INTERNATIONAL NUCLEAR ATLANTIC CONFERENCE
INAC 2019 – XIV ENAN

Radiation Technology for Science and Industry

Wilson Aparecido Parejo Calvo

Nacional Nuclear Energy Commission
Nuclear and Energy Research Institute
IPEN-CNEN/SP
4 R&D NUCLEAR REACTORS:
✓ 100 W - 5 MW

6 CYCLOTRONS:
✓ Siemens (11 MeV)
✓ IBA (18/9 MeV, 30 MeV)
✓ TCC (24 MeV)
✓ GE (18 MeV)

2 ELECTRON BEAM ACCELERATORS
✓ RDI (1.5 MeV)

5 GAMMA IRRADIATORS
✓ Multipurpose (2 MCi)
✓ Gammacell (12 kCi)
✓ Panoramics (5 kCi, 60 kCi)

Source: CNEN
Safety Design, Construction and Operation

1. International Basic Safety Standards (BSS)
   - Protection against Ionizing Radiation
   - Safety of Radiation Sources

2. IAEA Safety Standards and Lessons Learned from Accidents in Industrial Irradiation Facilities

3. Safety Standards of the National Nuclear Energy Commission (CNEN) - Brazil

Source: IPEN-CNEN/SP
GAMMA RAYS AND ELECTRON BEAM TECHNOLOGY APPLICATIONS

Human & Animal Health
- Vaccines
- Blood sterilization
- Pediatric Cancer diets
- Tissue transplantation
- Artificial Tissues
- Novel Biotherapeutics

Food
- Food Pasteurization
- Protection against insects/pests – Global trade
- Shelf-life extension
- Reducing food waste
- Global Food Security

Novel Industrial, Agro, and Food Products
- Bioplastics
- Seed Enhancement
- Functionalized polymers
- Immobilized biofactories

Environment
- Water Reuse
- Sludge disinfection
- Industrial waste treatment
- Agriculture waste treatment

Source: Texas A&M University
PANORAMIC GAMMA IRRADIATOR

MDS Nordion/Canada (Category II – AIEA)

Source: CDTN-CNEN/MG
MULTIPURPOSE GAMMA IRRADIATOR

Brazilian Technology
(2MCI, Category IV – IAEA)

DUR / Efficiency:
1,33 / 11,6% (0,09g/cm³)
2,08 / 36,6% (0,49g/cm³)

Source: IPEN-CNEN/SP
Routine operations (semi-industrial scale)

- Disinfestation and disinfection of cultural objects (books, furniture, sculptures and paintings)

Source: IPEN-CNEN/SP
Extraordinary cultural objects irradiations

1.9 x 3.2m
XVII century

Source: IPEN-CNEN/SP
RHODOTRON TT200 (100 KW)

Source: Sterigenics

Sterilized Medical Devices: 135,000 m³/year

Source: Sterigenics
ELECTRON BEAM TECHNOLOGY APPLICATIONS

- Food Packaging: no Peroxides, less energy
- Cable & Wire: better properties, less / no additives, less energy
- Inks /Curing/ Adhesives: no UV-Initiators, less energy
- Heat shrinkable: better properties

- Sterilization: no chemicals, less energy
- Spice & Seed processing: no chemicals
- Tires: processability, less material

Break a bond and then...

A: ...leave it broken
B: ...let it bond to itself
C: ...let it bond to something else

polymer degrading
Cross linking, curing
reactive compounding polymer grafting (adhesion of coatings)

Source: COMET Ebeam
E-BEAM PRINTING AND CURING

- Integrated shield roll design
  - With sealed e-beam Emitter
- Features
  - Energy: 80kV to 180kV
  - Web width: 360mm
  - Web speed: 90m/min at 25kGy
- Applications
  - Pilot / development lines
  - Narrow web printing presses
  - Presses for shrink sleeve labels

- Sources: RadTech and COMET Ebeam

- Efficient
- Enabling
- Economical
- Energy savings
- Environmental friendly

- no VOC (like thermal)
- no Photoinitiators (like UV)
- low substrate heating
- electrons are “colorblind”
- higher speed
<table>
<thead>
<tr>
<th></th>
<th>Flue Gas Purification</th>
<th>Wastewater Treatment</th>
<th>Sludge Hygienization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contaminants to clear</td>
<td>SO₂, NOₓ, (Dioxin)</td>
<td>Complex COD, BOD, other</td>
<td>Disinfection of microorganism</td>
</tr>
<tr>
<td>Cleaning process</td>
<td>Simple</td>
<td>Limitation in depth Combined with others</td>
<td>Limitation in depth Handling system</td>
</tr>
<tr>
<td>Competition with other processes</td>
<td>Superiority proved in commercial plant</td>
<td>Complicate to analyze</td>
<td>Many advantages over chemical processes</td>
</tr>
<tr>
<td>Technology</td>
<td>Fully developed</td>
<td>Laboratory to pilot scale</td>
<td>Laboratory to pilot scale</td>
</tr>
<tr>
<td>Economies</td>
<td>Proved through pilot &amp; commercial plant</td>
<td>Complicate to analyze</td>
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</tr>
<tr>
<td>By-product</td>
<td>Useful for fertilizer</td>
<td>Wastewater (less toxic) Reuse</td>
<td>Useful for fertilizer or soil treatment</td>
</tr>
</tbody>
</table>

**Sources:** EB-Tech
WASTEWATER TREATMENT PLANT BY E-BEAM Dyeing Industrial Complex/KOREA (10,000 m³/day)

Source: IAEA and EB-Tech
92% of food stuffs are treated with Cobalt-60. Only 8% is represented by E-beam.

**Latina America Caribbean > 100,000 tons**

Food industry are looking for EB or X-ray machines:

- Lower capital cost
- Reliable
- Simple enough to operate
- Lower cost of operation
- Compact enough to integrate in existing
- Production in-line or a packing house space
Final Remarks

 ✓ Rhodotron Duo (EB, X-ray)
 ✓ Mobiles E-Beam Accelerators
**X-RAY CONFIGURATIONS**

**eXelis X-ray**
5 or 7 MeV X-ray
Pallets

**Rhodotron Duo**
10 MeV E-beam
+ 5 or 7 MeV X-ray
Boxes

*E-beam and X-ray top irradiation*

*E-beam/X-ray market is growing 1.5 to 2 times faster compared with the global sterilization market*

*Source: IBA*
GAMMA RAYS, ELECTRON BEAM AND X-RAYS

Gamma Rays ($^{60}\text{Co}$)
- 50 cm (1.0 g/cm$^3$)
- 10 kGy/h

Electron Beam
- (10 MeV, 50 kW)
- 5 cm (1.0 g/cm$^3$)
- 72 MGy/h

X-Rays (5-7 MeV)
- > 50 cm (1.0 g/cm$^3$)
- 100 kGy/h

Source: IBA and IPEN-CNEN/SP
Laboratorial scale experiments (1~50m³/day)

Pilot scale experiments (500~1,000m³/day)

Cost

Space

Operation & Maintenance, other

Laboratorial scale experiments (1~10,000Nm³/h)

Industrial scale wastewater plant (10,000m³/day)

Source: EB-Tech

MOBILE ELECTRON BEAM ACCELERATOR

Laboratorial scale experiments (1~10,000Nm³/h)

Industrialscale EBFGT Plant (~600,000Nm³/h)

Source: EB-Tech
MOBILE ELECTRON BEAM ACCELERATOR

- Beam Energy: 0.4 ~ 0.7 MeV
- Beam Power: 20 kW
- Total weight: 40 tons

Source: EB-Tech
MOBILE E-BEAM IN FLUE GAS PURIFICATION FROM OIL-REFINERY IN SAUDI ARABIA

Source: EB-Tech
ELECTRON TREATMENT OF SEED

- Mobile treatment plant
- Continuous treatment on air
- Throughput: 30 t/h
- 2 line emitting sources (150keV/30kW)
- Penetration of episperm by electrons with precise depth control
- Embryo keeps untouched

Source: Fraunhofer Institut-FEP (Seed-Health@fep.fraunhofer.de)
MOBILE UNIT WITH AN ELECTRON BEAM ACCELERATOR TO TREAT INDUSTRIAL EFFLUENTS FOR REUSE PURPOSES IN BRAZIL

Sources: Truckvan, IPEN-CNEN/SP
- **Dimension:** $\varnothing = 1,500$ mm (external)
- **Columns:** $\varnothing = 255$ mm - 400 mm
- **Detection system:** 7 multi-detectors array (NaI(Tl), 2"
- **Sources:** $^{60}$Co, $^{137}$Cs, $^{75}$Se, $^{192}$Ir (collimated in fan shaped planar beam)
- **Stepping motors:** 2 (rotation and translation movements)
Computed simulated column arrangement with resulting gamma ray profile and reconstructed tomographic image of a trayed column

Source: IPEN/CNEN-SP
DEVELOPMENT OF A IRRADIATION SYSTEM FOR PRODUCTION OF GASEOUS RADIOISOTOPES APPLIED IN INDUSTRIAL PROCESSES

PARTNERSHIP - TRACERCO (Worldwide Company)
Process diagnostics services and specialist measurement solutions to the world’s process industries (Oil and Gas, Refineries, Petrochemical, Chemical, Consumer Fuels)

Benefits in Brazil: US$ 450 millions/year

Source: IPEN-CNEN/SP
THANK YOU!

Source: Russian weather satellite Elektro-L