CHAPTER 7 ELECTRICAL CONDUCTORS AND CONNECTORS

7. 1 DESCRIPTION

The wiring methods and materials covered in Chapter 3 of the NEC apply to all wiring installations at PPPL. The requirements and recommendations in this Chapter 7 apply to high-current, -voltage, -frequency, liquid-cooled, and other special conductor and connector applications specific to research and development (R&D) activities that are not covered in the NEC. Examples include:

A. High-current pulsed systems.
B. Radio-frequency (rf) coaxial cable transmission systems.
C. Waveguides for microwave transmission systems.
D. Conductors that are cooled by internal or external means.
E. Conductors with low self-inductance requirements that use special insulations to permit minimum conductor separation.
F. Single-point grounding systems traceable to one monitored ground-connection point in an effort to reduce noise interference associated with instrumentation.
G. Flat conductor cables used for providing power to equipment although covered in NEC articles 322 and 324 are considered special cables.

7 .2 TYPES OF HAZARDS

7.2.1. Hazards can occur from conductor insulation damage or deterioration caused by chemical reactions, mechanical forces and abrasion, corona, ionizing radiation, transient over-voltages, or conductor overheating.

7.2.2. Metallic cooling-water pipes that are also used as electrical conductors present shock hazards (i.e., they may not be readily recognizable as electrical conductors). Leakage current through coolant may present shock hazards. Rupture of high-coolant pressure and/or temperature lines present personnel hazards.

7.2.3. Improper application or installation of connectors can result in overheating, arcing, shock hazards, and reversed phase rotation.

7.2.4. Inadequate separation between high-voltage and low-voltage cables or terminations can result in hazardous-induced voltages and arcing at the terminations.

7.2.5. Exceeding the design capacity of raceways or cable trays can cause overheating of the cables and deterioration of their insulation, which can cause fire and electric-arc hazards.

7.2.6. Pulsed operation of cables or high-current faults can produce sizeable electromagnetic forces causing movement of cables. Physical movement of components and sudden cable failures can create hazardous conditions.

7.2.7. Ungrounded or improperly grounded shields of cables can result in shock hazards.

7.2.8. Unprotected and unguarded live parts are potentially lethal in circuits operated over 50 V.

7.3 Design and Construction Criteria

7.3.1 Assure that the type of conductor insulation and jacketing selected is appropriate for the installation and operating conditions as follows:

A. thermal ratings,
B. dielectric and mechanical strength,
C. moisture,
D. chemical,
E. radiation,
F. and fire resistance).

7.3.2 The shields of all cables shall be capable of handling the current to which the shields are subjected. Provide suitable routing and additional protection for coaxial cables used in pulsed-power applications where the braid of the coaxial cable rises to high-voltage levels.

7.3.3 Conductors shall be adequately sized for their intended load, with energy dissipation capability (I^2Rt rating) in excess of energy supply capability, without exceeding the maximum Insulated Cable Engineers Association (ICEA) hot-spot temperatures (Ref. ICEA Publication P-32-382). The blanketing effect of fire stops and wall penetrations in excess of two linear feet shall also be considered. When using conductors rated at temperatures above 60˚C, all terminals, switches, circuit breakers, or other devices to which the conductors are connected shall have a compatible temperature rating.

7.3.4 Cable manufacturer's recommended maximum cable-pulling tension, sidewall pressure, and minimum bending radius shall be observed. See Chapter 16, Reference C.

7.3.5 Avoid loops (wide spacing between a high-current supply and return conductors) to prevent voltage and current induction in adjacent circuits or structural members.

7.3.6 In areas where conductors are bare, or where sufficient insulation and mechanical barriers are not provided, PSIs or locks shall be used to provide satisfactory safety to personnel and assure access by only Qualified Personnel .

7.3.7 Provide bracing and conductor supports that are physically and electrically adequate to withstand expected mechanical forces and voltages.

The mechanical force between two parallel current-carrying conductors of circular cross-section and not in an external magnetic field is:

$$F = \frac{4.5\ I_1 \times I_2 \times L}{D} \times 10^{-8}$$

Where: F = force (in pounds)
I_1 = current in one conductor (in amperes)
I_2 = current in other conductor (in amperes)
L = conductor length between supports (same unit as D)
D = spacing between conductors (same unit as L)

For example, the force is about 0.02 pound per foot for conductors spaced 0.25 inch and carrying 100 amperes. If short-circuit or pulse-current is 10,000 amperes, conductors spaced 0.25 inch will experience a force of 216 pounds per foot. If conductor bracing and supports are not adequate, this is enough force to bend metals, to break insulators or plastic tie-wraps, and to disconnect any conductor terminations that are not securely fastened.

7.3.8. Provide adequate separation between high voltage and low voltage cable terminations or alternately treat low-voltage circuits as high voltage in terms of personnel protection. Verify correct phase rotation before making final connections.

7.3.9. Cables or bus bars used to reconfigure either power supplies or their loads in recurring activities should be arranged to prevent hazardous and improper connections. Unique bolt-hole locations and alignment pins can serve this purpose.

7.3.10. The use of aluminum conductors in commercial building wire and cable is restricted. See Engineering Standard ES-ELECT-004, Wire and Cable.

7. 4 OPERATING CRITERIA

7.4.1. Walking or climbing on cable trays is prohibited. Exceptions may be approved when the circumstances are documented and approved on Form No. 5008.2-1 in Chapter 17, Appendix C.

7.4.2. Laying cables across the floor should be avoided. Where this is unavoidable, suitable protection for personnel and cables shall be provided.

7.4.3. Cable connectors and terminals should be checked periodically to assure required tightness. Recommended torque values are found in the National Electrical Code Handbook 2002, Article 110-14, Tables 1.2 through 1.5 and in the manufacturer's installation recommendations. All circuits are to be de-energized and Locked and Tagged Out per PPPL procedures prior to tightening.

7.4.4. Plug-in cable connectors, particularly for high voltages or high currents, should be mechanically fastened in place. Unless listed as a motor disconnecting means, the power source shall be de-energized before unplugging a connector used in either a Class C, Class D, or Class E circuit.

7.4.5. Flat cable conductors shall be uniquely keyed to prevent unintentional damage to its circuits. All foreign power plugs shall be replaced with U.S. standard connectors if they are to be plugged into the PPPL AC power distribution system outlets and receptacles.