SYNTHESIS OF BENCHMARKING VISITS ON THE ORGANISATION AND PRACTICAL IMPLEMENTATION OF RADIATION PROTECTION IN NUCLEAR POWER PLANTS

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1. Introduction

Since the beginning of the 90s, EDF has made great efforts to improve ALARA for occupational exposures in the French nuclear power plants. This resulted in the important reduction of the individual doses (581 workers received more than 20 mSv in 1996; in 2006 no one received more than 20 mSv and only 17 received more than 16 mSv) and of the average collective dose per reactor (reduction by more than a factor two in ten years). EDF wishes to continue its efforts. One of the ways of improvement is the analysis of the feedback experience in the foreign power plants having good dosimetric results or with a recent significant improvement of the dosimetric results.

Thus, since 2003 the CEPN has organized for EDF nine benchmarking visits on the organisation and practical implementation of radiation protection in foreign nuclear power plants. For each visit, a team, composed of two representatives from EDF and two representatives from CEPN, goes to the site during a week and meets representatives of services implied in the implementation of the specific topic, which was selected. The sites are selected using ISOE data due to their good dosimetric results or due to a recent improvement of these results. The nuclear power plants, which were visited, are the following:

- Almaraz (Spain – 2 PWR of 930 MWe), July 2003;
- Doel (Belgium – 2 PWR of 400 MWe and 2 PWR of 1000 MWe), October 2003;
- Ringhals (Sweden – 1 BWR of 830 MWe, 1 PWR of 875 MWe and 2 PWR of 915 MWe), October 2003;
- Sizewell B (United Kingdom – 1 PWR of 1200 MWe), September 2004;
- Saint-Lucie (USA – 2 PWR of 840 MWe), September 2005;
- Beznau (Switzerland – 2 PWR of 365 MWe), July 2006;
- Vogtle (USA – 2 PWR of 1150 MWe) and Calvert Cliffs (USA – 2 PWR of 840 MWe), October 2006;
- Paks (Hungary – 2 VVER of 470 MWe and 2 VVER of 500 MWe), September 2007.

Several good practices of radiation protection were identified during these visits:

- The good integration of radiation protection in the management of the plant,
- The efforts in reducing the source term,
- The fundamental impact of the reduction of exposed volumes of work through the optimization of the maintenance programmes and modification of the design reducing the necessity of maintenance,
- A close and experienced radiological protection staff, and
- New tools in the service of radiological protection for the 21st century, in particular the use of remote monitoring systems.

The objective of this presentation is to summarize and synthesize the conclusions of these visits by underlining the key points, which could explain the good dosimetric results in the NPPs.

2. Radiation protection well integrated into the management of the NPP

The management plays a fundamental role in the motivation of the workers and, as a consequence, in the effectiveness of the implementation of radiation protection on the site. Recognition of the importance of radiation protection by the management and clear display of this choice allow for easier

directing the requirements on the field by the department in charge of radiation protection and greater ownership of these requirements by other specialties and contractors.

2.1. Radiation protection plays an important role in the NPP

In almost all sites, radiation protection has an important position in the hierarchical and functional organisations of the plant. Thus, the person in charge of the radiation protection department often occupies a high managerial position (for example at Almaraz, Saint Lucie, and Beznau NPPs). In addition, radiation protection is often grouped together with other specialties (mainly chemistry, nuclear logistics and/or environment) in a single department (Almaraz, Doel, Ringhals, Sizewell B, Beznau and Paks NPPs). However, it is almost always totally separated from classical security (the two only exceptions are Doel and Ringhals NPPs).

At Almaraz NPP, the head of the Environmental and Radiological Protection Department is a member of the Management Committee of the plant (as required by the Spanish nuclear safety authority) and participates on a statutory basis to the General Management coordination meetings at the corporate level.

At Saint Lucie NPP, following the increase of dosimetric results over several years, the management of the plant placed radiation protection as a top-priority for ensuring the good operation and success of the plant. This decision was followed by the increase of the budget of the Radiological Protection Department, the increase of the controls of workers on the compliance with procedures, and efforts on education and training programmes in radiation protection. It is important to note that in general, in the USA, the INPO considers that radiation protection is a key element of the benchmarking between sites. Indeed, the indicator of collective dose is used, along with other INPO indicators, in determining the amount of the insurance for plants.

At Beznau NPP, the head of the Health Physics, Radwaste and Chemistry Department is also the deputy director of the plant.

2.2. The setting of objectives and the regular monitoring of performance indicators for radiation protection

Radiation protection objectives are systematically set by the management of the plants. In addition to the criteria on doses (collective and individual, annual and per outage), there are also criteria on radiological cleanliness, contamination, incidents, etc. However, given the diversity of these criteria and of the persons who determine them (operator, authority, etc.), the comparison between different sites using these criteria is more difficult than a comparison using dose criteria.

These objectives are usually set annually, but they are sometimes established in the scope of a multi-year plan (Almaraz, Doel and Saint Lucie NPPs). In some plants, these objectives are assessed and analyzed every 6 months (Doel and Ringhals NPPs). Generally, the amount of the annual bonus for managers (and more rarely for all the workers) will partly depend on the achievement of these objectives. Performance indicators (related to the radiation protection, but sometimes also to safety, environment, etc.) are also regularly evaluated (usually every month) by the radiation protection department.

2.3. Clearly displayed ALARA policy

In most of the NPPs, an ALARA program formalises the ALARA approach to be followed for the jobs, especially for maintenance works (Almaraz, Doel, Ringhals, Saint Lucie, Vogtle and Calvert Cliffs NPPs), and an ALARA Committee is in charge of the ALARA review of studies relating to work with high radiological risk (Almaraz, Doel, Saint Lucie, Beznau, Vogtle and Calvert Cliffs NPPs). These ALARA organizations have been operational for more than 10 years. It should be noted that contractors never take formally part of the ALARA Committees. However, there are permanent informal exchanges with them to feed the thoughts of the committee. Finally, due to its importance in some plants (high managerial positions), the decisions in favour of radiation protection are often taken at the top-management level.

In terms of organisation, the choices made are different from one site to another: they reflect the context and constraints of each site. Thus, at Almaraz NPP, works on the steam generators, very costly in terms of dosimetry, led to the creation of a dedicated radiation protection engineering and of a specific programme for reducing doses (1984). This programme was subsequently accepted as the ALARA programme of the plant by the Spanish nuclear safety authority. In addition, the management of the NPP set up an ALARA Committee and several ALARA working groups with specific topics: Work Planning Group, ALARA Group, ALARA Improvement Group. Although no contractor takes part of these groups, they systematically participate to the estimation of the dosimetry and to the ALARA studies for their jobs.

At Doel NPP, the early setting of a dose constraint (15 mSv/yr when the dose limit was 50 mSv/yr, now 10 mSv/yr) induced a specific reflection on the organisation of human resources, which led to the establishment of an ALARA programme.

At Beznau NPP, an ALARA team, multidisciplinary and consisting of 9 persons from 4 departments was created in 1998. This group, chaired by head of the Health Physics, Radwaste and Chemistry Department, meets regularly (35 meetings since 1998) to prepare action plans for the establishment of means of optimization, to participate in the preparation of outages (optimization of high dose jobs) etc. Here again, contractors do not participate in this group. They do not participate to ALARA studies for their jobs as well.

3. Actions to reduce dose rates

The control of the source term and of associated dose rates is a key element to limit the dosimetry of the workers. This source term, resulting from the contamination of the circuits following the activation of the corrosion products under neutron flux, can be reduced by actions on the materials used or on the chemistry of primary loop to control the corrosion. Other actions, such as the use of biological shielding or radiological cleanliness, are designed to protect the workers from the term source.

3.1. Acting on the design of the plant

Several sites have worked on optimizing the design of their facilities, either during the conception of the plant (detailed analysis of feedback experience from other power plants at Sizewell B NPP, in operation since 1995) or during maintenance operations and replacement of equipments in order to reduce the source term.

The new steam generators contain systematically less nickel and cobalt than the previous ones, thereby reducing the activation of the material and therefore the dose rate.

At Almaraz NPP, for the last 10 years, important efforts have been made on the design of the two units to favour the reduction of the source term. The replacement of the steam generators, of the reactor vessel heads, and the removal of by-pass RTD were made in 1996 on unit 1 and in 1997 on unit 2. Shielding was also installed on the blowdown lines of the reactor vessel. A programme for reduction of stellites was set up and still ongoing in 2004: there is almost no valve with stellites.

3.2. The reactor coolant chemistry closely linked to radiation protection

At most of the sites (Doel, Ringhals, Sizewell B, Saint-Lucie, Beznau and Paks NPPs), lots of efforts focused on the management of reactor coolant chemistry in operation and during outages. These efforts include:

- Optimization of pH (Ringhals and Beznau NPPs),
- Optimization of the duration of oxygenation at the beginning of the outage (Ringhals NPP),
- Zinc injection (Saint-Lucie, testing at Vogtle and Calvert Cliffs NPPs),
- Optimization of the purification systems (Saint-Lucie and Paks NPPs).

In the same time, close collaboration between the chemists and radiation protection workers are established. Even more, in Beznau and Sizewell B NPPs, these two specialties are joined in the same department.

3.3. The optimization of the installation of biological shielding

At Doel and Beznau NPPs, the optimization of the installation of biological shielding during outage, with the objective of making this operation a scheduled, organized and optimized task in its own, is described as an explanatory factor for good dosimetric results. The two main objectives are to develop a real engineering for the installation of biological shielding to optimize their quantity and locations, and to professionalize this task.

At Doel NPP, the company responsible for the installation of biological shielding prepared several years ago a standard programme for installing the protections at the beginning of the outage. About 40 tonnes of lead are installed during each outage. There are particular permanent anchor points, thus optimizing the duration of the installation. The contractors are highly skilled and trained. They are the only workers in the site with radiation protection workers (contractors and from the site) to be empowered to perform measurements of dose rates.

At Beznau NPP, the Health Physics, Radwaste and Environment department, in charge of the biological shielding programme, developed a new policy in early 2000 to reduce the amount of protections used during outages. The lead shields are installed before the start of the maintenance works in areas where there are tasks during the outage. This policy induced a reduction by a factor 2 of lead used during the outage (about 80 tonnes of lead per outage before 2000, about 40 tons after 2000) without penalising dosimetric results.

3.4. Important efforts on radiological cleanliness and on the monitoring of facilities

Nuclear power plants are facilities that require a considerable maintenance programme with a large co-activity. In this context, maintaining the radiological cleanliness of the premises is a major element to avoid contamination during operations but also at the end of the works, to leave the working area with the same level of cleanliness as it was at the beginning.

The Beznau site is very clean. Each contamination point is systematically monitored or cleaned if necessary. The duty of the workers is to clean their working area at the end of the activity. Moreover, a specialized company performs ongoing cleanup of the ground in the controlled area. As a consequence, no internal contamination has been detected for about 30 years. Regarding surveillance, for each unit, the radiation protection service carries out radiation measurements (contamination or irradiation) on about 70 points daily and on about 70 other points weekly.

At Paks NPP, the cleaning of the controlled area is performed routinely. The controlled area is clean, the walls and grounds are painted with decontaminable coating. As far as the surveillance is concerned, each pair of units has a radiation protection control room, where the radiological conditions in the controlled area (dose rate, concentration of radioiodine, noble gases and particulates) can be followed. In the four units, there are about 800 installed monitors performing continuous measurements. During outages, each day, the Radiation Protection Section makes specific measurements in the reactor building.

At Sizewell B NPP, the operator must verify radiation contamination of all the tools used, when work is completed.

4. Actions to reduce the time of exposure

The reduction of maintenance volume (by in-depth optimization of maintenance activities or by modifications resulting in a reduction in the need for maintenance) has a clear impact on the volume of exposed work and, consequently, on dosimetry. Several sites (Almaraz, Doel, Ringhals and Beznau NPPs) try to optimize the workload for maintenance works during outages to avoid unnecessary work,

thus contributing to the reduction of exposures. For example, several NPPs have greatly reduced, with the agreement of safety authorities, the frequency of the tests on their steam generators.

At Almaraz NPP, following the replacement of steam generators, it is possible to control only one of the three steam generators at each outage. The workload for maintenance is also generally decreasing due to the good radiological cleanliness of the units.

At Doel NPP, over the last 10 years, efforts are systematically made to reduce the workload, in particular by reducing the number of inspections, which are judged unnecessary (for example by avoiding any preventive maintenance on equipments that are not classified “important for safety or for production”). The Belgian nuclear safety authority also agreed, after negotiations with the operator, that the two steam generators are inspected once every 6 years (instead of an annual control of a steam generator). This decision allows two consecutive outages without opening any steam generator. Finally, the workload for maintenance operations is below 30000 person.hours for a simple visit, and less than 50000 person.hours for a decennial visit.

At Ringhals NPP, the volume of maintenance, mainly decided by the plant itself under the supervision of the safety authorities, is low. The operator seeks to shorten the length of “long outages”: 29 days in 2004, 22 days in 2005, 17 days in 2006.

5. A close and experienced radiation protection staff

5.1. A close collaboration between radiation protection specialists and other workers

In all sites, radiation protection specialists work in direct contact with other specialists, especially for the preparation and implementation of the outages. This is translated into a strong presence of the radiation protection workers on the field. In particular, they are present a lot in the controlled area for control and consulting and, at the entrance of the area, there is always a radiation protection office, where it is mandatory for the workers to go for the issuance of their radiation work permits.

At Doel NPP, the collaboration between radiation protection specialists in charge of the preparation of the activities, and the other specialties has been strengthened in recent years. For the latter, the recent reorganization of the site has led to greater involvement in preparing their activities from the radiation protection point of view, in the dosimetry previsions and in the analyse of events. Finally, the preparation of activities has improved considerably.

At Ringhals NPP, radiation protection workers are in direct contact with workers throughout the duration of the outage (radiation protection office, permanent presence of radiation protection workers in the reactor building, etc.).

At Sizewell B NPP, a pragmatic approach to radiation protection has been adopted since the start of the plant. On many aspects, the way of working appears less procedural than in other plants. Moreover, the important and permanent discussions between radiation protection specialists and some other workers (in particular with the contractors during the outage) have encouraged other groups of professionals, such as those dedicated to the maintenance of the facility, to talk openly and to work directly with radiation protection staff. It has to be underlined that the radiation protection engineers and technicians have a great experience on the site and a detailed knowledge of the activities realised by other groups. Finally, many radiation protection technicians have knowledge in mechanical engineering, which helps them understand the tasks performed by other groups.

At Paks NPP, it exists a nominated radiation protection worker network, composed of 89 persons, who are not radiation protection specialists, 23 of them being contractors. The nominated workers, which received a special education and training in radiation protection, are responsible for the implementation of radiation protection and ALARA issues in their department. They work in collaboration with the Radiation Protection Section and meet once a year during a workshop, which allows them to share their practical experiences and difficulties.

5.2. The management of skills and the education and training in radiation protection
The turnover is generally very low in the NPPs, particularly in the radiation protection departments. Most employees have many years of experience on the site, some of them even working since the first criticality (Almaraz and Sizewell B NPPs). This observation has not for origin the fact that the arrival of young radiation protection specialists is insufficient to ensure the renewal of the staff. However this implies that the staff knows perfectly the plant, its organization and its radiological state.

At Almaraz NPP, most employees (managers and technicians) have been in the site since the first criticalities of the units. The less experienced employees have at least fifteen years of experience. At Doel NPP, the turnover of radiation protection technicians is almost non-existent. At least half of the staff has over 10 years of experience in the site. At Sizewell B NPP, most of the radiation protection specialists have been working in the plant since the first divergence.

In Saint-Lucie NPP, even if the turnover exists, the new radiation protection technicians arriving at the site, already have an experience acquired in other sites, in particular in Turkey Point NPP. In addition, contractors have also a great experience of the site and are well integrated into the radiation protection team.

Regarding radiation protection education and training for non radiation protection specialists, the duration and topics depend on the type of staff. For permanent employees, an update is usually carried out every year (Almaraz, Doel and Saint-Lucie NPPs), or every two years (Sizewell B, Beznau and Paks NPPs). These courses sometimes end with a formal exam (Doel, Ringhals, Saint-Lucie, Beznau and Paks NPPs). For contractors, the update is usually annual and systematically ends with an exam. Finally, at Sizewell B, Saint-Lucie, Calvert Cliffs and Paks NPPs, mock-up trainings in non controlled area are provided. In particular, the Paks NPP has an important training centre with most of the main components of a VVER unit. The specificity of this training centre is that the components are exactly the same as those in the controlled. It can thus be used for example to prepare maintenance works or to validate new techniques in an ALARA perspective.

6. New tools in the service of radiation protection for the 21st century

6.1. The information system adapted to radiation protection
A nuclear power plant is a highly complex and constantly evolving facility. A large number of data, in particular radiological data, are necessary for the maintenance of the facility. In most NPPs, efforts are made to organize these data. Access to some data is not restricted to radiation protection specialists.

Some plants have computer and photographic databases easily accessible. These databases collect a variety of information and parameters (levels of contamination, dose rates, historical records for dosimetry, chemical parameters of the primary circuit, etc.).

At Almaraz NPP, the Environmental and Radiation Protection Department has a mapping database, including comprehensive radiological conditions of the two units: 300 maps of rooms are computerized, containing for each zone the historic values of 3 to 10 points of dose rate measurements (ambient, or on contact) according to the different states of the unit (before or during outages). The database also contains surface and atmospheric (aerosols and halogens) contamination measurements. The maps are updated regularly and displayed at the entrance of each room. Moreover, these data can be consulted from the radiation protection office at the entrance of the controlled area.

The Doel NPP has a software, which contains a database with maps of the facility. The main equipments (large valves, pumps, heat exchanger, etc.) are indicated on the maps. Each mapped area may contain the following information: volume and surface contamination, ambient dose rate, dose rate on contact, activity, iodine concentration, neutron dose rate, presence of alpha emitters, etc. Measurements from 1990 are available.

At Sizewell B NPP, radiation protection specialists produce information sheets, which include pictures, maps and information on the dose rates for many components of the plant. Workers have also

the possibility of knowing their work area and its radiological conditions by using a software called Surrogate-Tour.
The Beznau NPP has developed a software gathering daily contamination and dose rate measurements and the evolutions of these measurements. These parameters can be accessed from the radiation protection offices located at the entrance of the controlled area. Another software (CIS - Chemistry Information System) can track the different chemical parameters of the primary and secondary circuits in real time. The data are stored in a database and can be consulted at any time.

At Paks NPP, the radiation protection control rooms, situated at the entrance of each pair of units, are used to follow more than 800 measuring points inside the units, but also measurements around the reactor buildings (gamma dose rates) and in the environment around the plant (radioiodine, particles, tritium, etc.). These data can be followed in real time, and their historic and evolution can also be consulted.

6.2. Remote Monitoring Systems (RMS)

6.2.1. Presentation of the RMS

A Remote Monitoring System (RMS) is usually made up of three distinct elements:

- A teledosimetry system allowing in real time the transmission and centralization of information provided by a set of electronic dosimeters attached to transmitter devices (up to several hundred dosimeters),
- A system that allows video monitoring of an activity, and, in some case, the video recording of an activity,
- An audio communication system that allows the whole staff (exposed workers, radiation protection technicians) to communicate (individual to individual or to a group of individuals).

The system (whole or in part) can be based on a wireless data transfer. The use of wireless technologies sets the necessity of mapping areas, which are sensitive to wavelengths used for the transfer of data, in order not to interfere with the instruments in place.

6.2.2. Interests for radiation protection

<u>Decrease of the radiation exposures</u>

The RMS allows remote monitoring (from the non controlled area in Saint-Lucie, Vogtle and Calvert Cliffs NPPs) of the conditions of exposure to ionizing radiation for each worker: localization and identification of the worker; nature of the activity and related dosimetric data (including alarm in collective dose, in individual dose and in dose rate); duration of exposure; etc. The flexibility of the system also makes it possible to follow the evolution of dose rates, which tends to favour a wide range of applications. Thus RMS can also be used as an information source for other departments than radiation protection department, particularly during the outages, where it can help to correct unseen problems, which may have an impact on outage schedule and costs. Moreover, the data measured by air monitors (aerosol and iodine) can also be followed by the RMS. Finally, centralization of all these information in a single location enables effective and reactive monitoring of the exposed workers by a small staff. This will allow avoiding the permanent presence of radiation protection technicians in the field, while maintaining their role of support and advice through the audio communication.

At Sizewell B NPP, when it was firstly use in 2004, it was estimated that the audio and video surveillance system and the teledosimetry system induced a reduction by about 10% of the total dose during the outage (reduction of about 20 person.mSv). The radiation protection staff benefited the most from this reduction.

At Vogtle NPP, the number of radiation protection technician contractors in outage dropped from 118 to 40 in a few years following the implementation of RMS. The exposure of the radiation protection staff in outage has been reduced from 0.4 (before RMS) to 0.1 person.Sv (after RMS). About 10 year after the implementation of RMS, the exposure of the radiation protection staff in outage is approximately 0.05 person.Sv. Part of the dose reduction may be directly associated with the

implementation of the RMS and not only with the reduction of the number of radiation protection contractors.

At Calvert Cliffs NPP, from 1999 to 2006, the number of radiation protection technician contractors in outage dropped from 93 to 62 and the workforce of the Health Physics Department decreased from 63 to 44 permanent workers. The exposure of radiation protection staff dropped from 0.3 (1999) to 0.14 person.Sv (2006).

However, it must be underlined that, even when RMS is implemented, the presence of radiation protection technicians around the working areas (in low dose rate area) is still necessary. In fact, when a technician from the monitoring centre detects an event (quick increase of the dose rate, exceeding, atmospheric contamination, etc.), a radiation protection technician is immediately send on the field.

Training and preparation of activities

In terms of training and preparation, the use of video (recording of specific tasks) is used to prepare a work, to improve technical gestures and to become acquainted with the equipments and tools. In addition, the centralization of monitored information allows the electronic storage of the radiological characteristics of an activity, and the use of these characteristics for preparation and dosimetry estimates of future activities.

Social acceptance

In terms of social acceptance, using the case of Vogtle NPP, it seems that a gradual approach, based on working groups per specialty and emphasizing the exchange is the more appropriate way to avoid conflicting situation.

Particular attention must be paid to the process of appropriating the RMS tool throughout the radiation protection department, and in particular appropriate balance must be found between the time spent in the central monitoring room and the time spent on the field.

The interest for the RMS technology is not only due to its valuable use for radiation protection purposes. Many specialties wish to have access to this technology (activity monitoring, technical improvements, etc.). Such requests must be taken into account without undermining the objective of improved performance in radiation protection and without mobilizing radiation protection staff for missions that does not fall within its field of activity.

7. Conclusion

These nine benchmarking visits on the practical and operational radiation protection in nuclear power plants, have brought together several good practices, which participate in the reduction of dosimetry in these plants:

- The important role of radiation protection in the management of the plant: high hierarchical positions for the head of radiation protection department, clear ALARA policy, etc.,
- Reducing the source term, in particular for outage activities, by acting on the design of the facility, by keeping the radiological cleanliness and monitoring the facility, by optimizing the chemistry of the primary circuit and by installing and optimizing the installation of biological shielding,
- Reducing the amount of exposed work by optimizing maintenance works, by a good knowledge of the installation, by regular education and training and by a close collaboration between the radiation protection staff and other specialties,
- The benefits from using Remote Monitoring Systems.

The good practices identified during these visits have enabled EDF, the French operator, to feed its reflections on some specific topics:

- Examples of radiological work permits feed the study of ergonomists on the establishment of specific radiological work permits at EDF,

- Following the visits in plants in the USA, the American practice of "blind tests" for the development of passive dosimeters by laboratories was been applied at EDF. The aim of this practice is to give for development to laboratories witness dosimeters, that were irradiated in very specific circumstances, in order to verify the validity of the results provided by these laboratories,
- The information collected on the RMS in different sites have contributed to the working group set up by EDF on this topic.

In addition, these visits allowed representatives of French nuclear power plants to see how other operators deal with problems similar to their own.