

Radiological Protection Control at a Cyclotron Facility

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Abstract: High energy cyclotrons in use by several decades for the production of radionuclides in the diagnosis of diseases have been applied, particularly to supply the short-lived products to nuclear medicine services. The cyclotrons operate at relatively high beam currents which result in high dose rates in the vaults and there is potential risk of acute exposure of personnel. The cyclotron staff was identified among the higher exposure groups in the Instituto de Pesquisas Energéticas e Nucleares – IPEN – CNEN/SP. The radiological protection staff has established a radiological protection program whose purpose is providing an adequate occupational worker protection system in agreement to national and international radiological protection standards. The goal of this paper is to review the characteristics of unusual events occurred in the workplaces at cyclotron facility during the year of 2007. In addition, another objective is also to relate the main causes of unusual events occurred in the workplaces that resulted some worker irradiation or workstation contamination. The data analysis included the radiological protection records and reports examination, provided by radiation protection supervisor, complemented by interviews with radiation protection technician and workers involved in the processes. It was verified that in the period of study occurred nine events. Improved technology and dosimetry systems, the use of dose mapping techniques, innovative approaches to task analysis and the application of management skills to the planning of maintenance work have all contributed to this success. A major gain has been made but continues procedures reviews to cyclotron group are recommended according to the ALARA program.

KEYWORDS: *radiological protection, potential risks, dosimetry systems, unusual events, contamination, cyclotron facility.*

1. Introduction

The accelerator Cyclotron of the Instituto de Pesquisas Energéticas e Nucleares - IPEN is a radioactive facility that works with the production of short lived radioisotopes used in medicine for diagnosis. This facility began their activities in the middle of the 70s years. In this time, with the installation of Cyclotron CV-28 (The Cyclotron Corporation - USA), were performed the first experiments to produce radioisotopes of great interest in nuclear medicine (Gallium-67, Iodine-123, Thallium-201 and Indium-111). In 1991 started up the production of Iodine-123 and in 1998 it is started the production of Fluorine-18. In the same year, 1998, was installed a new Cyclotron accelerator, Cyclone 30, which can accelerate protons with energies between 15 and 30 MeV and beam current of up to 350 μ A, designed and built by the company Ion Beam Applications (IBA), Belgium .

Actually, the Iodine-123 (^{123}I) and Fluor-18 (^{18}F) productions are performed in the Cyclone 30. The Iodine -123 is produced once a week, to attend a demand of 37 GBq and Fluorine-18 is produced daily to assist a demand of 74 GBq to 148 GBq per day [1].

The cyclotrons operate at relatively high beam currents resulting in high dose rates in the vaults with potential risk of acute exposure of personnel.

The Radioprotection Service established, in the installation, a monitoring programme based on the radiological protection principles [2, 3, 4], which goal is to provide an adequate occupational worker protection system. The monitoring programme include: the radiological control of workers, the access control to radiological areas and the control of the radiation sources and equipments.

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In this study is described briefly the radiological protection programme for the facility workers according to their main tasks [5]. The goal of this paper is to review the characteristics of unusual events occurred in the workplaces at cyclotron facility during 2007. In addition, another objective is also to relate the main causes of unusual events occurred in the workplaces that resulted some worker irradiation or workstation contamination.

2. Methodology

2.1 Radiological Protection Programme

The workforce consists of 18 workers who perform operation and maintenance tasks, preparation and targets irradiation assembly, cleanings of areas and radioprotection. Before starting any operation involving the ionizing radiation, it is necessary that the worker notifies the radioprotection group to be observed radiological conditions in the workplace. The control is done by survey mapping during the operations with the both purpose of estimating the time spent by worker in the radiation area and the reducing dose rates. The work planning includes workers motion to carry out a specific job, according to their annual report dose.

The worker must to wear a dosimeter type TL (Thermoluminescent) and an additional integrating dose dosimeter (Dosicard) during your routine activities. In this sense, it is essential that a radioprotection technical evaluating the operating conditions so that any deviation from normality situation it can be rapidly detected. At the end of operations, the workers performing self-monitoring with a contamination monitor, type feet and hands, to prevent the spread of contamination outside the workplace. The tools used in the process are also monitored with a surface contamination monitor with the same purpose.

The 2007 data analysis were derived from examinations of radiological protection records and reports, interviews with the radioprotection supervisor and technical, and also with the workers involved in the operations.

3. Results

In Table 1 are shown the main events that contributed to the external individual dose of the workers as well the task performed, the likelihood cause event, numbers of workers involved and external individual dose. The doses (mSv) presented were obtained through direct reading of dose integrators dosimeters and represent the accumulated dose of each worker involved in the operation, at the working time.

Table 1: Main events that contributed to the external exposure of the workers.

POTENCIAL RISK OF EXTERNAL EXPOSURE					
Place	Task performed	Case	Event	Workers involved	Individual Dose (mSv)
Irradiation of targets liquids.	Maintenance ¹⁸ F target.	1	Preventive maintenance in the ¹⁸ F target, but at the time the machine test there was leak of enriched water (H ₂ ¹⁸ O) used in the ¹⁸ F production, being required a new corrective maintenance.	2	1.48
					1.31
	Intervention ¹⁸ F target.	2	Failure in the automatic opening valve to release ¹⁸ F, being required the entry of an operator in the room for manual opening of the valve.	1	1.20
	Maintenance ¹²³ I target.	3	During the ¹²³ I loading it was found a leak in the Helium (He) hose used for cooling the target.	1	0.93
Manipulation of targets irradiated (hot cells)	¹⁸ F Production.	4	The tweezers handling of the hot-cell was accidentally loose at the time of release of production of ¹⁸ F, being required opening the cell for transfer, with a small tweezers, the bottle containing material for the transport shielding.	1	0.172
Vault cyclotron	Intervention on the machine.	5	Failure in the Cyclotron radiofrequency system (1).	3	0.0174
					0.0151
					0.0152
		6	Failure in the Cyclotron radiofrequency system (2).	3	0.0047
					0.0183
					0.0191

In table 2 are shown the events that resulted in contamination of the worker and the workplace, as well the occurrence local, task performed, number case, event and number of workers involved.

Table 2: Events that resulted contamination to the worker and workplace

CONTAMINATION				
Local	Task performed	Case	Event	Workers involved
Irradiation of targets liquids.	Intervention ¹⁸ F target.	7	A failure of opening automatic valve to release ¹⁸ F, being required the entry of an operator in the room for manual opening of the valve. The operator accomplished the task without using gloves, resulting in contamination of one of his hands.	1
	Maintenance for replace the sheet of extraction the ¹²³ I target.	8	At the end of the operation was detected contamination in the work bench and on the floor of the room. It was detected a point of contamination in the corridor of access, next the room. Two workers had their boots contaminated and left the room without monitoring their feet spreading the contamination to the corridor.	2
Manipulation of targets irradiated (hot cells)	Withdrawal of liquid waste in the hot cell.	9	During the transference procedure of the effluent of the bottles for plastic vessel the material splashed in one of the operators, causing a contamination in the skin surface of the operator.	1

Figure 1 shows the doses distribution for workers in Cyclotron Facility for the year 2007 and in Table 3 are presented the individual external doses accumulated for the 18 workers of the facility.

Figure 1: Distribution of workers doses of Cyclotron Facility at dose intervals.

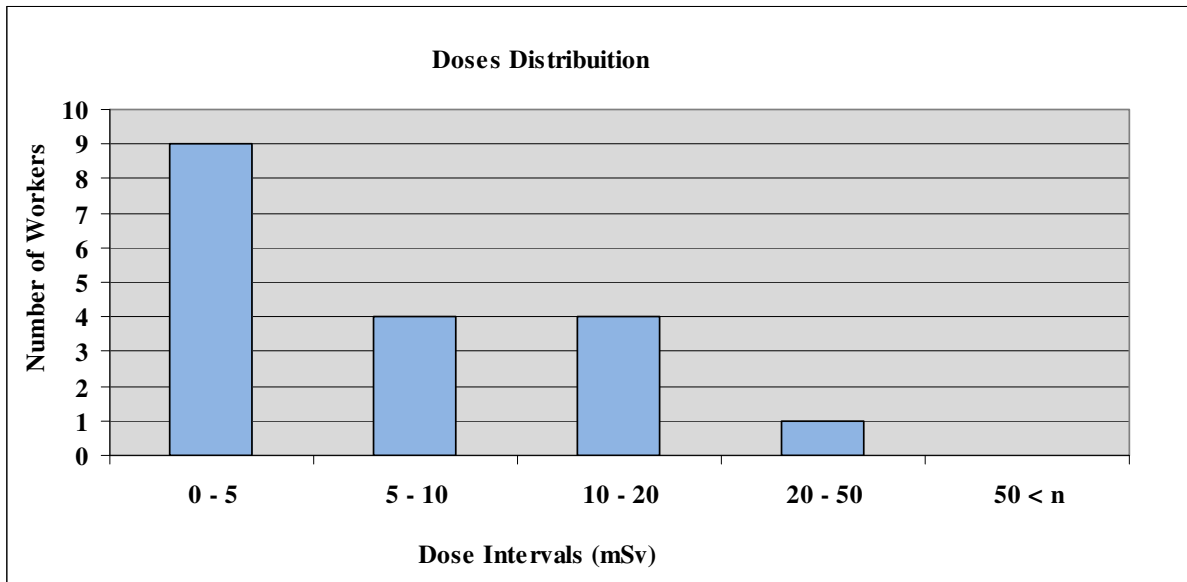


Table 3: Individual external doses accumulated for the 18 workers of the facility during the year 2007.

Groups	Worker	Doses (mSv)												Annual Dose (mSv)
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	
Targets	01	2.63	2.27	0.65	2.37	2.74	1.72	2.67	5.54	2.66	0.50	0.59	1.46	25.80
	02	2.05	1.42	0.67	0.99	1.39	0.97	2.39	2.97	0.65	1.22	1.22	1.19	17.13
	03	1.14	1.28	1.02	DE	1.26	1.25	1.51	1.58	2.04	1.27	1.28	1.47	15.10
	04	M	M	M	0.21	0.71	M	0.24	0.62	1.86	0.40	0.41	0.42	4.87
Operation and Maintenance	05	0.56	2.04	0.63	0.99	0.78	0.52	0.21	1.05	1.69	0.40	0.56	0.76	10.19
	06	0.41	0.28	0.53	0.33	0.54	M	M	0.49	0.34	0.42	0.42	0.57	4.33
	07	0.72	2.29	0.39	0.66	0.73	0.25	1.26	0.89	0.41	0.47	0.30	0.52	8.89
	08	0.34	0.29	0.23	0.38	M	M	M	1.00	0.46	M	M	0.45	3.15
	09	M	M	M	M	0.51	M	M	0.43	M	0.25	0.26	M	1.45
	10	M	M	0.20	M	0.46	M	0.56	M	M	0.21	0.21	0.40	2.04
	11	1.42	0.58	0.51	1.72	0.75	M	0.39	1.13	0.91	0.40	0.43	1.37	9.61
Cleaning	12	M	M	M	M	M	M	M	M	M	M	M	M	0.00
	13	M	M	M	M	M	M	M	M	M	M	M	M	0.00
	14	M	M	M	M	M	M	M	M	M	M	M	M	0.00
Radioprotection	15	0.57	0.51	1.08	M	0.44	0.24	0.70	0.60	0.92	0.60	0.64	M	6.30
	16	M	M	0.25	M	M	0.23	0.67	1.03	0.32	M	M	0.35	2.85
	17	0.80	1.27	0.25	1.00	1.12	0.53	0.70	1.65	1.18	0.60	0.75	1.38	11.23
	18	1.86	M	0.20	0.29	1.08	0.27	0.46	1.25	0.57	0.59	0.59	0.40	7.56

M: Minor than the Level of Registration (<0,20 mSv); DES: Off the Centre; DE: Dosimeter astray.

4. Discussion

The data analyzed in Tables 1 and 2, show that most events, despite the compliance of predictive and preventive maintenance, had the facts starter failures of equipment, generating corrective maintenance and, consequently causing dose workers.

The contamination cases described in Table 2, with except of the case 8, were in consequence of non-compliance with operating procedures by the workers involved.

The Comissão Nacional de Energia Nuclear – CNEN recommends a limit on annual dose of 20 mSv, averaged over defined periods of 5 years, and may not exceed 50 mSv in a single year. But the ideal is that these values are optimized to values of doses below 10 mSv / y, used as criteria for optimization.

In Figure 1, it appears that 9 workers received doses below 5 mSv/y, 4 workers received doses between 5 and 10mSv/y, 4 workers received doses between 10 and 20 mSv/y, and a worker received dose above 20 mSv/y. The higher doses were received by the group of targets, accounting for 48% of

total doses of the 18 workers, followed by the group of operation and maintenance with 31% and finally by the group of radioprotection with 21%.

5. Conclusion

Data analysis indicates that to reduce the doses for all workers to acceptable values of 10 mSv/y is necessary the implementation of new technologies for utilities, for example, the power network stabilization, increased specialist staff to apply the technique of worker motion in order to maintain the collective dose in the current value and reduce the individual dose.

In cases surface and skin contamination, was promoted a training of workers emphasizing operational procedures and radioprotection.

Despite the 9 events in the year 2007, it was found that the doses of workers of the facility will not exceed the national regulatory requirements.

References

- [1] INSTITUTO DE PESQUISAS ENERGÉTICAS E NUCLEARES - IPEN. **Centros de Pesquisa - Aceleradores Cíclotron - Quem Somos - Histórico.** <http://www.ipen.br/sitio/>.
- [2] COMISSÃO NACIONAL DE ENERGIA NUCLEAR. **Diretrizes Básicas de Proteção Radiológica – CNEN-NN-3.01.** Janeiro, 2005.
- [3] COMISSÃO NACIONAL DE ENERGIA NUCLEAR. **Serviço de Radioproteção – CNEN-NE-3.02.** Agosto, 1988.
- [4] INTERNATIONAL COMMISSION ON RADIOLOGICAL PRTECTION, **Recommendations of the International Commission on Radiological Protection**, ICRP Publication 60. Vienna, 1991.
- [5] RODRIGUES, Demerval Leônidas. **Otimização no Controle dos Valores de Radiação nas Dependências do Cíclotron de 30 MeV do IPEN.** Dissertação (Mestrado) – Instituto de Pesquisas Energéticas e Nucleares, São Paulo, 2002.