



**Presentation**

**INDUSTRIAL RADIOGRAPHY**

**METHODOLOGY FOR DOSE ESTIMATES IN**

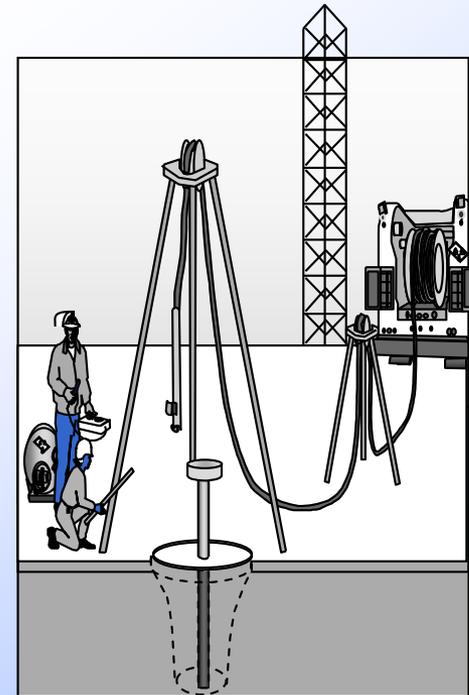
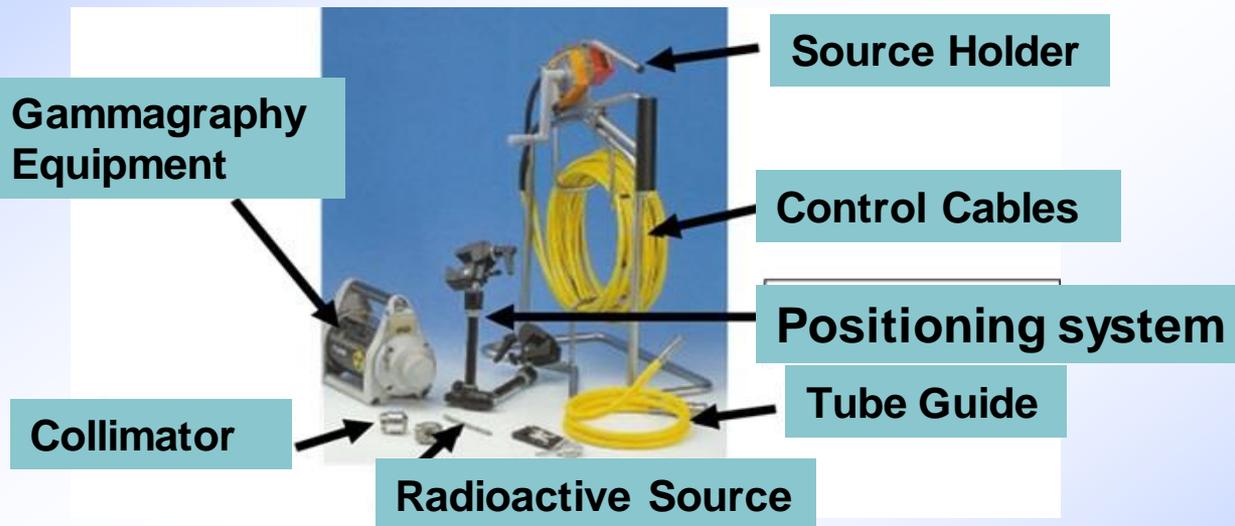
**NORMAL OPERATION.**

**International Atomic Energy Agency.**



# OBJECTIVE

- To show an example of dose estimates in industrial practice installations during normal operation.





# INTRODUCTION

Dose estimates under normal operating conditions are based on identifying the exposed persons and the exposure conditions during the performance of the different tasks.

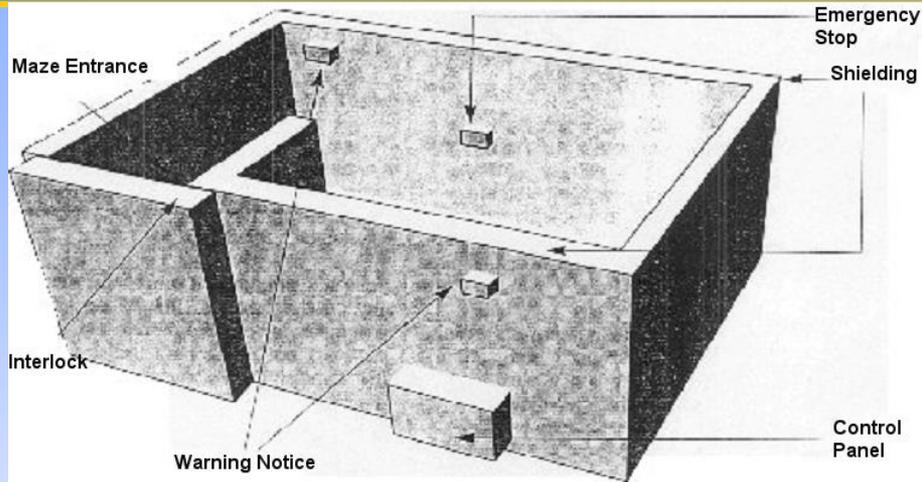
**Estimates are made for:**

- 1. Occupationally Exposed Workers.**
- 2. Members of the Public.**



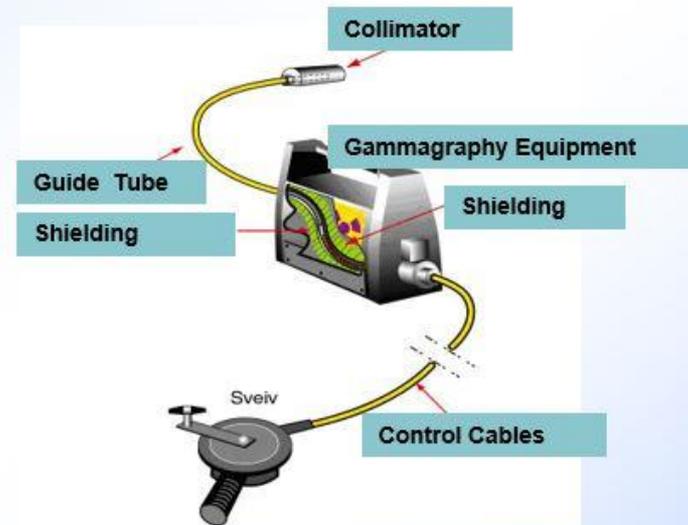


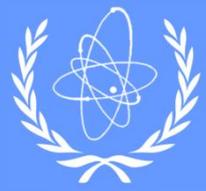
# INTRODUCTION



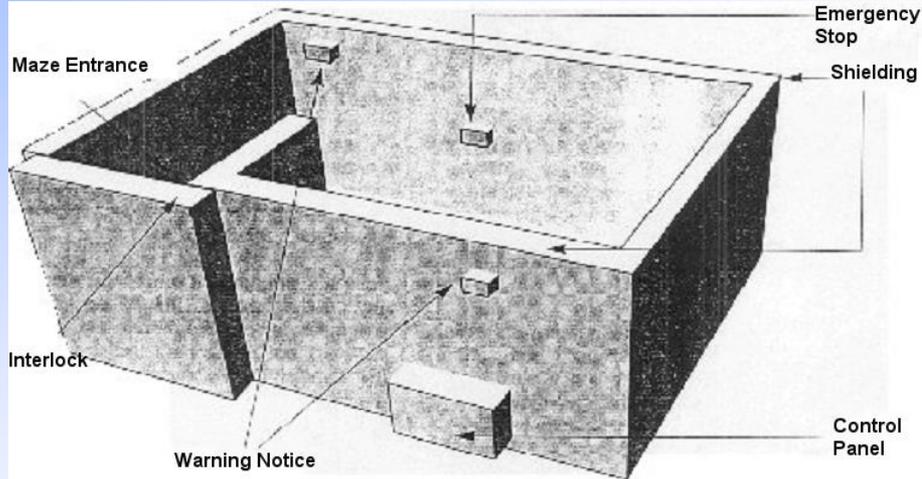
## Gammagraphy in Bunker.

## Mobile Gammagraphy.





# GAMMAGRAPHY IN BUNKER





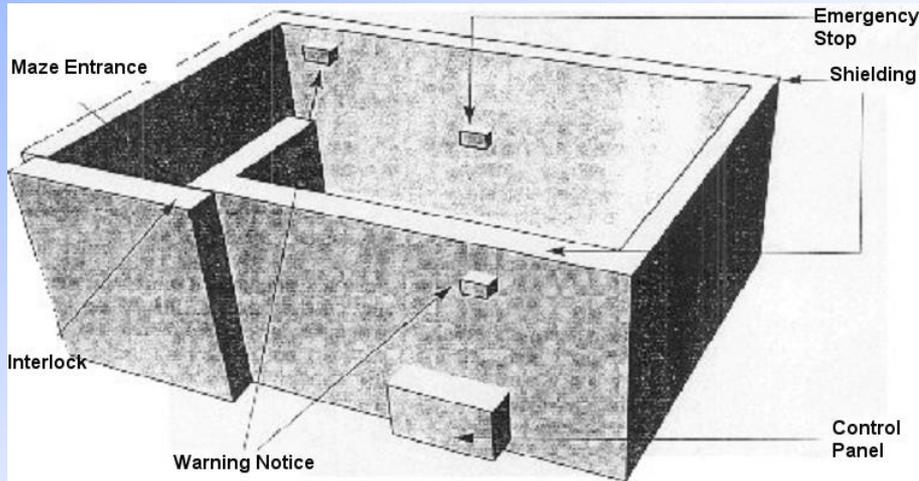
# GAMMAGRAPHY IN BUNKER

## Occupationally Exposed Workers in the Practice of Gammagraphy in Bunker

No.	Workplace	Tasks performed	Dose
1.	Operator of Gammagraphy equipment	Operation with the Gammagraphy equipment from the control panel.	?
<b>Total Doses for the Operator</b>			?
2.	Operator Assistant.	Carrying the Gammagraphy equipment	?
		Operation with the Gammagraphy equipment from the control panel.	?
<b>Total Doses for the Operator Assistant</b>			?



# GAMMAGRAPHY IN BUNKER. DOSES RECEIVED BY THE OPERATOR



The dose estimate during equipment operation from the control panel depends on the dose rate received by the operator in the control panel. (Depending on the effectiveness of the shield)

## Considerations for dose estimation.

- Simplifications relating to the "point source".
- Work without using collimators at the end of the guide tube.
- It is assumed that the source is, during all the irradiation episode, in a fixed position. The source, in a fixed position, is located at half the length of the guide tube.



# GAMMAGRAPHY IN BUNKER. DOSES RECEIVED BY THE OPERATOR

## Dose received by the operator in the Control Panel.

- The instantaneous dose rate (IDR) in the control panel barrier :

$$IDR = \frac{DR_0 \cdot B}{d^2}$$

$DR_0 = H$ , Is the dose rate at one meter from the source.

If you do not know the value of "B" but you know the shield thickness (S), you can calculate B using the following equation :

$$B = 10^{-[1+(S/TVL)]}$$



# GAMMAGRAPHY IN BUNKER. DOSES RECEIVED BY THE OPERATOR

## Dose received by the operator in the Control Panel.

- The average dose rate received by the operator in a week can be estimated from the Instantaneous Dose Rate (IDR):

$$D_w = IDR * N * t * d_i$$

$N$  – Is the number of x-rays taken in a work day,

$d_i$  – Is the number of work days per week,

$t$  – Is the average time, used to perform a gammagraphy.

The annual dose received by the operator in the control panel is :

$$D_t = D_w * N_w \quad \longrightarrow \quad N_w \text{ Is the number of weeks worked per year.}$$



# GAMMAGRAPHY IN BUNKER

## Doses received by members of the Public in the Practice of Gammagraphy in Bunker.

No.	Member of the public	Conditions of exposition	Dose
1.	Worker of the company that works in functions not related to the practice of gammagraphy	It is exposed during its work, in a place contiguous to the bunker	?
<b>Total Doses for the worker</b>			?
2.	Member of the public, which is temporarily in areas adjacent to the Gammagraphy bunker	It is exposed a fraction of the time during which Gammagraphy works.	?
<b>Total doses for the public</b>			?



# GAMMAGRAPHY IN BUNKER. DOSES RECEIVED BY THE PUBLIC

## Dose received by the Public.

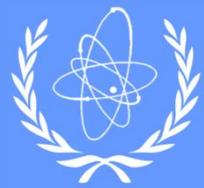
- The instantaneous dose rate (IDR) at the point to be protected is :

$$IDR = \frac{DR_0 \cdot B}{d^2}$$

$DR_0 = H$ , Is the dose rate at one meter from the source.  
 $d$ , Is the distance to the point to be protected.

If you do not know the value of "B" but you know the shield thickness (S), you can calculate B using the following equation :

$$B = 10^{-[1+(S/TVL)]}$$



# GAMMAGRAPHY IN BUNKER. DOSES RECEIVED BY THE PUBLIC

- The average dose rate, which receives the member of the public in a week, can be estimated from the Instantaneous Dose Rate (IDR):

$$D_w = IDR * N * t * d_i * T$$

$N$  – Is the number of x-rays taken in a work day,

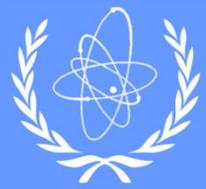
$d_i$  – Is the number of work days per week,

$t$  – Is the average time, used to perform a gammagraphy.

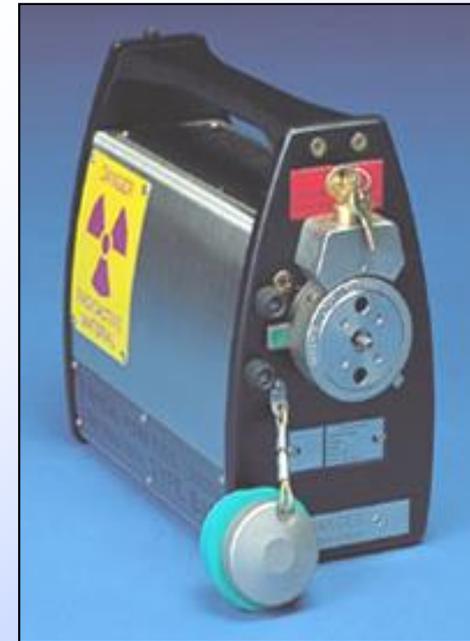
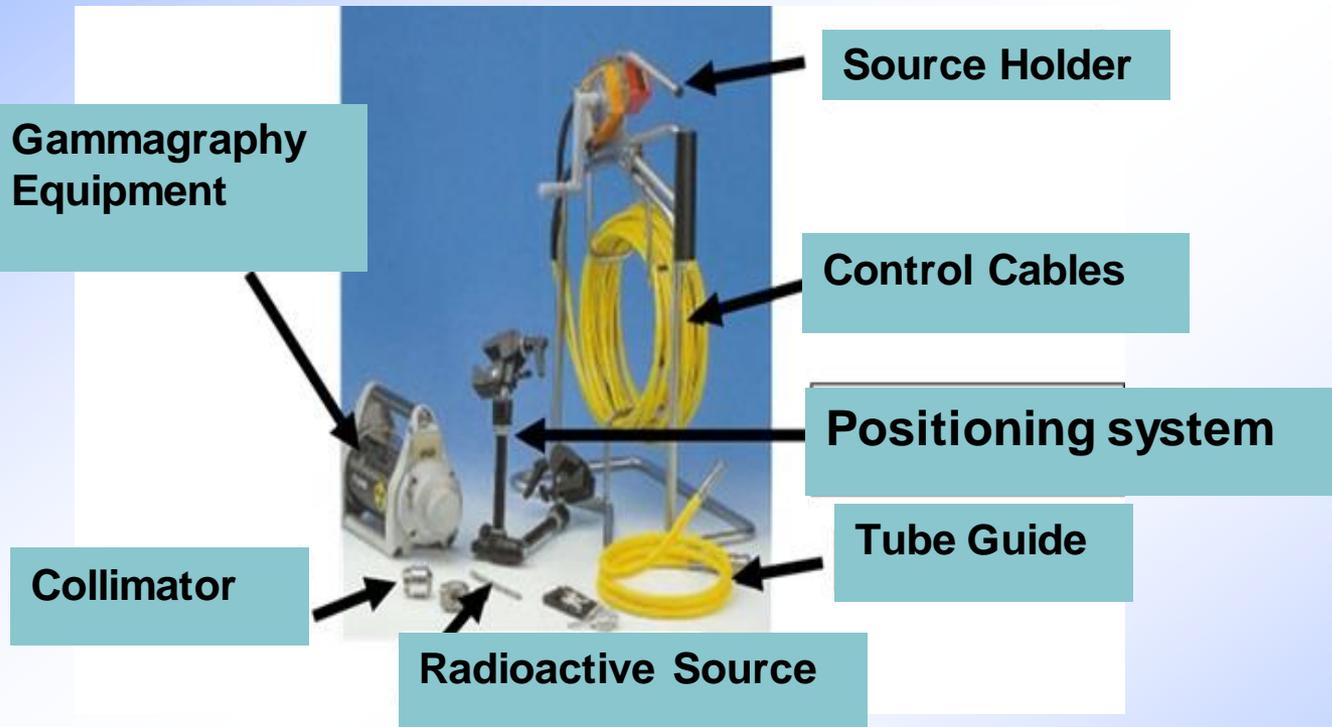
$T$  – Factor of occupation of the area.

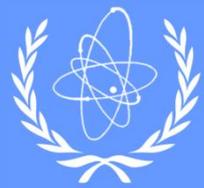
The annual dose received by the member of the public is :

$$D_t = D_w * N_w \quad \longrightarrow \quad N_w \text{ Is the number of weeks worked per year.}$$



# INDUSTRIAL MOBILE GAMMAGRAPHY

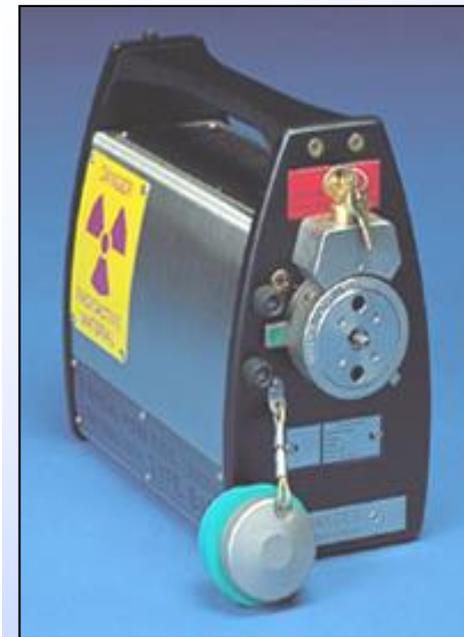


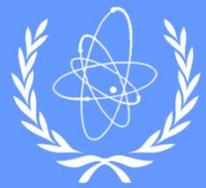


# INDUSTRIAL MOBILE GAMMAGRAPHY

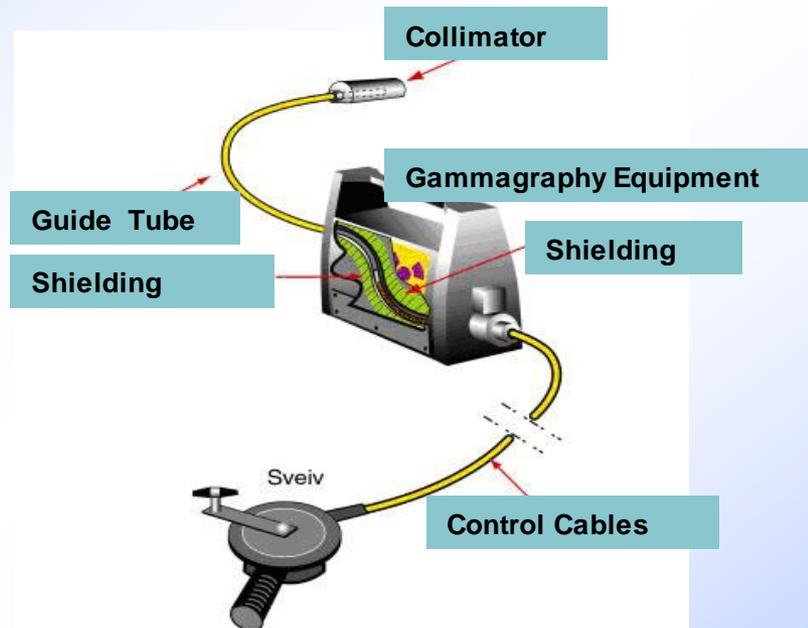
## Occupationally Exposed Workers in the Industrial Mobile Gammagraphy

Nro.	Workplace	Tasks performed	Dose
1.	Operator of Gammagraphy equipment	Operation with the Gammagraphy equipment from the control panel.	?
<b>Total Doses for the Operator</b>			?
2.	Operator Assistant.	Carrying the Gammagraphy equipment	?
		Operation with the Gammagraphy equipment from the control panel.	?
<b>Total Doses for the Operator Assistant</b>			?





## Gammagraphy Equipment Operator.





# INDUSTRIAL MOBILE GAMMAGRAPHY. DOSES RECEIVED BY THE OPERATOR

## Dose received by the operator in the Control Panel.

The dose received by the operator in the control panel of the equipment is given by two basic contributions:

- Dose received during transit of the source from the equipment to the point where the gammagraphy is to be performed ( $D_{tr}$ ).
- Dose received while the gammagraphy is being performed (exposure to the source) ( $D_{ir}$ ).

**Total Dose is**  $D_{tot} = D_{ir} + D_{tr}$

Note: the worst conditions are when the procedures are performed without the use of collimators.





# INDUSTRIAL MOBILE GAMMAGRAPHY. DOSES RECEIVED BY THE OPERATOR

## Dose received by the operator in the Control Panel.

Dose received during the time of exposure of the source to perform the gammagraphy ( $D_{ir}$ ).

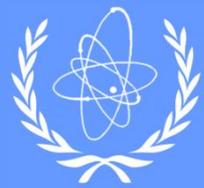
The dose rate from irradiation can be determined by the equation :

$$\dot{H}_{ir} = \frac{\Gamma \cdot A}{d^2}$$



- $\Gamma$ , is the gamma constant for the radioisotope used ( $\Gamma$  for I-192 is 0.135 mSv m<sup>2</sup>/ GBq h).
- A, is the activity of the source.
- d, is the distance between the irradiation point and the remote control. (Usually 20 meters)

Note: This equation is applicable when making point source considerations.



# INDUSTRIAL MOBILE GAMMAGRAPHY. DOSES RECEIVED BY THE OPERATOR

## Dose received by the operator in the Control Panel.

Dose received during the time of exposure of the source to perform the gammagraphy ( $D_{ir}$ ).

- **Consideration respect to the variation of the source activity.**

The Ir-192 source decays, reducing their activity by half, in about 74 days. For this reason, the dose received by the worker decreases with time. If we assume that the source is replaced approximately every 5 months (150 days) we can, for the purposes of the calculation, consider that, for the whole year, we work with a source of constant activity equal to half of the initial activity of the source ( $A = A_0/2$ ), where  $A_0$  is the initial activity of the source.





# INDUSTRIAL MOBILE GAMMAGRAPHY. DOSES RECEIVED BY THE OPERATOR

## Dose received by the operator in the Control Panel.

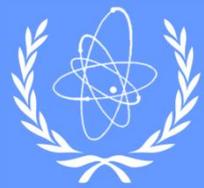
Dose received during the time of exposure of the source to perform the gammagraphy ( $D_{ir}$ ).

General considerations for the calculation of the dose from irradiation( $D_{ir}$ ).

- The company performs  $N$  gammagraphy a year.
- At each gammagraphy, on average, the source is exposed for a time  $t$ .

$$D_{ir} = H_{ir} * N * t$$





# INDUSTRIAL MOBILE GAMMAGRAPHY. DOSES RECEIVED BY THE OPERATOR

## Dose received by the operator in the Control Panel.

Dose received, during transit of the source, from the equipment to the point where the gammagraphy is performed ( $D_{tr}$ ).

The dose rate during the transit of the source can be determined by the equation :

$$\dot{H}_{tr} = \frac{\Gamma \cdot A}{d^2}$$

- $\Gamma$ , is the gamma constant for the radioisotope used ( $\Gamma$  for I-192 is 0.135 mSv m<sup>2</sup>/GBq h).
- $A$ , is the activity of the source.
- $d$ , is the distance between the remote control and the virtual position of the source.

Note: This equation is applicable when making point source considerations.





# INDUSTRIAL MOBILE GAMMAGRAPHY. DOSES RECEIVED BY THE OPERATOR

## **Dose received by the operator in the Control Panel.**

Dose received, during transit of the source, from the equipment to the point where the gammagraphy is performed ( $D_{tr}$ ).



## **Consideration regarding the distance from the source to the remote control.**

The distance between the source and the remote control varies during the transit of the source from the container of the gammagraphy equipment to the irradiation position. This causes the increase of the dose rate at the location of the remote control when the source approaches the container of the equipment and decreases when it moves away to the irradiation position. Therefore it is accepted to perform the calculations considering that, during the entire transit time, the source is virtually stopped at the middle of the guide tube ( $d = d_1 + (d_{tg}/2)$ ).

*$d_1$ , is the distance between the remote control and the equipment container, and  $d_{tg}$ , is the distance between the equipment container and the irradiation point (guide tube length).*



# INDUSTRIAL MOBILE GAMMAGRAPHY. DOSES RECEIVED BY THE OPERATOR

## Dose received by the operator in the Control Panel.

Dose received, during transit of the source, from the equipment to the point where the gammagraphy is performed ( $D_{tr}$ ).

$$D_{tr} = H_{tr} * N * t_{tr} \quad (*)$$

(\*) General considerations for the calculation of the dose per transit ( $D_{tr}$ ):

- The company performs  $N$  gammagraphy per year.
- On average, the source transits at a speed of 1 m/s in each radiography, so the transit time of the source is:

$$t_{tr} = 2 * (d_{tg} / 1 \text{ (m/s)})$$

Note:  $d_{tg}$  is the length of the guide (usually 10 m)





# INDUSTRIAL MOBILE GAMMAGRAPHY. DOSES RECEIVED BY THE PUBLIC

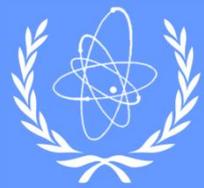
**Dose received by the Public located outside the controlled area.**

$$D = 2.5 \mu\text{Sv/h} * N * t \quad (*)$$



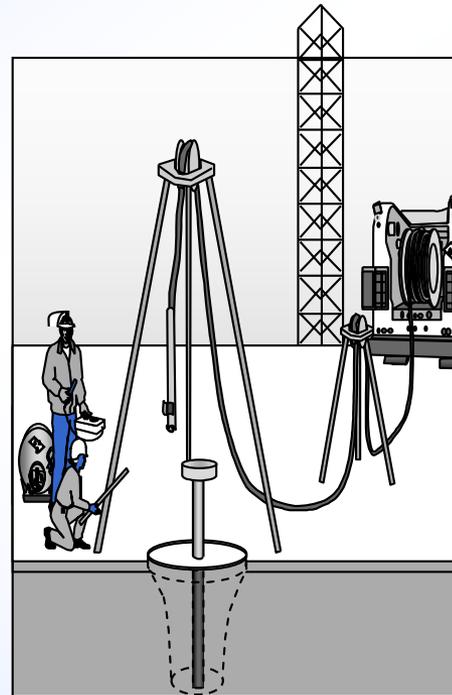
**(\*)** General considerations for the calculation of the dose to the public:

- The company performs **N** gammagraphy per year.
- At each gammagraphy, on average, the source is exposed for a time **t** (**usually two minutes**).
- According to international regulations, it is considered that the dose rate at the boundary of the controlled area is **2.5 μSv/h**.
- Being conservative, it is considered that the public is in the limit of the controlled zone during all the time of performance of a gammagraphy.



# WELL LOGGING

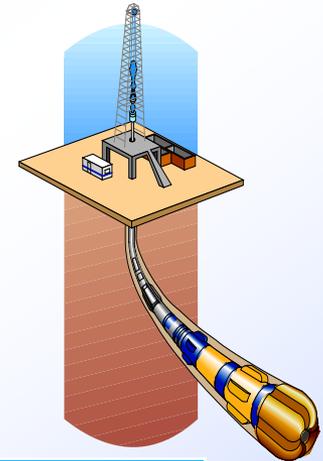
- **Example of dose estimates in well logging practice.**





# INTRODUCTION

## 1. Sources used in well logging practice.



No.	TYPE	Serial Number	Radionuclide	Source activity		Reference date
				GBq	n/s	
1	GSR-J	1111	Cs-137	55	-	14/2/2013
2	NSR-F	5555	Am <sup>241</sup> -Be	592	-	14/2/2013



# WELL LOGGING PRACTICE. DOSES RECEIVED BY THE OPERATOR

## Dose estimation for gamma emitting sources.

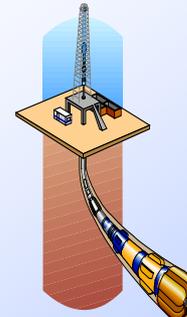
$$\dot{H} = \frac{\Gamma \cdot A}{d^2}$$

- $\Gamma$ , is the gamma constant for the radioisotope used.
- $A$ , is the activity of the source.
- $d$ , is the distance between the source and the operator.

Data: ( $\Gamma$  for Cs-137 is  $1.032 \cdot 10^{-4} \frac{mSv m^2}{MBq h}$  ).

( $\Gamma$  for Th- 232 is  $1.848 \cdot 10^{-5} \frac{mSv m^2}{MBq h}$  ).

( $\Gamma$  for Am- 241 is  $8.478 \cdot 10^{-5} \frac{mSv m^2}{MBq h}$  ).





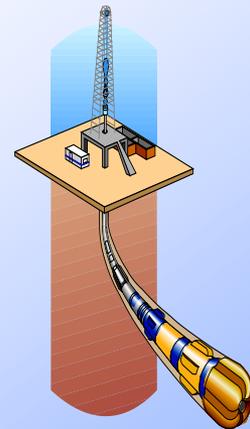
# WELL LOGGING PRACTICE. DOSES RECEIVED BY THE OPERATOR

## Dose estimation for neutron sources.

If we only know the activity of the ALFA emitter (from the source), we need to calculate the neutron emission considering the efficiency of the reaction (alpha-neutron)

$$\Phi_n = A * E_f$$

- $\Phi_n$ , is the neutron flux
- A, is the ALFA source activity.
- $E_f$ , is the efficiency of the ALFA-NEUTRON reaction.  
(For Am-241,  $E_f$  is 70 neutrons per  $10^6$  alpha particles emitted).





# WELL LOGGING PRACTICE. DOSES RECEIVED BY THE OPERATOR

## Dose estimation for neutron sources.

*Considering the neutron dose coefficient, for neutrons of 5.45 MeV, ( $C_{dn} = 282 \text{ pSv/cm}^2$ ).*

$$H = (C_{dn} * \phi_n) / 4\pi(d_h)^2$$

$H$ , is the dose rate per neutron.

$d_h$ , is the distance at which the source is manipulated, (Usually the length of the tool used).

**The neutron dose ( $D_n$ ) is calculated by the equation :**

$$D_n = H * T$$

$T$ , is the time used in the manipulation of the source



