

# **DESIGN STANDARDS**

## **APPENDIX**

### **Section VI. Division 16**

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Yale University  
Facilities Planning & Construction

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**VI. DIVISION 16 – ELECTRICAL**

16100 GENERAL

- A. Provide electrical equipment whose design; manufacture and testing meet the requirements for seismic zone #2.

16120 RACEWAYS

- A. Rigid metallic conduit shall be zinc-coated steel that conforms to industry standards, by Allied Tube and Conduit, Republic Steel, or Wheatland Tube.
- B. Intermediate metallic conduit (IMC) shall be zinc-coated steel that conforms to industry standards, by Allied Tube and Conduit, or Triangle/PWC.
- C. Electrical metallic tubing (EMT) shall be zinc-coated steel that conforms to industry standards, by Republic Steel, Allied Tube and Conduit, or Triangle/PWC.
- D. Wireways shall be sheet steel with hinged spring-latched covers, galvanized or painted to protect against corrosion. Provide necessary bends, couplings, connectors and other appurtenances. Interior parts shall be smooth and free of sharp edges and burrs. Wireways shall be by Square D.
- E. Non-metallic conduit shall be Schedule 40 or Schedule 80, 100% virgin polyvinyl chloride (PVC), 90°C UL-rated, by Carlon.
  - 1. Conduit shall meet NEMA requirements and shall be UL-listed as required by Article 347 of NEC.
  - 2. Conduit, fittings and solvent cement shall be by single manufacturer.
  - 3. Material shall have minimum tensile strength of 7,000 psi at 73.4°F, minimum flexural strength of 11,000 psi, and minimum compressive strength of 8,600 psi.
- F. Liquid-tight flexible metallic conduit as specified for specific equipment.
- G. Conduit expansion fittings shall be threaded hot-dipped galvanized malleable iron with internal bonding assembly by O.Z./Gedney.
- H. Provide threaded malleable iron or steel connectors and couplings with insulated throats; manufactured elbows; locknuts; and plastic or bakelite bushings at terminations, as necessary. Couplings and connectors shall be gland and ring compression or stainless steel multiple point locking or steel concrete-tight set screw. Compression couplings and connectors shall form positive ground. Set-screw connectors and couplings shall have wall thickness equal to conduit, case-hardened, hex-head screws and separate ground wire. Bushings for rigid steel and connectors for EMT shall have insulating inserts that meet requirements of UL 514 flame test.

16122 OUTLET BOXES

- A. Outlet boxes on concealed work shall be at least 4" square or octagonal, galvanized pressed steel with plaster rings as required. Outlet boxes for exposed conduit work shall be cast aluminum alloy with cast aluminum alloy covers.
- B. Where installed in plaster, boxes shall be fitted with galvanized steel plaster covers of required depth to finish flush with finished wall or ceiling.
- C. Switch boxes, receptacle boxes and other outlet boxes shall be standard 4" square with plaster rings or gang cover as required.
- D. Outlet boxes shall be by McKinstry, Appleton Electric Company, or RACO.
- E. Floor outlets shall be heavy-wall cast iron bodies with edge frames and floor plates of polished bronze. Boxes shall be watertight, fully adjustable with interior leveling screws for precise adjustment, and adequate angular adjustment to meet off-level floor conditions. Provide insert floor plates with hinged covers for duplex receptacles or for telephone connection, as necessary. Provide carpet plates where required.
- F. Waterproof boxes shall be Condulet cast boxes with water-proof devices and covers. Provide hot-dipped galvanized corrosion-resistant epoxy enamel finish or PVC-coated products in corrosive areas.
- G. Weatherproof boxes shall be screw-joint outlet boxes, with gasketed weatherproof covers.

16130 PRIMARY POWER CABLE - (ABOVE 600 V)

- A. Medium voltage power cable shall be by Kerite or Okonite, 500 kcmil, 15 kV, copper conductor, EPR insulation, shielded, PVC jacketed, 133% insulated cable as specified and as approved by power company.
1. Conductor: Uncoated or coated annealed Class B stranded copper as required by UL 1072, Paragraphs 4 through 12 and IPCEA S-66-524/NEMA WC7, Part 2.
  2. Conductor Shield: Extruded semiconducting thermosetting compound as required by UL 1072, Paragraphs 13 and 14 and IPCEA S-66-524/NEMA WC7, Part 2.
  3. Insulation: Extruded thermosetting cross-linked polyethylene as required by UL 1072, Paragraphs 16 through 18G and IPCEA S-66-524/NEMA WC7, Paragraph 3.7.1.
  4. Insulation Shield: Free stripping semiconducting coating with overlying semiconducting tape as required by UL 1720, Paragraphs 24 through 28 and IPCEA S-66-524/NEMA WC7, Paragraph 4.1.1.
  5. Metallic Shield: No. 24 or No. 22 AWG uncoated annealed copper wires as required by UL 1072, Paragraphs 25 through 25B and IPCEA S-66-524/NEMA WC7, Paragraph 4.1.1.3.
  6. Jacket: Black PVC as required by UL 1072, Paragraphs 40 through 43, and IPCEA S-66-524/NEMA WC7, Paragraph 4.3.1.

16131 WIRE AND CABLE (600 V INSULATION)

- A. Provide single-conductor, annealed copper wire and cable with insulation rated 600 V, by General Electric, Rome or Okonite. Wire insulated for 300 V may be used where voltage is less than 100 V, if isolated from higher voltages. Wire sizes specified are American Wire Gauge for copper.
- B. All wire shall be stranded. Wire and cable shall have THWN-THHN or XHHW insulation.
- C. Wiring within light fixtures and other high-temperature equipment shall have 150° C insulation as required by NEC.
- D. Cable for direct burial shall be UF.
- E. Provide three-ply marlin twine lacing or self-extinguishing nylon straps with -65 to 350° F range for bundling conductors.

16132 SAFETY DISCONNECT SWITCHES

- A. Switches shall be by Furnas, Square D, General Electric, Allen Bradley, or Cutler Hammer.
- B. Provide quick-make/quick-break safety switches: Type HD, heavy duty, Class 3, Design 3, unless specified otherwise. Provide (stainless steel) (dust-proof) NEMA 1 or NEMA 12 enclosure for dry applications and NEMA 4X for wet. Switches shall be rated 240 or 600 V minimum as required for voltage of associated circuit and shall be rated in horsepower. Fuses shall interrupt locked rotor current of associated motor or ten times full rated load current, whichever is greater.
- C. Mount switch parts on insulating bases to facilitate replacement from front of switch. Current-carrying parts shall be high-conductivity copper. Contacts shall be silver-tungsten or plated. Provide positive pressure fuse clips and switch operating mechanism suitable for continuous use at rated capacity without auxiliary springs in current path.

16140 FUSES

- A. Provide current-limiting, high-interrupting-capacity fuses.
- B. Fuses larger than 600 A shall be Class L time delay Bussman, Littelfuse, or Gould-Shawmut. Fuses 600 A and smaller that serve motors, fusible circuit breaker panelboards, transformers and motor control centers shall be Class RK-1 dual-element current limiting Bussman, Littelfuse, or Gould-Shawmut.

16142 WIRING DEVICES

- A. Provide wiring devices by single manufacturer: Hubbell, General Electric, Leviton, Bryant, or Lutron. Catalog designations of Hubbell and Lutron are specified to establish standards of quality for materials and performance.
- B. Toggle Switches:
  - 1. Single-pole shall be No. 1221, 20A., 120-277 V AC.
  - 2. Double-pole shall be No. 1222, 20A., 120-277 V AC.
  - 3. Three-way shall be No. 1223, 20A., 120-277 V AC.
  - 4. Four-way shall be No. 1224, 20A., 120-277 V AC.
- C. Miscellaneous Switches:
  - 1. In vaportight applications, switches shall be enclosed in Condulet with vaportight cover.
  - 2. Key switches shall be No. 1221-L, 1223-L, or 1224-L, 20 A, 120-277 V.
- D. Receptacles:
  - 1. Duplex shall be No. 5352, 125 V, 20 A, 2-pole, 3 W, grounding.
  - 2. Heavy duty receptacles shall be sized as required for intended service.
  - 3. Duplex convenience outlets and other outlets on emergency circuits shall be red melamine, 125 V, 20 A, 2-pole, 3 W, grounding.
- E. Combination Devices:
  - 1. Combination switch and red neon pilot light shall be No. 1221 switch with No. 1221-ILC-7, 277 V pilot, in two gang combination box.
- F. Dimmers (Incandescent):
  - 1. Provide dimmers rated for incandescent load of 1000 W or 2000 W.
  - 2. Rotary push-on, push-off dimmers shall be Lutron Centurion. Linear slide control dimmers shall be Lutron Nova.

16143 AUTOMATIC CONTACTORS

- A. Contactors shall be by Allen-Bradley, Square D, Furnas, or Cutler-Hammer.
- B. Contactors shall be single-coil, electrically-operated, electrically-held arranged for 2-wire or 3-wire control. Positive locking shall be obtained without use of hoods, latches or semi-permanent magnets.
- C. Main contacts shall be silver-surfaced and shall be protected by arcing contacts and magnetic blowouts with arc barriers. Contacts shall be renewable from panel front.
  - 1. Provide manual operating lever.
  - 2. Contactors shall have integrally-fused control circuits.

16150 MULTI-OUTLET ASSEMBLIES

- A. Multi-outlet assemblies shall be by Wiremold.
- B. Fixed multi-outlet assemblies shall consist of surface metal raceway.
- C. Provide snap-on blank covers or snap-on receptacle covers or both, by raceway manufacturer, with no open cracks.
- D. Raceway and cover shall have neutral gray or buff standard factory finish.

16160 CABLE TRAY SYSTEMS

- A. Provide ladder cable tray systems with straight sections, splice plates, bends, fittings, covers, expanded metal bottoms, hanger assemblies and other necessary components, sized no wider than 18". The cable tray system shall be by B-Line or Mono-System.
- B. Construction:
  - 1. Ladder cable trays shall have 6" high side channels with cross channels on 12" centers.
  - 2. Maximum straight section lengths shall be manufacturer's standard, but shall not exceed 24 feet.
  - 3. Design shall prevent contact between cut metal edges and cable.
- C. Materials: Tray components shall be hot-dipped galvanized steel or aluminum alloy. Materials shall meet ASTM requirements.
- D. Fittings:
  - 1. Fittings for ladder tray shall have 24" bending radius to meet cable manufacturer's bending radius criteria.
  - 2. Fittings for basket and trough trays shall have minimum bending radius of 12".
- E. Simple beam deflection shall not exceed 0.004 of span based upon loads as follows:
  - 1. galvanized steel ladder @ 55 lbs./linear foot,
  - 2. galvanized steel basket or trough @ 45 lbs./linear foot,
  - 3. aluminum alloy ladder @ 40 lbs./linear foot, and
  - 4. aluminum alloy basket or trough @ 50 lbs./linear foot.
- F. Provide galvanized steel wall brackets, hangers, clips, rods, beam clamps, spacers and associated support hardware suitable for 200% of permissible tray load. Bolts, screws and nuts shall be galvanized or shall have zinc or cadmium plate, with anti-corrosion coating.

16250 BUSWAY SYSTEM(S)

- A. Provide UL-listed, low-impedance, fully-enclosed, prefabricated busway with 50% capacity integrated ground bus, by Square D (I-line) or General Electric. Busway shall be suitable for mounting in any position without derating. Temperature rise shall not exceed 55° F above ambient at rated load current.
- B. Perforated busway that meets NEC and UL floor and wall penetration requirements may be used where protection from dust and mechanical damage is not required.
- C. Joints shall be one-bolt, torque-indicating, two-headed and fully-insulated and section of busway shall be removable without disturbing adjacent sections.
- D. Provide insulated electrolytically-plated (copper) bus bars with bolted connections.
- E. For plug-in sections, provide five plug-in openings on each side of ten foot lengths, capable of simultaneous use. It shall be possible to tap at least 40% of busway nameplate ampere rating from single plug-in opening. Plugs shall be side mounted for use of all 10 plug-in openings. Hangers shall not block any plug-in opening. Each phase position of plug-in openings shall be insulated individually.
- F. Provide circuit breaker plug-in units or fusible switch plug-in units with visible blade quick-make/quick-break mechanism. Plug-in units which cannot be operated directly from floor shall have suitable means for hookstick operation.
- G. Provide mechanical interlocks with operating handle between housing and plug-in units 100 A or smaller to prevent insertion or removal with switch ON. Positive ground shall be established between plug-in unit enclosures and busway housing before jaws contact bus bars. Grounding shall not be affected by painting of busway housing. Plug-in units shall have internal barriers to prevent contact of fish tape and conductors with live parts on line side of protective device during wire pulling. Provide releasable interlocks to prevent opening of cover with switch ON. Provide plugs with brackets necessary to padlock switch OFF. Provide plug-in units with means of direct-positioning on busway before plug-in jaws make contact.

## 16330A DRY TYPE TRANSFORMERS

- A. Transformers shall be manufactured by Square D, General Electric, Cutler-Hammer, Acme, or Heavy-Duty. Acme transformers are only acceptable up to 50 kVA.
- B. Provide dry type transformers whose design, manufacture and testing meet the requirements of NEMA No. ST 20 and UL Standards.
- C. Transformers shall have separate primary and secondary windings for each phase, except that three-phase transformers rated 15 kVA or less may have separate tee-connected windings. Primary winding of transformers rated 15 kVA or less shall have at least two taps, each providing 5% increment below full rated voltage. Each primary winding of each transformer larger than 15 kVA shall have four or six taps, two of which shall provide 2-1/2% increments above full rated voltage and two or four of which shall provide 2-1/2% increments below full rated voltage.
- D. Transformers rated 25 kVA or less shall have 150° C, 185° C, or 220° C insulation system rated for continuous operation at rated kVA. Transformers rated higher than 25 kVA shall have 220° C insulation system and shall be rated for continuous operation at rated kVA. Transformer surface temperature rise shall not exceed 65° C.
- E. Provide suitable terminal compartment to accommodate required primary and secondary wiring connections and side or bottom conduit entrance. Transformers rated 25 kVA or less shall have terminal leads with factory-installed connectors arranged and supported in workmanlike manner. Transformers rated higher than 25 kVA shall have terminal boards equipped with factory-installed clamp connectors. Terminal compartment temperature shall not exceed 75° C when transformer is operating continuously at rated load with ambient temperature of 40° C. Terminals for wiring connections shall be suitable for copper or aluminum wiring.
- F. Sound levels determined by NEMA Standards, shall not exceed:

<u>Transformer Rating</u>	<u>Std. Sound Level</u>	<u>Quiet Sound Level</u>
9 kVA or less	40 dB	34 dB
Over 9 but not over 50 kVA	45 dB	38 dB
Over 50 but not over 150 kVA	50 dB	40 dB
Over 151 but not over 300 kVA	55 dB	45 dB
Over 300 kVA	60 dB	48 dB

- G. Transformers 45 kVA and larger shall have integral vibration isolation supports between core and coil assembly and transformer enclosure. Transformers less than 45 kVA shall have integral or external vibration isolation supports.
- H. Transformers shall be air-cooled. Single phase transformers larger than 25 kVA and three- phase transformers larger than 15 kVA shall be fully enclosed in steel enclosures. Smaller transformers shall be fully enclosed in steel enclosures, with or without compound fill, or shall have exposed cores, impregnated windings, and steel enclosures for live parts.

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## 16330B DRY-TYPE TRANSFORMERS - CAST RESIN

- A. Transformers shall be manufactured by Square D, General Electric, Cutler-Hammer, Acme, or Heavy Duty. Acme transformers are only acceptable up to 50 kVA.
- B. Average temperature rise of transformer windings shall not exceed 100° C in low voltage winding, or 80° C in high voltage winding, at full nameplate rating. Transformers shall carry 100% of nameplate kVA rating in 40° C ambient.
- C. HV and LV windings shall be copper, cast separately under vacuum as one rigid tubular coils and arranged coaxially, reinforced with glass cloth. Coils shall be supported by cast epoxy bottom supports and spacer blocks and spring-loaded top blocks, without rigid mechanical connection between coils.
- D. Windings shall not absorb moisture, and shall be suitable for storage and operation in adverse environments, including prolonged storage in 100% humidity from -40° C to +40 C, and shall be capable of immediate activation after storage without predrying.
- E. Transformers shall be free of partial discharge to at least 1.2 times rated line-to-ground voltage. Perform partial discharge test to verify partial discharge of each transformer.
- F. Impulse rating of high voltage winding shall be equal to basic impulse level specified by ANSI for oil-filled distribution transformers of same voltage class, without supplemental surge arresters.
- G. Impulse rating of low voltage winding shall be at least 25 kV for 600 V rms and below.
- H. Cores shall be high grade, grain oriented silicon steel cruciform laminations with mitered corners, with high magnetic permeability. Magnetic flux density shall be less than saturation point. Provide 1-mm thick resin coating on core.
- I. Enclosures shall be heavy gauge sheet steel. Ventilating openings shall meet NEMA and NEC requirements for ventilated enclosures. Enclosures shall have jacking pads flush with enclosure. Base shall be structural steel members that permit skidding or rolling in any direction.
- J. Provide factory-installed rubber vibration isolating pads between core/coil and enclosure. Core shall be grounded visibly to enclosure ground with flexible grounding conductor as required by NEMA and NEC standards.
- K. Provide forced air cooling with: special under-carriage with air plenum chamber, thermal sensors (thermistors), fan and motor, control wiring, control box with pilot switch, current limiting fuses, control power transformer, indicating lights, alarm bell, bell silencing relay and push buttons. Fans shall be heavy duty and of 10" or larger diameter. One thermistor shall be provided in each winding. Operation at increased capacity shall not exceed maximum design temperatures at 40° C maximum ambient. Forced air cooling shall be regulated automatically by thermistors. Percent increase of kVA capacity shall be as follows:
  - 1. 750 kVA and below - 33.3%.
  - 2. 1000 kVA and above - 50.0%.

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- L. Primary taps shall be full capacity, with two taps 2-1/2% above and two taps 2-1/2% below rated voltage. Impedance shall be manufacturer's standard. Sound level shall not exceed NEMA Standard maximum dB for applicable kVA size of dry-type transformers as set forth in NEMA publication TR1-1974.
- M. Transformers shall be able to withstand a fault current rating at 13.8 kV of 500 kVA.

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## 16330C FLUID COOLED TRANSFORMERS - SILICON FILLED

- A. Provide liquid filled transformers which shall be compartment type, self-cooled, for mounting on a pad and shall comply with the latest applicable standards. Provide provisions for future fan-cooled capability. Transformers shall be deadfront construction.
- B. The average temperature rise of the windings, measured by the resistance method, shall be 55/65° C when the transformer is operated at rated kVA output in a 40° C ambient. The transformer shall be capable of being operated at rated load in a 30° C average, 40° C maximum ambient, as defined by ANSI C57.12.00 without loss of service life expectancy.
- C. Coolant and insulating fluid shall be dimethyl polysiloxane 561-silicone transformer fluid by Dow Corning.
- D. The high and low voltage compartments shall be located side by side, separated by a steel barrier. When facing the transformer, the low voltage compartments shall be on the right. Terminal compartments shall be full height, air-filled, with individual doors. The high voltage door fastenings shall not be accessible until the low voltage door has been opened.
- E. The following accessories shall be provided as standard on all transformers:
  - 1. Nameplate in low voltage compartment, 1 inch upper filter press and filling plug, and 1 inch drain valve with sampling device.
  - 2. Tap changer, for deenergized operation only, which is externally operable and padlockable. The front of both compartments shall be removable to allow the transformer to be rolled or skidded into position over conduit stubs. ANSI tank grounding provisions shall be furnished in both compartments.
- F. The transformers shall have a self cooled (OA) rating as shown. Primary voltage as shown. Secondary voltage as shown with two 2-1/2% full capacity above normal and two 2-1/2% below normal taps. Impedance shall be 5.75 %, 7-1/2%. Basic impulse level of the primary winding shall be as specified in ANSI C57.12.00 for comparable kV class.
- G. Transformer shall be able to withstand a fault current rating at 13.8 kV of 500 kVA.
- H. The transformer shall be of sealed-tank construction or sufficient strength to withstand a pressure of 7 psi without permanent distortion. The cover shall be welded and the fastenings tamper-resistant. The transformer shall remain effectively sealed for a top oil temperature range of -5° C to 105° C. When required, cooling panels will be provided on the back and sides of the tank. Lifting eyes and packing pads will be provided.
- I. Coils shall be wound with copper conductors.
- J. Core and coil assembly shall be the five-legged wound core type, using high grade, grain oriented silicon steel laminations carefully annealed after fabrication to restore high magnetic permeability. Magnetic flux is to be kept well below the saturation point.
- K. The high voltage terminations and equipment shall be dead front and conform to ANSI C57.12.26.
- L. Dead front bushings shall be either universal wells or one-piece integrated for use with separable connectors. Bushings shall be externally clamped and front removable.

- M. The low voltage bushings shall be molded epoxy, and provided with blade-type spade terminals with NEMA standard hole spacing arranged for vertical take-off. The low voltage neutral shall be an insulated bushing, grounded to the tank by a removable ground strap.
  
- N. Accessories
  - 1. Dial type thermometer.
  - 2. Magnetic liquid-level gauge.
  - 3. Pressure vacuum gauge.
  - 4. Pressure relief valve.
  - 5. Automatic pressure relief device self resealing.
  - 6. Key interlocks to high voltage door.
  
- O. Testing - Tests shall be conducted in accordance with the provisions of ANSI C57.12.90 and shall include, as a minimum, the following tests:
  - 1. Ratio
  - 2. Polarity
  - 3. Phase Rotation
  - 4. No-Load Loss
  - 5. Excitation Current
  - 6. Impedance Voltage
  - 7. Load Loss
  - 8. Applied Potential
  - 9. Induced Potential
  - 10. QA Impulse Test
  
- P. Additional Testing: Test dielectric liquid to ASTM D877 using 25,000 volts minimum breakdown voltage.

## 16332A MAIN SWITCHBOARD (FUSIBLE SWITCH)

- A Provide UL-listed service entrance distribution switchboards supplied by Square D, General Electric, or Cutler-Hammer.
- B Enclosure Construction
  - 1 Switchboard shall be dead-front with front and rear accessibility. Framework shall consist of steel channels bolted to frame to support entire shipping section rigidly for moving on rollers and floor mounting. Framework shall be code gauge steel, rigidly welded and bolted together to support cover plates, bussing and component devices.
  - 2 Each switchboard section shall have open bottom and individual removable top plate for installation and termination of conduit. Wireway front covers shall be hinged. Paint finish shall be medium light gray, ANSI #49. Provide rear-hinged doors with 3-point latch on switchboard sections.
- C Bussing
  - 1 Switchboard bussing shall have cross-sectional area sufficient to meet UL Standard 891 on temperature rise. Through-bus shall be copper and braced for short circuit current rating consistent with manufacturer's short circuit coordination study.
  - 2 Through-bus shall have provisions for addition of future sections. Through-bus supports, connections and joints shall be bolted with grade 5 hex head bolts and Belleville washers.
- D Short Circuit Current Rating: Switchboard units shall have a given single short circuit current rating by manufacturer established by actual tests as required by UL specifications, on similar equipment.
- E Bolted Pressure Contact Switches
  - 1 Provide 800 A and larger fusible bolted pressure contact main and branch switches.
  - 2 Make pressure contacts by bolting blades to top and bottom stationary contacts. Switches shall have quick-make/quick-break Kinematic-Action mechanisms, inter-phase barriers and arcing equipment.
  - 3 Switches shall be manually or electric-trip-operated, piloted by output of ground fault sensing circuitry or from other signal source. Power for electric trip circuit shall be obtained from control transformer connected from phase-to-phase on line side of switch. Electric trip coil shall operate at 55% of rated voltage.
  - 4 Switches shall have (1) interrupting rating of 12 times continuous rating and (2) operating mechanism for closure of switch only after opening mechanism has been charged, as required by UL-977. Switches shall be by Square D Company (Bolt-Loc), General Electric or Cutler Hammer. Electrically-operated switches shall include blown fuse device to open switch if one or more fuses blow.

F Fusible Switches (30-600 A)

- 1 Fusible switches shall be quick-make/quick-break and shall be group mounted in panel. Switches of 30-200 A shall have plug-on line side connection and built-in fuse pullers.
- 2 Provide separate steel switch enclosure with hinged cover interlocked with operating handle to prevent opening when switch is in ON position. Interlock shall be constructed so that it can be released with standard electrician's tool, for testing fuses without interrupting service.
- 3 Provide for padlocking in OFF position. Operating handle position shall give positive switch position indication, i.e.: red is ON, black is OFF. Switches shall pass industry standard  $I^2t$  withstand ability tests and fuse tests.

G Ground Fault Protection

- 1 Ground fault protection system shall include current sensor and appropriate relaying equipment. Current sensor shall enclose all phase and neutral conductors of circuit to be monitored. Current sensor frame shall be constructed so that one leg can be opened without disturbing cables or requiring drop-links in bussing.

H Metering Compartment

Secondary metering shall be Yale Standard Power Measurement Model 3300 (3300 ACM-79) including PT, CT, and shorting block.

16332B MAIN SWITCHBOARD (480/277 V)

- A. Switchboard shall be dead-front, totally-enclosed, self-supporting cubicle steel structure supplied by Square D, General Electric, or Cutler Hammer.
- B. Switchboard shall be designed for 480/277 V, 3-phase, 4-wire, with copper ground bus.
- C. Switchboard shall have gray enamel finish. Steel parts shall have two coats of zinc chromate primer before finish painting.
- D. Provide die-formed steel base assembly with formed steel and commercial channel welded or bolted together for rigid support necessary for moving on rollers and floor mounting. Framework shall be code gauge steel, rigidly welded and bolted together to support cover, plates, bussing, and component devices.
- E. Switchboard section shall have open bottom and individual removable top plate. Wireway front covers shall be hinged. Provide hinged front plates for mounting meters, selector switches and other devices. Closure plates shall be screw removable. Provide hinged rear doors with three-point latch.
- F. Bussing shall be plated and of sufficient cross-sectional area to conduct continuously rated full load current with maximum temperature rise of 50° C, above ambient temperature of 40° C.
- G. Bus shall be rigidly braced to comply with integrated equipment rating of switchboard. Minimum bracing for short circuit faults shall be 65,000 A symmetrical rms.
- H. Main horizontal bus between sections shall run on back of switchboard. End section shall have bus bar provisions for future addition of switchboard section, with bus bars to extreme side of switchboard, prepunched to receive splice plates. Horizontal main bus bar supports, connections, and joints shall be bolted.
- I. Main disconnect shall be solid-state, manually-operated, insulated case circuit breaker, with adjustable long time and short time circuit pick-ups and adjustable ground fault trips. Breaker shall be 100% equipment rated according to UL requirements.
- J. Sub-main breakers shall be molded case or current-limiting or molded case circuit breakers.
- K. Provide isolated solid neutral bus and required lugs. Provide 1/4" x 2" equipment grounding bus on top rear of switchboard. Both neutral and ground bus shall extend full length of switchboard and shall be bolted to each section. Provide lugs on ground bus.
- L. Secondary metering shall be Yale Standard Power Measurement Model 3300 (3300 ACM-79) including PT, Ct, and shorting block.
- M. Switchboard shall be NEMA Class II.

16340 PANELBOARDS

- A. Panels shall be by Square D, Type NQOB for 225 A and below, and I-line distribution for 400 A and above, or approved equal by General Electric or Cutler-Hammer.
- B. Provide UL-listed safety dead-front lighting and power panelboards. Panelboards shall meet or exceed requirements of NEMA Standard Publication PB-1, and UL-50 and 67. Provide cabinets with flush hinges and combination catch and lock. Provide wiring gutters to accommodate large multiple feeder cables and lugs. Wiring gutters shall be at least 4" for lighting and 208 V panels and 6" for 480 V panels.
- C. Where two section panels are required, bolt boxes together to form one unit. Trim shall be two-piece construction with doors of equal size over each section.
- D. Provide molded case, bolt-on, thermal-magnetic trip, single, two or three pole branch circuit breakers. Multiple pole breakers shall be single handle, common-trip.
- E. Main buswork of panels shall carry at least full rating of feeder overcurrent device that supplies panel.
- F. Provide separate equipment ground bus for each panelboard. Ground bus shall be insulated from panel enclosure if isolated.
- G. Power and lighting panels shall have heavy-duty, continuous, section vertical-hinged to box section for access to wiring gutters in addition to trim door (door-in-door construction).

#### 16360A NONAUTOMATIC TRANSFER SWITCH

- A. Nonautomatic switches shall be by ASCO, Square D, or Russelectric.
- B. The nonautomatic transfer switch shall be double throw, actuated by a single electrical operator, momentarily energized and connected to the transfer mechanism by a simple overcenter-type linkage. The transfer switch shall be capable of transfer successfully in either direction with 70% of rated voltage applied to the switch terminals. Transfer shall be initiated by an electrical operator through local or remote pushbuttons.
- C. The normal and emergency contacts shall be positively interlocked mechanically and electrically to prevent simultaneous closing. Main contacts shall be mechanically locked in position in both the normal and emergency positions without the use of hooks, latches, magnets, or springs and shall be silver-tungsten alloy. Separate arcing contacts, with magnetic blow-outs, shall be provided on all transfer switches. Interlocked molded case circuit breakers or contactors are not acceptable.
- D. The transfer switch shall be equipped with a safe manual operator designed to prevent injury to operating personnel. The manual operator shall provide the same contact-to-contact transfer speed as the electrical operator to prevent a flashover from switching the main contacts slowly. The transfer switch shall be designed for easy conversion to automatic operation with the addition of a control panel with minor wiring changes.
- E. Contacts, coils, springs and control elements shall be removable from front of transfer switch without major disassembly or disconnection of power conductors.
- F. Nonautomatic transfer switch shall be rated to withstand rms symmetrical short circuit current available at automatic transfer switch terminals.
- G. Provide switches in NEMA 1 locking cabinet.

## 16360B AUTOMATIC TRANSFER SWITCH

- A. Automatic switches shall be by ASCO, Square D or Russelectric.
- B. Automatic transfer switch shall consist of power transfer module and control module, interconnected to provide complete automatic operation. Automatic transfer switch shall be mechanically held and electrically operated by single-solenoid mechanism energized from source to which load is to be transferred. Switch shall be rated for continuous duty and shall be inherently double throw. Switch shall be mechanically interlocked to ensure only one of two possible positions: normal or emergency. Automatic transfer switch shall be suitable for use with engine-driven or turbine-driven emergency generator or other utility source.
- C. Main contacts shall be silver protected by arcing contacts 400 A and over. Contacts shall be blow-on configuration and segmented or brush construction in ratings 600 A and over. Operating transfer time in either direction shall not exceed one-sixth of one second.
- D. Automatic transfer switches shall have a manual override to allow the switch to be manually operated.
- E. Contacts, coils, springs and control elements shall be removable from front of transfer switch without major disassembly or disconnection of power conductors.
- F. Control module shall have protective cover and shall be mounted separately from transfer switch. Sensing and control logic shall be solid-mounted on plug-in printed circuit boards. Printed circuit boards shall be keyed to prevent incorrect installation. Provide industrial control grade plug-in interfacing relays with dust covers.
- G. Automatic transfer switches with components of molded-case circuit breakers, contactors or components not designed for continuous duty or repetitive load transfer switching will not be accepted. Circuit breaker switches will not be accepted.
- H. Automatic transfer switch shall meet NEMA ICS 2-447 and UL-1008 standards and shall be UL-listed for use in emergency systems in accordance with NEC Articles 517 and 700, and rated in amperes for total system transfer including control of motors, electric-discharge lamps, electric-heating and tungsten-filament lamp loads as specified in Paragraph 30.9 of UL-1008.
- I. Transfer switches rated 400 A and less shall be suitable for 100% tungsten-filament lamp load. Switches rated above 400 A shall be suitable for 30% or 400 A tungsten-filament lamp load, whichever is higher.
- J. Automatic transfer switch shall be rated to withstand rms symmetrical short circuit current available at automatic transfer switch terminals.
- K. Operation: Automatic transfer switch control panel shall use solid-state sensing on normal and emergency for automatic positive operation.
  - 1. Phases of normal shall be monitored line-to-line. Provide close differential voltage sensing. Pickup voltage shall be adjustable from 85% to 100% of nominal; dropout voltage shall be adjustable from 75% to 98% of pickup value. Transfer to emergency shall be initiated upon reduction of normal source to 85% of nominal voltage and retransfer to normal shall occur when normal source reaches 95% of nominal.

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2. Time delay to override momentary normal source outages shall delay transfer switch signals and engine starting signals. Time delay shall be field-adjustable from 0.5 to 6 seconds and factory set at 1 second.
  3. Time delay on retransfer to normal source shall be bypassed automatically if emergency source fails and normal source is available. Time delay shall be field-adjustable from 0 to 30 minutes.
  4. Unloaded running time delay for emergency generator cooldown shall be field-adjustable from 0 to 5 minutes.
  5. Time delay on transfer to emergency shall be field-adjustable from 0 to 5 minutes for controlled timing of load transfer to emergency, where indicated.
  6. Independent single phase voltage and frequency sensing of emergency source: pickup voltage shall be adjustable from 85% to 100% of nominal; pickup frequency shall be adjustable from 90% to 100% of nominal; transfer to emergency shall occur upon normal source failure when emergency source voltage is 90% or more of nominal and frequency is 95% or more of nominal.
  7. Provide gold-plated contact that closes when normal source fails for initiating engine starting, rated 10 A, 32 V DC.
  8. Provide gold-plated contact that opens when normal source fails for initiating engine starting, rated 10 A, 32 V DC.
  9. Provide white signal light to indicate when automatic transfer switch is connected to normal source, and yellow signal light to indicate when automatic transfer switch is connected to emergency source.
  10. Provide three auxiliary contacts that are closed when automatic transfer switch is connected to normal and two auxiliary contacts that are closed when automatic transfer switch is connected to emergency. Contacts shall be rated 10 A, 480 V AC, 60 Hz.
- L. Provide engine generator exercising timer adjustable in 15-minute increments.
- M. Provide switches in NEMA 1 locking cabinet.

## 16420 LIGHTING SYSTEMS

### A. Lamps

1. Provide lamps by General Electric, Philips or Osram-Sylvania.
2. Lamps shall meet ANSI C78 requirements.
3. Incandescent lamps shall meet LM-45 and LM-49 IES testing and measurement requirements.
4. Fluorescent lamps shall meet LM-9 and LM-40 IES testing and measurement requirements. Provide circuit interrupting lampholders.
5. High intensity discharge lamps shall meet LM-47 and LM-51 IES testing and measurement requirements.

### B. Ballasts

1. General
  - a. Provide ballasts by Magnetex, Advance, or Universal. Ballasts shall be ETL- CBM- and UL-listed.
  - b. Provide emergency ballasts by Bodine.
  - c. Ballasts shall have at least 0.9 power factor unless specified otherwise.
  - d. Furnish manufacturer's two-year warranty, including replacement parts and labor. Date of manufacture shall be stamped on nameplate.
  - e. Ballasts shall not contain PCB.
2. Fluorescent Ballasts
  - a. Ballasts shall meet ANSI C82 and UL 935 requirements.
  - b. No more than four lamps shall be served by one ballast.
  - c. Ballasts shall have current leakage of less than 50 milliamperes.
  - d. Ballasts shall have sound rating A (20-25 dB).
  - e. Indoor ballasts shall have starting temperature of at least 50° F.
  - f. Outdoor ballasts shall have starting temperature of at least 0° F for 430 mA and -20° F for 800-1500 mA.
3. High Intensity Discharge Ballasts
  - a. Ballasts shall meet ANSI C824 and UL-1029 requirements.
  - b. Input power shall be not more than 115% of lamp power.

- c. Maximum ballast crest factors shall be:
  - 1. 1.5 for mercury lamps,
  - 2. 1.8 for metal halide lamps and,
  - 3. 1.8 for high pressure sodium lamps.
- d. Furnish KTK fuse and fuse holder, sized and installed by luminaire manufacturer, in addition to internal ballast thermal protection.
- e. Indoor ballasts shall have starting temperature of at least 0° F.
- f. Outdoor ballasts shall have starting temperature of at least -20° F.
- g. Indoor encased ballasts shall be capable of operating in at least **(105° F)** **(150° F)** ambient temperature.

C. Luminaires

1. General

- a. Provide complete factory-wired luminaires that meet UL 57 and ANSI C81 requirements.
- b. Finish shall be uniform with no defects such as whirls, discoloration, sand or dust spots, cracks or chips. Steel rustproofing shall be by five-stage cleaning cycle and iron or zinc phosphate coating with rust inhibitor.
- c. Luminaires in damp or wet locations shall bear correct UL label. Luminaires in hazardous locations shall bear UL 885 and UL 1225 labels.
- d. Luminaires that require incandescent or high intensity discharge lamps shall provide adequate ventilation.
- e. Provide safety chains on luminaires. Chains shall support eight times luminaire weight including fixture components. Maximum distance luminaire may fall shall be 1 foot.

2. Incandescent Luminaires

- a. Provide incandescent luminaires that meet UL 1571 requirements.
- b. Recessed luminaires shall have thermal protection.
- c. Position lamp socket in downlight luminaires as recommended by manufacturer.

3. Fluorescent Luminaires

- a. Provide factory-tested, 20 gauge (0.9 mm) or reinforced 22 gauge (0.8 mm) steel or aluminum fluorescent luminaires.

- b. Luminaires shall meet UL 542, UL 1570 and NEMA LE1-1974 requirements.
  - c. Photometric testing shall meet LM-41 IES requirements.
  - d. Open strip fluorescent luminaires shall have spring-loaded or turret sockets.
  - e. Recessed luminaires shall have provisions to replace ballast without removing luminaire from ceiling.
  - f. Interior finish shall have at least 85% reflectance.
  - g. Ballast sound rating shall be raised no more than 2 dB.
4. High Intensity Discharge Luminaires
- a. Provide HID luminaires that meet UL 1572 and NEMA LE3 requirements.
  - b. Photometric testing of indoor HID luminaires shall meet LM-46 requirements.

D. Lens Diffusers

- 1. Provide lenses of at least 1/8" thick, 100% clear acrylic, tinted acrylic or glass. Lenses shall not be inverted.
- 2. Acrylic lenses shall meet or exceed Grade 8 requirements of ASTM D-788 Table 2.
- 3. Acrylic lens prismatic pattern 20 shall have 1/8" square base male cones on base parallel to lens edge. Prism height shall be at least 0.05". Lens shall be KSH-20 or approved equal.

E. Louver Diffusers

- 1. Parabolic louver shall be at least 0.025" thick, semi-specular pre-anodized aluminum.
- 2. Metallic louvers shall be at least 20 gauge steel.
- 3. Plastic louvers shall be 100% acrylic.
- 4. Coated plastic louvers shall be destaticized polystyrene.

F. Site Lighting

- 1. Provide lighting, wiring, controls and other devices as specified.
- 2. Equipment shall meet requirements of NEMA FA1-1973, Tubular Floodlighting Equipment, and NEMA SH5-1969 Tubular Steel, Aluminum Roadway Lighting Poles.
- 3. Poles and luminaires shall be grounded with ground wire tied back to lighting panel.

## 16421 DIMMING SYSTEMS

### A. General

#### 1. Description

- a. The system shall consist of factory pre-assembled dimming and/or relay racks, extra low-voltage control stations and/or interface panels, and electronic dimming ballasts.
- b. The entire control lighting system meet all necessary standards. Each dimming and switching/non-dimming module shall be specifically designed for control of the type of lighting load (i.e., incandescent, inductive or electronic low voltage, fluorescent, neon/cold-cathode, HID, nondim and variable fan speed).
- c. The dimming system shall be supplied by Lutron, Crestron, Lehigh or Lightolier.

### B. Products

#### 1. Panels

- a. Panels shall be wall or floor mounted NEMA grade, constructed of sheet steel plates not less than #16 U.S. gauge.
- b. Panels shall be completely pre-wired by the manufacturer. The contractor shall be required to provide input feed wiring, load wiring, and control wiring which terminates to a set of clearly marked low voltage terminals. No other wiring or assembly by the contractor shall be required.
- c. Dimming panels shall contain branch circuit breaker protection for each dimming module.
- d. Branch circuit breakers shall have the following performance characteristics:
  - 1) Be UL listed under UL 489 as a molded case circuit breaker for use on lighting circuits.
  - 2) Contain a visual trip indicator and shall be rated at 10,000 AIC (120 V) or 14,000 AIC (277 V), unless otherwise noted.
  - 3) Be thermal-magnetic in construction for both overload and dead short protection. The use of fully magnetic breakers shall not be acceptable, even when used in conjunction with individual dimmer thermal cut-outs.
  - 4) Be switching duty (SWD) rated so that the loads can be switched off via the breakers.

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- e. Panels shall be shipped with each dimmer in a BYPASS position via a jumper bar inserted between the input and the load terminals. These jumpers shall carry the complete load current and shall be clearly labeled and reusable at any time.
- f. Panels shall be cooled via free-convection, unaided by fans, and capable of continuous operation to all of these section specifications within an ambient temperature range of 0° C (32° F) to 40° C (104° F).
- g. Panels shall provide the capability to electronically assign(soft patch) each circuit to any zone in the dimming system. Panels using mechanical switches, rewiring or EPROM's are not acceptable.
- h. Multiple panels shall be capable of operating in one system, up to a maximum of 32 panels and 768 dimmers.
- i. Dimmer output voltage shall be a minimum 95% of input voltage at maximum intensity setting.
- j. Once installed as part of a complete system, the silicon thrustors used to control the power furnished to the loads shall be both designed and tested to withstand surges, without impairment to performance, of 6000V, 3000A.

## 2. Dimming Modules

- a. Quantities of dimmer module shall be provided to control each type of load. All dimmers shall provide a smooth and continuous "square law" dimming curve throughout the entire dimming range for the following load types that are to be controlled:
  - 1) Incandescent, Inductive Low voltage.
  - 2) Electronic Low Voltage.
  - 3) Electronic/High Frequency Fluorescent Dimming Ballasts: Fluorescent dimmers shall be rated to control T-8, T-5, or compact fluorescent lamps. All lamps of the same circuit must have the same current rating (i.e., T-8) and ballast type. The dimming performance shall provide a dimming range down to 1% light output for T-8 lamps (5% for T-5 and compact fluorescent).
- b. A positive air gap relay shall be employed with each dimmer to ensure that the load circuits are open when the "off" function is selected for that dimmer.
- c. All dimmers shall be voltage regulated so that a nominal change in line voltage shall not cause a perceptible change in output voltage.
- d. Under full-load conditions in a 40° C environment, all silicon thrustors shall operate at a minimum 20°C safety margin below the component temperature rating.
- e. Dimmer output voltage shall be a minimum 95% of input voltage at maximum intensity setting.

- f. Once installed as part of a complete system, the silicon thrusters used to control the power furnished to the loads shall be both designed and tested to withstand surges, without impairment to performance, of 6000 V, 3000 A.
  - g. Minimum and maximum light levels shall be user adjustable for each dimmer.
3. Switching Modules
- a. Switching/Non-dim modules shall be rated to switch 16 A of resistive, inductive or capacitive loads. Non-dim output shall provide full conduction function. Relays shall be of the positive air-gap type and shall be of the sealed construction type in order to prevent contact degradation.
4. Emergency Full-on Systems For Designated Emergency Circuits
- a. All lighting circuits listed as emergency shall be connected to their respective circuit breakers in the emergency dimming panel. They shall be controlled simultaneously with other lighting circuits within that control zone during the presence of normal supply. Upon loss of the normal supply and the subsequent presence of emergency supply, the circuits listed as emergency shall immediately go to a full-on condition. All local control stations are inoperable during this period. Once normal supply is restored, all lighting zones shall revert back to their status prior to the emergency condition (restoration to some other "default" level is not acceptable).
5. Controls
- a. General
    - 1) Definitions: A "scene" is a specific look or mood created by different lighting zones set at different intensities. A "zone" is one or more lighting circuits which are controlled together as a group.
    - 2) Controls shall be low voltage type as specified here and as listed below and/or shown on the drawings. Controls shall use low voltage wiring, electrically isolated from power wiring by means of a low voltage transformer.
    - 3) All control stations shall provide power-failure memory. Should power be interrupted to the control station and subsequently returned, the lights will come back on to the same levels set prior to the power interruption. Restoration to some other default level is not acceptable, unless specifically noted elsewhere.
    - 4) Faceplates shall attach to the wallbox using no visible means of attachment, and in a manner so as to discourage unauthorized removal. Alternatively, where pre-approved by the Architect, controls shall be mounted in an enclosure with a locking translucent cover. Paint enclosure per Architect's sample.

- 5) Controls shall be engraved with appropriate zone and/or scene descriptions, furnished to the manufacturer prior to fabrication. Size and style of engraving type shall be determined by the Architect.
- b. Multiple Area Control System
- 1) The Lighting Control System consists of touchbutton wall controls, ceiling mounted photosensors and handheld remote programmer.
- c. Four Scene Preset Control
- 1) Control shall provide 4 preset lighting scenes and off for up to 8 control zones. Control shall be capable of storing an additional 12 preset lighting scenes. Up to 8 controls may be tied together for more than 8 zones.
  - 2) Controls shall incorporate built-in wide angle infrared receiver, providing control via a separate wireless remote control transmitter from up to 50 feet away.
  - 3) Preset shall be set via easy-to-use raise/lower switches, one raise and lower switch per zone. The intensity for each zone shall be indicated via an illuminated paragraph, one paragraph per zone. More than one zone may be proportionately raised or lowered at the same time. Programming of preset scenes shall be accomplished without the use of an ENTER or STORE button.
  - 4) Additionally, one or more zones may be temporarily overridden without altering the scene values which are stored in memory.
  - 5) Lighting levels shall fade smoothly between scenes at time intervals of 0-59 seconds or 1 to 60 minutes. The fade time shall be separately selectable for each scene and shall be indicated by a digital display for the current scene.
  - 6) Pressing a scene select button will also light the corresponding scene LED and simultaneously begin changing the paragraph levels to reflect the currently selected scene. In the event that a preset scene with a fade time greater than 5 seconds is initially selected from an OFF condition, the programmed fade time shall be temporarily overridden, unless otherwise noted, and the lights shall fade up to that scene over a five-second time span.
- d. Remote Control Options: Provide the following controls for use with the central preset control system:
- 1) Four Scene/Raise/Lower Remote Control. Station(s) shall be capable of recalling any one of four pre-set scenes plus OFF and provide master raise/lower control.
  - 2) Two Scene/Raise/Lower Remote Control. Station(s) shall be capable of recalling two pre-set scenes and provide master raise/lower control.

3) Interface Control. Interface shall provide automatic selection of pre-set scenes and/or OFF. Where the control system is being controlled by the building management system or an external A/V system.

e. Hand-Held Programmer

1) Provide a total of four (4) hand-held programmer to set up pre-set scenes in each area. Programmer shall be self-teaching and shall allow selection of which area or room is being programmed via ceiling mounted photosensors.

## 16422 OCCUPANCY SENSORS

### A. Equipment Qualification

1. Products supplied shall be from a manufacturer that has been continuously involved in the manufacturing of occupancy sensors for a minimum of five (5) years.
2. All components shall be U.L. listed, offer a five (5) year warranty and meet all state and local applicable code requirements.

### B. Products

1. All products shall be Watt Stopper or equivalent approved equal.
  - a. Ceiling sensors: W-500A, W-550A, W-1000A, W-1050A, W-2000A, W-2050A, W-2000H, W-2050H, WPIR, DT-100L, CI-100, CI-105, CI-200, CI-205.
  - b. Wall Sensors: WI-200, WS-120/277, WM-120/277, WA-100.
  - c. Power and Slave Packs: A120E, A277E, S120/277, AT-100 Power Supply.
  - d. Low Temperature: CB-100.
  - e. IntelliSwitch: TS-200.
2. Wall switch sensors shall be capable of detection of occupancy at desktop level up to 300 square feet, and gross motion up to 1000 square feet.
3. Wall switch sensors shall accommodate loads from 0 to 800 watts at 120 volts; 0 to 1200 watts at 277 volts and shall have 180° coverage capability.
4. Wall switch occupancy sensors shall utilize Zero Crossing Circuitry which increases relay life of sensor and increases sensor's longevity.
5. Wall switch sensors shall have no leakage current to load, in manual or in Auto/Off mode, for safety purposes and shall have voltage drop protection.
6. Passive Infrared sensors shall utilize custom ASIC specifically designated for PIR sensors which provides high immunity to false triggering from RFI (walkie talkies) and EMI (electrical noise on the line), superior performance, and greater reliability.
7. Passive Infrared sensors shall have a multiple segmented Lodif Fresnel lens, in a multiple-tier configuration, with grooves-in to eliminate dust and residue build-up.
8. Where specified, Passive Infrared and Dual Technology sensors shall offer daylighting footcandle adjustment control and be able to accommodate dual level lighting.
9. Dual Technology sensors shall be corner mounted to avoid detection outside the controlled area when doors are left open.

10. All sensors shall be capable of operating normally with any electronic ballast, PL lamp systems and rated motor loads.
11. Coverage of sensors shall remain constant after sensitivity control has been set. No automatic reduction shall occur in coverage due to the cycling of air conditioner or heating fans.
12. All sensors shall have readily accessible, user adjustable controls for time delay and sensitivity. Controls shall be recessed to limit tampering.
13. In the event of failure, a bypass manual "override on" shall be provided on each sensor. When bypass is utilized, lighting shall remain on constantly or control shall divert to a wall switch until sensor is replaced. This control shall be recessed to prevent tampering.
14. Ultrasonic operating frequency shall be crystal controlled to within plus or minus 0.005% tolerance to assure reliable performance and eliminate sensor cross-talk. Sensors using multiple frequencies are not acceptable.
15. All sensors shall provide a method of indication to verify that motion is being detected during testing and that the unit is working.
16. Where specified, sensor shall have an internal additional isolated relay with Normally Open, Normally Closed and Common outputs for use with HVAC control, Data Logging and other control options. Sensors utilizing separate components to achieve this function are not acceptable.
17. All sensors shall have UL rated, 94V-0 plastic enclosures.
18. Provide power packs and slave packs as required.

C. Circuit Control Hardware - CU

1. Control Units - For ease of mounting, installation and future service, control unit(s) shall be able to externally mount through a 1/2" knock-out on a standard electrical enclosure and be an integrated, self-contained unit consisting internally of an isolated load switching control relay and a transformer to provide low-voltage power. Transformer shall provide power to a minimum of two (2) sensors.
2. Relay Contacts shall have ratings of:
  - 13A - 120 VAC Tungsten
  - 20A - 120 VAC Ballast
  - 20A - 277 VAC Ballast

- D. Control wiring between sensors and controls units shall be Class II , 18-24 AWG, stranded UL Classified, PVC insulated or Teflon jacketed cable suitable for use in plenums, where applicable. Provide conduit sleeves from cable tray to sensor/pack.

## 16500 LIGHTING DESIGN STANDARDS AND CRITERIA (Change # 13, 9/1/2005)

### A. GENERAL

#### 1. SUMMARY

- a. This section describes general requirements for lighting systems.
- b. Refer to sections listed below for related requirements:
  - 1) Photocontrols, motion sensors, and dimming switches: Section 16141.
  - 2) Lighting contactors: Section 16485.
  - 3) Lamps: Section 1650.
  - 4) Ballasts: Section 16502.
  - 5) Interior luminaries: Section 16510.
  - 6) Exterior luminaries: Section 16530.
  - 7) Emergency lighting fixtures: Section 16535.
  - 8) Exit signs: Section 16538..
  - 9) Dimming control systems: Section 16421

#### 2. REFERENCES

- a. Designs shall conform to applicable portions of the following reference standards:
  - 1) ASHRAE - 1999 Energy-Efficient Design of New Buildings Except Low-Rise Residential Buildings.
  - 2) The energy Policy Act of 1992
  - 3) IES Lighting Handbook.(most recent)

#### 3. SUBMITTALS

- a. Designers shall submit the following information to Owner:
  - 1) Lighting calculations for all types of spaces, including foot-candle levels and watts per A point-to-point photometric layout shall be submitted for each typical space. foot. A point- to- point photometric layout shall be submitted for each typical space.

#### 4. SYSTEM DESCRIPTION/PERFORMANCE

- a. Lighting systems shall be designed to achieve required levels of illumination while minimizing energy consumption. Lamps and luminaries shall be selected for high efficiency, and systems shall operate at the highest practical voltage level available. High reflectivity interior finishes should be specified to achieve the following minimum reference:

- 1) Ceilings: 80 percent.
  - 2) Walls: 50 percent.
  - 3) Floors: 20 percent.
- b. Interior lighting systems shall be designed to achieve the following levels of illumination, measured in maintained horizontal foot-candles on a working surface located 30 inches above floor level, within a tolerance of plus or minus 20 percent. or in non-work areas, in accordance with Illuminating Engineering Society. Handbook, latest edition, for average maintained foot candles.

1) Auditoriums:	30
2) Bedrooms:	20
3) Classrooms:	50
4) Conference rooms:	40
5) Corridors:	9*
6) Dining halls:	15
7) Elevators:	15
8) Gymnasiums (general):	30
9) Gymnasiums (varsity):	50
10) Kitchens:	75
11) Laboratories:	75
12) Lecture halls:	30
13) Libraries (reading areas):	50
14) Libraries (stacks):	30
15) Lobbies:	15
16) Locker rooms:	15
17) Lounges:	15
18) Mechanical rooms:	20
19) Music rooms:	40
20) Offices:	50
21) Stairways:	15
22) Storage areas:	15
23) Toilets:	15
24) Waiting areas:	15
25) Workshops:	75

\* Minimum light levels in corridors shall be no less than 9 foot-candles measure 3'-0" above finished floor with light meter held facing the floor. This is a reflected light value. Deviations below the minimum light level shall be brought to PM for review.

- d. In occupancies where specialized tasks are performed (for example, at serving areas in dining halls and at mirrors in toilet rooms), levels listed above may not be sufficient for adequate illumination. At such locations ambient lighting levels shall be increased as necessary. Ambient lighting may also be supplemented by task lighting with approval of project manager (ambient level should not be less than one-third the level at the task).
- e. Exterior lighting systems shall be designed to achieve a minimum level of illumination of 0.5 maintained horizontal foot-candles at ground level along main walkways, with a maximum uniformity ratio of 6:1. Provide luminaries at all building entrances. Lighting levels in other exterior occupancies shall be determined by Yale Project Manager. Coordinate all new exterior lighting with existing lighting so that areas are not lit excessively.

## 5. DESIGN REQUIREMENTS

- a. Lighting throughout all critical areas (including means of egress, assembly occupancies, health care facilities, public safety operations, etc.) shall be arranged such that failure of any single element of the system, such as a lamp, ballast, switch, circuit breaker, or conductor, shall not leave any portion of the means of egress in darkness or illuminated to less than the levels required by Code.
  - 1) Where only the normal distribution system is available, self-contained emergency lighting units connected to an unswitched conductor of the lighting branch circuit shall be provided.
  - 2) Where both normal and alternate distribution systems are available, lighting fixtures shall alternate between each source along the entire length of the means of egress
  - 3) Systems which utilize a central battery are acceptable only if wired in accordance with subparagraph 2 above.
- b. In lighting calculations, lamp lumen depreciation factor multiplied by luminaire dirt depreciation factor (LLD x LDD) shall not exceed 0.75. For high intensity discharge fixtures, ballast/factors shall not exceed 0.90.
- c. Light sources in interior areas shall be fluorescent or compact fluorescent except as follows:
  - 1) High ceiling spaces (over 12 feet) in finished areas where not subject to frequent switching shall be metal halide.
  - 2) High ceiling spaces (over 12 feet) in unfinished areas, such as warehouses and workshops, shall be high pressure sodium.
- d. Light sources in exterior areas shall be metal halide, except that areas for primarily vehicular traffic such as driveways and parking lots shall be high pressure sodium.
- e. In areas where variable levels of illumination may be required by multiple uses of the space or for energy conservation purposes, provide multi-level switching or dimming capabilities. Such areas may include corridors, auditoriums and lecture halls, classrooms, gymnasiums, laboratories, offices, and workshops.
- f. Motion detectors shall be used to control lighting in areas subject to extended unoccupied periods during normal hours of occupancy. The selection of type (single or dual technology) shall be made based on the programmatic use of the space. Such areas include the following:
  - 1) Classrooms
  - 2) Conference rooms
  - 3) Private offices
  - 4) Laboratory support rooms
  - 5) Auditoriums

- 6) Bathrooms(locate sensors such that interiors of toilet stalls are within field of view).
- g. Exterior lighting systems shall be controlled by photocell-actuated combination lighting contactors. Manual—automatic selector switches shall be mounted on contactors.
- h. Coordinate luminaries locations with architectural features of space and with adjacent structural and mechanical elements.

## B. EXECUTION

### 1. FIELD QUALITY CONTROL

- a. Testing shall be required as follows:
  - 1) Foot-candle measurements, made during periods of darkness but not before lamps have been in service for 100 hours, at sufficient locations to demonstrate that design criteria are met. Submit results to Owner

16510 TELEPHONE AND DATA SYSTEM

- A. Telephone and data terminal locations and backboards shall be fabricated from 3/4" thick, type AC, exterior grade plywood. Backboards shall be painted with two coats of gray fire-retardant paint on all six surfaces. Provide 1" non-magnetic raceway from service backboard ground bus to building grounding bus as required with a #6 AWG bare wire for telephone ground.
- B. Typical wall mounted telephone and data outlet shall consist of the flush mounted, two gang outlet box (4" x 4" x 3-3/4" deep) plus 1" conduit raceway to cable tray or backboard.
- C. Provide 1-1/2" conduit raceway from each surface metal raceway strip to cable tray or backboard. Provide a "J-Hook" distribution system (3'-0" J-Hooks on center) above office ceilings in lieu of 1" conduit raceway. From outlet to cable tray; i.e., provide 1" conduit stubbed from outlet to above accessible ceiling; also provide 1 1/2" conduit sleeve with bushings from cable tray in to each office. J-Hooks shall be installed in a manner in which a minimum distance of 36" is maintained from lighting fixture ballasts, transformers, motors, etc.
- D. Provide a "reusable means" raceway from each unit interface panel back to the plywood backboard on that floor.
- E. Provide 4" galvanized rigid conduit sleeves through floors, walls, and across corridors as shown on the drawings. Fireproof all sleeves after installation of cables.
- F. Bushings shall be provided on all conduits and sleeves.
- G. All empty raceways and J-Hooks are to be provided with nylon pull strings or wires.

16562 SECURITY SYSTEM (Change # 35,1/22/08)

- A. Provide a complete system of conduits, electrical boxes, cables, wire and backboards for the access control and asset management and security system as shown on plans and indicated herein.
- B. Provide all conduits, electrical boxes, cables and wire as recommended by Integrated Security Systems, 43-A Miry Brook Road, P.O. Box 3356, Danbury, CT 06815 (203) 797-8377.or ADT (R. Marino 203 741 4073; M. McNamara 203 741 4131)
- C. All access control, asset management and security system equipment shall be provided by Integrated Security Systems., ADT or Siemens (Video only).

16572 FIRE ALARM SYSTEM

A. General Requirements

1. The system shall be an integrated and multiplexed fire detection system.
2. The system shall include all required hardware and software to accomplish the requirements of this specification whether itemized or not.
3. System shall be manufactured by Cerberus Pyrotronics.

B. Materials and Services

1. The system shall include, but not be limited to, the following elements:
  - a. Master command center MXL with main CPU and control for fire alarm.
  - b. All remote control panels MXLR as required by the system.
  - c. Power supplies, batteries and battery chargers for each panel enclosure as required. Batteries larger than 15 AH rating may be installed in a separate enclosure.
    - 1) Provide batteries sufficient for 60 hour, 10 minute alarm battery back up.
  - d. Intelligent, addressable, manual pull stations, heat detectors, analog smoke detectors, alarm monitoring modules, and supervised control modules.
  - e. Audible and visual evacuation signaling devices.
  - f. Software and firmware as required to provide a complete functional system.
  - g. System logging system.
  - h. Remote annunciator panel.
  - i. Wiring and raceway.

C. Listing and Approvals

1. The system shall be listed under underwriter Laboratories (UL) Category UOJZ conforming to basic standards UL864 "Control units for Fire Protective Signaling Systems" and shall be configured for installation per any of the following:
  - a. ANSI/NFPA 72 1993 National Fire Code
  - b. NFPA 71 for central station type system
  - c. NFPA 13 for sprinkler system
  - d. NFPA 101 Life Safety Code
  - e. ADA Americans with Disabilities Act

- f. NFPA 70 - NEC
- g. Fire Safety Code State of CT.
- h. Fire Prevention of the City of New Haven
- i. Fire Marshal Yale University
  
- j. Insuring Authority

- 2. The system shall also be listed for the use as Security device monitoring system conforming to UL standards UL1076.
- 3. The system shall meet Factory Mutual Research Corporation (FMRC) and American Disabilities Act (ADA) Standards.

D. System Features

- 1. The system shall be Cerberus Pyrotronics MXL, a complete, electrically supervised multiplex style integrated fire detection system with intelligent, addressable, analog, alarm initiation devices, and as indicated on bid plans.
- 2. System shall be fully field programmable using a laptop computer and AccuLink software program disk. It shall be possible to download the existing program from MXL panel to an IBM PC or compatible laptop for editing and upload into panel when done. A backup copy of system program shall be stored on a floppy disk and all programming shall be multi-level password protected.
- 3. System operating system shall be stored in EPROM on main CPU board MMB-1 in main control panel. Customer generated application program shall be stored on FLASH memory chips. No loss of information shall occur even if both normal and system battery back up power are removed.
- 4. Initiation Circuit:
  - a. Analog initiation circuits shall be two (2) wire Style "4" wiring. The ALD-2I analog initiating circuit driver modules shall be installed in the fire alarm control panel enclosures or in remote circuit interface panel enclosures. Each ALD-2I card shall have two analog initiating circuit drivers. Each initiation circuit shall be capable of communicating with up to sixty intelligent analog alarm initiating input devices or sixty intelligent controllable output devices, or any combination of both type of devices up to a total of sixty point per circuit. Any combination of any type of compatible addressable devices shall be operable on a circuit including smoke or heat detectors, manual stations and remote interface and output modules as specified.
  - b. Smoke detectors shall be capable of driving a RLI series remote LED light, or a programmable relay. No additional power circuit shall be required to operate these relays.
  - c. Style "4" initiation circuits shall parallel branching or T tapping without loss of supervision of any devices on the circuit. No end of line device shall be required for any analog initiation circuit.
  - d. 100% of the devices connected to the system shall be capable of going into alarm at the same time without hampering system operation.

- e. All initiation circuits shall be listed as power limited circuits per article 760 of the National Electric Code. Power limitation shall be provided using on-board self restoring solid state thermal devices. Units using fuses for this purpose and requiring board replacement or exchange are not considered equal.
5. Indicating Circuits:
- a. System shall provide Indicating Appliance Circuits as shown on plans. Each circuit shall be supervised power limited, separately fused, rated 24 VDC, 1.5 A, configured Style "Y" wiring. Circuit originating from the MXL panel shall use CSM-4 modules. System shall also support use of remote field installed ICP-25 modules to drive IAC circuits where shown on plans. Refer to Section 2.04.09 for full specifications and description of ICP-25 modules.
  - b. CSM-4 module shall be used to provide Municipal tie or Lease line Connection and for sprinkler circuits.
  - c. Each circuit shall be individually programmable to drive compatible bells, horns, strobes, or multizone devices with customer specified zone coding, march time, uniform code 3 on non-coded.
  - d. Connection is to be made to Campus Police Proprietary System for Alarm, Trouble and Alarm over Trouble Signal.
6. System shall be modular in construction using add-on modules for input and output devices as required. The system as installed shall be expandable to its predetermined maximum capacity of 2880 initiation devices.
7. Controls and Display on Main Control Panel
- a. Main control panel shall have system display consisting of an 80 character, back-lighted, alphanumeric, super twist, LCD readable at any angle. Any off normal condition shall display the address of the device/module, 32 character custom message assigned to the device/module, type of the device/module, date, time, and status viz, alarm, trouble, supervisory, the display shall display other information upon request from the key pad as described elsewhere in the specification.
  - b. Individual LEDs shall be provided in front of the panel for "ALARM," "AUDIBLE SILENCED," "SUPERVISORY," "TROUBLE," "SECURITY," "POWER ON," AND "PARTIAL SYSTEM DISABLED." Power On LED shall be green and Alarm LED shall be red, all other LEDs shall be yellow.
  - c. Individual touch activated membrane switches shall be for "ALARM ACKNOWLEDGE," "AUDIBLE SILENCED," "SUPERVISORY ACKNOWLEDGE," "TROUBLE ACKNOWLEDGE," "SECURITY ACKNOWLEDGE," "RESET," "DISPLAY HOLD," and "DISPLAY NEXT."
  - d. All membrane feedback switches shall be tactile with audible feedback when pressed.

- e. There shall be at least 12 touch activated membrane switches, programmable to perform custom functions such as drill, relay control, bypass automatic control commands or other special functions as required by the system user.
- f. Only LDC display and LEDs and optional thermal strip printer shall be visible and only NEXT/HOLD key shall be accessible while the front door is locked.
- g. Controls at Keypad
  - 1) No system configuration or software programming changes shall be allowed using the keypad on control panel.
  - 2) An authorized operator shall be able to perform the following tasks using the keypad:
    - a) Acknowledge alarm, supervisory trouble and security.
    - b) List system status, alarm supervisory trouble and security points, sensitivity of detectors, analog voltages of addressable device, module type, device type, custom message assigned to device and software version. Operator shall be able to view every list item on the display or generate a printed report.
  - 3) The panel shall be UL listed as a test instrument for the measurement of the sensitivity of connected addressable analog smoke detectors to comply with the testing requirements of NFPA 72H. The sensitivity measurements shall be discrete voltage readings, accurate to .01 VDC. The readings shall be dynamic, providing a constant display of voltage shifts when in the sensitivity voltage list mode.
  - 4) Control functions: Reset change sensitivity (high, medium, normal or low), arm or disarm a device, output on/off, energize or de-energize an output. Access to control menu shall require a 5 digit level 1 authorization code.
  - 5) Test functions: Set time, check ground faults on main and remote panels, check system AC main power, voltage and current on all modules and batteries in main or remote panels. Voltage and current readings shall be printable on system printer for a hard copy. Lamp test and system network diagnostic tests shall also be printable. Access to Test menu shall require a 5 digit level 2 authorization code.
  - 6) Walk test: Access to Walk Test menu shall require a 5 digit level 3 authorization code.

8. System Printer:

- a. The system panel shall have internal 40 character thermal strip printer TSP-40 which shall generate hard copy of every event such as alarm, trouble, supervisory, security, time change, etc. Paper out condition shall generate a trouble condition. Paper to operate printer during installation and one year supply shall be supplied.

9. RS-232C Communication Port:
  - a. System main panel and every remote panel shall be capable of having an RS-232C port capable of supporting a standard dot matrix serial printer. Fully interactive 132 character wide carriage printer RC-119 with a key board. CRT for the display of information in a formate equal to that of the system logging printer, fully interactive video terminal with a keyboard or the color graphics terminal with a keyboard.
  - b. At least four drivers in the system shall be fully supervised and with independent communication parameters from each other allowing one or more type of peripheral terminals described above. Baud rate shall be program selectable up 9600 bps.
10. History logging:
  - a. The system shall have an event history logging feature capable of logging up to 800 events in non-volatile FLASH memory chip and can be retrieved via keypad on control panel to be displayed, printed or downloaded by classification for selective event reports. The software program AccuLink shall allow selection of events to be securities, status change, device alarm verification: audible control and output activation system configuration change, system reset, set sensitivity, arm/disarm, override, password, set time, and acknowledge by time and date.
  - b. The software shall also allow the operator to pick finite or circulating modes of history logging. In both modes, when the log becomes 80% full, system shall cause a trouble and display a message indicating the condition and when the log is 90% full, system shall cause second trouble warning. Both troubles can be cleared by panel reset. If the history log becomes full, in circulating mode oldest load will be lost when a new event will be discarded and only first 800 events shall be logged.
  - c. History logging data formate for downloading shall be compatible with the database handling program. Paradox by Borland allowing custom report generation to track alarms, troubles, and maintenance.
11. Alarm Verification:
  - a. System shall be capable of providing alarm verification on addressable area smoke detectors and on conventional zones of CZM-4 module with conventional detectors. Alarm verification shall be selectable by device or zones in system programming software.
  - b. When a detector with a alarm verification senses an alarm, the system shall turn off the detector for 50 seconds. Should the system see an alarm from the detector within 60 seconds after the completion of 50 seconds turn off period, the alarm shall be processed as programmed.
12. Adjustable Sensitivity:
  - a. System shall allow to adjust the sensitivity of analog ionization or photoelectric smoke detectors via software program. Seven levels sensitivity, 3 higher than normal and 3 lower than normal within UL specified limits, shall be selectable in software programming. Also, these sensitivity adjustments shall be available using the keypad on control panel. Sensitivity shall be selectable per detector basis.

- b. It shall be possible to automatically change the sensitivity of a detector based on time of day or system logic function output. It shall be done by including special instruction in software programming.

13. Environmental Drift Compensation:

- a. EnviroLink feature of the system shall Automatically compensate for drift due to dirt accumulation or environmental conditions in analog voltage of an addressable photo or ion smoke detector. This feature will be software selectable only, and no special detector or bases will be required. Adjustment in threshold values shall be both downward and upward direction as required to maintain constant sensitivity.
- b. The system shall display a message when a detector is approaching the limits of adjustment due to the contaminates.
- c. The system shall be capable of recognizing that a detector has been cleaned and display a "detector cleaned" message, readjusting that detector's normal sensitivity setting reference.

14. One-Man Walk Test:

- a. The system shall have a one-man walk test feature allowing to test the alarm devices on the system. The mode of walk test shall be selectable as Silent (audible bypassed) or with audible active. During the walk test mode the circuit or zone under test only shall be disabled along with bypassing city line, control relay functions. The system shall indicate partial system disable on a distinct yellow LED on the system and a system trouble. Alarm from remaining part of the system shall be processed as programmed.

15. Remote Control Panels:

- a. Remote control panels MXLR shall be provided as necessary to provide a complete Functional system. Communication between remote panels shall be on a style 4 network using a twisted shielded pair of wires. Each remote shall have its own power supply and battery back up.
- b. In case of communication circuit failure each remote panel shall be capable of receiving alarm from initiation circuit tied to it and activating signal circuits on CSM-4 module in the same enclosure and shall activate local alarm relay.

16. Degrade Mode Operation:

- a. The system shall recognize initiating of an alarm and indicate the alarm condition in a degrade mode of operation in the event of processor failure or the loss of system network communication to the remote interface panels.
- b. The system shall indicate a trouble condition during degrade mode operation and shall give a visual indication of an alarm condition.

- c. Each remote interface panel shall be capable of operation in its own degrade mode. In this mode, the system shall receive an alarm from any intelligent analog or conventional initiating device connected to it and shall activate local indicating appliances and local alarm relay.

17. Default Operation:

- a. The system shall provide a default operation program to allow reporting of alarms from installed devices before loading of custom system software.
- b. During program upload or download the system shall retain the capability for alarm reporting.
- c. The system shall report alarms from devices installed, but not yet add to the system custom program. Alarm reports from these devices shall activate, indicating appliance circuits.

18. Remote Annunciators:

- a. Remote LCD display Annunciator panels Model RCC-1 using MKB-3 module with necessary hardware and enclosure. This type of annunciator shall have functional LCD display and all switches same as those on main command center. Each KMB-3 shall be capable of driving a PIM-1, RS-232 serial printer interface. At least four MKB-3s shall be supervised and have supervised printer output.
- b. Each annunciator shall require only 2 wire for data communication and 2 #14 for 24 VDC power. Each annunciator shall be wired on the same 2 wire network communication loop as that used for interconnecting remote MXLRV panels and MKB-3 annunciators.

E. System Operation:

- 1. Activation of any fire alarm initiating device shall cause the following actions and indications:
  - a. Display a custom message describing the device originating the alarm condition, at the fire alarm control panel LCD alphanumeric display. Remote LCD annunciators shall display the alarm condition via unique messages as required by the system owner. LED type annunciator displays, conventional and graphic style, shall indicate alarm zoning as specified.
  - b. Horn/strobes to be wired and programmed for entry of incidence and two adjoining entrances.
  - c. Trouble and supervisory conditions. Supervisory conditions to include all valve tampers and low air switches. System alarm to over ride any trouble or supervisory condition.
  - d. NOTIFY CAMPUS POLICE VIA LEASED LINE.

F. Fire Alarm Control Panel:

1. Fire alarm control panels shall be designed for wall mounting. Wall location to be determined.
2. The control panel shall be Cerberus Pyrotronics model MXL, modular in construction and shall include, but not be limited to: the hardware, software and firmware required to perform the following major system functions.
  - a. Surface mounted steel cabinet with indicator viewing window, hinged door and cylinder lock, dead front construction, and factor finished in baked enamel. Locks shall be BEST with key code BY0Z/AUZV.
  - b. System power supplies, including necessary transformers, rectifiers, regulators, filters, and surge protection required for system operation, with capacity to power the system in a worst case condition with all devices in alarm and all local indicating appliances active without exceeding the listing ratings. The system devices shall display normal and alarm conditions consistently whether operating from normal power or reserve (standby) power.
  - c. Total system response time shall not exceed 2.5 seconds on a system configured to the maximum capacity.
  - d. All system processors shall be supervised by the individual watchdog circuitry furnishing automatic restart after loss of activity. System with a single watchdog circuit for all processors shall not be acceptable.
  - e. Selectable Style "4" system digital communication capabilities required for the control panel to communicate with remote circuit interface panels, annunciators and displays. System processing signals using pulse width or voltage level techniques are not considered acceptable.
  - f. Provide Cerberus Pyrotronics model ALD-21 analog loop driver for additional analog initiating circuits conforming those described in section 1.07.03.
  - g. Provide Conventional Zone Module, Model CAM-4, to interface conventional detection zones. This module shall be installed in one of the system panels and shall be operated by the MXL control panel. Each circuit shall be capable of Style "B" wiring. Style "B" wiring shall require an end of the line device for beam detectors.
  - h. Provide Controllable Signal Module CSM-4 for output circuit originating from a panel for the operation of DC (coded if required) audible devices, leased line or city tie section 1.07.04.
  - i. The module shall be supervised by the MXL control unit for open and shorted circuits. Open and short circuits shall report trouble only and respond with circuit identification. The module shall contain two (2) programmable open collector outputs capable of serving 250 ma at 40 VDC for relay or LED activation.

- j. Programmable relays in a panel for auxiliary control functions shall be provided a Controllable Relay Module Model CRM-4. The module shall be installed in a system panel and shall be operable by the MXL control unit. It shall contain four independent relays, fitted with form "C" contacts, rated at 2 amps 28 VDC/120 VAC resistive. All relays shall be supervised for coil open or shorted conditions.
- k. The enclosure for the system shall provide complete dead front construction. Human interface modules shall be on a hinge mounted frame to provide easy access to wiring, and system plug in cards. Enclosure door shall be pin hinged and removable for easy system operation by firefighter's and technicians in testing and maintenance modes.

G. Fire Alarm System Power Supplies

1. System primary power:

- a. Primary power for the FACP and the secondary power battery chargers shall be in a separate conduit and obtained from a dedicated 1P., 20A circuit breaker in a power panel located in the basement of building. Circuit breakers shall be capable of locking in on one position.  
INSTALL BREAKER LOCK.
- b. MXL power supply and battery charging shall be provide by the MMB-1 main board and a MPS-6 power supply.
- c. MXLR power supply and battery charger shall be provided by the PSR-1 remote power supply and an MPS-6 (6A) or MPS-12 (12A) power supply.

2. Secondary power supply:

- a. Provide sealed gelled electrolyte batteries as the secondary power supply for the fire alarm control panel and each system circuit interface panel.
- b. The battery supply shall be calculated to operate its load in a supervisory mode for 60 hours and 10 minutes of alarm at the end of supervisory backup period. Batteries shall be housed in the control cabinets or a separate cabinet.
- c. Provide battery charging circuitry for each standby battery bank in the system low voltage power supply or as a separate circuit. The charger shall be automatic in design adjusting the charge rate and thermal voltage shall be read using the fire alarm control panel LCD display in the service mode, indicating directly in volts and amps.
- d. Meters reading percentage are not acceptable. Charger shall be housed in the main fire alarm control panel or the batter y cabinet.

H. Remote Circuit Interface Panels:

- 1. Remote circuit interface panels shall be Cerberus Pyrotronics type MXLR and shall consist of an enclosure, a PSR-1 Remote Power Supply, NET-4 for style 4, digital communications circuitry, mother boards MOM-4, batteries and hardware, modules and circuitry described for inclusion in the fire alarm control panel as required to function as specified.

I. Smoke Detectors, Intelligent (Addressable):

1. General:

- a. The detectors furnished shall be listed for use in environments as covered by Factory Mutual, UL (JROX) conforming to UL standard UL268 for open area type smoke detectors and UL268A for duct smoke detectors. The detectors shall be installed according to the requirements of NFPA 72E for open area coverage.
- b. The intelligent (addressable) detector shall be suitable for two wire operation and two way communications on the intelligent analog signaling circuit.
- c. The detector shall display a flashing LED when in the alarm state when the system is operating from normal or standby power.
- d. Address and sensitivity assignments shall be programmed electronically and devices requiring dip switches, rotary switches, staples or jumpers are not acceptable.

J. Remote Circuit Interface Panels:

1. Remote circuit interface panels shall be Cerberus Pyrotronics type MXLR or and shall consist of an enclosure, a PSR-1 Remote Power Supply, NET-4 for style 4, digital communications circuitry, motherboards MOM-4, batteries and hardware, modules and circuitry described for inclusion in the fire alarm control panel as required to function as specified.

K. Smoke Detectors, Intelligent (Addressable):

1. General

- a. The detectors furnished shall be listed for use in environments as covered by Factory Mutual, UL (JROX) conforming to UL standard UL268 for open area type smoke detectors and UL268A for duct smoke detectors. The detectors shall be installed according to the requirements of NFPA 72E for open area coverage.
- b. The intelligent (addressable) detector shall be suitable for two wire operation and two way communications on the intelligent analog signaling circuit.
- c. The detector shall display a flashing LED when in the alarm state when the system is operating from normal or standby power.
- d. Address and sensitivity assignments shall be programmed electronically and devices requiring dip switches, rotary switches, staples or jumpers are not acceptable.
- e. The detector shall be compatible with all features of the MXL panel mentioned in Section 1.

- f. The detector shall be tested every 24 hours by raising the detector sensitivity level to the alarm threshold, to check the operation of the detector without system alarming.
2. Ionization detectors, Intelligent (addressable):
- a. Addressable ionization detectors shall be Cerberus Pyrotronics, I series dual chamber and selfcompensating for ambient temperature and humidity.
  - b. Detectors furnished shall be available in the following separate configurations to serve all possible environmental requirements.
  - c. Model ILI-1 for normal open area coverage.
  - d. Model ID-60IB listed for installation in air ductsmoke detectors housing using STA series sampling tubes for the detection of smoke in HVAC system ducts.
3. Heat Detectors, Intelligent Rate Compensated:
- a. Furnish and install where indicated in the drawings, Cerberus Pyrotronics type ID-60T-135 heat detectors, rate compensated type rated at 135 degrees. 200 degree detector will be a type DT-200 with a TRI-60 Interface.
  - b. The detectors furnished shall have a listed spacing for coverage up to 2,500 square feet for use in environments as covered by Factory Mutual and UL (UQGS) and shall be install according to the requirements of NFPA 72E for open area coverage.
4. Fire Detector Bases, Universal:
- a. Detector bases shall be Cerberus Pyrotronics type DB-3S, low profile twist lock type with screwclamp terminals and self wiping contacts. Bases shall be installed on an industry standard, 4"square or octagonal electrical outlet box.
    - 1) Where selective localized control of electrical devices is required for system operation, furnish and install type DBX-3RS addressable relay integral to the base. The relay shall switch electrical loads, as indicated on the drawings.
    - 2) The detector bases shall be compatible with, and allow the installation of, detectors operating on the flame ionization, photoelectric, or rate compensated heat principle of detection.
5. Manual Stations, Intelligent:
- a. Provide Cerberus Pyrotronics type MSI-20 double action intelligent addressable manual stations, where shown on drawings, flush or surface mounted as required.

- b. Address assignments shall be set electronically and reside within the station in no volatile memory. Devices using rotary switches, pins, jumpers, or staples are not acceptable.
  - c. Shall be located, adjusted for height, and installed to meet ADA requirements, 48" above finished floor.
6. Furnish as part of the installed system, a Cerberus Pyrotronics SensorLink (FPI-32) UL listed programmer and tester.
- a. The programmer shall set and verify the device address and perform a device test to ensure operation within UL defined detection window. The programming and testing shall be done independent of the control panel and system wiring.
  - b. The programmer tester shall dynamically display, in real time, the detector chamber analog voltage.
7. Intelligent Interface Input/Output Modules:
- a. Furnish and install, for the monitoring of contact type initiation devices and for the control of electrical devices where required, Cerberus Pyrotronics Type TRI series intelligent analog signaling circuit interface modules. The module shall be suitable for two wire, two way communications on the ALD-2I initiation analog circuit.
    - 1) The module shall display a steady LED for each circuit, in the normal power or standby power condition, when in the alarm state or during control circuit activation.
    - 2) Model TRI-60 for single address intelligent interface module for monitoring alarm, trouble, supervisory security, or status contact type devices, TRI-60D Model For dual addresses.
    - 3) Model TRI-60R shall be same as TRI-60 but with a system software programmable SPDT form C relay output with contacts rated 2A 120VAC/30VDC resistive. The relay shall be programmable to change the state independent of the status of the device being monitored by the host TRI-60R module.
  - b. Signal outputs shall be supported in Style "Y" configuration. All connected field wiring shall supervised for opens, short circuits, and ground circuits.
  - c. All controlled circuits shall be power limited at 1.5A.
  - d. The module shall report a trouble condition in the event of loss of the 24VDC signal operating supply voltage.

L. Duct Smoke Detectors:

1. Pyrotronics AD-3XRI housing and Type STA sampling: Mount ID-60IB detector inside unit. Units shall operate on 24VDC, shall be two-wire and shall be provided with auxiliary contacts for control of AHU equipment. Units shall reset from the CPU reset push button. A remote indicating light, #RL-40 with MR-201C relay, shall be provided.

M. Indicating Appliances:

1. General

- a. All audio/visual devices shall meet or exceed requirement of American with Disability Act (ADA).
- b. Xenon type strobe visual alarm signals shall be furnished with minimum light intensity of 15/75 candela complying with the ADA act. It shall have a dome type lens with letters "FIRE" inscribed in red on both sides.
- c. Provide suitable mounting boxes.
- d. Combination Strobe/Horn: Pyrotronics MTS 15/75 Series, slow whoop. End of line resistors shall be installed in the proximity of last unit on each circuit. Provide surface and weatherproof.

N. Sprinkler Flow, Tamper Switch, And Supervisory Switch

1. Existing and new tamper switches, waterflow devices air supervisory switches, etc for wet sprinkler and dry sprinkler system, and standpipe system shall be connected into the new fire system. Refer to drawings for quantity, type, and location of devices.
2. Provide all required interfacing modules for a complete operational system.

O. ADA Strobe

1. Strobe model S15-SUR 24VDC as manufactured by Pyrotronics. DBB surface backbox.

P. Installation

1. All wiring shall be in conduit of a minimum size of 3/4" and shall be installed in strict compliance with all the provisions of NEC, Article 760 A and C power limited fire protective signaling circuits or if required may be reclassified as non-power limited and wired in accordance with NEC, Article 760 A and B. Upon completion, the Contractor shall so certify in writing to the Owner and Contractor.
2. A separate ground (isolated from conduit ground) must be pulled to all cabinets.
3. Loads greater than 10 Amperes (for auxiliary functions) shall be in an isolated conduit.
4. The manufacturer's authorized representative shall provide on site supervision of installation. Final connection between equipment and the wiring systems shall be made under direct supervision of the manufacturer's representative.

5. Wiring color code requirements for fire alarm systems.

- |    |   |  |
|----|---|--|
| a. | Detection circuits:<br>+ Black<br>Negative - White  | Positive                                 |
| b. | Manual pull station:<br>+ Black<br>Negative - White | Positive                                 |
| c. | Audible circuits:<br>Negative - Blue                | Positive + Red                           |
| d. | Water flow<br>+ Black<br>Negative - White           | Positive                                 |
| e. | Pressure Switch:<br>+ Black<br>Negative - White     | Positive                                 |
| f. | Tamper switch<br>+ Black<br>Negative - White        | Positive                                 |
| g. | Low air switch<br>+ Black<br>Negative - White       | Positive                                 |
| h. | Door holders<br>+ Yellow<br>Negative - Orange       | Positive                                 |
| i. | Remote Reset<br>Wire: Brown                         | Zone                                     |
|    | Annunciator:  | AC Neutral: White or<br>DC Neutral: Gray |
| 1) | Key Switches  |  |
|    | Alarm Silence                                       | Blue w/ White Stripe                     |
|    | System Reset  | Red w/ White Stripe                      |
|    | Trouble Silence                                     | Green w/ White Stripe                    |
| j. | Remote lights:<br>Wire: Brown<br>DC Neutral: Grey   | Zone                                     |
| k. | 24 Volt DC Power<br>+ Red<br>Negative - Black       | Positive                                 |

- |    |   |            |
|----|---|------------|
| l. | 120 Volt AC Power<br>+ Black Hot<br>Negative - White Neutral<br>Ground - Green Ground | Positive   |
| m. | Firemen's Phone<br>+ Yellow<br>Negative - Blue  | Positive   |
| n. | Fan shut-down<br>Purple<br>Negative - Pink  | Positive + |

6. Wiring:

- a. Initiation Loops: #14 AWG, CU, Solid, Twisted Shielded Pair, Class B, 2 Wires.
- b. Horn/Strobe Circuit: 2 #14 AWG, CU, Solid, THHN
- c. 24VDC Power Circuit: 2 #14 AWG, CU, Solid, THHN.

Use #12 AWG, CU, THHN, conductors for 120VAC power application and battery connections.

Use of stranded conductors with maximum of 7 strands for #16 awg and 19 strands for sizes #14 and larger is permitted in replacement of solid copper only. Proper UL connectors must be used with stranded wire.

7. Conduit and Wiremold

- a. New vertical runs to be made in conduit. New horizontal runs can be made in wiremold.
- b. Conduit sizes shall be proper and shall not be smaller than 3/4".

8. Wiring of Flow Switches, Pressure Switches, Low Air Switches, Tamper Switches are not to be combined. They are to be addressable points interfaced with TRI Modules with the main Fire Alarm Panel. Furnish and install a minimum 18" of liquid tight flexible metallic conduit for the conductor at each water flow device, tamper switch, and pressure switch.

9. Cabinet Locks. Best Lock. Key Code BYOZ/AUZV.

10. Provide 3/4" empty conduit, with drag line, to telecommunications closet for telephone tie into main campus police.

Q. Warranty

- 1. The Contractor shall warrant the completed fire alarm system wiring and equipment to be free from inherent mechanical and electrical defect for a period of one (1) year from the date of the completed and certified test of from the date of first beneficial use.

2. The equipment manufacturer shall make available to the Owner a Contract proposal to provide a minimum of two (2) inspections and tests per year in compliance with NFPA-72K guidelines.

R. Labeling of Devices

1. A permanent label is to be placed on the base of each device with the address number of that device. The label size will be large enough to be read from the floor and approved by Yale Fire Marshall.

## 16620 MOTOR CONTROL CENTERS

### A. General

1. Provide motor control center (MCC), Model 4 by Square D Company or approved equal by General Electric or Cutler-Hammer.
2. Unit shall be rigid, free-standing assembly, and shall meet UL-845, NEMA ICS-2-322 and NEC requirements.
3. Enclosure shall be NEMA rated according to location.

### B. Vertical Sections

1. Provide 90" high, 13-gauge hot-rolled steel vertical sections to support horizontal and vertical busses, combination starter units, covers and doors. Provide 10-gauge reinforcing steel where needed.
2. Divide line-ups into shipping splits no wider than 60". Provide 7-gauge, 3" high, removable lifting angle on top of and extending entire width of shipping split.
3. Provide two 1-1/2" high base channels with holes for bolting MCC to floor.
4. Provide removable end closing plates.
5. Provide removable, one-piece top plate on each vertical section. Top plate shall allow standard conduit entrance area without significant sag or deformation.
6. Vertical sections shall accommodate plug-on units.
  - a. Sections housing plug-on units shall be 20" wide. Wider sections will be permitted for bolted construction units not fitting 20" wide sections.
  - b. Divide mounting area into 1/2 space factor divisions of approximately 6". NEMA size 1 and 2 combination starter units shall use one space factor, 12", only.
  - c. Provide flanged blank plates and captive screws for unused mounting spaces.

### Horizontal Wireways

7. Provide horizontal wireways in top and bottom of each vertical section. Clearances shall permit unrestricted wire installation. Provide wireway covers with captive screws.
  - a. Top wireway shall have cross-sectional area of at least 20 sq. in. with openings between sections of at least 11-1/2 sq. in.
  - b. Bottom wireway shall extend through length and depth of vertical sections and shall have openings of at least 11-1/2 sq. in.

C. Vertical Wireways

1. Provide wire trough with at least 19-sq. in. cross-sectional area on right side of vertical section. Extend from top of horizontal wireway to bottom mounting space.
2. Provide separately hinged door with captive screws.
3. Isolate wireway from bus bar.

D. Bus Bars

1. Provide continuous main, three-conductor horizontal bus fully rated horizontal neutral bus, 1200 A maximum over full length of control center.
  - a. When necessary, split bus to facilitate in moving and handling.
  - b. Provide splice bars to join bus where split has been made. Make splice connections with at least two bolts and Belleville washers.
  - c. Mount horizontal bus bars edgewise and support with insulated bus supports.
2. Provide three-phase vertical bus, bolted to horizontal bus.
3. Horizontal and vertical busses shall be electrolytically tin-plated copper.
4. Bus supports shall be high strength glass-reinforced alkyd material. Surface clearances in vertical plane shall shed dust and maintain dielectric integrity. Bus supports and insulators shall be red.
5. Provide copper ground lug capable of accepting #8 to 250 MCM cable in each incoming line vertical section.
6. Provide tin-plated horizontal and vertical copper ground bus in bottom of each section.
  - a. Horizontal ground bus shall have cross-sectional area of 28% of main horizontal bus cross-sectional area and shall run continuously throughout control center except where splits are necessary. Provide splice bars at splits.
  - b. Vertical ground bus shall run parallel to power distribution bus in each vertical section. For plug-on unit, ground bus slab shall make contact with ground bus before power bus contact is made.

E. Bus Barriers

1. Provide red, insulated horizontal and vertical bus barriers. Vertical bus barriers shall have interlocking front and back pieces to segregate phases.
2. Provide openings in vertical bus barriers to permit unit plug-on contacts to pass through and engage vertical bus bars.

3. Provide bottom bus covers. Unused plug-on openings in bus shall have plastic snap-in closing plates.

F. Main Incoming Lug Compartments

1. Provide accessible main lug compartment with main lugs to accommodate at most two 3/0 - 750 MCM cables per phase.
2. Provide hinged access door with captive screws.

G. Starter Units

1. Provide UL-listed combination starter units with magnetic starters, adjustable magnetic only circuit breakers and auxiliary control devices.
2. Mount auxiliary equipment within compartment, except that specified for mounting on door.
3. Provide doors, support pans, saddles and disconnect operators.
4. Enclose unit compartments and isolate from adjacent units, busses and wireways except for openings for conductor entrance.
5. Unit shall be designed and constructed to localize fault within compartment.
6. Plug-on combination starter units of same NEMA size and branch feeder units of same trip size shall be interchangeable. It shall be possible to withdraw each plug-on unit to de-energized position without disturbing structural support and to lock unit in this position with one padlock.
7. Full voltage non-reversing combination starter units shall have plug-on connections and shall have ample space for wiring room. Units shall satisfy following minimum space factor requirements:

<u>Circuit Breaker</u>	<u>Space Factor</u>	<u>Fusible Space Factor</u>
Size 1	1	1
Size 2	1	1
Size 3	1-1/2	1-1/2
Size 4	2	3-1/2

8. Starters shall be plug-in, draw-out or bolted connection as required for mechanical support and electrical connection. Plug-in connections shall be high-quality, two point connections with floating, self-aligning silver-plated fingers with low-resistance compound coating for each phase, to tighten on vertical bus bar during current surge.
9. Unit Doors
  - a. Provide door with concealed hinges for 112° swing.

- b. Provide captive screws and self-aligning cage nuts to close door. Screws shall provide at least two threads of engagement to hold doors closed under fault conditions. Provide interlocking disconnect mechanism to prevent door from opening with unit energized.
  - c. Provide defeat mechanism to over-ride interlock.
  - d. Provide removable door panels with captive screws for mounting push buttons, selector switches and pilot lights. Provide blank door panels for future pilot devices.
  - e. Provide external, low-profile overload reset button in door.
10. Unit Support Pan: Provide removable pan to support and guide unit rearrangement.
11. Unit Saddles
- a. Provide 14-gauge, galvanized steel saddle to isolate unit from bus compartments and adjacent units, with flanged edges.
  - b. Provide captive, self-aligning mounting screws to secure unit during shipment.
12. Disconnect Operators
- a. Provide external operator handle for each switch or breaker, color-coded to display red in ON and black in OFF position. Handle shall be engaged with switch or breaker regardless of door position.
  - b. It shall be possible to lock handle in OFF position with as many as three padlocks.
  - c. Handle shall be interlocked with unit door to prevent switching ON while door is open.
  - d. Provide defeat mechanism to override interlock.
13. Magnetic Starters
- a. Provide electrically-operated and held, three-pole assemblies with arc extinguishing characteristics and silver-to-silver renewable contacts.
  - b. Provide thermal bimetallic overload relay assembly, resettable from outside enclosure with insulated button.
  - c. Provide overload heaters in each phase sized for actual nameplate current of motor.
  - d. Provide fused control power transformer, hand-off-auto selector, two indicating lights (red RUNNING and green ON) and at least two normally open and two normally closed auxiliary contacts for each starter.

14. Motor Circuit Protectors (MCP)

- a. Provide molded-case (adjustable magnetic only) circuit breakers (with integral current-limiting fuses) with push-to-trip feature in starter and branch feeder units where required.
- b. Circuit breakers shall be Square D MAG-GARD FAL, KAL, MAL Type or approved equal by General Electric or Cutler-Hammer.

16621 MOTOR STARTERS

- A. Provide 120/208 V control transformers for line voltage magnetic starters provided under other Sections. Install starter units in NEMA I enclosure.
- B. Motor starter shall be by Square D, Furnas, General Electric, Allen Bradley, or Cutler-Hammer.

16622 VARIABLE FREQUENCY DRIVES

A. Acceptable Manufacturers

1. Variable frequency AC motor drives shall be manufactured by Square D, Allen-Bradley, or ABB. Manufacturer shall coordinate and verify compatibility with motors being served.

B. Variable frequency AC motor drives shall conform to the codes and standards of the organizations listed. In case of conflict they shall take precedence in that order.

C. Codes and Standards

1. National Electrical Manufacturers Association (NEMA)
  - a. ICS 1 Industrial Controls and Systems.
  - b. ICS 3 Industrial Systems
  - c. ICS 3.1 Safety standards for construction and guide for selection, installation and operation of adjustable speed drive systems.
2. Underwriters Laboratories (UL): UL
3. ASTM

D. Equipment Identification

1. Nameplates shall be furnished on the front of each unit.
2. Provide a plate with a one line diagram of that line-up for mounting on the front of the assembly.
3. Nameplates shall be laminated phenolic with black outer layers and white inner layer. Lettering shall be vertical gothic engraved into phenolic to produce white letters on black background. Letters shall be 3/16" high, minimum. Edges of the nameplates shall be beveled. Attach nameplates with cadmium plated No. 6 slotted pan head screws.

E. Accessories

1. Furnish the following:
  - a. One set of all standard accessories as required by ANSI Standards.
  - b. Any necessary lifting angles and rigging lugs to unload or position each assembly.
  - c. Two sets of spare fuses of each type and rating supplied with the equipment.

F. Equipment

The ratings for variable frequency A.C. motor drives shall be as follows:

1. Power ratings - HP as required, Variable Torque
  2. Input Volts - 460 V 10%
  3. Input Frequency - 60 HZ 2HZ
  4. Line Transient Protection - up to 5,000 volts peak, 120 joules
  5. Output Voltage - 0 to 460 V AC
  6. Output Frequency - 0 - 66 HZ
  7. Volts per Hertz - programmable
  8. Waveform - Sine coded pulse width modulation waveform(PWM), rectifier to be diode bridge type.
  9. Boost - 0 to at least 20% of rated voltage (460V) programmable.
  10. Accel/Decel - Separately programmable deceleration and acceleration times. Adjustable from 1 to 60 seconds.
  11. Current Limit - programmable from at least 50 to 110% of rated motor current.
  12. Power Factor - Power factor constant at 95%.
  13. Efficiency - 98% at full load and speed.
  14. Short Circuit Withstand Rating - 25,000 amps short circuit symmetrical current, minimum.
  15. Output and Overload Capability - Capable of delivering 110% of rated output current continuously.
  16. Voltage Distortion Limits -
    - a. Maximum individual harmonic voltage and current distortion: 3%
    - b. Maximum Total harmonic distortion: 5%
  17. Integral mounted circuit breaker
  18. A 3% reactor on the output shall be provided to limit voltage reflections at the motor.
- G. Variable Frequency Drive shall be designed to give successful operation over full speed and load range under the following conditions:
1. Operating Temperature - 0 to 60°C, indoors  
Operating Humidity - 5 to 95 percent relative humidity, non-condensing
  2. Line Stiffness - VFD will be connected to a 480V motor control center. VFD should be capable of successful operation under these conditions. If additional equipment such as line reactors are required it must be specified in quotation. Reactors shall be factory installed when required.

3. Line Distortion - VFD will be connected to the same industrial power source as several other motors. VFD shall be able to operate successfully with the given harmonic distortion generated from operation of the two VFD's and industrial noise. If additional equipment, such as line reactors, are required it must be specified in quotation. Reactors shall be factory installed when required.
  4. Motor - The VFD shall be matched with the selected motor to deliver proper load requirements over total speed range of motor (10 - 60HZ). In addition, VFD shall be designed to successfully operate motor at low speeds (10HZ) and higher speed (66 HZ) continuously without motor overheating or instability. The motor to be controlled by the VFD shall be listed for inverter duty. The motor nameplate shall include allowable frequency range.
- H. The variable frequency drive will be designed with the following features:
1. Physical Packaging of VFD
    - a. The VFD's shall be individually packaged in stand alone NEMA enclosures. The enclosures shall be rated for area they are installed. Enclosure shall be capable of being lined up (side touching side) against a wall without overheating. It is desirable to mount VFD's remote from hazardous areas.
    - b. Provide access to VFD controls without opening door of enclosure.
    - c. If reactors are required they must be factory installed so as not to increase the enclosure foot print.
    - d. Coordinate VFD requirements with motor control center manufacturer where VFDs are to be integral to the motor control centers.
  2. Disconnecting Means: Provide integral circuit breaker or fused disconnect switch on line side of each enclosure with through the door lockable operator. Operator shall be interlocked to prevent door from opening when operator is in the on position. Provide mechanical override to interlock that shall be a spring return screw type mechanism.
  3. Shortcircuit and ground fault protection - The VFD shall have an instantaneous electronic trip circuit to protect the VFD from output line to line and line-to-ground short circuits. The VFD must be capable of withstanding short circuits at 480V without damage to VFD.
  4. Automatic/Manual Operation: Each VFD shall be equipped to accommodate a remote speed signal(4-20 mA or 2-10 VDC) and a remote start and stop signal. These remote signals shall be from a DDC system, coordinate with ATC vendor. In addition, a manual emergency stop button shall be provided at enclosure which shall override all controls and stop motor. Provisions for local control consisting of start/stop and speed potentiometer shall be provided. All enclosure mounted controls to be labeled with laminated plastic tags engraved to show white letters on a black background.

5. Display - Provide integral digital display indicating output voltage, output current and frequency, as well as being able to make adjustments to operating parameters and display fault indicators. Display to be visible and operable without opening door of enclosure. In addition, provide provisions for remote speed indication via a 4-20mA signal output that is proportional to the speed.
  6. Memory Back Up - All parameters for operation of drive shall be stored in nonvolatile memory (EEPROM).
  7. Fault Indication: Provide means to maintain the last fault condition even after loss of power.
  8. Cable Connections:
    - a. Provide for top or bottom entry of both incoming and outgoing cables. Lugs will be provided for both incoming and outgoing cables. Equipment ground lug shall tie together both incoming ground and motor ground.
    - b. Minimum wiring bending radius and wiring gutter size shall conform to tables 373-6A and 6B in National Electric Code 1996 edition.
  9. All control circuits shall be physically isolated from power circuit voltages to ensure safety to maintenance personnel. Components, inside drive enclosure, above 120 V AC or DC shall be barriered from control circuits and control boards to prevent accidental contact with these components.
  10. Provide manual bypass switch and controls which will allow an operator to engage the motor without the drive. Provide feedback to control system on status of bypass switch.
  11. Provide starter contactor for bypass manual mode with start/stop controls.
  12. Provide separate Class 20 bimetallic overload relay on output of drive with auxiliary NC contact tied into run, enable circuit to shut down drive when overload trips.
- I. The VFD shall have the following analog/digital outputs and inputs.
1. Outputs
    - Run - 2 spare N.O. contacts-closed when drive is in run position.
    - Fault - 1 set of Form C contacts that change state on drive fault or momentary loss of power.
    - Warning -1 set of Form C contacts that change state indicating that the drive is operating outside the prescribed limit and that fault is imminent.
    - Analog Speed Output - 4-20MA signal proportional to the frequency output of drive
- All analog outputs shall be capable of driving 500 OHM load.

## 2. Inputs

Overload - Thermal overload contacts in motor (N.C.) wired in series. When contact opens VFD stops.

Automatic Start/Stop - 1 maintained contact which closes to start drive and opens to stop drive when in Automatic mode.

Manual Stop - 2-wire stop circuit wired to remote local and remote mounted stop buttons. Maintained contact from stop buttons stop drive when opened.

Manual Start - 2-wire start circuit wired to remote local and remote mounted start buttons. Maintained contact from start buttons start drive when closed.

## 16740 TELECOMMUNICATIONS SYSTEM

### A. GENERAL

#### 1. SUMMARY

- a. This section describes the design and construction parameters recommended by Yale I.T.S., Telecommunications for the installation of telecommunications (Telecom) facilities in new and renovated structures owned or operated by Yale University and I.T.S. affiliates.
- b. Refer to sections listed below for related requirements:
  - 1) Conduit systems: Section 16111
  - 2) Surface raceway systems: Section 16112
  - 3) Seismic requirements: Section 16190.

#### 2. REFERENCES

- a. Designs shall conform to applicable portions of the following reference standards:
  - 1) Building Industry Consulting Service International (BICSI), Telecommunications Distribution Methods (TDM).  
Electronics Industries Assoc./Telecommunications Industry Assoc.( EIA/TIA)

#### 3. SUBMITTALS

- a. Designers shall submit the following information to Owner:
  - 1) Construction documents which contain the following:
    - a) Building entrance of telecom services.
    - b) Telecom/Data outlet schedule and riser diagram. (See Attachments 1 and 2 for models.)
    - c) Telecom rooms and closets.
    - d) Horizontal raceways (trays, conduits....)
    - e) Outlet locations and identification numbers.
    - f) Details of backboards, lighting, power circuits receptacle outlets, and sleeves.
    - g) Modular furniture locations with details of telecom raceways and outlets.
    - h) Provisions for elevator, emergency, area of refuge. exterior and coin telephones.

- i) Legend of telecommunications symbols.

#### 4. SYSTEM DESCRIPTION/PERFORMANCE

- a. It is essential that new and renovated structures be prepared for telecom facilities. Designers shall consult with Yale Project Manager, Yale I.T.S., Telecom, and facility occupants to provide adequate telecommunications facilities for all current and anticipated future uses.
  - 1) Design changes shall be submitted to Yale University FACPC for review to ensure that changes do not render telecommunications facilities unusable or cause significant additional expense in the installation of telecommunications services.
  - 2) Construction changes, including conduit routings and pull box or manhole placement, shall also be submitted to Yale University FACPC for review to ensure that pulling and placement limitations of large diameter cables and optical fiber cable are met and to ensure that preordered equipment and wiring will be suitable for the actual installation.
- b. Telecom duct banks, manholes, equipment rooms, backboards, raceways, boxes, etc., including 120 VAC power as required, are to be included within the scope of construction documents and shall be designed in accordance with the requirements set forth in this standard. Telecom equipment, device plates, wiring, and terminations will be provided by Yale I.T.S., Telecom. Designers shall coordinate all specific project requirements with Yale I.T.S., Telecom.

#### 5. DESIGN REQUIREMENTS

- a. A Main Distribution Terminal, (MDT), room shall be provided in each building to function as a transition between the backbone distribution (exterior conduit duct system between buildings), and the riser distribution, (vertical or horizontal distribution within the building). MDT rooms should generally be dedicated to telecom distribution only. (See attachment 3 for a model.) However, in certain cases data communications equipment (such as computer networks, fire alarm, CATV, intrusion detection, access control, and energy management and control systems) may be located in the MDT room. In such cases power, ventilation, and backboard requirements described below may change.
  - 1). Generally a room of approximately 80 square feet in the building's basement will be sufficient, although the exact size and shape shall be coordinated with Yale I.T.S., Telecom for specific installation and maintenance requirements. The recommended ceiling height is 8 feet 6 inches

**Closet Size**

Serving Area Ft <sup>2</sup>	Closet Size Ft
10,000	10 x 11
8,000	10 x 9
5,000	10 x 7

- 2) Security of telecom equipment is essential. Doors to the room shall solid, minimum 80 inches high by 36 inches wide and preferably fire-rated steel, with hardware installed to prevent unauthorized access. Locks shall be keyed to the Telecommunications master key; if data communications or telemetry equipment is located in the room, the key shall be a sub-master of the Telecommunications master key. The MDT room shall be identified with the legend "Information Technology Services, Telecom" in accordance with any building sign system. The room shall not be included in any building specific alarm or access system without the agreement of Yale I.T.S.
- 3) For mounting of telecom distribution equipment only, a 4 foot by 8 foot backboard as described on Page 8, 2A shall be mounted horizontally on one wall approximately 24 inches off the floor. Additional backboards may be required for data communications or telemetry systems.
- 4) With the exception of ethernet hubs, telecom equipment has no specific ventilation requirements unless there is a known problem with heat, cold, or dampness. In cases where ventilation from adjoining spaces is necessary, grills shall be of substantial strength to resist vandalism and attempts at unauthorized entry.
- 5) The Yale Fire Marshall will determine if automatic fire detection or extinguishing capabilities are required in the MDT room.
- 6) Unswitched receptacle outlets located in double-gang boxes below the backboard and fed from a dedicated 15 ampere, 120 volt circuit shall be provided for telecom distribution use. Where data communication devices are located in the MDT rooms, one such additional circuit shall be provided, which may require an uninterruptible power supply. Numbers and locations of all such outlets shall be confirmed with Yale I.T.S., Telecom.
- 7) Lighting with emergency or alternate system backup shall be provided for equipment maintenance, with switch at entry door. Illumination levels shall be equivalent to office occupancies.

- 8) Specific conditions in the area of the building in which the MDT is located may require additional facilities such as drains, sump pumps, cabinets or covers.
  - 9) In order to develop appropriate equipment room requirements, the telecommunications distribution designer should become familiar with the National Electrical Code (NEC). Paying special attention to these sections:
    - Article 110 - general requirements including working spaces
    - Article 318 - cable trays
    - Chapter 2 - most system requirements including services, feeders, and branch circuits.
    - Chapter 5 - special occupancies including hazardous locations and health care facilities.
    - Chapter 7 - standby systems.
- b. Intermediate Distribution Terminals (IDT's) shall be provided to serve as cross connection points between riser distribution and outlet distribution (station runs) that serve each floor. IDT's shall be located in dedicated closets, preferably stacked above one another on each floor to facilitate risers and near the center of the building so that the circuits run from the closet are equidistant to the ends of the building (important for supporting high speed data over unshielded twisted pair cable.). Locate IDT's such that raceways to individual telecom outlets do not exceed 298 feet, including elevation changes. IDT's are always designed for shared use of low voltage communications services such as fire alarm, building alarms, telemetry, CCTV, and CATV; designers shall coordinate specific requirements for each location with data service providers and Yale I.T.S., Telecom.
- 1) Minimum size for IDT's shall be 48 inches wide, 36 inches high and 6 inches deep, although larger dimensions may be necessary due to data services requirements.
  - 2) The preferred access method for shallow IDT's is to have double doors that swing out to fully expose the IDT; hardware for such doors shall include a set of bolts that secure the inactive leaf to the frame at the top and to the floor at the bottom. Locks shall be keyed to a sub-master of the Telecommunications master key. Telephone closets shall be identified with the legend "Information Technology Services, Telecom.." in accordance with any building signage system.
  - 3) The entire back wall of the IDT shall be covered by a backboard as described on Page 8, 2A.
  - 4) IDT's shall be ventilated to support data services, whether or not provided as part of the current project. Natural ventilation by grills at top and bottom of space is preferred; grills shall be of substantial strength to resist vandalism and attempts at unauthorized entry. where grills cannot be used, provide mechanical ventilation.

- 5) Unswitched receptacle outlets located in double-gang boxes and fed from a dedicated 15 ampere, 120 volt circuit shall be provided for telecom distribution use. Where required, power for data services shall be fed by separate isolated and dedicated circuits. The number and location of all such outlets shall be coordinated with Yale I.T.S., Telecom and providers of data services.
  - 6) Lighting for shallow IDT's shall be wall mounted, with a wall switch. Larger IDT's shall have ceiling-mounted lighting with switch at entry door. Illumination levels shall be equivalent to office occupancies.
  - 7) Data services may require racks or shelves; locations of such equipment shall be coordinated with Yale I.T.S., Telecom.
  - 8) Some users may require patch panels to define data communication circuit configurations. Where provided for a large number of circuits, IDT's may increase in size or patch panels may be installed in remote locations.
  - 9) Some IDT's and MDT's may require a building ground via a minimum #6 solid copper ground wire terminated on an approved ground bar.
- c. Facility distribution structures described below include duct banks, manholes, raceways, pull boxes, outlet boxes, etc., provided for routing of telecom cables. Coordinate specific requirements with Yale Information Technology Service.
- 1) All underground telecom facilities shall be installed in buried duct structures, except that direct-buried cable may be used for temporary installations such as construction trailers. Minimum size shall be 4 inches. Duct structures shall be straight and level between pull points to the greatest extent possible. Maximum distance of any duct run between pull points is 350 feet. Direction changes shall be as gradual as possible; total bends between pull points shall not exceed two 90 degree sweeps with no more than a total of 90 degrees within any 50 feet. Duct bank formations should permit standard cable racking without changing formations as they enter the manhole or building.
  - 2) Manholes may be either precast or cast in place. Configuration may be inline two-way type for straight-through main conduit runs or multi-directional for three- or four-way conduit runs. Minimum interior size shall be 12 feet long, 6 feet wide and, 7 feet high, with knockouts or duct terminators arranged for conduit entrances on all four walls. Manholes shall be equipped with cable racks, pulling irons, ladder, sump pump, entrance collar and frame, and cover. Manhole frames and covers shall be bolted down to manhole collar and roof.

- 3) Riser distribution where IDT's are aligned shall be by means of 4 inch sleeves; otherwise 4 inch conduits shall be used. The number of sleeves or conduits is dependent on building size and configuration; however, the minimum is three, with more required closer to the MIDT. Maximum conduit distance between pull points shall be 90 feet, with not more than two 90 degree bends between pull points.
- 4) Outlet distribution shall be by means 1 inch, (or larger), conduits stubbed into the ceiling space with a sweep and bushing and terminated at the outlet location with a 4 inch box and a single gang plaster ring. Solid wall construction or special applications such as laboratories may require surface raceways; where raceways such as 3000 SMR and 4000 SMR are used, provide mounting bracket for single gang device. Minimum surface raceway size for outlet distribution shall be 2100 SMR unless Yale I.T.S., Telecom approves use of 700 SMR. All raceway and conduit to be EIA/TIA 569 compliant (See Attachment 4 for model.)
- 5) Horizontal distribution from outlet stub locations to IDT's through ceiling space shall be via Telecom approved raceway, either tray or conduit or a combination. Due to large numbers of cables for distribution the use of rings or hooks is not recommended. Special circumstances requiring rings or hooks must be approved by Telecom.

#### CONDUIT SIZING

CONDUIT		Number of Cables or Wires									
Internal Diameter	Trade Size	wire outside diameter inches									
		.13	.18	.22	.24	.29	.31	.37	.53	.62	
0.62	1/2	1	1								
0.82	3/4	6	5	4	3	2	2	1			
1.05	1	8	8	7	6	3	3	2	1		
1.38	1 1/4	16	14	12	10	6	4	3	1	1	
1.61	1 1/2	20	18	16	15	7	6	4	2	1	
2.07	2	30	26	22	20	14	12	7	4	3	
2.47	2 1/2	45	40	36	30	17	14	12	6	3	
3.07	3	70	60	50	40	20	20	17	7	6	
3.55	3 1/2							22	12	7	
4.02	4							30	14	12	

This table above provides guidelines on cable capacities for conduits that have no more than 2- 90 degree bends and no longer than 100'. It is based on 40% fill and a derating factor of 15% for each 90 degree bend. The radius of a conduit bend must be 6 to 10 times the diameter of the conduit. Under 2" conduit = 6x, 2" conduit and over = 10x.

- 6) Requirements for Yale I.T.S., Telecom special telephones are as follows:

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- a) Standard emergency telephones which are hands-free and weatherproof require a 3/4 inch rigid conduit connection. Each emergency telephone location shall be identified by a standard blue light as described below, to be illuminated 24 hours per day.
- b) Coin boxes will be provided by SNET. Wiring to coin box locations as well as housings for flush mounted coin boxes will be provided by Yale I.T.S., Telecommunications. Raceways and architectural custom shelving or booths shall be described in construction documents.
- c) Elevator telephones are generally provided under Division 14, but can be provided by Yale I.T.S., Telecommunications. Elevator telephones are considered to be emergency telephones. Battery-operated automatic dialers are not acceptable. Provide a 3/4 inch conduit from the traveling telephone pair in the elevator machine room to the nearest IDT.
- d) Area of Refuge phones shall be hands free as required by code

## B. MATERIALS

### 1. ACCEPTABLE MANUFACTURERS

- a. All products shall be approved by Yale I.T.S., Telecom

### 2. PRODUCTS

- b. Backboards shall be fabricated from 3/4 inch thick, type AC, exterior grade plywood. Backboards shall be painted with two coats of gray fire-retardant paint on all six surfaces.
- c. Conduits shall be as described in standard 16111, in accordance with the following requirements:
  - 1) Below ground in non-traffic areas: Rigid non-metallic conduit, schedule 40.
  - 2) Below ground in areas subject to vehicular traffic: Rigid metal conduit or schedule 80 rigid non-metallic conduit, except that schedule 40 rigid non-metallic conduit may be used if encased in concrete.
  - 3) Within buildings: As described in section 16111.
- d. Conduit elbows shall be long radius type, minimum IOx the diameter of the conduit, except that where structural considerations so not permit long-radius elbows, smaller radius types minimum 6x the conduit diameter, may be used. Under no circumstance may the radius of conduit bends be less than 6x the diameter of the conduit.

- e. Blue lights for emergency telephones shall be 28 watt compact fluorescent for 120 volt operation. Blue globe must be specified. Manufacturer and catalog numbers are as follows:
  - 1) Ceiling mounting: Stonco #VCXL28NFL.
  - 2) Wall Mounting: Stonco #VWXL28NFL.
  - 3) Recessed box Mounting: Stonco #VC28NFL.

C. EXECUTION

1. INSTALLATION

- a. Trenches for duct banks shall be excavated the width of the duct structure plus 2 inches on each side. Trench depth shall provide for minimum 24 inches earth cover above top of duct structure. All conduits that are to be encased in concrete shall have minimum 1 inch clearance between the bottom tier of ducts and the trench bottom.
- b. Conduits not encased in concrete shall be bedded with 6 inches of sand above and below and sand on all sides.
- c. In underground raceways, angle couplings and bends alone or in combination with straight sections shall be used for direction changes; direction changes made by skewing straight sections of conduit will not be permitted.
- d. All joints in plastic conduits shall be chemically welded.
- e. Where the number of ducts entering a manhole is significantly less than the capacity of the manhole, ducts should enter the lower portion of the knockout slot in order to simplify future additions.
- f. Sleeves or conduits which penetrate floor/ceiling assemblies shall terminate no less than 4 inches above finished floor.
- g. All sleeves shall be fire-stopped after installation of cables, as described in Division 7.
- h. Bushings shall be provided on all conduits and sleeves.
- i. All empty raceways are to be provided with pull strings or wires.
- j. Mounting heights of outlet boxes, measured from finished floor to center of outlet box, shall be as follows:
  - 1) Standard outlets for desk-type terminals: Same height as adjacent receptacles.
  - 2) Wall-mounted telephones: 60 inches, except that mounting height shall be 48 inches where required to allow access to handicapped persons.
  - 3) Emergency, security, and entryway telephones: 48 inches.

- 4) Coin-operated telephones: 60 inches, except that at least one in each building shall be 48 inches.

2. FIELD QUALITY CONTROL

- a. To ascertain that underground conduits have been properly installed, the work will be inspected throughout the construction period by Yale I.T.S., Telecom. After back-filling, but before paving the conduit structure should be mandreled. If the Mandrel fails to pass through the ducts being tested, the conduit shall be exposed and the condition corrected.

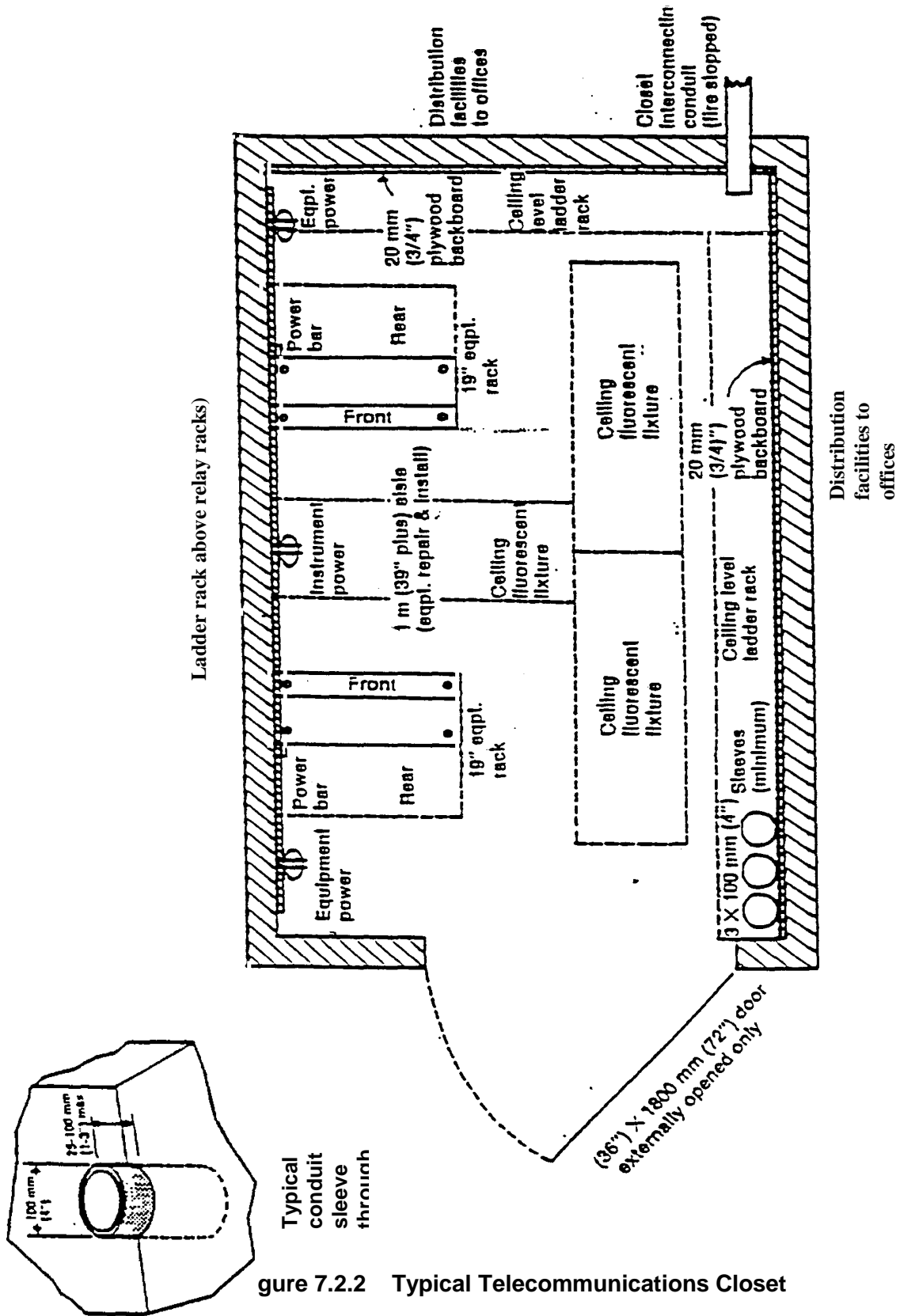


Figure 7.2.2 Typical Telecommunications Closet

