Process Control Methods in Radiation Technologies

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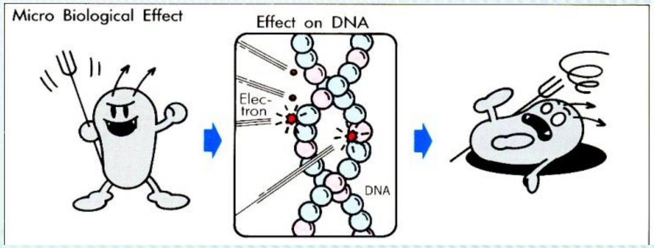
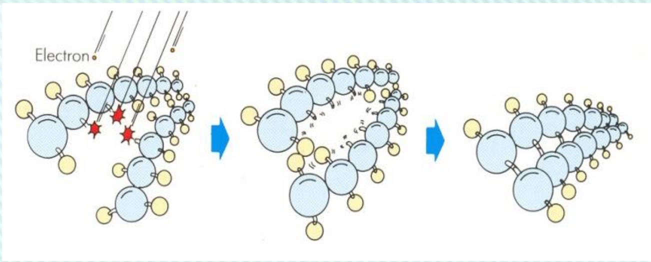
Radiation Processing Applications

- ***Radiation sterilization: 25 - 50 kGy***



- ***Radiation crosslinking : 10 – 200 kGy***



- ***Food irradiation: 50 Gy – 10 kGy***


- ***Environmental protection: 1 – 10 kGy***


Dosimetry Principles

- In radiation processing, validation and process control depend on the measurement of absorbed dose.
- Determination of absorbed dose in product specific dosimeter systems;
- Measurements of absorbed dose shall be performed using a dosimetric system or systems having a known level of accuracy and precision.
- The calibration of each dosimetric system shall be traceable to an appropriate national standard.

Validation and Process Control

To assure that

- the necessary (biological, chemical, physical) <u>effect is achieved</u> and

- the radiation technology is <u>performed safely</u>

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the RELATIONSHIP between

<u>machine parameters of irradiation facilities</u>

(like dwell time, position of source rack, electron energy and current, conveyor speed, scanning width and homogeneity, etc.)

and

<u>absorbed dose and dose distribution in the product</u>

have to be measured and controlled with suitable

<u>dosimetry systems!</u>

Dosimetry systems in radiation processing

Reference standard systems:

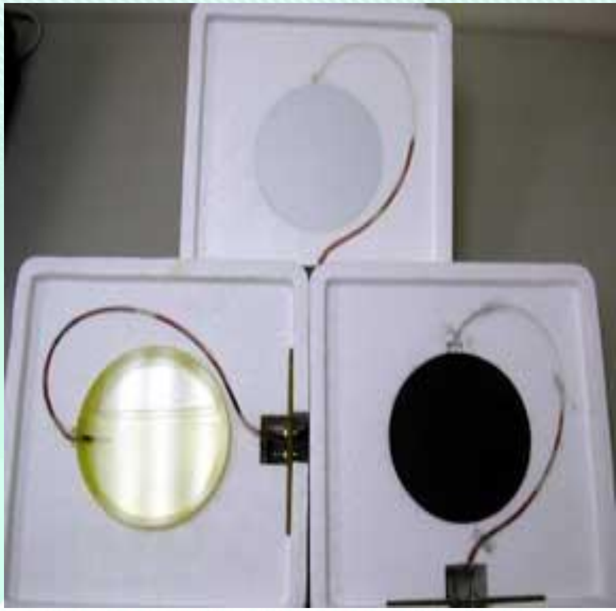
- **Dosimeter of high metrological quality used as a standard to provide measurements traceable to measurements made by primary standard systems;**

- **These systems <u>require calibration</u> and are used to calibrate radiation environments and routine dosimeters;**

- **Solid phase dosimetry systems :**
  alanine (pellet, rod, film);

- **Liquid phase dosimetry systems :**
  Fricke solution;
  potassium dichromate solution;
  ethanol-monochlorobenzene solution;
  ceric-cerous solution;

- **Process calorimeters;**



Dosimetry systems in radiation processing

Routine systems:

- **Dosimetry systems used in radiation processing facilities for absorbed dose mapping and process monitoring;**
- **Systems, capable of giving reproducible signals;**
- **These systems require calibration;**
- **Dosimeter systems:**
    - ***Fricke solution;***
    - ***Perspex (Red- and amber);***
    - ***Radiochromic films (FWT-60, B3 - Gex, Gafchromic);***
    - ***Radio-photoluminescent film (Sunna);***
    - ***ECB, ceric-cerous solutions;***
    - ***Process calorimeters (water, graphite, polystyrene);***

Dosimetry systems in present practice

Dosimeter system	Method of analysis	Useful dose range, Gy	Nominal precision limits	References
Fricke solution	UV – spectro-photometry	$3x10 – 4x10^2$	1 %	ASTM E 1026 - 04
Ceric – cerous sulphate	UV – spectro-photometry	$10^3 – 10^6$	3 %	ISO/ASTM 51205
Potassium dichromate	UV-VIS spectrophoto.	$5x10^3 – 4x10^4$	1 %	ISO/ASTM 51401
Ethanol-mono-chlorobenzene	Titration,or HF oscillometry	$4x10^2 –3x10^5$	3 %	ISO/ASTM 51538
L - alanine	EPR	$1 – 10^5$	0.5 %	ISO/ASTM 51607
Perspex systems	VIS - spectro-photometry	$10^3 – 5x10^4$	4 %	ISO/ASTM 51276
FWT – 60 film	VIS - spectro-photometry	$10^3 - 10^5$	3 %	ISO/ASTM 51275
B 3 film	VIS - spectro-photometry	$10^3 - 10^5$	3 %	ISO/ASTM 51275
Calorimetry	Resistance/ temperature	$1.5x10^3 – 5x10^4$	2 %	ISO/ASTM 51631

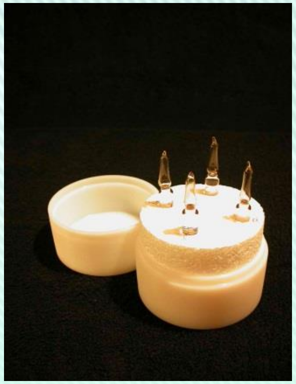
CALIBRATION OF DOSIMETRY SYSTEM

- **Aim of calibration:**

*Determine **relationship** between **response** of a dosimeter and **absorbed dose**.*

- **Subject of calibration:**

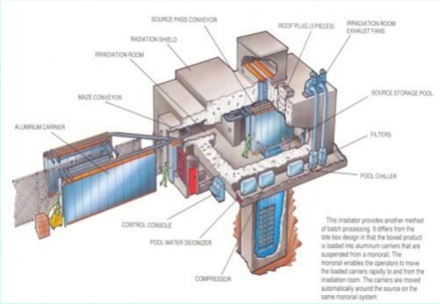
*Calibration of **dosimeter** and measurement **equipment**.*

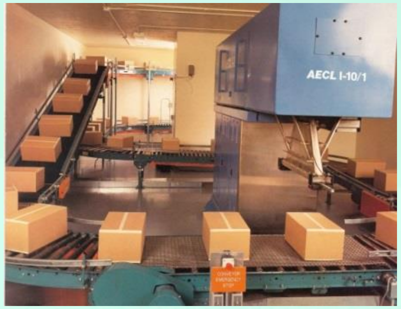


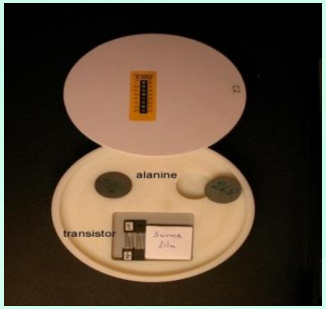
- **Calibration methods:**

1. *Irradiation at **calibration facility***

2. *Irradiation **in-plant** with reference dosimeters*







Validation procedures – EN ISO 11137 Standard

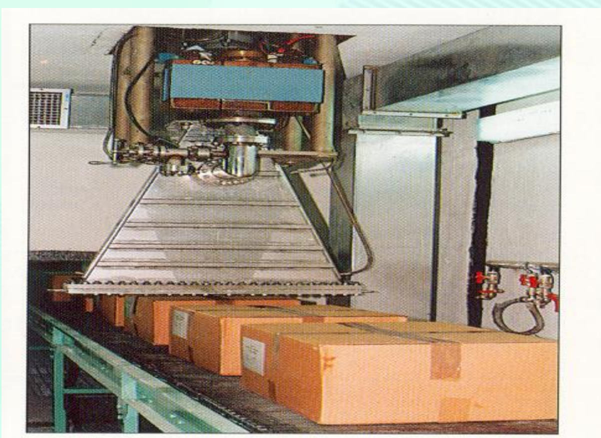
1. Process definition

- Establishing maximum acceptable dose (e.g. 50 – 75 kGy);
- Establishing process (e.g. sterilization) dose (25 kGy);

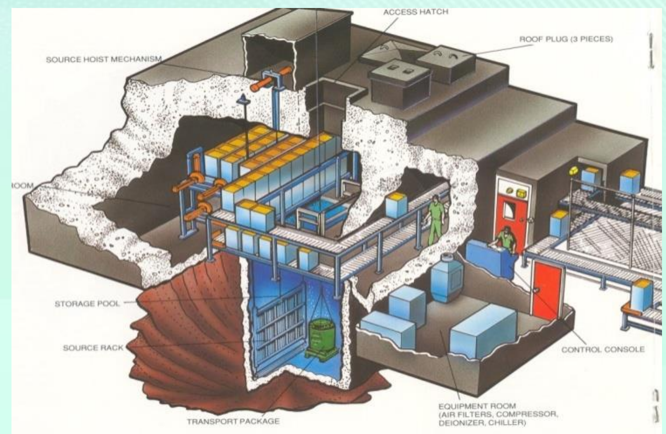
2. Installation qualification

- To demonstrate that the irradiation facility has been supplied and installed according to its specifications:

To determine beam characteristics by dosimetry;



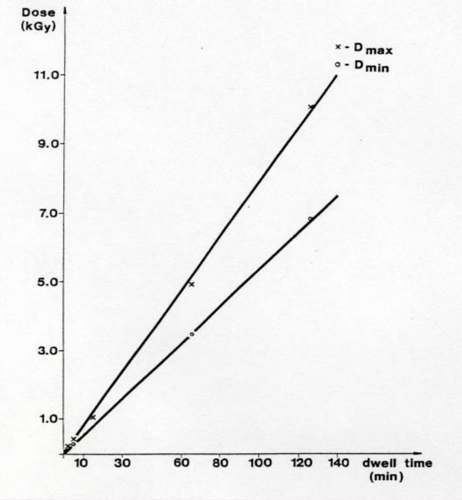
No specific dosimetric requirements to verify operation within specifications;



Validation procedures – EN ISO 11137 Standard

3. Operational qualification

dose-irradiation time:



Aim:

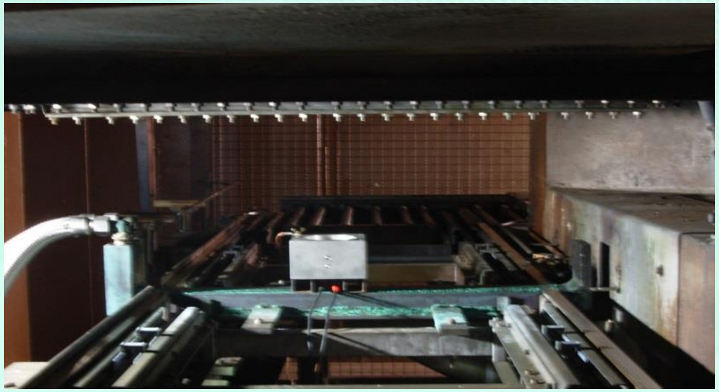
To characterize the irradiation facility relating plant parameters to absorbed dose;

Gamma facility:

nominal dose vs. dwell time, dose distribution, process interruption, transit dose;

Dichromate, ECB, ceric-cerous, Gex (B3), alanine FWT- 60, Perspex,;

On-line energy measurement:



Electron beam facility:

nominal dose vs. conveyor speed, beam characteristics; dose map in reference product, process interruption;

Calorimeters, ECB, alanine, Gex (B3), dichromate; FWT-60;

Validation procedures – EN ISO 11137 Standard

4. Performance qualification

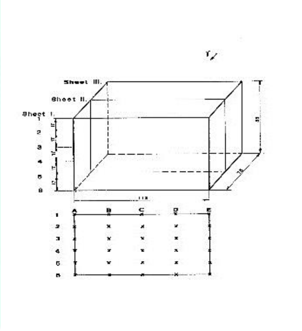
Aim:

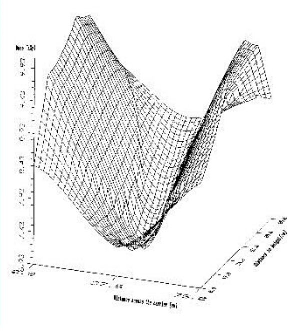
- To measure <u>dose map</u> in real product in order to locate D_{min} and D_{max}:

- to establish irradiation conditions according to required specifications:

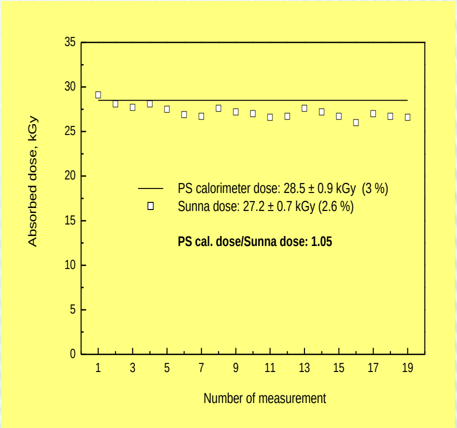
D(product) > D(required)   and   D(product) < D(acceptable)

- To determine relationship between D_{min} and D_{max} and the dose at the routine monitoring position





Process control



1. Measurement of process parameters:

To measure dose at the monitoring position to verify that the irradiation process is within established/required limits

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knowing the relationship between D_{min}, D_{max} and $D_{monitoring}$.

2. Control and monitoring of operating parameters:

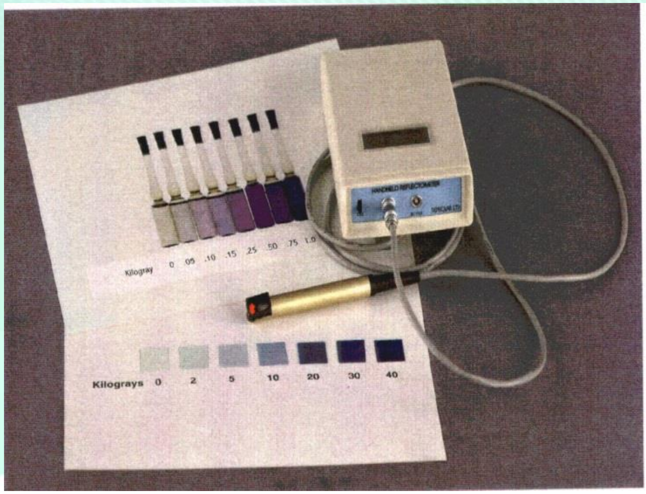
Controlled parameters:

Electron beam facility:

- **Electron energy**
- **Beam current**
- **Scanned beam width**
- **Conveyor speed**
- **Routine dose**

Gamma facility:

- Timer setting
- Other products present
- Routine dose



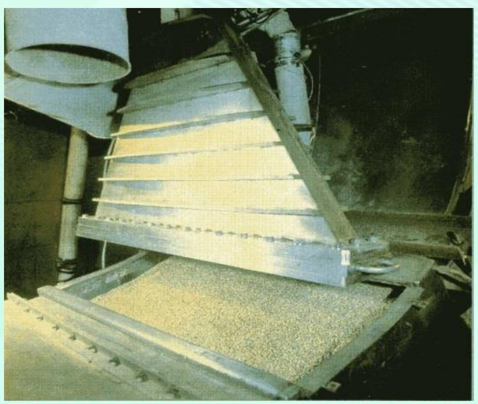
Process control in „flow systems”

1. ***Waste water treatment:***

Aqueous alanine solution

2. ***Grain irradiation***

Al_2O_3 TL dosimeters



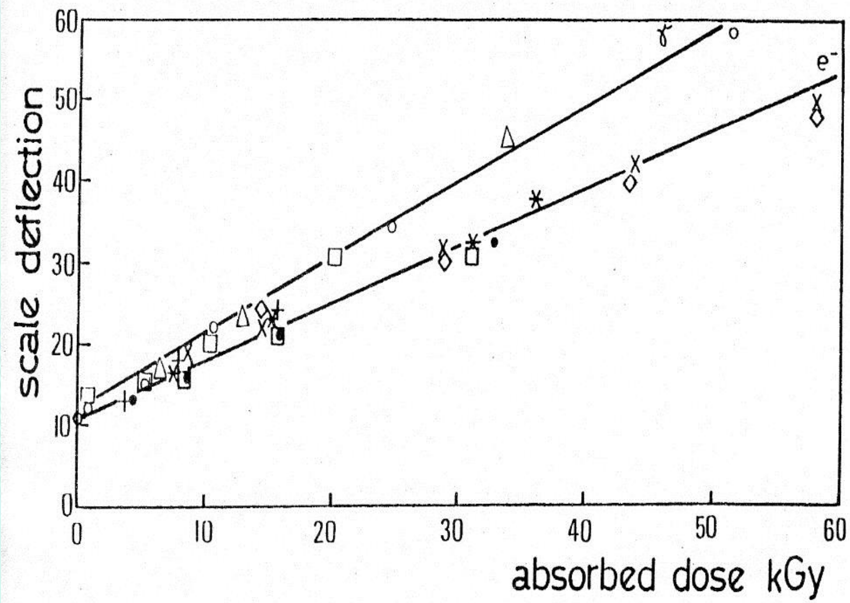


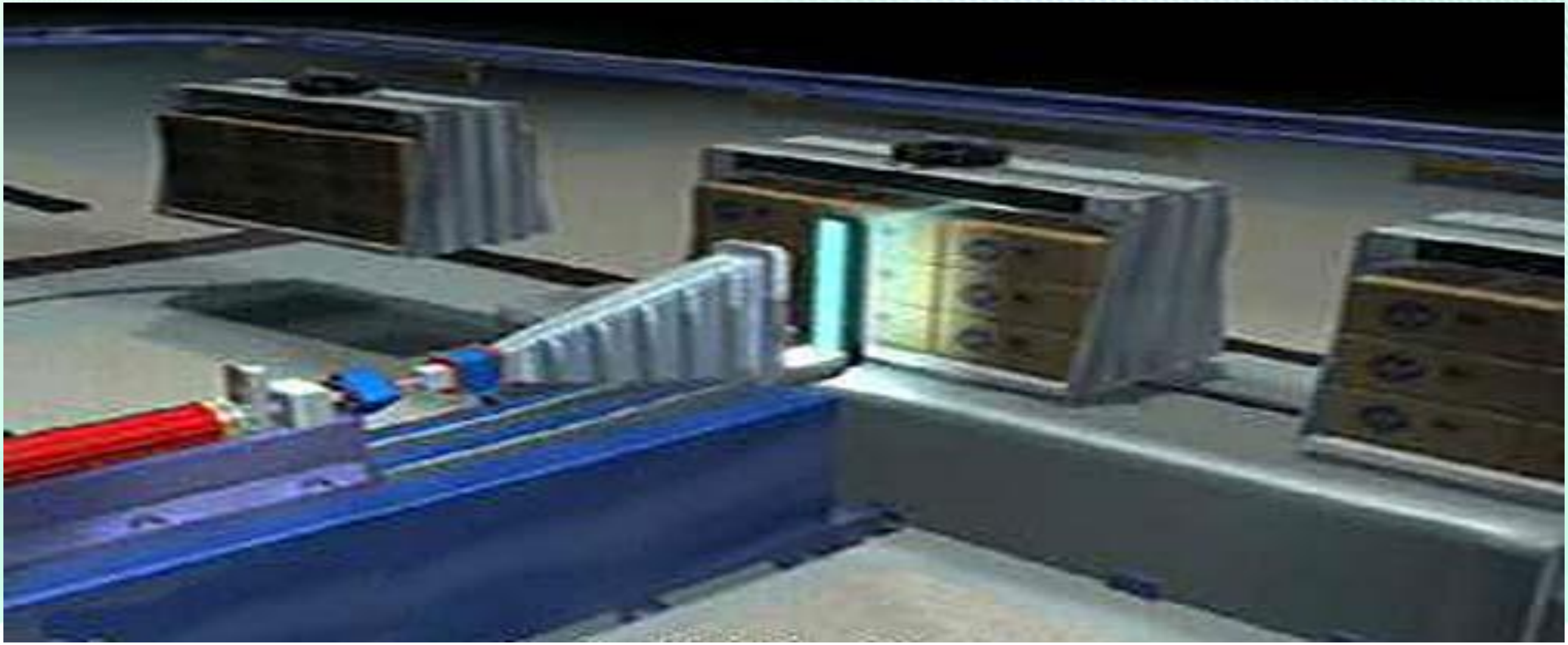
Fig. 2.

Oscillometric response of alanine solutions as a function of dose at various dose rates (^{60}Co irradiation), electron energies and currents (electron irradiation). ^{60}Co irradiation: 0.13 kGy/h: □ ;3.5 kGy/h: △ ;30 kGy/h: ○ ; electron irradiation: 4 MeV, 2.6 μs, 13 μA: ◇ ; 4 MeV, 2.6 μs, 26 μA: × ; 10 MeV, 0.5 μs, 0.4 A: + ; 10 MeV, 1 μs, 1 A: ∗ ; 10 MeV, 4 μs, 1 A: • ;

X-Ray Machines

Dosimeters applied in gamma processing have been proven to be suitable for X-ray dosimetry:

Dosimeters tested: Alanine, ECB, dichromate, ceric-cerous ;



Summary

1. Safe, economic technologies with reliable QA/QC methods

2. EN ISO, ISO ASTM standards with continuous upgrading

- e.g. ISO 11137 – 3: Guidance on dosimetric aspects of development, validation and routine control

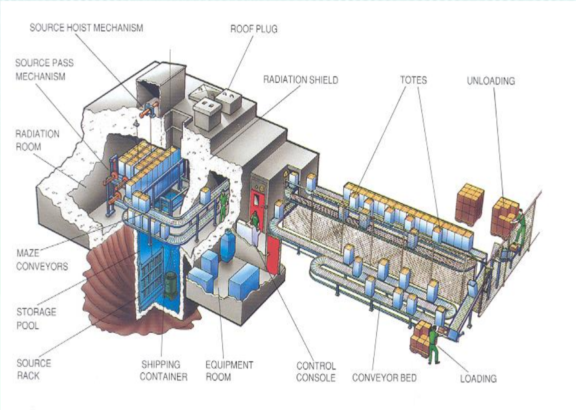
3. Role of IAEA Regional TC projects in radiation processing:

- e.g. RER 1017: „Using advanced radiation technologies for materials processing”

- training courses in using QA/QC methods

- e-learning and IAEA guides in QA/QC

- dosimetry intercomparison exercises (Warsaw, Poland)



Thank you for your attention