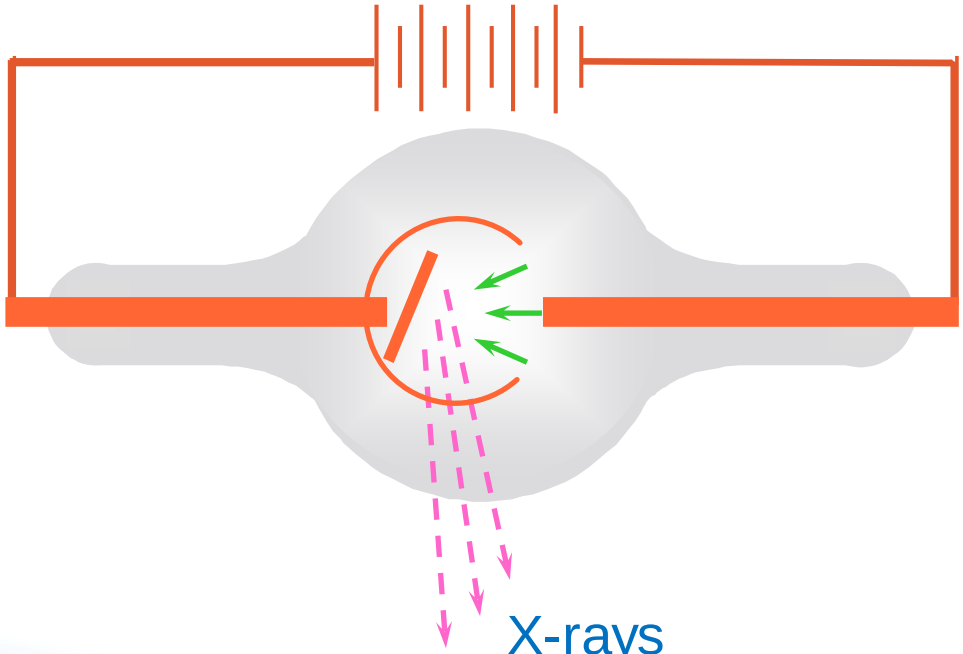
IAEA
International Atomic Energy Agency

4.2 Optimization of occupational radiation protection in industrial radiography part 2

X-ray Tube



X-ray energy

Increasing kV

Increasing X-ray energy

More penetrating X-rays

X-ray tube, control panel and cable

X-ray tube, control panel and cable

control panel

X-Ray Equipment

Conventional (150 kV to 400 kV)

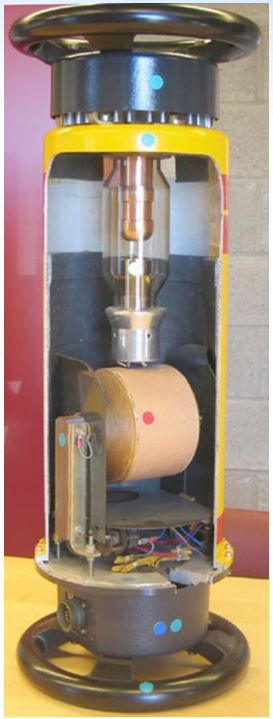
Real Time Radiography (RTR)

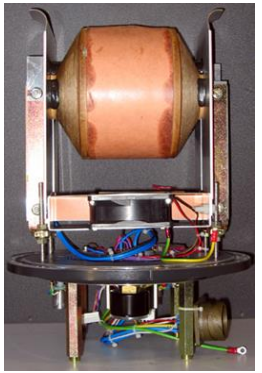
Accelerators

- high energy (up to 6 MeV)
- static, mobile, portable

The dose to the radiographer is affected by:

- The cable length
- The X-ray tube parameters
- The tube assembly

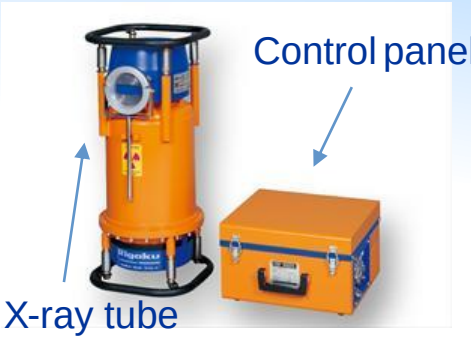




Internal view of X-ray tube

X-ray Radiography Equipment

- Typical specification:
  - 300 kVp
  - 6 mA
  - Dose rate (@ 1 m) 6 tot 20 Sv/h
  - Unidirectional of panoramic



Unidirectional

Panoramic

Site X-ray radiography

Typical voltages used in IR

X-Ray generating voltage	Maximum steel thickness (mm)
150 kV	15
200 kV	25
300 kV	50
400 kV	60

Requirements for Radiation generator

01 Cable length

- cannot be carried out in a shielded enclosure
- <20 meters for generator < 300 kV
- Cables should be laid out as straight as possible

02 Collimators

can be used to reduce the radiation beam to the minimum size necessary for the work

03 Control panel 1

The control panel shall be fitted with :

1. A label
2. A labelled warning light A key switch

04 Control panel 2

The control panel shall be fitted with :

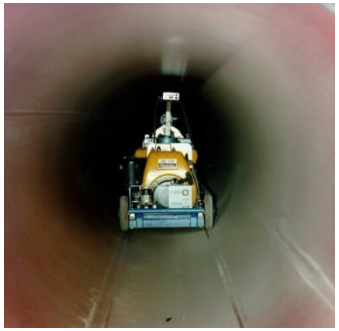
1. A separate labelled warning light
2. A timer
3. Indicators kV and mA
4. Labelled termination of generation of radiation

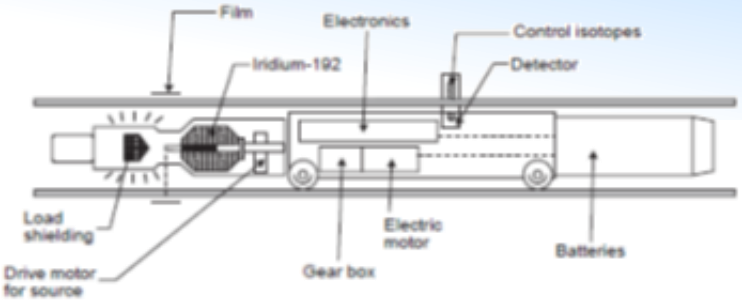
05 Tube head

- Be supported with stand or be clamped
- Restrict the Leakage radiation from the tube-head

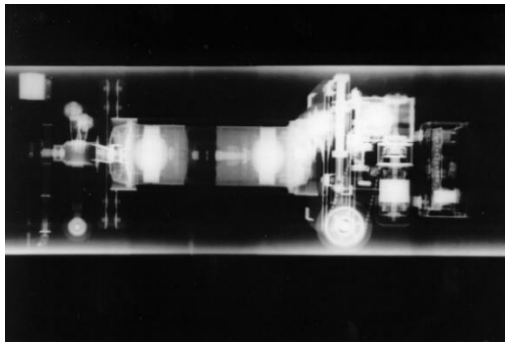
Support for tubeheads

X-ray crawler





Commands are given from the outside of the pipeline with a control isotope (Cs-137 source)



(courtesy of Applus RTD, The Netherlands)

Requirements for pipe line crawler equipment

Pipeline crawler equipment used for industrial radiography shall meet the applicable minimum standards for gamma sources or X ray tubes;

Furthermore, such equipment shall be designed, constructed and tested to withstand the rigors of its expected working environment.

Maintenance of X ray equipment and other radiation generators

Licensees shall ensure that the following pre-operational safety check are carried out:

- There is no visible damage to the equipment.;
- Cables have no cuts, kinks or broken fittings;
- Any cooling systems (water, oil) are not leaking;
- Any interlocks are operational;
- Required warning signs are legible;
- All warning indicators are functioning with no light bulbs, etc. broken;
- All fastenings are tight and any threaded connectors undamaged.

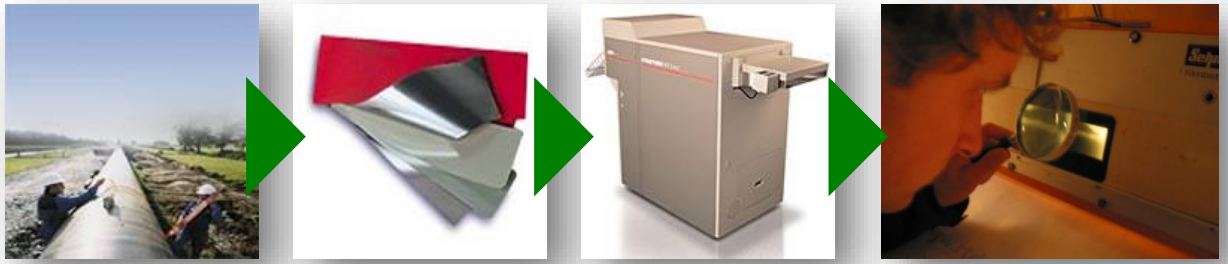
Periodic inspection and servicing -1

The periodic inspection and servicing (done by the supplier, their agents, or specially trained staff within the operating organization) shall include the items listed above plus the following:

- Checks for electrical safety including earth bonding;
- Cleaning/replacing any filters in cooling systems;
- Other servicing as recommended by the supplier;
- Check for X ray leakage from the tube;
- Checks to ensure that all cables are in good condition, with no fraying or exposed wires;
- Tests on electrical insulation of cables;
- Tests on all interlocks and emergency cut-out switches;
- Tests on all permanently installed radiation detectors in radiography enclosures.
- Tests on all warning signals installed inside radiography enclosures. This shall be done in a safe manner on a regular basis (without exposure of persons inside the enclosure)

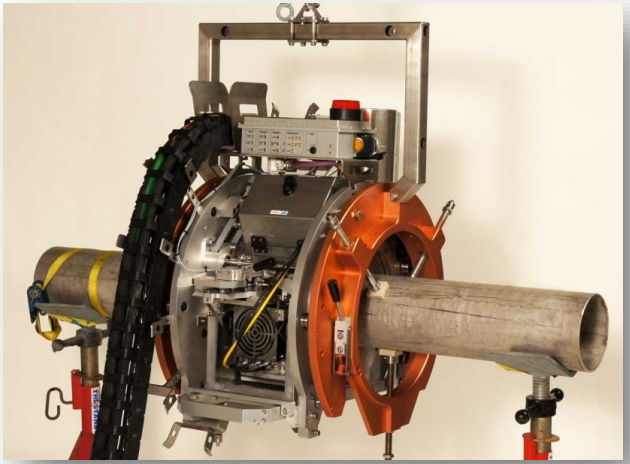
Film radiography vs digital radiography

Radiographic image = x-ray image (film photography)



Real Time Radiography (RTR) = direct digital x-ray image

RTD RAYSCAN



(courtesy of Applus RTD, The Netherlands)

(courtesy of Applus RTD, The Netherlands)

RTR at Landline

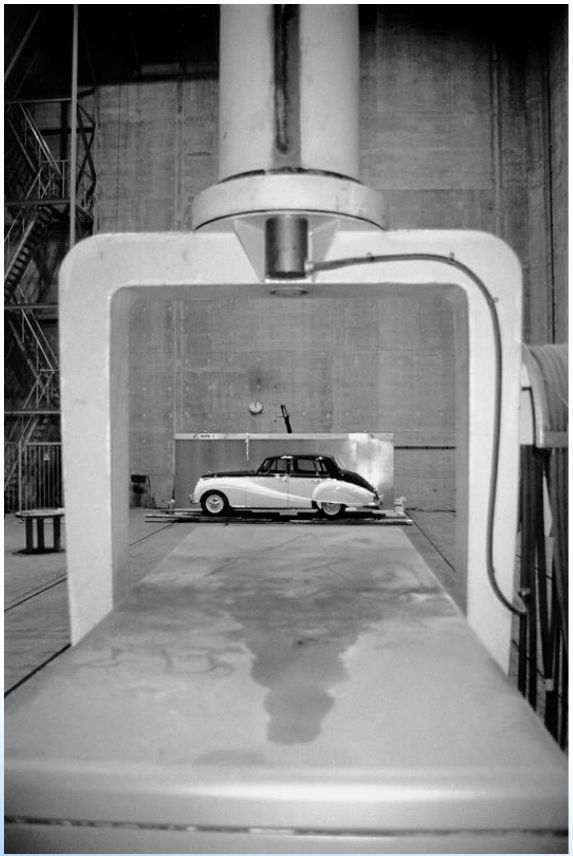
(courtesy of Applus RTD, The Netherlands)

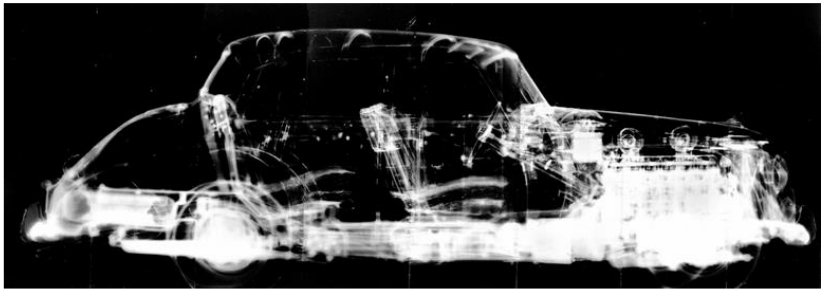
(courtesy of Applus RTD, The Netherlands)

Linear Accelerator (linac)

(courtesy of Applus RTD, The Netherlands)

Radiograph of car with linac





Industrial Radiography in Shielded Enclosures

01

Shielded Enclosures

Where practicable all industrial radiography should be carried out in a shielded enclosure in order to keep doses as low as reasonably achievable. The shielded enclosure should be purpose-built for the specific range of activities to be performed.

Enclosure Design and Use

Basic requirements
Maze entrance
Wall thickness
Roof

Scatter - sky shine
Warning lights
Emergency buttons

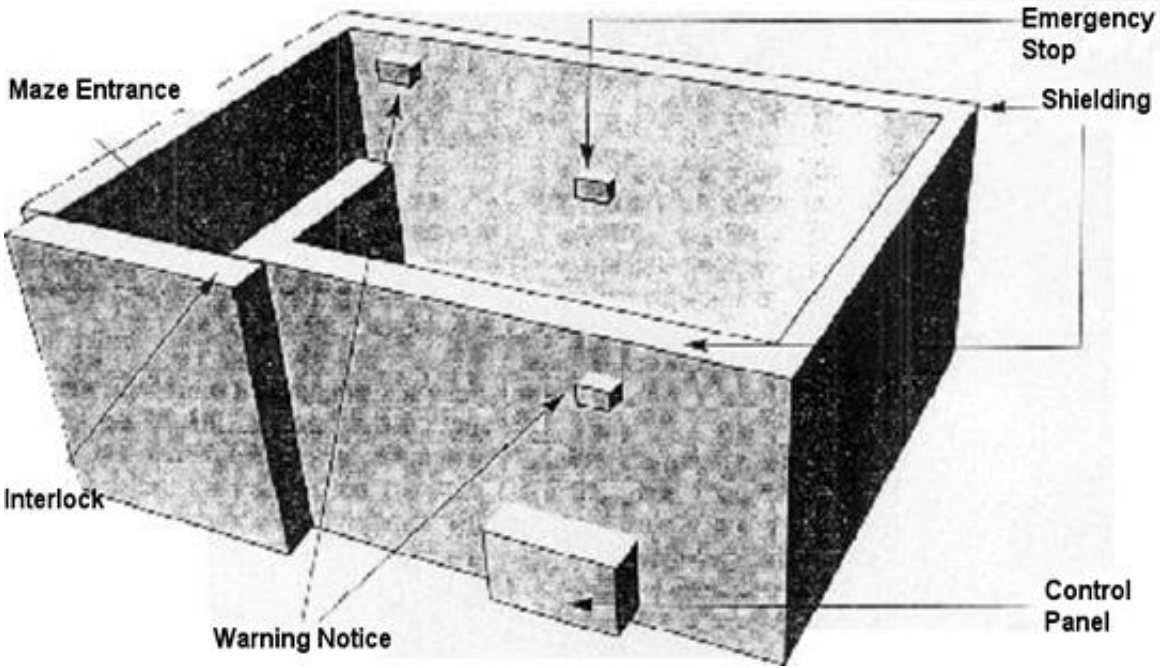
02

03

Shielded Design for Enclosure

Use of standard data tables/drawings for basic wall thickness based on the radiography device and radiation source to be used.
Calculation using attenuation coefficients and transmission factors
ALARA considerations should be incorporated into the design.

Shielded Design for Enclosure (cont)



Enclosure Warning Systems

- Shielded Enclosures must be posted with warnings of radiation areas
- Entry must be interlocked
- Gamma alarms or audible warning signals must be installed inside and outside the enclosure.
- A visible alarm should activate when the radiation source is exposed, or x-rays generated.
- An audible alarm should sound when the door is opened.

Control of the Exposure

Initiation of the exposure must be from controls positioned outside the room.

Access to the shielded enclosure should be interlocked to prevent inadvertent entry during exposures (or automatically shields the source or terminates an x-ray exposure).

Emergency stop switches should be installed to provide for immediate termination of an exposure.

Operating Procedures

For use as an approved shielded enclosure, the room must be used in accordance with the initial design parameters, i.e. for the approved types of procedures and radiation source(s).

If used otherwise, the room must be treated as if it was a field site with all the required safety procedures that apply in such situations.

Safety interlocks must not be defeated.

The room must be used in accordance with established written procedures.

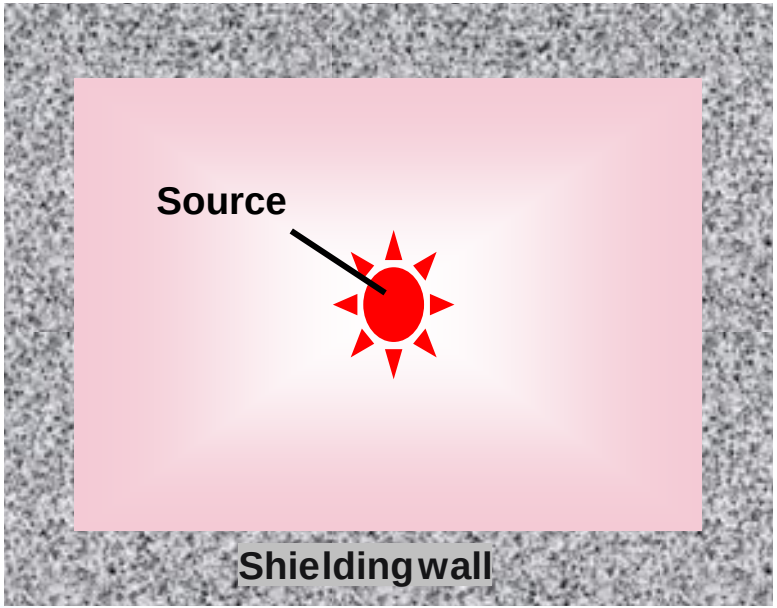
Confirming Safety Prior to Use

Before approval for use is given, the Regulatory Authority must be satisfied that:

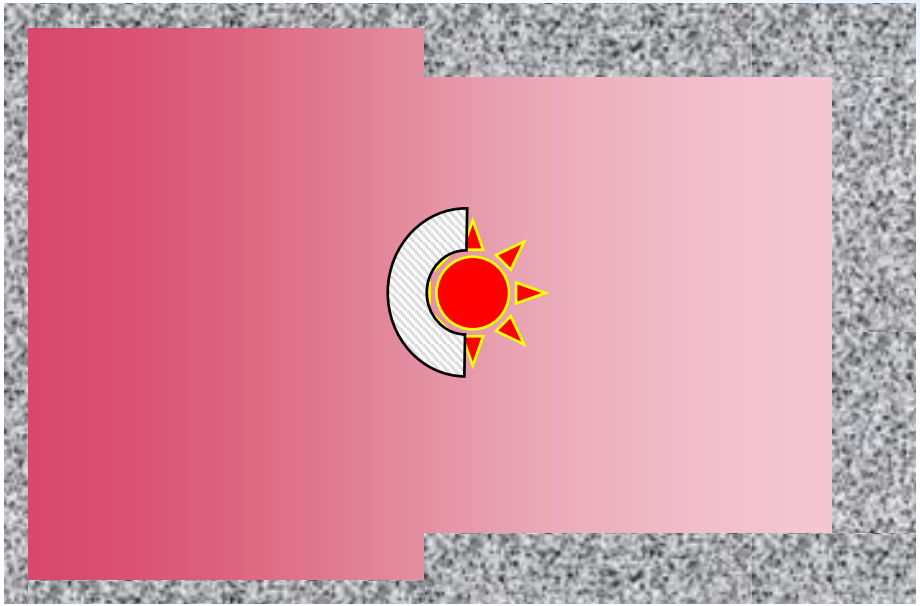
- radiation surveys have been taken to verify the required shielding is in place;
- interlocks and warning systems have been tested to ensure they operate as designed.

This requires inspection by the Regulatory Authority following a report from the qualified expert

Basic Shielded Enclosure

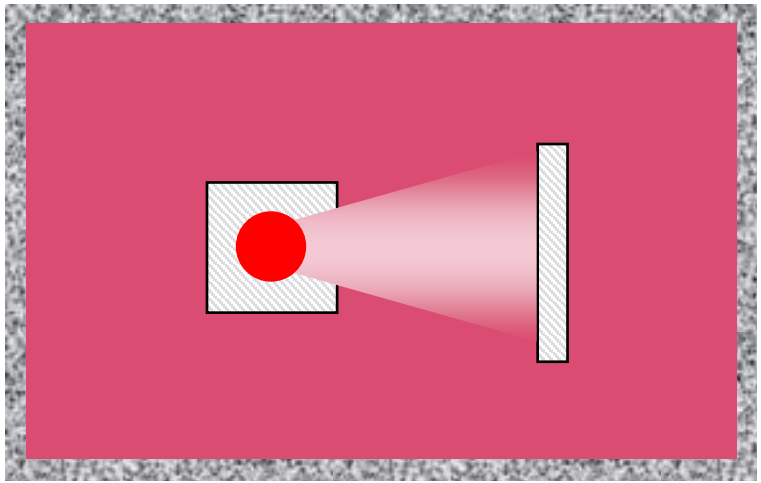


Shield for Directional Field

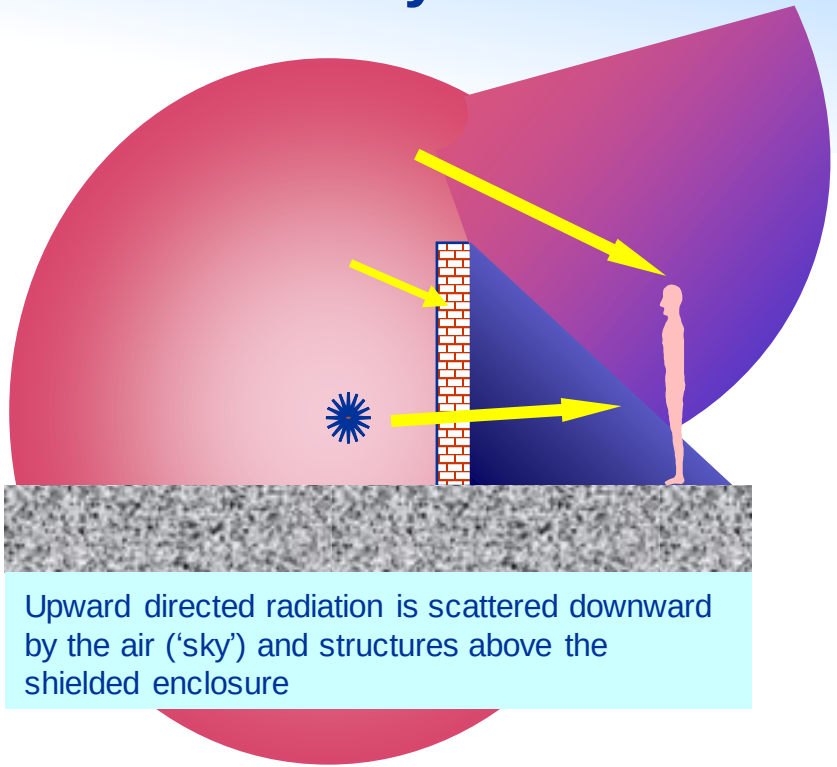


Primary barriers - protection against primary radiation beam
Secondary barriers - protection against scattered radiation

Shadow Shielding



Effect of Skyshine



Upward directed radiation is scattered downward by the air (‘sky’) and structures above the shielded enclosure

Enclosure Roofs

Shielded Entrances

- personnel
- equipment

Hinged, sliding, or plug doors

Maze entrances

Make sure it is big enough!

Make sure that the engineering is adequate

- 1 cm thick lead ~ 100kg per m2!

Enclosure Access

Heavy shielding roofs are expensive to engineer

Reduced shielding roof requirements

- Ensure that only secondary radiation impinges on the top of the enclosure

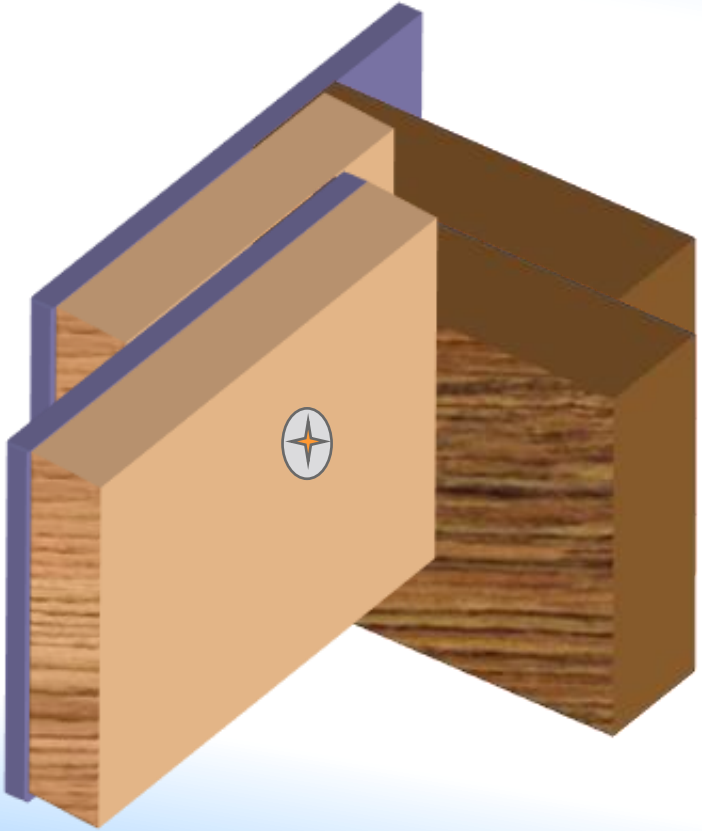
Consideration of occupancy above the facility

- crane drivers, upper floor occupancy

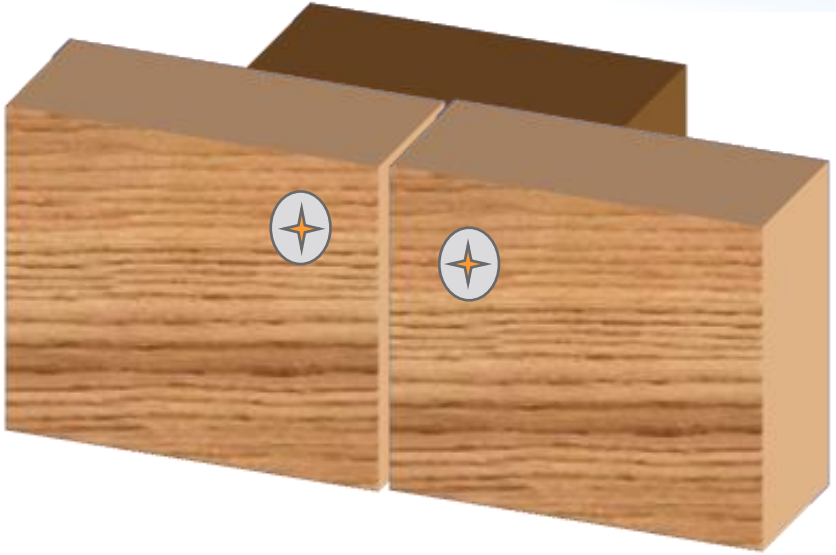
X-ray Enclosure with Sliding Door

Acknowledgements to Wardray Premise Ltd

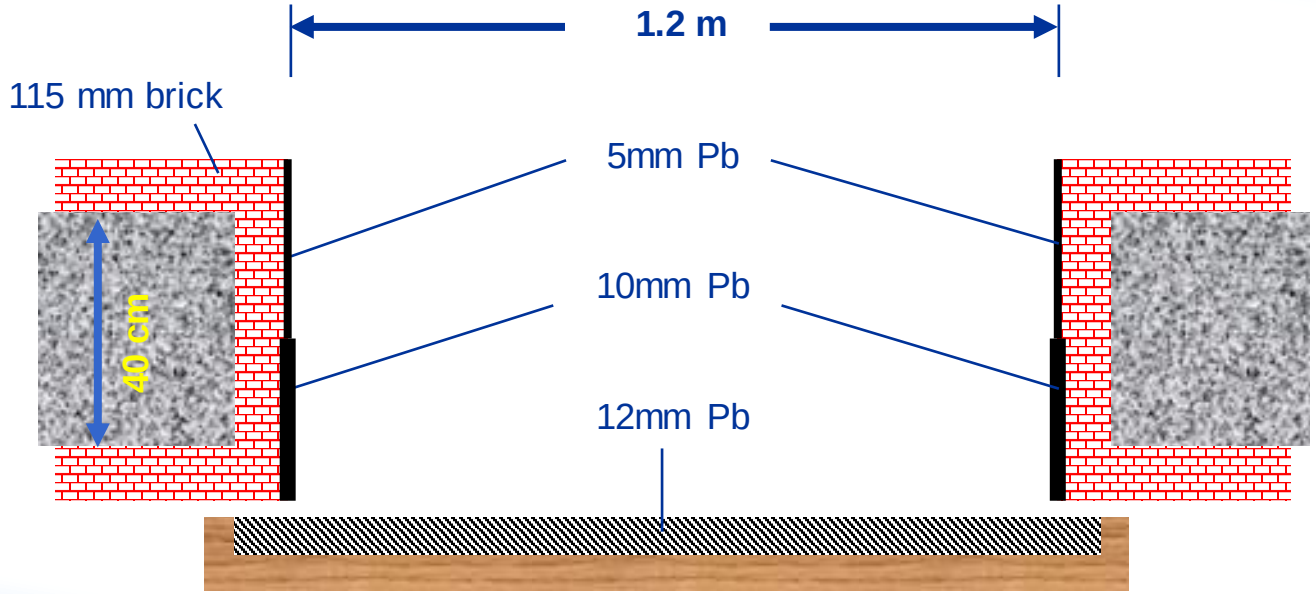
Dealing with Corners



Dealing with Joints



Sliding Door Design
250 kVp X-ray Enclosure



Sliding Door Design
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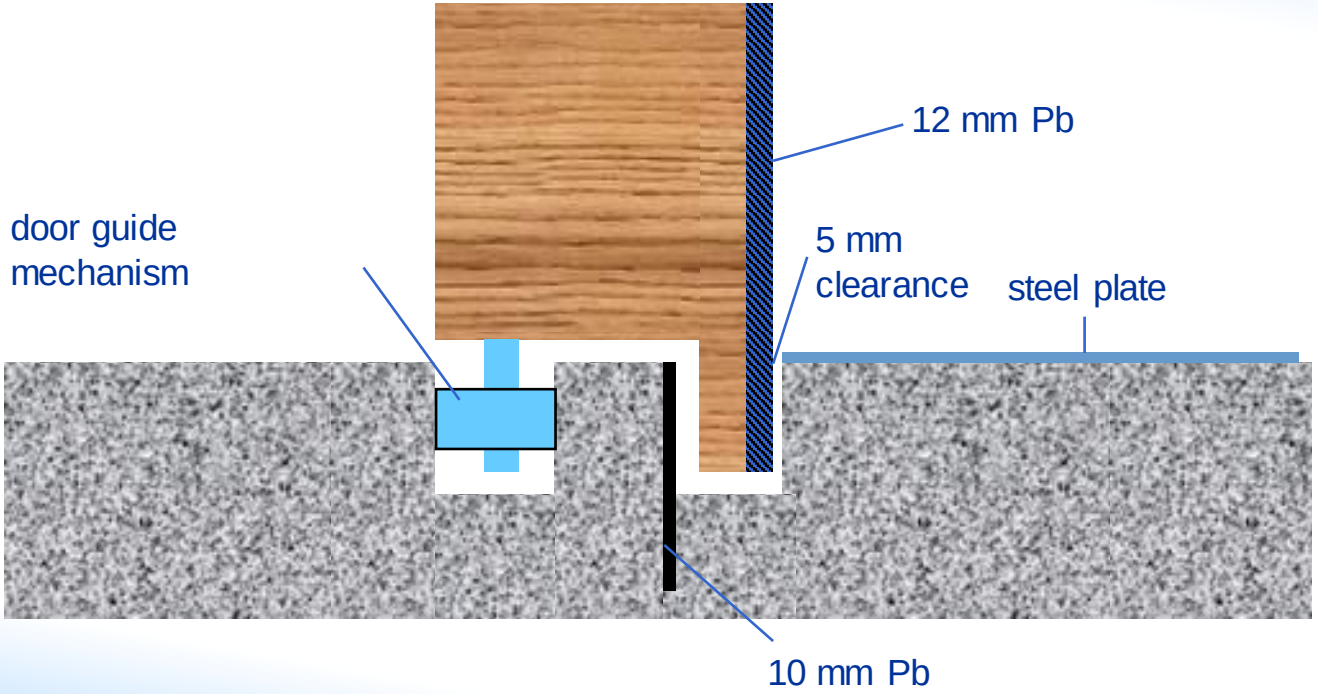
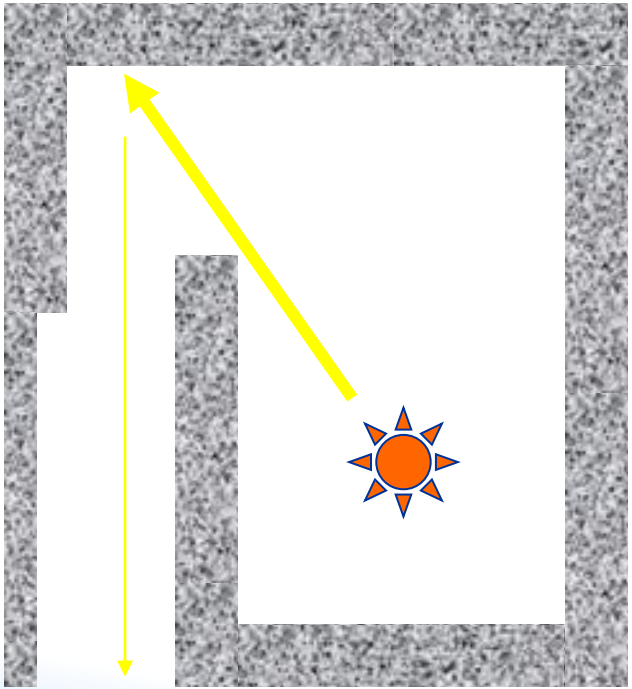


Maze Entrance



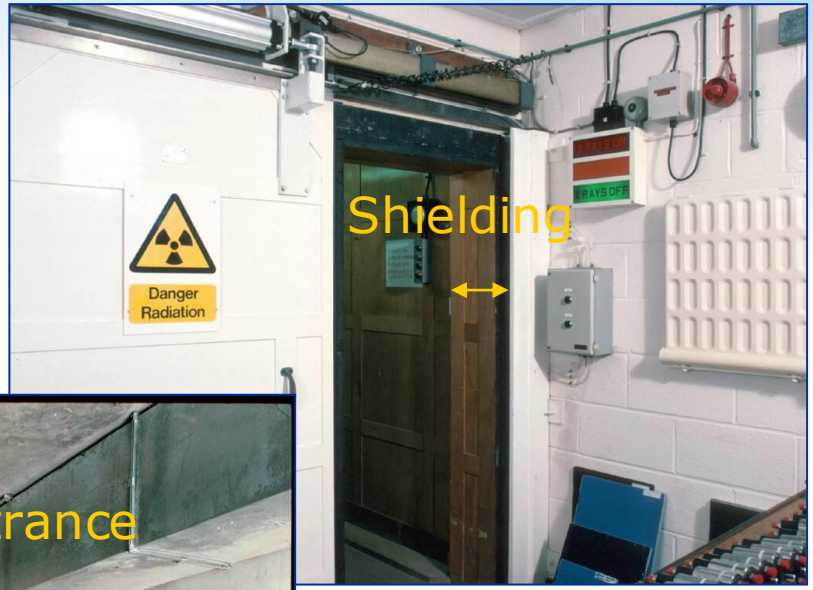
Relies on dose rate reduction by scattering

Very high primary dose rates may need multiple scattering to effect adequate dose rate reduction, i.e. more corners

Entrance to maze often gated to prevent access

- provision of additional shielding

Tight corners limits equipment size


Danger
Radiation
Shielding
X-RAYS OFF


Maze Entrance

Provision of Services

Cabling, pipework and ducting require penetrations through the shielding

Maintain shielding integrity:

- avoid exposure to primary beam
- locate penetrations at high or low level
- form the penetration into a maze
  - but remember that services need to be got in and out
- with poured concrete shielding, consider all future requirements - changing your mind after construction is expensive (if not impossible)!

Practical protection

- Shielding material
- Shielding design
- Safety and warning systems
- Other protection measures
- Procedures
- Personal protective equipment
- Safety and security of sources

Safety features and Warning devices

- Interlocks
- Emergency stops
- Warning signals
  - lights
  - sirens
- Shutter status indicator
- Search and lock-up

Interlocks

Fail to safety

Not easily defeated

Easy to operate if frequent access required

Guarded interlocks to prevent tampering

Exposure controls should be provided and properly used where they can prevent access to high dose rate areas

Types of interlocks

- Position switches
- Trapped key control
- Captive key switch
- Magnetic switch

Door interlocking

‘Search and lock-up’

An interlock system that forces the operator to go to various locations in the cell before an exposure can be made.

Buttons/switches positioned at locations around the interior of the cell.

Have to be pressed prior to making an exposure.

Exposure must be initiated within a set time after the setting of the buttons/switches.

Emergency stop controls

Signs and notices

Warning signals

Location of safety and warning systems - shielded enclosure