PERSONNEL MONITORING AROUND THE CERN HIGH-ENERGY ACCELERATORS

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Abstract—The present methods of personnel monitoring applied near the CERN high-energy accelerators are reviewed. This includes the technical as well as the administrative procedures in use. Results of statistical analyses of the data are presented, discussed and compared with data obtained from radiation survey measurements. The apparent limits of validity of the system are deduced and discussed with a view of possible improvements.

INTRODUCTION

Sources of radiation of all kinds exist in the CERN site. Some are classical, such as radioactive isotopes used to calibrate and check detectors and others arise from the induced radio-activity in the accelerators. In addition, there is the stray radiation resulting from the operation of the accelerators. This either emerges through the main shielding or comes from experimental areas when primary or secondary beams are used for experiments.

The radiation hazard at the various places is estimated by frequent and extensive radiation survey measurements.[1] According to the results obtained it is possible to divide the CERN site into two main regions as shown in Fig. 1. However the greater part of the Laboratory is not considered as a radiation area and this explains why about half of CERN staff are not classified as radiation workers and therefore are not subject to regular personal monitoring.[2]

The CERN radiation workers are defined in accordance with the Recommendations of the ICRP, that is, those people working in an area where a dose-rate exists that could give to an individual a yearly dose exceeding 1.5 rem.[3] Due to the existence of very high local dose-rates in some of these areas, people occasionally carrying out special work in these areas are also considered as radiation workers.[4]

Before a newcomer or a CERN staff member is classified as a radiation worker, he has to go through a medical examination including haematology tests, the results of which are used for a medical clearance for the radiation worker. Routine medical examinations are made at regular intervals in order to avoid confusion as to the origin of an eventual future illness.

All newcomers when arriving at CERN visit the Health Physics Group where information is given about the radiation hazard at CERN and the relevant precautions to be taken. The previous radiation history of the new staff is investigated and information collected from previous employers. The Health Physics Group also decides whether or not a person should be considered as a radiation worker depending on the proposed nature of the work and his location within the Laboratory.

THE RADIATION AREAS AT CERN AND THE PERSONNEL MONITORING

The radiation encountered at CERN varies in nature and energy as well as in distribution from one place to another.[5] It also varies with the mode of operation of the accelerators. Figure 2 gives an overall picture of dose-rates and Quality Factors (QF) at various places during the operation of the proton-synchrotron. The composition of the radiation and the ratio of the different components also vary from one place to another.

Figures 3 and 4 show typical dose-rates due to the induced radioactivity inside the machine

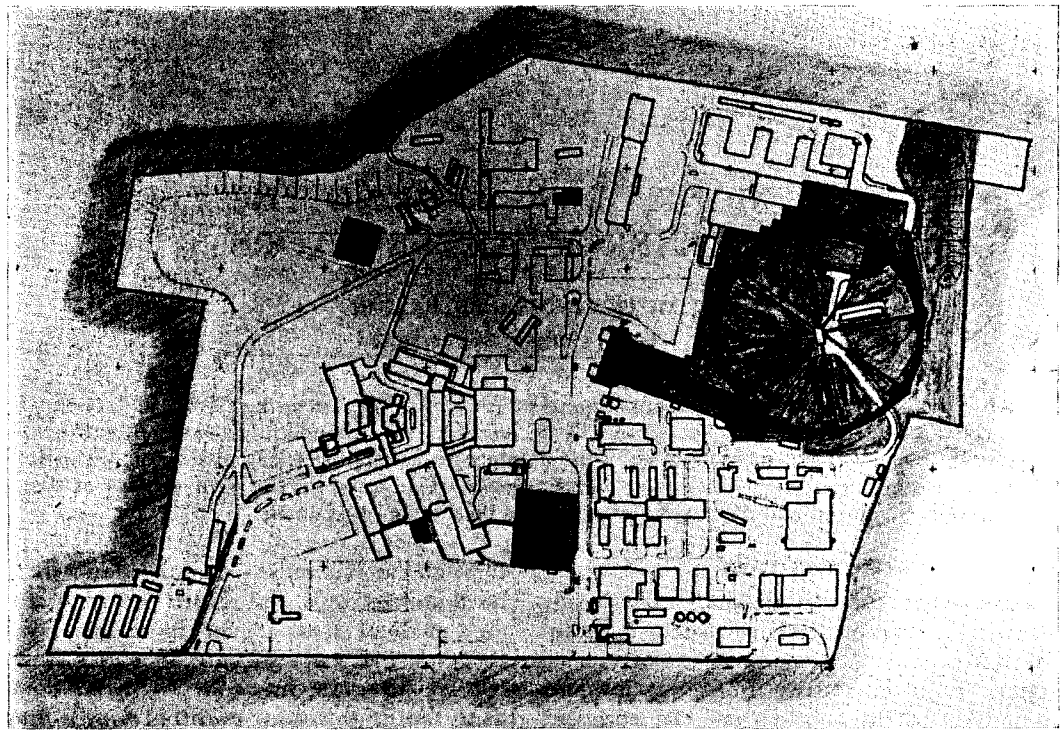

FIG. 1. CERN site and radiation areas.

halls and inside the machines themselves. In certain areas where most of the maintenance and repair or modification work has to be carried out, radiation levels are often of the order of several rem/hour.

To monitor people working in such areas the classical method of film-badges is applied. The β-γ sensitive film used is the Kodak RM. This film has been adopted because it has a good sensitivity, a large recordable dose range due to the two different emulsions and it has also acceptable variations in the fog. To extract the maximum information about the greatly degraded γ-rays near the accelerators and also about the β doses, a film holder with seven different areas corresponding to seven filters has been adopted. This is shown in Fig. 5.

The γ film records the dose due to γ and to the ionization of charged particles of any energy and also to slow neutrons by the use of a cadmium filter. The neutron film, NTA type B, records fast neutrons and also, to a certain extent, the spallation effects of high-energy particles through the observation of nuclear stars.[6] About half of the CERN radiation workers are issued with a neutron film. For this reason a film holder has been designed which can accept both types of films simultaneously, or the neutron film is replaced by a cardboard phantom. We have observed no unacceptable directional sensitivity changes resulting from this arrangement.

CALIBRATION AND READING OF FILM-BADGES

Calibration of film-badges is performed with reference to a standard radium source and a calibrated PuBe fast neutron source. The response of the γ film under the various filters has been studied for energies ranging from 40 keV up to 2 MeV. The practical limits of sensitivity are 10 mrem for the γ film, and twice the background for our neutron film. The calibration factor for the neutron films is expressed in mrem/track/standard area. The reading is made with a semi-automatic projection microscope, using a magnification of about 500. The doses are expressed with a

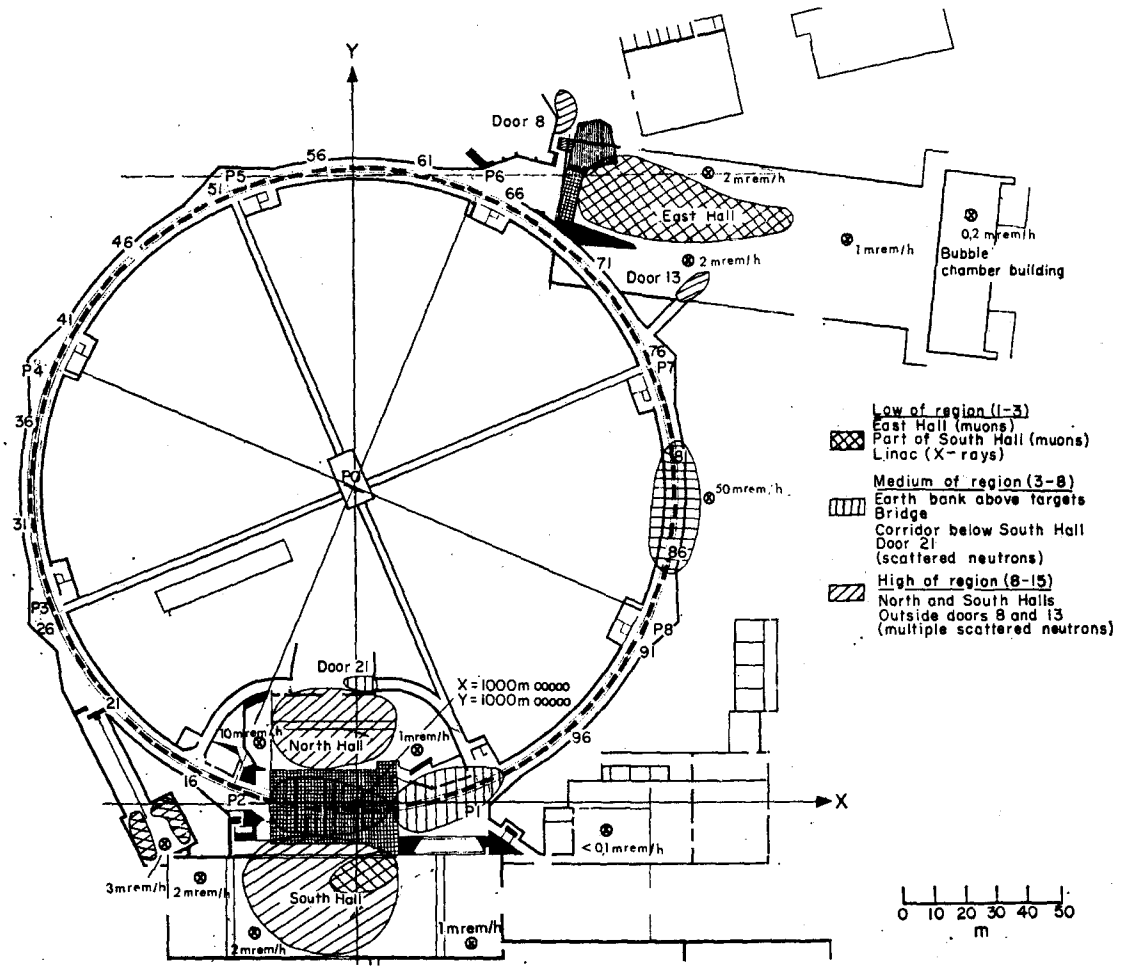

FIG. 2. Typical quality factors and dose-rates (expressed in mrem/hr) in experimental areas of the proton-synchrotron.

Quality Factor corresponding to that of the PuBe source.

The standard method used for the treatment of the exposed films, including the calibrated and background films, ensures the reproducibility of the results. The different areas of the γ films are read with a special densitometer using the optical transmission of light. The output is in BCD and translated in the form of punched cards. The identification code is still manual.

Due to the radiation encountered near high-energy accelerators all neutron films have to be scanned. Frequently no dose is recorded on the γ film while a substantial fast neutron dose exists. Among people wearing neutron films more than one third have a neutron dose higher than the dose recorded by the gamma films, and 10% have a neutron dose without detectable gamma dose.

ORGANIZATION AND DATA ON PERSONNEL MONITORING AT CERN

The administration of the film-badge service has been set up following the structural organization of the CERN staff. The staff is divided

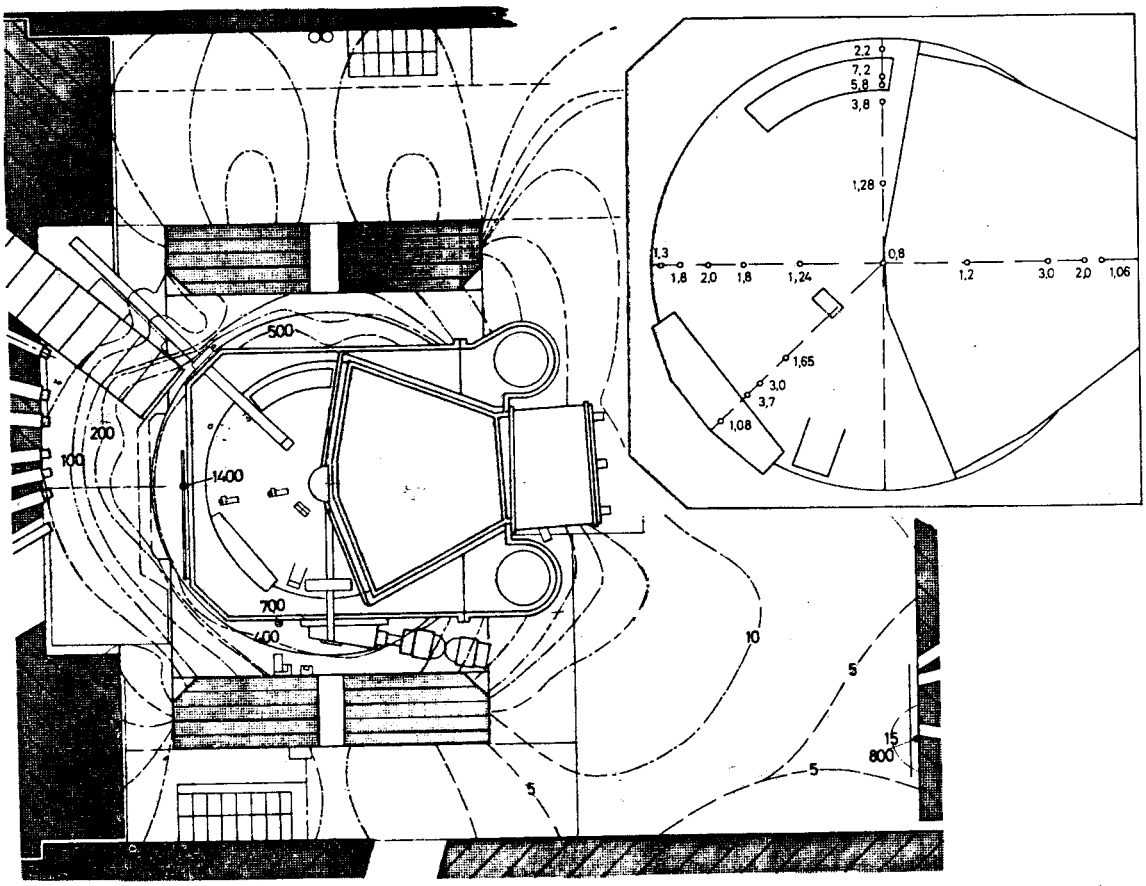

FIG. 3. Dose-rates inside the synchro-cyclotron hall during shutdown (dose-rates expressed in mrad/hr). Inside view of the vacuum chamber with dose-rates expressed in rad/hr, 14 days after machine stop.

into divisions and each division into groups or working teams. Identification of the films is facilitated by this system and requires only four figures, plus the code for the related period. The distribution and exchange of films is made by the internal mail, through the responsible person of each group or working team. Newcomers and people leaving as well as transferred personnel are treated automatically, as they have to report to the Health Physics group. Visitors may be incorporated into a standard CERN group or into special groups that can be set up, depending on the anticipated period of the project at CERN.

The information is recorded automatically on punched cards for gamma films and manually for neutron films. This is then treated by our CDC 6600 computer as shown in the block diagram (Fig. 6). The programme has been made as flexible as possible to facilitate introduction of new numbers, transfers or extractions. The calibration and other basic data are easily changed if necessary. To ensure accuracy, a number of tests are made during the process and any eventual errors introduced with cards are ignored and messages are duly recorded concerning these errors. This procedure is adopted to protect previous data retained by the memory tape.

The routine output presents lists per division, per group and per individual including information about the doses recorded during the

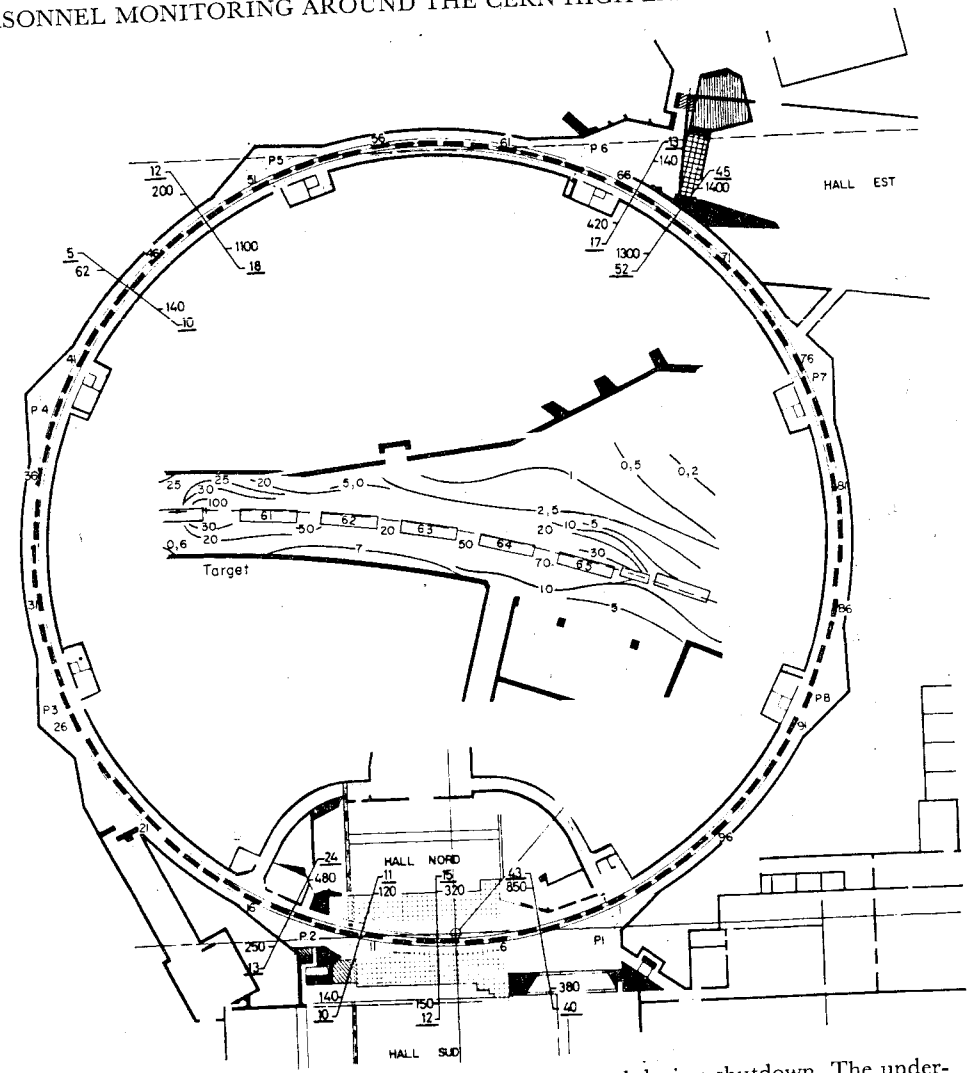

FIG. 4. Dose-rates inside the proton-synchrotron tunnel during shutdown. The underlined values correspond to measurements at 1 m from the vacuum chamber, the other values correspond to measurements at 10 cm from the vacuum chamber.

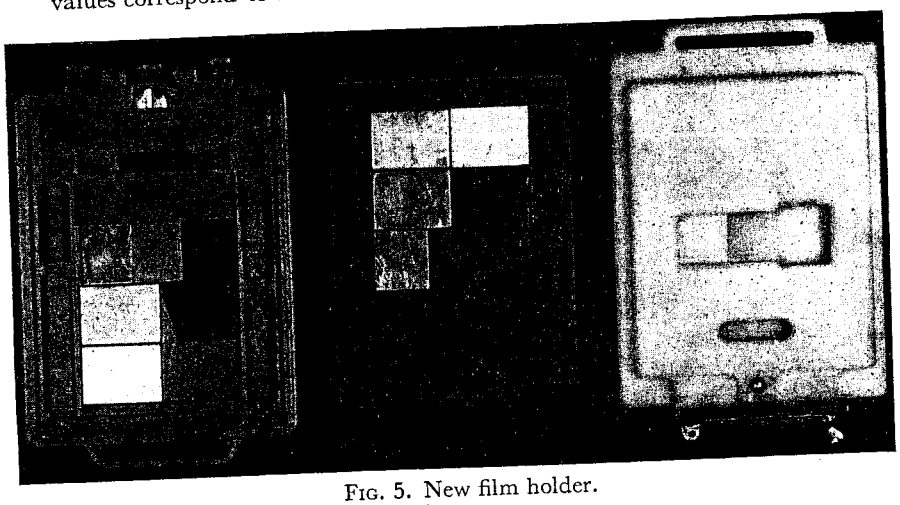

FIG. 5. New film holder.

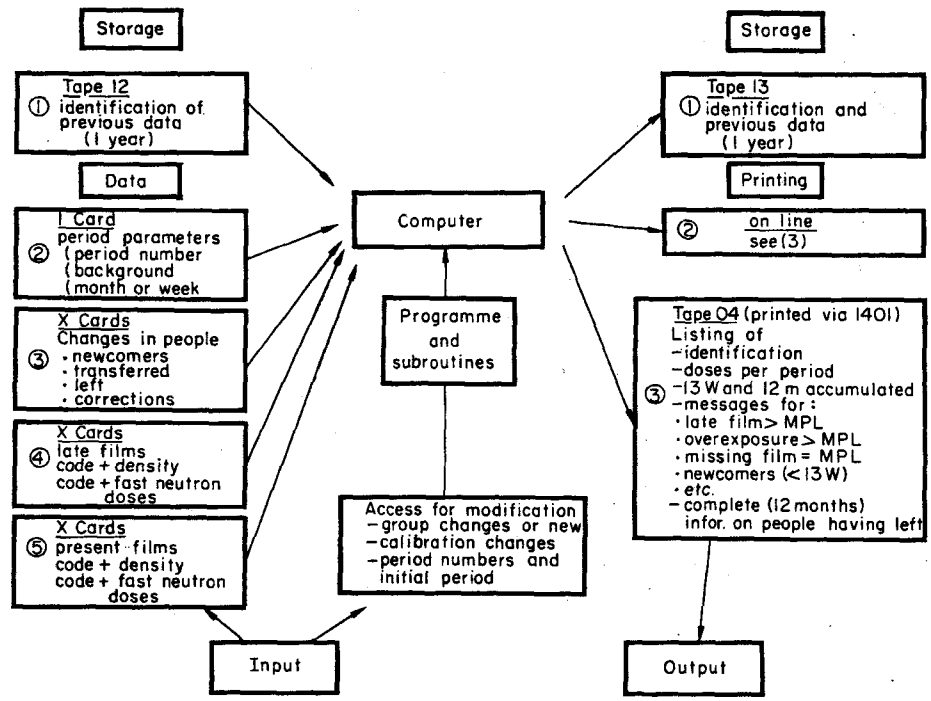

FIG. 6. Block diagram of the film-badge results processed by the Computer.

current period (β, γ, slow neutrons, fast neutrons and total dose in mrem, and in addition the accumulated total doses for the previous 13 weeks and 12 months). Films that are not returned are assigned the average maximum permissible dose for the period in question, but this value is corrected if the films are subsequently returned. Other messages, such as overexposure, etc., are also printed out.

The information for a complete year is memorized on a tape. It is then an easy task to work out relevant statistics or to extract at any time any useful data. The copies of the results are filed with the Health Physics group, as a whole and per group. A copy of the result is sent to each group or team leader for information on his own staff. The responsible Health Physics technician for a radiation area also receives a copy in order to know the radiation received by the workers. This information is used for issuing access permits to radiation restricted zones and also for the control of individual exposures on the spot.

RESULTS AND DISCUSSION

The number of people at CERN under routine personnel radiation control is increasing from year to year. This can be seen from Table 1. With the exception of about 10% of the radiation workers whose film-badges are changed weekly, all film-badges are changed every month.

In 1965, more than 20,000 gamma films and 6000 neutron films were processed and read. The percentage of lost films was the same for the last two years and amounted to 3.1%.

Any dose exceeding the recommended average maximum dose for any one period (400 mrem/month or 100 mrem/week), is considered as an overexposure: 228 such cases occurred in 1965. This is understandable since these overexposures (almost exclusively due to gamma radiation) were received by people carrying out repair and maintenance work of the accelerators. Access to the accelerators for this kind of work is limited to only one to two days in

Table 1. Distribution of doses

Dose (rem/year)	Number of persons			
	1962	1963	1964	1965
0–1	687	871	1058	1220
1–2	42	45	105	36
2–3	11	18	22	21
3–4	8	12	8	3
4–5	6	2	5	0
5	3	1	1	1
Number of people under routine cont.	757	949	1199	1280

every two-week period, and this explains such overexposures. In some of these cases there were exposures exceeding the ICRP recommended dose value for 3 and 12 month periods.

One of the most important problems in assessing the personnel radiation dose near high-energy accelerators is to what extent the results obtained are valid and reliable. This problem reflects the method of interpretation of the film-badge reading. No attempt is made in this paper to elucidate this problem, but some few remarks can be given in the light of comparison with the results obtained from the rather complicated set of radiation survey instruments used near the CERN accelerators. Such comparison has shown that the film-badges normally overestimate the dose by a factor of about 1.5. In regions with low dose-rates it has been observed that an underestimation of 20% occurs. These figures are sufficiently conservative and at the same time not restrictive for the work to be done. This applies however only to regions outside and far away from the shields. As soon as direct beams exist close to weak shielding, the readings become irregular and might lead to large factors of over-estimation or underestimation of the dose. Such conditions are normally recognized by the existence of special tracks on the neutron film-badges.

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