INDUSTRIAL RADIATION INCIDENTS IN THE UNITED KINGDOM

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Abstract

Certain categories of radiation accidents, incidents and excessive radiation exposures are reportable to HM Factory Inspectorate. This paper describes the method of analysing reports of excessive radiation doses. The analysis includes the processes and locations associated with these reports, the magnitude of the radiation doses received and the age groups of the exposed persons. Causes are divided into management errors, operator errors and equipment failure. The analysis shows that industrial radiography on engineering construction sites is the process which produces most excessive radiation exposures. Unsuitable equipment, inadequate supervision and training of radiographers are found to be the main causes of excessive exposures.

Introduction

Objective

The purpose of this paper is to review and analyse radiation incidents reported to HM Factory Inspectorate between 1968 and 1972, to identify areas where radiation doses in excess of the maximum permissible are occurring, to indicate where, if any, additional effort needs to be deployed in industry and what particular problems need to be solved. Incidents occurring during 1972 are analysed in detail.

Scope

This paper deals with incidents reported to HM Factory Inspectorate under the Ionising Radiations (Sealed Sources) Regulations 1969.[1] The application of these regulations has been described in previous papers.[2,3] In particular they do not apply to hospitals, nor to research and teaching establishments. Incidents reported under the Ionising Radiations (Unsealed Radioactive Substances) Regulations 1968[4] have been excluded because these regulations only apply to a small proportion of persons employed in establishments where unsealed radioactive substances are used and consequently would not be representative.

Reportable Incidents

Reportable incidents are defined as those reportable to HM Factory Inspectorate under the regulations;[1] namely

(a) Incidents where it appears that a person has received a radiation dose in excess of the maximum permissible dose specified in the regulations.

(b) Breakage or leakage or sealed sources.

(c) Lost or mislaid sealed sources.

Only category (a) is analysed and discussed. The word incident is used in preference to accident because most excessive exposures result from chronic causes rather than acute accident situations.

Notification

Where a dose assessment on a single film badge is in excess of the maximum permissible it is most unlikely that the incident remains unreported due to the close liaison between HM Factory Inspectorate and approved dosimetry laboratories. On the other hand where it arises from the summation of a number of film badge dose assessments over the calendar quarter the position is probably less satisfactory. It is, of course, impossible to assess whether significant numbers of persons not wearing film badges receive doses in excess of the maximum permissible, but the operation and enforcement of the various legislative requirements in the United Kingdom ensures that this is unlikely to occur.

Incident Analysis

Identification of genuine incidents

All reported incidents are investigated and analysed. Since there is an obligation on factory occupiers to report all apparently excessive doses, the first task is to separate the genuine incidents from the obviously false. Inevitably there is a grey area between the two categories where in spite of all efforts no specific circumstances can be identified to account for the film badge assessment. These doubtful cases, which are few in number, are included with the genuine incidents. Incidents which are found on investigation to be false are discarded from further consideration.

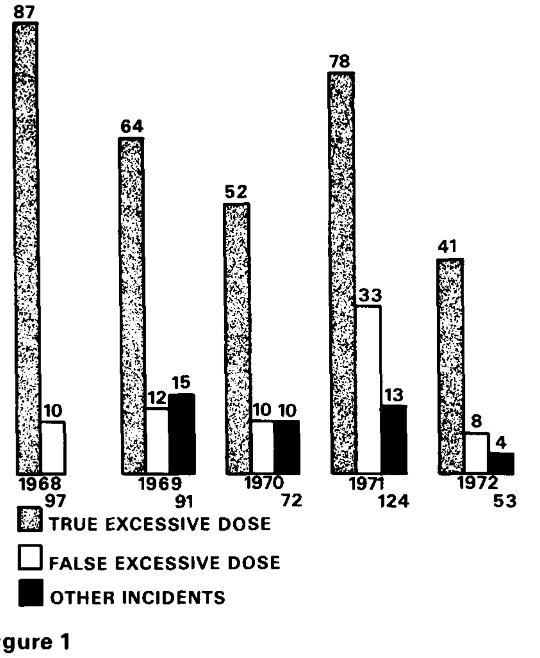

Figure 1
RADIATION INCIDENTS REPORTED TO H M F I

Figure 1 shows the number of incidents reported to HM Factory Inspectorate in the years from 1968 to 1972. There is no obvious trend in the number of genuine excessive exposures reported and analysed in the years quoted although the number in 1972 was the lowest so far recorded. The number of incidents which proved on investigation to be false remained fairly constant with the exception of 1971 when there was an abnormally large number arising out of two incidents involving twelve personal dosemeters. In one case seven film badges were accidently irradiated while not being worn when a radiographer was carrying out a radiograph during the night shift. In the other incident five film badges were exposed to organic vapours while being worn.

The other incidents shown in figure 1 refer to breakage or leakage of sealed sources or lost or mislaid sealed sources. All lost sources were eventually recovered.

Process and location

An analysis of the place at which incidents occur and the type of work involved is very useful in identifying the areas of risk and in allocating the limited resources available for inspection and enforcement.

Figure 2 shows the location of radiation doses in excess of the maximum permissible reported from 1969 to 1972. Whereas it was reported in 1969 that gamma radiography of pipelines was the major area of risk, the position has changed markedly. From a peak of 54% of the total in 1969, excessive exposures on pipeline sites had fallen to only 17% in 1972. This is partly due to a reduction in the total mileage of pipeline laid during this period and partly to the considerable increase in the use of X-ray Crawlers for pipeline radiography. There was however an increase in the use of sealed sources at engineering construction sites, for example, petro-chemical factories and power stations under construction or repair. Incidents arising from the use of ionising radiations in other processes show no significant pattern over these years.

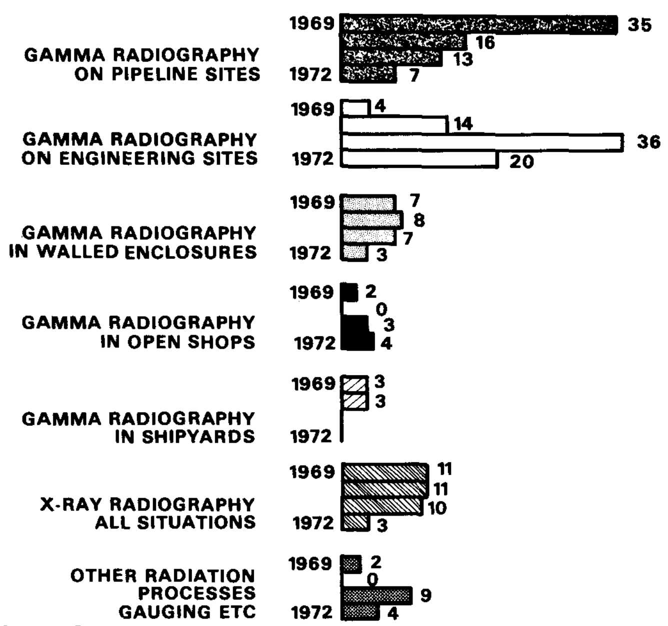

Figure 2
PROCESS/LOCATION OF EXCESSIVE RADIATION EXPOSURES

The situation for 1972 is summarised in figure 3. It shows that in spite of all efforts in the field of radiography, this process still accounts for 90% of all reported excessive doses. Gamma radiography accounts for the majority although X-ray radiography is widely used. A comparative review of the incidents associated with radiography on construction sites and in factories has been published.[5] That the other categories account for less than four incidents each suggests that a high standard of radiological protection exists in other processes using ionising radiations.

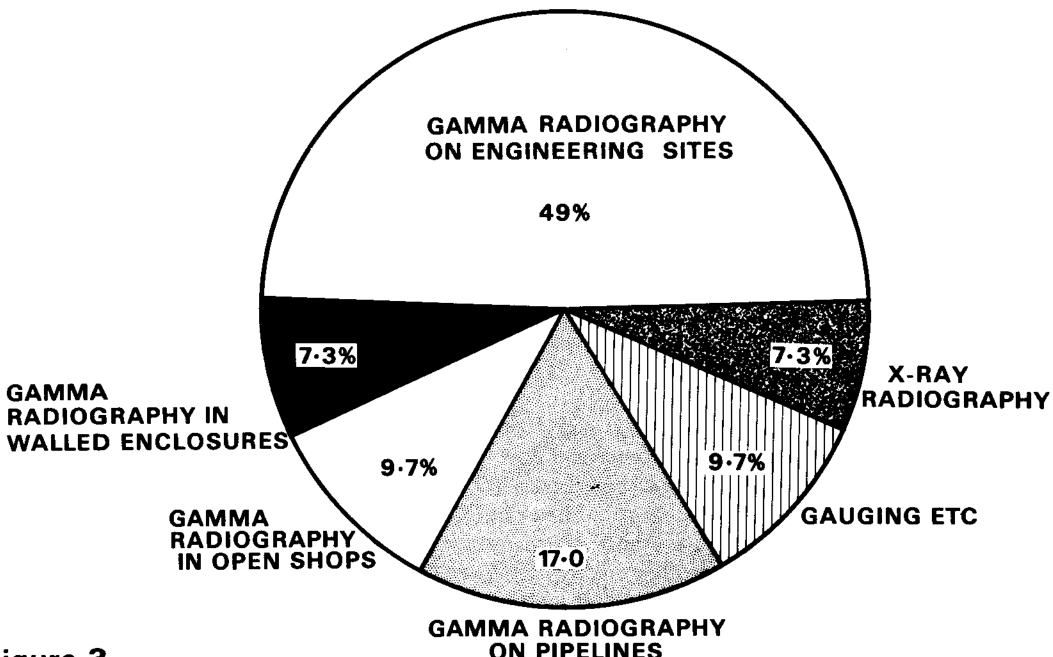

Figure 3
PROCESS/LOCATION OF EXCESSIVE RADIATION EXPOSURES IN 1972

Magnitude of radiation doses

Figure 4 gives an indication of the radiation doses received by the individual in the calendar quarter to which the report relates. These figures are normally those given by film badge dose assessments. However, in some cases a person was exposed to a grossly non uniform radiation field and the film badge did not give a reasonable indication of the dose to that part of the body most affected. In these cases the figures have been amended to show dose assessments to the organ of interest.

The table therefore contains those doses in excess of the maximum permissible to the whole body or to other parts of the body where these doses have exceeded the appropriate maximum permissible doses to that part of the body. The table should therefore be interpreted with care.

70% of the 1972 reports fall in the 3 to 5 rem range. These were usually chronic exposures resulting from a number of frequent increments of small doses accumulated over the calendar quarter giving a cumulative total in excess of the maximum permissible. These cases usually arise from long hours of work, unsuitable equipment, relatively unsatisfactory working conditions or methods of work.

DOSE RECEIVED	1969	1970	1971	1972
3·3·5 REM	11	8	17	13
3·5-5·0 REM	26	24	35	16
5·0-10·0 REM	12	8	11	4
10·0-25·0 REM	8	9	6	4
25-50 REM	1	2	1	2
50-100 REM	4	0	1	0
>100 REM	2	0	5	1
ACCURATE EVALUATION NOT POSSIBLE	0	1	2	1

Figure 4 MAGNITUDE OF EXCESSIVE DOSES

Doses in excess of 5 rems consist in the main of acute doses arising from a single relatively high dose received in one exposure due to accident conditions. All the radiation doses in excess of 100 rems were received either to the head or hands in extremely non uniform radiation fields. There were one or two circumstances over this period where it was not possible to make an accurate evaluation of the radiation dose received by the individual. In most of these cases the individual was not wearing a personal dosemeter.

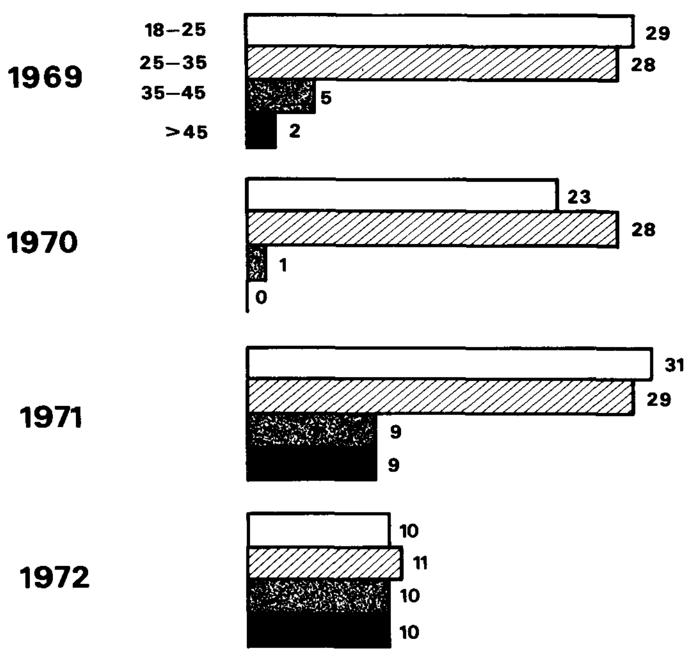

Figure 5 AGE GROUPS OF EXPOSED PERSONS

Somatic Injuries

Five cases of acute somatic injuries were reported during the period 1968 to 1972. Four involved finger burns as a result of handling sealed sources or source holders without handling tongs. In three cases it was estimated that the doses to the fingers were of the order of several thousand rems over fairly short periods. In the fourth case where the practice was carried out over many months biological dosimetry [6] gave an estimate of 200 rems as the equivalent whole body dose. In the fifth case, the cause of which was not clearly established, a dose of not less than 2,000 rems was received to the chest and it was estimated [7] that the equivalent whole body dose was between 70 and 105 rems.

Age groups of exposed persons

The proportion of excessive exposure to persons in the most genetically significant age groups, that is those up to twenty-five years old and those between twenty-five and thirty-five years old was considerably lower in 1972. (See figure 5). It is too early to say whether this trend is significant.

Incident causation

In terms of preventing the recurrence of an incident and to help in the allocation of limited resources available to users and enforcement agencies, causation is the most important factor in incident analysis. Unfortunately the categorisation of causation is a subjective process and is likely to be significantly affected by the attitudes of those involved. Following Catlin's paper [8] we reviewed and reorganised our classification system but we found that it was impracticable to allocate a primary cause to each event. Incidents cannot often be ascribed to a single cause and many are the result of a sequence of events which may involve errors on the part of the management or employee or failure of the equipment, each of which played an important part in the incident. For these reasons, three basic categories were chosen

Management error.
Operator error.
Equipment failure or malfunction.

Where more than one error in a particular category (for example, more than one management error) contributed to an incident, the most significant in relation to that incident was chosen.

Management error

Figure 6 shows that in 78% of the incidents reported in 1972 a management error contributing to the causation sequence was identified.

Equipment 34% of these incidents were ascribed to the provisions of unsuitable equipment. This category primarily relates to gamma radiography exposure containers and ancillary equipment used by itinerant radiographers. It is not always easy to provide operators with an optimum selection of such equipment together with suitable source types and strengths for a protracted series of tasks which may vary widely in scope. Nevertheless in our view a significant improvement in this area should materially reduce the number of incidents.

We have classified gamma radiography exposure containers into three categories; torch type, shutter type and projection type. The torch type

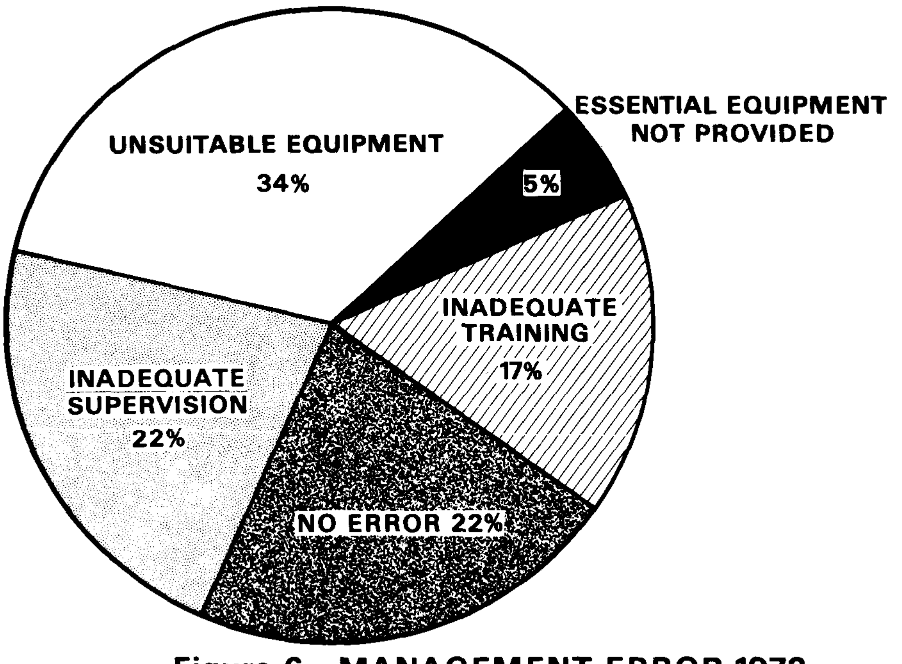

Figure 6 MANAGEMENT ERROR 1972

is the most frequently used due to its advantages of lightness, simplicity, robustness and flexibility in use. It does however suffer from the disadvantage that the operator needs to be relatively close to the source at the time of exposure. Good methods of work are therefore vital. Poor working practice leads to chronic excessive doses.

There have been several instances where insufficient shielding has been provided by the torch/castle combination of a radiography exposure container thus exposing the radiographer to high radiation dose rates. In another case a radiographer was provided with an exposure container which, when he arrived on the site after a long journey, was found to be too large to use in the working space available. In order to avoid delay the source was used without the castle and the radiographer received an excessive dose of radiation. Another common fault was the use of sources with too high an activity for a particular series of radiographic shots. This enables a very large number of shots to be carried out in a short time but invariably results in the radiographer receiving a higher radiation dose.

Shutter type containers are relatively light but slightly less robust since there are more working parts. They are however usually larger than torch type containers and sometimes it is necessary to remove the source from the container for difficult exposures . This is a delicate operation and can lead to chronic excessive exposures or, if the operation is mishandled, to an accident situation.

Remotely controlled projection type exposure containers are more expensive and usually much bigger and heavier. Unfortunately the equipment is often not robust enough for the very arduous conditions of use on site. This results in damage to the projection cable and the source is sometimes left in the projection tube when the operator believes it to have returned to its fully shielded position. This is often not discovered until much later. This accident condition gives rise to acute radiation doses in excess of the maximum permissible.

Figure 7 shows the number and type of exposure containers associated with excessive radiation exposures from 1969 to 1972.

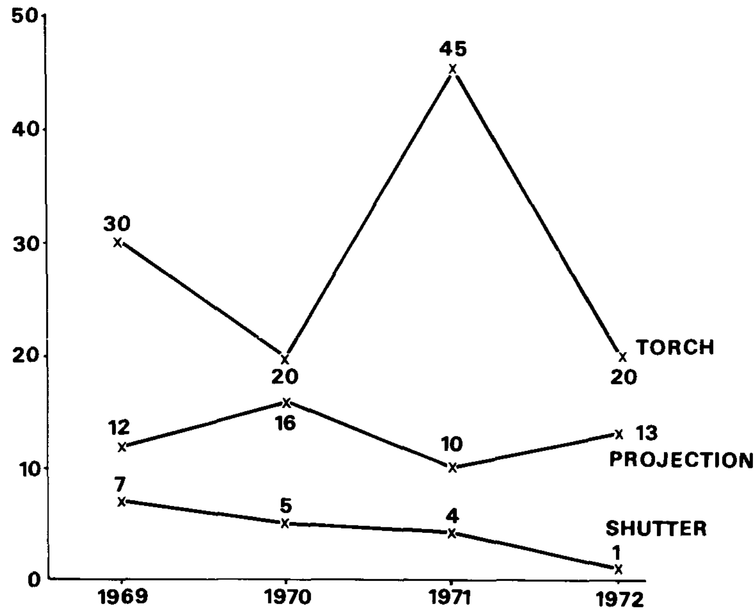

Figure 7 TYPE OF EXPOSURE CONTAINER

As we mentioned in a previous paper[3] it is our view that there is still considerable potential for the development of exposure containers and suitable accessories particularly for situations where access is difficult and clearance is limited. Unfortunately it is by no means easy to develop a performance standard for this equipment due to the variety of conditions in which it is used. Various recommendations by the International Labour Office, ICRP and the British Standards have amongst other criteria, specified the exposure rate at the outside of the closed container. This is useful in limiting the exposure of radiographers while the apparatus is in transit or temporary storage. However when one considers that the exposure rate outside a closed container may only be 20 mR/h while it may be 2,000 mR/h or more when the apparatus is in use it is quite obvious that the latter situation is the critical factor in determining the radiographers exposure.

In our radiation laboratory we are evaluating the protection afforded by a range of exposure containers both under conditions of use and storage with a view to determining parameters for a performance standard. We hope to publish a paper in due course.

Supervision Lack of supervision accounted for 22% of the excessive exposures. In most cases these incidents arose as a result of operators failing to use suitable techniques in the field. It is managements responsibility to ensure that the operators are trained to use approved techniques, and supervision is necessary from time to time to ensure that this is done. A careful and frequent check on radiation dose records will identify cases where special supervision is necessary.

Training Failure to provide adequate training for operators was still an important factor in the area of management errors. It still accounted for 17% of the excessive doses although this is a significant reduction from the 1970 figure of 40%. Some radiography contractors organise excellent training schemes. Others, particularly small firms have no formal training facilities themselves and rely on a combination of "on the job" training sometimes supplemented by external courses. Some of these courses are not orientated towards the detailed process knowledge or the technical equipment used for radiography and fail to demonstrate clearly and in simple terms the techniques of minimising radiation exposure under site conditions. We believe that formal training in radiological protection is essential. It should, nevertheless, be practically based on the equipment used by radiographers. We have sought the advice and help of the National Radiological Protection Board to improve the situation in this field.

Safety equipment The provision of essential safety equipment such as dose rate meters, warning signals and barriers was relatively satisfactory and did not contribute significantly to management errors.

Operator error

Most operator errors such as failure to monitor or the use of unsuitable techniques are related to management errors such as inadequate training or lack of supervision. Only wilful disregard of instructions, failure to use equipment provided and human error are wholly attributable to the operator. These are classified as other causes in figure 8.

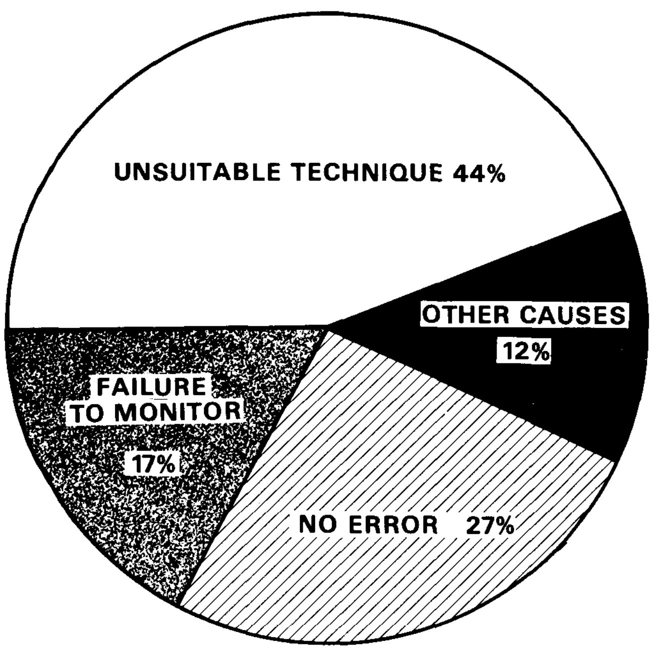

Figure 8 OPERATOR ERROR 1972

Unsuitable or poor techniques increased from 27% in 1971 to 44% in 1972. These were mainly associated with torch type exposure containers, for example, using sources of too high an activity or failing to retire to a safe distance during the exposure

Failure to monitor, usually in connection with a remotely controlled projection type exposure container accounted for seven (17%) of the incidents involving operator error. Two incidents were caused by radiographers failing to lock the exposure containers in the closed position before transportation.

For the first time since 1969 no worker handled a source holder directly.

Equipment Failure

Equipment failures or malfunctions are classified in figure 9. Equipment failure was identified as a contributory factor in 30% of the reports.

While these equipment failures were important factors in twelve accidents in 1972, excessive exposure would probably have been avoided in most cases if the operators had been adequately trained and had followed the correct procedures.

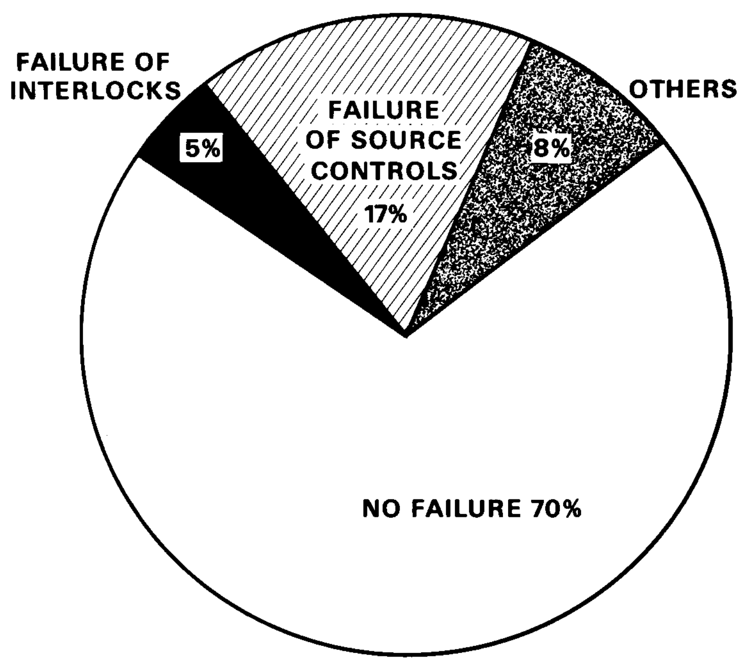

Figure 9 EQUIPMENT FAILURE 1972

Failure of source controls, that is sources becoming disconnected from remote control devices while exposed and shutters failing to close showed little variation at 17% of the total compared with previous years.

Interlock failures at X-ray enclosures contributed to 5% of the incidents in 1972. In terms of actual numbers this must be very small proportion of the total X-ray enclosures in use but this makes them all the more unexpected when they do occur. No failure of warning signals for X-ray enclosures were reported during the year.

Conclusions

Analysis of industrial radiation incidents in the United Kingdom shows that gamma radiography at engineering construction sites is now the type of work giving rise to most excessive radiation doses. The advent of X-ray crawlers appears to have reduced the risk on pipeline work. The frequency of excessive radiation doses in work other than radiography involving the industrial use of ionising radiations is very low.

Most excessive doses are in the range of 3 to 5 rems in a calendar quarter and are received chronically over the period rather than as a result of accident conditions.

We believe that greater attention needs to be paid by manufacturers to improving the design of gamma radiography equipment to provide better protection for the operator and to prevent failures under the arduous conditions of use. It would be helpful if a performance standard could be developed for this equipment to specify the protection which should be provided under conditions of use.

Users should select their equipment more carefully for the particular conditions of use and ensure that radiographers are adequately trained paying particular attention to minimising exposure under difficult field conditions and the procedures to be followed when accident conditions arise.

Acknowledgement

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References

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