CHAPTER 9 INDUCTORS AND ELECTROMAGNETS

9.1 DESCRIPTION

This section covers inductors and electromagnets with stored energies of 10 J and above. These are used in the following applications:

A. Energy storage, where power is provided by a dc source or low-frequency ac power supply and then switched to a load or test device.

B. Inductors used as impedance devices in a pulsed system with capacitors to provide oscillatory or resonant conditions.

C. Electromagnet coils that produce magnetic fields to guide or confine charged particles.

D. Inductors used in dc power supplies.

9.2 TYPES OF HAZARDS

A. Overheating due to overloads, insufficient cooling, or failure of the cooling system could cause damage to the inductor and possible rupture of the cooling system.

B. Large electromagnets may produce external force fields that can affect the calibration and proper operation of protective instrumentation and controls. These can cause nearby equipment such as motors and transformers to overheat or overload. Such external fields could also attract nearby loose magnetic material and cause injury or damage by impact.

C. Whenever a magnet is suddenly de-energized, production of large eddy currents in adjacent conductive material can cause excessive heating. A fast rate of change of field strength, producing high turn-to-turn and terminal voltages, can also induce hazardous voltages in adjacent conductors.

D. An inductor is also capable of producing large electromagnetic forces.

E. When one inductor is used with a second, improper conductor polarity can result in abnormal forces and field strengths.

F. Loose and/or broken inductor or electromagnet connections can produce excessive heat and arcing.

G. The large amount of energy stored in the field of an energized inductor can damage equipment and injure personnel if not discharged in an appropriate manner.

H. Large amounts of stored energy can be released in the event of a “quench” in a superconducting magnet.

I. The relatively long time constants in highly inductive circuits can cause the prolonged release of energy into a fault, producing severe equipment damage and possible fire.

J. Exposure to high static or time-varying magnetic fields can have biological effects on the human body. For the purposes of these guidelines, a high-magnetic field is defined as one in which the static flux density exceeds 100 gauss (0.01 tesla). Guidelines for time -varying, low-frequency (300 Hz and below) magnetic fields have not been determined.

K. Security cards and credit cards may degrade in high dc magnetic fields.

L. Personnel exposure to magnetic fields greater than 0.1 tesla should be restricted.

9.3 DESIGN AND CONSTRUCTION CRITERIA

The following shall be provided:

A. Sensing devices (such as temperature and coolant flow) interlocked with the power source for safe shutdown of water-cooled or air-cooled inductors and electromagnet coils in the event of excessive temperatures or cooling-system failure.

B. Protective enclosures fabricated from material not adversely affected by external electromagnetic fields produced by the equipment. See NEC article 470 for further details on fabrication of enclosures.

C. Equipment supports and bracing adequate to withstand forces produced during normal operation and fault conditions.

D. Grounding for electrical-supply circuits and electromagnetic cores wherever feasible and for adequate fault protection.

E. Ground-fault detection for grounded or ungrounded (floating) systems and electrical circuits for alarm purpose, or equipment shutdown.

F. Means for safely dissipating stored energy when excitation is interrupted or a fault occurs.

9.4 OPERATING CRITERIA

A. Provide safety signs and/or warning lights to indicate equipment hazards.

B. Advise personnel of the hazards of stray magnetic fields by posted instructions or by other means. There should be no magnetic material in the clothing or on the bodies of personnel who are in the immediate area of large energized inductors or electromagnets. For maximum permissible exposure to static magnetic fields, see Section 4.0, “RF, Microwave, and Magnetic field Safety,” of ES&H Manual 5008.

C. Before disconnecting the leads of any high-energy inductor (50 J or more), follow the safe-accessing procedure of Chapter 11, paragraph 11.4.

D. Exercise extreme caution when checking continuity or measuring resistance of large inductors or electromagnet coils with a common ohmmeter. Severe shocks can result if both hands are in contact with the terminals when the test probes are removed.

E. Avoid high dc magnetic fields (100 gauss and above) when carrying security or credit cards. Security cards and credit cards use barium ferrite as their permanent magnetic material. Security cards after magnetization have a flux retentivity of between 120-180 gauss and when degraded to 75 gauss are considered a bad card. If exposed to a dc magnetic field, the magnetization degrades approximately 20 percent in a 100 gauss field and completely demagnetizes in a 300 gauss field , assuming the magnetic field is perpendicular to the credit card.