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DE LA PROTECTION DANS LE DOMAINE NUCLEAIRE

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BENCHMARKING VISIT
AT THE BRAIDWOOD NUCLEAR POWER PLANT

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ABSTRACT

At the request of the French utility EDF, CEPN - ISOE European Technical Center - organized a benchmarking visit at the Braidwood nuclear power plant in the United States of America, Illinois. The mission took place from 20 to 22 October 2009. The French team was composed of two representatives of EDF and two representatives of CEPN. The first part of the mission allowed discussing the general organization and management of radiation protection in the Braidwood station, especially during outages. The second part was mainly focused on two peculiar topics that EDF is currently interested in: the radiation protection training of RP specialists and exposed workers and the RP instrumentation available in the plant. This benchmarking visit allowed underlining the following points.

Radiation protection benefits from an important consideration in the daily running of the Braidwood plant. In particular, during outages, a strong RP organization is implemented. Thus, during the preparation period, a detailed "RP Outage Preparation Checklist" is established: it includes more than 275 tasks and allows ensuring that every RP item is taken into account. During outages realization, the RP Department relies on 12 hour-shifts covering both day and night. Finally, the RP Department ensures a permanent presence in the Outage Control Center: it is represented by a "superintendent", which is the hierarchical level just under the radiation protection manager.

Several comments can be proposed on the structure and the roles of the RP Department. From a first view, the RP personnel can appear quite numerous for a 2-unit plant compared to the situation in EDF plants. However, RP specialists don't have the same roles in Braidwood as in EDF units. Indeed, in Braidwood, the RP staff deals with any activity related to radiation protection including decontamination and shielding; in EDF plants, RP specialists do not manage these last two activities but cover industrial risks. The Braidwood RP personnel is very present on the field and assists every worker in respecting radiation protection requirements. This role is all the more important because exposed workers receive a short training on radiation protection and are not responsible for their own protection.

As far as the training is concerned, the Institute of Nuclear Power Operations (INPO) recently engaged a specific program to reinforce RP initial training and face ageing of the experienced RP workforce. Exelon and the Braidwood station are strongly involved in this program. Their initial training sessions appear quite complete and include a significant part of practical works (on-the-job training process). Moreover, continuing training sessions are offered all along the year. It is also worth underlining that a specific 4-week training is mandatory for RP contractors to be authorized to work in the station.

The Braidwood plant is preparing the renewal of its RP staff. Its aim is to compensate every future retirement by hiring a junior technician two years before the departure of the experienced person. In this way, the NPP would be ensured that new comers would be fully competent when they got the job.

Finally, as for instrumentation, it can be noted that the Braidwood station runs with a low quantity of RP equipments compared to EDF plants. Besides some monitoring domains are not covered in the same way: for instance, the permanent monitoring of gamma dose rates in controlled areas is only performed by fixed instruments and does not rely on specific beacons. Otherwise, the peculiarity of Exelon to work with a central company (Powerlabs) that purchases, provides and ensures maintenance of equipments appears to be very efficient.

RESUME

A la demande de l'exploitant français EDF, le CEPN – Centre Technique Européen d'ISOE – a organisé une visite d'intercomparaison à la centrale nucléaire de Braidwood aux Etats-Unis (Illinois). La mission s'est déroulée du 20 au 22 octobre 2009. L'équipe française était composée de 2 représentants d'EDF et de 2 représentants du CEPN. La première partie de la mission a permis de discuter de l'organisation générale et de la gestion de la radioprotection à la centrale de Braidwood, en particulier pendant les arrêts de tranche. La deuxième partie a principalement été consacrée à deux sujets auxquels EDF s'intéresse plus particulièrement : la formation des spécialistes en radioprotection et des travailleurs exposés et le matériel de mesure de radioprotection disponible sur le site. Cette visite d'intercomparaison a permis de mettre en avant les points suivants.

Tout d'abord, la radioprotection est particulièrement bien prise en compte dans le fonctionnement quotidien de la centrale nucléaire de Braidwood. Lors des arrêts de tranche, le Département Radioprotection met en place une organisation solide. En phase de préparation de l'arrêt, une liste détaillée des tâches à réaliser (RP Outage Preparation Checklist) est notamment établie : près de 275 activités sont mentionnées. Cette liste permet de s'assurer que toutes les activités/actions de radioprotection sont bien prises en compte. Durant les arrêts, le Département Radioprotection repose sur une organisation en 2x12. Enfin, il assure une présence continue au sein du Comité de Pilotage de l'arrêt de tranche (OCC) au sein duquel il est représenté par l'un des adjoints au chef du Département.

Par ailleurs, plusieurs remarques relatives à la structure et aux rôles du Département Radioprotection peuvent être soulevées. A première vue, si l'on compare les effectifs du Département RP de Braidwood avec ceux des Services Prévention des Risques (SPR) d'EDF, ceux-ci peuvent paraître conséquents pour un site deux tranches. Toutefois, il est important de noter que ces personnels n'assurent pas des fonctions similaires à Braidwood et au sein des CNPE français. En effet, à Braidwood, le personnel de radioprotection s'occupe de l'ensemble des aspects associés aux actions de radioprotection, et participe notamment aux activités de décontamination et à la pose/dépose des protections biologiques ; au sein d'EDF, les SPR ne gèrent pas ces deux dernières activités, mais couvrent par ailleurs l'ensemble des risques industriels. Le personnel RP de Braidwood est particulièrement présent sur le terrain et aide les travailleurs exposés à respecter les procédures RP. Ce rôle est d'autant plus important que ces travailleurs ne reçoivent qu'une courte formation en radioprotection et ne sont pas responsables de leur propre protection.

Dans le domaine de la formation, l'INPO (Institute of Nuclear Power Operations) a récemment engagé un programme spécifique visant à multiplier les offres de formation initiale en radioprotection et ainsi compenser les prochains départs en retraite de nombreuses personnes qualifiées en RP. Exelon et la centrale nucléaire de Braidwood sont fortement impliqués dans ce programme. Leurs sessions initiales de formation à la radioprotection apparaissent relativement complètes et incluent une part importante de cours pratiques réalisés en zone contrôlée. De plus, des sessions de formation continue en RP sont proposées tout au long de l'année. Enfin, il est aussi intéressant de souligner que tout prestataire en RP devant intervenir sur le site de Braidwood doit

obligatoirement suivre une formation de quatre semaines relative aux procédures et aux pratiques RP de la centrale.

Il est important ici d'ajouter que la centrale de Braidwood prépare aujourd'hui le renouvellement de son personnel en RP. Elle espère notamment pouvoir compenser chaque départ en retraite par l'embauche d'un technicien junior, deux ans avant le départ du technicien sénior, et s'assurer ainsi que les nouveaux arrivants seront directement opérationnels quand ils seront nommés.

Enfin, dans le domaine de l'instrumentation, il peut être souligné que la centrale de Braidwood semble fonctionner avec une quantité de matériels RP relativement faible, comparée à celle utilisée dans les CNPE d'EDF. Certains domaines de mesure sont par ailleurs couverts de façon différente : par exemple, le suivi continu des débits de dose ambiants en zone contrôlée est réalisée uniquement par le biais d'équipements fixes ; le site n'utilise pas de balises mobiles. Enfin, il reste à noter que la collaboration de la centrale de Braidwood avec un fournisseur unique dédié (Powerlabs), qui achète, fournit et assure la maintenance des différents équipements, apparaît particulièrement efficace.

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INTRODUCTION

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The first part of the mission allowed discussing the general organization and management of radiation protection in the Braidwood station, especially during outages. The second part was mainly focused on two peculiar topics that EDF is currently interested in: the radiation protection training of RP specialists and exposed workers and the RP instrumentation available in the plant. This report provides an overview of the key findings associated with the visit.

1. ORGANIZATION AND MANAGEMENT OF RADIATION PROTECTION

1.1. General organization

The Braidwood NPP is operated by Exelon Nuclear, which is a business unit of Exelon Corporation. Exelon operates the largest nuclear fleet in the US: its ten stations (with 17 reactors) represent approximately 20 percent of the US nuclear industry's power capacity. The Braidwood 2-unit plant began commercial operation in 1988. Both of Braidwood units are pressurized water reactors designed by Westinghouse. Unit 1 is capable of generating 1,194 net megawatts of electricity while Unit 2 is capable of generating 1,166 net megawatts.

The Braidwood station gathers around 800 people (among whom 150 persons are dealing with site protection).

1.1.1. Organization of the site

The organization charts of the site (updated in September 2009) are provided in Figures 1 and 2. It should be noted that in each plant operated by Exelon, a vice-president represents the corporate level. He is responsible of general strategic issues and long-term planning. He is in direct link with the corporate headquarters[1]. The daily running of the NPP relies on the plant manager who shall ensure its global performance.

As shown in Figure 2, the Radiation Protection Department is directly linked to the plant manager, Larry Coyle. M. Coyle is strongly involved in radiation protection and is notably the animator of the station ALARA Committee. This committee meets every month to study operations whose dose estimates are greater than 1 person.rem (10 person.mSv). It gathers all the managers mentioned in Figure 2 as well as contractors if relevant. Operations and radiation protection analyses are generally presented by an ALARA analyst from the RP Department.

[1] Regional headquarters are notably composed of 2 vice-presidents, a radiation protection manager, an engineering direction, a maintenance direction and a training direction.

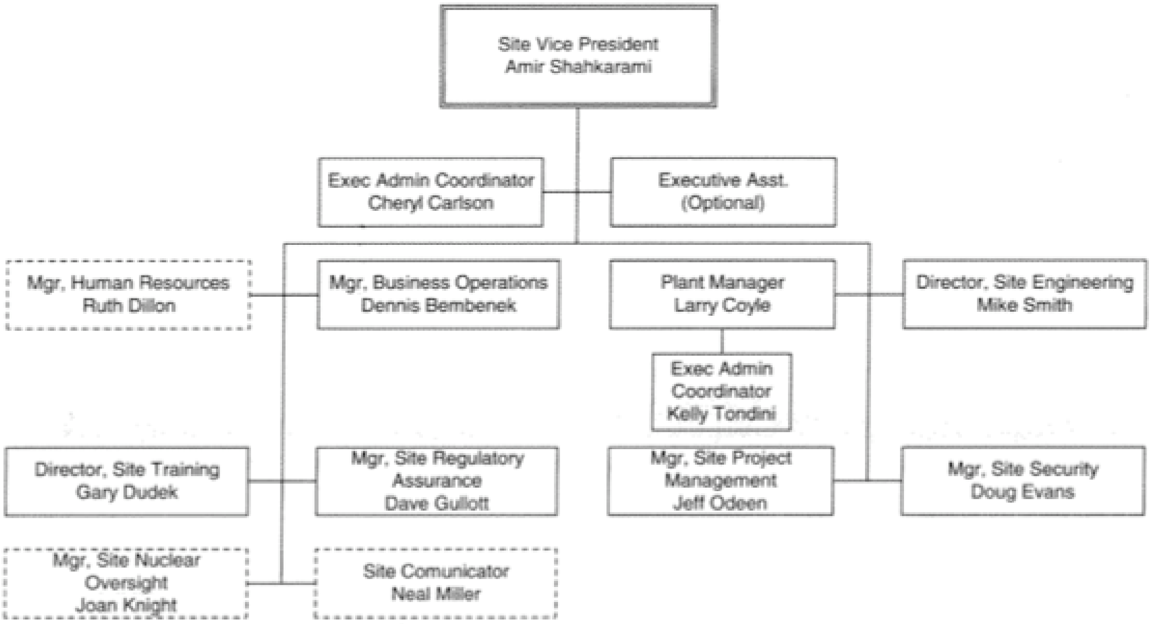

Figure 1. Corporate organization of the Braidwood NPP

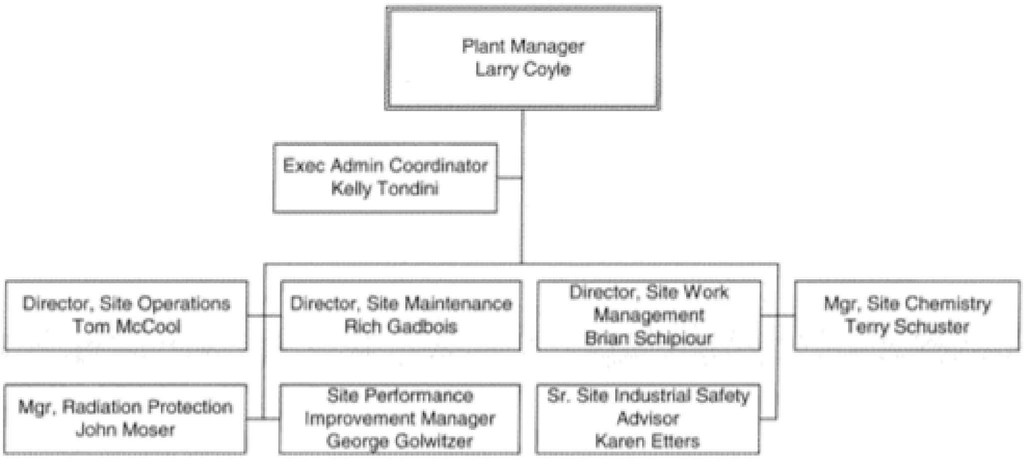

Figure 2. Site organization at the Braidwood NPP

The Nuclear Safety is integrated in the missions of the Site Operations Department. It is interesting to note that this Department runs a "Plant Operating Review Committee" (PORC), which meets once a week during outages and three to four times during non-outage periods. This committee reviews and authorizes every change in plant procedures that may have an impact on nuclear safety. It is composed of the managers from the Radiation Protection, Chemistry, Operations, Maintenance, Engineering and Work Management[2] Departments.

Finally, close relationships are established between RP and industrial safety. This is illustrated by the fact that the site industrial safety advisor reports to the RP manager.

1.1.2. Organization and roles of the Radiation Protection Department

The organization chart of the RP Department is provided in Figure 3. The Department has been managed by John Moser for 7 years.

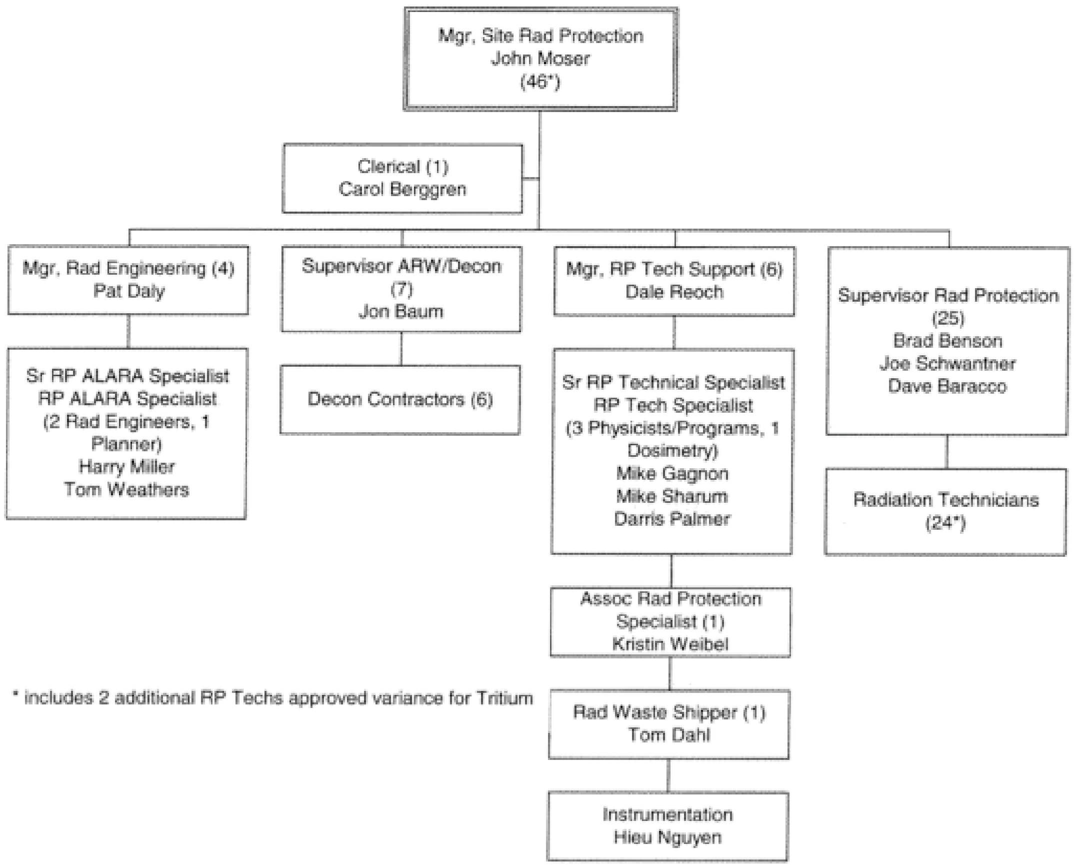

Figure 3. Organization of the RP Department

At a whole, the RP Department gathers around 50 people. It is composed of four sections:

- The "Radiation Engineering" section is composed of 4 engineers. They are responsible for radiation protection planning during outages, source-term reduction long-term program, temporary shielding, hot spot reduction, engineering control…

2 The Work Management Department is responsible for planning operations and scheduling outages.

- The “Decontamination” section is composed of a supervisor and 6 technicians. They are in charge of decontamination operations, installation and removal of shielding, furniture of protective clothes...
- The “Technical support” section is composed of a supervisor and 6 technicians (no field technicians). They are in charge of instrumentation, external and internal dosimetry and radioactive material shipping[3]. They also run the implementation of a corrective radiation protection program based on field observations (see below).
- Finally, the last section deals with “Field operations”. It is constituted of 3 supervisors and 24 technicians. They are notably in charge of performing survey maps.

During on-line periods, RP technicians work on 3x8 shifts from Monday to Friday (with a minimum of 2 individuals on the field). During outages, they change for 2x12 shifts: they work 6 consecutive days and get a day-off on the seventh day (it is to note that 2 technicians benefit from reduced workload to be available in case of emergency situations). Outages last 16 to 17 days on an average (20 days are a maximum).

According to the needs of the RP Department, a crew of 6 contractors can reinforce the “Decontamination” section. They are the only contractors that can join the Department during online periods (for outages, see part 2). This section ensures shielding operations during non-outage periods; as far as outages are concerned, a specific contract is signed with a Labor Force.

From a general point of view, the RP Department staff intervenes to help workers in respecting radiation protection procedures and requirements. They are very present on the field and are considered as advisers and supporters. However, they also ensure a role of control, which they perform through “Field Observations”. These observations are included in a general “Observation Program” that concerns industrial safety, radiological safety, configuration control, human performance, foreign material and exclusion housekeeping (Annex 2). They are realized by each member of the head staff: the RP manager, the supervisors and the first line supervisors (technicians can proceed to these visits but it is not required). During on-line periods, each person has to perform 2 visits per week. During outages, a visit per day is requested. For each theme, the evaluator should note if it exceeds the expectations, meets the expectations, needs improvement or is below the standards. The results of observations are entered in a dedicated database. A formal report is provided every Friday to the plant manager to comment observations and request, if needed, corrective actions. This global overview is used to develop corrective RP program and to review training contents (see part 3).

During their fieldwork, RP technicians and supervisors have the responsibility and authority to stop any work activity involving RP if continued performance of the work would result in the violation of NRC (Nuclear Regulatory Commission) regulations, RP standards, plant procedures, Radiation Work Permits or ALARA instructions, or would otherwise endanger the safety of personnel. In Exelon nuclear power plants, this is

[3] Up to 15 transportations of radioactive material can be organized by week during outages.

called the "Radiation Protection Stop Work Authority". The following criteria can for instance cause jobs to be stopped:

- Multiple unplanned personal contaminations on a single job during a shift (e.g. > 3).
- A significant unplanned intake (> 7400 Bq) or unexpected airborne activity (> 0.3 LDCA).
- Significant spread of contamination that may impact other work groups or activities.
- Significant unintended exposure to a single worker.
- Significant increase in area dose rates compared to those that the worker was briefed on (e.g., a 25% increase in dose rates in areas greater than 1 mSv/h).
- Refusal to comply with or disregard for RP standards and procedures or RP personnel instructions, either written or verbal.
- Significant degradation of radiological engineering controls.

Finally, the RP staff is also responsible to deal with every RP event. Specific guidelines exist to allow a prompt notification of the corporate RP staff for events that may require Exelon oversight or support: according to their characteristics and severity, events should be notified within 4 or 12 hours to the corporate Radiation Protection manager. For serious events, a quick investigation has to be performed resulting in a report sent to the corporate senior executive.

It is to note that traffic lights are installed at the entrance of the site: when the red light is on, it means that a RP event or an industrial safety injury happened in the last 24 hours. After 24 hours, the light goes orange and backs to green. This allows getting workers aware of the risks they are facing daily.

All the actions performed by the RP Department are reported in an "Excellence Plan"[4] which allows following if the RP staff meets its objectives. This plan is a living document that is revised every three months.

1.2. Radiation protection results and performance

In 2008, dose performance had both Braidwood units in the third quartile for US PWRs[5]. Units 1 and 2 were respectively at 650 person.mSv and 680 person.mSv for single cycle (18 months) whereas industry top quartile was at 450 person.mSv.

Consequently, the RP Department developed an "Exposure Reduction Plan" for the 2009-2013 period (it is expected that this plan will be annually reviewed, updated and presented to the station ALARA Committee for approval). This plan includes major initiatives for dose reduction within the next five years; they are categorized in four strategic areas:

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[4] This document is comparable to "tableaux de bord" used in EDF RP Departments.

[5] The Institute of Nuclear Power Operations (INPO) points are one measure used to determine a plant's dose performance. Full INPO points (10) are awarded when the dose is below 600 person.mSv/year, averaged over the previous 18 months. The INPO points awarded are inversely proportional to dose and 0 point is awarded when the dose is above 1200 person.mSv/year averaged over the previous 18 months.

- Source-term reduction: actions include U1/U2 zinc injection, use of a purolite orthoporous resin[6], fuel cleaning, increase in the primary system pH from 7.2 to 7.35 and then to 7.4 to reduce corrosion products transport to the core.
  To assess source-term reduction, gamma dose rate measurements are performed at standard RP monitoring points every outage. Last measures showed that dose rates strongly decreased (divided by 2). However, the site is struggling to identify the contribution of each specific action that was implemented. Today, the RP Department is also working in close relationships with the Chemistry Department to identify the isotopic mix and understand changes in the source-term[7].
- Technological improvements (especially of remote monitoring technologies): e.g, it is envisaged to install remote monitoring technology in pump rooms to reduce operator round dose and RP staff dose, to install wireless monitoring for base point surveys in auxiliary building to reduce RP staff dose, to increase use of teledosimetry during refueling outages.
- Process improvements: e.g., every two outages, at the beginning, the plant uses an isolation valve between the reactor and the steam generator to isolate the SG loops prior to peroxide addition and prevent hot particles from contaminating the reactor.
- Implementation of permanent and temporary shielding.

For each action, the "Exposure Reduction Plan" provides with dose saving per outage, total dose saving and approximate cost. All these initiatives are expected to reduce collective dose for both units. Table 1 presents the dose objectives of the Braidwood plant for the 2009-2013 period. It is planned that the station will achieve full INPO points in the very next years.

Table 1. Braidwood dose objectives from 2009 to 2013

(person.mSv/year, averaged over 18 months)

Year	2009	2010	2011	2012*	2013
Unit 1	540	560	580	760	760
Unit 2	480	480	550	630	630

* During 2012, alloy 600 issues with reactor nozzles are scheduled and will expend collective dose to about 250-300 person.mSv/unit.

Beyond the collective dose, other RP performance indicators are followed by the Braidwood station and the RP Department (Table 2). They are checked every month and compared to plant objectives. The RP Department does not follow specific indicators linked with average individual doses of exposed workers. However, it can be

6 Braidwood installed this new resin (5 ft^3 = 0.15 m^3), which is more resistant than classical resins, on the top of the existing one. In parallel, during outages, they change the RCV filter eight times to allow a progressive decontamination of water. It is to note that the last change was made on a pressure difference criterion and not on a dose rate criterion as usually. The RCV filter size is 0.1 µm (in US plants, filters from 1 to 0.1 µm are usually used).

7 Both units do not present a similar source-term. Unit 1 had a steam generator replacement about 10 years ago and a conception default in the new SG caused a cobalt-58 contamination due to high nickel concentration in tubes.

noted that every worker in Braidwood is below 20 mSv/year while the US regulation only imposes an annual dose below 50 mSv (see Annex 1 for a reminder on the US regulation).

Table 2. Radiation protection performance indicators used in Braidwood

1. COLLECTIVE EXPOSURE
a. Monthly non-outage exposure b. Monthly outage exposure c. Site exposure - *Cumulative goal* - Cumulative actual - *Monthly goal* - Monthly actual d. *Cumulative goal per unit* Cumulative actual per unit e/ TLD results (hard dose)
2. GENERAL RP PERFORMANCE
a. RP significant events b. High Rad Area events c. Rad Material Control events
3. RAD WORKER PERFORMANCE
a. Rad worker adherence - Rad worker performance event - 12-month rad worker adherence rate b. Personal Contamination Events - On-line PCEs - *On line PCEs goal* - Outage PCEs - *Outage PCEs goal*
4. PLANT AREA CONTAMINATED
- *Monthly goal percent* - Average monthly actual percent - Average monthly square footage

1.3. Miscellaneous

Radiation Protection procedures
Specific RP guidelines or procedures are generally elaborated by RP engineers from the corporate level or from the plant. If they are written by Exelon, they can be applicable to all plants, to a specific fleet, or to a specific site. Moreover, they can have different status: general policy, executing procedure or craft capability.

Human performance tools
Many human performance tools are used in Braidwood. Their application is checked during field observations.

- Pre job brief: when assessed, it is checked if:
    - Workers are present, qualified and engaged.
    - It includes discussion on error precursors, defense, hazards…
    - It includes discussions on 5 key questions/ critical steps.

  - It includes discussions on verifications and responsibilities.
- Post-job critique: when assessed, the craft involvement is evaluated.
- Technical Human Performance.
- Work stopped for procedure inadequacy.
- Placekeeping practices.
- Self-check/ STAR (Stop, Think, Act and Review).
- Peer check.
- Independent/ concurrent verification.
- Flagging/ robust operational barriers.
- 3-way communications/ phonetic alphabet.

Complement to the Radiation Work Permit

Braidwood has implemented "Radiation Worker Pocket data sheets" (Annex 3). They summarize for each exposed worker: the number of his/her radiation work permit (RWP), the specific component or the location of the area he/she is expected to work, the work to be performed, the electronic dosimetry alarms associated with his/her work and the working area information (dose rate range, contamination levels, dose goal). This sheet is filled in by every worker before he/she enters in controlled areas; it helps him/her understanding the risks he/she may encounter.

Spent fuel pool decontamination

The Braidwood station uses specific techniques to perform the pool decontamination (RP technicians or contractors could intervene). Today, when the pool is emptied until the level of the vessel cover, the floor is dried with vacuum, walls and floor are sprayed with H_2O_2 and then rinsed with water. This operation lasts 4h30 and is associated with a collective dose of 7 person.mSv.

Up to a few years, when the pool was empty, walls were washed and then painted with a specific product that dries very quickly. After a few hours, the painting was pilled and the pool was considered as decontaminated (a movie describing this procedure is available). The whole operation lasted about 5 hours and was associated with a collective dose from 7 to 10 person.mSv. The cost was around 70,000 $ per outage.

Radiation protection during radiography shots

When a radiography shot is organized, the RP Department implements the following arrangements:

- The shot is widely announced through leaflets and posters. When the shot begins, an audio announcement is performed in the whole plant.
- During shots, each access point is watched by a RP technician (15 to 20 technicians are mobilized).
- The exclusion zone is roped.

Radiography shots are preferably organized at nights and during weekends to minimize risks of exposure of co-workers. As far as possible, low activity sources are used to limit the size of the exclusion zone.

Protective clothes in case of airborne contamination

For operations in water boxes of steam generators, ventilated protective suits with autonomous battery (TRIAN/3M) are used (contrary to France where suits are ventilated with external air).

2. RADIATION PROTECTION ORGANIZATION DURING OUTAGES

2.1. Preparation of outages

Before each outage, a detailed “RP Outage Preparation Checklist” is established. It includes a series of tasks to be done. More than 275 tasks are gathered according to 22 themes:

- Personnel (e.g.: develop outage staffing plan, identify contracted resources required…).
- ALARA planning (e.g.: determine jobs requiring ALARA plans, develop area initial survey plans…).
- Radiation Work Permits (preparation and validation of RWP).
- Lead shielding (e.g.: determine shield packages required for the outage, complete necessary scaffold requests to support shielding, determine needs for shielding mock-ups…).
- Remote technology (e.g.: determine exact scope of remote technology, arrange resources for audio/video installation and removal, request the number of electronic teledosimetry dosimeters transmitters needed…).
- Dosimetry (e.g.: identify number of electronic dosimeters needed for the outage).
- Engineering controls (e.g.: inventory of stock of HEPA ventilation and vacuums, determine jobs requiring tents/ containments…).
- Respiratory protection (e.g.: identify respiratory protection required to support the outage, order delta suits and hoses, inspect sand blast hoods…).
- Training (e.g.: determine mock-up training requirements, schedule training for contractors…).
- Instruments (e.g.: determine specialized instrumentation, schedule emplacement of outage instrumentation, complete calibration of whole body counters, complete calibration of small articles monitors…).
- Facilities (e.g.: prepare area housekeeping plan, secure temporary lockers if needed, obtain adequate number of people to support RP staff…).
- Outage indicators (e.g.: establish Personal Contamination Events goals, establish pre-outage safety goals, develop outage budget, create daily RP briefing sheet…).
- Consumables (e.g.: ensure adequate number of bags, smears, posting and signs…).
- Procedures (e.g.: determine, modify and evaluate procedures requiring revision prior to the outage).
- Source-term reduction (e.g.: determine and schedule hydrolasing, determine what systems need to be flushed, arrange air samples/ smear counting and alpha counting, needs with chemistry…).
- Failed fuel shutdown considerations.
- Elevated dose rate action plan (e.g.: develop action plans for elevated dose rates, optimize shutdown cooling windows…).
- Contamination control (e.g.: develop a detailed plan that includes cleaning schedule, floor machine usage, use of tacky pads for trending, order decontamination and housekeeping supplies…).
- Radiography (e.g.: develop detail job estimates and implement an ALARA review).
- Radioactive waste.
- Hot shop.
- RP control points (e.g.: determine plans for low dose waiting areas…).

For each task, the list indicates the responsible person and the associated milestone. It is updated every time an item is completed.

2.2. RP organization during outages

During outages, two different organizations are implemented, one during day (Figure 4) and another during night (Figure 5). In each case, five specific sections are distinguished:

- Steam generator operations,
- Refueling operations,
- Upper containment (above the level 412') operations,
- Lower containment (below the level 412') operations,
- Auxiliary building operations.

During outages, the RP Department relies on extra people coming from:

- Other Exelon plants: 20 to 30 persons join the Department. They often ensure roles of technicians or management personnel.
- Contractors: around 80 people are hired to execute specific tasks. Indeed, during an outage, the site decides the actions that will be performed by contractors according to their qualification. Generally, 12 tasks over a hundred are concerned: for instance, performance of survey maps, surveillance of steam generator jumpers… Some tasks like steam generator operations, transportation… are considered as specialized jobs and are usually not performed by contractors except if they are very qualified.
  The breakdown of contractor personnel used to support the outage that was in course during the benchmarking visit is the following: 45 senior RP technicians, 20 junior RP technicians, 9 ALARA specialists, 1 shielding specialist, 2 RP leads, 1 RP supervisor and 1 site coordinator.
- During an outage, the RP manager (RPM) is responsible of all these people as if they were his own staff.

Two weeks prior to the start of the outage, Braidwood RP technicians and one RP first line supervisor go onto 12 hour-shifts covering both day and night shift. They install shielding and scaffoldings, calibrate instrumentations, check the probes… (see the preparation list above).

Contractors start to process in two weeks prior to the outage (or, even three weeks, for contractors who support dosimetry). A specific training is organized according to their initial RP level and the tasks they will have to perform (see part 3). They will not start working 12 hour-shift until the Sunday night the plant is going to shut down. Exelon travelers show up the Sunday before the outage.

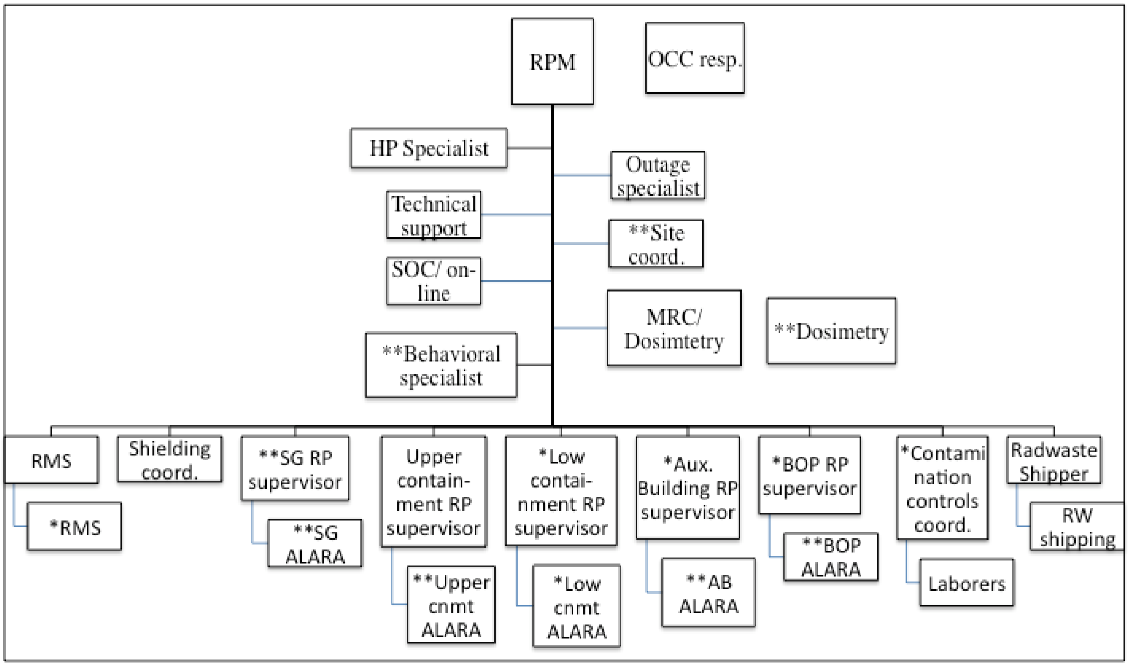

Figure 4. Radiation protection outage organization in day shift

See legend below Figure 5.

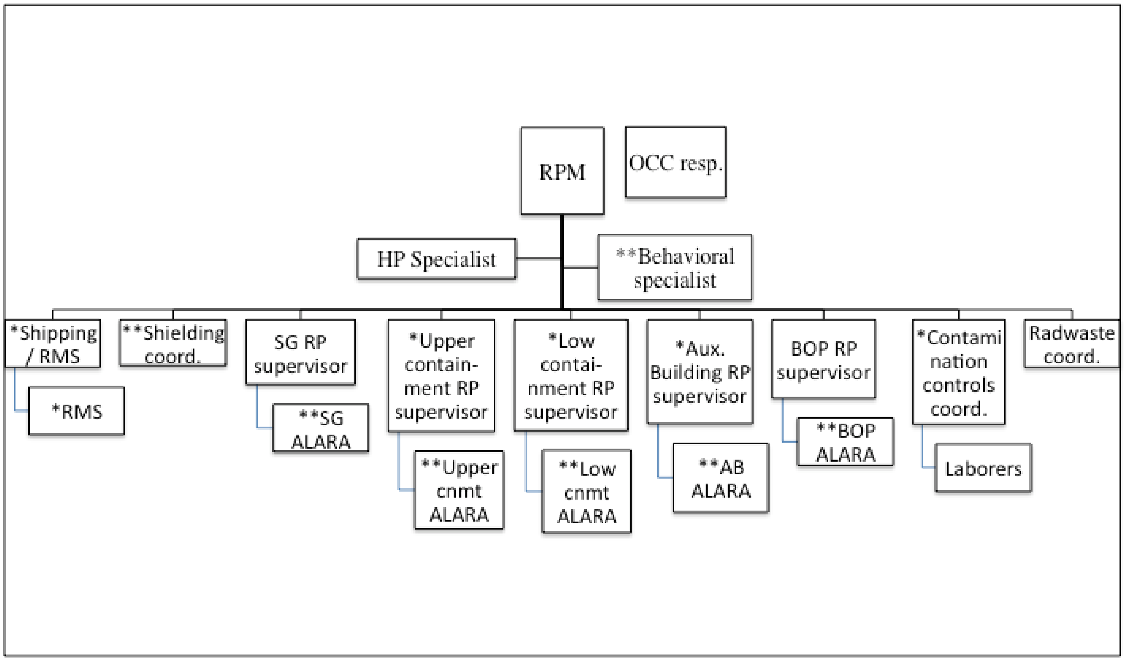

Figure 5. Radiation protection outage organization in night shift

*	Travelers from Exelon sites
**	Contractors (the site coordinator is responsible for the contractors)
AB	Auxiliary Buildings; BOP = Balance Of Plans; OCC = Outage Control Center; RMS = Remote Monitoring System

SG Steam Generator. Steam generator operations are supervised by an RP supervisor: they often correspond to operations with the highest doses, even if large efforts have been recently made on source-term reduction.

SOC Station Ownership Committee. This committee is responsible for issuing reports on any special event (lost of TLDs, repairing of valves…).
The contamination control coordinator is responsible for cleaning up of contaminated areas and prevention of leakages.

The HP specialist is for instance in charge of air sample analysis, isotopic analysis…

During outages, the RPM tries to be 6 hours a day on the field (vs 2 h per week during non-outage periods). His objectives are to make field observations, reinforce the respect of standards and multiply interactive talks with workers on RP practical aspects. It is to note that a "behavior specialist" (see Figures 4 and 5) is also in charge of facilitating the respect of RP fundamentals (dressing, dosimetry…).

During outages, a briefing takes place daily between 5h and 5h30 in the morning. It gathers all the representatives of the RP Department of both shifts and each section (steam generator, upper containment, low containment, auxiliary buildings and refueling operations) provides a quick report. A similar meeting is organized at 5h in the afternoon with the shift-change. Otherwise, two specific deadlines have been implemented after 100 hours and 250 hours of outage to organize "industrial and radiological safety and human performance updates". These two meetings are mandatory and take place in each Department. They aim at presenting results in terms of industrial safety, human performance and radiation workers practices and re-focusing attention on these domains.

Everyday during outages, a datasheet is published to present the state of advancement of operations (Annex 4). It is available at the entrance of the site and in each Department: any worker can also read it. It sums up the outage goals and the updated figures, gives a list of the main tasks to be done during the outage with their milestones and some recommendations according to the results of field observations.

In parallel, the Human Resources Department also publishes daily a "Braidwood station's standards' team report" (Annex 5). It presents facts, incidents and events that happened the day before and evaluates what looks good and what needs to be improved. The following themes are dealt with: safety, human performance, housekeeping and radiological safety.

Finally, 3 months after the end of an outage, RP engineers write a post-outage ALARA report that is then reviewed by the RP head staff. Generally, these reports are made of about 80 pages and include a summary of the outage planning and organization, a description of each operation (with estimate and actual dosimetry, good practices, job weaknesses, recommended improvements…), an analysis of exposure results, a study of personnel contamination events as well as lessons learned. Labor forces on decontamination/ shielding have also to provide their feedback experience (through a report) before leaving the plant.

2.3. Interactions with the Outage Control Center

The Outage Control Center (OCC) runs during the whole outage with a 12-hour shift. The OCC team stays the same during the whole outage (about 16 to 20 days), it is maintained a few days after the outage to gather feedback experience of the operations. Every Department is represented in the OCC and can ensure its management.

The RP Department is represented by a superintendent (hierarchical level just under the RPM) for each shift. He is responsible for:

- Tracking and statusing of RP activities.
- Assisting work groups with RP issues as they arise.
- Communicating up coming work and change of priorities to the first line supervisors in the field.
- Participating in troubleshooting teams to ensure the RP perspective is taken into account for solutions that are to be considered.
- Reporting out on dose and Personnel Contamination Events.

2.4. Running of the Remote Monitoring System

The Braidwood plant has been equipped with a Remote Monitoring System (RMS) since 2003. 23 cameras (fixed or mobile according tasks to be done) are installed inside the containment, 3 ones are outside. The RP Department runs all the cameras. Some extra cameras are used by the OCC, but they are also managed by the RP staff.

In the RMS room (located in the RP Department), 8 screens are available (2 work stations equipped wit 4 screens): 6 ones display only one video but 2 others display 4 videos. There is also the possibility to follow 14 jobs or activities at the same time. Moreover, 4 of these 8 screens provide with quantitative data: dose rate measurements, electronic dosimetry transmission… 40 audio liaisons (Telex) are available. Audio equipments are specially adapted to hardhats.

On each shift, the RMS is run by the Steam Generator RP first line supervisor with designated support from one or two extra persons. If a problem is detected by a RMS operator, he/she calls first the RP technician who is located at the nearest of the incident place, and then, if needed, the RP OCC representative. During the critical path, the “10/30 rule” is applied: it is expected that the RP technician solves the problem in 10 minutes. If it is not the case, the RMS operator calls the RP OCC representative who benefits from 30 extra minutes to solve the incident.

3. RADIATION PROTECTION EDUCATION AND TRAINING FOR RP SPECIALISTS AND WORKERS

3.1. Radiation protection training of RP specialists

3.1.1. Initial training

During the past thirty years, traditional sources of US RP specialists were universities and the Nuclear Navy. However, after the Three Miles Island accident, most of the universities stopped their program (due to a stop in the new plants building program) and in parallel, the Navy has continuously reduced its staff.

Since 10 years, the Nuclear Energy Institute (NEI) and INPO have become aware of this problem and have performed several studies. They notably showed that the current RP staff was ageing and that it could decrease of 75% in the next five to ten years due to many retirements. Moreover, they highlighted a huge lack of initial radiation protection trainings.

As a consequence, INPO has recently engaged a peculiar program with 22 colleges[8] to train young people to radiation protection. In Braidwood, a specific partnership has been implemented with the Linn State College (which is located not too far from Braidwood: this allows hiring local people who want to stay and work in their birth place). Exelon finances partially the College. The College training lasts two years (about 30 students per year): it follows a standard curriculum prepared by INPO.

After these first two years, students[9] follow a qualification that consists in two parts: a first one common to all Exelon plants and a second one, which is site-specific.

- Common initial training consists of 14 weeks of training on entry-level topics and performance based instruction and evaluation on common basic theory and fundamental topics (see Annex 6). It is conducted in Exelon premises at the regional or the fleet level.
- The site-specific training is performed in the Exelon plant where the junior technician will be hired. It lasts 4 weeks: 2 weeks are devoted to systems and instrumentation; the 2 others allow covering policies and practices, and procedures unique to the site.

Finally, after these 18 weeks, students go through “On-the-Job Training”[10] (OJT) and “Test Performance Evaluation” (TPE) for a series of tasks they should be able to perform. For each task, only one failure is allowed; if the candidate fails more than

[8] In the US, colleges concern 16 or 17 year-old students.

[9] Students with comparable education or previous radiation protection training can also enter the Exelon radiation protection training program. All Exelon trainees do not come from INPO colleges.

[10] “On-the-Job Training” consists in a training conducted in the job setting demonstrating actual task performance to prepare students for TPE. Task Performance Evaluation (TPE) is a one-on-one evaluation conducted in the job setting evaluating actual task performance in support of qualification.

twice, a performance evaluation board assesses if he/she has the technical capabilities to pursue the program.

At the end of the training, the trainee is hired as a junior RP technician in the plant. He/she can then evolve, according to his/her wish and abilities, as a senior technician (after a minimum of 3 years) or a first line supervisor (after a minimum of 5 years according to ANSI requirements). It is to note that when a RP technician is hired in Braidwood, it is very rare that he/she changes of plant during his/her career. According to agreements with unions, he/she can only change of site (in the Exelon fleet) if he/she changes of job. In the same way, inside Braidwood, the technician can leave the RP Department only if he/she gets a higher position in another Department.

3.1.2. Continuing training

On an average, RP technicians benefit from a continuing training of 16 to 18 hours every year. Courses are provided by the staff of the Braidwood plant, for instance by RP specialists and engineers, and are evaluated by an "instructor technologist".

A continuing training program also exists for first line supervisors, supervisors and managers: it lasts about 40 hours per year. These people can decide to pass the National Registry of Radiation Protection Technology (NRRPT) certification examination, which is a national test validated by a board of HP specialists.

In Braidwood, continuing RP training programs are mainly elaborated and updated by a RP Curriculum Review Committee (CRC)[11], composed of the RP manager, representatives of the RP Department and managers of the Training Department. The CRC meets every quarter. It bases its works on an INPO guidance that describes a systematic approach to training and recommends following 5 steps to constitute training programs: analyze, design, develop, implement and evaluate (each step is described in a Exelon "Training Qualification" procedure). The CRC usually selects the continuing training topics based on the following three elements:

- Required topics that should satisfy Exelon, Occupational Safety and Health Administration (OSHA), Environmental Protection Agency (EPA) and NRC training requirements.
- RP fundamental refresher topics (covering both theoretical and technical knowledge) such as radiation detection and measurement, radiation monitoring systems, contamination control… (an exhaustive list is provided in Annex 7).
- CRC selected topics, based on worker performance, new equipments/tools, new/revised procedures, industry events, upcoming plant evolutions…

Each year, different courses are also proposed. It is important to note that according to CRC analyses and needs, the committee can also impact the initial RP training program.

Proposals of the CRC are reviewed and approved by an upper committee: the Training Advisory Committee (TAC), which gathers the managers of the RP, Chemistry and

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[11] Curriculum Review Committees (CRC) exist in each Department.

Training Departments, as well as the plant manager. The TAC takes particularly into account questionnaires that are filled in by students or workers at the end of training sessions to assess their quality, identify if changes are needed and if CRC proposals are suitable. Finally, at the plant level, training topics and sessions are endorsed by the Senior Training Council, which is composed of all the Department managers, the plant manager and the corporate vice-president. This committee should ensure that trainings are organized as defined in INPO and NRC guidance and respect their requirements.

The RP CRC follows the training of every RP worker and advises his/her according to his/her individual capabilities and qualifications. It is to note that every worker can send a request to the CRC and asks for specific training. As far as possible, the CRC tries to answer to everyone.

A Dynamic Learning Activities Laboratory exists in an off-site training center (shared between three plants) where RP workers can repeat tasks and be evaluated. It is required that each RP technician visits this centre three times a year.
Otherwise, Braidwood benefits from numerous mock-ups in its Training Building (steam generator, instrumentation, pumps and valves, tanks…). They are used to test new tools and processes and repeat maintenance operations.

Finally, it can be added that every year, training sessions are proposed by specific organizations, universities or vendors on topics such as HP survey instrument selection and calibration, gamma spectroscopy, whole body counting… These sessions are usually reviewed by the RP Curriculum Review Committee for possible inclusion into the RP continuing and/or initial training program.

3.1.3. Training of RP technicians from other Exelon plants and contractors

As previously said, the Braidwood station relies on supplementary RP technicians during outages. According to the tasks they will have to perform, the plant systematically organizes specific training sessions for them two or three weeks prior to the outage:

- As far as Exelon RP technicians are concerned, the training is quite light and can include reminders on site-specific procedures or operations.
- For supplemental RP technicians, it is required that they complete the RP site-specific procedures (see initial training for RP technicians in 3.1.1.).

3.1.4. Evolution for the next years

The RP Curriculum Review Committee is responsible for the long range training plans. Consequently, it has already planned continuing training sessions for RP technicians for the next five years: they will progressively be updated according to RP performance and events.

Today, the Braidwood station is preparing the renewal of its RP staff. Its aim is to compensate every future retirement by hiring a junior technician two years before the departure of the experienced person. In this way, the NPP would be ensured that new comers would be fully competent when they got the job. To date, the corporate level has not accepted the proposal yet as it will induce a strong overstaff in the RP Department for the next years.

3.2. Radiation protection training of workers

The RP training of any exposed worker is performed through the "Nuclear General Employee Training" (NGET) and is organized by the employer. It is common across all Exelon sites but includes a small site-specific portion. The NGET is required initially and then annually, for all workers. It is mainly accomplished by computer-based trainings. As far as Braidwood is concerned, the NGET is provided in a training center off-site that allows gathering workers from three plants as well as contractors.

3.2.1. Content of the Nuclear General Employee Training

The general purpose of the "Nuclear General Employee Training" (NGET) is *"to provide information on the company's access authorization and fitness for duty policy so that nuclear workers can perform their jobs safely and competently in an environment free of drugs and alcohols"*. Two modules concern radiation protection topics: "Radiological orientation" and "Radiation worker training".

The first module ("Radiological orientation") aims at providing information on radiation terminology, radiation exposure risks, use of dosimetry and restrictions in radiation controlled areas (RCA[12]). It lasts 30 minutes. At the end of the first module, the trainee shall be able to:
- Define the terms "radiation, radioactive material, contamination, dose" and state their differences.
- Define background radiation and contrast the average amount of radiation received by radiation workers vs members of the public.
- State the federal limit for the declared pregnant worker.
- State the purpose of thermoluminescent dosimeter (TLD) and the whole body contamination monitor (exit portal monitor).
- Identify potential long-term effects from exposure to low levels of radiation.
- Contrast the risk of working in a nuclear facility to the risk in other industries.
- State the colors and symbols used in radiological postings and identify the methods used to mark radiological areas.
- State the actions to be taken if a radiological area or radioactive material is encountered.

Students are evaluated by answering questions given on the examination. They should at least have an accuracy of 80% if they want to succeed.

The second module ("Radiation worker training") lasts 8 hours and provides a worker with the knowledge and skills necessary to enter and work safely within a RCA. It

[12] Definitions of RCA, High Radiation Area (HRA) and Locked High Radiation Area (LHRA) are provided in Annex 1.

contains the radiological training required for unescorted access to the RCA. At the end of the second module, the trainee shall notably be able to:

- List the sources of radiation in the plant.
- State the radiation dose limits.
- Describe the plant ALARA program.
- Explain how to wear dosimetry devices properly.
- State the modes, methods and frequency for operating and reading dosimetry.
- Explain the individual's actions for removing material from the RCA or a contaminated area.
- Explain situations that require personnel to exit a contamination area.
- State the function of a Radiation Work Permit (RWP) and extract information from one RWP.
- Extract information from a survey map.
- State the required actions to be taken if the work scope or radiological conditions change so that they are not within the scope of the RWP.
- Define and recognize radiological areas and postings.
- State the requirements to enter a High Radiation Area (HRA) or a Locked High Radiation Area (LHRA).
- State the radiological alarms used in the station and explain the proper responses.
- Explain the steps for inspecting and donning protective clothes.
- Explain how to perform whole-body frisk.

As previously, students are evaluated by answering questions given on the examination. They should at least have an accuracy of 80% if they want to succeed.

3.2.2. Modalities of training

As explained before, the initial training can be done in one day (30 min + 8 hours). It is realized more and more through computer-based training (CBT) and self-study; less and less instructors intervene.

As for the continuous training, each worker should perform a refresher examination every year. As previously, this training is based on CBT and self-study. In Braidwood, it is offered every two weeks throughout the year.

3.2.3. Evolution for the next years

Training materials and methods are trending towards self-paced and computer based materials utilizing forums such as "Nantel". The methods also favor "just in time training" (JITT) where training is provided "just in time" to individuals or teams to prepare them for upcoming evolutions, address emergent performance issues or perform infrequent tasks.

Today, the Braidwood plant does not envisage strengthening the RP training of its workers and evolving towards self-protection. Even if advanced radiation workers programs exist in some plants, mid-West plants are not concerned because of agreements with unions.

4. INSTRUMENTS FOR RADIATION MONITORING

4.1. Fixed instruments

The fixed instruments available in the Braidwood NPP are listed in Table 3 (the main supplier is Thermofisher). Some calibrations methods are presented in Table 4.

Table 3. Characteristics of fixed instruments available in Braidwood

	Type	Detector	Alarm set point		Counting time
Personnel Contamination Monitors (exit of the RCA or exit of the site)					
1 Thermo PCM-2	Beta/Alpha	Gas Proportional	$\beta = 3750$ dpm/100cm^2	$\beta \approx 0.6$ Bq/cm^2	2 x 15s
8 Thermo IPM-9	Beta	Gas Proportional	$\beta = 3750$ dpm/100cm^2	$\beta \approx 0.6$ Bq/cm^2	2 x 15s
6 Thermo PM-7	Gamma	Plastic Scintillation	$\gamma = 70$ nCi	$\gamma \approx 2600$ Bq	5s
1 Canberra Argos-5AB*	Beta/Alpha/Gamma	Gas Proportional	$\beta = 3750$ dpm/100cm^2	$\beta \approx 0.6$ Bq/cm^2	-
Staged Friskers					
RM-14	Beta/Gamma	GM	< 1000 dpm/100cm^2	< 0.16 Bq/cm^2	-
3 CM-11	Alpha/Beta/Gamma	Gas Flow Scintillation	< 1000 dpm/100cm^2	< 0.16 Bq/cm^2	-
Tool Monitors					
4 Small Article Monitors SAM-11 (Thermo)	Gamma	Plastic Scintillation	< 5000 dpm	< 80 Bq	-

* This portal has been installed very recently. Today, only beta measurement is used. In the near future, gamma measurement will be available (with the same alarm set point as PM-7).

Table 4. Calibration methods of some fixed instruments

	Calibration source	Calibration Geometry (1 inch = 2.5 cm)	Detection probability	Others comments
Personnel Contamination Monitors (exit of the RCA or exit of the site)				
Thermo PCM-2	Mix of Cs-137 and Co-60	≈ 3 inches from the center of the detector	97.5%	0.1% of false alarms
Thermo IPM-9	Mix of Cs-137 and Co-60	≈ 3 inches from the center of the detector	97.5%	0.1% of false alarms
PM-7	Cs-137	3 inches from the center of the detector	97.5%	Equipped with 6 detectors: 1 feet, 1 head, 2 right, 2 left 0.1% of false alarms
Tool Monitors				
SAM-11	Cs-137	≈ 3 inches from the bottom of the monitor	-	Lead shielding on the 6 faces

At the exit of the RCA, several instruments are available:

- Every worker should go through Personnel Contamination Monitors (PCM): the first one (PCM-2 or IPM-9) allows a beta measurement, the second one allows a gamma measurement (PM-7). There is no peculiar adjustment for alarm set point. If background[13] elevates in such a manner that PCMs automatically go out-of-service, then the background will be mitigated rather than adjusting the alarm set point.
- Moreover, each worker from the RP Department should use the frisker to check his/her contamination before the PCM. Detection limit of the frisker is 1000 dpm (about 16 Bq). If the background is high, smears are performed.
- Small Article Monitors (SAM) can only be used by the RP personnel. They are installed on carts whose wheels are locked.

At the exit of the plant, workers go through 2 PM-7, which are the same as the ones installed at the exit of the RCA (and which are adjusted with the same alarm set points).

It is interesting to note that these PM-7 are very sensitive to background radiation. Lead shielding is also installed all around portals to avoid any false alarm. Finally, contrary to EDF plants, portals are not equipped with barriers. Signs painted on the floor indicate workers where they have to stand before to be monitored.

Today, the main difficulties encountered by the Braidwood plant with its fixed instruments are the following:

- Maintaining consistent monitoring without false alarms of personnel leaving the RCA at decreased alarm set points forth by INPO.
- Changing backgrounds effecting PCM operability (radon).

[13] In Braidwood, the average background is about 3000 dpm = 50 Bq. It may increase due to radon.

4.2. Mobile instruments

The mobile instruments available in the Braidwood NPP are listed in Table 5. Again, the main supplier is Thermofisher.

Table 5. Characteristics of mobile instruments available in Braiwood

	Type	Detector	Use	Quantity
Ludlum 3030P	Alpha/Beta	Solid State	Smear Counter	5
Bicron RSO-50E	Beta/Gamma	Ion Chamber	Surveys	40
Thermo RO-20	Beta/Gamma	Ion Chamber	Surveys	20
Eberline* RM-14	Beta/Gamma	GM	Contamination Meter	30
Eberline* PRM-6	Beta/Gamma	GM	Contamination Meter	20
MGP Telepole	Beta/Gamma	GM	Surveys	25
Eberline AMS-4	Beta Particulate	Sealed Gas Proportional	Continuous Containment Air Monitor	3
Radeco HD-28	Air Sampler	N/A	Take Air Samples	15

* Equipped with a lead shielding (≈ 2mm) above the probe.

<u>Monitoring of gamma dose rates</u>
Gamma dose rates are measured with Ram Ion instruments equipped with probes. According to circumstances, telescopic probes can also be used: 6 MGPi Telepole (see Table 4) and 6 teledetectors 6112B SAPHYMO are available. All results are displayed in mSv/h. There is no gamma radiation beacon. Only fixed instruments (Thermofisher) ensure the permanent control of gamma dose rates in controlled areas.

<u>Monitoring of neutron dose rates</u>
No equipment is available.

<u>Monitoring of contamination levels</u>
If the background is below 3000 dpm, contamination levels are directly measured with friskers or contamination meters with a detection limit of 1000 dpm (16 Bq).
If the background is above 3000 dpm, it is too high to allow a direct measurement: smears are also performed. Smears counters present the following characteristics for counting times related to alpha measurements:

- 9 dpm (0.15 Bq) in 1 minute,
- 3 dpm (0.05 Bq) in 5 minutes.

They offer the possibility to measure 8 smears at the same time.

<u>Monitoring of airborne contamination levels</u>
Aerosols are measured with Thermofisher AMS 4 (the filter is fixed). The first alarm is set up at 189 dpm/ft^3 (≈ 107 Bq/m^3), the second one at 1890 dpm/ft^3 (≈ 1070 Bq/m^3). There is no beacon for iodine and noble gas, which are only monitored by fixed instruments (Thermofisher).

A distinction is made between "contaminated" and "non-contaminated" RP mobile instruments. Only equipments with a yellow stick can be used in contaminated areas.

In complement, dosimeters used in the Braidwood station are the following:

- For passive dosimetry: use of TLD dosimeters integrating a gamma and a neutron detector. The gamma detection limit is 10 mRem = 100 µSv.
- For electronic gamma dosimetry (ED): use of Siemens EPD dosimeters with a detection limit of 1 mRem = 10 µSv (calibration with caesium-137). On an average, ED provides measurements 20 to 25% below TLD results (registration of ED results is made "at the nearest integer": e.g. 0.6 is registered as 1; 1.4 is registered as 1).
- There is no electronic neutron dosimeter.

4.3. Extra instruments during outages

Exelon shares outage equipments through a central calibration lab, PowerLabs. According to the program of outages, this company distributes instruments and materials (RP equipment, temporary shielding, scaffold, equipment for steam generators operations) to the 10 Exelon plants, including Braidwood.

The Braidwood station is equipped of a containment access facility (CAF) for both units (Figure 6). This installation allows loading and unloading any type of equipment (coming from Powerlabs or Westinghouse) very easily and quickly into the containment building. Loaded trucks arrive at the basis of the building and are "paste" to the CAF (containers can be disconnected from vehicles). Then, the chosen equipment is transferred inside the containment access facility, which is classified as a RCA.

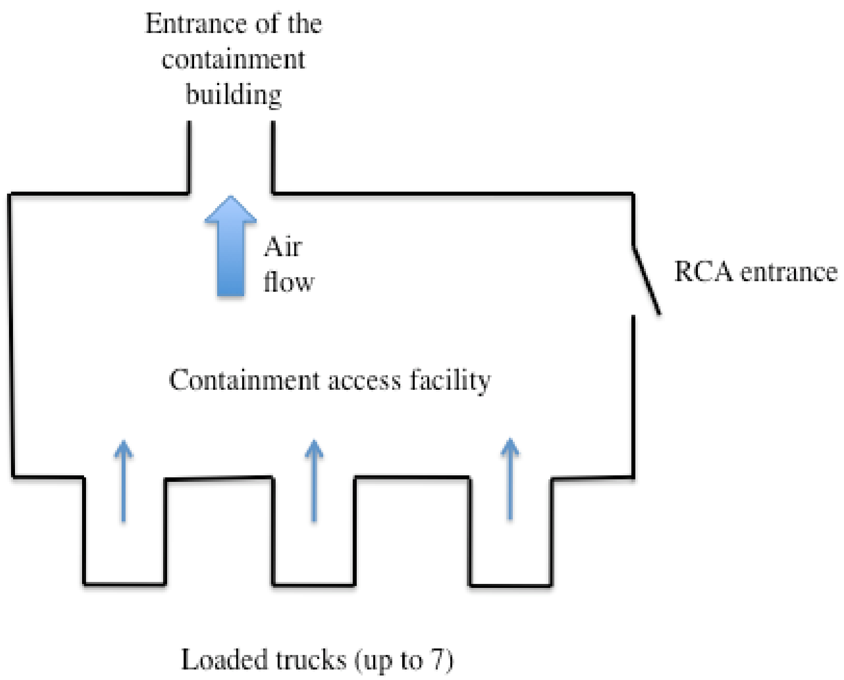

Figure 6. Scheme of the containment access facility

This containment access facility is considered as an equivalent to a mobile shop. When the outage is over, doors are closed (several Exelon plants benefit from the same installation).

4.4. Adjustment, use and maintenance

Annual maintenance and calibration procedures are under the responsibility and generally performed by Powerlabs. On an average, 90% of instruments are controlled and calibrated by Powerlabs. If instruments cannot be sent back to Powerlabs (by a lack of time), the RP Department uses its own calibration machine (mainly for gamma dose rate monitors and high flux probes). This device (Shepherd, Figure 7) is equipped with a source of caesium-137 of 15 TBq. It is calibrated by the supplier every two years.

Figure 7. Calibration device used in Braidwood

The Braidwood station can intervene on its instruments on a daily basis:

- Repairs of instruments are made on a demand basis by the in-house Instrument Maintenance Department.
- The RP Department calibrates and source-checks instruments: daily source-checks are notably performed for Personnel Contamination Monitors and radiameters used to make survey maps[14].

As far as replacement of RP instruments is concerned, the Braidwood plant does not perform any purchase. Actually, each Exelon plant provides Powerlabs with an annual

[14] The NRC requests an inventory of sources and their location every 6 months. Braidwood NPP updates it daily. Part of the sources is stored in the tool shop to facilitate daily source-checks.

financial support, which is used to replace instruments according to the needs expressed by the fleet and the corporate level. Specifications of instruments are also written by Powerlabs who is in charge of contacting vendors (instruments need to satisfy requirements of ANSI, INPO and NRC as well). Otherwise, when new equipment is purchased, it is often tested by the plant that requests it, before to be installed in the whole fleet.

Thus, in the next five years, the Braidwood plant intends to:

- Upgrade all Personnel Contamination Monitors to more sensitive and better measuring geometry PCMs. The objective is notably to benefit from a single PCM for beta and gamma measurements at the exit of the RCA.
- Upgrade all friskers to more modern type.
- Upgrade continuous air monitors to more modern type.

CONCLUSION

Descriptions provided in this report can allow drawing some concluding remarks on arrangements implemented in the Braidwood station.

Radiation protection benefits from an important consideration in the daily running of the plant. In particular, during outages, a strong RP organization is implemented. Thus, during the preparation period, a detailed “RP Outage Preparation Checklist” is established: it includes more than 275 tasks and allows ensuring that every RP item is taken into account. During outages realization, the RP Department relies on 12 hour-shifts covering both day and night. Finally, the RP Department ensures a permanent presence in the Outage Control Center: it is represented by a superintendent, which is the hierarchical level just under the radiation protection manager.

Several comments can be proposed on the structure and the roles of the RP Department. From a first view, the RP personnel can appear quite numerous for a 2-unit plant compared to the situation in EDF plants. However, RP specialists don’t have the same roles in Braidwood as in EDF units. Indeed, in Braidwood, the RP staff deals with any activity related to radiation protection including decontamination and shielding; in EDF plants, RP specialists do not manage these last two activities but cover industrial risks. The Braidwood RP personnel is very present on the field and assists every worker in respecting radiation protection requirements. This role is all the more important because exposed workers receive a short training on radiation protection and are not responsible for their own protection.

As far as the training is concerned, INPO recently engaged a specific program to reinforce RP initial training and face ageing of the experienced RP workforce. Exelon and the Braidwood station are strongly involved in this program. Their initial training sessions appear quite complete and include a significant part of practical works (on-the-job training process). Moreover, continuing training sessions are offered all along the year. It is also worth underlining that a specific 4-week training is mandatory for RP contractors to be authorized to work in the station.

The Braidwood plant is preparing the renewal of its RP staff. Its aim is to compensate every future retirement by hiring a junior technician two years before the departure of the experienced person. In this way, the NPP would be ensured that new comers would be fully competent when they got the job.
Finally, as for instrumentation, it can be noted that the Braidwood station runs with a low quantity of RP equipments compared to EDF plants. Besides some monitoring domains are not covered in the same way: for instance, the permanent monitoring of gamma dose rates in controlled areas is only performed by fixed instruments and does not rely on specific beacons. Otherwise, the peculiarity of Exelon to work with a central company (Powerlabs) that purchases, provides and ensures maintenance of equipments appears to be very efficient.

ANNEX 1. REMINDER ON US REGULATIONS

Dose limits

NRC regulations limit individual's annual dose to 50 mSv for the nuclear workers. The standards were issued in 1991 and are based on ICRP 26 recommendations. Today, NRC intends to change this limit and apply ICRP 103.

Zoning

- Radiation Area:
  50 µSv/h < dose rates at 30 cm from the radiation source < 1 mSv/h.
- High Radiation Area (HRA):
  1 mSv/h < dose rate at 30 cm from the radiation source < 10 mSv/h.
  Any worker who intends to enter in a HRA needs to go the RP Department to ask for the key. He/she will be briefed on the risks associated with the area.
- Locked High Radiation Area (LHRA):
  Dose rate at 30 cm from the radiation source > 10 mSv/h.
  Only the staff from the RP Department can use the keys of LHRAs. If these areas cannot be locked: "stop" signs are installed as well as red flashing lights (2 supplied on battery and 1 on the plant electric network).
- Very High Radiation Area:
  Absorbed dose at 1 m from the radiation source > 500 rads/h.

ANNEX 2. EXAMPLE OF OBSERVATION PROGRAM SHEET

Standards & Behaviors		EXCEEDS	MEETS	NEEDS	BELOW
INDUSTRIAL SAFETY					
1.	'2-Minute Drill' use				
2.	Chemical usage & storage				
3.	Clearance & Tagging requirements met				
4.	Electrical flash preparations				
5.	Falling objects / suspended loads				
6.	Fire hazard assessment				
7.	Heat stresses & defenses				
8.	Heights / fall protection equipment				
9.	Lifting & carrying techniques				
10.	Lighting assessed & adequate				
11.	Pinch points identified & avoided				
12.	PPE for: Head, face, eyes, hearing, hand & foot				
13.	Projectiles / unexpected pressure assessment & preparations				
14.	Slip / trip hazards – marked or corrected				
15.	Ventilation assessment / respirator use				
16.	Confined space work permit obtained & appropriate use				
17.	Electrical safety standards				
18.	Lifting and rigging techniques				
19.	Compressed gas cylinder handling appropriate methods				
20.	Safety barriers / postings & acknowledgement				
21.	Ladder use / 3 points contact				
22.	Scaffold structure and usage				
23.	Temp power practices (GFCIs)				
24.	Tools / equipment checks & appropriate use				
25.	Welding practices / hot work permits				
26.	Safety concerns addressed or work stopped				

Standards & Behaviors		EXCEEDS	MEETS	NEEDS	BELOW
RADIOLOGICAL SAFETY					
1.	RWP knowledge – Job scope and stop work criteria				
2.	RWP knowledge – Exposure allowed, ED alarm settings				
3.	RWP knowledge – Rad survey for dose rates, low dose areas & smearable contamination				
4.	RWP knowledge - PC requirements				
5.	RWP knowledge – Radiation Protection Technician present				
6.	Dosimetry / ED / TLD placement				
7.	Low dose areas used				
8.	Accumulated exposure as expected				
9.	Worker stops when ED alarms				
10.	HRA briefing received when required				
11.	PC donning – booties inside coveralls, gloves overlap sleeves, hood & coveralls secured				
12.	Rad barrier compliance				
13.	Hoses/cords secured in contaminated areas				
14.	Rad bag use				
15.	PC removal / step off pad use				
16.	Frisking technique / portal monitor use				
17.	Respirator use				
18.	RAD barriers adequate – gates / ropes / signs & postings				
19.	Step off pad placement for: tools, equipment & laundry hampers				
CONFIGURATION CONTROL					
1.	Actions taken to ensure proper configuration control				
2.	Distance maintained to prevent inadvertent bumping				

ANNEX 3. RADIATION WORKER POCKET DATA SHEET

Radiation Worker Pocket RWP Data Sheet

NAME: ____________________

RWP #: 10010344 REVISION: Ø

Specific Component/Location or Area:

____

Work To Be Performed

____

Electronic Dosimetry Alarms

ED Dose Alarm: 1000 mrem

Dose Rate Alarm: 240 mrem/hr

Working Area Information

Expected Dose Rate Range: ____________ mrem/hr

Expected Contamination Levels: ____________

My Dose Goal: ____________ mrem

High Radiation Area: YES NO (Circle One)

If YES, then a High Radiation Area Briefing by Radiation Protection is required prior to entering the area.

Name of the RP Technician who performed the HRA Briefing:

(Name): ____________________

RP-AA-1008

5 Key Good Rad Worker Practices

1. Read AND Understand YOUR RWP.
2. Wear your TLD within 6 inches of your ED.
3. Contact RP prior to going above 7 feet in the RCA.
4. Secure all hoses or wires crossing a contaminated boundary.
5. Exit your work area safely and contact RP if:
   a. Failure or suspected failure of PCs
   b. Loss or damage of personal dosimetry
   c. Unexpected change in or unexpected radiological conditions
   d. Any unexpected ED alarm
   e. Unexpected ARM alarm
   f. You have any concerns with working in the area.

<u>Submit ALARA Suggestions Below</u>

____

____

____

ANNEX 4. OUTAGE INFORMATION SHEET

OUTAGE DIRECTORS		Day 9 of 17 - October 21, 2009
DAYS	JEFF BURKETT 4620	**WELCOME TO A2R14**
NIGHTS	RANDY LARSON 4620	

A2R14

Unit Status

Mode 6

Safety System Status

YELLOW

REACTIVITY CONTROL	Yellow
SHUTDOWN COOLING	Green
INVENTORY CONTROL	Green
FUEL POOL COOLING	Green
POWER ELECTRIC CONTROL	Yellow
CONTAINMENT	Green
VITAL SUPPORT SYSTEMS	Green

PROTECTED EQUIPMENT

1 FC
B RH
PA08J
Bus 242
nstrument Bus 212
C 212
B SX

	Contractor		Exelon		
	Days	Nights	Days	Nights	Totals
OSHA	0	0	0	0	0
FIRST AID	5	1	2	1	9
TOTALS	5	1	2	1	9

Remember the *2 Minute Drill at the Job Site*!!
Human Performance/Safety Topic of the Day – Walking and Hand Safety

CRITICAL PATH

- **Core Reload**
- **2A CV Pump Replacement**
- **Steam Generator Secondary Sludge Lancing**

2B RH train was restored yesterday morning allowing entry into mode 6 and core reload to begin at 13:08. Unfortunately a Fuel Transfer System cart cable failure at 16:38 caused fuel moves to stop after 14 of 193 assemblies had been loaded into the vessel. Underwater repairs in the Fuel Handling building transfer canal using diver support will be completed today to allow fuel moves to resume.

2A CV Pump scope expanded as a result of FME concerns discovered during disassembly when missing screw heads could not be found after failing during service. Based on Industry Operating Experience and risk to continued reliability of this safety significant piece of equipment to needed to maintain nuclear safety decisions were made to replace the rotating element of the pump.

Focus on Housekeeping. Leave the site as good as or better than you found it. Poor Housekeeping can lead to FME issues, Siesmic Houskeeping problems, Fire Transient Combustible violations, unnecessary radiological exposure and traps for Industrial Safety Accidents.

OUTAGE GOALS	**ZERO OSHA RECORDABLE INJURIES**	**<62.9 R revised** **42.602 R to date**	**ZERO HUMAN PERFORMANCE LERs**	**≤17 DAYS**
TO DATE	**ZERO**	**35.059 R**	**ZERO**	**64 Hrs behind**

A2R14 MILESTONES

MILESTONE	TARGETED FINISH DATE/TIME	ACTUAL FINISH DATE/TIME
TURBINE GENERATOR OFF LINE (G 1005OP)	10/11/2009 23:00	10/11/2009 2300
START SWITCHYARD ACTIVITIES 1ST WINDOW (SY1-WS)	10/11/2009 23:00	10/11/2009 2300
MODE CHANGE 4=>5 (G 1045OP)	10/12/2009 06:00	10/12/2009 0532
BEGIN H2 PEROXIDE ADD/CLEANUP OF RCS (G 8500OP)	10/12/2009 18:00	10/12/2009 1817
COMPLETE H2 PEROXIDE ADD/CLEANUP	10/12/2009 22:00	10/12/2009 1924
STOP LAST RCP (G 1201OP)	10/13/2009 01:00	10/13/2009 0102
CLOSE ALL LOOP STOP VLVS (LSIVCLOSED)	10/13/2009 03:00	10/13/2009 0240
COMPLETE SWITCHYARD ACTIVITIES 1ST WINDOW (SY1-WC)	10/13/2009 07:00	10/13/2009 0700
DRAIN RCS TO BELOW FLANGE (COMPLETE/G 1137OP)	10/13/2009 13:00	10/13/2009 1430
MODE CHANGE 5=>6 (G 3090MM START DETENSIONING)	10/13/2009 18:00	10/14/2009 0014
2B S/G MANWAY REMOVED (SGB-PRI-001)	10/14/2009 12:00	10/14/2009 1600
FLOOD RX VESSEL TO 420 FT, TO UNLATCH (G 1139OP)	10/15/2009 00:00	10/15/2009 0015
ECCS AS FOUND TESTING COMPLETE (ECCS-WC)	10/15/2009 06:00	10/15/2009 0600
START SWITCHYARD ACTIVITIES 2ND WINDOW (SY2-WS)	10/15/2009 07:00	10/15/2009 1700
LIFT/STORE UPPER INTERNALS (G 3185MM)	10/15/2009 09:00	10/15/2009 1630
START CORE UNLOAD (G 9061FH)	10/15/2009 13:00	10/16/2009 1120
2B DG TESTING COMPLETE (DGBTESTCOMP)	10/16/2009 06:00	10/16/2009 1100
CORE UNLOAD COMPLETE (G 9061FH)	10/17/2009 01:00	10/17/2009 2147
COMPLETE SWITCHYARD ACTIVITIES 2ND WINDOW (SY2-WC)	10/17/2009 05:00	10/17/2009 2045
BUS 241 WORK START(LCO BUS241S)	10/17/2009 05:00	10/18/2009 0400
BUS 241 ENERGIZED EXIT UNIT 1 LCO (LCO BUS241F)	10/18/2009 17:00	10/20/2009 0438
2B TRAIN RH WORK COMPLETE (RHB-WC)	10/19/2009 12:00	10/20/2009 1200
START CORE LOAD (G 9065FH)	10/19/2009 12:00	10/20/2009 1308
BUS 241 WORK COMPLETE (APA-WC)	10/19/2009 19:00	
2A TRAIN RH WORK COMPLETE (RHA-WC)	10/20/2009 23:00	
CORE RELOAD COMPLETE (G 9065FH)	10/21/2009 02:00	
2A CV PUMP WORK COMPLETE (CVA-WC)	10/21/2009 08:00	
ECCS AS LEFT TESTING COMPLETE (ECCS-WC1)	10/21/2009 23:00	
LOWER RX CAVITY LEVEL BELOW FLANGE (G 1148OP)	10/22/2009 07:00	
FAC INSPECTION COMPLETE (FACCOMPLETE)	10/22/2009 16:00	
2CD02A FINAL RETORQUE OF E & W 418' CONDENSER MANWAYS (0114688716)	10/22/2009 17:00	
MODE CHANGE 6=>5 (G 1065OP)	10/23/2009 05:00	
2RC01PA PERFORM UN-COUPLED MOTOR RUN (ARCP39)	10/23/2009 06:00	
2A TRAIN SX WORK COMPLETE (SXA-WC)	10/23/2009 08:00	
PLACE MAIN TURBINE ON TURNING GEAR (MEV12)	10/23/2009 18:00	
PERFORM CW LINEUPS S/U FILL & VENT PER BWOP CW-1 & 3 (G 1923OP)	10/23/2009 19:00	
2A DG TESTING COMPLETE (DGATESTCOMP)	10/24/2009 07:00	
2A/2D S/G MANWAY INSTALLED (SGA-PRI-014,SGD-PRI-014)	10/24/2009 14:00	
2C RCFC WORK COMPLETE (2CRCFC-WC)	10/24/2009 19:00	
2D RCFC WORK COMPLETE (2DRCFC-WC)	10/25/2009 03:00	
ALL LOOP STOP VLVS OPENED (G 1206OP)	10/25/2009 04:00	
VACUUM FILL RX VESSEL HEAD (G 1426OP)	10/25/2009 10:00	
CONDENSER VACUUM ESTABLISHED (G 1118OP)	10/25/2009 15:00	
DRAW BUBBLE START 2D RCP (G 1036OP)	10/25/2009 20:00	
ESTABLISH CONTAINMENT INTEGRITY (MEV16)	10/25/2009 21:00	
MODE CHANGE 5=>4 (G 1054OP)	10/26/2009 07:00	
MODE CHANGE 4=>3 (G 1043OP)	10/26/2009 15:00	
MODE CHANGE 3=>2 (G 1032OP)	10/27/2009 12:00	
MODE CHANGE 2=>1 (G 1021OP)	10/27/2009 20:00	
MAIN GENERATOR ON LINE (G 1101OP)	10/28/2009 23:00	
POWER ASCENSION TO 48% POWER (NIRAMP4048)	10/29/2009 11:00	
POWER ASCENSION TO 75% POWER (NIRAMP6575)	10/30/2009 09:00	
POWER ASCENSION TO 100% POWER (NIRAMP100)	11/02/2009 16:00	

ANNEX 5. STATION STANDARDS' TEAM REPORT

Braidwood Station Standards' Team Report

What looks good and what needs to be improved

October 20, 2009 (Day 8)
A2R14 Outage Observations

Results for last 24 hours as of 1600 on 10/20/09

SAFETY

Fire Hazard Assessment – Some workers are performing grinding activities without readjusting weld blankets to keep the sparks from hitting the ground. In one instance, the fire watch did not have control of the walkway and it was not posted for the hazard. Also, an observation noted another Hot Work permit that was not authorized by the supervisor prior to start of work.

Ladder Use – Worker was climbing down scaffold ladder with tools in his left hand and was not maintaining good 3-point contact. Another worker was observed standing one foot above grade on a small tire to reach into a truck. He should have obtained a small step ladder.

Slip / Trip Hazards Identified – Workers exhibited an excellent eye for detail in noticing some spilled resin and the potential for a slip hazard. They alerted workers in the area about the hazard until it could be controlled. Excellent behaviors!

Lifting and Rigging – Observations are noting good behaviors when rigging and lifting equipment in the plant. Workers involved with these lifts are making sure the work is performed safely and error-free.

HUMAN PERFORMANCE

Pre-Job Briefs – Observations are still noting very good behaviors with the performance of PJBs. They are observing good use of OPEX and Lessons Learned, plus all workers are staying engaged and asking pertinent questions to ensure information is understood. Great job everyone!

HOUSEKEEPING

Job Site Left as Found or Better – In general, housekeeping is good in the plant. However, observations are starting to identify that housekeeping standards are not being met in a few areas, especially those that are beginning to demob. Remember, good housekeeping helps to prevent slip/trip injuries!

RADIOLOGICAL SAFETY

Radworker Practices – One worker was observed leaning across an RCA boundary; another worker was carrying work gloves in his pocket while monitoring through exit portals; and another worker removed rubber shoe covers, and then placed his shoe on the change area floor.

Low Dose Areas Used – An observation noted good use of low dose area by the 426' Containment FME watch. Also, other workers are being observed effectively using low dose areas.

Adhering to the Exelon Fundamentals will ensure you are:
Doing the **Right** thing
At the **Right** time
For the **Right** reason

REAL
HERO 2009

Exelon Nuclear

ANNEX 6. CONTENT OF THE RADIATION PROTECTION TECHNICIAN COMMON INITIAL TRAINING

Math concepts - Basic math concepts - Exponents - Logarithms - Scientific notation - Basic equation solving - Graphing and charts - Statistics **Basic physics** - Measurement, force, power and energy - Forms of energy - Physics, electrical science - Mechanics and instrumentation **Fundamentals of chemistry** - Chemistry, periodic table **Health physics fundamentals** - Basic atomic structure - Radioactivity and the nucleus - Modes and laws of radioactive decay - Interactions of radiation with matter - Chart of the nuclides - Health physics fundamentals - Radiation biology - Biological effects - Natural background radioactivity **Instrumentation** - Gas filled detectors - Small articles monitor - Detector efficiency and calibration - Statistics of radioactive decay - Scintillation, neutron and solid state detectors - Radiation protection portable survey instruments - Personnel contamination monitoring **Standards** - Radiation work permit - Federal regulations **Dosimetry/exposure control** - ALARA - Radiation dose calculations - External dosimetry - External exposure monitoring	**Contamination control** - Contamination and decontamination - Crud formation and control - Discrete particles and control - Personnel decontamination - Survey of contaminated personnel **Radiation applications** - Surveys - Unconditional release survey - Radioactive materials shipping - Sealed source design and leak test - Radiography - Personnel communication skills - Radiation protection litigation - Observation and correction - Radiation protection violations in the nuclear industry - Radiological postings - Temporary shielding - Diving coverage - Shepherd calibrator source - Industrial hygiene surveys - Labeling - New fuel receipt - High risk job coverage - Stop work authority - Pumps/ valves/ seals **Emergency response** - Field monitoring - Emergency tasks - Medical emergency training **Administrative topics** - HAZCOM - Scaffold user - Clearance and tagging: general employee - Documents and procedures - Configuration management - Chemical control - FME and housekeeping - Hearing conservation - Intro to CAP system/EDMS - Restraint of portable equipment - Compressed gas cylinder - Pre-job briefs/ reverse PJB - Electrical safety - Verification activities/ lab

- Siemens electronic dosimetry **Respiratory** - Airborne radioactive material - Respiratory protection theory - Air sampling techniques and air sampling equipment - Mask-fit theory and operation - Non-rad air sampling **Internal dosimetry** - Biological intake and distribution of radionuclides - Whole body counting	- Heat stress - Unplanned exposures - Accreditation and SAT primer - On-the-job training and Task Performance Evaluation - Confined space supervisor - Fall protection - RCRA - Technical human performance - Technical task risk, rigor assessment, PJB, post-job briefing - BWR/PWR systems overview
Total = Approximately 12 weeks	

ANNEX 7. RADIATION PROTECTION TECHNICIAN FUNDAMENTAL REFRESHER TOPICS

RP Technician fundamental topic	Recommended frequency (in years)
Mathematics/ Physics/ Electrical science	4
Basic atomic and nuclear physics	4
Chemistry	4
Radiation detection and measurement	4
Radiological survey and analysis instruments	4
Radiation monitoring systems	4
Sample collection equipment	4
Calibration sources and equipment	4
Radioactive material control	4
Radioactivity and radioactive decay	4
Source of radiation ad interaction with matter	4
Biological effects/ risks of ionizing radiations	4
External exposure control	1
External dosimetry	4
Internal dosimetry	4
Contamination control	4
Decontamination	4
Airborne radioactivity control	4
Conduct and monitoring of radiological work	2
Radiological incident evaluation and control	4
Non radiological air sampling	4
Reactor coolant/ CVS/ RWCU	4
Rad waste systems	4
RHR/ shutdown cooling	4
Condensate/ feedwater/ main steam	4
Plant ventilation	4
Incore detectors/ transverse incore probes	4
Waste gas decay/ off-gas	4
Valves/ pumps and seals	4
RP fundamentals of safe nuclear operation	1