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Safety Procedures In Electronic Equipment

By the Engineering Department, Aerovox Corporation

ELECTRIC shock and fire are the principal hazards which may accompany the operation of electrical equipment, including electronic apparatus. The first is dangerous to personnel only; the second to personnel, equipment, and surroundings. The causes often are related and sometimes are identical. Safety measures related to electronic equipment accordingly are directed toward reduction of shock and fire hazard.

Varied attitudes exist toward the potential dangers of electronic equipment. In general, the tendency is to pay little attention to such matters when apparatus is manned by skilled persons, and to become concerned only when workers with limited training and experience will be exposed. Unfortunately, a fatal or crippling shock or a destructive fire, either incident blamable to skilled but unalert persons, must occur to point up the need for more attention in this direction. All electronic equipment should be safe, regardless of the caliber of people assigned to its operation and maintenance. The laboratory should be no more hazardous than the assembly-line test position.

Safety measures may be applied effectively in three areas: design, installation, and operation. When apparatus is designed for maximum safety and is installed and operated with due regard to the prevention of shock and fire, maximum freedom from danger usually is obtained. Concentration of precautionary steps in only one area imposes additional responsibility in each of the other two and jeopardizes life and property.

Designing for Safety

Safety devices and circuit arrangements can be included in electronic equipment at the design and construction stages. It is easier to build them

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into such apparatus than to add them later. It is well to survey the common devices of this sort, with a view to their inclusion in a given electronic product.

Interlock Switch. The interlock switch is one of the oldest electrical safety devices, but strangely is one of the least used in modern equipment. Ordinarily, it is wired in series with one or both of the power-line leads to the electronic power supply unit, and is installed on the lid, cover, or door of the enclosure so as to break the circuit when the enclosure is entered. A true interlock switch is automatic in action. It does not depend upon manual manipulation by the operator.

Multiple interlock switches, wired in series, may be used for increased safety. Thus, one switch may be installed on the access door of a transmitter, and another on the dust cover of the power supply section.

Complex interlock systems are provided when separate circuits should be opened for safety. An example is the use of separate open-up switches for the a. c. power line and the high-voltage d. c. output of a power supply.

Since electronic equipment often must be serviced "hot", interlock switches must be operable by responsible personnel when access doors are open. However, they should always be located in such a manner as to make closure difficult and therefore attention-catching.

Interlock switches can be used to advantage on transmitters, oscilloscopes, high-voltage power supplies, photoflash equipment, precepitators, and television receivers.

Bleeder Resistors. A bleeder resistor is connected permanently across the output terminals of a high-voltage d. c. power supply. As its name implies, its purpose is automatically to bleed the dangerous charges off the filter capacitors.

No medium- or high-voltage power supply should be constructed without a bleeder, since high-grade filter capacitors can store murderous charges for long periods of time. The bleeder resistance must be the lowest value which can discharge the capacitors *quickly* without excessive loading after the power has been switched off. In power equipment the resistor is chosen to give a discharge time constant of 1 min. See Time Delay Circuits, Dec. 1937 Research Worker, Fig. 7.

The bleeder current is an additional load on the power supply, but the system should be designed with this slight additional burden in mind. Good insurance is provided by the automatic charge-draining action of the bleeder resistor.

Current-Limiting Resistor. A current-limiting resistor is an inexpensive safety device in a high-voltage power supply. It should be incorporated in every supply from which potential only, or small currents, will be required. Such a resistor is connected in series with the output and limits the current to a safe value during short-circuit or accidental contact. A familiar example is the high-resistance (usually 1-megohm) series resistor in r. f.-type d. c. kilovolt power supplies.

Capacitor-Shorting Devices. In some equipment (e. g., high-voltage radar apparatus) where large, high-voltage capacitors must be operated without adequate bleeding, the operator must discharge these capacitors before working on the high-voltage circuits. For this purpose, metallic grounding or shorting rods with insulated handles should be chained inside the equipment within easy reach of the operator. Short-circuiting rods, wands, or bars should be insulated beyond the voltage they will handle, in order to be grasped safely by the operator, and they should be non-removable from the equipment.

Note: Do not discharge high voltage capacitors with a low resistance bar. A large resistor of 200 watt 10,000 ohm rating should be used.

Meter Protection. Old-style panel meters having metallic zero-set screws should be avoided in electronic equipment. Such setscrews run "hot" in high-voltage circuits and constitute both shock and fire hazards.

Metal-case meters should not be used except on *grounded* metal panels or chassis, since such instruments will, in the event of internal ground or short-circuit, have high potential on their cases and flanges.

For maximum safety, meters in high-voltage circuits should be mounted behind a window of glass or thick plastic.

AC-DC Circuitry. Whenever possible, transformer-isolated power supplies should be used in preference to transformerless (AC-DC) circuits. Although the line-operated supply is simple and compact and furnishes sufficient power for many applications. its negative return is at power-line potential and therefore dangerous.

When there is no choice in the matter, design the circuit so that no connections are made directly to the chassis or metal panel. If the chassis *must* be included in the circuit, mount the completed equipment in a case or cabinet made of insulating material, and use only insulated knobs, dials, and switches.

It is good practice also to polarize the power plug of a line-operated power supply so that the circuit returns always will be connected to the grounded side of the power line.

Insulated Controls. Use metallic knobs, dials, switches, and levers only in equipment known to be of the "cold-chassis" type. Never use such attachments with AC-DC devices.

As an added precaution, short setscrews should be used in all insulated knobs, so that the operator's fingers normally will not touch the tops of these screws. When this is not possible, cover the top of each screw with a spot of sealing wax or coil dope, after tightening.

The shafts of rheostats and potentiometers in high-voltage circuits should not be brought out directly to knobs or dials, but should be recessed far enough back of the panel or below the chassis to include an insulated shaft coupling and an ample length of insulated rod. Common examples of high-voltage components of this type are the intensity, focus, and beam-centering controls of an oscilloscope.

High-Voltage Jacks. Jacks occasionally are employed in power circuits for the insertion of meters, keys, output lines, etc. Good practice is to connect such jacks in the grounded B-minus leg of the monitored circuit, rather than at any point in the B-plus sections.

When this method of connection is not practicable in a particular circuit, however, the jacks should be recessed behind the main panel, where they cannot easily be touched, and clearance holes provided for insertion of the plugs. This will prevent accidental contact by the operator, and also accidental grounding and firing as a result of contact with wires or other metallic objects.

Switch Firing. Electronic circuits should be designed so as to minimize sparking, arcing, and firing in switches, relays, and similar make-and-break devices. Finished equipment must be inspected fully for verification of the design. In addition to shortening the life of the switching device, firing can create a fire hazard.

Only explosion-proof switching devices should be employed when electrical equipment is to be used in an atmosphere of explosive gas or vapor.

Mercury switches and other mercury-containing devices must be adequately protected against breakage of the glass containers. An additional precaution is to mount a mercury switch in such a location in the equipment that the mercury will not spill on a hot surface *if the container should break.* Mercury vapor is a pronounced health hazard, a factor which must be considered in addition to the electrical mischief which might be caused by the liquid metal on the loose.

Power-Line Safety. Engineers and designers are inclined to confine their safety considerations to high-voltage apparatus. It is important to note, however, that considerable hazard lies in the power-line end of electronic equipment. Fires, bad shocks, and serious burns are known to result from personal contact, short circuit, and grounding at the a. c. line. The danger is heightened when the supply is 220 or 440 volts.

Only line cords bearing Underwriter's Laboratories approval and in good physical condition should be employed. Such cords must pass through grommet-lined holes in chassis or panels never through raw-edged metal.

Three-conductor line cords should be used whenever facilities are available for using the third wire as an equipment ground.

Adequate fusing of the equipment should be provided. It is a form of negligence to assemble any complete radio or electronic apparatus without including one or more fuses *in the equipment itself.*

Positioning of High-Potential Components. Each component with exposed terminals, in medium- or high-voltage portions of a circuit should be protected from short-circuit, grounding, or accidental contact by the operator.

Such parts include selenium rectifiers, bleeder resistors, capacitors with exposed terminals, switches, rheostats, and 115-volt pilot lights. Wherever possible, such components should be mounted under the chassis where they are not exposed. However, ventilation requirements do not always permit this. Therefore, when it is impracticable to conceal the components below chassis, protective housings, with ventilating holes or louvres, should be provided. When housings cannot be used, the exposed terminals of the components should be oriented away from the direction of easy contact. These expedients will lessen shock and firing.

Installation Measures

Permanent electronic equipment, whether in a laboratory or in a non-technical environment, should be installed in strict accordance with the Electrical Code and any applicable fire department rules and regulations as applied to wiring.

Some of the pitfalls to be avoided include: dangling, trailing, draped, or frayed power cords; overloaded power outlets; overheated or damp locations; overloaded power switches; unfused power lines or lack of circuit breakers; and use of multiple attachments (cube taps).

Provide a safety ground at every installation. This consists of connecting together with a heavy wire all of the metal panels, chassis, racks, cabinets, etc. and running this wire directly *to a good ground.* In most cases, the grounded electrical conduit is an adequate path to ground. But as an added guarantee, use a good earth ground consisting of a cold water pipe, or a long pipe driven into moist soil. Three-wire cords, with the third wire connected to the electrical conduit, are handy because they connect the equipment automatically to ground whenever the power plug is inserted into the outlet.

In some States, 3-wire power cords are mandatory in industrial installations, but the rule often is not enforced in laboratories unless there have been hazardous situations or serious accidents of record. Where 3-wire safety outlets are provided in a building, do not fall into the habit of inserting 2-prong plugs. Take full advantage of the safety provided, by replacing the 2-prong with 3-prong plugs.

Many commercial electronic instruments have a grounding pigtail on the end of their power plugs. Signal generators, vacuum-tube voltmeters, amplifiers, oscilloscopes, and tube testers are among the familiar devices so equipped. Do not clip these leads. Use them for the safety-grounding purposes for which they were supplied.

Place DANGER — HIGH VOLTAGE signs conspicuously both outside and inside the equipment at all important points where an operator needs to be reminded of the hazard.

Mount an approved fire extinguisher near the equipment. Carbon dioxide extinguishers are desirable for electronic equipment fires, since they usually do not cause any chemical or moisture damage.

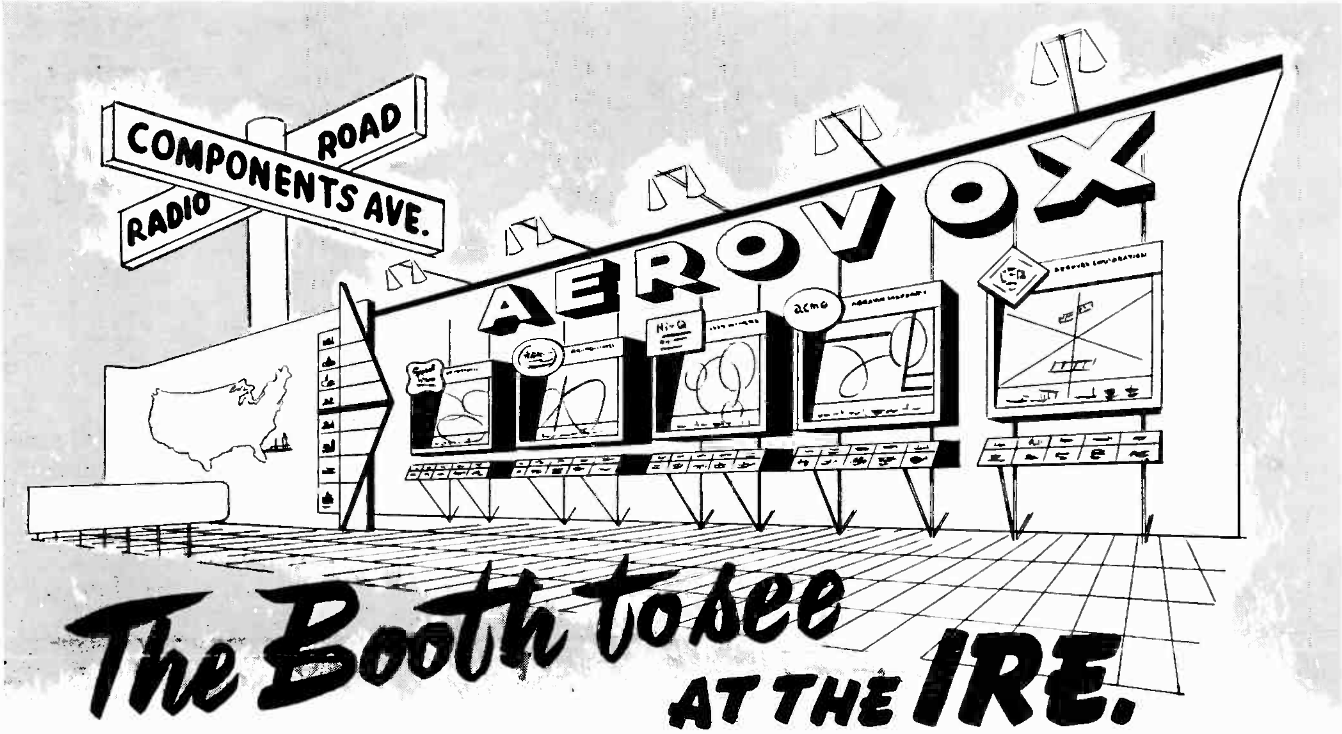
A proposed location for a stationary electronic installation should be surveyed beforehand with respect to favorable temperature, humidity, vibration, power-line stability, magnetic fields, and traffic conditions to determine which elements should be removed or modified in the interest of safe operation.

Failure vs. Safety

Electronic equipment breaks down in spite of the best engineering and maintenance. Failure is considered as falling into two categories. When the breakdown of a component causes dangerous overloads or voltage peaks, or places high potentials in undesirable places, the failure is said to be *unsafe.* When breakdown places the system out of operation without in any way introducing trouble in the system or to the operator, the failure is said to be *safe.*

No blanket rule can be stated for designation of all cases. A particular failure must be viewed in terms of an analysis of the circuit or system in which it occurs, in order to determine into which category it falls. Consider these examples: A bleeder resistor in a power supply fails unsafe because in burning open it allows a dangerous charge to be held by the filter capacitors. A short-circuited filter capacitor also fails unsafe because it draws excessive current which may destroy the rectifier (producing much heat), filter choke, or transformer. An open-circuited secondary winding in a power transformer in a simple power supply fails safe because it removes the power automatically from the entire system. But the secondary would fail unsafe if the power supply furnished fixed bias voltage to high-power tubes, since these tubes would draw excessive plate current in absence of the bias.

The cautious designer of electronic equipment will take every possible precaution to favor fail-safe operation. For example, the inclusion of a fuse in series with a filter capacitor will change a fail-unsafe probability into a fail-safe situation, since the fuse will open if the capacitor short-circuits.



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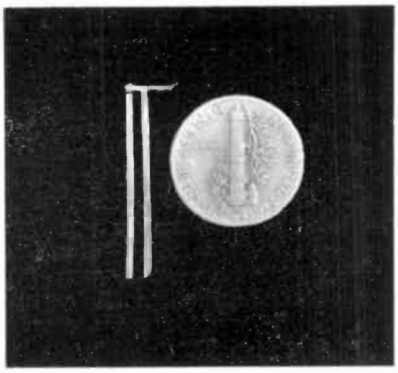

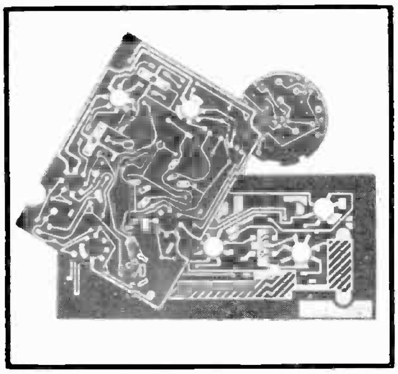

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