Some radiation protection aspects concerning industrial radiography as seen by German trade unions

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1. Description of the situation

Gamma rays of sealed radioactive sources can be used in industry for non-destructive testing in order to detect flaws and other failures in materials. These procedures must be subject to radiation protection. This is also the case, if X-rays are used.

Generally radiography exists since the discovery of X-rays in 1895. In 1900 the first radiography with gamma rays was performed by Marie Curie using radium as radioactive source. The use of naturally occurring isotopes was uneconomic and technically unsatisfactory. This changed after the discovery of nuclear fission. It became possible to use fission products and neutron activation products such as cesium-137, iridium-192 and cobalt-60 as radioactive sources [1].

In the early days of radiography radiation protection for the users was not a matter of concern. The radioactive sources were handled more or less in direct contact or at close range and shielding was not applied [1]. This changed near the middle of the 20th century. But nevertheless radiation accidents were and are quite frequent as are elevated radiation doses received by workers ([2], [3] and [4]). Most endangered are extremities – especially hands. But it has been demonstrated that radiation protection can be successfully applied ([5], [6] and [7]). The improvement of radiation protection in radiography is one of the major concerns of the involved German trade unions.

2. Basis for the protection of workers

Two regulations for the protection of workers have to be discussed:

- Council Directive 96/29/Euratom concerning radiation protection [8]
- Council Directive 89/391/EWG concerning the safety and the protection of the health of workers [11]

The Council Directive 96/29/Euratom defines limits of effective and equivalent doses for an exposed worker:

- The limit on effective dose shall be 100 mSv in a consecutive five-year period, subject to a maximum effective dose of 50 mSv in any single year (Article 9 in [8]).
- The limit on equivalent dose for the lens of the eye shall be 150 mSv, for the skin 500 mSv and for the hands, forearms, feet and ankles 500 mSv in a year (Article 9 in [8]).
- Exposed workers of category A are liable to receive an effective dose greater than 6 mSv per year or an equivalent dose greater than 3/10 of the dose limits for the lens of the eye, skin and extremities laid down in Article 9. Exposed workers of category B are those who are not classified as exposed category A workers (Article 21 in [8]).

The German Radiation Protection Accordance has the Council Directive 96/29/Euratom as its basis. The German Radiation Protection Accordance defines limits on effective and equivalent doses for an exposed worker:

- The limit on the effective dose is set at 20 mSv in a year. The competent authority can admit 50 mSv in an individual case in any single year, if 100 mSv are not exceeded in a consecutive five-year period (§ 55 in [9]).
- Additional limits are defined for the equivalent dose of several organs with respect to the Council Directive 96/29/Euratom. The additional limits on the equivalent doses are for the gonads, uterus, red bone marrow 50 mSv, for the thyroid gland, bone surface 300 mSv and for colon, lung, stomach, bladder, breast, liver, oesophagus and other organs 150 mSv in a year (§ 55 in [9]).
- For the whole working live the effective dose is limited to 400 mSv. The competent authority can permit an additional annual effective dose up to 10 mSv on terms with an authorized physician (§ 56 in [9]).
- Exposed workers of category A are liable to receive an effective dose greater than 6 mSv or an equivalent dose greater than 45 mSv for the lens of the eye or an equivalent dose greater than 150 mSv for the skin, hands, forearms, feet and ankles in a year. Exposed workers of category B are liable to receive an effective dose greater than 1 mSv or an equivalent dose greater than 15 mSv for the lens of the eye or an equivalent dose greater than 50 mSv for the skin, hands, forearms, feet and ankles in a year (§ 54 in [9]).

The German Radiation Protection Accordance [9] is in some aspects more stringent than the Council Directive 96/29/Euratom [8]. That is allowed. Regulations by EURATOM formulate minimum requirements only. This was confirmed by the European Court of Justice. It is also in the interest of workers because further optimisation of radiation protection such as exposure reduction is not only possible but mandatory.

Before the Council Directive 96/29/Euratom [8] and the German Radiation Protection Accordance [9] were formulated the limit on the effective dose for an exposed worker was 50 mSv in a year. The reduction of the limiting value from 50 mSv to 20 mSv must not be understood as improvement in radiation safety. It is rather a correction due to the state of scientific knowledge. E.g. the probability of attributable death and the mean loss of live expectancy due to ionising radiation are preserved (§ 157 and Table 5 in [10]). The International Commission on Radiological Protection recommended this reduction of the limiting value in 1990 already (§§ 160-162 in [10]).

The Council Directive 89/391/EWG has to be observed also. This regulation formulates e.g. the following duties of the employer (Article 6 in [11]):

- Avoidance of risks,
- evaluation of unavoidable risks,
- containment of dangers at their sources,
- consideration of the human factor,
- consideration of the state of technology,
- elimination or reduction of dangers,
- planning the prevention of dangers,
- priority of collective protection over individual protection and
- issuing of qualified instructions for employees.

The employees have to be involved by the employer and they have to cooperate. The employer as well as the employees have to pay attention to the fulfilment of injunctions of the competent authorities concerning safety and health protection also.

The German law for the protection of safety and health at work realized the regulations of the Council Directive 89/391/EWG ([11] and [12]).

Radiography is taking place under the auspices of radiation protection as well as realisation of safety and health care at work.

3. Reasons for deficiencies in radiation protection

It has been mentioned already that radiation accidents were and are quite frequent as are elevated radiation doses received by workers ([2], [3] and [4]). Industrial radiography accounts for approximately 50 % of all reported radiation accidents in developed and developing countries. Several explanations can be given for this [13].

Failure to follow operational procedures is a major reason. Usually a lack of shielding can be observed. This is a failure to ensure that the radioactive source is in a shielded position before approaching. This happens especially, if a worker tries to remove malfunctions or defects.

Inadequate training is another frequent cause especially, if unskilled workers are involved without adequate supervision.

Inadequate regulatory control is a major reasons for problems. Reasons are e.g. an insufficient authority, lack of an established radiation protection infrastructure or missing regulations concerning the use and handling of radioactive sources or X-ray generators. Another problem can be the inadequate management of discarded radioactive sources.

Inadequate maintenance, equipment malfunctions or defects may result into unsafe conditions and failures of equipment. Consequences are often e.g. improper repair procedures. Especially, if these mishaps occur during operation.

Human error occurs especially under stress conditions. Reasons can be the amount of work load, inadequate time schedule or strenuous working conditions.

Design flaws may occur but they are not common any more.

Wilful violations are more likely to occur in organizations lacking a sufficient safety culture. The probability of such acts increases e.g. when working under stressful conditions, fatigue, economic factors, production pressure or physical exertion.

Management blunders are e.g. the absence of essential institutional arrangements such as a quality assurance programme or a safety culture. Actually they may be the origin of other problems mentioned above in this chapter. An inadequate management is the foundation-stone of failure.

4. Solutions of problems

Solutions of the problems have to consider and to realize e.g.:

- Establishment of a qualified management,
- hiring and maintaining a well trained work force,
- assurance of qualified and maintained equipment,
- assurance of realistic time schedules for jobs to do and
- adequate institutional control.

If these conditions are fulfilled, the annual effective dose of an exposed worker can easily be kept below 5 mSv ([5] and [6]). This is a good step forward to adequate radiation protection. The limits for the effective dose of the Council Directive 96/29/Euratom [8] and the new German Radiation Protection Accordance [9] can be observed easily. This has to be the case for the equivalent dose limits also.

It has to be kept in mind that with respect to radiation protection an annual effective dose of more than 20 mSv is not acceptable, 10 mSv through 20 mSv are tolerable, several mSv are acceptable and less than 1 mSv is considered to be trivial.

Industrial radiography is more and more applied as a service and very often performed in facilities of customers. The use of mobile radiography units is becoming more and more frequent. Therefore, care has to be taken that bystanders and other people not involved in the testing procedure are excluded in order to avoid unnecessary radiation exposure. A close cooperation of the contractor and the customer is a must. Of help for needed procedures and regulations is a brochure which is recommended [14]. Its basis is a German law concerning the safety of workers [12], a follow up of the Council Directive 89/391/EWG [11].

5. Perspective

It has been shown that for industrial radiography the annual effective dose of an exposed worker can be kept below 5 mSv ([5] and [6]). Further optimisation is a desirable goal.

But there exists at least one imminent danger in the future. The competition and the pressure for cost reduction are immense on the national and international markets. It must be assured that these conditions do not compromise radiation protection [15].

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(Status: 10 August 2001)