PORTABLE ELECTRON BEAM SYSTEMS

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The use of ionizing radiation to treat food products is a technology which has existed for almost 40 years. Many pathogens such as L. Monocytogenes, Y. Enterocolitica, and A. Hydrophila as well as Salmonella, Campylobacter and E. Coli can be reduced or eliminated with ionizing radiation. As an added benefit many organic chemical contaminants such as PCBs and chlorinated hydrocarbons, are also significantly reduced by E - beam treatment. In this paper we will (1) present a simple description of electron beam and radiation processing and, (2) describe a portable high energy electron beam source

Accelerator output is usually specified in watts of power. Using that information as well as factors concerning the absorption of radiation in the target allows one to calculate the dose, the amount of energy absorbed by each gram of the irradiated material. Dose is usually specified in either Rads or Grays (Gy). 1 Gy=100 rad; typically industry uses both.

For E - beam processing the dose level used is in one of three ranges. Low doses are less than 1kGy, medium doses are 1kGy to 10 kGy and high doses are greater than 10kGy. Many factors determine appropriate dose level, and covering them would fill many volumes of books. As an example, the January 1994 issue of the Journal of Food Protection, pages 73-86, lists the D10 values for most common pathogens. Doses indicated from this put the maximum required level between 1kGy to 10 kGy, or 0.1 megarad (Mrad) to 1 Mrad). The FDA has set maximum allowable doses which range from .2kGy to 30 kGy depending on the product (FDA Consumer, "Food Irradiation," Nov 1990, p.14). This article indicated that some research and testing may be required to establish the required dose levels.

Once the total dose requirements have been specified, the required product throughput must be determined next. This number specifies the pounds of food per hour processed. This is primarily a factor of the beam power. Table 1 below shows the processing throughput, for a typical installation, for 0.5 Mrad and 1 Mrad, for various available accelerator powers.

For example, a 5kW electron beam accelerator can treat 2,775 lb. of food to a dose of 0.5 Mrad. The numbers in Table 1 are based on a conservative 35% application efficiency: this means only 35% of the radiation actually hits the product. This number can be much higher; one advantage of using electrons is that the scanning magnetic can adjust the treatment area to achieve maximum efficiency.

Electrons have a predictable penetration depth, or range, in material. Range is affected by

two parameters: electron energy and product density. The penetration is proportional to the energy and inversely proportional to the density. This is the basic formula which describes penetration.

Penetration (cm) = (0.524E -0.1337)/d

E = beam energy in MeV and d = density in grams/cc.

This equation applies to energies greater than 1 MeV. Penetration for several materials is shown in table 2. The most important of these is water as most things which are being radiated can be regarded as the same density as water.

Dose levels are divided in three categories: low, medium, and high. The functions and levels are described in table 3 below. The viability of irradiation for various fruits and vegetables is based on empirical studies and practical experience. Table 4 is very superficial list of products which have been studied.

The L&W Portac electron linear accelerator was developed for Los Alamos National Laboratory as a powerful X-ray source to inspect suspected damaged nuclear weapons as part of the program to dismantle these weapons. The requirements were 6 MeV, 500 watts in a package which was portable and extremely rugged. Portability required that the accelerator was in several sections, non of which weighed more than 200 lb.. The requirements also were to assemble the system in arctic conditions with radiation protective clothing. We have now developed a larger version which gives 10 kilowatts of power at 5 MeV. Although larger, this unit is still transportable. The whole system including a 50 kW generator will fit easily in a 20 ft trailer.

Such a system can easily be arranged for field treatment of fruit or vegetables. It could also be adapted to treat soil directly. In this application the penetration would be a limiting factor. A 10 MeV accelerator could treat the top 1.5" of soil.

The accelerator is in four sections, the head, the power cabinet, the control and the TCU.

- **The head, has the accelerator and any electron beam scanning components.**
- **· The power cabinet supplies power to the head through several cables.**
- **· The control is a computerized controller. This controls the accelerator and also provides data logging and record keeping.**
- **· The TCU is the cooling unit for the system. This keeps the temperature of the accelerator components below 90^{o}F.**

Problems

The biggest problem with high energy accelerators is shielding. Although the electrons are not hitting a tungsten target, they still make a lot of x-rays. The high energy of these x-rays makes shielding quite difficult. So the higher the energy the more difficult the shielding. On a fixed installation we specify up to 9 feet of concrete, sand or earth as shielding. When mounted on a truck we can reduce the

shielding requirements two ways. First we can use 12 to 15" of lead as the major shielding. Second we can move the control to a distance away and keep all people several hundred feet away. We can get sufficient

82-2

shielding using 10 tons of lead, which is high but not impossible. Couple this with an exclusion zone, and field operation is quite feasible.

Tables

Table 1. Product Power Requirements

Linac Beam Power (kW)	Processing Capability (lb./hr) Exposure Level - 0.5 Mrad	1.0 Mrad
1	550	270
3	1,660	830
5	2,775	1,390
10	5,550	2,775
20	11,100	5,550
40	22,204	11,100

Table 2. Product Penetration

Material	Density(g/cc)	Penetration Depth(cm) 8 MeV	10 MeV	12 MeV
Air	0.001	3051	3838	4626
Water	1.0	4.0	5.1	6.1
Plastic	1.2	3.3	4.2	5.1
Glass	2.4	1.7	2.1	2.6
Aluminum	2.7	1.5	1.8	2.3
302 SS	7.9	0.5	0.6	0.7

Table 3 Dose Levels

Level	Function	Dose (Gy)
Low	Inhibit Sprouting	50 to 150
	Delay Ripening	200 to 1,000
	Prevent Trichinosis	300 to 1,000
Medium	Kill Spoilage Organisms	1,000 to 3,000
	Kill Parasites	1,000 to 8,000
High	Sterilize	25,000 to 50,000

82-3

Table 4 Foods to benefit from E-beam processing

Food	Benefit		No Benefit
apricots	X		
avocados			X
bananas	X		
cantaloupes	X		
cherries	X		
citrus			X
figs	X		
garlic	X		
grains	X		
mangoes	X		
mushrooms	X		
papaya		X	
pears			X
plums			X
potatoes	X		
strawberries	X		
tomatoes	X		