ANALYSIS OF OCCUPATIONAL EXPOSURE IN A NATURAL-URANIUM HEAVY-WATER REACTOR

E. Palacios, A. Curti and O. Agatiello
Comision Nacional de Energia Atomica
Buenos Aires, Argentina

INTRODUCTION

The Argentine Nuclear Programme contemplates the installation of six nuclear stations before the end of this century. Presently, two nuclear stations are in operation: Atucha I, 360 MW_e, and Embalse, 600 MW_e. A third station -Atucha II, 745 MW_e- is in its construction step. Additionally, uranium extraction, concentration and purification, and the manufacture of fuel elements are being performed within the country, while a heavy-water production plant and a semi-industrial reprocessing plant are in an advanced stage of construction.

Atucha I is a plant of the pressure-vessel reactor type, moderated and refrigerated with heavy water. Its operation started in 1974 and it has produced until mid 1983 2.5 GW_ea. This station was the first one of this type and capacity that was built in the world and this prototype condition has made the number of persons occupationally exposed higher than that in equivalent reactors. Accordingly, the use of cobalt alloys in various components of the reactor made dose rates relatively high along the primary circuit and, consequently, so were the doses resulting from the operations carried out in this sector. The prototype condition did also provoke a significant contribution of occupational exposures as a result of specific repairs about which no previous experience was available.(1)

An analysis is made herewith of the occupational doses at the Atucha I Nuclear Station, while the tasks with a greater contribution to the collective dose commitment were identified. Finally, an evaluation was made of the detriment expected during the whole useful life of the installation.

DOSIMETRIC EVALUATION

For the purposes of this paper, it was considered that the doses due to external irradiation, obtained as from readings of the personal dosimeters, are representative of the effective dose equivalent (further on doses). The doses due to internal contamination were calculated taking into account ICRP Publication 30.(2)

The United Nations Scientific Committee on the Effects of Atomic Radiations (UNSCEAR) (3) has provided a few approaches for the evaluation of the collective effective dose equivalent (further on collective dose) as from the distribution of the individual doses. For the case of Atucha I, the dose distributions due to external radiation deviate from the log-normal function at individual doses above 1.5 10^{-2} Sv. Opposedly, the dose distributions due to tritium inhalation follow the log-normal function quite closely at any value.(4)

Dose values below 0.20 mSv for external radiation and far below such value for internal contamination have been recorded as zero. The assignment of zero dose to all those workers receiving doses below the registered level brings along errors in the evaluation of the collective dose. However, the error introduced for this reason is, in this case, below 1% of the total collective dose. Therefore, the collective dose introduced herewith was calculated as from the summation of the individual doses due to external radiation and to internal contamination.

Table 1 shows the collective dose incurred by all the personnel in the Station, while distinctions have been made among the doses incurred by personnel in three areas: plant operation, radiological protection and maintenance. Such dose includes that due to personnel training for future stations, which was estimated in approximately 20%. Also, distinction has been made between doses received by permanent and temporary personnel. 60% of the total collective dose is incurred by the maintenance staff.

TABLE 1

Collective dose incurred by personnel in Atucha I Nuclear Station (man Sv)

YEAR	TOTAL	OPER-ATION	RADIO-PROTEC.	MAINTE-NANCE	PERMA-NENT	TEMPO-RARY
1974	0.9	0.2	0.2	0.5	0.6	0.3
1975	1.6	0.5	0.2	0.9	1.3	0.3
1976	1.8	0.7	0.3	0.8	1.6	0.2
1977	6.8	1.5	0.9	4.4	4.9	1.9
1978	4.1	1.2	0.8	2.1	3.5	0.6
1979	5.9	1.3	1.0	3.6	4.7	1.2
1980	9.9	2.2	1.4	6.3	6.1	3.8
1981	5.8	2.0	1.0	2.8	4.9	0.9
1982	11.2	2.7	1.3	7.2	8.0	3.2

TASKS IMPLYING A HIGHER COLLECTIVE DOSE

The Atucha I station has showed a relevant performance and has operated with a load coefficient above 85% during long periods of time. However, maintenance tasks scheduled to be performed every 30 months, plus shutdowns involving interventions in the primary circuit, were the reasons for 40% of the collective dose incurred by the personnel during the last six years.

The tasks showing a greater contribution to the collective dose are shown in Table 2. Those tasks have been individualized as resulting from scheduled shutdowns, from non-scheduled repair tasks and from inspection operations.

TABLE 2

Maintenance tasks with greater contribution to the collective dose (man Sv)

YEAR	TOTAL	SCHEDULED TASKS		NON-SCHEDULED TASKS			
		INSPECT.	OTHER	QM	QF	QP	OTHER
1977	3.4	0.6	1.3	1.2	0.3		
1978	0.8			0.7	0.1		
1979	2.8			1.2	0.5	0.6	0.5
1980	5.2	1.6	3.1		0.4		0.1
1981	0.8				0.4		0.4
1982	6.4	2.0	4.4				

QM = Moderator circuit piping QF = Cooler circulation pump
QP = Moderator pump

ASSESSMENT OF THE RADIOLOGICAL DETRIMENT

The concept of radiological detriment was introduced by the International Commission on Radiological Protection (ICRP) and its evaluation is an essential step in the optimization of radiation protection against radiation sources. The linear dose/effect ratio allows for evaluating the health detriment produced by a given source by adding the doses incurred by each individual (collective dose) due to the operation of such source.

The detriment produced among occupationally-exposed workers at the Atucha I Station was mostly due to maintenance, repair and inspection tasks performed during the plant operation (Table 2). The expected detriment resulting from the operation of Atucha I during its whole useful life will depend on the frequency of the tasks performed in the vicinity of the primary circuit, on the evolution of the dose rates in the rooms where those tasks are carried out and on the way in which the maintenance tasks are performed.

The frequency of non-scheduled interventions kept increasing during the first years in operation and has stabilized during the last six years. Presently, maintenance tasks are scheduled for every 30 months and inspection operations are performed once a year.

The exposure rate in the vicinity of the primary circuit suffered a 100% increase during the last six years. This was mainly due to the deposition of cobalt activation products resulting from the corrosion of elements in the reactor. The tendency of the dose rates will be attenuated during the next few years by means of decontamination operations.

The experience collected during the operation of Atucha I has provided the necessary elements for planning maintenance operations towards decreasing the number of man-hours necessary for their accomplishment and, consequently, decreasing radiological detriment (5).

The occupational detriment that would result from the operation of Atucha I between now and the end of its useful life (the latter estimated in 30 years) was evaluated as from the tendency observed in the annual collective dose during the last six years. The resulting collective dose would be 160 man Sv and the collective dose per unit of practice would be 27 man $Sv/GW_e a$. These values may be substantially reduced if special intervention systems are introduced, such as robots and special shields.

CONCLUSIONS

One of the factors that mostly contribute to a relatively high collective dose per unit of practice at Atucha I is that cobalt activation products, settled along the primary circuit, maintain dose rates at relatively high levels. This should be avoided in the future.

Maintenance tasks are the ones mostly contributing to the total collective dose and this is where most efforts must be made toward reducing the doses. Considering that the Argentine Authority has adopted a detriment cost value of US$ 10,000/man Sv, a significant investment has to be made in order to reduce detriment as far as it is reasonably achievable. It must also be considered that some of the radiation protection systems could be later used in both Atucha I and Atucha II stations. This would justify a considerably higher investment in radiation protection.

BIBLIOGRAPHY

(1) Gonzalez, A.J. IAEA-CN-42/158.

(2) ICRP Publication 30. Oxford, Pergamon Press, 1979. Annals of the ICRP v.2: N° 3/4, 1979.

(3) United Nations Scientific Committee on the Effects of Atomic Radiation. 1982 Report to the General Assembly, with annexes. New York, United Nations, 1982. 773 p.

(4) Palacios, E.; Campos, J.M. and Curti, A. 1981 CNEA-NT 11/81.

(5) Gonzalez, A.J. et al. IAEA-SM-258/54.