Cernavoda NPP – Using dose constraints as ALARA instruments

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1.0 INTRODUCTION

Cernavoda Nuclear Power Station – CNE Cernavoda – is a two unit plant with 700 Mw_e Pressurized Heavy Water Reactors located in Romania, by the Danube River. The reactors are CANDU 6 type designed by AECL Canada. The Station is owned 100 % by Romanian state and managed by S. N. Nuclearelectrica S.A.

The main mission of the company is the industrial production of electricity and heat, by using nuclear power, in terms of maximum safety, reliability and respect towards the environment.

Optimization of radiation protection is a principle of the system recommended by the International Commission on Radiological Protection (ICRP). Optimization of protection is not minimization of dose. Optimized protection is the result of a balance between the detriment from the exposure and the resources available for the protection of individuals. Thus the best option is not necessarily the one with the lowest dose.

Since the effective dose is a risk-related quantity based upon the consequences of whole body exposure, measure of the potential detriment on the health of an individual following the exposure of the human body to ionizing radiation, it is a conservative attitude from the radiation workers protection point of view, to use all the appropriate method for keeping the individual effective doses ALARA.

The management of Cernavoda Nuclear Power Plant is committed, as a matter of policy, to keep all radiation exposures As Low As Reasonably Achievable, economic and social factors being taken into account.

2.0 ICRP APPROACH ON CONSTRAINTS

Optimization is always aimed at achieving the best level of protection under the prevailing circumstances through an ongoing, iterative process that involves:

- evaluation of the exposure situation, including any potential exposures (process framing);
- selection of an appropriate value for the constraint or reference level;
- identification of the possible protection options;
- selection of the best option under the prevailing circumstances; and
- implementation of the selected option.

> *The [second radiation protection] principle of optimization of protection:* the likelihood of incurring exposures, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and societal factors.

This means that the level of protection should be the best under the prevailing circumstances, maximizing the margin of benefit over harm. In order to avoid severely inequitable outcomes of this optimization procedure, there should be restrictions on the doses or risks to individuals from a particular source (dose or risk constraints and reference levels).

The concepts of dose constraint and reference level are used in conjunction with the optimization of protection to restrict individual doses.
A level of individual dose, either as a dose constraint or a reference level, always needs to be defined. The initial intention would be to not exceed, or to remain at, these levels, and the ambition is to reduce all doses to levels that are as low as reasonably achievable, economic and societal factors being taken into account.

For **planned exposure** situations, the source-related restriction to the dose that individuals may incur is **the dose constraint**.

Dose constraint:
A prospective and source-related restriction on the individual dose from a source, which provides a basic level of protection for the most highly exposed individuals from a source, and serves as an upper bound on the dose in optimization of protection for that source. For occupational exposures, the dose constraint is a value of individual dose used to limit the range of options considered in the process of optimization.

Following, we will discuss about dose constraints, and other limiting values usually named "individual dose constraint" or "individual dose restriction" or "individual dose objective". They are formulated at Cernavoda NPP like “nobody above X mSv" or "special authorization needed if a person would exceed X mSv" and used to control and optimize occupational exposure of nuclear workers.

3.0 DOSE LIMITS AT CNE CERNAVODA NPP

Since first year of operation (1996) Cernavoda NPP implemented dose limit values recommended by ICRP 60 Council of European Union Directive 96/29/EURATOM, for both occupational and public exposure:

Table 1 Dose limits at Cernavoda NPP

	Dose limit (legal)		Administrative limit	Dose Constraint
	Occupational	Public	Occupational	Public
Effective dose	20 mSv/ year	1 mSv/year	18 mSv/year	0.1 mSv/(year unit)
Equivalent dose in the lens of the eye	150 mSv/year	15 mSv/year		
Equivalent dose in the skin	500 mSv/year	50 mSv/year		
Equivalent dose in the hands and feet	500 mSv/year	-		

ICRP limits were adopted by the Romanian laws in 2000; the annual limit for effective dose is more restrictive since the possibility of “20 mSv/year, averaged over defined period of 5 years” for normal exposures was eliminated from the national regulations.

For special authorized exposures, regulatory body (CNCAN) may approves the exceeding of 20 mSv effective dose limit but without exceeding any equivalent dose limit and provided that average over 5 years does not exceed 20 mSv/year.

The occupational exposure of women
The control of the occupational exposure of women who are not pregnant is the same as that for the men. Once pregnancy has been declared the fetus is protected by applying a supplementary equivalent dose limit to the surface of the woman’s abdomen of 1 mSv for the remainder of the pregnancy.

Emergency exposures

For the emergency situations limits presented above are replaced with emergency dose limits provided in the emergency plans and approved by the regulatory body. For special cases (life threatening dangers) emergency limits can be exceeded.

At Cernavoda NPP, the 20 mSv/y individual legal dose limit is the only dose constraint required by the national regulatory body.

Nevertheless, since the beginning we established an administrative individual annual limit of 18 mSv, 2 mSv lower than the legal limit, supported by:

- the Dose Control Point (DCP);
- 2 mSv investigation level for unexpected external single exposure;
- 1 mSv committed dose, investigation and removal level for internal acute exposure (single intake);
- 0.3 mSv follow-up level for internal acute exposure.

Dose Control Point (DCP) is an internal administrative limit, a very useful tool for control and limitation of occupational exposure to ionizing radiation. It represents half of the effective dose available until administrative limit of 18 mSv/year is reached; at the beginning of a dosimetric year the DCP is 9 mSv, and it lowers with every dose recorded in the database (external doses measured with TLDs and EPDs, neutron doses, internal doses due to intakes of tritium and other internal contaminants).

This limit cannot be exceeded (in single exposure) without Station Health Physicist approval.

External doses, $H_p(10)$, equal or higher than 2 mSv, in single exposure, due to gamma radiation, measured with the thermo-luminescent individual dosimeter, TLD, are investigated. Also, we usually investigate individual external gamma doses equals or higher than 1 mSv, in single exposure, measured with EPD.

External individual doses equal or higher than 2 mSv, in single exposure, due to neutrons, as they are measured with integrating portable neutrons monitor, they are also investigated.

Based on conclusions in the investigation reports are established corrective and / or preventive actions.

Corrective and preventive actions and recommendations aim both work planning (exposure control) and technical aspects, so that work conditions (especially radiation work) to be improved.

Despite the protection measures operating experience to date of CANDU reactors has indicated that the major contributor to the internal dose of professionally exposed workers is the tritiated heavy water (DTO) which is present chronically at many work locations.

Besides the administrative total effective dose limit of 18 mSv/year there are implemented other administrative controls in order to optimize the internal doses due to the intake of tritiated heavy water:

- **investigation and removal limit of 1 mSv committed dose**: when DTO concentration in urine exceeds 1.2 MBq/L, daily sample submission is required and the subject is not allowed to enter into radiological zone with tritium in air contamination until the concentration decrease; investigations are made by the health physics staff in order to determine the actual dose due to this single acute intake and the time of intake; removal is intended to avoid further intakes which could interfere with the dose calculation.
- **follow-up level of internal exposure to tritium of 0.3 mSv** (lower than the investigations and removal level of 1 mSv); investigations are made by the compartments' ALARA coordinators.

The threshold for the use of respiratory protection equipment was lowered to 0.03 mSv anticipated committed dose, even when the tritium dose rate does not exceed 0.05 mSv/h, when respiratory protection become mandatory.

4.0 OTHER METHODS FOR LIMITING INDIVIDUAL DOSES

At Cernavoda NPP, we don't use a daily dose limit but we have several instruments to control the exposure of our employees:

– Workers only perform radiation work based on a Radiation Work Permit (RWP). RWP are released for both routine work (generic RWP) and specific job (specific RWP).

In case of generic RWPs the EPD received by the worker has established dose, dose rate and time limits based on the radiological conditions in the areas he/she will perform radiation work. The pre-alarm is established at 80% of the dose limit. If the EPD alarms the worker must leave immediately the area and report to the radiation control technician.

For the specific jobs in the RWP are established individual (total, internal and external) and collective dose limits. If these limits are reached before finishing the job the RWP is re-evaluated and the individual dose limits can be exceeded only with the approval of Station Health Physicist.

– Since 2007 when the ALARA program was implemented more individual and collective dose objective were established as ALARA performance indicators:
a) maximum individual dose at the end of the year – 9 mSv for 2008, 8 mSv for 2009, lowered to 7.5 mSv for 2010 (planned exposures)

b) maximum individual internal dose due to tritium intake at the end of the year – 5 mSv – established for 2010 (planned exposures)

c) Unexpected acute individual internal exposures – any intake leading to an unforeseen committed dose higher than investigation / removal level of 1 mSv.

d) Unexpected acute individual external exposures – every inappropriate response at the EPD alarm for exceeding the dose that have been set for a particular job;

e) number of workers with internal contamination with other nuclides than tritium.

Table 2 ALARA Performance indicators

	2008		2009		2010	
	Target	Achieved	Target	Achieved	Target	Achieved (end of September)
Acute internal exposures	0	6	0	0	0	0
Acute external exposures	0	3	0	7	0	1
Internal contaminations	5	27	5	45	10	18

5.0 RESULTS. CONCLUSIONS

Average and maximum annual individual dose

No significant variations of annual individual average dose were observed since commercial operation of the plant started. Maximum individual doses were well below the national limit of 20 mSv. (See Table 3 and Figure 1).

Year	Individual average dose (mSv)	Individual maximum dose (mSv)
1997	0.99	9.96
1998	0.76	6.2
1999	1.29	9.57
2000	1.25	6.85
2001	1.26	7.94
2002	1.12	9.23
2003	1.26	9.68
2004	1.17	8.15
2005	1.42	12.21
2006	1.15	9.01
2007	0.74	7.03
2008	0.77	15.32*
2009	0.57	7.18

Table 3 Cernavoda NPP average and maximum individual doses

*This dose was due to an abnormal external exposure of 15.04 mSv, of a fuel handling operator. There were no doses higher than 9 mSv due to cumulative planned exposures.

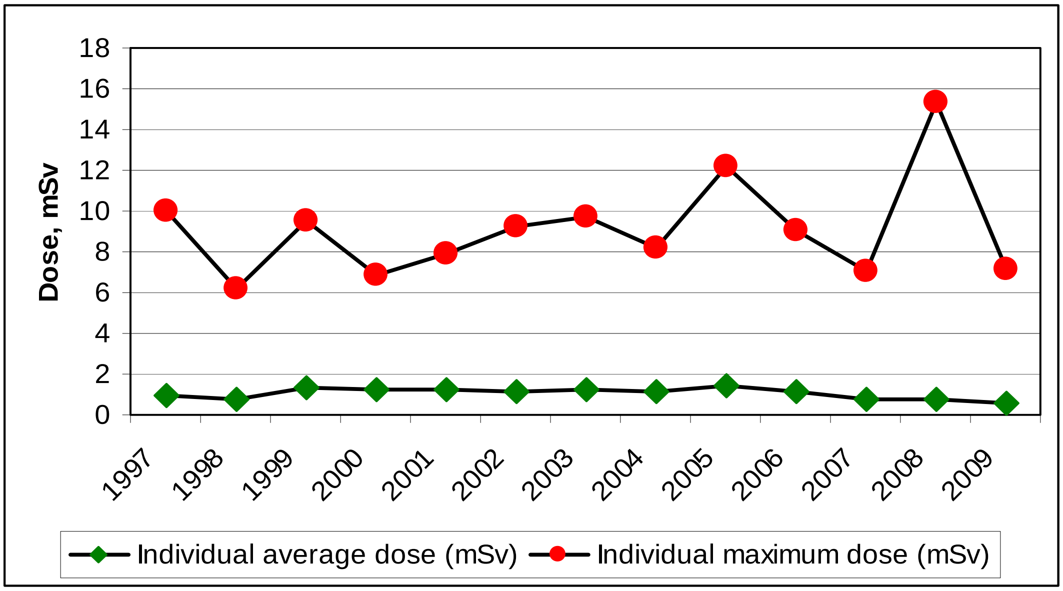

Figure 1 Cernavoda NPP average and maximum individual doses evolution

The actual levels of individual and collective effective doses due to external and internal exposures reveal the effectiveness of implementation of the Radiation Safety Policies and Principles established by the management of the Cernavoda NPP.

During 14 years of operation, most of the exposures were below the Recording Level and the majority of recordable doses were less then 1 mSv. Any legal or administrative individual dose limit has not been exceeded (Table 4).

Since the objective of the optimization of radiological protection is to reduce individual and collective doses, the most relevant indicator is the dose (collective or individual).
The station's exposure control program continues to be in full compliance with the regulatory requirements. In particular, the station exposure control level of 18 mSv/calendar year is below the single year regulatory limit of 20 mSv / year.

Table 4 Total effective dose distribution by dose interval

Year	**0.0**	**>0.0 <1.0**	**1.0 – 5.0**	**5.0 – 10.0**	**10.0 – 15.0**	**15.0 – 20.0**	**Over 20.0 mSv**
1999	1258	209	135	10	0	0	0
2000	1304	191	173	6	0	0	0
2001	1332	264	171	16	0	0	0
2002	1484	312	162	14	0	0	0
2003	1520	372	254	22	0	0	0
2004	1774	328	210	16	0	0	0
2005	1912	273	212	20	3	0	0
2006	2074	292	175	14	0	0	0
2007	3033	285	62	6	0	0	0
2008	2159	679	184	19	1	1	0
2009	1851	712	112	13	0	0	0

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