cable shall be submitted for approval before cable manufacture commences.
  - b. Warranty – The manufacturer shall warrant that the cable to be furnished is of first class material and workmanship throughout, and that cable is free from defects in design, material or workmanship, for a period of 40 years when installed, terminated and operated within acceptable industry practices. The manufacturer shall agree to replace any defective section of cable free of charge, and extend the same warranty on the replacement cable.
  - c. Installation instructions and recommendations.
  - d. Splicing equipment and kits.
  - e. Termination equipment and kits.



- f. Manufacturer's factory test data.
  - g. Recommended field test procedures
2. Field Test Reports
- a. After installation perform field acceptance testing and submit certified field test reports. Sections of cable fail the test shall be replaced and retested.

### D. Product Standards

Products shall conform to the following standards:

1. ICEA S-93-639
2. NEMA WC 74
3. AEIC CS-8
4. UL-1072 (For Type MV-105 Cables)
5. ASTM B-496-Compact Strand and ASTM Standard 1000
6. IEEE Standard 383 and Standard 386
7. ANSI Standard C119.1
8. NFPA 70

### E. Manufacturers

1. Subject to compliance with the design requirements, provide medium voltage cables by one of the following manufacturers:
  - a. Kerite (preferred)
  - b. Okonite
2. Subject to compliance with the design requirements, provide medium voltage splicing, terminating kits and connectors by one of the following manufacturers:
  - a. Raychem
  - b. 3M Electrical Products Division
  - c. Thomas & Betts Corporation/Elastimold
  - d. Cooper Power Systems



3. Subject to compliance with the design requirements, provide medium voltage fire proofing tape by one of the following manufacturers:
  - a. 3M Scotch 77 Fire Retardant Arc Proofing Tape with banding of Scotch 69 Glass Cloth Electrical Tape
  - b. Plymouth-Bishop 53 Plyarc Arc and Fire Proofing Tape
  - c. Industrial Energy Products “Hot-Stop” XLN Tape

### F. Material

1. Splice kits shall be a single in-line per conductor (3 kits per feeder) for splicing medium voltage cable in manholes and where it is required.
2. Splice kits, 3M QS and QS II or approved equal, shall be molded EPDM rubber, waterproof, capable of passing ANSI C119.1-1986 water immersion tests, heat-shrink type, compatible with the cable construction, dimensions, and materials. Taped splices will not be acceptable.
3. Connectors for splicing shall be a compression type, compatible with splicing kits and conductors, applied with oxidation-inhibiting compound where applicable and approved for application, for each conductor.
4. Indoor termination kits shall be one per conductor (3 kits per feeder) at medium voltage switchgear. Outdoor termination kits shall be one per conductor (3 kits per feeder) at customer’s dead-end pole for connection to overhead service or in the underground/manhole installation. Outdoor termination kits shall have multiple skirts to increase surface creepage distance. The termination kits shall be compatible with the cable construction, dimensions, and materials, and shall meet Class 1 requirement per IEEE-48-1996. The termination kits package shall include shield ground strap for shielded cable termination.
5. At the primary side of each padmount transformer or padmount switch shall require six, 15 kV, 600A deadbreak elbow connectors and, if required, six matching deepwell inserts. Elbows shall meet the requirements of ANSI/IEEE Standard 386-1995 for separable insulated high-voltage connectors, and shall be fully compatible with 15 kV construction, dimensions, and materials, and with the bushing wells and switching modules provided on the transformers.



6. Connectors and lugs for 15 kV terminations shall be a compression type, compatible with the equipment to which being connected and conductors, applied with oxidation-inhibiting compound where applicable and approved for application.
7. Connectors shall be made by Cooper Power Systems or Elastimold or approved equivalent.
8. The fire proofing tape shall be fire-retardant, arc-proofing, and shall consist of a flexible conformable fabric having one side coated with a fire-retardant, flexible polymeric coating and/or an intumescent elastomer. Tape shall conform to ASTM-1000 standards. The tape shall be 1/16" thickness by 3" width, with non-corrosive to the cable jacket, and shall not be fabricated from any hazardous substances.

### G. Accessories or Special Features

1. Wherever the design called for, usually at padmount loop-fed feeder cables, fault indicators shall be mounted. Fault indicators shall be automatically current reset type with inrush restraint feature, arranged to clamp to cable sheath and provide a display after a fault has occurred in cable. Fault indicators shall not be affected by heat, moisture, and contusive conditions and shall be installed at other conditions recommended by manufacturer. Current reset rated shall be at minimum 2.4A, trip rating 600A, for 0.25"-2.0" diameter cable such as made by Power Delivery Products indicators Cat # 29-3114-000 with automatic reset time of 4 hours.

### H. Special Requirements

1. All MV power cables shall be rated 15 kV including Alternate Power Systems.
2. All power cables in the electrical manhole shall be protected with fire proofing tape.
3. Where alternate power wiring is in a manhole along with the normal power service, all efforts shall be made to insure that the alternate power cables are separated and run as far apart as possible from the normal power cables.

### I. Quality Control Testing

1. Perform factory production tests to insure that conductor resistance, insulation resistance, and high voltage meet all requirements in accordance with above mentioned industrial standards criteria.



2. Specifically voltage withstand, tested for 5 minutes minimum, shall be 47 kV AC and 94 kV DC, minimum.

### J. Preparation

1. Cable reels shall be shipped in an upright position supported by both outside flanges.
2. Water tight seals shall be applied to cable ends to prevent the entrance of moisture during transit, storage and installation.

### K. Installation Guidelines

1. Installation medium voltage cables, splices, terminations, and other required accessories in strict accordance with manufacturer's written instructions, applicable codes, and recognized industrial practices.
2. Prior to cables pulling all ducts shall be swept.
3. Prior to pulling cables into ducts, the contractor shall verify that manufacturer's cable pulling tension, side wall pressure, and bending radii limits and make sure they will not be exceeded.
4. Neatly train, rack, and strap MV cables at each manhole and termination. Install an 1 1/2" engraved plastic tag on each cable at each manhole and termination for feeder number and conductor phase identifications. The cable labeling tag shall be made by Tech Products see Section 16075 Electrical Identification.
5. Splices and taps shall be installed so that they possess equivalent-or-better mechanical strength, ampacity and insulation ratings than cables being spliced.
6. Install cables of less than 500 foot length without intermediate splices.
7. Install size #4/0, 600V, XHHW-2 insulated copper ground conductor with each primary circuit.
8. Prior to application of termination and splice kits, verify that sufficient space is available in the box, enclosure, or manhole enclosing each such termination or splice.
9. Exposed live portions of medium-voltage cable terminations shall be insulated with a minimum 1/4" thick covering of Kearney Air-Seal, or equivalent.



10. Exposed portions of medium-voltage cables in manholes, handholes and pullboxes shall be individually wrapped with arc and fireproofing tape for entire length, plus one inch (1”) into electrical ducts at each entry/exit. Tap shall be wrapped around conductor sets spirally in accordance with manufacturer’s instructions. Non-adhesive tapes shall be banded with a layer of glass cloth electrical tape per manufacturer’s recommendations.
11. Maintain continuity of concentric neutrals and/or metallic shields across splice points, within the waterproof splice kit jacket.
12. Ground shields of shielded cable at terminations, splices, and separable insulated connectors. Ground metal bodies of terminators, splices, cable and separable insulated connector fittings, and hardware.

## L. Field Quality Control

1. Field Testing: Engage a qualified testing and inspecting agency to perform the following field tests and inspects and prepare test reports:
  - a. Perform each visual and mechanical inspection and electrical test stated in InterNational Electrical Testing Association (NETA) Acceptance Testing Specifications (ATS). Provide a written report and certify compliance with test parameters.
  - b. After installing medium-voltage cables and before electrical circuitry has been energized, test for compliance with requirements.
  - c. Remove and replace failed units or sections and retest as specified above.

**End of Section**



## 16130

### **Raceways and Boxes**

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## CONTENTS

- A. [Summary](#)
- B. [System Design and Performance Requirements](#)
- C. [Product Standards](#)
- D. [Manufacturers](#)
- E. [Materials](#)
- F. [Installation Guidelines](#)

### **A. Summary**

This section contains design criteria for conduit, metal raceways, multi-outlet assemblies, and various box systems for general electrical construction. For all underground services refer to Section 16600 Underground Electrical Duct Bank.

### **B. System Design and Performance Requirements**

1. Design metal conduit systems to maintain a continuous grounding path redundant to the grounding path provided by insulated grounding conductors.
2. Where necessary, field-paint conduit or raceway systems to match the color of existing surfaces upon which they are installed.
3. Provide dedicated conduit systems for the following:
  - Alternate service circuits
  - Emergency circuits
  - Fire alarm systems
  - Intrusion detection systems
  - Access control systems
  - Telecommunications systems
  - Public address systems
  - Audio/visual systems





4. Where wiring for environmental controls (including EM&C and isolated HVAC systems) must be run within conduits, provide a dedicated conduit system.
5. Ensure that conduit or raceway routings shown on construction drawings follow actual proposed routings as closely as possible.
6. Give priority over conduit or raceway runs to runs of ductwork and piping that pitch or have similar elevation or location requirements.
7. As much as possible, conceal conduit that runs through finished areas. Design conduit routings that enable conduit to be fished through existing hollow walls and ceilings and routed through adjacent unfinished areas, such as basements, storage rooms, mechanical rooms, closets, and attics.
8. Avoid embedding conduit within concrete slabs.
9. Do not run exposed conduit on exterior walls.
10. Minimum conduit sizes:
  - a. Conduit sizes must be one trade size larger than the minimum sizes permitted by NEC calculations.
  - b. The minimum conduit size above grade must be 3/4 inches, except as noted in paragraph d.
  - c. Where a conduit connects to a single device, such as a wall switch, or to a system, 1/2-inch conduit is permitted if not filled to more than 20 percent of its cross-sectional area.
  - d. The minimum conduit size below grade is one inch, unless noted otherwise in the specification.



11. Use surface raceways only in finished areas where conduits cannot be concealed in existing construction. Types 3000 and 4000 SMR and multi-outlet assemblies may be used in laboratories and offices for flexibility in locating outlets, but must have devices or brackets to fasten them to the base.
12. If unavoidable, design surface raceway routings to blend in with existing architectural elements. Where possible, locate equipment in areas that will keep raceway runs unobtrusive.
13. Wherever possible, route exposed raceways along the tops of baseboards. Where raceways are routed along ceilings, run them tight along the junctions with wall surfaces. To keep raceway installations unobtrusive, rise and drop tight along corners, along door and window casings, or along beams, columns, or other existing features. Raceway runs directly across open wall or ceiling surfaces are not acceptable unless preferred routings are not feasible. Where raceways must be run across open surfaces, minimize extent of the run.
14. Minimize the use of fittings and boxes.
15. Size boxes in accordance with NEC requirements for maximum capacity of the largest conduit entering the box, unless restricted by available installation space.
16. Locate boxes in finished areas above accessible ceilings. Where boxes are installed above inaccessible ceilings, locate them within six inches of the access panel.
17. Enclosures or boxes must be suitable for the locations in which they are installed.
  - a. Dry locations: NEMA 1 (general purpose).
  - b. Damp and wet locations: NEMA 3R (rain-tight).
  - c. Swimming pools and certain laboratories where corrosive fumes may be present: NEMA 4X (corrosion-resistant watertight and dust-tight).
  - d. Areas where gases and vapors create explosion hazards: NEMA 7 (Class I hazardous locations – air-break equipment).
  - e. Areas where combustible dust creates explosion hazards: NEMA 9 (Class II hazardous locations – air-break equipment).
  - f. Carpentry shops, machine shops, and similar locations: NEMA 12 (dust-tight and drip-tight) or NEMA 13 (oil-tight and dust-tight), as applicable.



### C. Product Standards

Ensure that all products conform to the following standards:

- NEMA RN1, Polyvinyl-Chloride Externally Coated Galvanized Rigid Steel Conduit and Electrical Metallic Tubing
- NEMA TC2, Electrical Plastic Tubing (EPT) and Conduit (EPC-40 and EPC-80)
- NEMA TC3, PVC Fittings for Use with Rigid PVC Conduit and Tubing
- UL 1, Flexible Metal Electrical Conduit
- UL 6, Rigid Metal Electrical Conduit
- UL 360, Liquid-Tight Flexible Steel Conduit, Electrical
- UL 514B, Fittings for Conduit and Outlet Boxes
- UL 651, Schedule 40 and 80 Rigid PVC Conduit
- UL 651A, Type EB and A Rigid PVC Conduit and HDPE Conduit
- UL 797, Electrical Metallic Tubing
- UL 886, Outlet Boxes and Fittings for Use in Hazardous (Classified) Locations
- UL 1242, Intermediate Metal Conduit
- UL 5, Surface Metal Electrical Raceways and Fittings
- UL 498, Electrical Attachment Plugs and Receptacles
- UL 50, Electrical Cabinets and Boxes
- NEMA OS1, Sheet-Steel Outlet Boxes, Device Boxes, Covers and Box Supports
- UL 514A, Metallic Outlet Boxes, Electrical
- UL 870, Electrical Wireways, Auxiliary Gutters, and Associated Fittings

### D. Manufacturers

1. Acceptable plastic-coated conduit manufacturers include:
  - Robroy
  - Carlon
2. Acceptable surface raceway systems manufacturers include:
  - Walker
  - Wiremold
  - Hubbell



3. Acceptable rigid galvanized conduit manufacturers include:
  - Allied Tube and Conduit
  - Republic Conduit
  - Western Tube and Conduit

### E. Materials

1. Rigid galvanized metal conduit (RGC), electrical metallic tubing (EMT), and flexible metal conduit (FMC) must be galvanized steel, unless specific design conditions require alternate material.
2. All conduits, liquid-tight flexible metal conduits (LFMC) running into switchboards, boxes, panelboards, or ground bushings must be of interlocked steel construction with a PVC jacket. Specify conduit up to 1-1/4 inch trade size with an integral continuous grounding conductor. Use of Green Field connectors is not acceptable.
3. Rigid nonmetallic conduit (RNMC) must be self-extinguishing, schedule 40 PVC, unless noted otherwise.
4. Fittings and supports must be compatible with conduit material. Die-cast zinc fittings are not acceptable.
5. Bushings must be of a metallic, insulating type, consisting of an insulating insert molded or locked onto the metallic body of the fitting.
  - a. Insulating material must be nylon or thermosetting phenolic. Bushings made entirely of metal or nonmetallic material are not permitted. However, metallic bushings may be used where EMT is terminated without entering a box (such as at telephone backboards).
  - b. Bushings on 1-1/4 inch trade size and larger conduits must be grounding-type.
6. Set screw fittings are not acceptable on EMT systems. Use split, clamp-type, threadless compression fittings.
7. All surface raceways must be steel, with a baked enamel finish, or aluminum. Nonmetallic raceways are not acceptable.



8. Designate raceway sizes and types on construction drawings as follows:
  - a. 500 SMR must be one-piece raceway with a 0.2 square-inch cross-sectional area (equivalent to Wiremold #V500 series) and an ivory finish, unless specific design conditions require an alternate finish.
  - b. 700 SMR must be one-piece raceway with a 0.25 square-inch cross-sectional area (equivalent to Wiremold #V700 series) and an ivory finish, unless specific design conditions require an alternate finish.
  - c. 2100 SMR must be a two-piece raceway with a 0.81 square-inch cross-sectional area, equivalent to Wiremold #2100 series.
  - d. 3000 SMR shall be a two-piece raceway with a 3.51 square-inch cross-sectional area, equivalent to Wiremold #3000 series.
  - e. 4000 SMR shall be a three-piece raceway consisting of a base, cover, and divider, with a 7.50 square-inch cross-sectional area, equivalent to Wiremold #4000 series.
9. Where receptacles are required in types 3000 and 4000 SMR, specify cover plates as described in [Section 16140: Wiring Devices](#).
10. Outlet and device boxes installed in dry locations must be galvanized steel with knockouts. Outlet and device boxes installed in damp or wet locations must be cast malleable iron.
11. Floor boxes must be fully adjustable, cast malleable iron for concrete floors and galvanized steel for wood floors.
12. Pull and junction boxes installed in dry locations must be sheet steel with an enamel finish. Pull and junction boxes installed in damp or wet locations must be cast aluminum with threaded hubs.
13. Wireways must be general-purpose, lay-in type, sheet steel with an enamel finish, and must include knockouts, fittings, and adapters, as necessary for a complete system.



14. Box covers must be suitable for use with boxes. Specify gaskets in damp and wet locations. Where necessary, specify plaster ring or extension covers. Where covers are required in finished areas, provide stainless steel covers with stainless steel fasteners, as described in [Section 16140: Wiring Devices](#). Specify brass covers with brass flanges where floor boxes are installed on carpeted floors. Specify screw covers for wireways, unless directed otherwise by the Yale University Project Manager.
15. NEMA 1 cabinets and enclosures must be sheet steel with an enamel finish. Where cabinets and enclosures are provided for housing controls, such as pushbuttons, pilot lights, and relays, covers must be mounted with a continuous hinge and close with a key-operated flush- or lever-type latch. Covers must also be equipped with an interior steel pocket for the storage of drawings and instructions. Provide an interior panel for mounting items such as terminal blocks, relays, and similar equipment. Provide accessory feet for free-standing units.
16. NEMA 3R enclosures must be sheet steel with an enamel finish.
17. NEMA 4X enclosures: stainless is preferred, but fiberglass-reinforced polyester is acceptable.
18. NEMA 7 and 9 enclosures must be cast aluminum. Covers must be of a threaded type or employ an alternate method to open and close quickly and easily. Covers with numerous bolts are not acceptable. Specify breathers and drains when enclosures are mounted in damp or wet locations.
19. NEMA 12 enclosures must be sheet steel with an enamel finish. Enclosures with knockouts are not acceptable.
20. Raceways used in plenums area shall be metallic construction only with no nonmetallic covering.



### F. Installation Guidelines

1. Unless otherwise noted, exposed raceways in finished interior locations must be surface metal raceway.
2. Specify EMT in all concealed or unfinished interior locations, with the following exceptions:
  - a. Specify FMC in dry locations to fish through inaccessible spaces (for example, within hollow walls or above hung ceilings not constructed of removable tiles or panels).
  - b. Specify FMC to connect to movable equipment, equipment installed in hung ceilings, or bus duct plugs in dry locations. Lengths of such flexible conduits must accommodate all anticipated ranges of movement. Lighting with ground conductor connections cannot exceed six feet.
  - c. Specify FMC to connect to vibrating equipment or equipment where sound isolation is required, including 25 KVA and larger transformers in dry locations.
  - d. Specify LFMC for the installation conditions described in paragraphs a, b, and c that occur in damp or wet locations, or where subject to contact with coolants, oils, corrosives, or other similar substances.
  - e. Specify rigid galvanized conduits for all other installation conditions in damp or wet locations.
  - f. Specify LFMC under raised floors.
  - g. Specify rigid galvanized conduits in hazardous locations. Where flexible connections are required in hazardous locations, specify fittings listed for such use.
  - h. In corrosive locations, specify PVC coated rigid galvanized conduit. Where conduit is also subject to physical damage, specify plastic-coated rigid galvanized conduits. In such locations, conduit fittings must also have plastic coatings.
  - i. Specify rigid galvanized conduits where conduit is subject to physical damage.
  - j. Specify rigid galvanized conduits where conduit is provided for systems operating above 600 volts.



- k. Conduits installed within interior concrete slabs or below grade within building walls are considered to be installed in exterior locations.
- l. All alternate services shall be run in a separate conduit system. If they are going through a common box with normal power system, a divider or barrier shall be installed.
3. Specify rigid galvanized conduits in all exterior locations, with the following exceptions:
  - a. Conduits installed underground must be PVC schedule 80 or fiberglass. Where such conduits are encased by two inches or more of concrete, PVC schedule 40 or fiberglass, may be specified. The minimum earth cover must be 30 inches. Underground conduits serving circuits over 600 volts must be concrete-encased.
  - b. Concrete-encased conduits within buildings must be HDPE or PVC, schedule 40.
  - c. Conduits installed on rooftops must be sunlight-resistant PVC, schedule 80.
4. Conduit bodies used in two-inch trade size runs and larger must be mogul size.
5. Where empty conduits are to be run, specify a pull wire with identification tags at each end, indicating the purpose of the conduit and the location of other end. Plug the end of the conduit with the pull wire in place.
6. Where conduits are to be run underneath metal roof decking, specify spacers that provide a minimum one-inch gap between the conduit and the roof deck to avoid penetration of the conduit by roofing fasteners.
7. Where indicated by seismic criteria contained in [Section 16072: Electrical Supports and Seismic Restraints](#), specify the following:
  - a. Sleeves for conduits 2-1/2 inch trade size and larger.
  - b. Flexible connections where conduit crosses points designed to allow structural movement.
8. Maintain a conduit clearance of at least six inches from hot water, steam, and other high-temperature lines if cross conduit. If parallel to conduit than distance shall be greater than 12". Maintain a clearance of at least six inches between power conduits and instrument or communication conduits.





9. Where multiple circuits serve outlets located in a single length of raceway, connect the outlets in such a way that successive outlets are served by alternate circuits.
10. Install types 3000 and 4000 SMR containing receptacles or telecommunications outlets and MOA 42 inches above the finished floor (measured to the center of the raceway), unless specific design conditions require a different mounting height. Do not, under any circumstances, install such raceways less than 15 inches or more than 54 inches above the finished floor (measured to the center of the raceway).
11. Specify that surface metal raceways be painted in accordance with the requirements of Division 9, Finishes to match adjoining finishes.
12. Conduit bodies may be substituted for conductor pull boxes up to #2 AWG, except in telecommunications systems. Given sufficient conduit quantities and wire fill, outlet boxes 4 inches square by 1-1/2 inches deep or larger may be substituted for pull and junction boxes in runs of 1/2-inch and 3/4-inch conduit
13. The minimum depth of outlet and device boxes is 2-1/2 inches, except for boxes containing only splices, which may be 1-1/2 inches deep. The minimum depth of pull and junction boxes is twice the trade size of the largest conduit entering the box.
14. The installation of back-to-back recessed boxes in walls or partitions is not permitted.
15. Methods of securing raceways and boxes to structures are described in [Section 16072: Electrical Supports and Seismic Restraints](#).
16. Cables, raceways, and equipment installed in the plenum shall be arranged and secured so as to allow the removal of panels and access to the equipment.
17. The connectors used with flexible metal conduit in plenums shall effectively close any opening in the connection.
18. Data and security wiring shall be run in EMT where exposed, including in mechanical and electrical rooms. In areas where these systems are run above drop ceilings, the wiring can be run in open tray.

**End of Section**



## 16140

### Wiring Devices

*This document provides design standards only, and is not intended for use, in whole or in part, as a specification. Do not copy this information verbatim in specifications or in notes on drawings. Refer questions and comments regarding the content and use of this document to the Yale University Project Manager.*

## CONTENTS

- A. [Summary](#)
- B. [System Design and Performance Requirements](#)
- C. [Submittals](#)
- D. [Product Standards](#)
- E. [Manufacturers](#)
- F. [Materials](#)
- G. [Installation Guidelines](#)
- H. [Quality Control](#)

### A. Summary

This section contains design criteria for receptacles, wall switches, and cover plates; as well as miscellaneous items, such as dimmers, small fan speed controls, interval timers, time switches, occupancy sensors, photocontrols, and call-for-aid devices.

### B. System Design and Performance Requirements

1. Confirm all receptacle configurations with the equipment plug to be connected. Use only standard NEMA configurations.
2. All receptacles must be grounding-type, including locking types, three-phase, and special configurations. Where areas of renovation projects contain ungrounded receptacles, remove and replace them with grounding-types receptacles. Replace the plugs and cords on associated equipment, and add grounding conductors to branch circuits to provide a continuous grounding path.
3. Use ground-fault receptacles in preference to ground-fault breakers located in panelboards.



4. Where subject to abnormal conditions, specify receptacles that will withstand the anticipated conditions.
  - a. Specify hospital-grade devices where receptacles are subject to physical abuse.
  - b. Specify pediatric safety-type devices where receptacles are subject to tampering.
  - c. Specify corrosion-resistant devices where receptacles are subject to water spray, high humidity, acid fumes, or other similar conditions.
5. Specify occupancy sensors with off delay for the control of exhaust fans in toilet rooms.
6. Use time switches only for mechanical loads. Use occupancy sensors and photocontrols for automatic control of lighting loads.
7. Locate occupancy sensors on walls. Where necessary, provide ceiling sensors to supplement wall sensors.
8. Locate photocontrols in areas where their operation will not be affected by lighting from buildings, vehicles, or other artificial sources.
9. It is the engineer's responsibility to provide and tag life safety dedicated circuits, such as the circuits for the fire alarm and direct digital controller. Incorporate locking devices for circuit breakers providing power to these circuits.

### C. Submittals

Furnish occupancy sensors with a minimum three-year manufacturer's warranty.



### D. Product Standards

Ensure that products conform to the following standards:

- NEMA WD1, General-Purpose Wiring Devices
- NEMA WD2, Semiconductor Dimmers for Incandescent Lamps
- NEMA WD5, Specific-Purpose Wiring Devices
- UL 20, General-Use Snap Switches
- UL 498, Electrical Attachment Plugs and Receptacles
- UL 508, Electric Industrial Control Equipment
- UL 773A, Non-Industrial Photoelectric Switches for Lighting Control
- UL 943, Ground-Fault Circuit Interrupters
- UL 1449, Transient Voltage Surge Suppressors

### E. Manufacturers

Subject to compliance with the design requirements, manufacturers offering products that may be incorporated in the work include, but are not limited to, the following:

#### 1. Wiring Devices, Fan Speed Controls, and Dimmers

- Bryant
- General Electric
- Hubbell
- Leviton
- Lutron (dimmers only)
- Pass & Seymour

#### 2. Occupancy Sensors

- Leviton
- Hubbell
- Sensor Switch –Preferred
- Switchomatic

#### 3. Interval timers, Time Switches, and Photocontrols

- Paragon



- Intermatic
- Tork
- Zenith

#### 4. Call-for-Aid Devices

- DuKane
- Edwards
- Florence

### F. Materials

1. Use specification-grade, side-wired receptacles only, with nylon or thermoplastic faces, and colored ivory in finished areas, unless other colors are more appropriate for adjacent wall finishes. Receptacles must be rated for a minimum of 20 amperes, except where 15-ampere locking receptacles are required to suit particular equipment.
  - a. Use duplex receptacles that feature break-off tabs for split wiring.
  - b. Use feed-through type ground-fault receptacles for downstream fault protection. For ground-fault protection for personnel, use Class A-rated ground-fault circuit interrupters with test and reset buttons unless in wet or steam areas where GFCI breaker shall be used.
  - c. Use isolated ground receptacles that feature an orange face or marking on the front to indicate an isolated grounding system.
  - d. Use feed-through type surge suppression receptacles for downstream protection that contain visual and audible means to indicate when the device no longer provides specified protection. Surge suppressors must protect against normal- and common-mode surges, with a clamping level maximum of 500 volts upon a 120 volts basis per UL permanently-wired test, a minimum peak energy rating of 140 joules, and a response time of five nanoseconds or less.
  - e. Specify receptacles connected to circuits with a distinctive face color to distinguish alternate circuits from normal circuits. In existing buildings, color codes must match existing systems. Color codes in new buildings are red or marked on front to indicate emergency circuit.



2. Use only specification-grade, side-wired switches, with grounding terminals where available and ivory toggles in finished areas, unless other colors are more appropriate for adjacent wall finishes.
  - a. Use full-capacity, 20 ampere-rated snap switches with resistive, tungsten, fluorescent, and high intensity discharge lighting sources. Use 80 percent capacity snap switches with motor loads.
  - b. Use long-life, LED-type pilot light switches with an illuminating toggle when the load is energized. Toggles must be red.
  - c. Use illuminated, long-life, neon-type switches with illuminating toggles when the load is de-energized. Toggles must be clear.
  - d. Use ivory, slide-type dimming switches with a positive off position and separate rocker switch to allow on-off switching without disturbing the preset light level. Use solid-state dimmers with circuitry to filter radio-frequency interference.
    - (1) Use incandescent dimmers rated for a minimum of 1000 watts.
    - (2) Use fluorescent dimmers that are suitable for use with 28 watt, T8 rapid-start lamps (minimum 6 lamps, maximum 30) and are listed for use with electronic ballasts. Thyristor-type dimmers are not acceptable.
  - e. Use single pole, double throw (center return), momentary contact switches.
  - f. Use ivory, slide-type fan speed control switches for fractional horsepower motors with a positive off position and a separate rocker switch to allow on-off switching without disturbing preset speed levels. The control switches must be single-pole with a minimum 10-ampere rating. Use solid-state speed controls suitable for use with split-capacitor or shaded-pole motors with circuitry to filter radio-frequency interference.
  - g. Use spring-wound, rotary electronic-type interval timer switches with a 30 minute range. The interval timer switches must be single-pole, single-throw, with a minimum 15-ampere rating at 120 volts.



- h. Use digital controller time switches with a capacitor backup requiring no battery. If the required configuration is not available with a capacitor backup, an alkaline battery backup may be specified. Time switches must be suitable for 120 volt control with minimum single-pole, double-throw dry contacts rated at 20 amperes inductive at 120/240 volts. Time switches must also contain an LCD display and must be capable of seven-day scheduling with automatic daylight savings time and leap year adjustments that include a minimum of 16 set points at one minute resolution and manual override capability to next scheduled event.
- i. Use passive, infrared-type occupancy sensing switches for lighting control. Sensing switches must be rated at a minimum of 600 watts and equipped with an Off-Automatic selector switch with manual override by special key only. The time delay must be field-adjustable from 1 to 20 minutes. Sensitivity must also be field-adjustable. The LED must indicate when motion is sensed. Sensor failure must result in a continuously-energized load. After a power failure, the sensor must energize the load instantly upon restoration of power. Sensors must be RFI resistant and compatible with electronic ballasts.
  - (1) The minimum sensing pattern of wall-mounted sensors must be 160° in the horizontal plane and 40° in the vertical plane, except in cases where a narrower pattern is required to eliminate detection of unrelated motion.
  - (2) The minimum sensing pattern of ceiling-mounted sensors must be 360° around the vertical axis, except in cases where a narrower pattern is required to eliminate detection of unrelated motion.
  - (3) Sensors must be capable of sensing, at a distance of 20 feet, the motion of a 12-inch long object rotating around the central axis of the sensor (with one end of the object fixed on the central axis) at a rate of 90° per second through a 90° arc in a plane perpendicular to the central axis of the sensor.
- j. Use single-pole, single-throw type photocontrol switches rated at a minimum of 2000 watts for tungsten loads and 1900 volt-amperes for ballast loads. The photocontrol must energize the load when the ambient illumination falls below 1.5 footcandles and de-energize the load when the ambient illumination rises above 4.5 footcandles. A minimum 15-second delay is required to avoid nuisance switching. Failure of photocontrol shall result in a continuously-energized load.



3. Use ASTM type 430, stainless steel cover plates for recessed boxes in finished areas and for boxes on surface metal raceway systems. Use nylon plates where colored cover plates are required. Use galvanized steel cover plates for surface boxes on exposed conduit systems.
  - a. Covers for cast boxes must be cast of the same metal as the box and equipped with a gasket.
  - b. Covers for weatherproof receptacles in damp locations must be cast aluminum for horizontal mounting, with an individual, spring-loaded, gasketed cover for each boss of a duplex receptacle.
  - c. Covers for weatherproof receptacles in wet locations must be polycarbonate for horizontal mounting, with a hinged cover enclosing sufficient space for attachment plugs and cords to be connected with the cover closed.
4. Call-for-aid devices located in single-occupancy handicapped toilets must be equipped with an actuating pull cord station that energizes a corridor lamp and buzzer until reset.
  - a. The pull cord station must be of a single pole, double-throw, toggle switch type bearing the legend "PULL FOR HELP" on a stainless steel cover plate.
  - b. The corridor light and buzzer must consist of a white plastic dome mounted on a stainless steel cover plate, with a 120-volt lamp and buzzer.





### G. Installation Guidelines

1. The following list identifies the standard mounting heights of receptacles and switches from a finished floor to the center of the device:
  - Receptacles (except as noted below): 18 inches.
  - Receptacles above counters: 12 inches above the counter surface to the center of the device.
  - Switches: 48 inches.
2. Install receptacles in the vertical position with the grounding pole at the top of the receptacle face. Receptacles installed in two-piece surface metal raceway systems, or with weatherproof covers, may be installed horizontally. Install switches on the strike side of a door, approximately four inches from the trim, in a vertical position with the load de-energized when the toggle is down. Arrange three-way switches such that the load is de-energized when both toggles are in the same position.
  - a. Switches should generally be located within sight of the controlled load. Where switches are within sight of the controlled load, pilot light toggles should be specified.
  - b. In dark rooms, install a switch for the control of safe light on strike side of the door and a switch for general room light on the hinge side of door to prevent accidental energizing of room light when the dark room is in use.
  - c. Whenever possible, install receptacles with protective functions, such as feed-through protection in ground-fault and surge suppressor receptacles, in locations where the protective function is evident from the location of the protected device.
  - d. All receptacles shall be marked with adhesive markers identifying the panel and circuit number.
3. Wrap conductors a 3/4 turn around screw terminals. Back wiring screwed terminations are allowed.
4. Install dedicated neutral conductors on the load side of dimmers and fan speed controls.
5. Use bonding jumpers to connect branch circuit equipment grounding conductors to devices and boxes.



6. Where switches are ganged on 277-volt systems, provide a barrier between each switch.
7. Where a controlled load is not within sight of the switch location, use pilot light switches, and specify an engraved cover plate describing the purpose of the switch.
8. In laboratories and health care facilities, install receptacle cover plates with adhesive markers identifying the circuit number.
9. Where receptacles are connected to emergency circuits, install red cover plates, "EMERGENCY" unless the receptacle face is color-coded in accordance with the standard in use throughout the building. Where receptacles are connected to alternate system circuits, install red cover plates engraved with the legend, "ALT. SYSTEM".
10. All emergency and alternate wiring and raceways shall be isolated from the normal system.

## H. Quality Control

Use a plug-in receptacle tester to verify proper receptacle wiring. Use an external, calibrated ground-fault simulator to test all receptacles protected by ground-fault circuit interrupters for proper operation.

**End of Section**