A. Summary

This section contains design criteria for individually-mounted, molded-case circuit breakers rated at 600 volts or less, low-voltage power circuit breakers, and safety disconnect switches.

B. System Design and Performance Requirements

1. Provide load-break rated safety switches as a means of disconnecting all equipment. The design engineer must determine whether the AIC rating of the equipment supplied can withstand the phase-to-phase short-circuit rating of the electrical system. Do not solely rely on references to NEC requirements.

2. Switches must be non-fusible, except where a feeder supplies more than one piece of equipment. In such cases, the branch circuit switches must be fusible and must be specified complete with fuses of the size required for each component.

3. Provide short-circuit protection for the motor circuit at the starter location. Where the starter is not located within sight of the motor, use a non-fused type disconnect switch at the motor location.

4. Provide six-pole safety switches when located on the load side of the following types of controllers:
   - Two-speed (two windings) starters
   - Wye-delta starters
5. The short-circuit interrupting ratings for circuit breakers shall be in accordance with a short-circuit analysis that accounts for all current sources and impedances between the sources and the circuit breakers. Series ratings are not acceptable.

6. Selectively coordinate all circuit breakers for all fault and overload conditions. Ensure that that breaker opens before any overcurrent device on its line side and remains closed throughout the clearing time of any device on its load side.

7. Where circuit breakers are specified with adjustable trip settings, ensure that the construction documents include the required settings for all trip adjustments, based on the result of short-circuit and coordination studies. The means of adjustment must be rendered inaccessible to unqualified persons by specifying locking covers or seals where commercially available. Where such covers or seals are not available, locate circuit breakers within dedicated electrical rooms equipped with locking doors.

8. Molded-case circuit breakers may be specified in switchboards, panelboards, individual enclosures, or in combination starters as described in the next paragraph.

9. Specify circuit breakers for motor branch circuits as follows:
   a. Specify magnetic-only circuit breakers only in combination starters.
   b. Type HACR circuit breakers may be specified only when the protected equipment is labeled for use with such breakers.

C. Submittals

Submit the following design and construction documents.

1. Designer Submittals
   Submit sizing calculations for switches over 100 amperes.

2. Construction Documents
   - Shop drawings
   - Operation and maintenance instructions
D. Product Standards

Ensure that all products conform to the following standards:

- NEMA KS1, Enclosed Switches
- UL 98, Enclosed Switches
- NEMA AB1, Molded Case Circuit Breakers
- NEMA SG3, Low-Voltage Power Circuit Breakers
- UL 489, Molded-Case Circuit Breakers and Circuit-Breaker Enclosures
- UL 943, Ground-Fault Circuit Interrupters

E. Manufacturers

Subject to compliance with the design requirements, provide products by one of the following manufacturers:

- Eaton
- General Electric
- Square D
- Challenger (for circuit breakers)
- ABB

F. Equipment

1. Use NEMA 12, heavy-duty type safety switches with quick-make/quick-break switching mechanisms, dual horsepower ratings, and minimum short-circuit withstand ratings of 100,000 amperes. Switches must be fully enclosed with defeatable cover interlocks and indicating handles that accept a minimum of three padlocks.

2. Switches used in conjunction with variable frequency drives must be able to completely isolate the power and control to VFDs. Disconnect switch between VFD and motor shall have an early break auxiliary contact interlock such that it will disable the open permissive circuit of the VFD prior to opening the motor power circuit.
3. Use quick-make/quick-break, trip-free, thermal-magnetic type, molded-case circuit breakers. Automatic tripping must be clearly indicated by the operating handle assuming a mid-position between "ON" and "OFF." Two- and three-pole breakers must have an internal common trip. All circuit breakers must be bolt-on type, and must be 100-ampere frame minimum, suitable for use in 40°C ambient temperatures.

4. Specify all circuit breakers with mechanical conductor terminations rated for use with 75°C wiring.

6. All 15- and 20-ampere, single-pole circuit breakers shall be marked for switching duty.

7. All circuit breakers rated over 400 amperes must be rated 600-volts AC, with an adjustable magnetic trip and interchangeable trip units.

G. Installation Guidelines

1. Specify a minimum 1/4-inch air gap between the switch and the wall when mounting the switch on the inside of a below-grade exterior wall.

2. Mount groups of switches or breakers at uniform heights. Specify mounting heights as follows (measured above the finished floor to the center of the handle):
   a. For stand-alone switches or breakers: 48 inches.
   b. For switches or breakers installed with starters below: 60 inches.

3. Specify handle locks for all critical circuits that should not be operated by unauthorized persons (for example, circuits feeding fire alarm systems, time clocks, communications equipment, and certain computers).

H. Quality Control

Verify proper operation of all ground-fault breakers by testing them with an external, calibrated, ground-fault simulator.

End of Section
16415
Transfer Switches

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.

Change History

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<td>Add Eaton/ Cutler-Hammer to the list of acceptable Manufacturers.</td>
<td>7 - 16415, E. #1 (Transfer Switches; Manufacturers)</td>
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<td>Add paragraph 10 at the end of section F.</td>
<td>9 - 16415, F. #10 (Transfer Switches; Equipment)</td>
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A. Summary

This section contains design criteria for automatic transfer switches and manual bypass or isolation switches.

B. System Design and Performance Requirements

1. Select three-cycle, short circuit closing and withstand ratings of transfer switches, including bypass/isolation switches, in accordance with a short circuit analysis that takes into account all current sources and all impedances between the sources and the switch.
2. Specify the automatic transfer sequence as follows:
   a. If the building has an emergency generator and when the normal source voltage drops below 80 percent on any phase (after a time delay adjustable up to six seconds to allow for momentary dips), the engine starting contacts shall close to start the generator.
   b. If the building has no emergency generator, the transfer switch shall transfer to an alternate source when the alternate source has reached or maintained 90 percent of rated voltage and frequency or better, with open transition and with no time delay for life safety loads and a 3- to 5-second delay for other loads.
   c. After restoration of the normal source on all phases to 90 percent of rated voltage, a time delay adjustable up to 30 minutes shall delay re-transfer to allow stabilization of the normal source. If the alternate source should fail during this time delay period, the switch shall immediately return to the normal source.
   d. The transfer switch shall be equipped with a programmable logic controller (PLC) based sensing operation, the logic must have a self-diagnosis capability to detect power or logic failure.
   e. For switches controlling engine-generator sets, the engines shall be allowed to operate at no load for a fixed, five-minute period after re-transfer to the normal source.

3. Specify an Automatic Transfer Switch (ATS) with an integral Bypass/Isolation Switch (BPS) where the transfer switch serves critical loads that cannot be interrupted at any time for testing and maintenance.

4. The nameplate ampacity of switches must be a minimum of 140 percent of the connected load at nominal system voltage.

C. Submittals
   Submit the following design and construction documentation.

   1. Designer Submittals
      Submit switch size calculations.

   2. Construction Documents
a. Product Data
   • Shop drawings and product data
   • Parts list

b. Operations and Maintenance Data
   Submit operation and maintenance instructions.

D. Product Standards
   Ensure that all products conform to UL 1008, Automatic Transfer Switches standards.

E. Manufacturers
   1. Subject to compliance with the design requirements, provide products by one of the following manufacturers:
      • Automatic Switch Co.
      • Eaton/Cutler-Hammer
      • Russelectric
      • Zenith
      • Square D
   2. Both the ATS and BPS must be supplied by the same manufacturer. The manufacturer must verify that the design has been in continuous production for not less than five years, with at least ten similar installations operating continuously and successfully for that period of time.

F. Equipment
   1. The ATS must have three poles and solid neutral, with all poles mounted on a common shaft. The ATS must be double-throw, actuated by a single electrical operator, momentarily energized, and connected to the electrical operator with a simple over-center type linkage. The total transfer time must not exceed one-half second. The transfer switch must be capable of transferring successfully in either direction with 70 percent of rated voltage applied to the switch terminals.
2. The normal and emergency contacts must be positively interlocked mechanically and electrically to prevent simultaneous closure. The main contacts must be mechanically locked in both the normal and emergency positions, without the use of hooks, latches, magnets or springs, and must be provided on all transfer switches. Interlocked, molded-case circuit breakers or contactors are not acceptable.

3. The ATS must be equipped with a safe manual operator, attached permanently to the motor operator and designed to prevent injury to operating personnel. The manual operator must provide the same contact-to-contact transfer speed as the electrical operator to prevent flashover from switching the main contacts slowly.

4. The BPS must provide a safe and convenient means for manually bypassing and isolating the ATS, regardless of the condition or position of the ATS. The BPS must also be able to be used as an emergency back-up system in the event of ATS failure. Operation of the BPS must be assured, regardless of the position of the ATS. In addition, the BPS must be used to facilitate maintenance and repair of the ATS. The ATS must be completely isolated from the BPS by means of insulating barriers and separate access doors to positively prevent a hazard to operating personnel while servicing the ATS.

5. Inherent double-throw (break-before-make) operation of the BPS must provide positive assurance against accidentally short-circuiting the normal and alternate power sources. Arrangements using the interlocking of single-throw devices are not acceptable. The operating speed of the contacts must be independent of the speed at which the handle is moved.

6. The BPS must be fully manually operated and must not be dependent upon electrical operators, relays, or interlocks for operation.

7. Provide indicating lights to show the BPS in the bypass position, in the fully isolated position, and to indicate source availability. Include a maintained-type test switch to simulate a normal power failure. Mount two auxiliary contacts, rated at 15 amperes, 120 volts, on the main shaft, one closed on normal and one closed on emergency. Wire both contacts to a terminal strip for ease of field connections. Provide one set of relay contacts that open upon loss of the normal power supply.

8. All control wires must be 600 volt, SIS switchboard-type. Identify all control wire terminations with tubular, sleeve markers that are typed with indelible ink.
9. BPS must have mechanical separation of normal and emergency to assure against accidental connection of unsynchronized sources. Electrical interlock will not be considered acceptable.

10. Each transfer switch shall have a Schneider/Square D PowerLogic 7300 ION Meter connected to the load side of the ATS switch. If there is enough room in the switch, this meter can be mounted on or in the switch. If there is not sufficient room in the switch, the Ion Meter shall be mounted in a NEMA 12 enclosure, located as close as possible to the ATS switch and wired to the components in the switch. See YALE standard 16950 Electrical Utility Metering for the complete specification on the ION Meter and the electrical components necessary to have a complete and functional system. Meter as installed shall be visible from the outside of either this enclosure or ATS switch. Contractor shall install a raceway for data cable to connect this meter with the Yale data collection system via a connection point within the building to be specified by Yale.

G. Quality Control Testing

1. Factory testing must be in accordance with UL Standard 1008 for Automatic Transfer Switches and certified by a nationally-recognized testing laboratory.
   a. During the three-cycle closing and withstand tests, there must be no contact welding or damage. Perform the three-cycle tests without the use of current limiting fuses. Furnish oscillograph traces across the main contacts to verify that contact separation has not occurred, and that there is contact continuity across all phases after completion of testing.
   b. When conducting temperature rise tests, the manufacturer must include post-endurance temperature rise tests to verify the ability of the transfer switch to carry full-rated current after completing the overload and endurance tests.

2. The manufacturer must provide certified copies of factory test reports upon request.

H. Installation Guidelines

Relays, timers, control wiring, and accessories must be front-accessible.
I. **Quality Control**

Demonstrate proper transfer operation by opening the circuit breaker or switch in normal distribution system on the line side of the transfer switch. After an alternate source is operational, demonstrate re-transfer by closing the breaker on the normal side. Demonstrate re-transfer again by opening the breaker on the normal side. After transfer, test immediate re-transfer by closing the breaker on the normal side and opening the breaker on the alternate side during the timing period.

End of Section
## 16420 Motor Controllers

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### A. Summary

This section contains design criteria for magnetic contactors, starters, and combination starters.

### B. System Design and Performance Requirements

1. Combination starters are the preferred motor control devices. Do not provide separate enclosures for switches and starters unless required by the application; for example, HVAC equipment furnished with a starter as part of the equipment package, where a separate disconnect must be provided in compliance with Division 16 standards.

2. Starters and contactors designed to NEMA standards are preferred over IEC standards. Where IEC starters are necessary, specify type 2 coordination.

3. Starters must be full-voltage type, unless the specific application requires other types.

4. A solid-state overload relay, with a class 20 trip curve and phase loss protection, is the preferred type of overload protection, except as follows:
   a. Where fractional motors are furnished with integral thermal protectors, separate overload protection is not required.
   b. Where a specific application requires alternate type of overload protection.

5. Motor Circuit Protectors (MCP) are the preferred type of short-circuit protection for motor circuits, unless the specific application requires other types.
6. Locate starters within sight of the motor, unless a motor control center is provided.

7. For loads other than motor loads, the preferred location for branch circuit protection is a panelboard. Consequently, avoid the use of combination contactors, except where tapping from a feeder or other source that does not provide adequate protection.

9. Select contactors specifically for the load served. Do not use lighting contactors for motor loads, or motor contactors for lighting. However, mixed loads may be connected where contactors are so rated.

10. Use mechanically held (latching) contactors in applications where the load returns to the previous state after loss of power (for example, certain lighting loads not controlled by timers or photocells). All devices controlling mechanically held contactors must be momentary-contact type to avoid coil burnout.

11. Locate contactors where the sounds of operation are not audible in normally-occupied areas.

C. Submittals
Submit shop drawings and product data.

D. Product Standards
Ensure that all products conform to the following standards:

- NEMA ICS 2, Industrial Control Devices, Controllers, and Assemblies
- UL 508, Electric Industrial Control Equipment

E. Manufacturers
Subject to compliance with the design requirements, provide products by one of the following manufacturers:

- Allen-Bradley
- Furnas
- General Electric
- Square D
- Eaton
F. Equipment

1. Magnetic starters or contactors shall include the following provisions:
   - Heaters sized 115% for magnetic starters must suit the actual nameplate ratings of the protected motor, unless integral overload protection is provided in the motor.
   - Holding circuit contact.
   - Auxiliary contacts.
   - Hand-off-automatic selector switch, unless other means of manual control, such as on-off pushbuttons, is provided in the control circuit.
   - Pilot light indicating load energized, unless the motor is within sight of the controller. All indication lights shall be LED type with RED (ON) and GREEN (OFF).
   - Control transformer for 120 VAC controls, unless other control voltage is required. If line voltage matches the control voltage, a transformer is not required. All CPT shall have two fuses on the primary and one fuse on the secondary. The secondary neutral shall be solid grounded. The CPT shall be sized for load requirement plus an additional 50 VA.

2. Combination starters or contactors must include the following provisions, in addition to the applicable provisions listed in paragraph F.1 for magnetic starters:
   - Lockout
   - Defeatable cover interlock
   - Class R fuse clips with all fused disconnect-type devices

G. Installation Guidelines

Mount control equipment at uniform heights, with the center of the disconnecting handle approximately 48 inches above the finished floor. Where separate switches and starters are provided, mount the switches 48 inches above the finished floor and mount the starters below or adjacent to the switches. Mount control equipment installed in motor control centers or switchboards to suit the required arrangement.
Panelboards

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<td>11/21/14</td>
<td>Add paragraph #2 to clarify power separation; sequence subparagraph numbering. Add text to paragraph #9 to clarify minimum rating.</td>
<td>15 – 16442 B. #2. (Panelboards; System Design and Performance Requirements)</td>
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<td>Add paragraphs #9. &amp; #10. for clarification.</td>
<td>15 - 16442, B. #9 &amp;#10., (Panelboards; System Design and Performance Requirements)</td>
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<td>Add text to subparagraph 2. a. for clarification.</td>
<td>18 – 16442. F. #2. a. Panelboards; Installation Guidelines; Identification Requirements)</td>
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A. Summary

This section contains design criteria for panelboards, including distribution panels and branch circuit panels.

B. System Design and Performance Requirements

1. Where possible, provide separate panelboards to serve each of the following load classifications:
   - Lighting
   - Motors and general-use receptacles
• Equipment requiring clean power

2. Where there is one feeder that goes to multiple panels, there shall be a disconnect switch that is separately mounted and placed before each panelboard or switchboard, on that feeder circuit.

3. Panelboards must be surface-mounted in electrical closets, where electrical closets are available. Where electrical closets are not available, locate panelboards in mechanical rooms or similar unfinished areas where surface mounting is permissible. Door hinges must be piano type, double hinged, with a lockable latch.

4. Where electrical closets, mechanical rooms, or similar unfinished areas are not available and panelboards must be located in finished areas, flush-mount the panels in walls with all branch circuit conduits concealed within the walls. Provide spare two-inch conduit to a spare 12-inch by 12-inch junction box mounted in an accessible, concealed location.

5. The nameplate ampacity of panelboards must be a minimum of 140 percent of the connected load at nominal system voltage.

6. Panelboards rated at 100 amperes must contain space for 30, single-pole circuits. Panelboards rated at 225 amperes must contain space for 42, single-pole circuits. At a minimum, panelboards must contain space for 125 percent of the active poles. Where necessary, provide double panels to conform to this requirement.

7. Include in each panelboard a minimum of one spare, 20-ampere, 1-pole circuit breaker for every 750 square feet of floor area served by such panelboard. Certain occupancies, such as laboratories, must be provided with more spares as directed by the Yale University Project Manager.

8. Ensure that panelboard schedules shown on construction documents include type designations, size of breaker ratings, and descriptions.

9. Panelboards shall be fully rated for the short circuit current available at the main terminals. Minimum rating shall be 22 KAIC including breakers.

10. All panelboards associated with emergency / alternate electrical systems shall be separated be a wall with a minimum of a 2 hour fire rating. All emergency / alternate panelboards, transformers, etc. shall be in a separate room from the normal power system.
C. **Product Standards**

Ensure that all products conform to the following standards:

- NEMA PB1, Panelboards
- UL 50, Electrical Cabinets and Boxes
- UL 67, Electric Panelboards

D. **Manufacturers**

Subject to compliance with the design requirements, provide products by one of the following manufacturers:

- Eaton
- General Electric
- Square D, types NQOD, NEHB, and QMB only

E. **Equipment**

1. Panelboards must include the following features:
   a. A copper bus with a full-capacity neutral.
   b. A ground bar. Panels on clean power systems shall include additional insulated/isolated ground bar.
   c. A hinged cover with externally-accessible screws.
   d. Bolt-on circuit breakers. Plugged-in type circuit breakers are not acceptable.

2. Where system expansion is anticipated, provide panelboards with feed-through lugs or sub-feed lugs.

3. Load centers are not acceptable.

4. Panelboards must be fully bussed with mounting brackets for all positions, including spares.

F. **Installation Guidelines**

Where panelboards are flush-mounted in fire-rated walls, include installation details to maintain the fire resistance rating of the wall assembly.
1. Panelboard Designation Format

Panelboard designations must adhere to the following format, which provides identifiers for system type and panel location, separated by a slash (for example, HPP/3M1, ELP/B2, CP/1).

a. The first component of the system identifier must indicate the type of distribution system.
   (1) For normal systems: no letter.
   (2) For emergency/alternate systems, use the letter E.

b. The second component of the system identifier must indicate the system voltage level.
   (1) For systems of 120/208 and 240 volts and below: no letter.
   (2) For systems of 480 volts, use the letter H.

c. The third component of the system identifier must indicate the classification of loads served.
   (1) For lighting, use the letters LP.
   (2) For ordinary power, use the letters PP.
   (3) For clean power, use the letters CP.
   (4) For the main distribution panels (maximum of one per building for each voltage level), use the letters MDP (a location identifier is not required).

d. The first component of the location identifier must indicate the floor on which the panel is located.
   (1) For sub-basements: use the letters SB.
   (2) For basements: use the letter B.
   (3) For numbered floors: use the floor number (for example, 1).
   (4) For mezzanines: use the number of the floor number from which access is gained followed by the letter M (for example, 2M).
   (5) For attics: use the letter A.
   (6) For penthouses: use the letter P.
e. The second component of the location identifier must indicate the location of the panel on the floor (for example, by riser number, entryway, or building subdivision).

f. The third component of the location identifier must indicate supplementary information, when applicable (for example, sections of multiple panels or the sequence of sub-panels).

2. **Identification Requirements**
   a. For the panel front, provide an engraved, phenolic nameplate indicating the panel designation. Nameplate shall be black background with white letters.

   b. The directory must be typewritten and indicate circuit designations assigned in the panel schedule.

   c. Number all circuit wiring with preprinted, adhesive identification labels.

G. **Quality Control**
   With all connected loads energized, measure the current in each phase and neutral of the panel feeder, and submit the results to Yale University.

**End of Section**
16443
Motor Control Centers

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<td>Add vendor under Section E.</td>
<td>20 – 16443, E. (Motor Control Centers; Manufacturers)</td>
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A. Summary

This section contains design criteria for motor control centers.

B. System Design and Performance Requirements

1. Motor control centers must consist of the following components arranged in a single assembly, as described in this section. Additional or alternative devices may be provided, as necessary, to suit particular applications.
   - Disconnect switches, circuit breakers, and motor controllers, as described in Section 16410: Enclosed Switches and Circuit Breakers and in Section 16420: Motor Controllers.
   - Fuses, as described in Section 16491: Fuses.

2. Single-sided lineups are the preferred arrangement. Avoid back-to-back arrangements.
C. Submittals
Submit the following design and construction documentation.

1. Designer Submittals
Submit control center layout detail (on construction drawings).

2. Construction Documents
   - Shop drawings and product data
   - Service manuals for operation and maintenance

D. Product Standards
Ensure that all products conform to the following standards:
   - NEMA ICS 2, Industrial Control Devices, Controllers, and Assemblies
   - UL 845, Electric Motor Control Centers

E. Manufacturers
Subject to compliance with the design requirements, provide products by one of the following manufacturers:
   - Allen-Bradley
   - Eaton / Cutler Hammer
   - Furnas
   - General Electric
   - Square D

F. Equipment
1. Provide motor control centers with Class I, Type B wiring, track-mounted terminal blocks for power, and control wiring mounted in the units, unless the specific application and continuous through the length of MCC requires otherwise.

2. All bus bars must be tin-plated copper. The neutral bus must be half-size and run continuous through the length of MCC, unless design conditions require a larger neutral. Provide horizontal and vertical ground busses. Specify full bussing in all vertical sections, with a minimum of 25 percent of the layout available for future use.
3. Design motor control centers and their components for available short-circuit current from a submitted short circuit study, but not less than 42,000 amperes RMS symmetrical.

4. Provide motor control centers with bus barriers and bottom covers to reduce risk of accidental contact.

5. Specify NEMA 12 enclosures for motor control centers located in mechanical rooms.

6. Identify each motor control center and individual unit therein using an engraved nameplate, as described in Section 16075: Electrical Identification.

7. MCC shall be equipped with vertical wireways and top and bottom wiring troughs.

G. Installation Guidelines

Install motor control centers on a four-inch concrete housekeeping pad. Wherever possible, size and locate the pad to allow the addition of future vertical sections. Two size #4/0 ground conductors shall be provided from each two locations from the building grounding system for each complete MCC lineup.

H. Startup and Training

Follow the procedure recommended in standard NEMA PB 1.1 to energize motor control centers.
A. Summary
This section contains design criteria for enclosed bus ducts rated at 225 amperes and higher.

B. System Design and Performance Requirements
1. Size bus ducts at standard ratings equal to or greater than the smaller of the following:
   - 160 percent of the connected load
   - The full-load transformer rating on the line side of busway
2. Bus ducts must be derated where ambient temperatures are expected to exceed 40°C.
3. Do not run bus ducts through fire-rated walls or partitions, unless fittings are specifically listed for such use.
4. Size busses in accordance with the NEC.

C. Submittals
Submit the following design and construction documentation.

1. Designer Submittals
Submit calculations for sizing bus ducts.
2. **Construction Documents**

Submit shop drawings and product data.

**D. Product Standards**

Ensure that all products conform to the following standards:

- NEMA BU1, Busways
- UL 857, Busways and Associated Fittings

**E. Manufacturers**

Subject to compliance with the design requirements, provide products by one of the following manufacturers:

- General Electric
- Square D
- Eaton

**F. Materials**

1. Use plated copper bus bars with polyester insulation or barriers to isolate the bus bars from each other and from the housing.

2. Use steel housings with an enamel finish.

**G. Equipment**

1. Except where feeder-types are specifically required, bus ducts must be plug-in types consisting of standard 10-foot sections, with special sections and fittings necessary to suit the installation. Feeder sections must be interchangeable without the use of special joint covers.

2. Neutral busses shall be the same size as phases. Specify an internal ground bus sized at 50 percent of the phase bus rating. Design busways for a maximum 55°C temperature rise above a 40°C ambient temperature. Brace busways to withstand a minimum 50,000-ampere short-circuit current or sized for the requirement per the submitted short circuit study.
3. Joints for busways rated at 600 amperes and higher must be of single-bolt design and permit safe testing of tightness without de-energizing. One side of the bus duct must be removable for access without disturbing adjacent sections. Provide joint covers with captive hardware.

4. Bus ducts must be non-ventilated and capable of being mounted in any position without derating. Horizontal runs must be suitable for hanging on 10-foot centers. On vertical runs, provide one adjustable hanger per floor.

5. Bus plugs must be circuit breaker types, but fused disconnect types may be used to feed individual motor circuits, if plugs are readily accessible.

H. Installation Guidelines

1. Run horizontal bus ducts at ceiling level.

2. Provide expansion fittings where straight runs exceed 150 feet and where runs of bus duct cross building expansion joints.

3. Bus ducts shall be grounded every 100 feet and connected with a 4/0 ground conductor to the building grounding system.

I. Quality Control

1. Test with megohmmeter or high potential voltage prior to energizing to be sure that excessive leakage paths between phases and ground do not exist.

2. Verify that a proper phase relationship exists between the bus duct and associated equipment.

End of Section
16461

Dry-Type Transformers
(600 Volts and Less)

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A. Summary

This section contains design criteria for low-voltage, dry-type transformers, general purpose power distribution and lighting.

B. System Design and Performance Requirements

1. Design transformers for continuous operation (24 hours per day) at rated KVA, with normal life expectancy.

2. All transformers must be of a delta-wye configuration, except where small loads require buck-boost transformers connected as autotransformers to change from 240 volts to 208 volts, or vice versa.

3. Transformer impedance levels must be minimum of three percent to limit short-circuit currents on secondary systems.
4. Transformers serving loads which generate excessive harmonics in the grounded circuit conductor, as defined for in system design Section 16120: Conductors and Cable, must be selected with K-factor ratings suitable for the load served. Such transformers must be of a delta-wye configuration, three-legged core construction, with full-width copper electrostatic shielding. Because there is no low-impedance path for the third harmonic current, three single-phase transformers and open delta arrangements are not acceptable.

5. Transformers rated up to 225 kVA must be air cooled. All transformers must have copper windings. Distribution transformers that exceed rated 300 kVA and over shall use secondary substation specification Section 16361 with no exception.

C. Submittals
Submit the following design and construction documentation.

1. Designer Submittals
Submit calculations for selection and sizing of all transformers, including:
   - Connected load
   - Future loads
   - Harmonics
   - Temperature considerations

2. Construction Documents
   - Shop drawings and product data
   - Factory test results
   - Operation and maintenance instructions

D. Product Standards
Ensure that all products conform to the following standards:
   - NEMA ST20, Dry-Type Transformers, for general applications
   - NEMA TR27, Commercial, Institutional, and Industrial Dry-Type Transformers
   - UL 506, Specialty Transformers
   - UL 1561, Large General Purpose Transformers
   - ANST Standard Doc for determining energy efficiency for distribution transformers
Yale University Design Standards

Section 16461: Dry-Type Transformers (600 Volts and Less)

- ANSI C57.12.90 Test Code for distribution power transformers
- Latest D.O.E. Efficiency for Transformers

E. Manufacturers

Subject to compliance with the design requirements, provide products by one of the following manufacturers:

- Asea Brown Boveri
- General Electric
- Eaton
- Square D

F. Equipment

1. Transformers must be dry-type with an insulation grade of 220°C total temperature system based on an 80°C rise. All insulation materials must be flame-retardant and must not support combustion, as defined in ASTM D635, Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastic in a Horizontal Position.

2. Transformer cores must be constructed with high-grade, non-aging, grain-oriented silicone steel, with high magnetic permeability and low hysteresis and eddy current losses. Maximum magnetic flux densities must be substantially below the saturation point. Core volume must allow efficient transformer operation at 10 percent above the highest tap voltage. Core laminations must be tightly clamped and compressed. Coils must be wound with electrical-grade copper wiring and continuous-wound construction.

   a. On units rated below 15 KVA, the core and coil assembly must be completely encapsulated in a proportioned mixture of resin and aggregate to provide a moisture-proof, shock-resistant seal.

   b. On units rated at 15 KVA and above, the core and coil assembly must be impregnated with a non-hygroscopic, thermo-setting varnish and cured to reduce hot spots and seal out moisture. Install the assembly on a vibration-absorbing pad and bolt it securely to the base to minimize sound transmission.

3. Transformer sound levels shall not exceed the following:
   - 9 KVA and below: 40 dBA
• 10–50 KVA: 45 dBA
• 51–150 KVA: 50 dBA
• 151–225 KVA: 55 dBA

4. Equip transformers with voltage taps in the primary winding, as follows:
   • 2 KVA and below: no taps required
   • 3–9 KVA: two, five percent FCBN
   • 10–25 KVA: four, 2-1/2 percent FCBN
   • Above 25 KVA: four, 2-1/2 percent FCBN and two, 2-1/2 percent FCAN

5. Transformers enclosures located indoors must be NEMA 1. Transformers located outdoors must be NEMA 3R. Wiring compartments must be suitable for conduit entry and large enough to allow convenient wiring. The core must be visibly grounded to the enclosure.
   a. On units rated below 15 KVA, the enclosures must be totally enclosed, non-ventilated, and equipped with lifting eyes.
   b. On units rated at 15 KVA and above, enclosures must be ventilated and equipped with lifting holes.

6. All transformers associated with emergency / alternative electrical systems shall be located in a separate room that has a minimum fire rating of 2 hours. The normal and emergency / alternative systems shall be in separate rooms.

G. Quality Control Testing
   1. Perform ratio tests on the rated voltage connection and on all tap connections.
   2. Perform polarity and phase-relation tests on the rated voltage connection.
   3. Perform applied and induced potential tests.
   4. Perform the following additional tests on transformers larger than 100 KVA:
      • Resistance measurements on all windings on the rated voltage connection of each unit and at the tap extremes of the first unit made of a new design
      • No-load and excitation current at rated voltage on the rated voltage connection
H. Installation Guidelines

1. Secure transformers to the building structure in compliance with the seismic provisions of the State Building Code, but in such a manner that vibrations are not transmitted to the structure during operation.

2. Make provisions to prevent heat buildup within transformers and within rooms containing transformers.

I. Quality Control

Perform insulation resistance and moisture tests prior to energizing a transformer.
Fuses

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.

A. Summary

This section contains design criteria for fuses rated at 600 volts and less.

B. System Design and Performance Requirements

1. Select the short-circuit interrupting ratings of fuses in accordance with a short-circuit analysis that accounts for all current sources and impedances between the sources and the fuses. The minimum interrupting rating must be 50,000 amperes.

2. Selectively coordinate all fuses for all faults and overload conditions so that a fuse clears before any over-current device on its line side and remains intact throughout the clearing time of any device on its load side.

3. Current limiting fuses may be specified, where appropriate, based on the results of the short-circuit and coordination studies described in paragraphs 1 and 2.

4. Fuses for use on motor circuits must incorporate time delay characteristics to pass motor starting currents.

C. Product Standards

Ensure that all products conform to the following standards:

- NEMA FU1, Low-Voltage Cartridge Fuses
- UL 198C, High-Interrupting-Capacity Fuses, Current-Limiting Types
- UL 198E, Class R Fuses
D. Manufacturers

Subject to compliance with the design requirements, provide products by one of the following manufacturers:

- Bussmann
- Gould Shawmut
- Littelfuse

E. Materials

1. Fuses connected directly to switchboard buses must be Class L. All other fuses must be class RK5, unless specific design conditions require class RK1.

2. The following fuses are not acceptable:
   - Class G fuses
   - Class H fuses
   - Class J fuses
   - Class T fuses
   - Plug fuses
   - Renewable fuses

F. Installation Guidelines

1. Install fuses so that ratings are readily visible.

2. Specify spare fuses as follows:
   - Two sets of three fuses of each size and type installed in main distribution center and distribution switchboards.
   - Ten percent, but not less than three additional fuses for each size and type of fuse used in all other locations.

End of Section