PART IV

DOSIMETRY AND CALIBRATION SECTION

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1 INTRODUCTION

The two tasks of the Dosimetry and Calibration Section at CERN are the Individual Dosimetry Service which assures the personal monitoring of about 5000 persons potentially exposed to ionizing radiation at CERN, and the Calibration Laboratory which verifies all the instruments and monitors. This equipment is used by the sections of the RP Group for assuring radiation protection around CERN's accelerators, and by the Environmental Section of TIS–TE. In addition, nearly 250 electronic and 300 quartz fibre dosimeters, employed in operational dosimetry, are calibrated at least once a year.

The Individual Dosimetry Service uses an extended database (INDOS) which contains information about all the individual doses ever received at CERN. For most of 1997 it was operated without the support of a database administrator as the technician who had assured this work retired. The Software Support Section of TIS–TE took over the technical responsibility of the database, but in view of the many other tasks of this Section and the lack of personnel, only a few interventions for solving immediate problems were possible.

The 1996 Radiation Safety Manual obliges external contractors to name an 'Expert in Radiation Protection' who provides information about working in controlled radiation areas to employees of his company, and who must keep the dose records of his personnel up-to-date. After having named their experts in 1996, and following a course in radiation protection organized by the Swiss Insurance in Case of Accidents (SUVA) early in 1997, the Federal Office for Public Health started to issue authorizations to contractors. They are valid for a duration of ten years for performing work in controlled radiation areas in Switzerland. With CERN's contract policy which tries to distribute contracts evenly amongst member states and gives preference to the lowest bidder, frequent changes of external contractors are common, and must be mastered. A contact person has been named in the Individual Dosimetry Service to assist the Experts in all questions concerning their duties. In the coming years, the RP Group will rely strongly on these Experts to enforce safe working rules in controlled radiation areas.

During the 1996/97 shutdown, the electronic dosimeter DMC 100 of MGP Instruments was introduced as an operational dosimeter for the most exposed teams on the CERN sites, staff and contractors. Experience has shown the sensitivity of the instrument, not only to ionizing radiation, but also to intense RF fields. Hence, the policy how to use it has been changed and is now documented in Radiation Protection Procedure PRP 18 'The Electronic Dosimeter DMC 100'.

Three major projects were conducted in 1997. A CERN Fellow, Mrs. Regina Müller, was recruited in May in order to work on computer-assisted scanning of NTA films, the personal neutron monitor used at CERN. Stefan Metz, a Technical Student from the University of Karlsruhe, developed a scintillation detector for tracking down activated material. It can be coupled to RP Group's standard instrument Automess AD 6 Ratemeter, and will replace the obsolete IPAB scintillation detectors. An automated laboratory for the development of Kodak Type 2 films was conceived and developed together with two specialized French firms. It was installed in the last days of January 1998.

2 INDIVIDUAL DOSIMETRY SERVICE

2.1 Administration

As in previous years, the distribution of personal dosimeters to about 5500 persons and their subsequent collection and evaluation functioned well and without delays in spite of continuing difficulties with the Individual Dosimetry database INDOS.

The last task of the technician who administered this database and half a dozen smaller applications written in Oracle was to adapt all forms and reports to the latest version of Oracle, which has become the obligatory 'CERN standard' at the moment. The Software Support Section of TIS–TE now handles the administration of all Oracle databases in TIS–RP, and to do this they have recruited a young computing professional. However, the priorities of this person lie with the ARCON system and the Individual Dosimetry Service is now left with an application which is essential for their daily work, but insufficiently supervised. For short-term interventions to solve immediate problems with the film distribution or the evaluation of dosimeters the Technical Students of TIS–TE helped, but no necessary maintenance and improvement was achieved in 1997. In 1998, a thorough documentation of the INDOS application by one of the students is foreseen, after which improvements and changes in selected areas of the application will be made.

The conditions under which a CERN user may obtain a dosimeter for a short period, i.e. a 'visiteur à court terme' (VCT) were restricted in 1997. This category of personnel responds to an important demand of visiting scientists: to make it possible to work for a short time in controlled radiation areas, i.e. nearly all experimental areas, without having to undergo a lengthy administrative procedure. CERN users can now pick up a VCT dosimeter after a minimum of formalities for a maximum stay of one month within a twelve-month period. Since individual doses for physicists at CERN are very low, the dose equivalent for VCTs is guaranteed to be limited to 1 mSv during their visit. In this way, they can be assimilated to the category of members of the public. If a user asks for a second VCT dosimeter within one year he must present a valid medical certificate authorizing him to work in the presence of ionizing radiation. The distribution of an information flyer with every VCT dosimeter has led to good discipline of its users as the form for a medical fitness certificate is printed on the reverse, which can be readily and is frequently used to prove fitness to work in controlled areas.

The shutdown of LEAR and most of the experiments in the West area led to a significant reduction of the number of regularly distributed dosimeters to experimental groups in EP

Division. In May 1997, a fire in BA3 brought SPS and LEP operation to a halt for two months. The summer months are usually the most busy in terms of visiting scientists and short-term visitors and their absence in 1997 is reflected in the decreased number of dosimeters distributed. This was further enhanced by the cancellation of the heavy ion run in autumn as experimental teams stayed in their home institutes.

The Service continued its efforts to reduce the number of dosimeters distributed to persons who have long left CERN or who no longer work in controlled areas. Regular visits to film badge distributors and to group secretaries, especially in EP division, helped to identify over 150 persons who do not need a film badge any longer. In addition, these visits motivate the distributors to continue their tedious task of distributing several hundred dosimeters every two months by showing them that they play an important part in CERN's radiation protection system.

As already mentioned, the Radiation Safety Manual obliges external contractors to name an expert in radiation protection. This is the prerequisite for authorization to work in controlled radiation areas in Switzerland issued by the Federal Office of Public Health (OFSP). The Service made a particular effort to enforce this obligation with the result that all external contractors fulfil the requirement. The Radiation Protection Group in turn offers all possible help to the experts. One person of the Service acts as a contact, and assists with the administrative questions related to the authorization and the subsequent duties of the expert. Experts in radiation protection are regularly invited to information meetings or to radiation safety courses organized at CERN.

2.2 Statistical analysis of the annual results

2.2.1 Personnel under dosimetric control in 1997

The number of persons under regular control decreased slightly in 1997. As of 31 December 1997, a total of 4971 persons were monitored: 4110 CERN staff and scientific visitors ('staff members' for short) wearing their dosimeters for two-month periods (Fig. 1a), and 861 contractors' personnel who change their dosimeter monthly (Fig. 1b). An additional neutron dosimeter is worn by 3371 (82%) of the staff members. The total number of regularly supervised persons has decreased by 3.3% in comparison with 1996.

In 1997, 660 films were distributed to VCTs. All of CERN's users requiring a VCT dosimeter are registered in EP division. The percentage of all supervised persons in EP Division (formerly known as PPE Division) they represent, has remained constant in recent years (Fig. 1c).

In 1997, 38080 Kodak Type 2 films for photon radiation and 20455 Kodak NTA films for neutron monitoring were distributed (Fig. 2). Of all the films, 755 were not returned in time to the Film Badge Service for evaluation. Contractors' personnel were more disciplined than in previous years (Table 1).

Table 1: Number of films not returned by 31 December 1997

Wearing period	CERN staff and short-term visitors	Contractors' personnel
January	0	9
February	43	7
March	0	9
April	60	7
May	0	6
June	97	7
July	0	5
August	101	1
September	0	7
October	177	6
November	1	6
December	190	16
Total	**669**	**86**

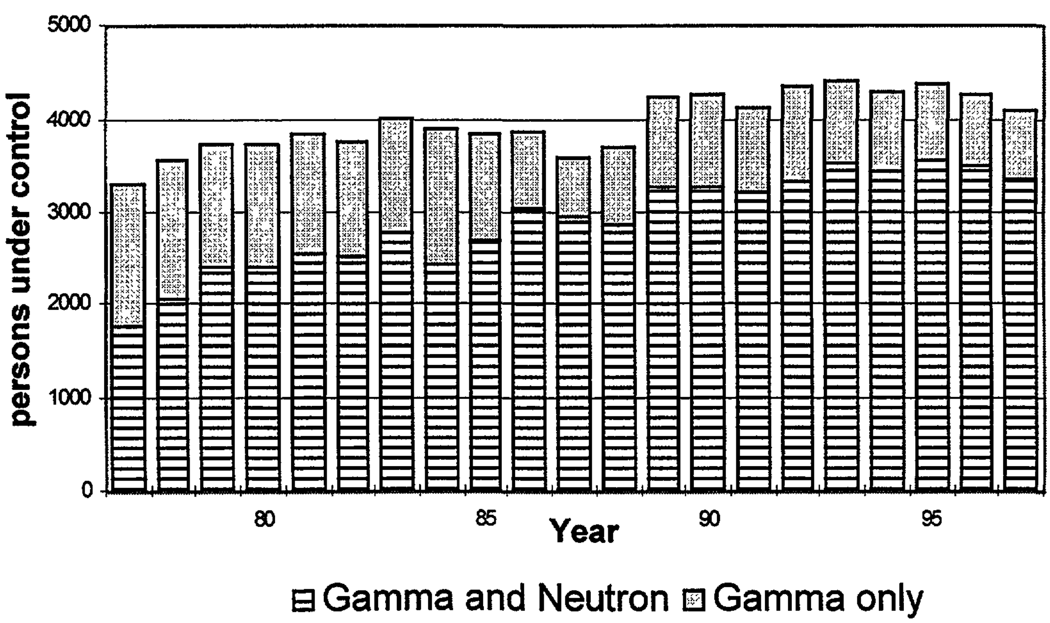

Figure 1a: CERN staff and visitors under dosimetric control on 31 December of the respective year.

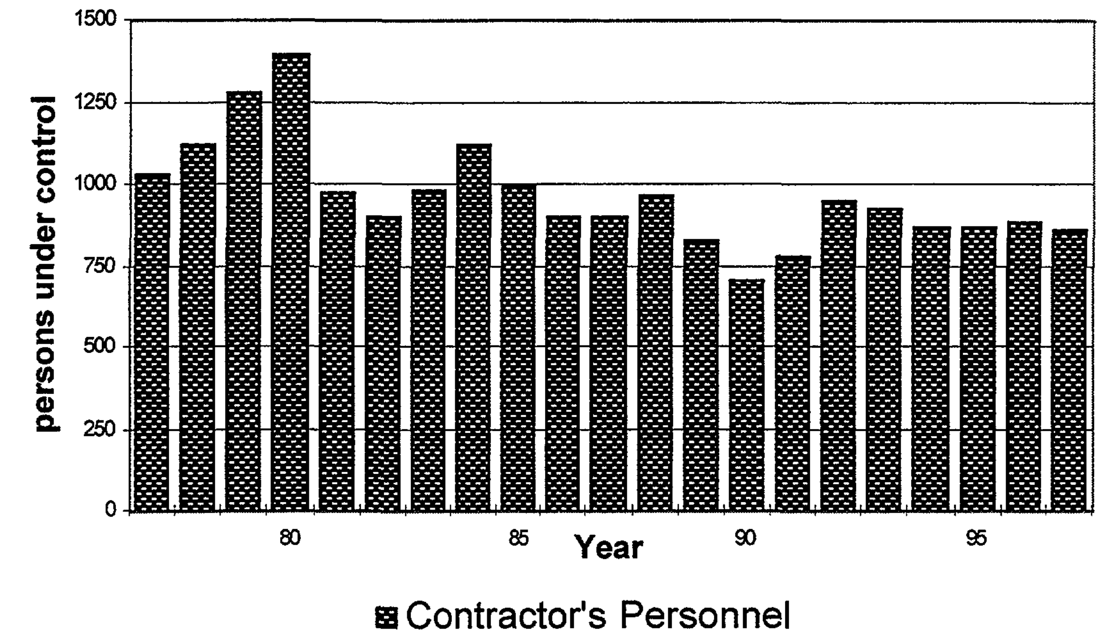

Figure 1b: Contractors' personnel under dosimetric control on 31 December of the respective year.

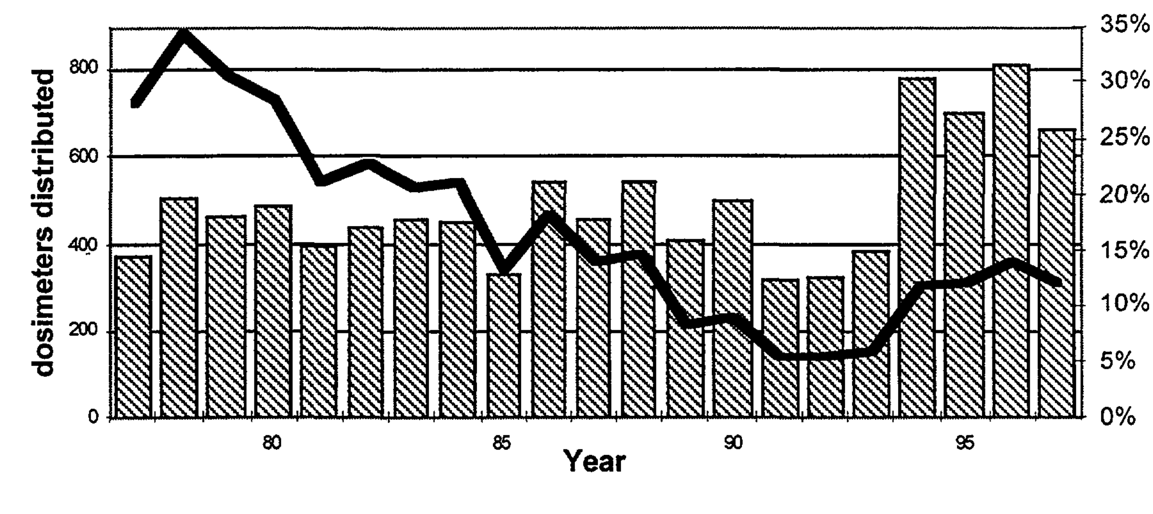

Figure 1c: Dosimeters distributed to Short Term Visitors (VCT) throughout the year (bars, left-hand scale) and the fraction that VCTs represent of all persons registered in EP division (line, right-hand scale).

2.2.2 *Total dose*

The total dose equivalent at CERN has decreased for all categories of personnel under individual control. The total dose of personnel registered at CERN on 31 December 1997 amounts to 1093 mSv. To this, the dose of persons who left during the year (234 mSv), has to be added. The total dose of 1327 mSv presents a reduction of 8.6% compared with 1996. Table 2 gives the breakdown of these numbers in neutron and gamma doses. The neutron dose represents 46% of the exposure of CERN staff and visitors, in line with observations since 1992. The development of these figures since 1977 is shown in Fig. 3.

Table 2: Cumulative doses in mSv registered at CERN in 1997

CERN personnel present at 31 December 1997	gamma neutron	415 359 774
Contractors' personnel present at 31 December 1997	gamma neutron	297 22 319
Personal doses for persons who left during 1997	gamma neutron	188 46 234
	Total	**1327**

Tables 3a and 3b allow detailed comparisons with previous years. The total dose to CERN staff and visitors decreased in proportion to their absolute numbers, with their average dose remaining the same as in 1996. The average dose to this group has not varied significantly since 1989. The total dose to contractors' personnel has decreased by more than 20%, their average dose in 1997 amounts to 0.38 mSv. Figures 4 and 5 trace the development of average doses since 1977.

The average dose to a group of persons can be arbitrarily biased towards low values by including persons with have a low probability of exposure in the group. At CERN, for example, physicists working exclusively in LEP belong to such a group of persons. A less biased quantity is the average dose for persons actually exposed during their work. As a selection criterion, persons are considered having received at least 0.2 mSv in 1997. For CERN staff and visitors the average dose amounts to 0.44 mSv, and for contractors' personnel to 0.91 mSv. Both values decreased slightly from their 1996 values of 0.48 mSv and 0.97 mSv. They are below the dose limit for the general public of 1 mSv/y and they demonstrate that at CERN dose equivalents are low even for persons exposed to radiation in the course of their professional duties.

Table 3a: Development of global statistical parameters for CERN staff over the last ten years as known on 31 December of the year mentioned (Doses are given in mSv)

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
No. of distribution groups	168	168	168	166	161	153	152	156	154	146
No. of persons	3698	4261	4278	4139	4354	4424	4302	4400	4272	4110
No. of persons under neutron control	2872	3271	3282	3202	3339	3521	3444	3566	3503	3371
Total dose for the year	1672	854	1006	999	848	636	777	898	788	774
Amount due to neutrons	638	212	274	287	281	297	338	503	225	359
Neutron dose as percentage of the total dose	38.2	24.8	27.2	28.7	33.1	46.7	43.5	56.0	28.6	46.3
Mean annual dose per person	0.45	0.20	0.24	0.24	0.20	0.14	0.18	0.21	0.18	0.18
Max. individual dose registered	10.5	10.0	10.5	11.5	9.2	11.7	7.5	7.5	10.4	8.9

Table 3b: Development of global statistical parameters for contractors' personnel over the last ten years as known on 31 December of the year mentioned (Doses are given in mSv)

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
No. of distribution groups	59	63	56	55	57	59	54	52	57	54
No. of persons	966	826	709	775	949	927	872	869	883	861
Total dose for the year	370	268	379	384	562	454	298	383	409	319
Mean annual dose per person	0.38	0.32	0.54	0.50	0.59	0.48	0.35	0.47	0.49	0.38
Max. individual dose registered	13.9	7.1	9.5	15.1	12.3	12.6	9.1	9.2	10.8	8.9

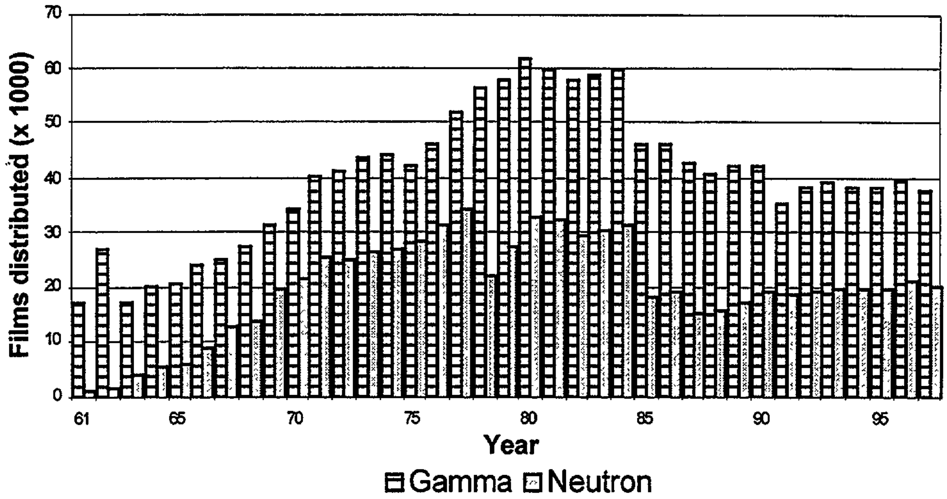

Figure 2: Number of films distributed yearly at CERN since 1961.

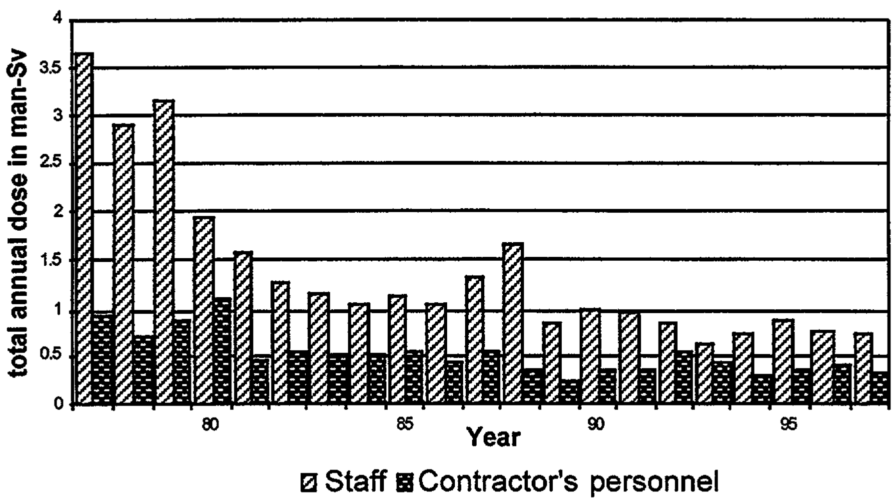

Figure 3: Total annual dose in Sv accumulated in a year by persons registered at CERN on 31 December of the respective year since 1977.

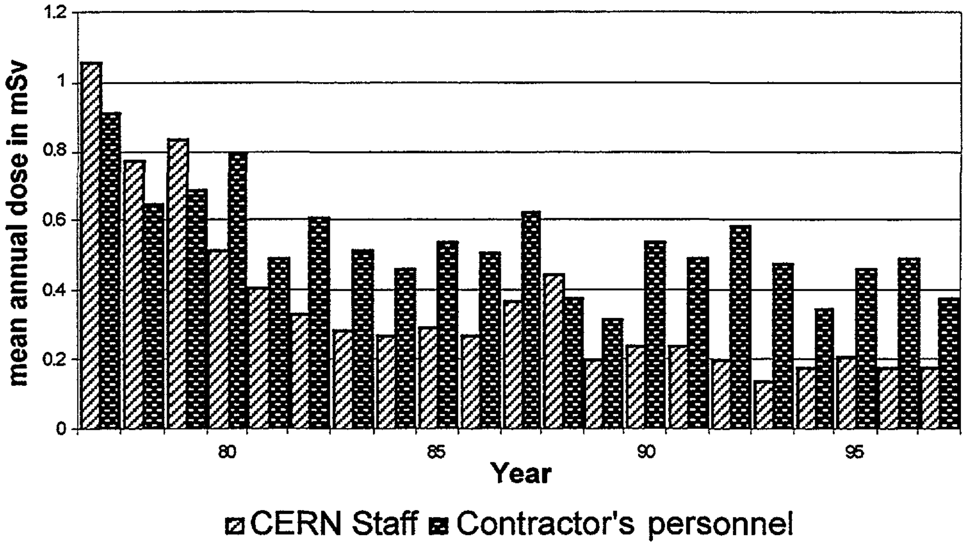

Figure 4: Evolution of mean annual dose for CERN staff and contractor's personnel since 1977

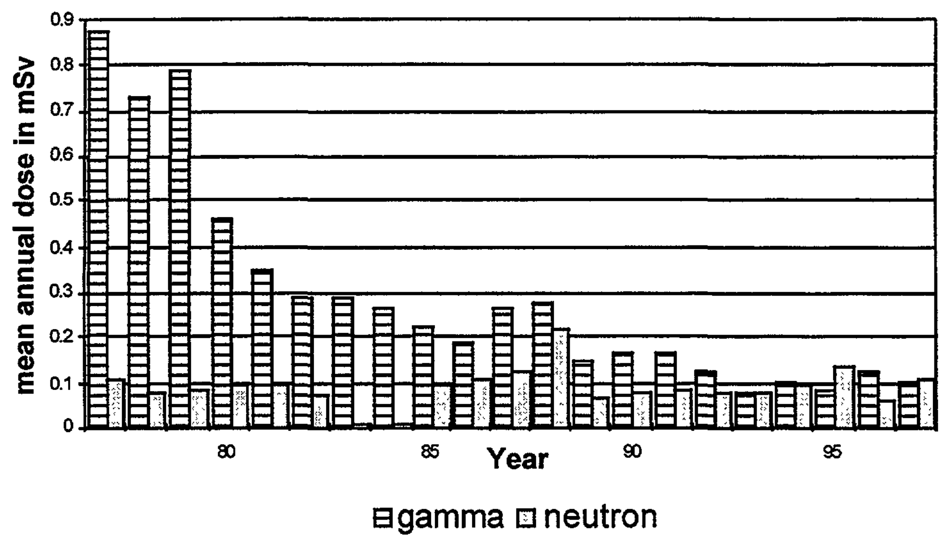

Figure 5: Evolution of mean annual gamma and neutron doses for CERN staff since 1977

2.2.3 Breakdown of doses

Tables 4a to 4c show the breakdown of personal doses into different classes for CERN staff and visitors (Table 4a), for contractors' personnel (Table 4b), and for all supervised persons, including short-term visitors (Table 4c and Fig. 6). More than 60% of the total CERN population under individual control did not receive any dose in 1997. This percentage has slightly decreased from its 1996 value, whereas the fraction of persons with a personal dose equivalent between 0.2 and 1 mSv has increased by the same amount. This is thanks to the continuing efforts of the Service to remove persons from the film distribution list who no longer work in controlled radiation areas (i.e. those who have a new job profile, or former users who have finished their experimental work at CERN but did not inform the service). Mrs. J. Lavanchy conducts this work in collaboration with the secretaries of the distribution groups around CERN.

Table 4a: Distribution of annual doses according to different classes for CERN staff and visitors present on 31 December 1997

Dose class (mSv)	Number of persons	%	Total dose per class (mSv)
0	2370	57.7	0.0
> 0–1	1648	40.1	548.2
> 1–5	84	2.0	170.9
> 5–15	8	0.2	54.9
> 15	0	0	0.0
Total	**4110**	**100.0**	**774.0**

Table 4b: Distribution of annual doses according to different classes for contractors' personnel present on 31 December 1997

Dose class (mSv)	Number of persons	%	Total dose per class (mSv)
0	512	59.4	0.0
> 0–1	277	32.2	96.8
> 1–5	60	7.0	141.2
> 5–15	12	1.4	81.0
> 15	0	0.0	0.0
Total	**861**	**100.0**	**319.0**

Table 4c: Distribution of annual doses according to different classes for all persons under individual control present on 31 December 1997 plus short-term visitors throughout 1997

Dose class (mSv)	Number of persons	%	Total dose per class (mSv)
0	3429	60.6	0
> 0–1	2061	36.4	681.2
> 1–5	150	2.7	321.1
> 5–15	20	0.3	135.9
> 15	0	0.0	0.0
Total	**5660**	**100.0**	**1138.2**

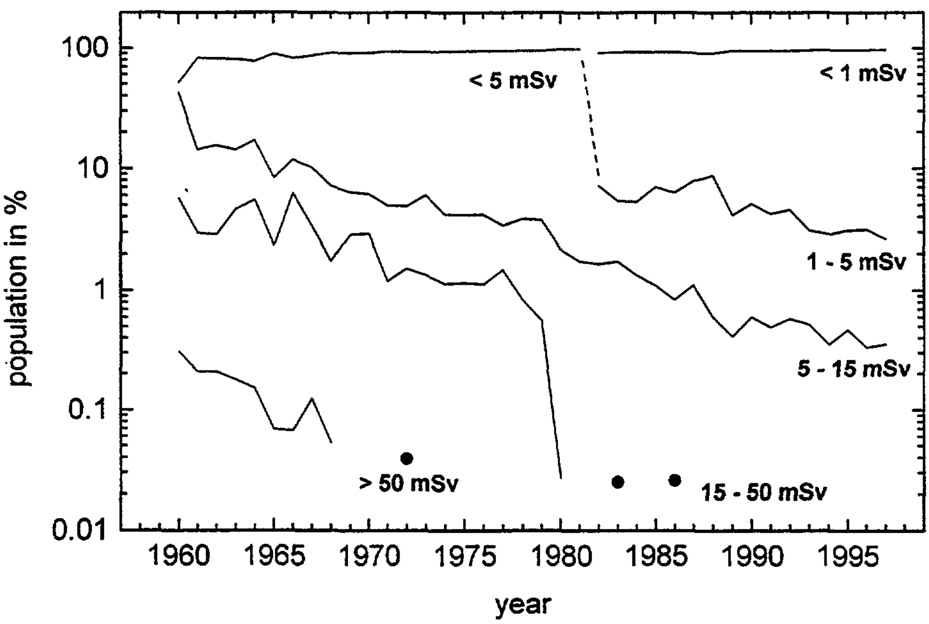

Figure 6: Distribution of individual doses in different dose classes for all persons under control at 31 December of the respective year. From 1982 on, one of the classes is split to provide better visibility

The (on average) most exposed CERN groups and contracting firms are listed in Table 5. The same CERN groups as in 1996 appear in this Table, but in a different order. The SPS Vacuum Group (attached to LHC Division for administrative reasons) leads, as in all of the previous years, the list. The five members of this group are actually all regularly working on activated SPS magnets. Other teams regularly appearing on this list are the Materials and High-dose Dosimetry Section of TIS–TE Group, and the Survey Section SPS/LEP of TIS–RP. Among the external contractors we find the personnel of Ansaldo, an Italian welding firm, also involved in the cabling of the neutrino facility at the beginning of 1997. One temporary worker of Multi-Personnel/Sintex also participated in this work. His personal dose of 8 mSv over two months was distributed amongst his seven colleagues in the company, resulting in an average of 1.14 mSv per person. Personnel from SGS Gottfeld are assisting in work on the vacuum systems of the CERN accelerators, often activated by beam losses.

Table 5: Distribution of mean annual doses for CERN divisions and contractors' personnel, in various groups that have exceeded a mean dose of 1 mSv per year in 1997

Division and group /Contractor		Number of persons	Mean dose per person (mSv)
LHC	Total for Division	216	0.26
	LHC–VAC–SPS	5	5.26
SL	Total for Division	320	0.45
	SL–MS	31	1.85
TIS	Total for Division	123	0.25
	TIS–TE–MHD	3	1.63
	RP Survey SPS/LEP	8	1.09
EST	Total for Division	138	0.16
	SU–ACC	5	1.22
	Total for external contractors	861	0.38
	Ansaldo	44	1.15
	Multi-Personnel / Sintex	7	1.14
	SGS-Gottfeld	32	1.13

The number of persons exposed to more than 100 mSv during their career at CERN decreased by 20 with respect to 1996 — nearly a third (Table 6). In a few years from now all persons with lifetime doses in excess of 100 mSv will have retired from the Organization.

Table 6: Number of CERN staff who, in the course of their work at CERN, have accumulated more than 100 mSv

Total accumulated dose (mSv)	No. of persons
100–200	33
200–300	5
300–400	5
> 400	0
Total	**43**

Table 7: Distribution of doses as a function of age and sex for CERN staff and outside contractors' personnel under individual control on 31 December 1997

Dose class	**18–20**		**21–30**		**31–40**	
(mSv)	**M**	**F**	**M**	**F**	**M**	**F**
0–1	3	0	666	141	1291	115
> 1–2	0	0	10	1	21	1
> 2–5	0	0	3	0	9	0
> 5–10	0	0	4	0	3	0
> 10	0	0	0	0	0	0
Total persons	3	0	683	142	1324	116
Mean dose (mSv/y)	0	0	0.18	0.11	0.18	0.15
Total dose per age and sex (mSv/y)	0	0	122.3	15.6	243.6	16.9

Dose class	**41–50**		**51–60**		**61–65**	
(mSv)	**M**	**F**	**M**	**F**	**M**	**F**
0–1	938	75	1220	61	241	8
> 1–2	16	0	29	0	5	0
> 2–5	14	1	31	0	3	0
> 5–10	3	1	9	0	0	0
> 10	0	0	0	0	0	0
Total persons	971	77	1289	61	249	8
Mean dose (mSv/y)	0.23	0.32	0.30	0.09	0.20	0.05
Total dose per age and sex (mSv/y)	221.5	24.3	387.0	5.6	49.4	0.4

The distribution of personal doses by sex and age is shown in Table 7. The values are very similar to those found in 1996, with one exception: whilst in last year's annual report women received, on average, less than two thirds of the dose of their male colleagues, the group of women aged between 41 and 50 years leads the table in 1997! This is not a sign of achieved equal opportunity, and even less one of increased professional risk, but an example of statistical bias. The group consists of 77 women, of whom two received personal doses in excess of 2 mSv respectively 5 mSv. The exposure of these two women fully explains the increased average dose equivalent of this group, which changed from 0.19 mSv (1996) to 0.32 mSv (1997).

2.3 Damaged dosimeters and radiation incidents

In 1997, the standard evaluation program refused 141 gamma dosimeters. This happens whenever the radiation quality recorded on the film does not match the typical CERN radiation from activated material with photon energies in the range 400–800 keV. Usually, the refusal is due to the film being wrongly inserted into the badge. In order to reduce this occurrence, an illustrated leaflet was issued to all film distributors. It shows precisely how to place the films into the holder. The page is reproduced in PRP 4 'Dosimétrie Individuelle' [1]. Other reasons for refusal are 'washing' of a film or leaving it in a car in summer (39 cases). Only rarely does the refusal of a film indicate to the Assistant of the Service non-standard irradiation conditions. A radiotherapy patient was identified in 1997, and also a technician who had kept his film badge in the vicinity of a gyroscope made of depleted uranium.

In 1997, the highest single doses in one calendar month of 6.6 mSv and 6.4 mSv were received during the winter shutdown by two technicians of the company Ansaldo, involved in cabling work in the Neutrino facility.

No personal dose over 1 mSv was contradicted by the dose result of a complementary dosimeter or could not be explained by the persons involved. Hence no formal inquiry into unexplained exposures had to be conducted in 1997.

In the past year, 93 persons or their employers asked for individual dose records, in addition to several hundred Italian physicists, for whom their home institutes make global inquiries.

2.4 Technical developments

In 1996, Kodak introduced a new emulsion for the photon-sensitive Type-2 film. The new emulsion has certain advantages over its predecessor, with a visibly reduced fog level and a longer range of the linear portion of the calibration curve. On the other hand, the two emulsions of the film are not as well balanced in their shrinking behaviour, such that films tend to curl when drying. Experience showed that the effect diminishes if the developed films are kept in the higher humidity of the laboratory until immediately before evaluation. Even then, a mechanical adaptation of the Melico densitometers became necessary. This was carried out in CERN's central workshop.

A new photographic emulsion necessitated the recalibration of the film evaluation algorithm. This algorithm, based on an analysis of the optical densities behind filters of various materials and thicknesses, determines not only the dose equivalent to the wearer but also identifies the hardness of the photon radiation he was exposed to. The tests for the new evaluation algorithm required that several hundred dosimeters be exposed to eleven spectra of the ISO 'narrow series' of X-rays and to sources of ^{137}Cs and ^{60}Co at the Institut de Radiophysique Appliquée (IRA) in Lausanne. One algorithm each was constructed for the sensitive and the normal emulsion of the film. The algorithms are being tested with the full data set of 1997 and will be introduced in the routine together with the documentation of the INDOS application.

At the beginning of 1997, the stability of the development conditions of the photon dosimeters was checked with a large number of control dosimeters. While the results over a full two-month period stayed well within acceptable uncertainties, a clear trend towards under-evaluation was nevertheless visible due to the exhaustion of the processing chemicals [2]. It was decided to include, in the course of the modernization of the development laboratory, a regeneration facility to keep the chemical concentration of the processing baths constant. After sending a detailed technical specification to a dozen European suppliers, a consortium of two French firms (Generys S.A. in Orleans, and Arinter S.A. in Tours) was chosen to supply an automated development bench with regeneration system. A robot which displaces the baskets filled with films from one processing step to the next, ensures the perfect timing of the development steps. After a full development, fresh solutions are injected into the developer, stop bath, and fixer in order to keep the concentrations at the original level. The new laboratory started work at the end of January 1998.

3 CALIBRATION SERVICE

3.1 Routine calibration of fixed and portable monitors

At the end of 1997, RP group has 1000 instruments which have to undergo regular calibration or a verification of their functional status. Table 8 summarizes the activities of the Calibration Laboratory in 1997. Ionization chambers and Rem-counters with a calibration interval of three years, categorized in the classes 'Site' and 'Area' are regularly checked. This can be seen in the last line of the Table, where the number of instruments calibrated in the last three years is given. It even surpasses the number of instruments in use on 31 December 1997, because monitors must be calibrated after being repaired, and some units have been eliminated. The class 'Pers' was created in order to classify the personal electronic dosimeter DMC 100. Only units received in 1996 were verified in 1997. The fact that in 1997 only 60% of the handheld ratemeters and their accessories ('Hand'), 53% of contamination monitors ('Cont.') and in 1995–1997 only 38% of the radioactive gas monitors ('Gas') were calibrated is due to two factors: the present state of the instrument database (see Section 4.3) does not allow reports of instruments which are due for calibration in a given period (e.g. in one specific month or quarter of a year) to be edited in a simple way. The calibration laboratory technician is therefore nearly without means to allow him to actively request an instrument for verification. A number of instruments from the Automess-family have been given to users outside TIS–RP. A radiation protection technician is responsible for these instruments on loan, in particular their calibration. Many users do not seem to realise this and their instruments were not calibrated in 1997.

Two sources of the low-level calibration system exceeded the age of 10 years and were exchanged against new sources. The activities of the four ^{137}Cs sources are chosen such that by varying the distances, dose rates over four orders of magnitude can easily be generated. The arrival of these new sources was a good opportunity for assessing the uncertainties of photon doses given in the calibration facility. It was found that doses are accurate to within 6% of the central value at the 95% CL [3]. This precision is sufficient for the routine calibration of radiation protection instruments. Radioactive sources used exclusively for the calibration of fixed and portable monitors (Nos. 3609, 3739, 3740) were used as extensively as in previous years. The ^{60}Co source, the strongest ^{137}Cs source, and the neutron source have very high operation times, due to their use in various irradiation experiments (Table 9) (see Section 3.3).

Table 8: RP instruments in the calibration database as of 31.12.97

Class	Area	Cont.	Gas	Hand	Pers.	Site	Surv.
Number of types	25	26	4	12	1	5	1
Instruments total	410	97	26	150	209	77	31
Instruments in use	343	90	24	122	202	76	14
Calibration frequency (years)	3	1	3	1	1	3	1
Calibrated in 1997	141	48	1	73	100	26	0
Calibrated in 1995–1997	380	-	9	-	-	84	-

Table 9: Activity and usage of the main radioactive sources in the calibration hall

Source (No.)	Radiation, E	Activity on 31.12.97	Usage (h)
^{241}Am (2619)	γ, 60 keV	181.1 GBq	61.8
^{137}Cs (2045)	γ, 662 keV	1.22 TBq	1015.9
^{137}Cs (3609)	γ, 662 keV	104.3 GBq	28.7
^{137}Cs (3740)	γ, 662 keV	14.49 GBq	4.5
^{137}Cs (3739)	γ, 662 keV	1.79 GBq	7.3
^{60}Co (1665)	γ, 1250 keV	24.4 GBq	4383.0
^{238}Pu–Be (1120)	n, ≅ 4 MeV	1.85 TBq	535.5
^{137}Cs (631)	γ, 662 keV	Exch.	13.7
^{137}Cs (477)	γ, 662 keV	Exch.	11.7

3.2 Swiss intercomparison of dosimeters

The Swiss Federal Office for Public Health is the licensing authority for the Individual Dosimetry Service. It organizes a yearly, countrywide intercomparison for gamma- and beta-dosimeters to check their reliability. In 1997, PSI exposed the dosimeters of all Swiss dosimetry services to 0.1 mSv, 0.2 mSv and 0.4 mSv with a ^{137}Cs source. The aim was to check the reliability of the results in the region of small exposures. CERN's results fell well within the uncertainty range required by the new Swiss Ordinance for Dosimetry, which will become law in 1998 or 1999. For the 'reference point', an irradiation with ^{137}Cs at a somewhat higher dose equivalent, CERN remains well within the strict requirement of a maximum deviation of 10%.

3.3 Irradiations by external users

In 1997, CERN groups involved in the construction of the CMS electromagnetic calorimeter continued to irradiate $PbWO_4$ crystals with the ^{60}Co source No. 1665. At 27 cm distance the source delivers a kerma rate in air of about 100 mGy/h. Irradiations of scintillation crystals either take 15 h (one night from 17:30 to 8:30) or 63 h (one weekend, from Friday 17:30 to Monday 8:30). The light output, which is affected by radiation damage, is monitored continuously during the experiment. Furthermore, the crystals are characterized before and after the irradiations. The results of these experiments have been published in a series of conference proceedings and CMS internal notes [4]. The irradiations are set up by the members of the CMS collaboration, and the calibration laboratory technician controls the radioactive source.

A CERN–INFN collaboration exposed submicron VLSI electronics to gamma radiation from the strong ^{137}Cs source with dose rates of about 1 Gy/h. The aim was to study the development of radiation damage at this rate compared with irradiations at much higher rates [5].

The Max-Planck-Institut für Kernphysik in Heidelberg has a working group for archaeometry. One of the techniques for dating prehistoric pottery is the thermoluminescence of quartz sand found on the burial horizon. The MPI acquired a new TL irradiator equipped with a ^{90}Sr source and wanted to intercalibrate it with quartz samples exposed to well-known radiation doses. Using the nights of one week and one full weekend, three discs were irradiated with the large ^{137}Cs source to air kermas of 15, 30, and 60 Gy. This exposure was an opportunity to measure precisely the kerma of the large sources at distances between 75 cm and 25 cm, with an ionization chamber of only 1 cm^3 volume. Until then, these parameters were only known from extrapolation.

It is understood that irradiations for calibrations and experiments within RP have priority.

4 INSTRUMENTATION AND DEVELOPMENT

4.1 New acquisitions - replacements

The acquisition of DMC 100 personal electronic dosimeters continued in 1997. By the end of the year, 209 units had been distributed. One technician in each of the two survey sections is the contact person for users of the dosimeters. He distributes *ad personam* a certain number to persons working regularly in limited stay areas, others he hands out for short periods to workers who have to intervene in such areas.

The first batch of 100 DMC 100 dosimeters acquired in 1996 and at the beginning of 1997 came back for annual calibration for the first time. The response of the instruments to gamma radiation was checked and no anomalies were found. Throughout the year, single DMC 100s were returned to the calibration service with various defects. Some of them were restored to working order by reparametrization, others were sent back to the manufacturer for repair or exchange. Until now, less than 5% of the acquired units have had problems. However, with an increasing number of units in circulation and an increasing age, one has to expect a higher workload for the technician in the calibration laboratory.

During the year, it was found that the DMC 100 is not only sensitive to static magnetic fields (where it stops accumulating or indicating a dose) but also to RF fields of high intensity. Wearing the DMC 100 close to the mobile GSM telephone recently introduced at CERN provokes the accumulation of some 10 μSv per call received on the phone. More serious is the rapid accumulation of doses up to 10 mSv in hall 864 in Prévessin, where maintenance work on activated parts is performed. It is assumed that the high RF transients provoked by the GSM antenna on the neighbouring building is responsible for this. New usage rules were discussed by the surveyors and the calibration service and stipulated in the Radiation Protection Procedure PRP 18 'The electronic Dosimeter DMC 100' [6].

The campaign for exchanging older rate meters for instruments in the Automess-series was completed. All physicists and technicians are now equipped with AD-6 personal rate meters. The survey sections possess additional plug-on detectors like Teletectors, and contamination probes stored close to potential intervention points. The older PDR-2 or RM-5 devices from Nuclear Enterprises were collected and eliminated. The Radiation Protection Group now has modern equipment for most of its daily routine work.

The introduction of new generation PCMAs ('Picomur'), wall-mounted scintillation detectors for checking potentially activated material at the exits of the accelerators necessitated the elaboration of a calibration procedure. This is a two-step process: a full procedure is used in order to set all operational parameters for a newly fabricated or repaired unit. A significantly simplified check with only one radioactive source is performed annually at the location of the PCMA, in order to verify its proper operational status.

4.2 Instrument database

After the departure of the technician who administered RP Group's databases, the instrument database has only maintained its status of past years. It consists of a simple table, listing all available instruments by inventory number. It contains information about the type and make of the instrument, its user and the person responsible for it (the holder), the date of the last calibration and the calibration factors obtained, or, for instruments with a scale in protection quantities, the affirmation that its reading falls at least within the 20% interval around the conventional true value of the calibration. The reports prepared with this database are limited, and make a close follow-up of calibrations throughout the year practically impossible.

In 1998, it is planned to develop a new database application in collaboration with the Software Support Section of TIS–TE, which will allow the follow-up of every single instrument in the Radiation Protection Group.

4.3 Development of a scintillation detector

In order to detect material of low specific activity as well as weak radioactive sources, RP technicians use an IPAB scintillation detector from Nardeux Instruments. This instrument is rapidly becoming obsolete because of its age and weight. Furthermore, it is not in line with the policy of using the AD-6 as a master unit together with additional detector heads.

Unfortunately, Automess only offer a plastic scintillator with a slow response time and therefore, in collaboration with the Technical Support Section of TIS–TE group, a development project for a scintillation detector was started.

Technical Student Stefan Metz from the Universität of Karlsruhe designed the addition to the AD-6 during his six-month stay in the Radiation Protection Group. The principle of operation is to observe a rise in count rate over background, which indicates the presence of activated material. The detector uses a BGO scintillator, which gives less photoelectrons per MeV than the classical NaI(Tl) crystal, but has a higher interaction probability for photons. In fact, the count rate above a certain threshold is higher for BGO at all energies, and this advantage even increases for higher energies. In a given background, smaller increases of count rate due to weak sources can be detected with equal stochastic uncercainty. The detector unit contains a cylindrical scintillation crystal 37 mm long and 37 mm diameter, the photomultiplier, the detection electronics, the high-voltage supply for the PM, and the interface to the AD-6 rate meter. The unit has an autonomy of 50 h on four 1.5 V cells [7]. TIS–TE and RP made a call for tender to find a producer of a small series of ten units according to Stefan's design.

4.4 Automatic scanning of personal neutron dosimeters

Every two months the Individual Dosimetry Services distributes more than 4000 neutron films to CERN staff and visitors. The Kodak NTA emulsion is used as its capability of detecting high-energy neutrons is still unencompassed. The manual evaluation of these dosimeters is a tedious job. The dose is estimated from the density of proton recoil tracks on the film under a projection microscope. One assistant is employed full time solely for the development and the evaluation of the neutron dosimeters.

Although computer-aided image recognition methods are used in an increasing number of fields such as object identification, fully automated production lines, materials testing and even hadron dosimetry with etch-track dosimeters, no commercial system is available yet for identifying and counting the recoil tracks in a nuclear emulsion. Expensive prototypes for very complex nuclear emulsion analyses exist in several research laboratories, such as for a few heavy ion experiments conducted at CERN (EMU 12, EMU 16) and for the CHORUS neutrino oscillation experiment. These instruments are operated by highly trained specialists and are not suitable for a rapid routine scan of the NTA film.

The Dosimetry and Calibration Section recruited Mrs. Regina Müller as a CERN Fellow in May 1997. She is working on an alternative approach to the problem using an integrated, commercial image analysis system [8] which can be tailored by a macro language to the specific task. The hardware consists of a microscope, a CCD camera, a computer with frame grabber and control of the x-y-z stage used to focus into the emulsion and to displace the film horizontally under the microscope.

After two months of intensive work the system is capable of determining reliably the dose equivalent of calibration films irradiated with the calibration laboratory ^{238}Pu–Be source. Neutrons from this source, with energies mainly around 4 MeV, create short (≈ 25 μm), dense tracks in the emulsion [9]. The program is now being extended in order to detect the recoil protons of high-energy neutrons (energies in excess of a few 100 MeV), which have a smaller linear energy transfer, thus leaving discontinuous and 'light' tracks in the emulsion.

4.5 Primary beam monitoring for the CERF facility

For the two runs of the CERN-EU reference radiation field facility (CERF) in 1997, a new monitoring system for the primary beam intensity was developed. The intensity of the primary beam, consisting of protons and positive pions at a momentum of 120 GeV/*c*, is measured with a cylindrical ionization chamber equipped with a charge digitizer. One pulse of the digitizer corresponds within 10% to 2×10^4 beam particles. The new acquisition hardware consists of an old office PC (Processor Intel 80386) running under Windows 3.11, and a National Instruments counter card. The software to drive the counter was written with LabView. This results in a more user-friendly application than in the past. In addition to a central counter, a number of user-settable software scalers are displayed on the PC screen. They are very useful for irradiations of passive detectors, permitting the primary beam intensity to be converted immediately into dose or dose equivalent by suitable conversion factors. This feature makes the task of the RP physicist on duty at the experiment easier, as the users can now obtain dose equivalents, on the spot and do not have to wait for an evaluation by RP staff. After extensive offline testing, the acquisition system worked to the entire satisfaction of all users during the CERF runs in April and September 1997. A short user manual is given in the report which gives the reference values for 1997 [10].

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