Electrophoresis: An Accident and Some Precautions

New safety measures have been devised following a fatal accident with high-voltage electrophoresis apparatus.

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Last summer, a graduate student was electrocuted while using high-voltage electrophoresis apparatus in a biology laboratory at Brown University. Examination of the apparatus after the accident revealed a short-circuit between the high-voltage cable and the connector shell which attached it to the electrophoresis tank. Apparently the student touched the energized connector shell and a grounded portion of the apparatus simultaneously after he had turned it up to 5000 volts. Upon being informed of the circumstances of the accident, the manufacturer of the equipment notified his customers of the potential hazard of leaving the connector shell ungrounded and suggested additional precautions be taken with the apparatus.

As a result of this accident we and colleagues at several other institutions have reviewed the safety features of electrophoresis apparatus. The large increase in use of this type of equipment prompts us to describe some of the dangers and some possible safeguards against accidents of this type. The following general principles should be applied when considering the use of high-voltage electrical equipment in the laboratory:

1) Equipment should be inspected, checked, and installed by a competent electrician in consultation with a safety engineer.

2) Safety devices should be duplicated or backed up by secondary devices to make the equipment fail-safe.

3) Equipment and component parts should be well grounded, preferably to a water pipe.

4) Laboratory personnel should be completely familiar with the equipment before being permitted to use it.

The hazard to the operator of electrophoresis apparatus is particularly severe because the technique requires the use of aqueous buffer solutions at voltages high enough that accidental contact would be dangerous to the operator. The most effective safeguard consists of placing the equipment, with the exception of the power supply, in a grounded enclosure. This enclosure can range from a home-made chicken-wire cage to a chemical fume hood. Regardless of the type of enclosure provided, all openings which allow the operator access to the equipment within should be interlocked in such a way that the equipment will be completely de-energized as soon as the enclosure is opened. The interlocks should also prevent operation of the equipment unless all the openings are closed. If a wire or expanded metal enclosure is built, terminals or current-carrying parts should be far enough from the sides to prevent contact by putting fingers through the openings.

A brief description of installations currently in use might be of interest. It must be emphasized that the safety measures described below are constantly evolving as our experience increases. Furthermore, we do not claim that all the safety measures described are necessary for all installations or that they will always prove sufficient as conditions change.

The electrophoresis apparatus is placed in a fume hood, with the high-voltage power supply outside the hood. Two heavy-duty switches have been placed on the inside of the hood, located so that an opening of 2.5 centimeters or more will de-energize the equipment. They are placed inside to minimize the possibility of tampering or accidental damage. They are wired in series to prevent current flow if one of them fails for any reason. Indicator lights signal when either of the switches has failed.

The operating unit inside the enclosure is placed on a metal tray, which is grounded. This protects against leakage of electrolyte, and in case of a metal-plate-type unit, insures that the metal plate is effectively grounded. A red warning light on the outside of the hood indicates when the unit is in use. The power supply unit, outside the hood, is in a grounded metal cabinet. The grounding of the power-supply case is especially important, since failure of a component inside could cause the case to become energized. All external metal surfaces are connected with visible straps to an efficient ground. It is important to test all units, home-made or commercial, for the adequacy of grounding. It cannot be assumed that this has been done by the manufacturer, although many manufacturers may make such a check routinely. The connections between the high-voltage power supply and the equipment inside the hood are in a grounded metal conduit, installed by a competent electrician. Although it may be theoretically possible to place the power supply inside the enclosure, locating the controls on the outside, we have not found a satisfactory arrangement of this type.

If a single power supply is used to control more than one electrophoresis unit, the interlocks and other safety devices should be wired in series.

There have been occasions when the electrical connection inside the electrophoresis apparatus has become broken or dried up. Under these conditions, it is possible for the power supply to retain in the smoothing condensers a large amount of stored electricty which will be discharged slowly after the primary power circuit is shut off. An incident occurred quite early in our operations which alerted us to this danger. The operator turned off the primary supply and then removed the high-voltage lead from the electrophoresis unit. Fortunately, she touched a ground, rather than herself, with the lead. There was a deafening discharge of the stored energy. We then realized that there was also a need for a bleeder resistor across the high-voltage outlet of the power supply to discharge any

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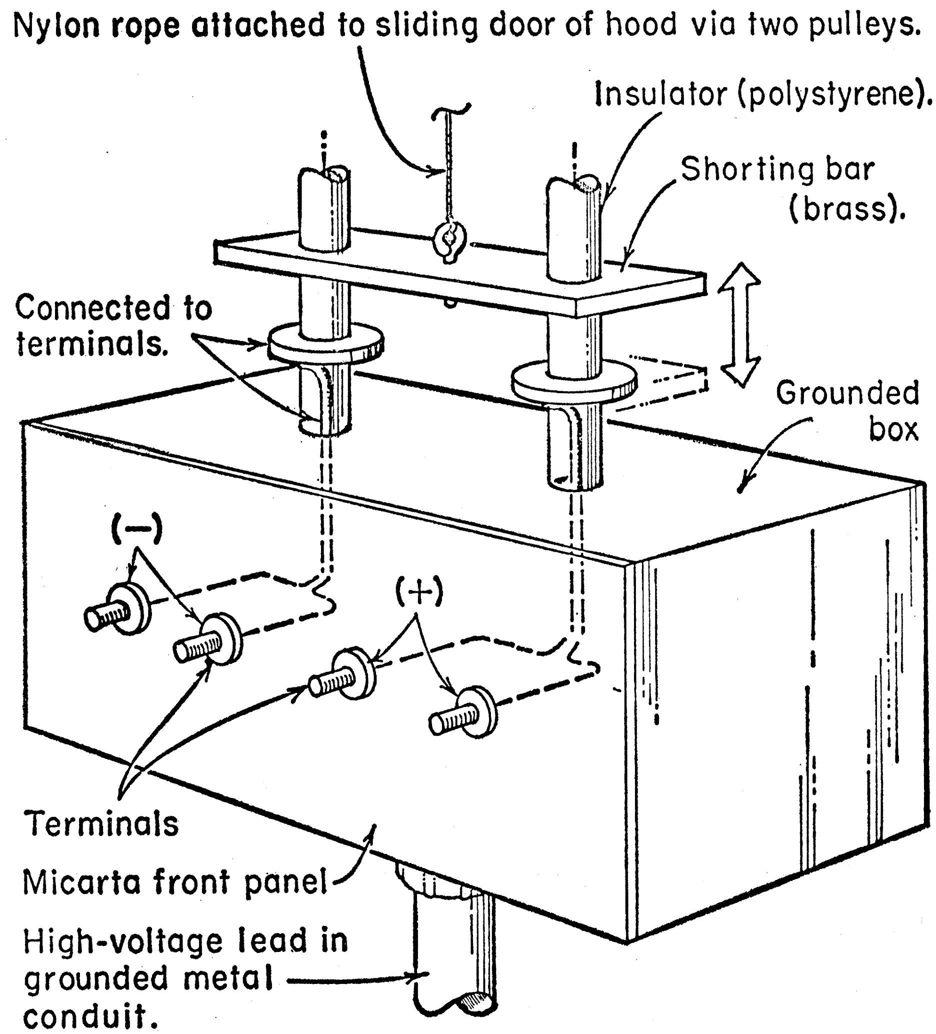

Fig. 1. Grounded fume hood to enclose electrophoresis apparatus.

residual electricity rapidly. In addition, a mechanical shorting bar was installed in the hood (Fig. 1). This bar makes contact as soon as the hood sash is raised 2.5 centimeters or more.

The use of electrophoresis apparatus outside an enclosure is not recommended. Although some commercial units are designed to be operated in the laboratory, standing on a bench, we believe they should be placed inside a sturdy, well-grounded enclosure with interlocks.

Relatively low-voltage paper-electrophoresis and gel-electrophoresis units in the 100-to-500-volt range are even more common than the high-voltage units and should be enclosed and protected in a similar manner. This may be particularly important for these units, since they are frequently operated in cold rooms which may be crowded with equipment and where help is not readily available.

It must be remembered that low voltage is not necessarily safer than high voltage. The amperage, or quantity of current flowing, is the determining factor in electrical shock. Voltage, resistence, quality and area of contact, time, and the path through the body are all important factors to be considered. The danger area begins at about 15 milliamperes, which is approximately the "let-go" threshold for most persons. If muscular contractions prevent a person from releasing an energized wire or part, the contact could be fatal. A current flow of 100 to 200 milliamperes is almost always fatal, because this is the range which produces ventricular fibrillation of the heart. Fuses are useless protection to the operation because circuits are usually fused for 1 ampere or more and are designed solely for the protection of the equipment.

It is impossible to cover the subject of safety measures in high-voltage electrophoresis equipment completely, since improvements are constantly being made as a result of experience. The recommended approach, however, is to isolate the hazard inside an enclosure so that no one can touch any part of the equipment without de-energizing it. Even if everything possible goes wrong with the equipment, it will then be inside a well-grounded enclosure.