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DE LA PROTECTION DANS LE DOMAINE NUCLEAIRE

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ORGANISATION OF RADIATION PROTECTION AT SIZEWELL NUCLEAR POWER PLANT IN THE UK

P. CROUAIL, B. JEANNIN, C. LEFAURE, L. PANISSET

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SIEGE SOCIAL ET ADMINISTRATIF :
ROUTE DU PANORAMA BP 48 F-92263 FONTENAY AUX ROSES CEDEX
TEL : +33 1 58 35 74 67 FAX : +33 1 40 84 90 34
E-MAIL : sec@cepn.asso.fr WEB : http://www.cepn.asso.fr/

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1. ORGANISATION AND MANAGEMENT OF RADIATION PROTECTION

1.1. General organisation

The Sizewell Nuclear Power Plant is a standard Westinghouse 4-loop1200 MW_e (3411 MW_{th}) PWR operated by British Energy. Its first criticality occurred in January 1995, it is now normally speaking operated in 18 months refuelling cycles, currently in cycle no 7, with outage durations comprised between 3 and 6 weeks according to the amount of maintenance works to perform. The refuelling outage dose is typically around 90% of annual total. More than 1000 contractors are employed during outages.

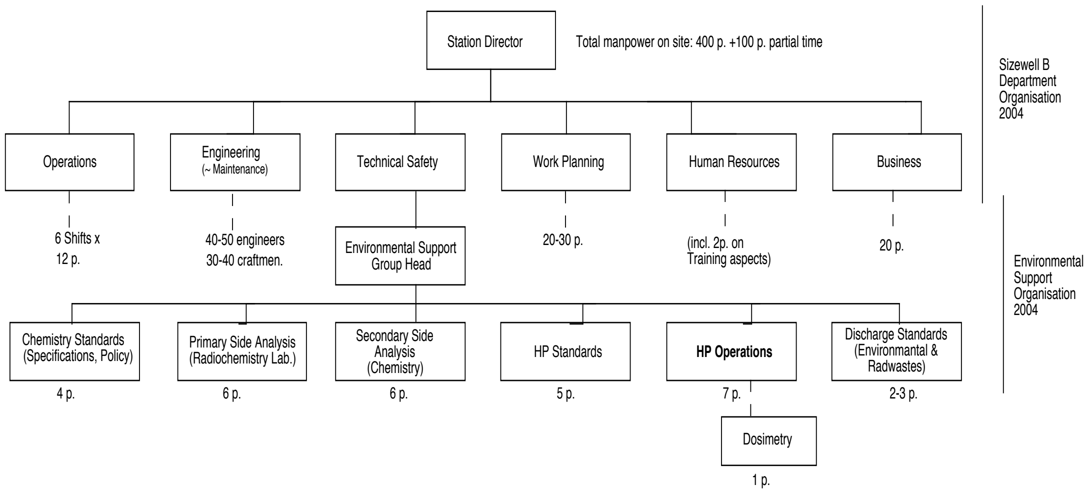

Figure 1. Sizewell NPP Organisation in 2004

The Station Director of Sizewell Nuclear Power Plant is in charge of six line departments (Operations, Maintenance, Technical Support, Work Planning, Business and Human Resources). At Sizewell Nuclear Power Plant, there are three different groups of people working in the radiological protection area ("HP Standards", "HP Operations" and "Discharge Standards" groups) along with three other groups responsible for chemistry. Radiological and Environmental Protection together with Chemistry are contained in the "Environmental Support Section" (headed by Mr.

Martin Cubitt[1]) which is part of the "Technical Support" department (headed by Mr. Chris Newell). Mr Guy Renn and Mr Matthew Lunn who organised our visit are respectively head of the "RP Standards" group, and an Accredited Health Physicist in the "Discharge Standards" group.

Currently, during normal operation approximately 30 persons belong to "Environmental support Section" fairly evenly divided between chemistry end radiological protection functions.[2] In 2005, the organisation of the plant will change but, as far as the "Environmental support Section" is concerned, no major change is expected: about 30 people will join the present staff, the majority of them in a new "Training" department.

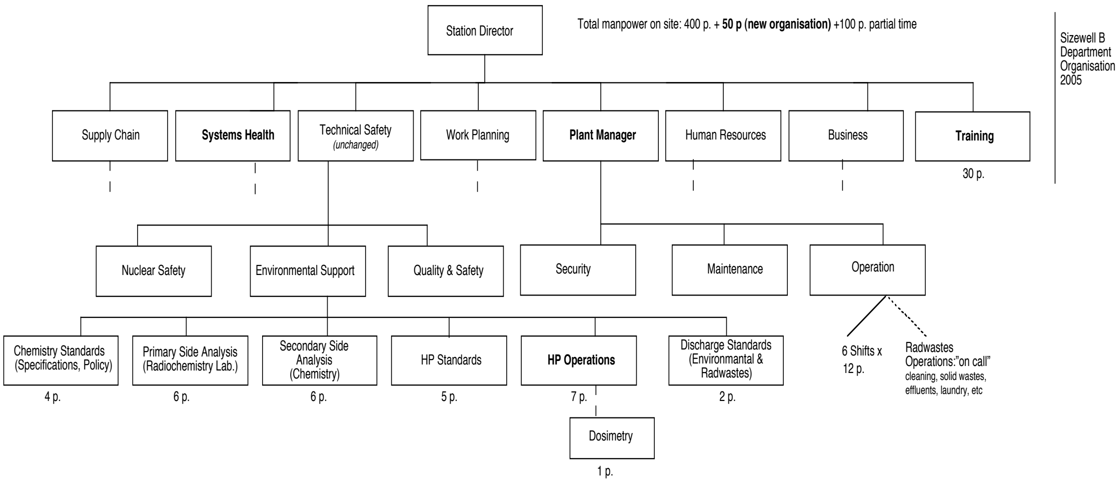

Figure 2. Sizewell NPP Organisation in 2005

At the corporate level (British Energy Headquarters, in Gloucester), about 4 persons work in domains related to RP: one is employed in the Engineering Department and is responsible for radiological assessments associated with the plant safety case, the management of contracts with external organisations for dosimetry and radiological instrument calibrations and for miscellaneous other duties in support of station operation. Three other people work in the Safety and Regulation Department and are

1 Since the visit, Mr Cubitt has moved within the station to become Head of Maintenance.

2 For the personnel of the section, the normal work time is 08:30-16:30 (only day time).

responsible for review of national regulation,, co-ordinating production and interpretation of company rules in RP and for periodic audits of compliance.

The British Energy procedures edited and compiled at the corporate level are implemented at all the operating nuclear plants (AGR mainly). Sizewell B plant, which is the only PWR operated in the UK is obliged to follow same standards in radiological protection as the gas-cooled reactors. As the corporate RP function is relatively small each station operated by the company[3] has the responsibility for developing a particular aspect of the radiological "safety rules". In that context, Sizewell B recently updated the procedure related to the "radiation work permits".

These procedures include for example, the rules for the designation of controlled and supervised areas, the arrangements for outside workers, the authorisation and notification of work with ionising radiation, medical surveillance, risk assessment and the application of the ALARP[4] principle, dose assessment and record keeping, monitoring levels of radiation and contamination, radiation events plans, transport of sources, radiological documentation, etc. A 2000 version of the company procedure was given to us; however, from our hosts viewpoints, the local way of working can be different than it is written, especially due to the specificity of Sizewell B NPP.

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3 British Energy operates 7 advanced Gas-cooled reactors at Hinckley Point B, Hunterston B, Dungeness B, Heysham 1& 2, Hartlepool, Torness and only one PWR: Sizewell B. http://www.british-energy.com/corporate/locations/index.html

4 "As Low As reasonably Practicable". The ALARP concept is similar to the "As Low As Reasonably Achievable" concept (ALARA) used in other countries (optimisation of radiological protection).

1.2. Organisation of the radiation protection department

1.2.1. HP organisation at power

As mentioned previously, the "Environmental support Section" comprises six groups: three are devoted to HP (elaboration of HP standards & dosimetry, HP operations, and environmental & radwaste aspects), and the three other to chemistry (elaboration of standards & specifications, and primary and secondary sides' chemistry).

About 15 people are working in HP groups (see Figure for the detailed manpower distribution). The expected re-organisation will not affect the present situation.

1.2.2. Health Physics (HP) organisation during outages

During outages, a specific organisation is put in place at the site level, the so-called "Outage Control Centre" (OCC). The Outage Control Centre is responsible for co-ordinating the outage and is headed by one of the station senior managers. A Health Physicist is continuously based in the OCC. A second health physicist is responsible for day-to-day operational health physics issues such as review of radiological measurements, investigation of minor events, liaison with operational monitoring teams etc.

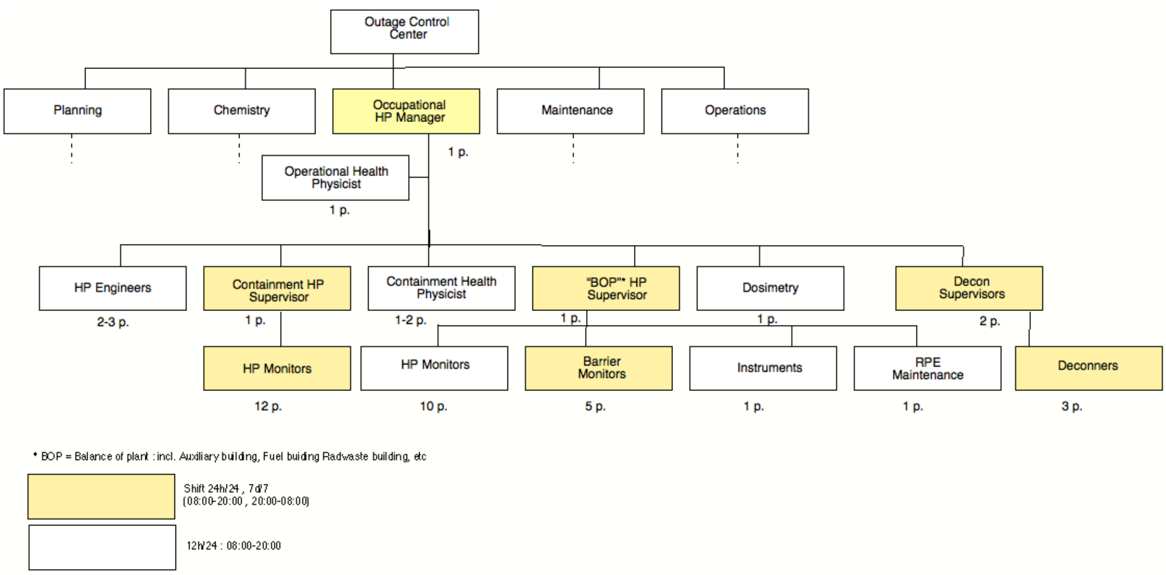

Figure 3. Sizewell NPP Organisation during outages

During the day shift another health physicist, the Containment Health Physicist, is based inside the Reactor Building and provides radiological protection oversight of activities occurring during the shift. The Containment Health Physicist is expected to ensure that high radiological standards are consistently applied. The teams of Health Physics and Decontamination personnel are supervised by a Containment, "Balance of Plant" (for work outside of the Reactor Building and Decontamination "Supervisors"; The Containment team and the Decontamination crew work 24 hours per day (2x12 hour shifts), whereas the Balance of Plant Team is present on a 12 hour day shift (07^{00}-19^{00} hrs). The major benefits of this two-shift system are a requirement for less contract HP personnel, and an easier communication between day and night shifts.

As a whole, during day hours the number of people attached to the OCC HP manager is about 40 to 45 (see Figure for the detailed manpower distribution). On night shifts there are around 20 persons.

During outages around 50 persons from external health physics contractors supplement the site health physics organisation. The main contractor is RWE Nukem. RWE sub-contract health physics personnel from other contract companies. In a typical outage approximately half of the contract HP and Decontamination personnel come from Swedish health physics service suppliers.

Radwaste and Active Laundry collection is carried out by the site facilities service provide (Eurest Site Services). These workers have their own management organisation but on a practical level work very closely with the RP organisation.

At Sizewell NPP, staff turnover is relatively low, and most of the personnel of the radiological protection teams have worked here since 1995, or even before the first criticality.

1.3. Radiation protection policy: goals at plant and corporate levels

In the United Kingdom the dose limit[5] for workers aged 18 years and older is 20 millisieverts per year. Where the worker is expected to receive more than 6 mSv per

5 Regulatory annual dose limits in the UK are: 20 mSv (employees 18+), 6 mSv (trainees 16-18), 1 mSv (public, fœtus, nursing mothers) for whole body effective doses, 500 mSv at extremities and 150 mSv at lens of eye (for employees), 150 mSv at extremities and 45 mSv at lens of eye (for trainees), 15 mSv at extremities and 50 mSv at lens of the eye (for other

year then the worker is treated as a Category A worker and is subject to annual medical surveillance by an appointed doctor.

At Sizewell (and other British Energy sites), a further Company Dose Restriction Level (CDRL or dose constraint) of 10 mSv applies to all classified staff and contractors. This CDRL applies to doses received on British Energy sites. Doses in excess of the CDRL are permitted however these must be approved by the Director of Safety and Regulation Department, based at Corporate Headquarters.

Business plans now include target for doses. The outage targets are issued 14 months before the outage. For the next one (RFO7 from 25 March to 26 April 2005), the radiological protection targets are the following:

- 320 man.mSv (none of the steam generators will be open this time)[6]
- maximum individual dose of 5 mSv
- less than 5 contamination events
- criteria on the mass of solid radwastes

14-16 months before the outage, the outage organisation issues the " Outage Intentions Document" on which it is stated what are the main works to be performed. This document is used by the RP group to perform broad estimates of doses and to set the outage RP targets. As a principle the Management seeks to set ambitious dose targets. The regulator also encourages this approach.
The outage dose target is mainly based on the dose budgets allocated to the major activities more considering previous dose history than a new detailed analysis.

As an example, the RFO7 (2005) dose target is broken down into the following tasks:

-	Refuelling	40 man.mSv
-	RPV Flange Work	3 "
-	In-Service Inspections (ISI)	35 "

adults). A three rolling months limit of 13 mSv at abdomen for women of reproductive capacity does apply also.

6 Steam generators are controlled every second outages with the following sequence: 0/4/0/4/…etc. 20 to 30 % of the tubes (inconel 690) are inspected.

-	Instrument Tunnel/seal Table	2 man.mSv
-	Health Physics & Decontamination	45 “
-	Sludge Lance & FOSAR	17 “
-	Reactor Coolant Pumps (RCP)	8 “
-	Scaffolding & Lagging	45 “
-	Radwaste & Cleaning	4 “
-	Operations	5 “
-	IST & LLRT	4 “
-	Maintenance	60 “
-	10 year Vessel ISI	7 “
-	Other works	5 “

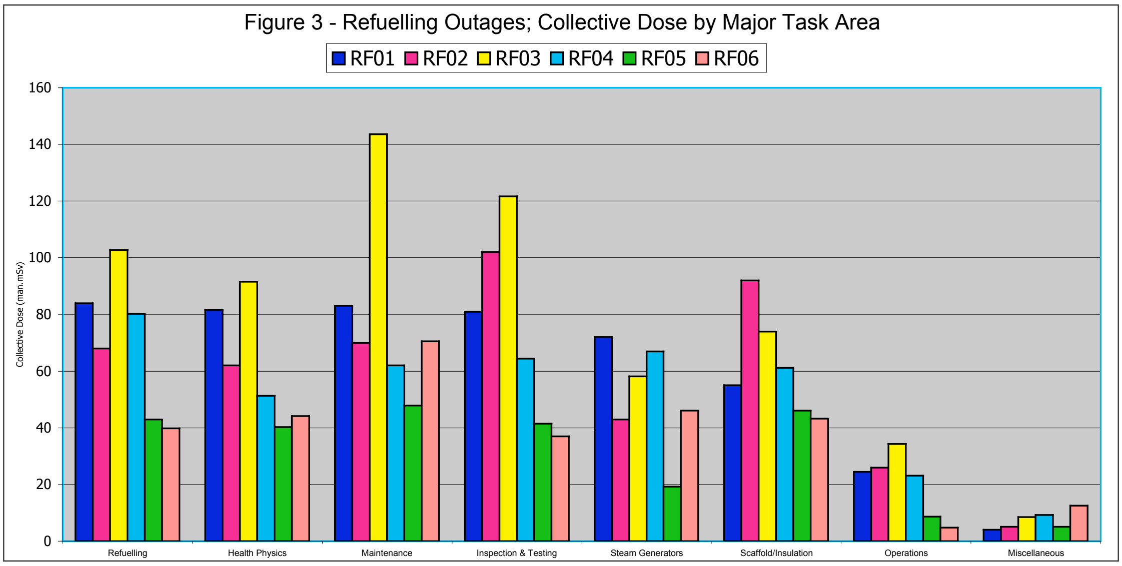

Figure 4. Refuelling Outages: Collective Dose by Major Task Area

The dose targets can be modified as the actual work scope is defined throughout the course of the outage planning stages. Usually the final version of the outage schedule is available about 6 months before the outage. If planned works are not routine then a specific ALARP[7] review may be organised during which the dose prediction will be calculated (there are less than 10 ALARP reviews per outage).

7 In the UK, the ALARA principle is better known by the acronym ALARP which means “As Low As Reasonably Practicable “ but, in practice, they are the same concepts.

Since the first two outages, the collective dose by major task has been divided by a factor of about 2 especially for refuelling works, health physics, scaffolding and insulation (See Figure 4). The decrease is less obvious for the maintenance works; it is more important for steam generator works (see Footnote no 6). For the long-term, no formalised dose reduction programme has been set up.

1.4. Measurement of radiation protection performance

During the outage, only the evolution of the collective dose is followed up.

Once a month, the Head of the "HP Operations" section reports environmental and radiological indicators. to the "Technical Safety" Manager (who will report them to the Station Director and then to Corporate Management). Collective dose is one of the important high level performance indicators.

There are tens of other HP indicators, the so-called "Key Performance Indicators" (KPIs) that are followed continuously and which are internally used. These can also be used for discussing RP performance with NII Sizewell B inspectors (attached to HSE, the English Safety Authority): Internal RP KPIs include:

- the cumulative radiation exposure (compared with the target)
- the cumulative radiation exposure for containment entries (compared with the target)
- the maximum individual dose (monthly)
- the number of personal contamination events (PCE)
- the PCE rate as percentage of RCA entries (a PCE rate of 0.1 %: one contamination event for every 1,000 entries is considered to be a good performance)
- the percentage of PCEs occurring in clean (uncontaminated) areas
- the number of radiation "hot spots" that exist in the plant (>0.25 mGy/h)
- the percentage of routine surveys completed (adherence to the routine survey programme)
- the number of radiological events other than PCEs: they are classified by radiological events categories (RECs) such as REC1 (individual doses which exceed 20 mSv), REC16 (contamination found in so-called clean

areas), REC22 (personal contamination at C2 monitors > $4 Bq.cm^{-2}$), REC6 (dose above regulatory limits), REC99 (near misses), etc.
- the number of rooms posted as temporary C2[8] areas.

The KPIs evolution is sticked up in different location of the plan (see Annex 4).

During the outage, the evolution of the collective dose is compared with a previous similar outage collective dose as well as with the global dose target.

A Safety Management Environmental Review Group (SMERG) is a organised on a monthly basis: it is a topical meeting for managers where conventional safety, nuclear safety, environmental and RP issues are discussed alternately.

1.5. Presence of Health Physicists in the plant

The philosophy of the radiological protection management is to encourage health physics personnel to spend as much time as possible inside the Controlled Area. Health Physicists are expected to carry out radiological surveys and to develop their plant knowledge. Sizewell believes that this helps HP staff to understand work better, to develop a good relationship with other workers and to generally be more effective as an RP organisation.

1.6. National and/or international comparisons

As there is no similar plant in the UK, the establishment of international relationships is an important point for Sizewell NPP.

As far as HP international feedback experience and exchanges are concerned, Sizewell B plant is participating to the International System of Occupational Exposures (ISOE) with a very good feeback from the "Requests" system in radiological protection domain. It is also involved as member in the WANO programmes. The information

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8 It is the highest level for an area classification based on the risk of contamination criteria (see further)

received from ISOE is generally considered more useful than WANO/INPO ones for radiological protection.

HP engineers have also developed good working relationships with counterparts in a number of foreign sister plants. The HP management hope to develop existing links with European plants with good RP performance auch as Ringhals and Doel NPPs and to use these as benchmarks for measuring RP performance. Recently members of the Sizewell RP group began an exchange with Borselle in Netherlands.

2. RADIATION PROTECTION TRAINING OF WORKERS AND RADIATION PROTECTION SPECIALISTS

2.1. Training

The RP training requirement is a function of the radiological protection requirement of the job. The following RP training courses (or education) are required at Sizewell NPP in ascending order of RP competence:

All workers attend to an initial 3 hours induction session, not especially focussed on HP but on site procedures including conventional and nuclear safety, environment, security etc.

All personnel must follow a short training course giving the theoretical and practical basic knowledge on the risk of contamination (1 hour), the radiation exposure risk in controlled area (1 hour) and a practical training session on practices in Controlled Areas (1 hour). For the theoretical sessions the workers assess themselves (using computerised Multiple Choice Questionnaires). The practical "dressout ") sessions are lead by the site Health Physics staff. Workers are required to demonstrate that they can dress and undress when entering and leaving a simulated Contamination Controlled Area.

Before an outage specific technical training on mock-up can be undertaken. Mock-ups are available for Steam Generators, RPV Head plus a number of weld inspection mock ups to test automated inspection equipment.

For specific jobs, those -between 20 and 30 for an outage - with the highest radiological risks, all workers who will take part are gathered for attending a PowerPoint® slide show ("Pre-Job ALARP Briefing "), presented by the HP staff. It gives all the necessary RP information (eg doserates, maps, pictures, equipments needed, etc). Where the radiological Work Permit specifies then attendance at the Pre-Job ALARP Brief is mandatory (see Annex 8).

Radworkers (90 BE + 40 contractors) is a qualification level given to maintenance/operations workers that allow them to perform radiological monitoring and decontamination of their own place of work. They attend to an initial 2 weeks training (theory and on-site practices) with an assessment at the end of the course (there is about 1 failure per group of 12 students). 3 days refresher courses are given every two years (see in Annex 7: Radworkers Training objectives and time table) [9].

Barrier Monitors who are normally contractors employed during the outages for monitoring equipment and personnel out of contamination zones and out of the RCA. Barrier Monitors are given a three to four day training course, delivered by the site health physics team. The training includes considerable practical training and an assessment.

HP contractors receive a 3 days training course; it is a topical training focussed on the outage. Sessions include standards and expectations, relevant parts of the outage programme etc and seeks to ensure a common understanding of important RP issues. The training is also intended to foster a sense of a single health physics team for the outage.

HP monitors (HP Technicians) are normally employed with basic school qualifications. After a period in the job they take a nationally recognised course known as City and Guilds Radiation Safety Practice. Courses are run by a number of Colleges throughout UK. Radiation Safety Practice Stage 1 when taken full time takes around two months and includes theoretical and practical examinations. Experienced HP Technicians can take a Stage 2 course that develops their RP knowledge further. This course is mainly intended for HP Technicians who have supervisory responsibilities.

HP engineers normally have a university qualification degree in science or engineering, often with post graduate qualifications such as a Masters degree in radiological protection. After a few years experience, they are evaluated by an panel comprising Corporate RP personnel and the Head of Health Physics from another site. If successful, they are appointedas an "Accredited HP Engineer" and authorised to formally give radiological protection advice, produce Radiological Work Permits (5 persons are accredited HP engineers at Sizewell NPP). After a second evaluation panel, they can have a specific accreditation on emergency response and can become part of the team that provide standby cover in the event of Nuclear Emergencies.

The upper qualification level is the "Radiological Protection Advisor" (RPA)[10] which is a role enacted in UK Law to fulfill the requirement of the Euratom Basic Safety

9 The file given to radworkers trainees (content of the course) is available at CEPN.

Standard on Qualified Experts (1 out of the 5 above HP engineers is a RPA). Prospective RPAs have to submit a portfolio of evidence to show that they have the core knowledge and experience to provide radiological protection advice.

2.2. Self Assessment

There is no formal HP self-assessment programme in Sizewell.

However, every single day Plant Supervisors and Senior Manager plant perform specific task observations. Similarly, regularly each HP engineer perform inspections on a specific job. These visits and inspections are supported by specific check-lists and generally the findings recorded.

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10 The RPA is an accreditation provided by peers within the professional radiological protection society in the UK (SRP).

3. MANAGEMENT OF ZONING AND SURVEILLANCE

3.1. Action to address the radiation risk

3.1.1. Designation of areas

At British Energy sites the responsibility for designating and demarcating controlled areas rests with the location manager, although generally delegated to the Accredited Health Physicists.

At the Sizewell plant, the zoning criteria (which are identical to those used in AGR plants, and quite different from those used in French PWRs) are as follows:

- Radiation supervised area (**R1**): 0.5 μSv/h < dose rate < 3 μSv/h. (the dosimeter is not mandatory in these areas)
- Radiation controlled area (**R2**): 3 μSv/h < dose rate < 50 μSv/h.
- Radiation controlled area (**R3**): 50 μSv/h < dose rate < 500 μSv/h.
- Radiation controlled area (**R4**): > 500 μSv/h. (locked, where practicable)

The lower limit of R1 and R2 area correspond to dose of 1/20th and 3/10th annual employee dose limit, respectively (2000 hours working year).

Specific signs also exist to locate low doserate waiting areas (see Picture 2) and high contact dose rates point (eg. above 0.25 mSv/h), and where HP staff has installed biological shielding.

(For details, see Document "British Energy Company Specification: Designation of Controlled and Supervised Areas").

Sizewell B is not equipped with a computerised system of designation of areas or of dose-rates surveillance. There is no "fixed points" doserates survey programme (however, about 50 Area Gamma Alarms are installed throughout the plant with their readings fed back to a central Engineering Computing System that is accessible by all of the HP Engineers at their desks and by the operators in the Main Control Room).

Radiation work permits are generally issued by the work supervisors before the job starts (the HP supervisor intervenes on the RWP only if an "ALARP Brief Training" is requested before the operation).

All those qualified as "radworkers" are empowered to measure radiation fields and contamination levels in the work areas; they have also a access to other HP equipment necessary to complete the task . The HP technicians are making a complementary routine survey (see the "Survey Programme" in annex 12, that indicates what are the daily, weekly, monthly, quarterly and yearly surveys to be performed. For specific jobs, the HP engineers specify who will make the survey (HP technician or, radworkers). As a normal rule radworkers will only be able to carry out measurements where the radiological hazard is low and well-understood.

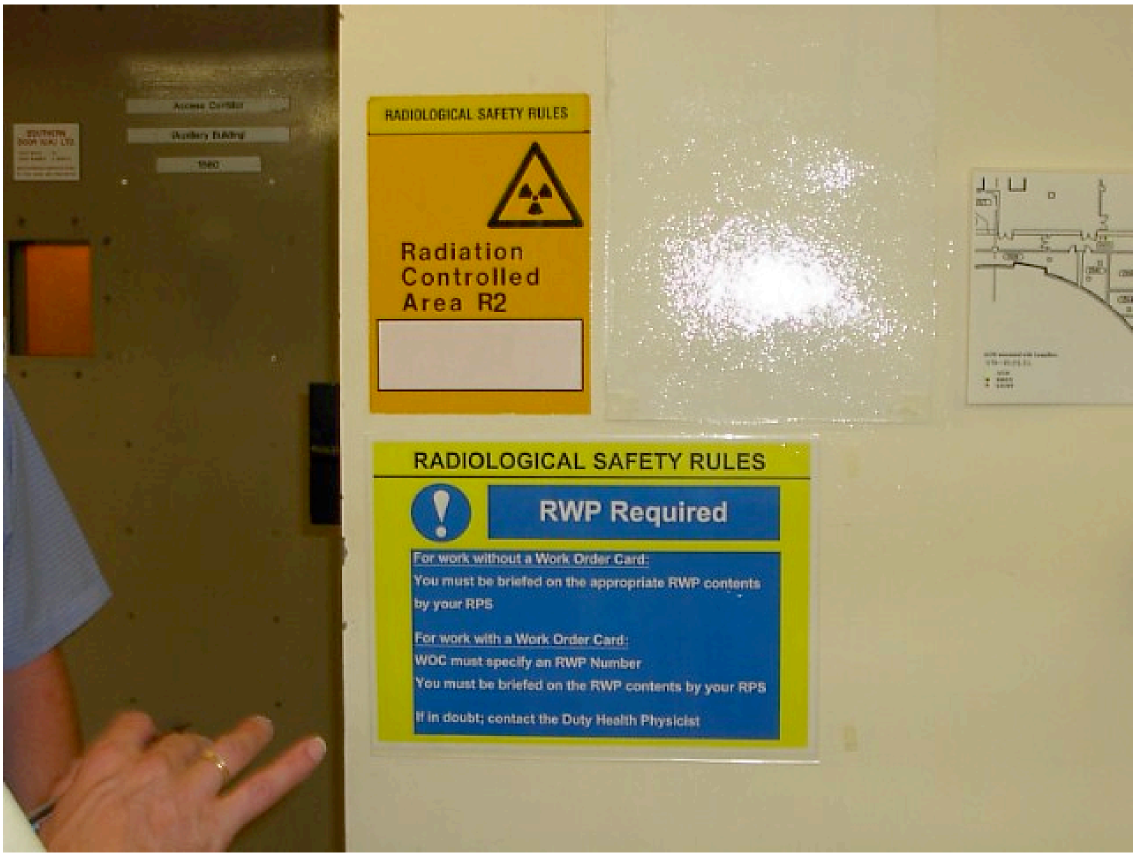
The duty HP Technician reviews the results of routine surveys and informs the HP Standards group in the event of any of the following:

1. Loose Contamination in excess of 4 Bq/cm^2 detected outside of a Contamination Controlled Area.
2. Loose Contamination generally in excess of 400 Bq/cm^2 detected inside of a Contamination Controlled Area (greater than 1000 cps by HP260 for a 300 cm^2 smear, greater than 2000 cps by HP260 for a 1000 cm^2 smear).
3. Radiation Doserates measured in excess of those allowed by the existing designation of the area, namely: R1 (3.0 μSv/hr), R2 (50 μSv/hr), R3 (500 μSv/hr).
4. Discovery of a radiation "hot spot" not previously posted.
5. Failure to locate a radioactive source during a source inventory check.

3.1.2. Work practices in controlled areas

During outages, the presence of health physicists is reinforced in the controlled area. When possible, tele-dosimetry, wireless digital communication and video surveillance are used (eg. for work in the reactor cavity or on steam generator platforms during an outage): Sizewell has been equipped with a very modern system networked audio/video surveillance and real time dosimetry packages used for the first time during the last outage (it has been assessed that this system saved around 10% of the total outage dose, i.e. 20 man.mSv, with HP staff being the group that benefited most from this reduction by allowing them to oversee the work from low doserate areas). Sizewell hope to extend the use of this system for all people who are working inside bioshield areas, in due course.

A map of the main circuits and valves is put on the wall at the entry of each high doserate area. These so-called Doserate Contour maps show high and low doserate areas. Information sheets are produced by health physics for many plant components with photographs, location maps and radiation doserate information. Workers can also get to know their work area with a Surrogate-Tour® software.



Picture 1. Zoning Designation, and Radiological Safety Rules at the entry of a "R2" area

Picture 2. "Low Dose Rate" Waiting Area

3.2. Action to address the contamination risk

3.2.1. Area designation

A contamination controlled “area C2” shall be designated where the loose contamination level averaged over an area not exceeding 1000 cm^2 (floor or ceiling) or 300 cm^2 (other cases), exceeds or may exceed the following values:

Contamination controlles area (**C2**):

> 0.2 $Bq.cm^{-2}$ (Ac-227, U-232, Am, Cm, Cf, Pu, Th)[11]

> 0.4 $Bq.cm^{-2}$ (Pb-210, Ra-228, and alpha emitters)

> **4 $Bq.cm^{-2}$** (other radionuclides)

> 40 $Bq.cm^{-2}$ (C-14, S-35, Cr-51, Mn-54, Fe-55, Ni-63, or, tritium contamination level

> 10,000 $Bq.cm^{-2}$ (or that could result in effective dose higher than 0.5 mSv).

Airborne contamination levels for designation of a contamination controlled area **C3** exist for each specific radionuclides (generally, C3 level corresponds to more than 0.01 DAC). The general values (lower air activity) 0.01 $Bq.m^{-3}$ for alpha emitters, and 10 $Bq.m^{-3}$ for beta emitters. If possible, the access to C3 areas is restricted with physical barriers.

(For details, see Document “British Energy Company Specification: Designation of Controlled and Supervised Areas).

3.2.2. Work practices in contaminated areas

Unlike most European Nuclear Power Plants access to the majority of Controlled Area is permitted in street clothes. From December 2005 it will become mandatory to wear long-sleeved general workwear (overalls or two piece garment – not radiological protective clothing). Smoking, eating and drinking are forbidden inside controlled areas. However, a water dispenser is available at the exit of the controlled area (R1 area).

11 With specific restrictions for Ac-227, Cm and Cf.

Before entering contamination controlled areas (C2), an extra layer of protective clothing must be worn over “normal street wear”. For work non-intrusive to systems containing active liquids, either Nylon or cotton overalls (made by ENS, Germany, or Overwear, UK respectively), overshoes, cotton gloves, mop cap and hard hat are worn. Where work involves opening active liquid systems, or where workers need to enter areas with very high levels of surface contamination (e.g. the refuelling cavity), a second pair of nylon coveralls or a water-proof plastic overall may also be required.

A very few number of areas are classified as “C3”. For these areas, an Accredited Health Physicist decides, on a case-by-case basis, what kind of suits or respiratory protective clothing has to be worn.

The exact protective clothing and respiratory protective equipment requirements for a task are specified on the radiation work permit (RWP) and also sign-posted on the “boot barrier” at the entrance to the contamination controlled area.

When leaving a C2 area, personal contamination monitoring is made after the removal of the protective suit. Either a Thermo IPM8, or Thermo HFM and CM9 or CM11 (depending on contamination risk in the area) is installed in the “change facility” that serves the contamination controlled area. All of these instruments are set to detect contamination of personal clothes and skin, and alarm levels are set at a nominal 4 $Bq.cm^{-2}$ (These instruments are sensitive to beta radiation, and exhibit low efficiencies for gamma radiations). There are no shower facilities in the change facilities.

Before leaving the radiation controlled area, personnel must go through a second (final) contamination checkpoint (using Thermo IPM8 personal contamination monitors. Each IPM8 consists of 18 gas-flow proportional counters, covering the body, plus one for the head. The alarm levels are set at a nominal 4 $Bq.cm^{-2}$ (the same alarm level as at the first contamination checkpoint). Two Thermo SAM11 (small articles monitor) and one RADOS RTM661/440 Waste Monitor are installed at this final barrier, to complement the control system. The SAM11’s are set to alarm at 80 Bq and the RTM661/440 is set to 0.4 Bq/g).

In 1999, Sizewell NPP had a bad experience with workers who went out of the site (after working in “satellite” contamination controlled area, outside of main controlled area) with

contaminated personal clothing (there is not a third contamination checkpoint - using gamma portal monitors - just before leaving the site, as in France).
There is an active laundry on site but it is not used anymore. British Energy ships contaminated clothes to the Netherlands (Euro Nuclear Service BV, Coeverden) in specific "class 7 radioactive materials - IP2" containers (maximum contact dose rate is 300 μSv/h): this represents about 1 delivery every two days during an outage (and once per month during the plant operation). It is recognised that washing protective clothing will not completely decontaminate the garments, therefore the limit for re-use of protective clothing is 40 Bq/cm^2 (ten times the level for clearance of clothing).
It is generally observed 1 or 2 whole body contaminations during an outage, and about 70-80 contamination events (clothes, face, or hands contaminations).
(See "Personal Contamination Report" in Annex 9).

4. RELATIONSHIPS OF HP WITH CONTRACTORS AND OTHER WORKERS TEAMS

The establishment of close relationship between the HP staff and contractors (more generally other workers) is probably one of the key factors of the efficiency and good dose results observed in Sizewell. HP engineers and technicians have a lot of experience of the site, they have detailed knowledge of the works performed by other groups, and many HP technicians have mechanical engineering backgrounds to help them understand the tasks performed by other groups. From the contractor's point of view, HP are considered to be omnipresent in the controlled area.

At the time of the visit, the HP engineers were participating in a lot of pre-outage technical planning meetings. HP and other workers meet several times before, during and after the outage (outage preparation meeting, Fragnet meeting, ALARP briefs meetings, post-outage meetings). For example, system engineers organise several "Modification Implementation Meetings" before the outage and HP is always invited to participate to (they actually participate in function of the radiological stakes).

During an outage, there is a contractors group (FMA = Framatome/Mistsui-Babcock/ Alstec) with its own manager on site under contract with British Energy. As far as radiation protection is concerned, FMA subcontracts with RWE-Nukem the complementary HP work force needs (often foreign workers). The outage BE contract manager has several site liaison managers (for health physics, steam generators, refuelling, etc), who help him in determining what would be their needs in terms of manpower for the next outage. Once the overall contract is signed, the day-to-day needs are directly discussed between supervisors (who can belong to BR or RWE) and FMA.

There is no problem of communication concerning ALARP with other people, especially with chemists. The radiation safety culture is at a high level in Sizewell. HP engineers have rarely had to fight, to make their arguments being understood by other workers.

French workers from Jeumont met during the visit said that the assistance given by HP staff is very impressive in Sizewell B NPP. They confirmed its permanent presence in the controlled area, HP technicians making dose measurements on tools and clothes very frequently in comparison with what happens in other plants (in France, or United States, for example), the result being that the plant is particularly clean. However, they deplored too much paper and administrative burdens and, they said that the 2x12 hours shift is a too long and very tiresome work time (the actual duration of the works being the same than everywhere). Unlike, many EdF sites, where workers often wear bubble suits for maintenance of contaminated equipment, Sizewell B have less onerous contamination controls, as there is a greater presence of HP in the workplace, they added.

At Sizewell, the “philosophy” consists more in trying to reducing the source term as low as possible than setting rules which would impose to systematically wear a ventilated mask in areas renowned as contaminated: for example, before to open a valve, a pre-decontamination is made. A compromise is established between the reduction of the risk of receiving an internal dose and the resultant increase in the time spent in the controlled area due to wearing restrictive protective clothing or masks.

5. RELATIONSHIP WITH SAFETY AUTHORITIES

The Nuclear Installation Inspectorate (NII) of the Health and Safety Executive (HSE) has one inspector who is full time appointed to the Sizewell B nuclear power plant. His office is located at NII Headquarters facilities but, he is also on the site (where he has another office) during operation, about one week per month. He participates at least to one meeting with HP managers before the outage (the content of the last HP outage report is the basis of the discussion). During the outage, his presence is more visible (he participates to several meeting and makes inspection visits in the containment). From the HP personnel point of view, his role and attitude are both more incentive than prescriptive.

The Technical Assessment Guide (TAG, T/AST/005) “Demonstration of ALARP” provides advice to inspectors to help them judge whether a licensee has met the requirement to reduce the risks as low as reasonably practicable (ALARP). This document is available on the HSE website (http://www.hse.gov.uk/nsd).

The Environment Agency (EA), which regulates radiological and non-radiological wastes and other practices with an environmental impact, also has an inspector appointed to Sizewell B. The EA inspector covers two other nuclear power plants and visits site approximately once per month whilst at power, and once (for one day) during each outage.

The regulator's inspection reports are issued as part of the Government's commitment to make information about inspection and regulatory activities available to the public (see for example http://www.hse.gov.uk/nsd/llc/2003/sizeb4.htm).

6. OUTAGE

6.1. General Planning

6.1.1. "Fragnet"

Every single job is recorded in the planning system called "Fragnet".

It represents about 8,000 recorded tasks in its first version, and 10,000 at the end of the outage. About 3,000 to 4,000 of these are reviewed by the RP staff.

Between eight and nine months before an outage, the first plan review meeting is organised. The "Fragnet" is sent to all participants of the meeting: system engineers, planners, industrial safety and health physics representatives, and sometimes contractors etc. depending on the case to be examined. Specific plan review meetings are organised for each type of works or systems (works on RCS, electric jobs, valves control, weld inspection, insulation, lagging, scaffolding, etc.). This allows to providing very detailed work plans (daily valve work plans, and outage weld inspection plans were shown as examples).

The Fragnet Review Checklist (Annex 3) gives a list of the topics to be addressed during that kind of meeting. If any disagreement appears (for example, between HP and another work group), actions are envisaged jointly, and a new meeting is scheduled a few weeks later. Especially, the impacts of activities on the critical path are examined here, but it is also the room to address "health physics impacts" which are systematically part of the items of the meeting.

A final version of Fragnet is available about 6 months before the outage. During the outage, the plan for the next 3 days outage planning is given every day to HP staff.

Planning and HP staffs meet together several times a week when the plant is at power, and at least once a day during the outage period.

6.1.2. HP Planning and Information Sheets

In parallel, using information from Fragnets and previous survey reports, HP staff makes plans by area, by system and by element (eg. valves). These are done to allocate RP requirements to each task and allow the Health Physicists to identify, and discuss with the planners, the optimum time to schedule work (according to water levels, for example). Both plans are prepared from one outage to another and, they are updated as soon as Fragnet is received.

For each plant item to be worked or inspected in areas where doserates are high (typically for R3 and R4 areas where dose rates are higher than 50 and 500 μSv/h, respectively), the HP prepares a "Health Physics Information Sheet". These contain a picture and a map, identifying the plant location and local radiological conditions. These information sheets are available on the intranet and they are also given to the foremen and work parties, either as part of the work order pack or during an ALARP brief (see three examples of information sheets, in Annex 2).

6.2. Health Physics Works Planning

Approximately 1.5 full-time equivalents from HP are devoted to outage planning and preparations.

Health Physics produce a specific schedule ("Radiological Protection Work Plan") for all HP activities. During an outage, this plan is made for each shift (12 hours duration); and on weekly basis, whilst the plant is at power. Moreover, for each outage shift, an "HP Work Briefing" sheet (See Annex 1) and a "Daily Valve Work" sheet (Document no 3) are prepared and issued by the HP engineers and given to the HP supervisor. These sheets present all HP requirements according to the tasks to be performed, the second one identifying more precisely the valve location (and its classification number).

About seven "HP information packs" are made for each outage. They contain telephone numbers, intrusive and non-intrusive work plans, background information to the plant, maps of the controlled area and copies of all relevant RWP's and Health Physics Checklists. These packs are distributed to the Health Physics Supervisors and copies are made available at the Health Physics Control Points inside containment.

According to what they have done, radworkers and HP technicians must fill a “Health Physics Survey Report” (see Annex 10), or, for a specific survey, a “Profile Survey Form” (see Annex 11). These pro-forma documents are supposed to be given back to the HP supervisor for review and further action where necessary.

6.3. ALARP Reviews and Meetings

As mentioned above, there are a tens of ALARP reviews per outage. They are the key meetings where HP problems are addressed.

The British Energy Radiological Safety Rules require a pre-job ALARP review to be performed for tasks where the individual dose is likely to be greater than 3mSv or result in a collective dose greater than 10 man.mSv. The criteria to declare that a particular job needs to have an ALARP review are not formalised. The decision is mainly based on the past experience. During ALARP reviews, detailed dose analyses (individual doses assessment, or collective dose per workers team) are not made as they are considered to be too time consuming and often unrealistic (outage contractors, especially Framatome, often produce very detailed dose plans but there have been big differences between the actual work durations and the predictions). Therefore, dose predictions are not specified on the Radiological Work Permits.

Other meetings to which HP engineers participate, can be the occasion for discussing radiological protection issues but, it is not systematic: eg. “High Impact Team meeting ”, that are organised once a month before the outage. They are involving a lot of persons and teams and, they can lead to the creation of topical working groups, with HP concerns.)

During the outage, twice a day (at the beginning of the 12 hours shift period), there is a short “Start of Shift Meeting ” during which HP staff reports what is going on. Contractors’ representatives and other stakeholders generally participate to these meetings. The NII inspector may, occasionally, attend this meeting. Whilst at power, there is a daily "Loss Control Meeting" that fulfils a similar function. The Environmental Support Group Head usually represents HP at this meeting.

7. MANAGEMENT OF PERSONAL DOSIMETRY

7.1. Radiation Work Permits (RWPs)

A Radiological Work Permit (RWP) is required for all activities inside a radiation or contamination controlled area and for any work involving radioactive substances or radiation generators outside of a controlled area. This system has been in place for 2 years[23]. Prior to this, Designated Work Instructions and Radiological Control Documents covered work inside controlled areas.

At Sizewell B, Radiation Work Permits are written and approved by an Accredited Health Physicist. There are three types of RWPs depending on the radiological hazard presented by the work: “Low”, “Medium” or “High”. Any person may receive a “Low” level RWP and they must be briefed on it’s contents by their Radiation Protection Supervisor, at least once a year. “Medium” and “High” RWPs are issued directly to a subset of workers who have been trained, regarding their responsibilities under the RWP. These are known as “Competent Persons (Nuclear Radiations). The RPS issues the RWP (medium or high) to the Competent Person every time the job is performed (or at suitable intervals of time for repetitive tasks). About one hundred “High” and “Medium” RWPs are active at Sizewell (see Annex 14). Over 90% of the tasks performed in the controlled area are classified as “Low” radiation risk level tasks (for example, scaffolding, radiochemistry and lab works, waste handling, painting, etc).

When an activity is classified as having a “high radiological impact level”, it is mandatory for the workers to attend a Pre-job ALARP Brief. This brief is delivered by an HP engineer and covers work to be performed, expected conditions, dosimetry and PPE requirements and it also reviews good practices and other feedback experience.

Each RWP contains a description of the work, radiation dose restrictions, whether there is a need for a pre-job briefing, radiological conditions (designations of the working area) and corresponding RP requirements (EPD alarm thresholds, protective clothing, respiratory equipments, etc) and a list of recommendations and general precautions, and

23 Sizewell B Power Station Health Physics Refuelling Outage Report, Fifth Refuelling Outage, 28 April-29 May 2002, M.A. Bone, November 2002.

details of contingency actions (see Annex 15). Following the instructions in an RWP is usually mandatory, but permit requirements may be slightly relaxed at the request of the HP Technician, without re-writing or re-issuing the permit, to facilitate the work implementation in a reasonable manner.

RWPs are not linked with individual badges (consequently, HP staff are not in a position to check if the worker who enters in the controlled area has been briefed on the RWP contents).

Electronic dosimeter (EPD) dose and dose rate alarm levels are specified on the RWP, but it is a worker entering a task code on the EPD access control terminal that actually programmes to alarm levels. Typical alarm thresholds are 200 μSv and 500 μSv/h for most general, low risk activities and 500 μSv and 5 mSv/h for specific, higher risk tasks (for example valve work).

7.2. Management of personal dosimetry

At Sizewell NPP, the unique and official dose measurement system is EPD (Siemens Mark 1.2 electronic personal dosimeters). The EPD dose record threshold is 1 μSv.

For neutron doses, the Albedo Dosemeter used was originally developed by Berkeley Nuclear Laboratories (then part of CEGB).

Sizewell do not perform any biological monitoring. Everyone is screened using a Quick Body Monitor (gamma in lung monitor using Plastic Scintillation Detectors) before they start work for the first time and when they finish work for the last time. Site employees and long term contractors are also screened annually at the time of their radiation worker medical review. The limit of detection of the Quick Body Monitor is about 100 Bq of Co^{60}. Screenings following any event are carried out where the occurrence of an intake is suspected.

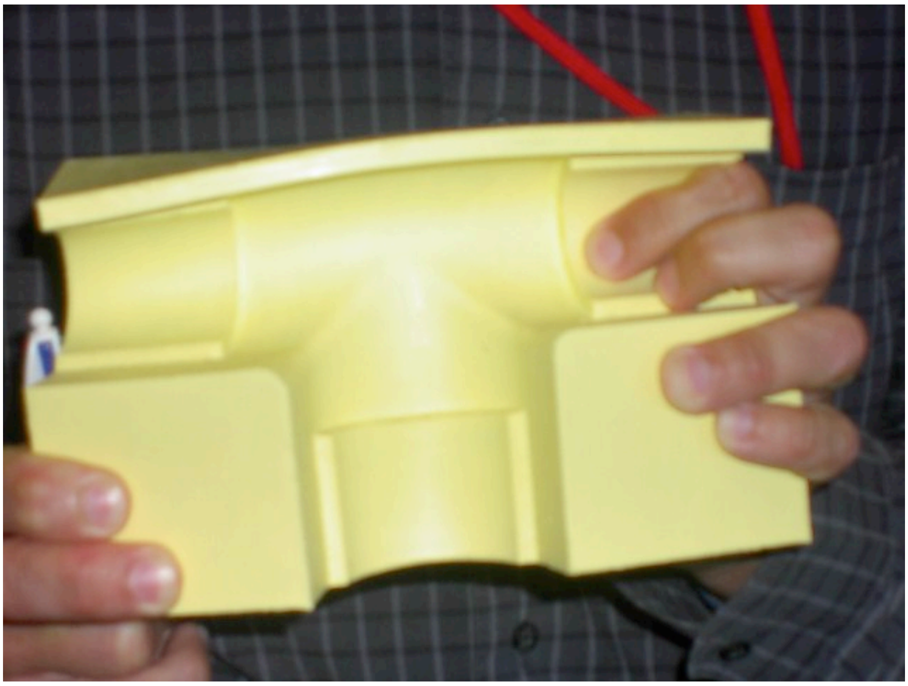
Within UK Regulations, any “significant” dose (defined as greater than 1 mSv) has to be formally assessed by an Approved Dosimetry Service. If the screening indicates that an intake had occurred that was likely to have resulted in an internal dose approaching 1 mSv then the worker is sent to a laboratory (for example NRPB) that would carry out a formal dose assessment using appropriate methodology. Fortunately the site has never had to send anyone for such monitoring. It is very rare to find positive result with the Quick Body Monitor and these are only very low levels.

7.3. Reduction of doses

Little use is made of the concept of monetary value of the man-sievert, when quantifying and justifying any dose savings, as the value is set so high and doses are so low, thus suggesting that any dose savings would be disproportionate in terms of cost. Instead, effort is directed towards workplace ergonomics, and the identification and implementation of good practices (from other plants and contractors) in order to reduce doses received by workers.

7.3.1. Biological shielding

Only HP technicians are allowed to install biological shielding. A dedicated team is trained and deployed for installing shielding during the first days of the outage. The annual shielding budget is about £20,000. About 10 tonnes of lead are installed in the reactor building and 2 tonnes in auxiliary building every outage. Detailed shielding plans are produced, based upon the outage Fragnet information. In many cases, the same shielding requirements are identified every outage, therefore permanent shielding is now being used in a few locations (e.g. drain line from the reactor cavity, and the primary coolant sampling system, for example), to minimise doses and conventional safety hazards to HP staff from repetitive shielding tasks.



Picture 3. Flexible shielding for a T-line

Lead-wool sheets covered in low-halide, temperature resistant bags (ranging from 1.25 kg to 30 kg). are used for shielding walls, floors, and pipes of various sizes. Lead-shot and bare metallic lead is never used at Sizewell B. This is due to strict chemical compatibility requirements to prevent stress-corrosion cracking of primary circuit components.Lead sheets used for shielding walls; floors, wrapping pipes are of various sizes (1.25 kg to 30 kg).

Radishield pipewrap and moulded (flexible) shields are also used as permanent shielding (see Picture no3) but it is a very expensive shielding (see Annex 17).

Mobile shielding also exists in Sizewell.

7.3.2. Insulation

Quick fixed insulation has been used in Sizewell since the first outage. Wherever possible, insulation is removed at the beginning of the outage (before the primary circuit oxygenation).

7.3.3. Reactor cavity cleaning

The technique is the same than the Swedish one (see CEPN report on the RP benchmarking visit at Ringhals NPP). All the walls are cleaned at each outage. It lasts about six hours.

7.3.4. Miscellaneous

Since Cycle 5, the amount of work being performed inside the reactor building before each outage has increased. During the last month of each cycle, containment entries are made into the reactor building, on a daily basis, to perform a variety of tasks that support outage mobilisation or remove work from the outage.
(http://isoe.cepn.asso.fr/Oral/session%204/Lunn.pdf)

During the first few days of the outage, whilst the reactor is in modes 1 to 5, containment has to be accessed via the airlocks. During periods of airlock operation, the number of people in containment is limited to 60. Unlike many other NPP's, Sizewell B is allowed to move irradiated fuel with the personal airlocks and the Equipment Access Hatch open.

The total number of works performed before the outage is increasing: it concerns for example the preparation of job areas, scaffolding, etc. “This saves doses and time”.

7.3.5. Future actions for dose reduction

There is no long-term dose reduction plan at Sizewell B, as doses are already low. However, there are a number of plant modifications proposed which may contribute to a further reduction in radiation fields, as an incidental benefit. The plant intends to install more permanent shielding; it is also envisaged to remove 50 percent of all secondary sources, to modify the fuel cladding, and to consider ion-exchange resins and zinc injection. However, the most important objective remains to be able to justify further maintenance reduction.

8. EXPERIENCE FEEDBACK

8.1. Feedback experience report and database

About one month after each unit outage, all HP interveners (from each group, including contractors) meet together for establishing lessons to be learned. In complement, they can take information from the "Lessons Learned" database, which can be filled by anyone who wants to do so (both paper and computer forms are available). A specific HP feedback experience report is also written for the main jobs performed during the outage, especially those for which pre-job ALARP briefs were conducted (it includes dose assessment, dosimetry results, personal contamination events, lessons learned (what has worked and what did not) and recommendations for the next outage (see Annex 8).

Moreover, a general "HP outage report" summarises the last outage as far as radiological protection and radwaste aspects are concerned. Good practices and areas for improvement are highlighted in this report. This report is sent to inspectors (NII), the Station Manager, FMA and RWE (contractors workers group and HP subcontractor), British Energy HP Headquarters, laundry, etc.

When the plant is at power, HP surveys feedback reports are also written: they mention identified problems and recommended actions (see Health Physics Plant Tour Surveys in Annex 13).

8.2. Events reporting

As mentioned on the corresponding form that can be found in different locations in the Sizewell B plant, British Energy has a policy on a blame free reporting of events (WANO recommendation), near misses and encourages open reporting (see Annex 16 for a copy of the reporting form). Approximately about 1000 events are have been reported in per annum, among of which 50 to 60 concern RP[12]. However, the introduction of a new "Corrective Action" process in June 2004 has increased

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12 The document "Reporting of events at Sizewell B Power Station" (49 pages) is available at CEPN.

significantly, the number of "events" now reported. Under the new process it is estimated that Sizewell B will report 3000 to 4000 events per annum, with 100 to 200 being relevant to radiation protection.

8. CONCLUSIONS

The first three points that can explain good dosimetric results at Sizewell NPP are: - a good plant chemistry from initial commissioning through to operation leading to a very low radiation source term, a good plant layout and design that took into account operational experience from plants, and - a good work management.

Sizewell have used the ISOE publication on work management as their guide. However, they consider that no job can ever be planned in too much detail, and that it is essential that radiological protection controls are integrated at the earliest level into work plans.

Moreover, during the visit, a strong health physics presence in the work place was actually observed. The health physics personnel has always been encouraged to be present in the plant and to develop a detailed practical understanding of the plant and its radiological conditions. Continuity of health physics staff has also helped. This permament presence of HP technicians very close to where the works are performed, allows to considerably reduce the size of the controlled areas that are, from the EDF observers' viewponts, much smaller in Sizewell plant than those delimited for similar works in French NPPs.

A pragmatic approach to RP has been adopted at Sizewell NPP since the starting-up of the plant. In many aspects, the way of working appeared less procedural than in other plants but, because a strong and permanent dialogue exists between health physicists and other professionals, it has encouraged other work groups, such as Maintenance to talk to HP staff very openly - they know that health physicists only say "no" when they really have to.

From the health physicists viewpoints, the Sizewell work force generally demonstrate a good radiation safety culture. Low doses on power plants in UK (especially in AGR plants) have lead to the workforce expecting low doses and to challenge tasks that are anticipated to result in elevated individual doses.

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ANNEX A

PROGRAMME OF THE BENCHMARKING VISIT AT SIZEWELL B NPP

6 September 2004:

- Introduction to "Technical & Safety" Support Manager
- Programme discussion

7 September 2004:

- RP Management & Staff Structure, RP Policies & objectives (corporate and site)
- Outage Planning & Outage Source Term Optimisation Techniques
- Outage Planning ("Fragnet")
- Plant design, operation & Chemistry (source term optimisation)
- RP staff qualifications, training & experience
- Worker training programmes: RCA Access, Radworker, ALARP Briefs, etc.

8 September 2004:

- Controlled Area designation, change facilities, survey programmes (incl. plant tour)
- Dosimetry arrangements, dose budgets, ALARP reviews
- RP KPI's, self evaluation programmes, interaction with regulators

9 September 2004:

- Radiological Work Permits & supervision of works
- Operational Experience Feedback
- Radwaste & discharges (incl. plant tour)
- Clearance Monitoring Issues

10 September 2004:

- General discussion
- Closing meeting with the plant manager and the head of the Environmental Support Section

People met: Mrs Tracey Henson, Messrs David Farr, Chris Newell, Martin Cubitt, Guy Renn, Steve Gower, Mark Jones, Matt Lunn, Gordon Pope, Dave Pipes, Gavin Lancaster.

ANNEX B

DATA ON DESIGN AND OPERATIONS

Steam generators

In Sizewell, the steam generators tube material is low cobalt Inconel 690 (Sandvik).

Dose rates are quite low inside channel heads. The EPRI survey results are given here after in mSv/h:

Steam Generator / leg (hot or cold side)	Mid-tube top	Centre	Door	0.5 m	Insert smear
SG A / h	33	23	15	2.5	2.2
SG A / c	34	28	15	2.5	13
SG B / h	29	19	12.5	7.5	2.4
SG B / c	32	20	16	9	0.3
SG C / h	28	17	12.5	8	0.7
SG C / c	22	16	10	8	2
SG D / h	24.5	21	20.5	2.7	0.85
SG D / v	28	26	23	3.5	7.5

The table below shows the summary of collective doses for steam generator primary side activities.

	RFO 1	RFO 2	RFO 3	RFO 4	RFO 6
Number of Steam Generators worked	4	2	2	4	4
Average doserate at centre of Channel Head (mSv/h)	29	32	35	27	21
Collective dose for outage (man.mSv)	35.5	28.3	26.7	35.5	31.2
Performance index (man.mSv/mSv.h^{-1} per SG)	0.31	0.44	0.38	0.33	0.37

Fuel

Significant fission products leakages occurred at cycle 4 (BNFL assemblies). Concequently, Sizewell B uses Siemens (Framatome ANP) fuel for re-load from cycle 5 onwards. 1 or 2 leakages only remains today.

Primary coolant chemistry

Sizewell is considered by the chemistry representatives met as a very “clean plant”.

Sizewell followed a modified $pH_{300°C}$ 7.4 regime in the first three cycles followed by a modified $pH_{300°C}$ 7.2 regime in the subsequent cycles.

Circulating corrosion products concentrations reached maximum values in cycles 2 and 3 but then fell over the next three cycles, especially at the ends of cycles 5 and 6 for Co58. (See also Graphs presenting the cumulative releases of soluble and particulate Co58, Co58, Mn54, Fe59, Cr51, in Annex 6).

It has to be noticed that Sizewell commissioned in 1995 and adopted a modified quite long Hot Functional Test passivation procedure (passivation stage during 10 days at 1.5 ppm Li/ $pH_{300°C}$ 7.65-7.75, followed by an 11 days- boric acid stage at 2 ppm Li/ $pH_{300°C}$ 6.85-6.90): it is, from the chemist point of view, the main reason which could explain the limited fuel crud deposition at Sizewell in comparison with French NPPs. A technical exchange meeting with EDF in June 2004 confirms this remark.

Operational filtering is specifications are 15 μ (for RCS) and 5 μ (for CVCS).

Primary pumps flow is 17 m^3/h in operation (23 m^3/h as a maximum).

For more details, read “Shutdown Corrosion Product, Radiation Field and Personal Dose Development at the Sizewell B PWR” (M. Cubitt et al.) in Annex 5.

At the beginning of the outage, nobody is authorize to work inside the reactor building between the RHR is brought into service and the shutdown criteria of the last RCP pump (11 GBq Co^{58}+Co^{60} , 3 GBq Xe^{133}) after peroxide adding (forced oxigenation).

Others

Sizewell was designed with stellite hard facing alloys eliminated from fourteen CVCS flow control valves to aid in minimising radiation fields. Design specifications imposes a cobalt content less than 0.015%. About 42 valves were stellited at the design stage. They are replaced progressively (2 CVCS stellited valves will be replaced at the next outage): about 20 remains today.

RCS surfaces were machined and ground to a good surface finish but there was no further treatment (eg. electropolishing).

No H2O2 injection. No zinc injection.

High Tritium concentrations were observed in the past in the RCS: it was due to the use of single encapsulated secondary neutron sources which have been replaced by double encapsulated sources since cycle 6.

A forced outage occurred in 2001 during which it was made extensive repairs to RPV flange and RPV Head O-Rings to rectify corrosion damages from RCS leakage of boric acid. The total dose result for the repair was 162 man.mSv (high Cs-137 doserates were observed).