EFFORTS AND ACHIEVEMENTS IN DOSE REDUCTION AT CERN

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1. INTRODUCTION

The European Laboratory for Particle Physics, CERN, presently operates several high-energy proton accelerators, the largest having a maximum energy of 450 GeV. In addition, a large electron positron collider (LEP) is under construction.

There are two principal types of radiation fields encountered at CERN: the stray radiation outside the shielded beam enclosures when the accelerators are in operation, and the field due to radioactivity induced in the accelerator structures, which is of particular significance during periods of accelerator maintenance and repair. In spite of regular increases in the number of protons accelerated in the machines, it has been possible to maintain stray radiation levels in experimental halls, on the CERN site in general and in the environment around CERN at relatively low levels by constantly improving the efficacy of shielding configurations. To give an example: the 26 GeV proton synchrotron (PS) was designed in the early 1960's to operate with an intensity of 10^{10} protons per pulse with a pulse period of 2.4 seconds; now it routinely accelerates more than 10^{13} protons per pulse while the pulse repetition rate has doubled. The increase in annual doses at the CERN perimeter fences due to accelerator operation has hardly been noticeable.

Such an increase in intensity, however, has major consequences for the levels of induced radioactivity around the accelerators themselves and in target regions: it therefore has a direct impact on doses received by personnel during maintenace and repair. Both the collective dose and the personnel doses received during work in the vicinity of activated accelerator structures are about one order of magnitude higher than those due to stray radiation. It was therefore natural to concentrate the major dose-reduction efforts on this sector.

2. DOSE REDUCTION BY CORRECT DESIGN

The CERN Radiation Safety Manual (1971 edition) clearly stated that "as a general principle unnecessary exposure of any person to radiation must be avoided" and that "all precautions must be taken to reduce individual exposure to a minimum, i.e. restricted to the smallest number of people and to the lowest possible dose". In addition, "occupationally exposed persons shall not receive a dose to the whole body exceeding 5 rem/year".

The spirit of these three statements is already rather close to the basic principles of ICRP 26: justification, optimization, and limitation (Ref. 1). Despite the similarity in ideals, when the ICRP recommendations were published in 1976 most staff and CERN management still maintained an attitude based on pre-1960 philosophy: as long as a person stayed below the limit of a maximum permissible dose, there was nothing to worry about.

Thus early measures to reduce personnel doses were mostly efforts to ensure the smooth running of the accelerator complexes without exceeding any maximum permissible exposure limit. Just to mention three examples: the introduction of more reliable vacuum joints required fewer interventions by the vacuum group around the machines, thereby reducing accelerator down-time, and only incidentally radiation exposure. Rubber hoses for cooling water that tended to break in high-radiation areas were replaced by metal tubing mainly to reduce down-time but also requiring less repair work in hot areas. However, preoccupation with the high dose rates in target stations allowed the development of quick-change mechanisms for the remote replacement of burned-out targets in extracted beams. The overall reduction in personnel dose by these and other similar measures was a beneficial side effect but, even so, certain machine specialists, mostly the same people, received high doses year after year.

With the construction of the 450 GeV SPS accelerator, serious efforts were made in the design phase to avoid or reduce personnel doses. These included the introduction of remote handling in target regions and of quick-connections of control and electricity cables and water hoses for beam elements likely to become highly radioactive. A system of beam loss monitors was introduced in order to optimize the operation of the machine.

Since radiation damage and induced radioactivity are closely related, improvements in older accelerators aimed at preventing proton losses around the machines and ejecting unwanted beam, preferably onto external, well shielded dumps. Both in the construction of the new accelerator and in improving the existing ones the Radiation Protection Group collaborated actively with the Machine Divisions with a view to applying the ALARA principle in the early design phases.

A rather unusual situation also existed within the Radiation Protection Group itself. Survey technicians were found to belong to the category of heavily irradiated personnel, and so efforts were necessary to reduce their doses. For example, in the past, maps of isodose curves were established in target regions or around hot splitter and septum magnets. As these surveys cost a great deal in dose received, the benefit of such an activity was seriously questioned. However, in order to continue to have information on dose levels in the vicinity of hot points where the probability of human intervention is high, very simple radiation monitor systems having the possibility of remote read-out were installed in these zones. It was however important to make sure that the installation (or later the repair) of such a system in a hot area did not cost more dose than saved by abolishing extended radiation surveys.

2. DOSE REDUCTION BY SENSITIZATION (OR THE IMPACT OF ICRP 26)

One of the basic changes introduced in Publication 26 of the ICRP compared with previous recommendations was the recognition that any exposure carries with it some detriment or risk. It was henceforth not "permissible" to irradiate persons at or near the dose-equivalent limits. This point was particularly emphasized by the Staff Association of CERN. The human attitude in the perception of risk here plays a decisive role. It did not impress people to see that the (calculated) detriment from professional radiation doses is much lower than from many commonly encountered hazards in daily life, or that other occupational hazards may be even less well understood than radiation. While more common risks are accepted (because accidents only happen to others), the argument of a stochastically unlikely detriment from a radiation exposure was too abstract to be convincing.

It was possible to identify within the highly exposed staff at CERN small groups who are regularly exposed at a higher level than the rest. These groups consisted primarily of accelerator maintenance staff (and the radiation protection technicians). The support of the CERN management was clearly needed (Ref. 2) to reduce their doses to a level lower than that achieved by the application of existing ALARA principles. This support was given in the form of a strong guideline introducing a reference dose of 15 mSv/year within the framework of a general CERN radiation policy (Ref. 3). The dose-equivalent limit of 50 mSv/year remains in line with the legislation of CERN's two host countries France and Switzerland, but it now needs the authorization of a division leader for a person to be exposed beyond the reference dose of 15 mSv/year. The value of 15 mSv was chosen rather arbitrarily but it was felt that most work in radioactive areas could well be completed within such a dose. It was also expected that any authorization should be made the subject of a management review which should propose alternative procedures and/or expenditure of money to ensure that a similar authorization would not be necessary in subsequent years.

In order to achieve this, schemes involving closer dose control were set up for those groups in which the personnel doses of a majority of the workers were above one tenth of the dose limit set forward by the ICRP. For example, the activities of these persons were closely watched by radiation protection technicians. They also appeared on a special "dose limit" chart issued monthly by the film-badge service. Such a list is easier to read than the list containing the complete results of over 4500 film-badge wearers.

Special efforts were made to eliminate doses received unnecessarily while simply waiting in hot areas. The introduction of a small pocket monitor, giving an audible beep in proportion to the dose rate, was particularly successful in this respect. The result of these efforts is seen in Tables 1 and 2, which show that no member of either the CERN personnel or of outside firms working on the domain of the Organization has exceeded the reference dose in 1981 or 1982. The increased dose-consciousness among the staff supported by the strong policy statement of management has led to a decrease of percentages in all higher dose classes (Tables 1 and 2). The reason that doses for outside contractors show a less favourable tendency than CERN staff is that these persons are often hired specifically for special work during accelerator shut-down. It should be stressed, however, that personnel from outside contractors benefit from the same radiation policy as the CERN staff in that their exposure is subject to the reference dose of 15 mSv/year and furthermore limited to 1 mSv/week for the duration of their stay at CERN.

It is often stated that when efforts are undertaken to distribute the high personal doses of a few workers among more people, the collective dose for a given operation will increase. Such a trend is not seen at CERN. The development of the collective dose of CERN over the years 1979 to 1982 is presented in Table 3. It should be noted that the decrease by a factor of two during the last four years cannot entirely be attributed to the success of the ALARA programme. The profile of CERN activities in high-energy physics has changed: some old, dose-costly installations have been closed down and new ones brought into operation which were constructed according to the ALARA principle.

4. CONCLUSIONS

Constant efforts over the years by the Radiation Protection Group at CERN, in collaboration with the accelerator divisions, have led to an overall decrease in doses to personnel. Annual exposures in the most exposed groups are now below a level of 15 mSv/year, the figure used by the CERN management as a guideline for present and future research activities. Support at top management level has been beneficial in keeping an ALARA spirit alive throughout CERN, from the accelerator divisions as staff units down to the individually exposed person principally concerned.

REFERENCES

1. Recommendation of the International Commission on Radiological Protection, Publication 26, Pergamon Press, Oxford (1977).

2. A Guide to Reducing Radiation Exposure to As Low As Reasonably Achievable (ALARA), U.S. Department of Energy, DOE/EV/1930-TS, UC-41 (1980).

3. CERN Radiation Protection Policy, Weekly Bulletin No. 29/81, July 1981.

Table 1

Percentage of CERN staff in different annual dose categories

Year	⩽ 2 mSv	2 mSv ⩽ 5 mSv	5 mSv ⩽ 15 mSv	> 15 mSv
1979	92.5	5.1	2.4	0.1
1980	93.9	3.9	2.2	0.1
1981	94.6	3.6	1.8	0
1982	95.7	2.9	1.4	0

Table 2

Percentage of contractors staff in different annual dose categories

Year	⩽ 2 mSv	2 mSv ⩽ 5 mSv	5 mSv ⩽ 15 mSv	> 15 mSv
1979	87.1	9.2	3.5	0.2
1980	88.8	8.5	2.7	0.1
1981	93.0	4.7	2.3	0
1982	90.6	7.0	2.4	0

Table 3

Collective dose in Sv of CERN staff and outside contractors
for the years 1979-1982

Year	CERN staff		Outside contractors	Total
	Gamma dose	Neutron dose		
1979	3.12	0.22	1.25	4.59
1980	1.96	0.26	1.30	3.52
1981	1.36	0.26	1.16	2.78
1982	1.13	0.17	0.68	1.98