

RADIATIONS AND THEIR PROPERTIES

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The applications of high-energy radiation to agriculture fall into two main categories. In the first of these the radiation is used to cause changes in living material, such as in the prevention of sprouting in potatoes, the killing of pests in stored grain, and the production of mutations in seeds; in the second, the radiation from a radioactive substance is used to trace the movement of something, such as insects in the ground or fertilizer in a plant. What follows is a summary of the properties of high-energy radiations that are of interest in agricultural applications, and a brief mention of units and methods of measurement.

Properties of Radiations

The principal high-energy radiations and their properties are listed in the table. *a*-particles are doubly charged helium nuclei emitted by certain radioactive nuclei. They lose energy gradually by ionization and excitation of the atoms of the matter through which they pass. Particles

of a definite initial energy have a definite *range* in matter, that is, they travel a definite distance before their energies are completely dissipated and they stop. Generally *a*-particles have ranges in tissue of less than a tenth of a millimeter.

Protons are hydrogen nuclei. Energetic protons do not occur naturally, but they can be accelerated to great energies in machines such as the cyclotron. They lose energy in the same way as *a*-particles, and while their ranges tend to be somewhat greater, they require very great energies (about 100 Mev) to penetrate as much as a few centimeters of tissue.

It is evident that *a*-particles and protons will not be of much use in most agricultural applications simply because they cannot penetrate beyond the outer layers of the sample.

Electrons are negatively charged and much less massive than protons. They can be accelerated to high energies in a number of kinds of machines, including Van de Graaff generators,

betatrons, and linear accelerators. They are also emitted by many naturally occurring radioactive elements and artificially produced radioactive isotopes; in this case they are referred to as *β*-particles. As well as losing energy by ionization, a fast electron in a close collision with a nucleus can lose a portion of its energy as electromagnetic radiation. (In fact, it is by this process that conventional x-rays are produced.) An electron of a particular energy loses energy much less quickly than a proton of the same energy, and consequently travels farther before stopping. The range of a 1-Mev electron in tissue is about 0.4 cm, that of a 30-Mev electron about 15 cm. The ranges of *β*-rays mostly lie between 0.2 and 1 cm.

When a beam of high-energy electrons strikes a solid or liquid medium, the absorption of energy is greatest near the surface and falls off steadily with increasing depth, reaching zero at a depth equal to the range. However, by choosing an appropriate

Radiation	Mass (Relative to H Nucleus)	Charge (Relative to H Nucleus)	Source	Mode of Energy Loss	Penetration of Tissue
<i>a</i> -particles	4	2	Radioactivity	Ionization	Fraction of mm.
protons	1	1	Accelerator	Ionization	.01 cm (2 Mev) to 10 cm (100 Mev)
electrons	1/1836	-1	Accelerator	Ionization and radiation	0.4 cm (1 Mev) to 15 cm (30 Mev)
<i>β</i> -rays	1/1836	-1	Radioactivity	Ionization and radiation	0.2 to 1 cm
x-rays	0	0	Accelerator	Transfer to secondary electrons	Exponential: reduced to ½ by 5-20 cm
g-rays	0	0	Radioactivity	Transfer to secondary electrons	
neutrons	1	0	Nuclear reactions	Transfer to recoil nuclei	Comparable to x-rays

electron energy, and irradiating the material from both sides, it is possible to achieve a reasonably uniform absorption of energy over a considerable thickness.

X-rays are high-energy photons of electromagnetic radiation, produced when fast electrons are slowed down suddenly in matter. Radiations identical in nature but emitted by radioactive nuclei are called *g*-rays. Rather than losing energy gradually in small amounts, an x-ray loses all, or a large part, of its energy to an atomic elect-

ron in a single chance encounter. Since such encounters occur with a rather low probability, an x-ray travels on the average through several centimeters of tissue before being absorbed.

A beam of x-rays falls off more or less exponentially in matter. In tissue such a beam loses half its energy in the first 5 to 15 cm, half of what is left in the next 5 to 15 cm, and so on. X-rays can therefore be used to irradiate substantial thicknesses of material, and again improved uniformity can be achieved by irradiating from more

than one direction.

Neutrons are uncharged particles of about the same mass as protons. They do not occur free in nature but they can be produced in certain nuclear reactions. They leave energy in matter through occasional collisions with nuclei much as x-rays lose energy to electrons. Neutrons are penetrating but difficult to detect.

For the irradiation of material in bulk, penetration is usually of prime importance, and x-rays or g-rays are

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From the above listing it is evident that the Plan Service covers a comprehensive range of designs for farm service buildings and associated equipment. In addition each catalogue contains a section dealing with management factors for the particular class of buildings in relation to features of building design and selection of equipment.

Distribution of Plan Service Material

Some confusion appears to exist in respect to public distribution of catalogues and plans. This has been due to a statement in the first four catalogues published, that is, Beef Cattle, Dairy Cattle, Sheep and Fruit and Vegetable Storage that catalogues may be had from Experimental Farms or the Canada Department of Agriculture, Ottawa. This statement has been amended in the Swine and Poultry Housing catalogues to read "copies of this catalogue may be had from Agricultural Representatives of Provincial Department of Agriculture". The reason for this change is that each Provincial Department of Agriculture either inserts a supplement or preferably stamps the catalogue with a statement on how and where to

order plans within the particular province. Any catalogues that are to be made available to the Public through Federal Agencies should be so stamped by the Provincial Department of Agriculture.

Revision of Plan Service Material

As indicated, arrangements have been made for the work of revision for the eight classes of plan catalogues to be supervised by the one remaining drafting centre at the Ontario Agricultural College. It is anticipated that revisions may proceed at the rate of one or two catalogues per year by insertion of additional sheets in the catalogues where this is practical or a revision of the catalogue when necessary. The drafting centre staff have, in recent weeks, met with representatives of Provincial and Federal Departments of Agriculture to discuss various details of the plan service including the demand for specific plans, additions, deletions and revisions. If this work goes according to plan the material presently available should be brought up to date every four to five years.

In conclusion, the development of

the Canadian Farm Building Plan Service has proceeded by four to five year stages. Early efforts from 1944-1949 to establish the service failed to secure sufficient support to launch a co-ordinated program of farm housing period from 1951 to 1954, a redirection of emphasis on farm service buildings only with more complete coverage for the proposed plan service gained widespread support due to the improvements in the proposed plan and possibly that the times were more receptive to the idea. In any event, official sanction and financial support were forthcoming. In the period 1955-58 all eight proposed plan catalogues and plan sets have been prepared. Six of these have been published and it is anticipated that the two remaining catalogues will be available by the end of 1958 or early 1959.

The fact that available plan service material has had reasonably widespread public distribution has, in the opinion of many, amply justified the establishment of the service and has given considerable gratification to the National Committee on Agricultural Engineering and all those associated with the development.

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most suitable. In tracer applications moderate penetration and high detection efficiency are generally desirable; in this case radioactive isotopes emitting β -rays are often used.

Units and Measurements

A beam of x- or g-radiation is measured by its ability to ionize air. The property measured is called the *exposure dose*, and the unit is the *roentgen*. Crudely speaking, a roentgen of x-radiation gives rise to one electrostatic unit of ionization in each cubic centimeter of air. Rotengens are a measure of the radiation itself, not what it does in, say, tissue.

The biological effects of radiation are assumed to be governed by, among other things, the amount of energy absorbed per unit mass at the place of interest, i.e., by the *absorbed dose*.

One unit of absorbed dose is the *rep* (rotengen-equivalent-physical), defined as the amount of energy absorbed per gram of tissue exposed to one roentgen of x-radiation. This corresponds according to the most recent values of certain constants, to about 95 ergs/gm. Unfortunately different authors have used different variations of the above definition, and values of

84 and 93 erg/gm are common in literature. This confusion has been resolved by defining a new unit, the *rad*, which is unambiguously equal to 100 erg/gm.

Rads (and reps) can be applied to electrons and neutrons as well as to x- and g-rays.

Exposure dose in roentgens is determined either by a free-air chamber, in which the ionization in a well defined volume of air is measured, or from the ionization in a small air-filled cavity surrounded by walls resembling air in composition. Absorbed dose can be determined in a variety of ways. In principle an attractive method is to measure the rise in temperature due to the energy absorbed in a small, isolated volume of the medium, but in practice the difficulties are very great. The ionization in a small gas-filled cavity at the point of interest can be interpreted in terms of absorbed dose. The exposure dose outside the medium can be measured and the absorbed dose at a point within deduced from the known behaviour of the radiation in the material. Other methods depend on the blackening of film, chemical changes in a vial of solution, and the change in colour of special kinds of glass. These latter methods depend on previous calibration against a device cap-

able of absolute measurement.

The shielding of radiation sources so that they do not harm those using them always requires consideration. G-ray sources require the most shielding, since the rays are penetrating and are emitted continuously in all directions. β -rays can be stopped completely by a thickness of material equal to the range. Accelerators present fewer problems, since the radiation is generally emitted in a directed beam, and the machine can be turned off when not in use.

Finally, a few words about the amounts of radiation involved in typical applications may be helpful. In tracer work it is only necessary to have enough radiation to detect, and a few millionths of a roentgen can be detected quite readily. On the other hand most irradiation effects require somewhere between a few thousand and several million roentgens. (Sprouting in potatoes is most effectively prevented by an exposure to twenty thousand roentgens.) The danger level to man lies between these two extremes: it is believed that he can be exposed to a tenth of a roentgen every week of his life without noticeable harm, but 500 roentgens at one time will kill him. In this respect men are evidently more sensitive than potatoes.