
Radiation exposures of workers resulting from the transport of gamma radiography sources in Germany

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Abstract:

Gamma radiation sources are widely used for industrial purposes e.g. for non-destructive material testing. Many of these sources are permanently installed at a facility within instruments e.g. for level or thickness gauging. Other radioactive sources are implemented in portable devices for industrial gamma radiography which have to be carried to the various remote usage sites. In Germany, approximately 20 000 - 25 000 shipments of gamma radiography sources are proceeding annually on public transport routes.

Since routine radiation monitoring programmes do not permit task-specific determination of occupational doses e.g. doses incurred during the movement phase and handling related doses, work has been carried out with the objective to determine the radiation exposures of the personnel attributable to transportation. For this purpose, a survey was launched in 2005 collecting data about e.g. the number and conditions of transports, the activity and type of transported radiation sources and the radiation level within the driver's cab to allow a dose assessment to be made for transport workers. The results of this survey covering the most important companies for gamma radiography services in Germany are presented in this paper.

1 BACKGROUND

Industrial radiation sources are widely used for industrial purposes, e.g. for non-destructive material testing, and a broad variety of other applications in civil engineering (e.g. density and humidity gauging at road construction sites). Many of these sources are non-portable or used in establishments at fixed sites (e.g. for level or thickness gauging) while others are highly portable devices and routinely transported on publicly accessible roads to remote construction sites, cross-country pipeline installations etc. The results of a recent survey indicates that the number of radiographic source shipments in Germany is in the range of about 20 000 - 25 000 movements per year. Road transportation is the predominant shipping mode.

The handling, use and management of industrial radiographic sources including their transport in the public domain gives rise to radiation exposures to both personnel and members of the public (working or living in close proximity to the radiation source). The radiation doses received by workers can vary significantly depending on a number of factors including the duration and conditions of exposure. However, while a significant body of information exists on the type and magnitude of doses incurred by gamma radiographers there is generally little - if any - information available on the adequacy and effectiveness of the radiation protection measures employed during transport and the radiation doses of industrial radiographers attributable to the movement phase of the radiation source transports. To bridge this gap of information work has been performed on behalf of the German competent authority with the objective to quantify the dose fraction of gamma radiography workers attributable to routine transportation and to allow some judgement to be

made on the efficacy of the radiation protection provisions and requirements of the IAEA Transport Regulations [1].

For this purpose a survey has been performed in 2005 with the aim to gather data on the number and conditions of gamma radiography source shipments, the radiation source characteristics (e.g. radioisotope, activity content), the radiation levels of the employed sources and those within the transport vehicle. The survey was undertaken in close co-operation with the German Society for Non-destructive Testing and covered all major non-destructive testing service companies in Germany. The details of the survey and the survey results are given below.

2 CHARACTERISTICS OF PORTABLE GAMMA RADIOGRAPHY DEVICES

Industrial radiography sources are routinely transported while being enclosed in a device for gamma radiography providing appropriate shielding. This apparatus includes an exposure container, a source assembly, and as applicable, a remote control, a projection sheath, an exposure head, and other accessories designed to enable radiation emitted by a sealed radioactive source to be used for industrial radiography purposes (see Fig 2.1). The radioactive source is generally completely enclosed and shielded when in rest position and is only exposed (e.g. via remote control) during the short period of carrying out the radiographic inspection. The apparatuses are dual purpose containers serving both as transport package and exposure container (Fig 2.2).

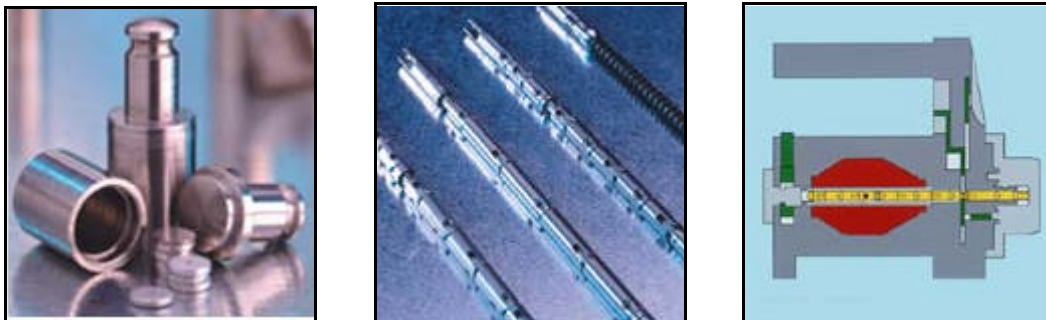


Fig 2.1 Source capsules containing the radioisotopes (left), projection sheath with source holder (centre) and schematic drawing of an apparatus for industrial gamma radiography (right) (<http://www.mds.nordion.com/agiris>)



Fig 2.2 GammaMat TI for industrial gamma radiography; weight approx. 12 kg; Type B(U) approved transport container (<http://www.mds.nordion.com/agiris>)

3 DATA COLLECTION AND HANDLING

A questionnaire survey was launched in 2005 in co-operation with a division of the German Society for Non-destructive Testing. This organisation (F-GZP) represents all major accredited non-destructive testing service companies in Germany. The data collection was carried out by mailing a questionnaire form to all members of the F-GZP. The following data were sought and collected for the calendar year 2004:

- number and activity of radiography sources shipped in 2004
- type of transport container used and the transport index
- details on the number of source transports and the related mileage
- number of passengers and radioactive sources per conveyance
- annual radiation exposure of personnel
- local dose rate in the driving cab
- expenditure of time for transport related procedures

Survey participation and provision of data was on a voluntary basis. Responses were received from 21 out of 28 contacted service companies; only 17 out of the 21 were routinely involved in transport of gamma radiography sources in the public domain. The survey results and the radiation dose estimates attributable to the transport of gamma radiography devices are given below.

3.1 Source characteristics

Depending on the field of application (i.e. the wall thickness of the material to be tested) different radioisotopes are used as radiation source. Iridium-192 and selenium-75 are the most common radioisotopes employed for gamma radiography (see Fig 3.1). The radiation energy is typically sufficient to penetrate e.g. materials of iron with a wall thickness ranging from 4 mm to 70 mm. The source activity varied between 0.2 TBq and 3.7 TBq. Most radiography devices are approved Type A or Type B(U) transport containers (packages), depending on the isotope's activity. The Transport index (TI) of the packages was in the range from 0.1 to 5, this corresponds to a package dose rate at 1 m from the external package surface of 0.001 mSv/h and 0.05 mSv/h, respectively. The maximum radiation level at the surface of the package is limited to 2 mSv/h by the IAEA Transport Regulations [1] and the International Standard ISO 3999 [2].

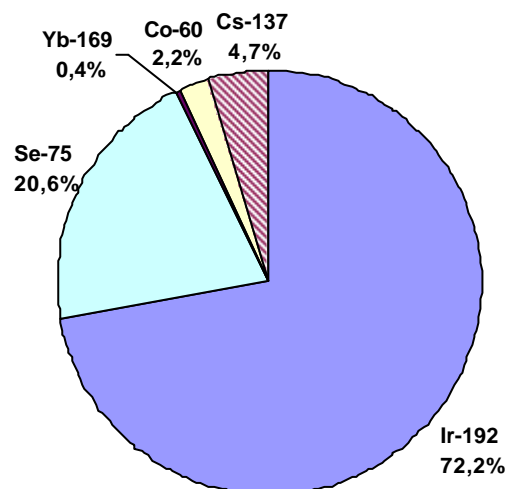


Fig 3.1 Radioisotopes used in gamma radiography devices in Germany (2004)

3.2 Transport conditions

According to the survey data provided, approximately 277 sources have been regularly transported in 2004. The number of annual shipments varied considerably between the service companies. The currently best estimate of the total number of shipments in Germany is in the range of 20 000 - 25 000 movements per year. Most companies operate as principal service contractors on a regional level. The travel distance covered per service (one way) ranged from 10 km to 200 km; the average mileage is approximately 65 km (one way). For safety reasons and radiation protection purposes, gamma radiography devices are typically placed inside a fixed transport box in the vehicle with additional lead shielding of several millimetres.

The reported local dose rate in the driving cab varied from 0.02 $\mu\text{Sv/h}$ to about 2 $\mu\text{Sv/h}$ (or less than detection limit), the lower values were prevailing in small van type vehicles (see Fig 4.2). Radiographic source transport vehicles are typically occupied by two persons, i.e. the driver and the escort. The reason for this is that during radiographic inspections two qualified persons (categorised as appropriately qualified radiation workers) need to be present at the inspection site. Depending on the company size between 2 and 207 radiation workers are entrusted with non-destructive material testing.

4 INDUSTRIAL RADIOGRAPHER RADIATION DOSES

The radiographer radiation doses available have been derived from routine monitoring program data and include consequently worker exposures arising from both transport operations and from carrying out radiographic inspections in enhanced radiation level (e.g. nuclear power plant inspections) and natural background radiation environments. The exposure data provided (effective doses) are shown in Fig 4.1 for the various service companies in terms of average and maximum reported doses.

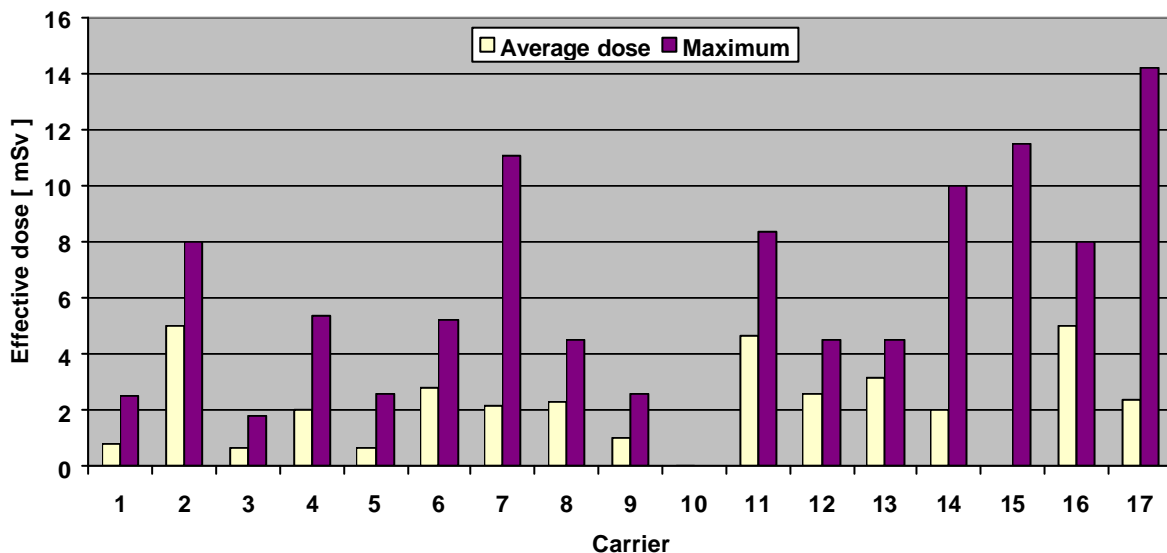


Fig 4.1 Personal radiation exposure of radiographers (individual effective dose per year) resulting from the use and transport of radioactive sources for gamma radiography in 2004 (results of the governmental radiation monitoring service)

The data shown indicate that the average radiographer doses are generally below 5 mSv/yr (averaged over the company’s radiographic personnel). The highest reported individual radiographer dose is about 14 mSv/yr. The applicable radiation worker dose limit according to the nationally relevant Radiation Protection Ordinance [3] is 20 mSv/yr.

The assessment of the radiographer doses attributable to the movement phase of radiographic source shipment has been estimated from the reported survey information including:

- local dose rate in the driving cab
- average travel time and mileage per road transport

In addition, as a conservative assumption it has been assumed that a radiographer travels annually 230 days with a radiographic source on the vehicle. Other transport-related steps like e.g. loading and unloading operations have not been considered in the dose estimation.

The results of this assessment approach are shown in Fig 4.2. The maximum annual effective dose resulting from shipment of gamma radiography devices is on the order of 450 μSv . This dose is within the range of natural radiation exposures resulting from external radiation in Germany (0.7 mSv/a on average with regional variations). In most cases the radiation exposures of radiation workers due to the transport of gamma radiography sources (movement phase) is far below 100 $\mu\text{Sv/a}$. Variations in estimated annual doses for workers are due to the different company's specific transport conditions i.e. the effective dose calculated per transport (round trip) which varies from 0.04 μSv to about 2 μSv .

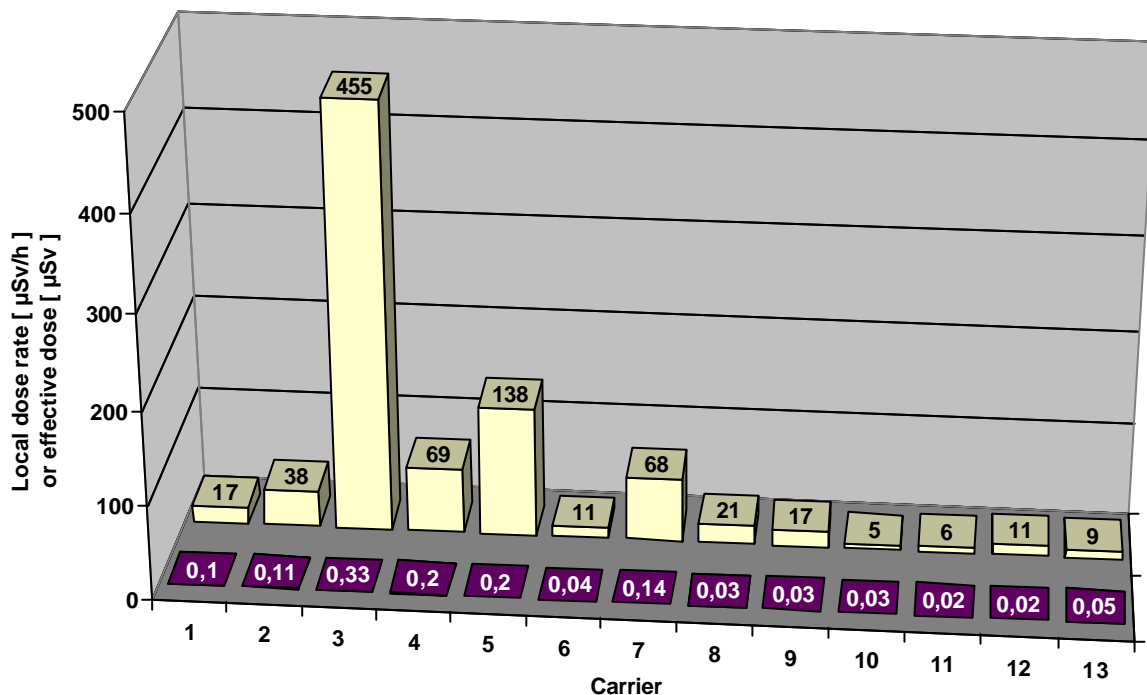


Fig 4.2 Local dose rate (red) measured in the driver's cab and annual effective doses of personnel (yellow) resulting from carriage of gamma radiography sources (movement phase only)

5 CONCLUSIONS

A survey has been performed in 2004 with the objective to determine the type, magnitude and characteristics of industrial radiographic source shipments and the related worker exposures in Germany. The radiation dose assessment results indicate that the industrial radiographer doses attributable to the movement phase during transport (loading/unloading excluded) are generally less than 1mSv per year. The assessment results support the conclusion that implementation and application of the international transport safety standards

and requirements ensure an acceptable level of radiation protection of the transport workers for normal conditions of transport. However, additional doses are accumulated by workers from the use and handling of the sources while carrying out radiographic inspections. The data available demonstrate that these additional doses generally constitute the predominant fraction of the total dose acquired by industrial radiographers.

6 REFERENCES

1. International Atomic Energy Agency (IAEA): IAEA Safety Requirements No. TS-R-1, Regulations for the Safe Transport of Radioactive Material, Vienna, 2005.
2. International Standard: ISO 3999 Radiation protection – Apparatus for industrial gamma radiography – Specifications for performance, design and tests, 2004.
3. Radiation Protection Ordinance (Strahlenschutzverordnung, StrlSchV) of July 20, 2001, last Amendment by the Act of September 1, 2005.