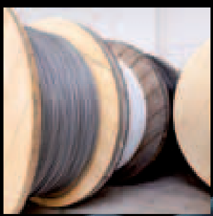
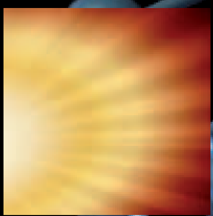
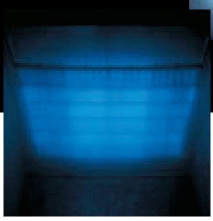
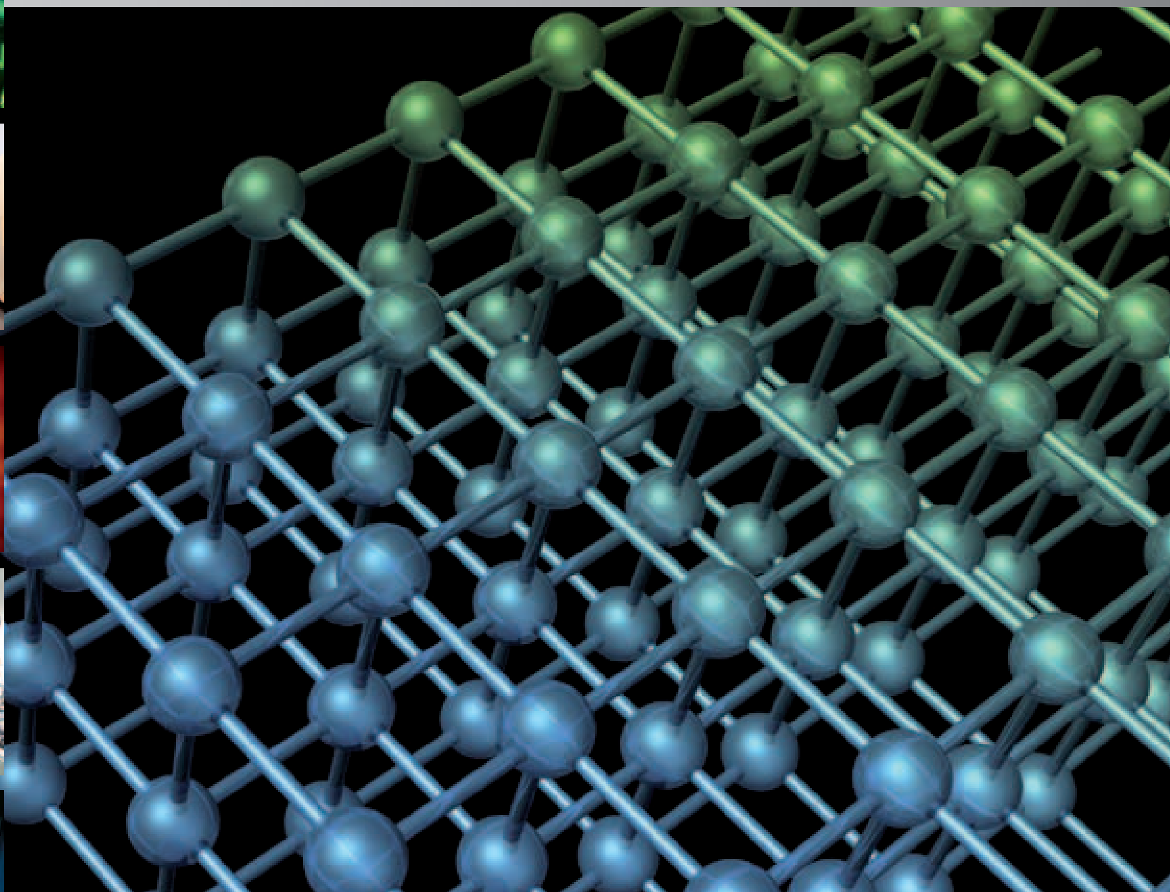
Process Technology

Product Enhancement by Irradiation









BGS

IDEEN PLUS ENERGIE

BGS: We optimize your products at three locations.

Your products are in good hands with us!

Low-cost, eco-friendly optimization of your plastic products

BGS is your specialized service provider with comprehensive knowledge and experience in the application of high energy radiation. We extend the use of your plastic products by improving their resistance to heat, abrasion and wear. We destroy pathogenic microorganisms fast and reliably, using a method which is environmentally friendly. Whether radiation crosslinking or radiation sterilization is required, we find the best solution for the customer's product specifications in every case.

Our employees are specialists in the industrial application of beta and gamma radiation. The product handling systems we use have been developed by BGS to ensure that products are gently treated during irradiation. This brings benefits for you as a customer: the know-how we have accumulated within the enterprise results in greater flexibility and speed in the treatment of your products.

Naturally, our radiation plants fulfil all legal requirements regarding safety at work and radiation protection. Our safety systems are continuously further developed in order to fulfil our responsibility to our employees, the environment and the products entrusted to our care.

BGS is an independent, medium-sized enterprise. For you, this means flexible order specifications, reliable order processing and comprehensive service. Put your trust in more than 25 years of experience in the application of high energy rays – your products are in the very best hands!

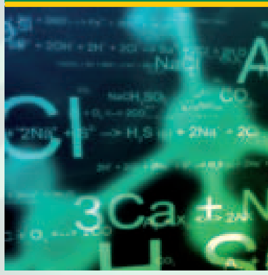
Contents

Units used in irradiation techniques

Dosage as an important parameter

In irradiation techniques – as in all technical applications – there are specific parameters which enable irradiation to be measured, documented and reproduced.

In the crosslinking or degradation of polymers by radiation, as in radiation sterilization, radiation dosage is the most important factor in achieving the desired property changes. In sterilization, it is the obtainable degree of sterility that determines the radiation dose (SAL = Sterility Assurance Level). Basically, the dose rate determines the product's final characteristics.



In terms of physics, the dose is defined as the radiation energy absorbed per mass. In the SI System (international system of units) the Gray (Gy) is used today, named after the British physicist and father of radiobiology, Louis Harald Gray (1905-1965). Previously the unit Rad (standing for 'radiation absorbed dose') was used. Strictly speaking, this unit is denoted as 'rd', but 'rad' is almost always used.

$$1 \text{ Gy} = 1 \text{ J/kg} = 100 \text{ rad}$$
$$10 \text{ kGy} = 1 \text{ Mrad}$$

The radiation energy absorbed by a product per unit of time, related to mass, is the dose rate. Its size plays an important role, for instance in crosslinking.

$$1 \text{ Gy/s} = 1 \text{ W/kg} = 0{,}36 \text{ Mrad/h}$$

The penetration depth of high energy electrons and gamma rays is a function of their energy and of the density of the products being irradiated. The unit for measuring energy is the Joule (J); previously it was the electron volt (eV). Electron volts are still often used today, as they yield figures that are convenient to work with.

$$1 \text{ MeV} = 1{,}6 \times 10^{-13} \text{ J} = 0{,}16 \text{ pJ (Pikojoule)}$$

With irradiation from one direction, the penetration depth/dose distribution is obtained as follows:

$$s = \frac{5{,}1\,E - 2{,}6}{\rho}$$

The performance of a radioactive source is described in terms of its activity. Previously the unit Curie (Ci) was used, named after Marie and Pierre Curie, who together with Antoine Henri Becquerel were awarded the Nobel Prize in 1903 for the discovery of radioactivity. Today the SI unit Becquerel (Bq) is used.

The Becquerel gives the number of atoms which can be expected to decay per second according to the statistics of radioactive decay.

$$1 \text{ Bq} = 1/\text{s}$$
$$1 \text{ Ci} = 3{,}7 \times 10^{10} \text{ Bq} = 37 \text{ GBq}$$

Differences between electron beams and gamma rays

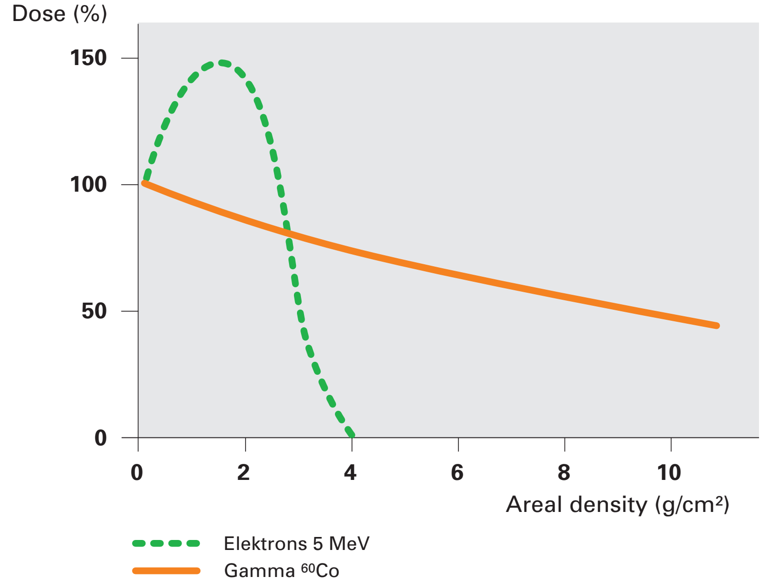
Penetrative capability and dose rate

The main difference between the two types of rays is their penetrative capability. Beta radiation is more a particle beam and thus has a limited penetration depth. By contrast gamma rays, as a form of electromagnetic wave, have a much higher penetrative capability.

In plants with electron accelerators, work is done with a limited penetration depth and high dose rates, whereas the work in gamma plants uses high penetrative capability at a lower dose rate.

The dose rate depends on the total installed activity. In terms of application technology, this means that electron accelerators deliver a dose in seconds for which gamma plants require several hours. In gamma plants, however, greater volumes can be irradiated at the same time.

Penetrative capability

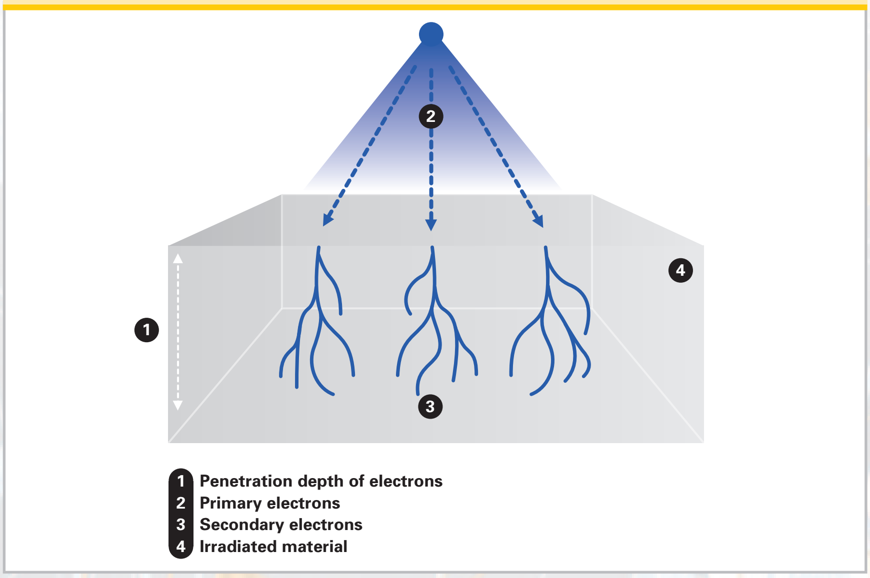


For the crosslinking of polymers electron beams are mainly used, since relatively high radiation doses are required. However, gamma radiation can also be used for compact components, due to its greater penetration depth. It is generally observed that when polymeric materials are irradiated, they suffer substantially fewer adverse effects from oxidation when exposed to the much shorter treatment times that are required with electron beams.

Today, gamma plants are used mainly for radiation sterilization and for decontamination. For purely physical reasons, the radiation sources used by BGS – electron accelerators with a maximum energy of 10 MeV, and gamma rays from the cobalt isotope ^{60}Co – cannot generate any radioactivity in the treated products.

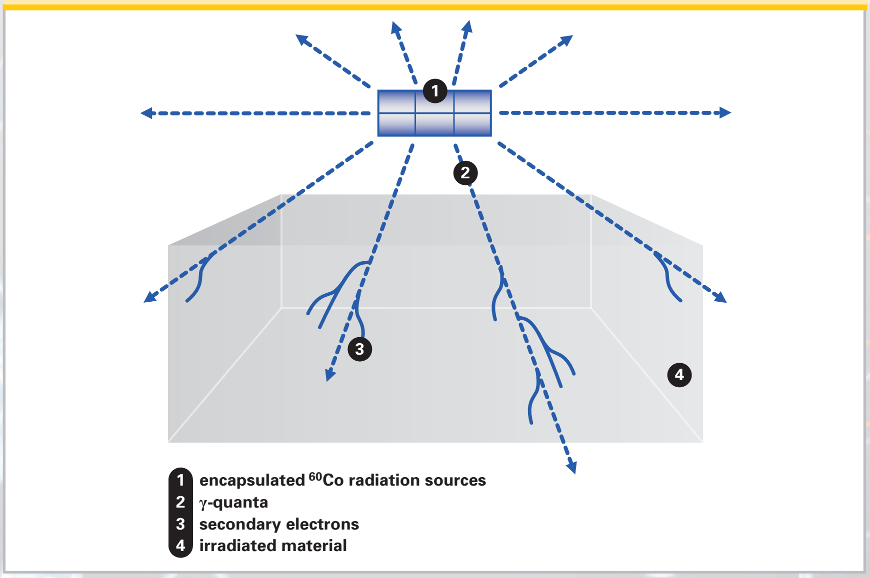
Electrons penetrate the material. Molecules in the irradiated material are excited and ionized.

Electron beams

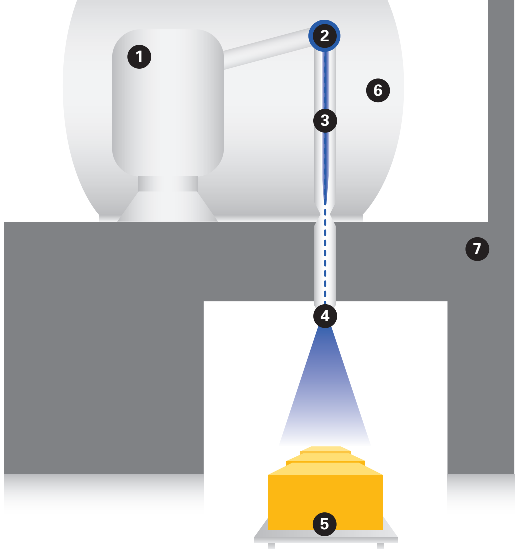


γ-quanta penetrate the material. By various interactive processes, secondary electrons are produced which then excite and ionize molecules in the material.

Gamma rays



Schematic representation of an electron accelerator with carton handling system.



1 High voltage generation
2 Cathode
3 Acclerator tubes
4 Scan horn
5 Conveyor System with cartons
6 Pressurized tank containing insulating gas
7 Protective concrete shield

The principle of electron irradiation

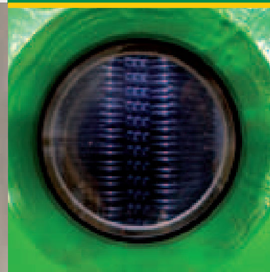
Using accelerated electrons

The principle of an electron accelerator can be compared with a cathode ray tube. A heated cathode emits electrons which are accelerated in an electrical field to approximately 99 percent of the speed of light. Their speed is a function of the voltage between the heated cathode and the anode (earth potential).

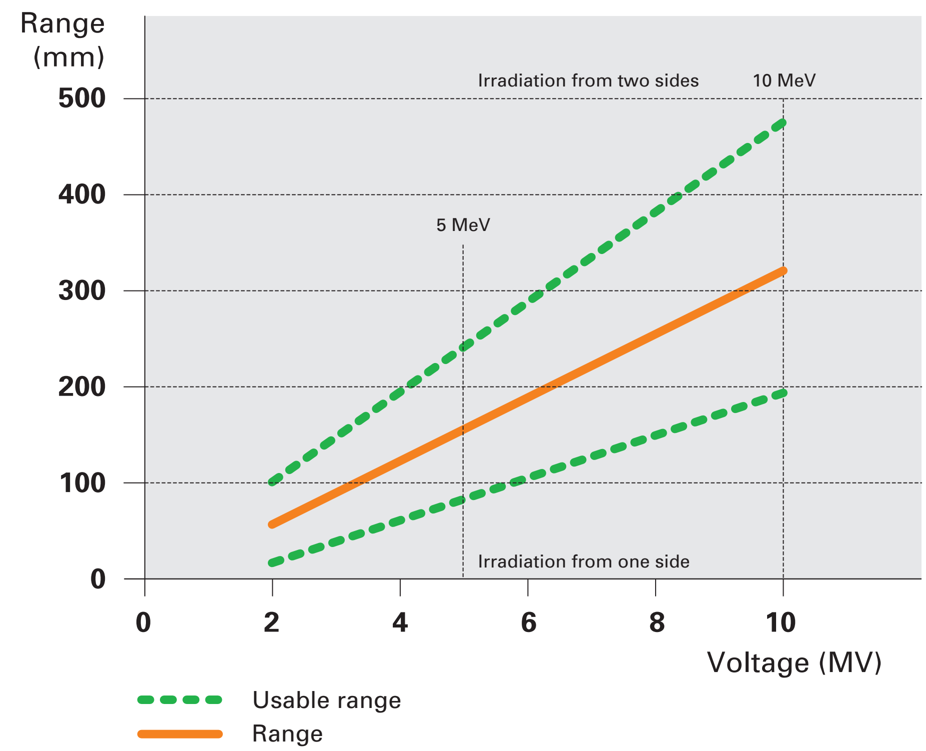
The high voltage is applied to the accelerator tubes, which are under high vacuum. On leaving the cathode, the electrons are focused and accelerated. The beam is deflected in an alternating magnetic field, so that at the end of the scanner it reaches the product to be irradiated as a fan-shaped electron beam. The penetration depth of high energy electrons depends on their energy, and thus on the acceleration voltage.

The accelerator components are kept in a pressure tank containing an insulating gas, in order to avoid flashovers. The scanner with the electron exit window, and the plant as a whole, are surrounded by concrete walls. This ensures that both the electron beam and the 'Bremsstrahlung' that is generated are absorbed, so that there is absolutely no danger to people working in the plant. When the electricity that generates the beam is switched off, the irradiation area can be entered completely safely.

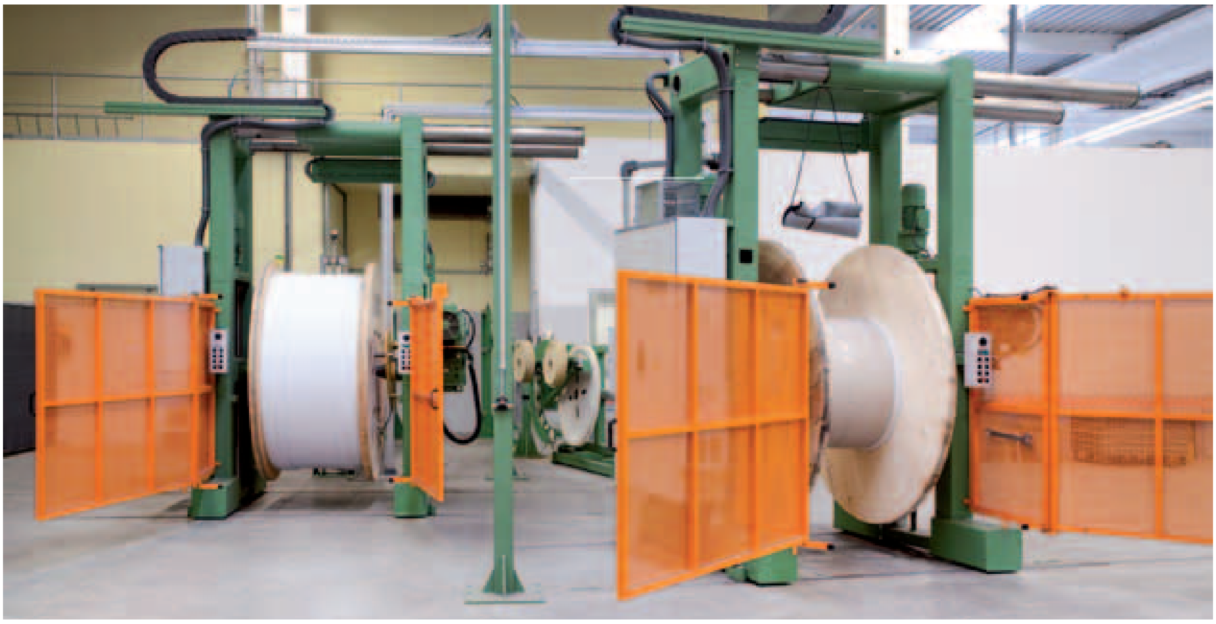
Different handling Systems are required, depending on the product concerned. Endless products, for instance, are unwound to pass through the radiation field and then rewound on their storage drum. There are various types of special equipment to convey every sort of product under the fan-shaped electron beam and ensure uniform irradiation: systems for continuous products on drums (pipes, cables, tubes), for pre-packaged articles in cartons, and for bulk goods.



The principle of electron irradiation

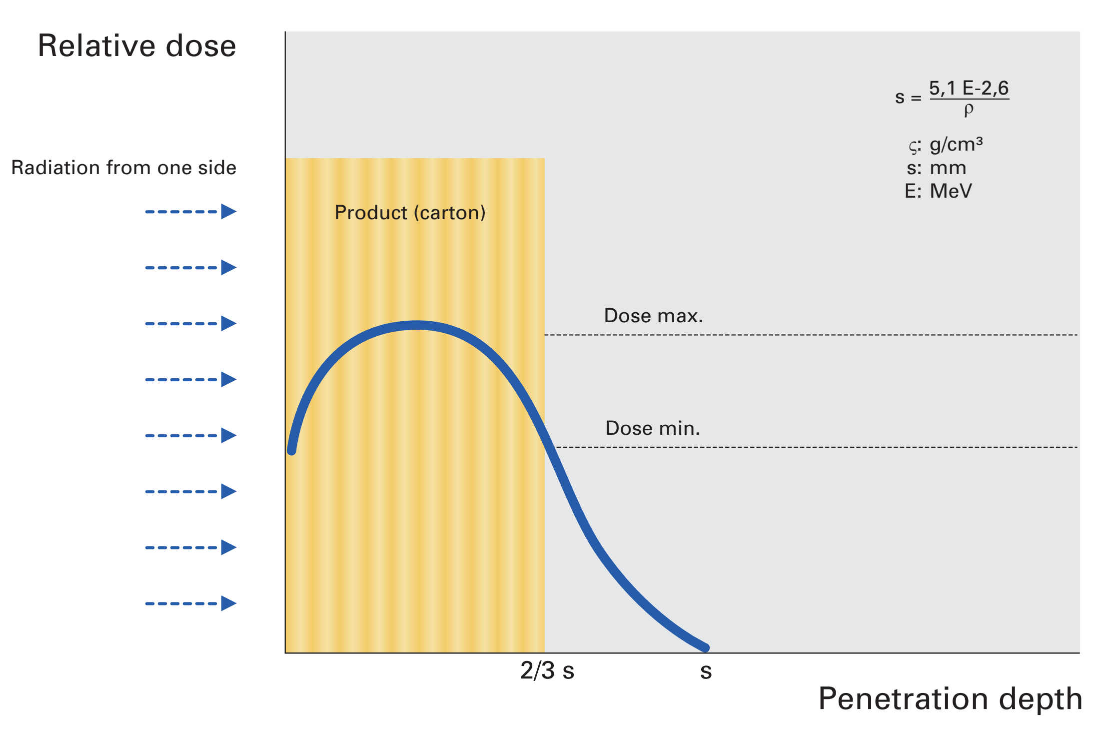


Range and usable range as a function of accelerating voltage. The example presented here is for a homogeneous product with a density of c. 0,15 g/cm³.



A continuous product is unwound from the drum before irradiation. On guide rollers, it passes through the shielding into the radiation area. There, it passes in several layers beneath the radiation field. During each passage it receives a part of the total dose. When irradiation has been completed, the product passes through the shielding once again and is wound onto another drum.

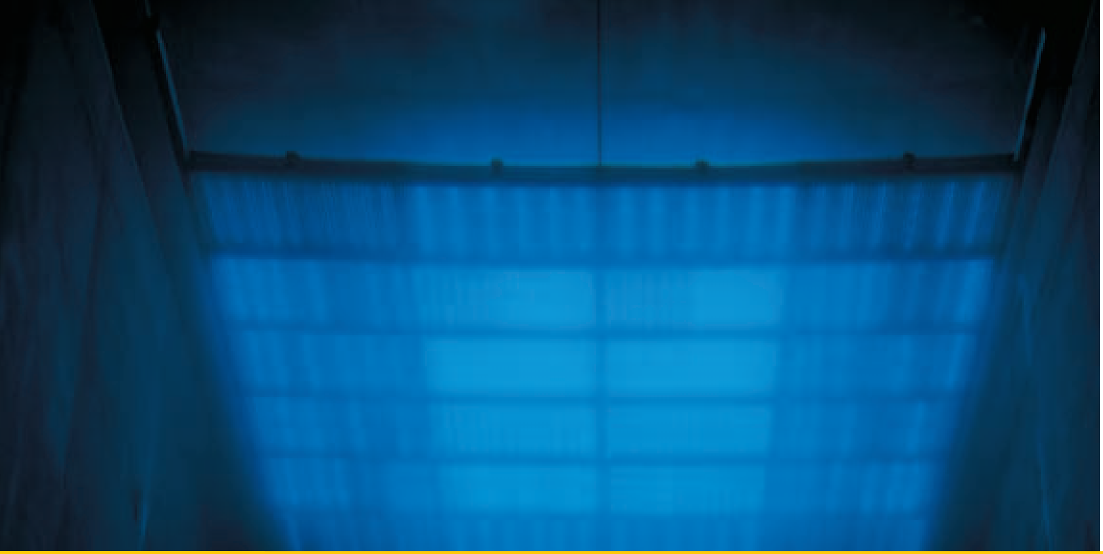
Dose distribution, radiation from one side



With irradiation from one side, the optimal layer thickness is 2/3 s.

Characteristics of electron accelerator plants

	WIEHL				BRUCHSAL			SAAL	
Electron energy (MeV)	**0,6**	**1,5**	**2,5**	**2,8**	**4,5**	**5**	**10**	**5**	**10**
Power (kW)	11	75	80	150	150	135	200	300	150



View of the source rack in the water basin. The radiation excites the water molecules, producing the characteristic blue glow known as 'Cherenkov radiation'.

The principle of the gamma plant

Reliable and safe to operate

In industrial gamma radiation plants today, the radionuclide Cobalt (^{60}Co) is usually used as a source of gamma rays. For this purpose the ^{60}Co isotope is safely enclosed in a number of stainless steel capsules which are then arranged in what is known as a 'source rack'. The radiation source emits gamma rays with an average energy of c. 1,3 MeV and a high penetration depth!

The dose applied varies from one product to another and is individually controlled by varying the time spent by the product in the radiation field. The total radiation dose is applied by passing the product around the sources several times.

At BGS, industrial pallets and Euro-pallets are used as the units for irradiation. Up to 24 pallets can pass through the radiation field at the same time. Treatment lasts a few hours. For medical products a treatment time of two to three hours is usually needed.

The gamma rays are reliably contained within massive reinforced concrete walls. It is perfectly safe to stay outside the radiation area, even when the plant is in operation.

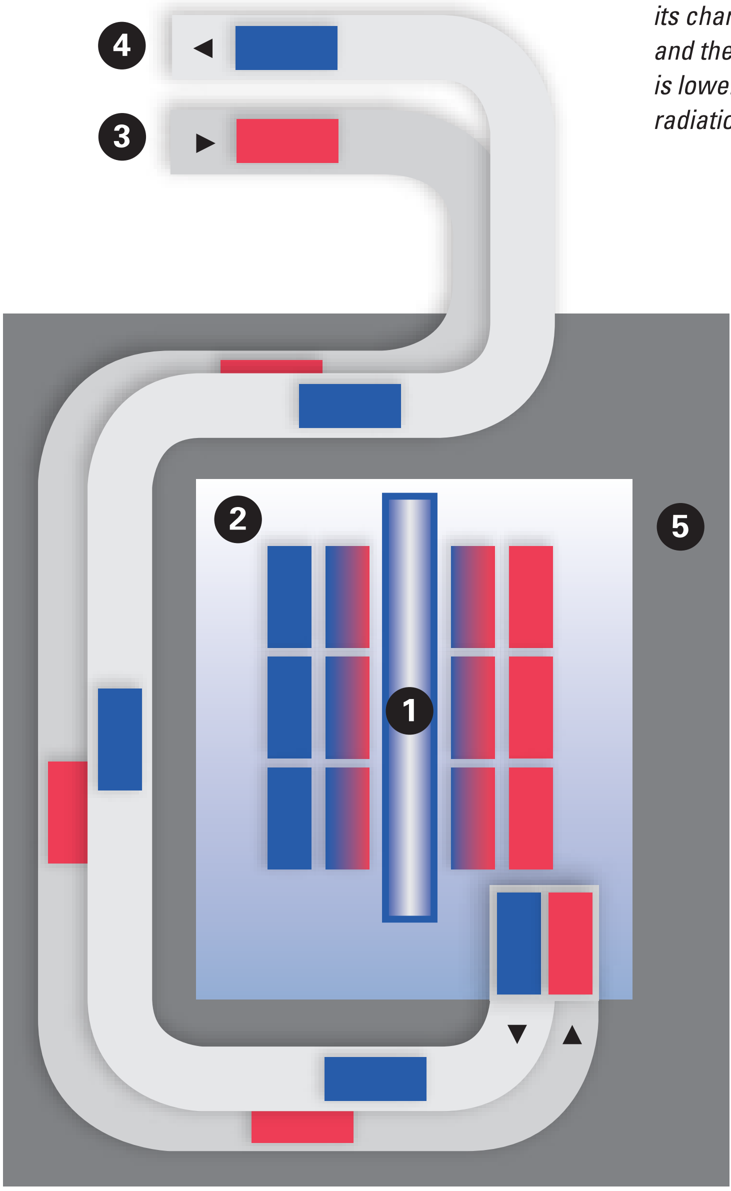
Radiation sources	encapsulated isotope ^{60}Co
Max. capacity	5 MCi
Power	75 kW
Location	Wiehl
Unit for irradiation	Industrial pallet 120 cm x 100 cm Euro-Pallet 120 cm x 80 cm max. height 190 cm (incl. pallet)

Unlike electron accelerators, the radiation source in gamma plants cannot be switched off. However, it is still possible to enter the radiation area, for instance to carry out maintenance. For this purpose the radiation source is shielded by lowering it into a water basin several metres deep. The column of water above the ^{60}Co source acts as a reliable shield.

Every month the ^{60}Co isotope loses approximately one percent of its activity through decay, so that used material has to be replaced at regular intervals. The used material can be reprocessed for other applications. After 200 years the material has generally turned into harmless ^{60}Ni and has lost nearly all activity.

Plant features of the gamma plant

The overhead view of the gamma plant shows its characteristic features: massive shields and the water basin into which the source wall is lowered during plant maintenance. In the radiation area there are 24 pallets on two levels.



non-irradiated
irradiated

1 ^{60}Co sources
2 Water basin
3 Loading Station
4 Unloading Station
5 Concrete shield

Handling

Product handling at the BGS plant in Saal is largely automated. This enables a high throughput and fast processing times.

Impressum

BGS Beta-Gamma-Service
GmbH & Co. KG
Fritz-Kotz-Str. 16
51674 Wiehl

Phone: +49 (0) 2261 7899-0
Fax: +49 (0) 2261 7899-45
E-Mail: info@bgs.eu
www.bgs.eu

Head Office in Wiehl,
Register Court Köln HRA 16938
USt.-IdNr (VAT No.): DE 122 533 721

General Partner:
BGS Beteiligungs GmbH

Head Office in Wiehl,
Register Court Köln HRB 38648

Managing Director:
Dr. Andreas Ostrowicki

Editing and design:
MediaCompany
Agentur für Kommunikation GmbH,
Bonn

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Mirgel + Schneider, Bonn

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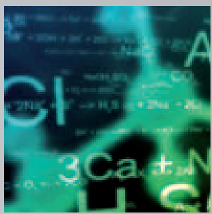

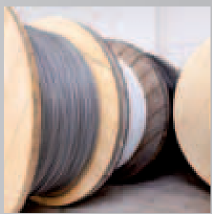

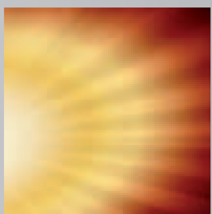

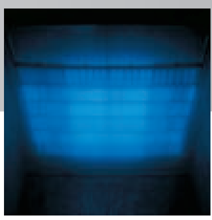

Head Office Wiehl
BGS Beta-Gamma-Service
GmbH & Co. KG
Fritz-Kotz-Straße 16
D-51674 Wiehl
Phone: +49 (0) 2261 78 99-0
Fax: +49 (0) 2261 78 99-45

Bruchsal Site
BGS Beta-Gamma-Service
GmbH & Co. KG
John-Deere-Straße 3
D-76646 Bruchsal
Phone: +49 (0) 7251 786-0
Fax: +49 (0) 7251 786-33

Saal Site
BGS Beta-Gamma-Service
GmbH & Co. KG
Industriestraße 9
D-93342 Saal a. d. Donau
Phone: +49 (0) 9441 1777-0
Fax: +49 (0) 9441 1777-44

Sales in France
Phone: +33 474 761 267
Fax: +33 474 761 758

Sales in Czech Republic
Phone: +420 518 324 510
Fax: +420 518 324 510

info@bgs.eu | **www.bgs.eu**

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