CHAPTER 10 INSTRUMENTATION AND CONTROL SYSTEMS

10.1 DESCRIPTION

This section covers instrumentation and control systems that are associated with research and development equipment and operations. Examples include interconnecting and some internal cable assemblies of:

A. Individual and Grouped Motor Controls

B. Electronic Computers/Data-Processing Equipment and Programmable Logic Controllers (PLCs)

C. NEC Class 1, 2, and 3 Remote-Control, Signaling, and Power-Limited Circuits

D. Communication Systems, including TV, Paging, and Energy-Management Systems, but excluding Fire-Protection Systems

E. Hardwired Personnel-Safety-Interlock Systems

F. Fiber Optic Cables and Cable Assemblies.

10.2 TYPES OF HAZARDS

A. Instrumentation and control systems may involve circuits that operate at potentially hazardous voltage levels (e.g., 120 V) and/or may be served from high-current (rated more than 50 A) power supplies. Power supplies used for instrumentation and control systems should have over voltage and over current protection built into them. Fuses shall protect all current carrying conductors (See Chapter 11 for further information.)

B. Inadequate separation from power circuits or failure of insulating and/or isolating devices could bring instrumentation and control systems in contact with circuits or components operating at hazardous voltages or currents.

C. Failure or malfunction of instrumentation can produce erroneous readings and prevent recognition of hazardous conditions.

D. Ionization-type vacuum gauges (see paragraph 10.4.E).

E. Failure of control circuits can cause unintentional operation of hazardous equipment and/or inhibit the operation of safety evices such as enclosure PSIs, warning lights, and overload protection.

10.3 Design and Construction Criteria

A. Instrument and control circuits shall not be designed to operate at voltages over 120 V ac or 125 V dc

B. Provide electrical instrumentation and control circuitry with adequate isolation at its interface with the main-power equipment being controlled and monitored. Consider both the normal and the fault conditions that can exist during operation of the main equipment. This includes physical separation of high-voltage and low-voltage circuitry and equipment, and use of surge protectors and isolation devices such as transformers, high-impedances, optical coupling, or telemetry.

C. Assure that relay and interlock contacts are rated at least as high as the voltage of the circuit and that current ratings are as high as the standard ampere rating of the line-side overcurrent protective device. Give particular attention to the inductance of the circuit in the proper application of relays and PSIs.

D. Control circuits shall be designed to be fail-safe. The degree of reliability of power sources should correlate with the degree of criticality of the interlock signal.

1. Where critical interlock signals are exchanged between physically separated systems or equipment, a reliable voltage shall be used, sourced at the signal's point of origin. Presence of this voltage shall either signify the safe state of the system or equipment, or shall act as a permissive to place a system or equipment into an operational condition. This approach prevents an unsafe condition due to broken or loose wires, wires shorted together or to ground, blown fuses, open circuit breakers, or any other loss of power.

2. Critical interlock signals shall not be exchanged between physically separated systems or equipment through the use of grounded circuits by monitoring the continuity through a remote contact closure. This approach would permit the generation of erroneous signals due to short circuits between the conductors or to ground. The remote contact shall be "dry" and shall be wired into the hot side of the local control circuit.

3. The presence of control power shall not be required to bring about the safe condition of a system or piece of equipment. The safe condition shall be automatically asserted upon the loss of control power. Indication that a system or piece of equipment is safe shall require the presence of control power. Loss of control power shall be interpreted as an indication that an unsafe condition may exist (assume the worst case when the condition is unknown).

E. Provide redundant controls and instrumentation on sections of a system where a credible single failure could result in a hazardous operating system (see single-failure criterion in Chapter 4, paragraph 4.3.5.

F. Provide a clear indication of the status of hazardous remote-controlled equipment, with positive feedback for each specific command.

G. Provide shorting devices for use on current-transformer circuits when instruments or controls are connected or disconnected.

H. Provide circuit isolation within enclosures as described in Chapter 8, paragraph 8.3.D.

I. Route instrumentation and Class A control circuits in separate raceways or barriered sections of cable trays to maintain physical separation from Class B through Class E conductors. See Chapter 3, Table 3.3 for Class definitions. See Chapter 4 for barrier descriptions. Communication circuits shall be run in dedicated raceways or barriered sections of cable trays.

J. Control circuits should be functionally verified to ensure that unintended operations cannot exist and accidental grounding of one conductor cannot cause safety devices to become inoperative.

K. Use consistent labeling for control panels and provide graphic control displays for large systems.

L. Route control wires so that no large-looped circuits are formed. Route hot, neutral, and ground in the same multiconductor cable. If single-conductor cables are used, route hot, neutral, and ground in the same raceway.

M. Design protective-interlock circuits and power-supply controls using three-wire undervoltage release with seal-in contacts so that reactivation of the interlock circuit (i.e., completing the circuit) will not result in automatic restoration of power to the equipment. Where two-wire controls are necessary, such as the controls for automatic restart of standby equipment, the standby equipment must have safety signs, described in PPPL ESH 002, warning that it may start automatically.

N. Programmable Logic Controllers (PLCs) have limited use in personnel-safety-related circuits. They may serve to monitor energy isolation device positions or to annunciate operating conditions. They are not a credible energy isolation device.

O. Multiconductor cables shall be color coded in accordance with ICEA Publication No. S-61-402 (NEMA WC-5), Appendix I, to prevent incorrect color coding of grounded (white - neutral) and grounding (green - ground) conductors. Theses cables should be uniquely keyed to prevent incorrect connections if they are used for power distribution.

P. Single and multiple fiber-optic assemblies shall be permitted to be installed in approved raceways and cable trays when pulled in separately from copper conductors and when not subject to forces exceeding the manufacturer's recommendations. The electrical-isolation properties of fiber-optic cables and approved cable assemblies shall not be compromised by common-mode failure between emitter and receiver, nor through the use of a conducting core, nor hybrid cables that include electrical conductors. When used, conducting cores shall be effectively bonded to either a single-point or electrical-equipment grounding conductor, but not both. When installed in cable trays, the jacketing shall be labeled either Underwriters' Laboratory (UL) type nonconductive optical fiber plenum (OFNP), nonconductive optical fiber riser (OFNR), nonconductive optical fiber (OFN), or tray cable (TC).

Q. Engineering Standard ES-ELEC-004 has installation details for fiber optic cable. See PPPL Engineering Standard ES-ELEC-001 for Electronics rack wiring, grounding, and AC power connections.

R. Instrument and control wiring installed within control enclosures should be fabricated in accordance with NFPA 79.

10.4 OPERATING CRITERIA

A. Carefully inspect and test all new or modified instrumentation and control systems to assure that they perform in accordance with operating and safety requirements. Also include simulation of failures, operation of upper-limit or lower-limit control features, personnel-safety- interlocks, and safety-interlock systems.

B. Give immediate attention to malfunctions or failures of instrumentation and control systems adversely affecting safety. Take corrective action.

C. Test personnel safety interlocks as required by Chapter 5, paragraph 5.8.4.

D. Bypass personnel safety interlocks and other safety devices only when absolutely necessary and only under the T-Mod provisions of Chapter 5, paragraph 5.8.3.

E. When operating ionization gauges on vacuum vessels, especially when degassing vacuum vessels by electron bombardment (glow discharge cleaning), precautions shall be taken to assure that vacuum vessel grounds are not lifted. At mTorr pressures, the plasma couples the vessel metal to the grid of the degassing power supply. If the vessel is floating, its touch potential could be raised to approximately 900 V.

Parts of certain ungrounded devices, such as bolometers and thermocouples, located inside the vacuum vessel but with terminations outside the vessel, can accumulate charge up to the level of voltage being applied to the plasma. They can discharge through the body of a person touching ground. The severity of the hazard from this source is dependent on the capacitance of the device and its cables, which can be large in some cases. Personnel access should be restricted by safety barriers during glow discharge cleaning operations. Qualified personnel shall use the appropriate PPE as specified in the Job Hazard Analysis when working on this type of equipment.