Industrial irradiators use sources that emit very high levels of penetrating ionizing radiation in a range of applications, e.g., to sterilize medical products, for food preservation and in the curing of resins and surface coatings. As the radiation levels inside the irradiation area are very high, it is important that no one is present in this area unless the sources are in the fully shielded position, or for accelerator systems, the high voltage has been disabled.

Radiation safety must be considered in the design of an industrial irradiator. If the safety features are correctly designed and safe working procedures followed, doses will be As Low As Reasonably Achievable (ALARA) and accidents will not occur.

Safe working procedures include:
- Observing the control panel for indications that the source has retracted safely or the accelerator high voltage has been disabled.
- A search and lock-up procedure forces the operator to check that there is nobody in the irradiation area when irradiation begins.
- Observing the warning lights above the entrance to the irradiation area.
- Using a survey meter to check radiation dose rates when entering the irradiation area.
- Checking the function of your survey meter, before entering the cell, using a small check source.
- Never entering the cell through the product entrance/exit.
- Never disabling any safety system.
- Never entering the cell unless you are sure it is safe to do so.

SAFE WORKING PROCEDURES SHOULD BE REGULARLY REVIEWED

PRINCIPLES OF RADIATION PROTECTION FROM AN EXTERNAL EXPOSURE

During normal use, you can only receive a radiation dose from exposure to industrial irradiator sources from outside the body.

External exposures can be controlled by consideration of time, distance and shielding.

<table>
<thead>
<tr>
<th>Time</th>
<th>Shielding</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 minutes</td>
<td>1 cm of plastic will totally shield all beta radiation.</td>
</tr>
<tr>
<td>15 minutes</td>
<td>Lead and concrete can be used to shield against gamma and X radiations.</td>
</tr>
<tr>
<td>30 minutes</td>
<td>1 cm of plastic will totally shield all beta radiation.</td>
</tr>
<tr>
<td>1 hour</td>
<td>1 cm of plastic will totally shield all beta radiation.</td>
</tr>
<tr>
<td>2 hours</td>
<td>1 cm of plastic will totally shield all beta radiation.</td>
</tr>
</tbody>
</table>

DOSE AND EFFECTS

Units of dose
- The unit of absorbed dose is the gray (Gy).
- The unit used to quantify the dose in radiation protection is the sievert (Sv).
- One millisievert (mSv) is 1/1000 of a sievert.
- One microsievert (µSv) is 1/1000 of a millisievert.
- The typical dose from a chest X-ray is 20 mSv.

Annual doses from natural background radiation vary on average between 1 mSv and 5 mSv worldwide.

The unit used is microsieverts per hour (µSv/h).
- If a person spends two hours in an area where the dose rate is 10 µSv/h, then they will receive a dose of 20 µSv.

Dose rate
- Dose rate is the dose received in a given time.
- Safe working procedures include:
  - Warning lights at the entrance and a lock on the door. Both must be actuated by a monitor inside the cell.
  - An interlock for terminating irradiation automatically if the door is opened during an exposure.
  - A fixed radiation monitor with alarms that provide independent verification of radiation levels in the irradiation area.
  - An alarm that sounds if a door is opened when the source is exposed. This alarm must alert another trained person on-site.
  - Observing the control panel for indications that the source has retracted safely or the accelerator high voltage has been disabled.
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THE SAN SALVADOR ACCIDENT

1. The accident happened when the source rack became stuck in the exposed position.
2. The operator bypassed the irradiator’s already degraded safety systems and entered the irradiation area with two other workers to free the source rack manually.
3. The doses were so high that radiation sickness occurred within an hour of the exposure, although the skin burns did not appear until many days later.

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THE CONSEQUENCES OF NOT FOLLOWING SAFETY PROCEDURES

Worker A Died
- Body dose: 8 Gy
- Dose to feet: 100 Gy

Worker B Survived, but leg amputated
- Body dose: 4 Gy
- Dose to feet: 100 Gy

Worker C Survived
- Body dose: 4 Gy
- Dose to feet: 10 Gy

The IAEA published a detailed report of its investigation into the accident. The report identified a range of serious errors and many lessons have been learnt.
- The safety features were disconnected, or in very poor condition.
- The control panel lights were dim and unlabelled.
- The door could be unlocked with a knife.
- The monitor based interlocks had been removed.
- There had been no training and instruction manuals were not in the local language.

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AS LOW AS REASONABLY ACHIEVABLE (ALARA)