REDUCING OCCUPATIONAL RADIATION EXPOSURES AT LWRs

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Abstract:

The paper reviews briefly the occupational radiation doses received by nuclear power plants personnel, during a period of several years of operation. Comparisons are made between the data for BWRs and PWRs in order to identify the more "critical" reactor type, from a radiological point of view. Attention is devoted to GCRs too.

Furthermore the areas which contribute most to personnel doses are considered and briefly reviewed. The main actions to be carried out in order to reduce occupational radiation exposures at LWRs are discussed.

1. INTRODUCTION

The problem of occupational radiation exposures in nuclear power plants has been receiving increased attention in the latest years. Light-water reactors, in particular, are affected by high radiation levels in areas with high occupancy factors, what results in high occupational doses, as compared with doses absorbed by workers in other reactors, e.g. GCRs.

This fact highlights the importance of controlling, limiting and possibly reducing the radiation detriment to personnel during the operation and the maintenance of LWRs.

In order to reduce occupational doses we must have a realistic picture of the existing situation; in this paper we shall examine such a picture of the occupational radiation exposures at LWRs, with also the aim of identifying the reactor type that is more "critical" from a radiological point of view.

Attention is briefly devoted to the occupational doses in gas-cooled reactors, as compared with LWRs.

In addition we shall try to identify the factors which affect the doses at LWRs, on which it is possible to act in order to reduce them.

2. ANNUAL COLLECTIVE DOSES

The dose data examined refer to 29 BWRs and to 40 PWRs of the western world, ranging from 150 to 1150 MW(e). Such data were obtained from about 100 reports and from informat ions directly collected by the Authors in 20 plants.

The reported values refer to the mean collective doses; variations in the doses, observed in different plants, may reflect either basic differences in the plant design or particular operational problems. Anyway if the differences in occupational exposures among similar LWRs could be traced to differences in plant design, rather than to accidental causes, it would help in designing better plants in the future.

The examination of the average annual radiation detriment allows to make a first evaluation of the radiological risk connected with the operation and maintenance of the plant; the time trends of the average collective dose equivalents are of particular interest in assessing the influence of plant age on the occupational hazard.

2.1. Light-water-cooled reactors

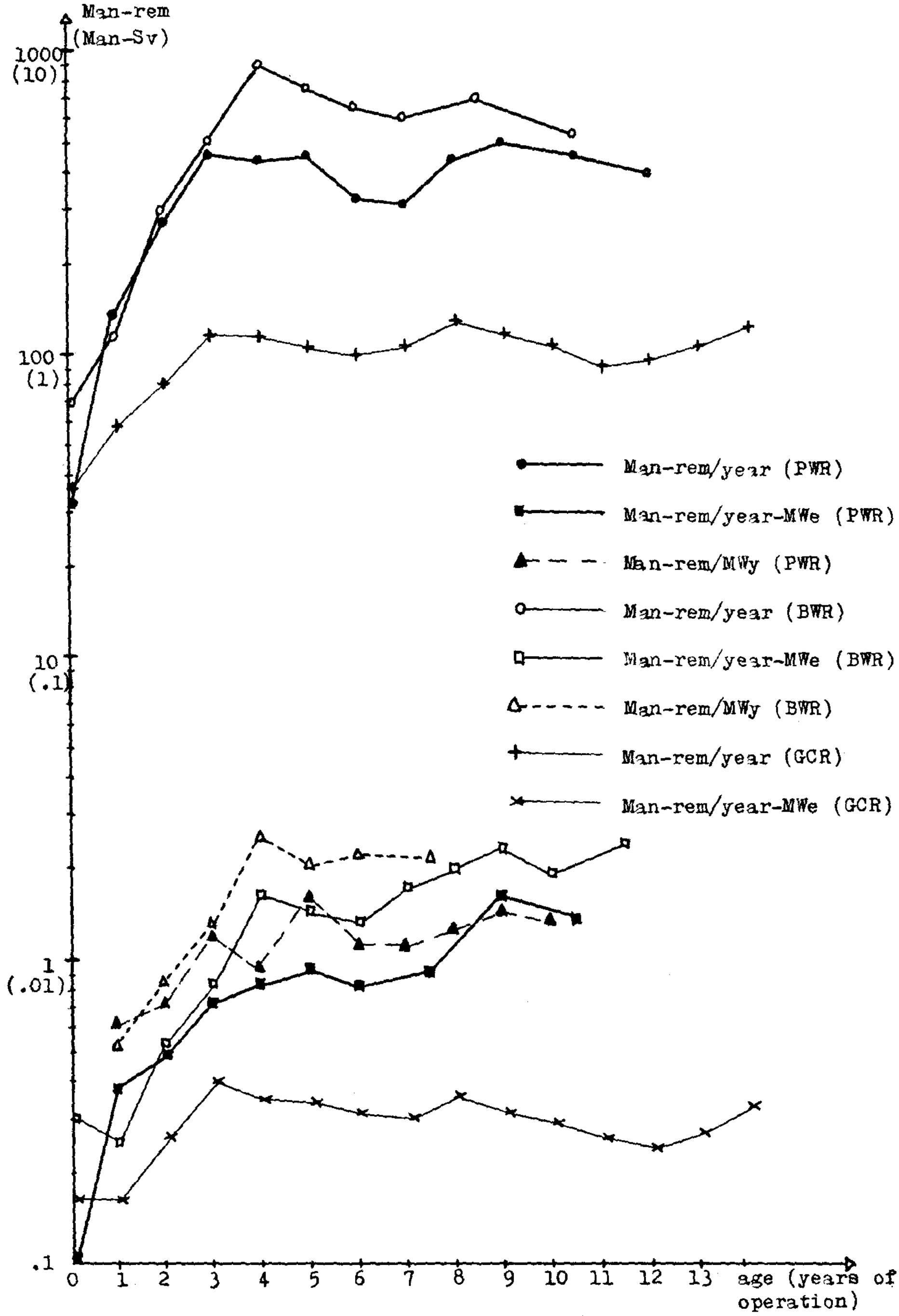
The general trend, during plant life, of the mean values of man-rem/year, man-rem/year-MW(e) and man-rem/MWy per reactor unit is examined. The two latest variables were considered in order to evaluate the radiological cost of the produced energy and of the installed power. The results are reported in fig. 1 and in table I for all the 69 LWRs..

Moreover, the 56 LWRs with electric power greater than 400 MW(e), which belong to newer generation, are examined (tab. I), in order to make an intercomparison between the radiological hazard in them and in all the LWRs.

2.1.1. Man-rem/year

The annual collective dose per reactor unit has a mean value, calculated over all the years of operation of the plants, equal to 370 man-rem/year in BWRs and to 315 man-rem/year in PWRs.

The behaviour of the average dose as a function of the plant age shows that, after an initial upward period of about four years, it seems to reach a levelling off value of about 600 man-rem/year in BWRs and of about 450 man-rem/year in PWRs (fig. 1). These data refer to about 300 reactor-years.



Man-rem
(Man-Sv)
1000
(10)
100
(1)
10
(.1)
1
(.01)
.1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
age (years of operation)
Man-rem/year (PWR)
Man-rem/year-MWe (PWR)
Man-rem/MWy (PWR)
Man-rem/year (BWR)
Man-rem/year-MWe (BWR)
Man-rem/MWy (BWR)
Man-rem/year (GCR)
Man-rem/year-MWe (GCR)

FIG. 1

2.1.2. Man-rem/year-MW(e)

In order to consider on the same basis the nuclear power plants with a different electric power, we examined the annual mean collective dose normalized at the installed electric power.

The average values, for all the years of operation, are about 0.93 man-rem/year-MW(e) at BWRs and 0.75 man-rem/ /year-MW(e) at PWRs.

The time trend shows that, after an initial increase in the first 4 years of operation, the mean annual collective dose per electric power unit increases slightly from 1.5 to 2.0 man-rem/year-MW(e) in BWRs and from 0.8 to 1.3 man-rem/year-MW(e) in PWRs, during the following six years (fig. 1).

2.1.3. Man-rem/MWy

The behaviour in relation to age of this variable (fig. 1) shows that, after the remarkable increase during the first 4 ÷ 5 years of operation, there is a levelling off at a value of ~ 2.4 man-rem/MWy in BWRs and of ~ 1.3 man-rem/ /MWy in PWRs.

Table I describes the situation of occupational doses at BWRs and PWRs. It is possible to see that the LWRs with electric power greater than 400 MW(e), which are also of new type, present a more favourable situation from a radiological point of view.

For what concerns the difference between occupational doses at BWRs and PWRs, at present time PWRs are responsible for lower doses: the difference between all BWRs and PWRs ranges from 16 % to 87 %, while for BWRs and PWRs of the new generation the difference ranges from 41 % to 108%, as far as the annual collective doses are concerned.

2.2 Gas-cooled reactors

In order to make a comparison between occupational radiation exposures in LWRs and in GCRs we considered the average annual collective doses also in these reactors.

Figure 1 shows the remarkable difference between the doses at LWRs and at GCRs: the mean values in GCRs, after about three years of operation, are about 100 man-rem/year per reactor unit and about 0.3 man-rem/year-MW(e). These values are calculated over 18 plants ranging from 150 to 590 MW(e).

TAB. I : Comparison between the mean values of annual collective doses in BWRs and PWRs

	All LWRs			LWRs > 400 MWe (new generation)		
	BWR	PWR	Δ *	BWR	PWR	Δ *
- Man-rem/year (for all the years of operation)	370	320	16 %	510	340	50 %
- Man-rem/year (after 4 ÷ 5 years of operation)	600	450	30 %	1000	480	108 %
- Man-rem/MWy (after 4 ÷ 5 years of operation)	2.4	1.3	85 %	2.2	1.1	100 %
- Man-rem/year-Mwe (for all the years of operation)	0.93	0.75	24 %	0.72	0.51	41 %
- Man-rem/year-MWe (after 4 ÷ 5 years of operation)	1.5÷2	0.8-1.3	87÷54%	1.5	0.8	87 %
- Rem/year per individual (for all the years of operation)	0.74	0.70	6 %	0.71	0.65	9 %

* The percentage difference Δ is referred to the dose value in PWRs :

$$\Delta = [Dose(BWR) - Dose(PWR)]/Dose(PWR)$$

3. ANNUAL INDIVIDUAL DOSES

Achievement of low collective doses is a desirable objective but it is not sufficient, as it could be achieved by having available a number of well-trained and skilled workers who could accumulate high individual doses.

On the contrary, the control of individual doses alone could be achieved by having available a large number of workers so as to share the dose among them; but in this way the total dose to personnel might be increased.

Only an adequate balance between the two requirements, individual doses reduction and collective dose reduction, can reduce the detriment to workers due to the operation and maintenance of the nuclear plant; for this reason, in addition to the collective doses, the individual doses also must be controlled and reduced. So our survey was extended to the examination of average annual individual doses at BWRs and PWRs: in this case also the situation is more favourable to the pressurized reactors. The mean annual individual dose, for all the years of operation, is about 0.74 rem/year at BWRs and 0.70 rem/year at PWRs, as reported in table I.

4. REDUCING OCCUPATIONAL EXPOSURES AT LWRs

As the ALARA criterion is difficult to be applied in the practice, mainly owing to the lack of a methodology for assessing the economic impact of the man-rem, another approach might be attempted; this process includes a review of the occupational doses with the aim of ensuring that the design and operating methods are such that the exposures are reduced.

A comprehensive program to reduce occupational radiation exposure at the new plants should be made of several measures that should act on various areas (fig. 2). The measures to be taken during the design stage should regard layout, ventilation, structural materials, monitoring, radioprotection program, and so on, while some of the action areas for consideration are:

1) reduction in maintenance and inspection time;
2) reduction in radiation fields;
3) reduction in failure rate of components;
4) contamination control.

The first area would include improved accessibility, which can be obtained by acting on the layout, and careful maintenance planning.

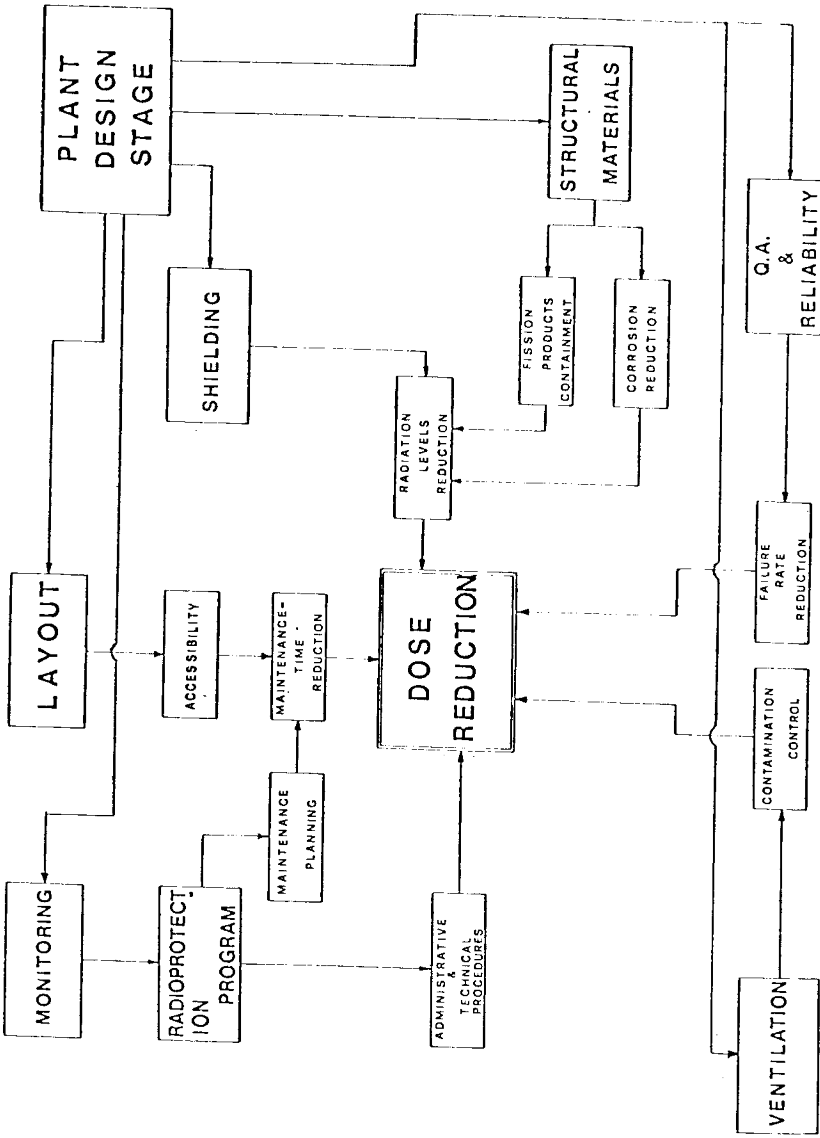


FIGURE 2 : SOME WAYS TO REDUCE THE OCCUPATIONAL DOSES

The layout of the plant, that is the arrangement of the buildings, of the working areas in them and of the components and equipment in the rooms, is a very important factor as the availability of space, improved accessibility and easiness of maintenance can reduce the maintenance time, optimize the radiation fields configuration and so reduce the collective and individual doses. In particular, potentially high radioactive components, that may require frequent maintenance throughout plant life, should be given a high priority in the plant design stage as to allocation in areas with low radiation and contamination levels and separation from other components.

The maintenance planning, that must be an important part of the radioprotection program, should include preventive maintenance programs which could lead to better use of time during shut-down and to dose reduction.

The second goal can be achieved by the use of adequate shielding, both permanent and temporary, and by materials selection in order to contain fission products and to reduce the formation of crud; also the cobalt content of materials must be limited.

The third area would include materials selection for durability and improved reliability especially of equipment with high radiological risk.

Finally the contamination control can be achieved by an adequate and flexible ventilation system, as well as "air-lock" doors.

At the plants already in operation the reduction of the doses can be achieved by an adequate maintenance planning and by suitable administrative and technical procedures established on the basis of the informations given by the monitoring system.

CONCLUSIONS

The occupational radiation exposures received by nuclear power plants personnel afford a method by which the level risk of workers can be evaluated and the "critical" reactor type can be identified; in addition the dose analysis is a useful tool by which the effectiveness of the measures used in a radiation protection scheme may be judged.

It is the Authors' belief that the implementation of the above-considered design measures, evaluated together through a balanced program, is a practicable approach that can lead to considerable savings in terms of occupational radiation exposure.