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Some Electrical and Radiation Hazards in the Laboratory*

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Summary—Some electrical and radiation hazards which are present in the laboratory are discussed. A constant reminder concerning some of the common dangers is worthwhile since even experienced workers may forget about them and injury or death can result.

Sixty-Cycle Electrical Supply

One electrical hazard which exists in the laboratory also exists in the home. This is the hazard of the alternating current electricity which is supplied from the wall at a frequency of sixty cycles. If one were to look for that electrical frequency which is the most dangerous one, one would find that it is near sixty cycles. If 110 volts is applied across the body in such a fashion that the resulting current to any great extent traverses the heart, then a condition known as ventricular fibrillation will probably result, and death will follow.

Under these circumstances the heart ceases its coordinated beating, the blood pressure drops to zero, and the pulse disappears. At the present time it is only through the immediate action of a surgeon that this condition can be stopped before irreparable damage to the nervous system results. Thus, when one works with electrical equipment, it is desirable in uncertain situations to always place one hand in a pocket so that any accidental current will not flow from one hand to the other, and thus traverse the heart. Hand-to-foot current paths are equally dangerous, but less likely, because the floors of laboratories often tend to be fair insulators. If a strong shock is administered, there may be an interruption in breathing, in which case artificial respiration is helpful. But to reverse the condition of fibrillation requires *immediate* medical attention. When one is working with electrical equipment and has wet hands, the previous dangers can be aggravated.

With some current pathways, the muscles activating the hands may be caused to contract in such a way that the person can not let go of the connection and must be pushed away. The rescuer in this case must knock the victim loose with a chair or other insulator in order to be certain that he does not become "frozen" himself. With distorted wave shapes having a low average value and high peaks, even a "low voltage" can be dangerous in this respect.

There is always the possibility that a severe shock can be administered even though one is not handling the insides of a piece of electrical apparatus. Thus, if there tends to be a thin spot in the insulation of a wire that is rubbing against the metal case of the apparatus, then simultaneous contact with the case and some grounded object such as a pipe or sink or water faucet can result in death. The three-prong wall plugs that one often sees are intended to prevent such a possibility by automatically grounding the case of all apparatus through the third wire. However, surprisingly often the third wire is not connected, or else a piece of equipment that started out with two wires merely has its plug changed to a three-prong variety. In the latter case no protection is supplied.

Electronic Devices—Direct Current and High Voltage

Unless they are completely transistorized, most electronic circuits must have within them a power supply which is capable of delivering 200 or 300 volts of direct current. This power supply can deliver a very nasty shock, although death due to a direct current is less likely than due to the causes outlined above. It is to be especially noted that electronic circuits can deliver a shock even after they are turned off because they contain condensers in which charge is stored. Thus, before investigating an electronic circuit it is wise to take some piece of metal with an insulated handle, such as a screw driver, and "short circuit" each of the major condensers.

However, it is surprising that a condenser which has once been charged can deliver a shock even after it has been momentarily short circuited to discharge it. This characteristic of condensers is sometimes called "soaking" and has to do with the absorption of charge in the dielectric in a state from which it is not instantly released. (It is a minimum in condensers with a homogeneous dielectric.) Thus, large condensers often have permanently attached across them a high resistance which will gradually dissipate any charge collected in them. However, such resistors can burn out and cease to supply protection.

When working around very high energy storage devices, extreme care must be taken. One colleague of the author's walked into his laboratory after having been gone for a full week, during which time all of his apparatus had been turned off. He walked around a group of chairs and reached over to adjust a condenser. When he regained his senses he was on the other side of the chairs and they had

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not been tipped over. It is a surprising fact that such high intensity shocks often produce a severe burn, but in fact do not necessarily cause death, partly because the person is so quickly thrown clear. Once again the final result depends on the path of the current through the body.

Any time high voltages (tens of kilovolts) are applied to vacuum or electronic equipment, X rays can be generated. This radiation hazard will be taken up in a later section. Here it might be noted that this has already caused trouble in connection with such diverse items as electron microscopes and radar magnetrons.

Low Voltage

One might suspect that if one has voltages that are low enough then there can be no possible danger, but this is not true. In the first place, working around such things as storage batteries or other high current capacity batteries can involve some hazard to a person who is wearing a ring. If such a bulky piece of metal accidentally comes across the terminals of the battery, or its connections, then it may pass the very high current that the battery is capable of supplying, that is, there is a good impedance match. Under these conditions tremendous power may be dissipated in the ring and a severe burn can be administered.

If a current is flowing in a sizable coil of wire because of the application of a fairly low direct voltage, one has a potential source of an unpleasant shock. For if one tries to open the circuit and interrupt this current suddenly, then a very high voltage will be generated across the terminals of the coil. Examples of apparatus in which one might find such a situation are electromagnets and the field windings of motors and generators.

Static Electricity

Because there is seldom much energy stored in the form of static charges, they ordinarily provide little danger from shock, though they can have a certain annoyance value. The real danger comes when one is working in an explosive atmosphere of inflammable vapors or dust. The classic examples of such situations are surgical operating areas employing explosive anesthetics, and the potential danger in some grain elevators. In these cases any spark can lead to a catastrophe. Grounding through wires of any potential sources of trouble is the most obvious precaution. Conducting floor materials are known which can dissipate static charges about as fast as they collect. However, the latter irritate the hazard of accidental shock from handling electrical equipment since they supply a good ground path for any leakage current through a person.

Electronic indicators for the presence and motion of charges can be built. They consist essentially of an exposed piece of metal or an antenna feeding the high impedance of the grid of a vacuum tube or electrometer circuit. With some of these units one can easily tell when a nurse enters the room wearing a nylon slip. They can be set to give an indication of the collection of a potentially dangerous level of charge.

When working in a potentially explosive atmosphere it is also wise to consider the effect of the failure of a piece of electrical equipment. Thus a cable that is to carry a low level signal, such as a bio-electric potential, from a subject back to a monitor, could conceivably carry appreciable reverse power if a tube failed in such a way that its plate and grid came into contact. Placing a resistor in series with the cable at the monitor would minimize the problem, though the capacity of the cable might still store enough energy to generate a spark. In this case the best solution would probably be to place a pair of clipping diodes at the probe end of the cable so that no voltage appreciably larger than the normal input could ever appear there.

Radio Frequency Power

Radio frequency currents are not very effective at producing shocks, but they can inflict burns if they spark at the skin. In a hospital laboratory there are few intense radio frequency sources other than diathermy machines and possibly some ultrasonic sources.

Electromagnetic radiation at frequencies in the radio range exercise much of their biological effect in a thermal fashion. One of the most sensitive areas is the eye which is subject to cataract formation. It is not known definitely at this time if the peak intensity of a pulsed wave might not have other undesirable effects. But it is unlikely that most workers would find a source intense enough to do accidental damage except when working near a large radar-like unit. One tolerance specification is that a worker should be shielded if he could be exposed to more than fields of 0.01 watts/cm^2. One must avoid concentrating reflections that unexpectedly increase intensity in regions beyond where they are measured (*e.g.*, from a metal wall).

Radiation Hazards

Almost every laboratory has so many very thorough rules and laws with regard to the use of radioactive materials that it may be rather impossible, when complying with local regulations, to get into trouble. These rules cover every phase of the use of such materials including their application, storage and disposal. It should be mentioned that each of these three phases has associated with it a rather complete set of prohibitions.

Here we might briefly review the types of radioactivity that a worker would normally encounter in a general laboratory. Gamma rays are quanta of radiant energy related to light rays or radio waves. A gamma ray and an X ray are the same if they have the same energy. Gamma rays are able to penetrate relatively large distances through all materials; shielding from them can thus become rather complicated, often involving considerable thicknesses of lead.

Beta rays are electrons. In traversing a material, they gradually give up their energy through the production of a trail of ions in the medium through which they are passing, and thus they come to rest. Thus their range is rather limited in comparison with the penetration of gamma rays. Alpha particles are heavy, being helium nuclei, and they ionize very intensely. Thus alpha particles do not travel very far before giving up all their energy. One can thus relatively easily shield against alpha particles but, on the other hand, it would be extremely undesirable accidentally to swallow any appreciable quantity of an alpha particle emitter.

Exposure to the ionization produced by such radiation is termed dose. Biological damage depends not only on the rate or total dose, but also upon the specific ionization along the path of the incident particle. Particles with higher density of ionization generally have greater biological effectiveness. If the relative biological effectiveness of X rays, gamma rays, and beta rays is taken as one, then for protons it is approximately five, for alpha particles ten, for fast nutrons ten, and for thermal nutrons five.

In the use of radiation there are a few comments that are not stated as rules but as safety suggestions. First of all, if one is ever working around any form of X ray machine, or high vacuum device to which is applied a high voltage, then one should monitor for X rays in the working area. Strong X-ray beams have been found coming from electron microscopes and from some early day projection television sets. One should never apply high voltages to old radio tubes, for example when playing with a Tesla coil, as this can produce X rays. If a beam of radiation comes on, do not stop to wonder why; leave the room and then think over what went wrong. A comment might be made about colimating apertures. It is sometimes necessary to produce a narrow beam of X rays or other radiation, and this is often done with pieces of lead into which pin holes have been drilled. It is rather difficult to see these holes and thus the lead, after the experiment, can readily become returned to a stock pile. If some other worker then uses this piece of lead for shielding, he may be subjected to an accidental beam through the pin hole. Thus this author would like to suggest that, after an experiment, any pin holes that have been placed in a material that might then be used for shielding, should be drilled out to a quarter of an inch, or else the section be cut out of the piece of the material that is involved. It is not adequate to merely paint a red circle, because paint can then become chipped off. If lead glass is used for shielding, then it is well that it be checked. Severe accidents have resulted from the unintentional replacement of lead glass with window glass.

Because radiation dose questions have entered our lives to the extent of even becoming a political issue, it seems well to add a few further general comments. In pursuing experiments involving radiation it is necessary that one become neither too cautious nor too lax, but that one approach the problem intelligently. Some people have become so fearful of radiation that they cannot perform a harmless job in its presence, and others routinely refuse to have crucial X-ray pictures made for medical or dental purposes. The added dose involved may not be as much as would be obtained in situations about which they would not give a second thought. Thus certain radiographs can be made with no more dose than would be involved if a person were to move from San Francisco (at sea level) and go to Denver or Reno, which are approximately a mile higher in the air. Similarly, the difference may be no more than would be involved in living in a wooden rather than a brick house (the shielding from cosmic rays in these two cases being rather different). The dose from certain radium dial wrist watches over a period of years can actually be surprisingly high, and with the arms hanging down it can be localized in a rather undesirable region. One would prefer that the extra man-made dose from all radiation forms not be above roughly the life-time average dose from background; dose localized in a particular bodily structure requires more detailed consideration. Radiation is one of the few hazards of our civilization that has been so carefully scrutinized, and this has led to irrational panic on occasions.

If you follow the safety precautions with which you will inevitably become acquainted before being allowed to use radioactive materials, then you can feel rather confident that you are safe. The precautions and shielding required with any particular material will depend on the nature and intensity of the activity of the material in question, and presumably this will be made known to you. In the event of some unforeseen circumstance, such as breakage or spillage on the floor, it is best to block off the area with chairs or any other handy object so that other persons will not spread the contamination, and then call for a specialist to take care of the difficulty. Contamination of one's person should be immediately washed off with soap and water, and without panic. In the event of accident, one should attempt to keep track of the radioactive materials so that they will not dry up and blow away or possibly get into food which might then be ingested.

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