a) Scientist resources: A study of the current output of universities and colleges. The Office of Education, at the suggestion of the ONR, has been gathering annually, starting in 1948, information on the Bachelor's, Master's, and Doctor's majors in each school subject. This is the first time this information, necessary for analysis of the oncoming research and development workers, has been available. The American Society for Engineering Education has for a number of years secured and analyzed data concerning engineering school enrollment and graduation. This, too, at the suggestion of the ONR, is being taken over by the Office of Education in order that more detailed analyses will be available.

b) Ph.D. list: The basic list of recent Ph.D. graduates is also being maintained in still another project, which will supply detailed analyses of the data.

c) Beginning scientists: Pilot Study of Candidates Resulting from Potomac River Naval Command Board of U. S. Civil Service Examiners P-1 Examination for 1947 and 1948 indicates the type and quality of applicants and appointees resulting from the Navy's tapping the universities for the beginning scientific and engineering worker.

The projects listed in this article are but steps in a program for the assessment of the nation's manpower for research and development. The Manpower Branch plans to support projects in this area which will give a well-rounded description and evaluation of the supply and demand for such personnel, by universities, industry, research organizations, and government.

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A Radiation Meter for Disaster Use

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UNTIL THE DEVELOPMENT OF ATOMIC ENERGY, the number of persons exposed to the harmful radiations from radioactive substances was very small. Most of those exposed were well aware of the hazards to life and health presented by such radiation, and could provide themselves with instruments enabling them to measure radiation intensity and avoid overexposure.

The large-scale development of atomic energy sources and the present emphasis in several countries on the production of increasingly powerful atomic weapons have, however, considerably changed this picture. Tremendous and altogether unprecedented quantities of dangerously radioactive substances can now be liberated in a single explosion, or manufactured in a nuclear energy plant and delivered in the form of radioactive poisons, producing radiation hazards of fantastic magnitude. Spectacular as are the immediate destructive effects of the explosion of a nuclear bomb, the aftereffects of the radiation and the contamination by radioactive elements bid fair to be even more decisive in future warfare. In the Hiroshima explosion, 15–20 percent of the casualties resulted from radiation damage inflicted at the instant of detonation: It is estimated that all exposed persons within a radius of approximately half a mile received lethal or near-lethal doses of gamma radiation (*2*). Because the bomb was exploded high in the air, the residual radioactive contamination was negligible. In test Baker, at Bikini, the explosion took place under water, and the instantaneous radiation was largely absorbed. On the other hand, the resulting "base surge" of mist and spray caused a precipitation of radioactive materials estimated to be lethal over several square miles, and the lagoon, together with its plant and animal life, was dangerously contaminated for some months.

When one considers that only a few pounds of radioactive materials are produced in such a bomb and that perhaps some tons would be produced by the neutrons resulting from an H-bomb explosion, it does not seem unreasonable to expect that such an explosion, under suitable meteorological conditions, could render a large city so "hot," in the sense of producing a high level of radiation, that it could not be inhabited for years or even generations. Nor need such a catastrophe be accompanied by an explosion: Thirring has pointed out in a careful and conservative analysis (*1*) that the by-product radioactive materials from a single nuclear power reactor of the size of the Hanford installation could be used to render a large city uninhabitable for an indefinite period. The active materials could be incorporated in a few hundred pounds of dust or sand and distributed from an airplane or from rockets launched from ships or submarines. About 60 percent of the reactor by-products have half-lives between a few days and a year: the effective life would be about a month. In a month's time a new supply could be produced by the reactor and used to maintain the contamination level if desired. Such a weapon has, from many points of view, considerable military advantage against an unprotected population, even over the much-publicized H-bomb. The target city would be completely undamaged and, after cessation of the periodic contaminations, could be taken over by the invading forces. These facts, together with the consideration that only waste products are used and no expensive energy-source materials are lost, suggest this as the most likely atomic weapon of a future attack on Western Europe and perhaps even on the United States.

An insidious feature of radioactive contamination, whether present as the aftermath of a nuclear explosion or as a primary weapon, is that the radiation is undetectable by the senses. A general body dose of the order of a few hundred roentgens, accumulated in a sufficiently short time, may produce no immediately visible effect but may, nevertheless, result in the death of the victim in a few days or weeks. Even at a much slower rate of a few tens of roentgens per day, grave damage may be done before identifiable physiological effects appear. In this respect, an overdose of radiation is analogous to sunburn, where the victim may receive a painful or dangerous burn without any effects being observable during the exposure period. In view of the impossibility of judging without instruments the extreme hazards to which large numbers of people will be exposed without warning in case of an attack, it is clear that there exists a need of quite a new order of magnitude for radiation meters suitable for evaluating these hazards.

The radiation-measuring instruments needed for the routine protection of those actually engaged in atomic energy work have received considerable attention and are available in relatively convenient form. These instruments are, for the most part, designed to deal with levels of radiation intensity in the general neighborhood of, or far below, the presently accepted "tolerance" magnitude;[1] they are therefore of relatively high sensitivity and accuracy. They are needed in rather small numbers, hence their cost is not a determining factor in design. They are used by people experienced in radiation measurement and therefore need not be especially rugged or simple. Such devices as the currently available ionization or counting-rate survey meters and pocket electroscopes or ionization chambers are typical of instruments in this class.

An entirely different problem is presented by the radiation instrumentation needed for citizens, rescue teams, and military personnel involved in an atomic disaster of the character discussed above. In such a case, one will have to deal with very high levels of radiation intensity, as compared with the "tolerance" level, and quick action in leaving a heavily contaminated area will be necessary to avert radiation illness or death. It is essential, however, to be sure that one is moving away from contaminated areas to areas where the radiation level is lower; this can scarcely be done except on a basis of continuous measurements of radiation intensity. Rescue activities must be conducted with some regard for the lives and safety of the rescue personnel. Only a measurement of radiation intensity can determine how long it is safe to stay in a given contaminated area without receiving a lethal dose or running an unreasonable risk. It will be imperative to determine, by some simple means, which living victims of an atomic disaster have received so large a dose of radiation that their death is inevitable, so that the limited rescue facilities can be concentrated on those victims who have some chance of survival. Recently the Atomic Energy Commission has announced the development of an identification tag that will indicate by change in color when a victim has received a lethal dose of radiation. This should fulfill a most important need if generally adopted, but such devices do not obviate the urgent need for a continuously indicating meter for use by less seriously affected victims and rescue personnel. The movement of combat troops through a contaminated area also requires a careful evaluation of radiation hazards, based upon radiation intensity measurements made at each point to be occupied.

Another important function of a radiation instrument under the circumstances envisaged is that of preventing mass hysteria and widespread panic. It does not require any imagination to see that the consequences of even a false alarm of a radioactive attack or of local contamination at some distance from a bomb blast could be disastrous in the absence of effective means that will enable each individual to ascertain for himself the true state of affairs. The very facts that radiation cannot be detected by ordinary means and that reaction is delayed make it possible to use the threat of radioactive attack as a most terrifying psychological weapon.

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[1] The "tolerance" level, of the order of 0.05 roentgen units per day, is the maximum rate at which the human body can absorb radiation continuously without demonstrable cumulative effects.

The properties of the radiation-measuring instruments needed for the purposes just described are quite different from the properties of existing instruments. Radiation meters for disaster use will be required in large numbers, hence they must be simple and cheap to make. They will be used by people unfamiliar with such techniques; therefore they must be extremely rugged, easy to use, and reliable both in what they indicate and in the ease of interpreting that indication. To serve their purpose adequately they should be as simple and common as flashlights, gas masks, or first aid kits, available to every rescue crew, civilian defense team, or squad of troops. Because many of the instruments in a bombed area will be out of commission, either from physical damage or neutron-induced radioactivity of the instruments themselves, emergency stores must be maintained for instant distribution from dispersed depots. In view of the uncertainty as to when and where such stores will be put into use, the maintenance required should be kept to a minimum. Even batteries, which require replacement once or twice a year, should be avoided.

The sensitivity of a radiation meter for disaster use need not be high. Indeed, a device which would give a measurable indication when a small percentage of a lethal dose, say 50 roentgens, had been received would cover most exigencies. On the other hand, it is preferable to have a means of estimating in a few seconds or minutes how long a contaminated area can safely be occupied. Even a dose of 50 roentgens may have deleterious effects and should be avoided if possible. With a more sensitive instrument, the degree of hazard can be estimated from the rate of discharge with negligible exposure of the user, and large areas can be rapidly surveyed in a short time. Operations in a contaminated area for hours or days ahead can be planned only if the radiation intensity is known long before dosages of dangerous magnitudes have accumulated. A sensitivity of the order of 0.1–1.0 roentgens full scale, which is easily attainable in a simple instrument, would appear to be a reasonable value, provided the instrument can be recharged at will. With a sensitivity of 1 roentgen, for example, a full-scale deflection in one minute would indicate the relatively high hazard of 60 roentgens per hour. An area where such a rate is observed should be immediately evacuated, and any entry into the area limited to as short a time as possible. On the other hand, if only 0.1 roentgen is indicated in one minute, operations can be executed at a more leisurely pace. The important point is that the information necessary to evaluate the hazard is immediately at hand and available to those most directly concerned.

The above discussion represents the personal views and opinions of the writers and may not conform with the views of responsible authorities, particularly in the Department of Defense; but, as such views are closely guarded secrets, we can only use our own judgment. Also, it is conceivable that our armed forces have already developed satisfactory instruments for these important purposes, but, for reasons that are not clear, such information is not available to the public. We can only proceed on the assumption that no fully satisfactory instrument for this purpose has so far been developed.

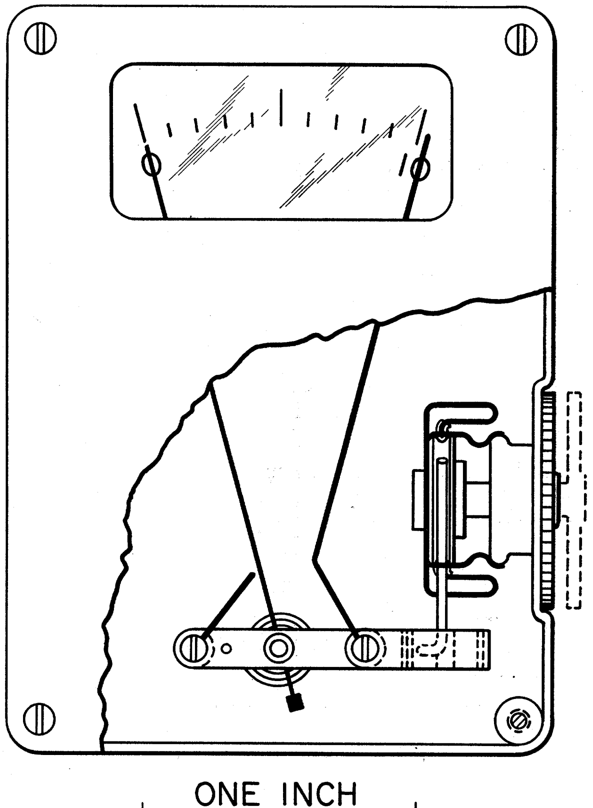

Fig. 1. Pocket-sized radiation meter with friction charging device.

One form of radiation meter that we believe to be suitable in its major features for disaster use is illustrated in Fig. 1. The instrument comprises essentially an electrostatic voltmeter of low capacity, mounted in a case that serves as an ionization chamber, and provided with a friction charging device. The voltmeter movement consists of a stiff, light aluminum needle, mounted in a simple pivot arrangement with a spiral restoring spring and repelled by a fixed arm at the same potential. The meter movement, including the repelling arm, is insulated from the case. A stop prevents accidental discharging by limiting the motion of the needle. With the dimensions shown, and a light hairspring, the sensitivity of the voltmeter is about 500 volts for 20° deflection, and the moving system has a time constant of the order of a few tenths of a second. Because of the lightness of the needle, the pivot loading is negligible and jewels are unnecessary. For the same reason, the movement is quite rugged and will survive any shock which does not damage the case. Although the deflection of the needle is not accurately linear with voltage, the departure from linearity can be made small by proper design of the instrument, and it is an easy matter to calibrate the scale in roentgens. The radiation sensitivity can be adjusted over a wide range by varying the size of the case or the capacity of the meter, and over a smaller range by adjustment of the hairspring tension or the length of the repelling arm. As a general rule, the depth of the case should be somewhat greater than the maximum travel of the needle; otherwise electrostatic forces between the needle and case will cause low sensitivity near maximum deflection. The efficiency of ion collection is also enhanced by so designing the case that all walls are roughly equidistant from the high potential collecting surfaces.

Aside from the not too stringent conditions on the general design enumerated above, the size and shape of the case may be varied considerably to suit the convenience of the user. The model illustrated is about the size of a cigarette package and would appear to be a practical choice for a pocket instrument. Another version has been made in the form of a pillbox 1.5 inches in diameter and 0.5 inch thick, conveniently carried on the wrist.

An essential feature of these instruments is the provision for recharging. A practical solution of this problem is the friction charging device illustrated, which is of a type that has been used for similar purposes for many years. Static electricity is produced by turning a hard rubber, lucite, or polystyrene drum against a leather friction pad; a metal band around the drum collects the charge and acts as a switch. In operation, the thumb wheel outside the case is snapped outward and rotated. The combination of these two motions engages a tab connecting the collector band to the voltmeter; a further rotation of one or two turns charges the instrument. When charging is completed, the contact is disengaged by snapping the thumb wheel in against the case. The shaft may be sealed with an O-ring packing to prevent entrance of moisture.

The question of the materials used in the radiation meter requires some consideration. For reliable indication of dosage, particularly of relatively soft x-rays, it is desirable that materials of low atomic number be used. If the instrument is likely to be exposed to any appreciable neutron flux, it must not contain materials which yield radioactive products of long half-life: iron, copper, and silver would be undesirable materials, whereas hydrogen, beryllium, carbon, oxygen, and aluminum would be quite suitable for the purpose.

Although some attempt has been made in the preceding discussion to indicate how a radiation meter might be used in an atomic disaster, it is clear that a complete solution to the problem of properly evaluating radiation hazards in such circumstances is a complicated matter. The exact character of the catastrophe will determine the type of radiation present. Thus, in the instant of detonation of a thermonuclear bomb, the principal radiation damage may be from neutrons: Here one will presumably estimate dosages received by measuring activities induced in various materials at the scene. After the blast, one will be confronted with a wide variety of problems of evaluation. The gamma radiation present is relatively easily measured, and its effects are relatively predictable; beta radiation can be fairly easily measured, for example, by means of a meter provided with a suitable window in the case, and its external effects are reasonably well known. Such materials as are breathed or otherwise gain entry into the human system present, on the other hand, quite considerable difficulties, particularly if they are long-lived, and if they enter into the body chemistry. Here even very small amounts of material can have effects entirely out of proportion to their activities as determined by a radiation meter. The identification of such substances will ordinarily require especially trained personnel and may involve analytical techniques not easily carried out in field operations. The particular case of plutonium contamination, as experienced in the Bikini tests, can be dealt with most simply, since the alpha particles can be detected readily if a very thin window is provided in the case of the instrument. Such a window will, of course, be vulnerable to damage from rough handling and may not be desirable for general use.

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