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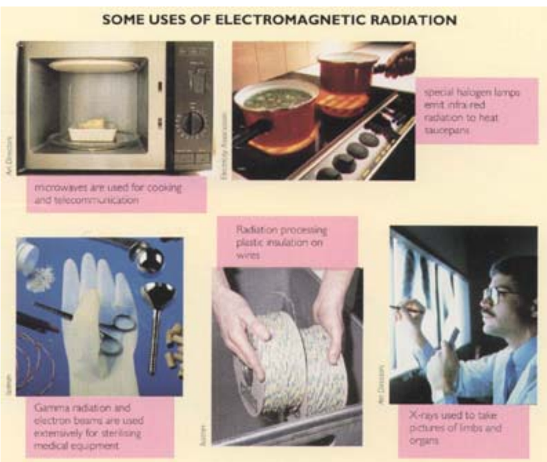
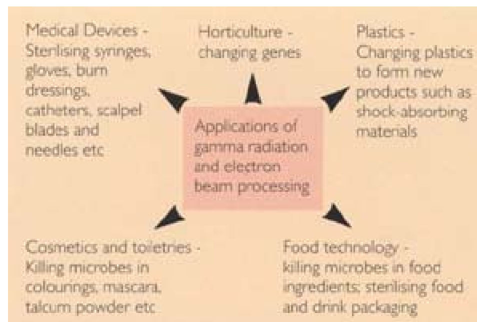
Science in Action

Produced in collaboration with the British Trade Association, 1995/1996

Radiation Processing

Treating substances with any form of electromagnetic radiation or high energy electrons is known as IRRADIATION. Electromagnetic radiation is essential for modern life. It includes X-rays, microwaves, and visible light. Recent advances in technology have brought about an increasingly important role for gamma rays and electron beams.





RADIATION - FIGHTING DISEASE

Infection after a hospital operation was a major problem in the 19th Century. Operations were often carried out with equipment and hands contaminated with microbes which caused infections. In 1865 an Edinburgh surgeon, Joseph Lister (1827-1912), was the first scientist to realise the importance of sterile equipment. He used a chemical called an antiseptic to kill the microbes

Today, infections after operations have been reduced significantly by the use of pre-packed, disposable items which have been sterilised by either gamma radiation or high-energy electrons. This helps to speed up treatment and reduce cross infection risks. Items to be sterilised arrive at the irradiation plant sealed in packages. They are conveyed through a concrete shielded room where the radiation penetrates the packaging, killing the microbes. The radiation passes through the items making them sterile and ready for medical use.

Uses of Ionising Radiation

Gamma radiation and high-energy electron beams are called ionising radiations and inactive microbes. Breaks occur in the helix of DNA which destroy the ability of the cell to reproduce itself. Hence cell division is prevented and the cell is "killed".

MEDICAL IRRADIATION

Sterilisation by gamma radiation or high energy electrons is more appropriate in many cases than heat sterilisation and is finding more and more applications. Dressings, disposable

gloves, plastic forceps and syringes as well as replacement hip joints and catheters are examples of medical equipment now sterilised by radiation. Sterilisation by radiation is also finding applications in other areas. Cosmetics and toiletries can be contaminated by microbes. Either the raw materials or the finished product may be sterilised by radiation.

Making X-ray images is another important radiation application used in hospitals. To make an X-ray picture (or radiograph) the patient is placed between the X-ray tube and a photographic

plate. The operator (radiographer) and parts of the patient's body that do not need X-raying are protected by lead screening. This is because too much exposure to X-rays can damage body tissue. The X-rays pass through the tissue but are stopped by the bones. A radiograph of the bones is obtained.

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FOOD IRRADIATION

Irradiation as a method of food preservation and control of food poisoning organisms is a relatively new idea when compared to drying, pickling, salting or freezing. For over 20 years scientists conducted experiments and collected data on all aspects of food irradiation. In the 1980's a committee supported by the World Health Organisation examined the data and in 1987 declared the process safe. The proper dose of radiation can inactivate the microbes responsible for food spoilage and food poisoning without affecting texture, flavour or colour of the food. By 1993 over forty countries had approved food irradiation for one or more items and in many placed it is replacing banned pesticides.

Purpose	**Applications**
Inactivation of harmful organisms in food ingredients.	Various spices and herbs. Onion powder. Mineral supplements.
Inactivation of salmonella food poisoning organism	Meat including poultry. Egg products. Prawn and shrimps. Meat and fish meal.
Extension of refrigerated shelf life.	Meat and fish.
Prevention of spoilage	
-Control of mould. -Control of insect infestation. - Minimizing deterioration.	Stawberries, Cocoa beans, Mangoes, papayas.
Control of parasites and insects to meet quarantine requirements.	Parasites in meat and insects in exotic fruits and beans.
Inhibition of sprouting in crops during storage.	Potatoes, onions and garlic.

The first license for food irradiation in the United Kingdom was granted in 1992 by the Ministry of Agriculture, Fisheries and Food for use with herbs and spices.

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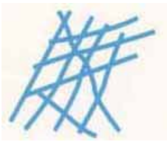
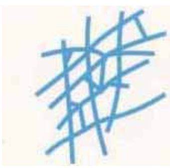
POLYMER IRRADIATION



Thermo-softening plastics - No cross-links between the chains or carbon atoms.



Thermosetting plastics - Cross-links between chain of carbon atoms.

Examples of irradiated plastic sleeves illustrating the heat shrinkable effect.

Radiation has two key effects on polymers:- - Making the polymer chain shorter. - Cross-linking between polymer chains. The balance between the two effects will determine the ultimate change in properties of the irradiated polymer. The plastic will still look the same but its properties will have changed. The change in properties allows the plastic to find a greater range of applications. Polyvinyl chloride (PVC) and polyethylene can be irradiated to improve their properties giving higher softening point, decreased flammability and improved resistance to abrasion.

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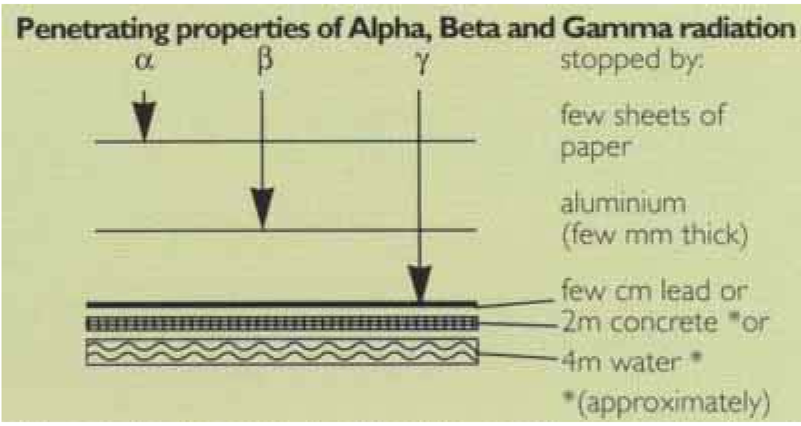
WHAT IS RADIOACTIVITY?

Radioactivity is the emission of radiation resulting from changes within the nucleus of atoms. It occurs because some atomic nuclei are unstable and they emit radiation to form new nuclei in seeking to become stable and can become new atoms. Radioactivity was first used as a term by Marie Curie. She and her husband Pierre started research into uranium compounds in 1898 and discovered two new radioactive elements - polonium (named after Madame Curie's native country, Poland) and radium (meaning 'giver of rays' because its salts glowed in the dark). The Curies were awarded the Nobel Prize in 1903 for their work. Unaware of the effects of radiation, Marie Curie died in 1934 from excessive doses of radiation received during her research work. Alpha radiation is the nucleus of helium atoms. Beta radiation consists of electrons. Gamma radiation is electro-magnetic.



IRRADIATION INDUSTRY
HOW IS IRRADIATION CARRIED OUT?

As radiation passes through dense materials such as lead, concrete or even water, it loses energy and ceases to be dangerous to microbes or humans. This is known as 'attenuation'. The key factor in the design and operation of an irradiation plant is safety. The process is carried out within an enclosure (cell) whose walls and roof are 2 metre thick. The source of gamma radiation, the element cobalt 60, is stored in a deep water pond or a shielded trench. Government controlled safety precautions are taken to protect people working with radiation. Exposure to high doses of radiation could be fatal. It is important to remember, however, that when a product leaves the irradiation process it is not radioactive because the energy of the

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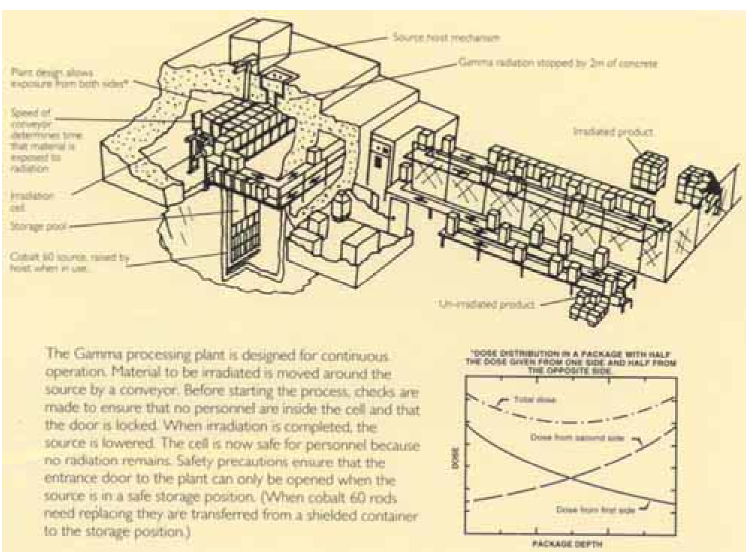
radiation used in processing is relatively low. PRODUCING GAMMA RADIATION All atoms of the naturally occurring element cobalt 59 have 27 protons and 32 neutrons present in the nucleus and 27 electrons moving outside the nucleus. Isotopes are atoms of the same

$$ {}^{1}_{0}n + {}^{59}_{27}Co \longrightarrow {}^{60}_{27}Co $$

element but with different numbers of neutrons. By bombarding cobalt 59 with neutrons an additional neutron can be captured by the nucleus converting it into cobalt 60. Cobalt 60 is specifically made for use in gamma irradiation plants - it is not a waste product of nuclear power plants.

Cobalt 60 is radioactive and is called a radioisotope. It is unstable and in trying to become stable it emits a beta-particle and two photons of gamma radiation. An isotope of nickel remains. The half-life of cobalt 60 is 5.27 years. A pellet of cobalt 60 has a useful life of 20 years by which time its activity is reduced to about 1/14th of the original. Long term storage will allow the activity of the pellet to decay to safe levels. The gamma processing plant is designed for continuous operation. Material to be irradiated is moved around the source by a conveyor. Before starting the process, checks are made to ensure that no personnel are inside the cell and that the door is locked. When irradiation is completed, the source is lowered. The cell is now safe for personnel because no radiation remains. Safety precautions ensure that the entrance door to the plant can only be opened when the source is in a safe storage position. (When cobalt 60 rods need replacing they are transferred from a shielded container to the storage position).



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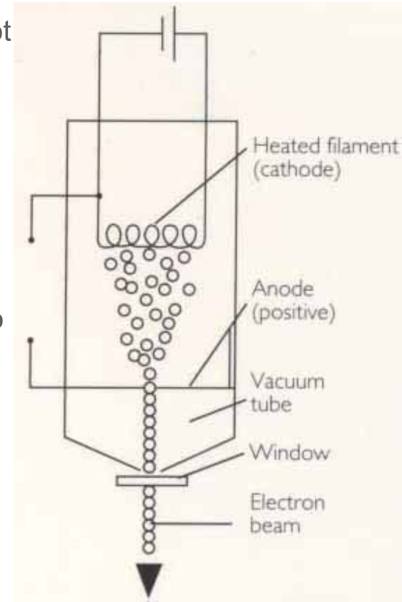
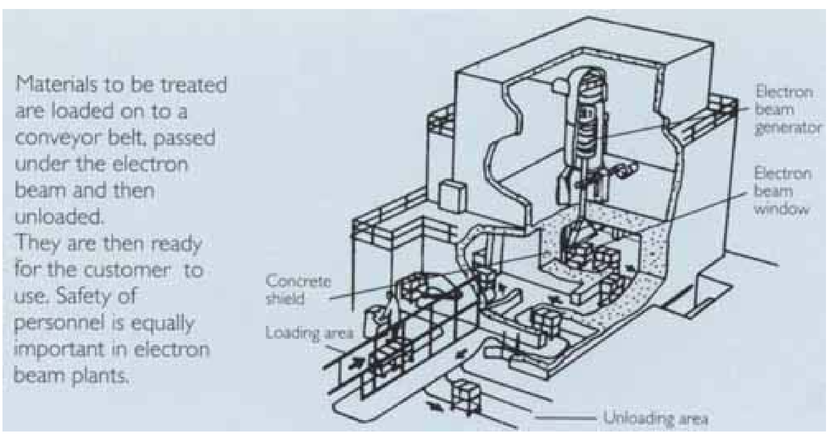
PRODUCING HIGH ENERGY ELECTRONS

Electrons are small negatively charged particles emitted by a hot tungsten filament. By having a large potential (voltage) difference between the cathode (the filament) and the anode, the electrons can be accelerated to almost the speed of light. The negatively charged electrons are accelerated, through a vacuum, towards the positive anode and are steered through a hold in the anode to form an intense electron beam. Materials to be treated are loaded on to a conveyor belt, passed under the electron beam and then unloaded. They are then ready for the customer to use. Safety of personnel is equally important in electron beam plants.





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ELECTROMAGNETIC SPECTRUM AND WAVES

When a wave has passed down a rope, the rope is still there. It is not carried along with the wave. It is energy that has been transferred from one end of the rope to another. A wave in a rope is an example of a mechanical wave. Mechanical waves disturb material by making particles oscillate to and fro. Energy is transferred between the particles as they oscillate. In a similar way electromagnetic waves transfer energy from one place to another but not by oscillating particles. They oscillate electric and magnetic fields. Light is an electromagnetic wave. Other examples are X-rays, gamma rays, microwaves and radiowaves.

WAVELENGTH is the distance from one wave peak to the next peak.

AMPLITUDE is the height of wave peak (which is the same as the depth of a wave trough). The bigger the amplitude the greater the energy transferred.

FREQUENCY is the number of complete waves passing a point in one second and is measured in hertz (Hz). (1Hz = 1 wave per second).

WAVESPEED = FREQUENCY X WAVELENGTH

All electromagnetic waves travel at the same speed (the speed of light) through a vacuum. The behaviour of the electromagnetic radiation depends upon the wavelength and its associated energy and how it interacts with the material.