

**650.5 Grounding or Double Insulation of the DC Power Supply.** The installation of the dc power supply shall comply with either of the following:

- (1) The dc power supply shall be double insulated.
- (2) The metallic case of the dc power supply shall be bonded to the input equipment grounding conductor.

**650.6 Conductors.** Conductors shall comply with 650.6(A) through (D).

**(A) Size.** The minimum conductor size shall be not less than 28 AWG for electronic signal circuits and not less than 26 AWG for electromagnetic valve supply and the like. The minimum conductor size of a main common-return conductor in the electromagnetic supply shall not be less than 14 AWG.

**(B) Insulation.** Conductors shall have thermoplastic or thermosetting insulation.

**(C) Conductors to Be Cabled.** Except for the common-return conductor and conductors inside the organ proper, the organ sections and the organ console conductors shall be cabled. The common-return conductors shall be permitted under an additional covering enclosing both cable and return conductor, or they shall be permitted as a separate conductor and shall be permitted to be in contact with the cable.

- Δ **(D) Cable Covering.** Each cable shall be provided with an outer covering, either overall or on each of any subassemblies of grouped conductors. Tape shall be permitted in place of a covering. Where not installed in metal raceway, the covering shall be resistant to flame spread, or the cable or each cable subassembly shall be covered with a closely wound listed fireproof tape.

Informational Note: See UL 2556-2015, *Wire, Cables and Cable Test Methods*, for one method of determining that cable is resistant to flame spread by testing the cable to the FV-2/VW-1 Test.

**650.7 Installation of Conductors.** Cables shall be securely fastened in place and shall be permitted to be attached directly to the organ structure without insulating supports. Splices shall not be required to be enclosed in boxes or other enclosures. Control equipment and busbars connecting common-return conductors shall be permitted to be attached directly to the organ structure without insulation supports. Abandoned cables that are not terminated at equipment shall be identified with a tag of sufficient durability to withstand the environment involved.

**650.8 Overcurrent Protection.** Circuits shall be so arranged that 20 AWG through 28 AWG conductors shall be protected by an overcurrent device rated at not more than 6 amperes. Other conductor sizes shall be protected in accordance with their ampacity. A common return conductor shall not require overcurrent protection.

**650.9 Protection from Accidental Contact.** The wiring of the pipe organ sounding apparatus shall be within the lockable

enclosure (organ chamber) where the exterior pipes shall be permitted to form part of the enclosure.

Informational Note: Access to the pipe organ sounding apparatus and the associated circuitry is restricted by an enclosure. In most pipe organ installations, exterior pipes form part of the enclosure. In other installations, the pipes are covered by millwork that permits the passage of sound.

## ARTICLE

## 660

## X-Ray Equipment

### Part I. General

**660.1 Scope.** This article covers all X-ray equipment operating at any frequency or voltage for industrial or other nonmedical or nondental use.

Informational Note: See Article 517, Part V, for X-ray installations in health care facilities.

Nothing in this article shall be construed as specifying safeguards against the useful beam or stray X-ray radiation.

Informational Note No. 1: Radiation safety and performance requirements of several classes of X-ray equipment are regulated under Public Law 90-602 and are enforced by the Department of Health and Human Services.

Informational Note No. 2: In addition, information on radiation protection by the National Council on Radiation Protection and Measurements is published as *Reports of the National Council on Radiation Protection and Measurement*. These reports can be obtained from NCRP Publications, 7910 Woodmont Ave., Suite 1016, Bethesda, MD 20814.

Article 660 covers X-ray equipment in industrial facilities or similar locations, where it is commonly used for inspecting a process or product. This permits nondestructive testing without dismantling or applying stress to detect cracks, flaws, or structural defects. Welded joints frequently are inspected with X-ray equipment to detect hidden defects that can cause failure under stress.

The most common industrial application of X-rays is radiography, in which shadow pictures of the object are produced. The type and thickness of the material involved govern the voltage to be employed, which can range from a few thousand volts (kV) to millions of volts (MV). Metal objects that are as much as 20 inches thick can be X-rayed.

Fluoroscopy is another X-ray technique used for industrial and commercial applications. Fluoroscopy is similar to radiography, but it operates at less than 250 kilovolts. Most of these systems project a shadow picture on a screen, similar to those used for security checks of luggage at airport terminals. Fluoroscopy is capable of detecting minute flaws or defects.

**660.3 Hazardous (Classified) Locations.** Unless identified for the location, X-ray and related equipment shall not be installed or operated in hazardous (classified) locations.



Informational Note: See Article 517, Part IV, for additional information.

#### 660.4 Connection to Supply Circuit.

**(A) Fixed and Stationary Equipment.** Fixed and stationary X-ray equipment shall be connected to the power supply by means of a wiring method meeting the general requirements of this *Code*. Equipment properly supplied by a branch circuit rated at not over 30 amperes shall be permitted to be supplied through a suitable attachment plug cap and hard-service cable or power-supply cord.

**(B) Portable, Mobile, and Transportable Equipment.** Individual branch circuits shall not be required for portable, mobile, and transportable X-ray equipment requiring a capacity of not over 60 amperes. Portable and mobile types of X-ray equipment of any capacity shall be supplied through a suitable hard-service cable or power-supply cord. Transportable X-ray equipment of any capacity shall be permitted to be connected to its power supply by suitable connections and hard-service cable or power-supply cord.

**(C) Over 1000 Volts, Nominal.** Circuits and equipment operated at more than 1000 volts, nominal, shall comply with Article 490.

**660.5 Disconnecting Means.** A disconnecting means of adequate capacity for at least 50 percent of the input required for the momentary rating, or 100 percent of the input required for the long-time rating, of the X-ray equipment, whichever is greater, shall be provided in the supply circuit. The disconnecting means shall be located within sight from the X-ray control and readily accessible.

*Exception: The disconnecting means for the X-ray equipment shall not be required under either of the following conditions, provided that the controller disconnecting means is lockable open in accordance with 110.25:*

- (1) *Where such a location of the disconnecting means for the X-ray equipment is impracticable or introduces additional or increased hazards to persons or property*
- (2) *In industrial installations, with written safety procedures, where conditions of maintenance and supervision ensure that only qualified persons service the equipment*

#### 660.6 Rating of Supply Conductors and Overcurrent Protection.

**(A) Branch-Circuit Conductors.** The ampacity of supply branch-circuit conductors and the overcurrent protective devices shall not be less than 50 percent of the momentary rating or 100 percent of the long-time rating, whichever is greater.

**(B) Feeder Conductors.** The ampacity of conductors and the rating of overcurrent devices of a feeder for two or more branch circuits supplying X-ray units shall not be less than 100 percent

of the momentary demand rating [as determined by 660.6(A)] of the two largest X-ray apparatus plus 20 percent of the momentary ratings of other X-ray apparatus.

Informational Note: The minimum conductor size for branch and feeder circuits is also governed by voltage regulation requirements. For a specific installation, the manufacturer usually specifies minimum distribution transformer and conductor sizes, rating of disconnect means, and overcurrent protection.

**660.7 Wiring Terminals.** X-ray equipment not provided with a permanently attached power-supply cord shall be provided with suitable wiring terminals or leads for the connection of power-supply conductors of the size required by the rating of the branch circuit for the equipment.

**660.9 Minimum Size of Conductors.** Size 18 AWG or 16 AWG fixture wires, as specified in 724.49, and flexible cords shall be permitted for the control and operating circuits of X-ray and auxiliary equipment where protected by not larger than 20-ampere overcurrent devices.

**660.10 Equipment Installations.** All equipment for new X-ray installations and all used or reconditioned X-ray equipment moved to and reinstalled at a new location shall be of an approved type.

### Part II. Control

#### 660.20 Fixed and Stationary Equipment.

**(A) Separate Control Device.** A separate control device, in addition to the disconnecting means, shall be incorporated in the X-ray control supply or in the primary circuit to the high-voltage transformer. This device shall be a part of the X-ray equipment but shall be permitted in a separate enclosure immediately adjacent to the X-ray control unit.

A control device provides means for initiating and terminating X-ray exposures and automatically times their duration.

**(B) Protective Device.** A protective device, which shall be permitted to be incorporated into the separate control device, shall be provided to control the load resulting from failures in the high-voltage circuit.

**660.21 Portable and Mobile Equipment.** Portable and mobile equipment shall comply with 660.20, but the manually controlled device shall be located in or on the equipment.

#### 660.23 Industrial and Commercial Laboratory Equipment.

**(A) Radiographic and Fluoroscopic Types.** All radiographic and fluoroscopic-type equipment shall be effectively enclosed or shall have interlocks that de-energize the equipment automatically to prevent ready access to live current-carrying parts.



**(B) Diffraction and Irradiation Types.** Diffraction- and irradiation-type equipment or installations not effectively enclosed or not provided with interlocks to prevent access to uninsulated live parts during operation shall be provided with a positive means to indicate when they are energized. The indicator shall be a pilot light, readable meter deflection, or equivalent means.

**660.24 Independent Control.** Where more than one piece of equipment is operated from the same high-voltage circuit, each piece or each group of equipment as a unit shall be provided with a high-voltage switch or equivalent disconnecting means. This disconnecting means shall be constructed, enclosed, or located so as to avoid contact by persons with its live parts.

### Part III. Transformers and Capacitors

**660.35 General.** Transformers and capacitors that are part of an X-ray equipment shall not be required to comply with Articles 450 and 460.

High-ratio step-up transformers that are an integral part of X-ray equipment are not required to comply with Article 450 and are generally used to provide the high voltage necessary for X-ray tubes. Because the fire hazard is lower due to the low primary voltage, X-ray transformers are not required to be installed in fire-resistant vaults.

**660.36 Capacitors.** Capacitors shall be mounted within enclosures of insulating material or grounded metal.

### Part IV. Guarding and Grounding

#### 660.47 General.

**(A) High-Voltage Parts.** All high-voltage parts, including X-ray tubes, shall be mounted within grounded enclosures. Air, oil, gas, or other suitable insulating media shall be used to insulate the high voltage from the grounded enclosure. The connection from the high-voltage equipment to X-ray tubes and other high-voltage components shall be made with high-voltage shielded cables.

**(B) Low-Voltage Cables.** Low-voltage cables connecting to oil-filled units that are not completely sealed, such as transformers, condensers, oil coolers, and high-voltage switches, shall have insulation of the oil-resistant type.

**Δ 660.48 Grounding.** Battery-operated X-ray equipment shall not be required to comply with the grounding requirements of this Code.

According to 90.3, the general requirements of Chapter 2 apply to all electrical installations. Therefore, Part I of Article 250, specifically 250.4(A)(2) and (3), would apply to the grounding of X-ray equipment.

## ARTICLE 665

## Induction and Dielectric Heating Equipment

### Part I. General

**665.1 Scope.** This article covers the construction and installation of dielectric heating, induction heating, induction melting, and induction welding equipment and accessories for industrial and scientific applications. Medical or dental applications, appliances, or line frequency pipeline and vessel heating are not covered in this article.

Informational Note: See Article 427, Part V, for line frequency induction heating of pipelines and vessels.

To prevent spurious radiation caused by induction and dielectric heating equipment, the Federal Communications Commission (FCC) has established rules that govern the use of this type of industrial heating equipment operating above 10 kilohertz (FCC, 47 CFR 18).

#### See also

**NFPA 86**, *Standard for Ovens and Furnaces*, for more information on electric heating systems using an induction heater or a dielectric heater in ovens and furnaces

**665.5 Output Circuit.** The output circuit shall include all output components external to the converting device, including contactors, switches, busbars, and other conductors. The current flow from the output circuit to ground under operating and ground-fault conditions shall be limited to a value that does not cause 50 volts or more to ground to appear on any accessible part of the heating equipment and its load. The output circuit shall be permitted to be isolated from ground.

If the load (object being heated) accidentally contacts the output coil, a voltage to ground will appear on the load, depending on the various impedances to ground of the coil and the load. If the voltage on the load is limited to less than 50 volts, guarding per 110.27(A) is not required. If the coil is isolated from ground and the load is grounded through an impedance that is low (less than 1 percent) relative to the coil impedance to ground, the voltage of the load to ground will be low no matter where the load contacts the coil.

In induction melting furnaces, an additional reason for isolating the coil from ground is to limit the fault current when a coil does go to ground. Limiting the fault current prevents severe damage to the water-cooled coil, resulting in a water leak and the potential for a water-molten metal explosion. If water is trapped under molten metal, the rapid transfer of heat to the water causes the water to turn almost instantly into steam. The resulting 1600-to-1 expansion of the steam results in the ejection of molten metal from the furnace.