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THE INTERNATIONAL EFFORTS TO REDUCE OCCUPATIONAL RADIATION EXPOSURE AT NUCLEAR POWER PLANTS

by

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Abstract

Staff at the ALARA Center of the Brookhaven National Laboratory have been carrying out a number of projects on occupational dose reduction for the Nuclear Regulatory Commission. One of the objectives of this program is to examine the international research efforts at reducing occupational radiation exposure. Thus the efficacy of various national programs on dose reduction is being examined with a view to evaluating the most significant factors that help in reducing occupational exposure. Among the most successful of the dose reduction programs at water reactors are those of France, Sweden, and Canada where average annual plant doses are significantly less than the dose at U.S. plants. Important research is also going on in other countries such as the U.K., West Germany, Switzerland, and Japan. Some programs are directed towards hardware solutions; others are oriented towards such approaches as better work planning and procedures. The general thrust and some of the specifics of these programs are examined and factors which may be applicable to U.S. conditions are discussed.

1 Introduction

Staff at the ALARA Center of the Brookhaven National Laboratory are carrying out a number of projects for the United States Nuclear Regulatory Commission. The principal objective of this program is to examine occupational exposure in U.S. nuclear power plants and to explore ways to minimize it.

In one project, which is now complete, occupational exposures from nuclear power plants in a number of countries were compared with the exposures obtained in the United States, and the reasons behind the reduced doses in some countries were examined. The results are outlined in the report NUREG/CR-4381 (1).

Another project, currently in progress, is an offshoot of the comparative study of foreign and U.S nuclear power plants. This project seeks to develop a data base on dose reduction research world-wide. It is also intended to evaluate each project on the data base from the point of view of its impact on dose reduction and to determine areas where increased research may be necessary. An additional objective of this project is to make the data base available to all contributors. Thus exchange of information on dose reduction research will be possible among researchers worldwide. The first report on the data base is in print (NUREG/CR-4409), (2) and the second will be issued shortly.

In this paper we will use the information obtained from these projects. First, occupational exposures at U.S and foreign nuclear power plants will be compared. Next, the principal factors that seem to affect occupational doses will be considered. Finally, we will briefly examine the occupational dose control programs of some selected countries which are successful in exposure reduction, to see if we can learn from their experience.

2 Comparison of World Water Reactor Occupational Exposures

Figure 1 shows the occupational exposures at pressurized water reactors in a number of countries, including the United States. The yearly collective dose equivalent per MWe has been averaged over five years in the figure. Note that several countries have collective occupational exposures significantly below those in the United States. The lowest occupational doses are found in France, Sweden, and Canada. In Canada, of course, the reactors are of the pressure-tube heavy-water CANDU type.

As an aside, it may be of interest to compare the occupational exposures in the West with the doses at Soviet pressurized water reactors. It should be pointed out that the data are not directly relevant because of the very different design philosophies behind the Soviet Reactors. A standard Soviet 440-MWe PWR has an annual occupational dose of 380 man-rem per year. Figure 2 shows how this dose is divided. Of the 380 man-rem plant dose, normal operation accounts for 130 man-rem and refueling for another 35 man-rem (3). The 215 man-rem used on maintenance tasks is rather high compared with Western PWRs. Their yearly collective dose equivalent is around 1 man-rem per MWe-yr.

Looking quickly at comparative boiling water reactor dose data , one sees that here again the U.S. plant dose is on the high side (Figure 3).

Thanks to information obtained from the Electric Power Research Institute, we have data up to 1985 for the United States (4). Figure 4 shows the data for PWRs. Figure 5 displays the BWR data, which are somewhat similar. It is seen that occupational exposures have been reduced appreciably in the United States during the last year. This is due to several factors: for example, capacity factors have risen during this period, and such an increase always reduces radiation exposures, since less maintenance work is possible with the reactors on-line. Moreover, occupational exposures due to such required activities as seismic upgrading and fire protection, which accounted for 40% of dose between 1979 and 1983 (5), have diminished in 1985. Lastly, it appears that the years of research in the area of dose reduction are at last beginning to pay off.

It may well be that in some cases the doses at U.S nuclear power plants are, in fact, in compliance with the ALARA principle. To prove this would require a cost-benefit analysis, and one of our projects is concerned with exploring this aspect (6).

3 Factors Affecting Dose at Water Reactors

Figure 6 outlines what we at the ALARA Center believe to be the most significant factors affecting occupational exposure at water reactor power plants. We have assigned a weight to each factor, based on a large number of case studies of nuclear plants. The assigned weight is the ratio of the dose at a hypothetical plant with poor control of that factor to the dose at a plant where the control is good. The product of the weights is around 100. Thus the doses at a power plant with optimum performance in all these factors, compared to those at a plant with poor control, should differ by a factor of about 100. Obviously no plant of either category exists, but one can see why doses between different power plants can vary by factors of up to 10 or more.

4 Some Findings of the International Exposure Reduction Research

We will now examine the exposure-reduction research of a few selected countries to see what can be learned from each. Obviously, considerable research is being carried out in many countries, as well as in the United States. For the sake of brevity, we shall confine ourselves to one or two important contributions from the countries we have chosen for this presentation.

4.1 Canada

Canada has developed its own CANDU reactors. A large development program related to the CANDU is under way which includes remote pressure-tube replacement, water chemistry, decontamination, and many other practices (7,8). Although many of these techniques may be adapted to U.S reactors, we will examine only those aspects of the program that are directly related.

One particularly interesting area of research is concerned with pre-operational chemical cleaning of PWRs. In the usual hot conditioning of pressurized water reactors, a double-layered oxide film is formed. The first layer protects against corrosion but the second layer traps activity. In a project under way at the Chalk River Laboratories, film composed of only the inner desirable layer has been grown on stainless steels and Inconel. When the films were exposed to corrosion products, growth of the outer layer was inhibited (7).

The Canadian program is also directly relevant to the methods of radiation protection and contamination control used during operations and maintenance. To consider a few of the practices followed, all operations personnel at Canadian power plants are given a fairly advanced course in radiation control. They are then made responsible for their own radiation protection. They may designate contaminated areas, carry out radiation monitoring, fill out radiological work plans, etc. (8,9).

Strict contamination control is practiced by establishing zones with different levels of contamination throughout the plant. Before going on duty, the plant workers enter a change area where plant-issued work clothing and shoes are donned. At the end of the shift, they return through the same area, where they leave their clothing at the attached laundry, and then pass through showers and monitors before they may reclaim their street clothes. Such practices have not only kept doses at very low levels but have also maintained a high level of contamination control.

4.2 West Germany

The principal lessons to be learned from the work in West Germany are concerned with proper material selection. One of the most serious problems encountered in boiling water reactors in nearly all countries is intergranular stress-corrosion cracking of the austenitic stainless steel piping. This has resulted in the accumulation of large doses during pipe replacement, maintenance, and inspections. Only the West German boiling water reactors are immune from this problem, because niobium-stabilized austenitic stainless steel is used in their contruction (7,10).

In the steam generators of their PWRs, the Germans have used Incoloy 800 (7). This material is highly resistant to steam generator cracking and has low cobalt content. Both characteristics are of course very desirable from the viewpoint of reduced exposure. At the present time, the West Germans are offering to replace steam generator tubes with Incoloy 800 tubes as a service to other countries (7). For tube replacement, they use fully automatic welding devices to reduce dose.

They have also determined, in a recent careful study, that radiation fields at PWR plants may be reduced by using zircaloy instead of Inconel fuel assembly spacers. The Inconel spacers currently in use have significant cobalt content. Since this cobalt is resident for long periods in the neutron flux, the result is a considerable increase in cobalt-60, and hence in radiation fields (11).

4.3 Sweden

An industry team from the United States recently toured Sweden to evaluate their radiation control program (12). Figure 7 shows some of the factors which this team thought contributed to low personnel exposures, among them: (a) a strong management commitment; (b) plant design and modifications to reduce exposures; (c) staffing, training, and work planning; (d) chemistry control; (e) regulatory environment.

Management commitment is emphasized in a variety of ways as shown in Figure 8. This commitment is reflected in the design and operation of the power plants, as well as in all levels of management. Personnel exposures are discussed in the annual report and are a subject for corporate management oversight. Goals are set and everyone at the plant from the plant manager to the maintenance worker has a responsibility to limit occupational exposure.

Some of the most significant contributions from Sweden in the area of dose reduction are in water chemistry (7,10,13). In PWRs they have been at the forefront of the thinking that operating in the realm of elevated pH for the primary coolant will reduce radiation fields significantly (13). Almost all countries are now beginning to follow this lead, and the dose rates at the newest Swedish PWRs are a fine example of how much radiation fields can be reduced if good water chemistry is used from the beginning. Steam generator channel head dose rates are a yardstick for radiation fields and doses at PWRs. Although radiation fields in channel heads in other countries are typically around 20 R/h, the newest Swedish reactors have channel head fields between 2 and 3 R/h.

4.4 Switzerland

Since intergranular stress-corrosion cracking is much harder to detect than the more common cracking due to metal fatigue, it is extremely important to carry out quick and accurate inspections. Inspections must be quick because of the large doses received during these inspections. The ultrasonic inspection technique developed by the Swiss is extremely accurate and reasonably rapid. In round robin tests of a number of testing teams, the Swiss team was at the top (14). They intend to mechanize the testing and the presentation equipment as a future development (7).

4.5 United Kingdom

The United Kingdom's nuclear power reactors have so far been mainly gas cooled. This type of reactor is known to be benign as far as occupational doses are concerned. The U.K.'s first PWR will be a Westinghouse reactor with certain advanced features such as improved plant layout and materials with a low cobalt content. They do have a significant research program on water reactors, much of it sponsored by EPRI.

The British have developed a decontamination process called LOMI (for Low Oxidation State Metal Ion) (7,15). It has proved to be extremely gentle to BWR materials and its modifications have also been used successfully on PWRs. The British, and the Canadians with their CAN-DECON process, are the only countries that have decontaminated the complete reactor primary system with the fuel in place. The results have been excellent, with typical decontamination factors of about 6, (16) and the resultant radiation fields have been exceedingly low.

At the present time the goal of the British is to develop a decontamination process with nearly zero waste (16).

5 Conclusion

The superior performance of the foreign power plants is of course partly due to the lessons learned from many reactor-years of experience accumulated in the United States. However, important new research programs are also in progress abroad, and it is time that the U.S. profited from this experience, not only in the design of the new generation of U.S water reactors but also in developing techniques to mitigate the problems in the present generation of power plants.

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Fig. 1: COLLECTIVE DOSE EQUIVALENT

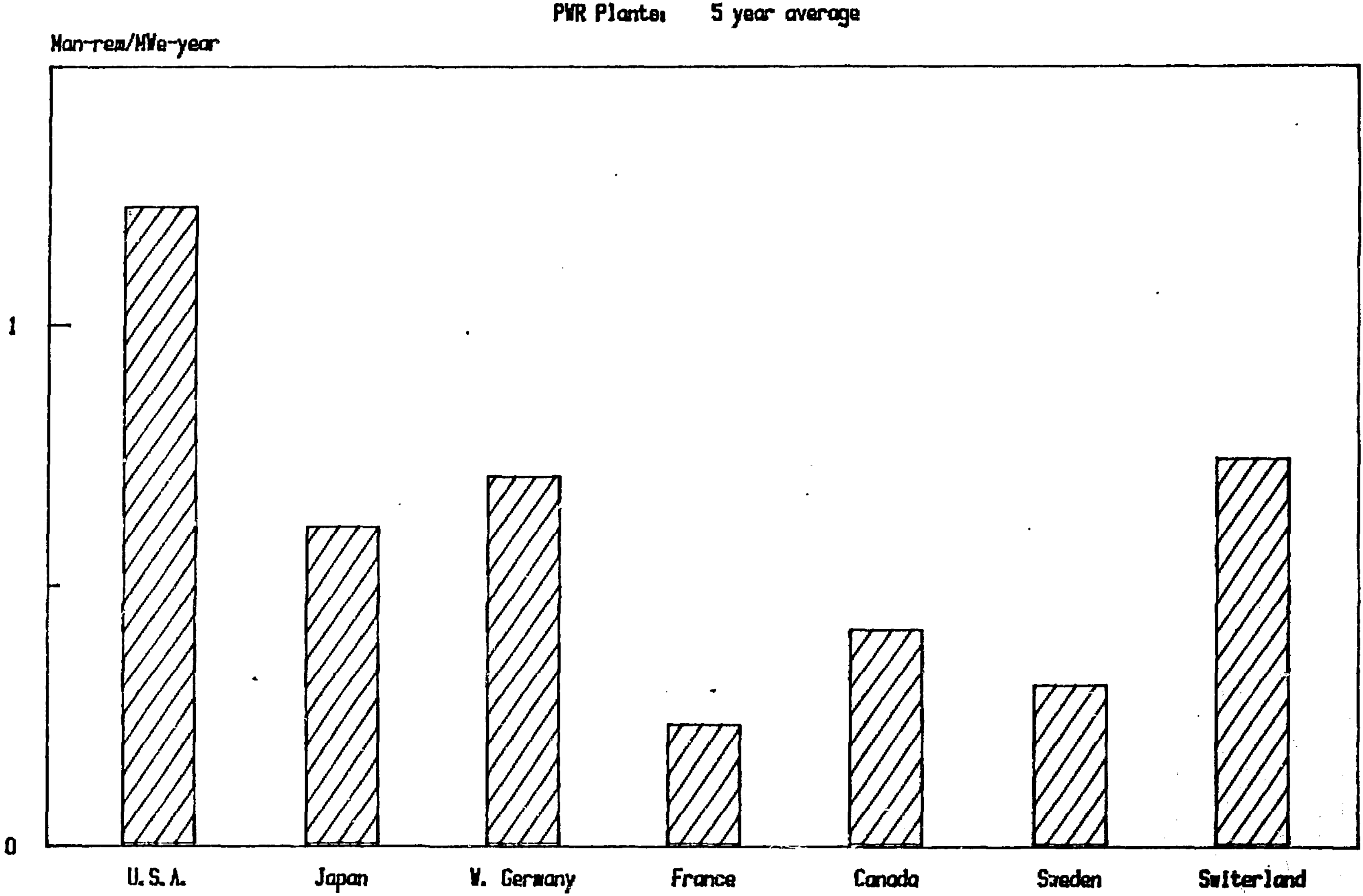


Fig. 2: Soviet PWRs

Collective dose equiv./plant=380 rem

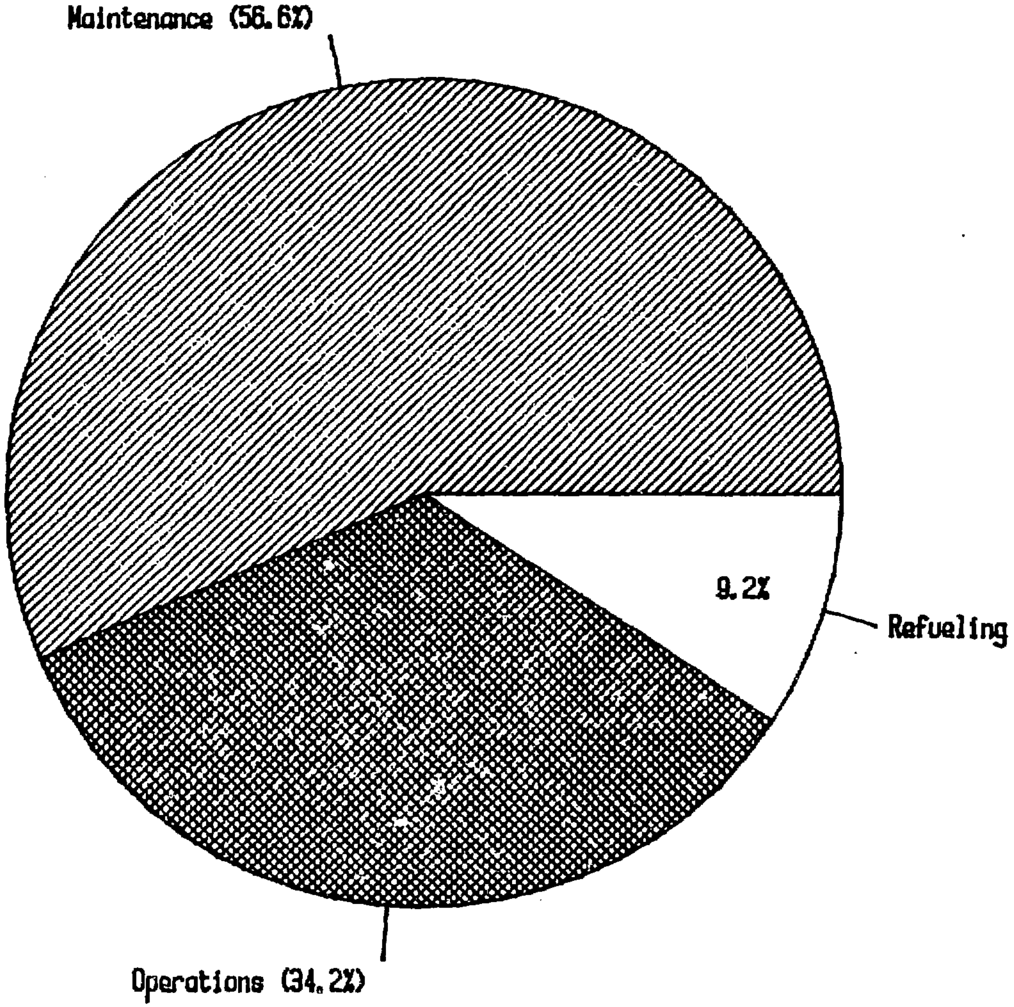


Fig. 3: COLLECTIVE DOSE EQUIVALENT

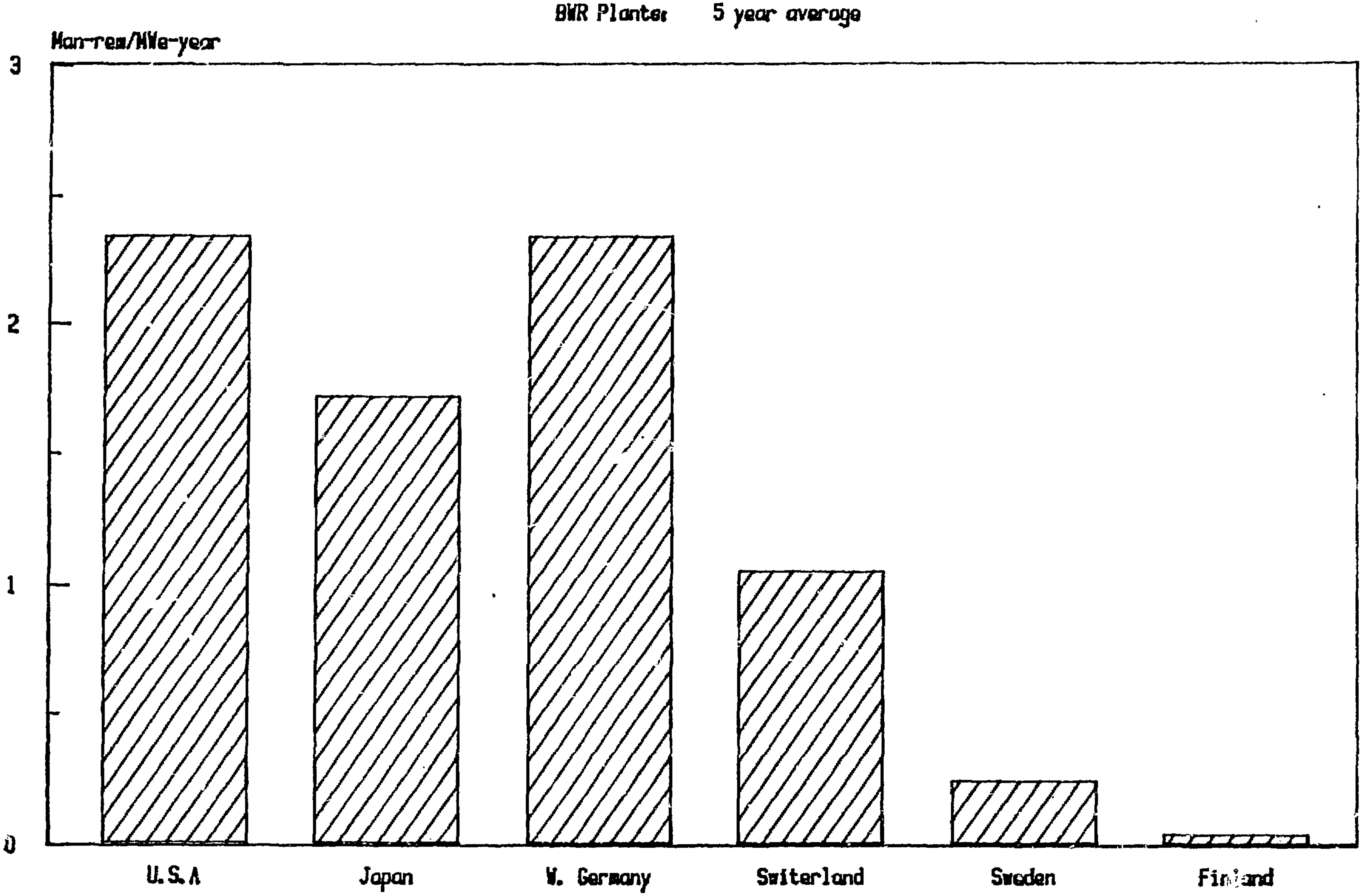


Fig. 4: COLLECTIVE DOSE EQV. vs YEAR

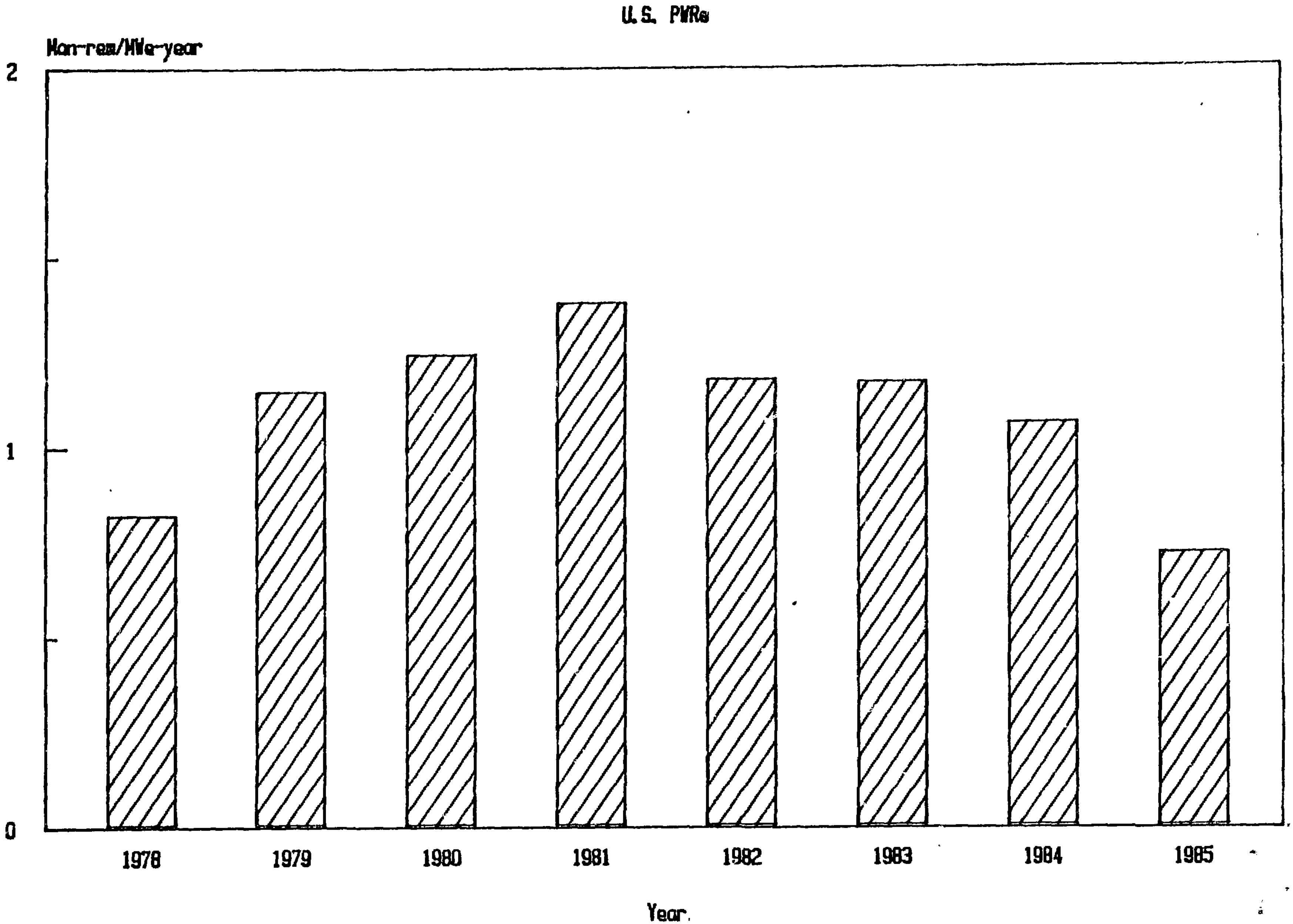
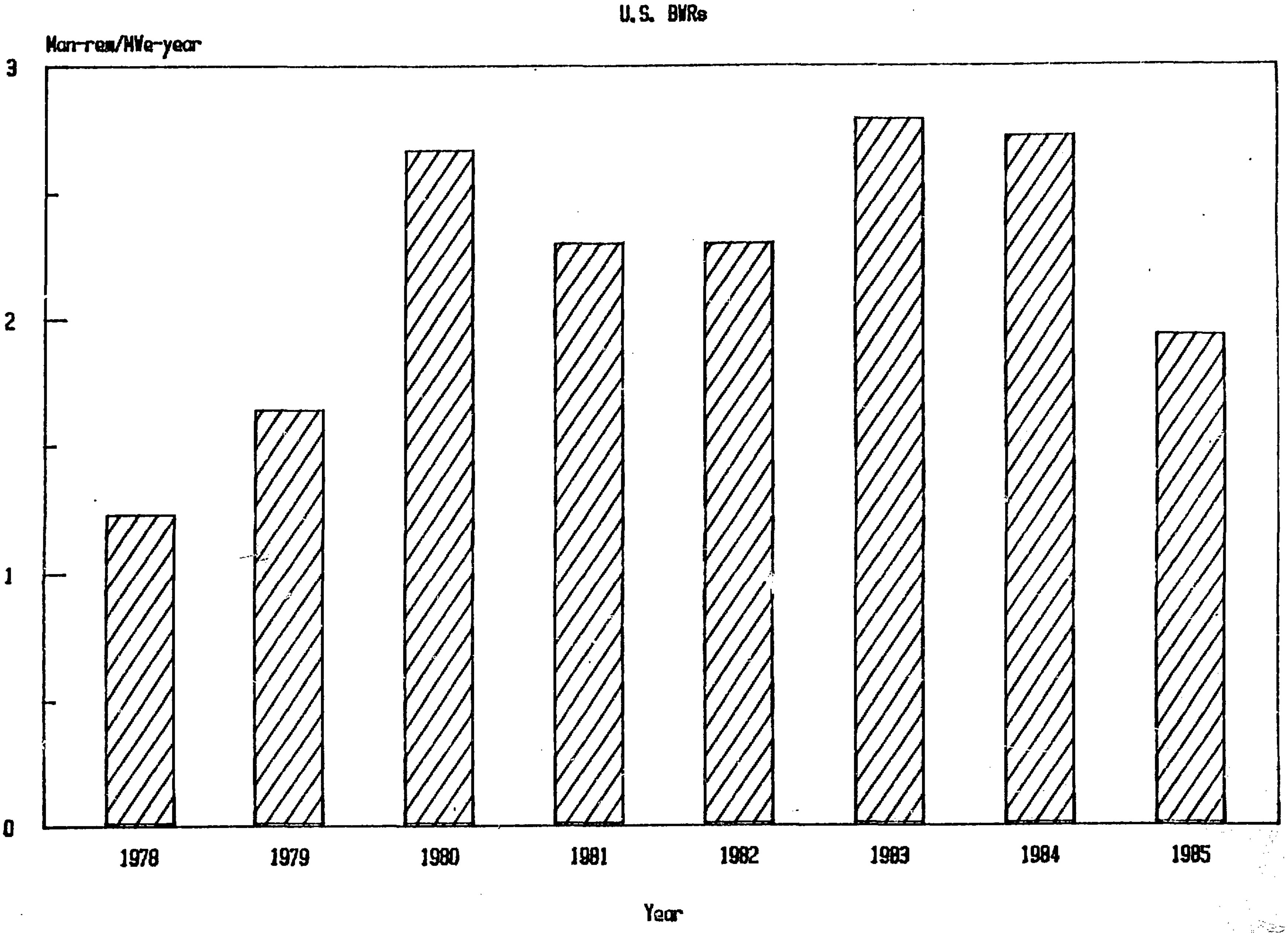


Fig. 5: COLLECTIVE DOSE EQV. vs YEAR



FACTORS THAT AFFECT DOSE AT NUCLEAR POWER PLANTS

	WEIGHTS
* Water Chemistry	1.7
* Water Purification	1.6
* Reduced Cobalt	1.6
* Robotics, Special Tools, Remote Surveillance	1.5
* Decontamination	1.5
* Backfits	1.4
* Worker Motivation	1.3
* Permanent vs Transient Work Force	1.3
* Management Commitment	1.3
* Multiple Reactors per Site	1.3
* Reliable Design	1.3
* Passivation	1.2
* Quality Assurance	1.2
* Standard Plant Design	1.2
* Shielding, Segregation of Active Components	1.2
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Figure 6

SWEDEN'S NUCLEAR POWER PROGRAM

FACTORS THAT LEAD TO LOW OCCUPATIONAL EXPOSURE

- A strong management commitment
- Plant design and modifications to reduce exposure
- Staffing, training and work planning
- Chemistry control
- Regulatory environment

Figure 7

WAYS MANAGEMENT USES TO EMPHASIZE ITS COMMITMENT TO EXPOSURE REDUCTION

* In the design of the power plant
* In operation of the plant
* At all levels of management
* Personnel exposures form an important section of the Annual Report.
* They are a subject of corporate management oversight
* Goals are set
* Everyone from Plant Manager to maintenance worker has a responsibility to reduce exposure

Figure 8