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Commissioning and Critical Examination of a new PET Imaging Centre

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INTRODUCTION

Serco Radiation Services were contracted to the University of Edinburgh to provide technical support and guidance during the commissioning of their new PET* Imaging Centre at the Queen's Medical Research Institute at Little France in Edinburgh.

Figure 1- The entrance to CRIC

*PET- Positron Emission Tomography

Protection of workers and members of the public from the potential risk from ionising radiation is regulated by the Health and Safety Executive (HSE) by means of enforcement of the Ionising Radiations Regulations 1999 (IRR99)[Ref 1]. In addition to the protection of individuals, the protection of the environment is achieved by adherence to the Radioactive Substances Act 1993,[Ref 2], which is regulated by SEPA, The Scottish Environmental Protection Agency. As a consequence of the production of radiochemicals there will be the potential for off-site impact in the form of gaseous, liquid or solid wastes. These discharges and waste disposals are controlled by adherence to the prescribed limits stated in the Authorisation document.

The Commissioning Report,[Ref 3] provided an overview of the facility in terms of broad compliance against all aspects of IRR99 and RSA93, but it was specifically intended to meet the requirements of Regulation

31(2), of IRR99. This Regulation requires the erector or installer of an article which is for use at work which involves the potential exposure to ionising radiation to carry out a critical examination on that article.

OBJECTIVES

In order to demonstrate that the applicable regulatory requirements had been met, a programme of tests, observations and measurements were proposed. These studies were designed to ensure the safe functioning of the engineered safety functions within the facility. A detailed series of tests and measurements were proposed by the University RPA, [Ref 4], and the Radiochemistry Facilities Integrator, these formed the basis of the Critical Examination.

It was the intended purpose of Serco to act as an independent witness/consultant during these tests and to assist in the process of collecting the relevant data. Nigel Reeves had been previously appointed as the RPA for Hammersmith Imanet and has relevant experience in providing advice in the area of radiation protection in the context of cyclotron operation and PET Radiochemistry production, and acted as the independent witness.

It should be noted that as the client and future operator of the facility the University was considered as the duty holder in regard to ensuring regulatory compliance. It was therefore important to ensure that the Universities' RPA was consulted as to the requirements of the commissioning exercise.

METHODS

Programme was designed to ensure that all the designed, engineered safety systems were assessed for safety and compliance. This programme was specified by the University RPA and is in line with the requirements of IRR99 Reg 31(2). Full details are included in the Commissioning Report.

Table 1- Outline of the Areas of Study

Technical Speciality	Facility Item
Monte Carlo Shielding Codes	Vault Shielding Design Specification
Principal Contractor/Civil Engineering	Vault Construction - Main Contractor
Radiation Detection	Area Monitoring System – interlocks, etc
PET Isotope Production	Cyclotron and Support Equipment
Shielded Enclosures	Hot Cells and Delivery System
Ventilation	HVAC System- including stack

Figures 2 to 4 Showing Engineered Safety Features

RESULTS

Penetration	Maximum Gamma Dose Rate	Maximum Neutron Dose Rate
A	7.2 μSv hr^{-1}	1.5 μSv hr^{-1}
B	0.8 μSv hr^{-1}	0.15 μSv hr^{-1}
C	1.1 μSv hr^{-1}	< 0.01μSv hr^{-1}
D	0.2 μSv hr^{-1}	<0.01 μSv hr^{-1}
E	0.2 μSv hr^{-1}	<0.01 μSv hr^{-1}
F	1.0 μSv hr^{-1}	0.025 μSv hr^{-1}

Table 2- Results of the Radiation Dose Rate Survey around the Vault

For each of the identified facility components a thorough radiation survey, both gamma and neutron, was carried out. It was anticipated that the highest radiation levels were likely to be as a result of neutron streaming through the penetrations in the Vault. As can be seen from the results in Table 2, all measured dose rates, gamma and neutron, were within acceptable levels. Further dose rate surveys were conducted around the shielded Hot Cells and delivery system. A couple of hot spots were detected on the delivery system leading to the Hot Cells, (gamma dose rates approaching 1mSv hr^{-1}), these hot spots were rectified by the addition of further lead shielding.

In addition to the radiation surveys a full functionality test was carried out on all of the designed engineering functions; area radiation monitoring system, delivery system, Vault clearance system including interlocks and the stack monitoring system.

DISCUSSION

A great deal of effort was put in at the design stage to ensure that the facility was inherently safe and compliant. By situating the Cyclotron Vault in the Basement of the building it was not necessary to consider radiation doses below. By use of a Monte Carlo shielding code and ensuring that there were no penetrations in straight lines, (penetrations were either "S" curves or rising diagonals lined with polythene), radiation levels were acceptable on the outside.

A fully automated, shielded delivery system ensured that the product was delivered directly from the Vault to the Hot Cells with minimal radiation hazard. At least 75mm of lead was used as primary shielding. A novel approach was used to test the shielding integrity of the facility, this being to use the active product itself, (up to 300 GBq of F^{18}). This has many advantages over large sealed sources as the product can be delivered automatically, it has a short half life < 2hours, and therefore decays away without the need for further handling and is of the correct gamma energy. This ensures that the process remains ALARP.

A fully integrated radiation area monitoring system was installed. This included the ability to install dose rate alarmed interlocks on the Vault and Hot Cells. In addition to dose rate a gas sampling system was designed to measure potential gas leaks from the system. Stack monitor was installed and calibrated to monitor the actual radioactive discharge to the environmental and it was able to demonstrate that the actual radioactive discharges were only a fraction of the authorised discharges. It should also be noted that these gasses all have short half lives, (O^{18} 2 minutes and C^{11} 20 minutes), so a delay system to increase the gas retention time was designed and installed which reduced the discharged activity markedly. This helped demonstrate the BAT principal, Best Available Techniques, to reduce the potential environmental impact.

Environmental dosemeters were also installed in the surrounding areas to demonstrate that the occupational exposure was negligible and provided staff reassurance.

It was the outcome of the Prior Risk Assessment, PRA, [Ref 5], which determined the requirement for the designation of a Controlled Area across the facility it was also necessary to ensure that the facility workers were Classified Workers. This helped ensure that worker doses were suitably restricted. Although worker doses will be significantly below 6mSv per annum it is appropriate to designate the area as controlled due to the need for special measures to be used to restrict exposure, (IRR99 ACOP Para 255).

CONCLUSIONS

It was demonstrated in the Commissioning Report by way of a programme of measurements, tests and observations that the CRIC Radiochemistry facility had met the stated objectives of Regulation 31(2), of IRR99.

It was also the intended scope of the report to provide a record of the tasks undertaken such that as a stand alone document it could demonstrate that CRIC had achieved a high level of regulatory compliance against all applicable statutory instruments. Radiation exposures to workers and members of the public were shown to be well within the IRR99 and RSA93 dose limit and constraint. These being the public dose limit of 1mSv per annum for IRR99 and the environmental impact of less than 0.3 mSv per annum as required by The Basic Safety Standard, Ref [6]. This Environmental Impact Assessment, was the subject of a separate study conducted by the University RPA and submitted as part of the RSA93 Authorisation application, [Ref 7]. Worker dose levels were also demonstrated to be As Low As reasonably Practicable, ALARP and the impact on the environment as being BAT.

REFERENCES:

1- IRR99, SI 1999/3232
2- RSA93, The Radioactive Substances Act 1993, as amended 2011.
3- CRIC Cyclotron Commissioning Report, SERCO/P8612/TR001, NJ Reeves March 2011

4- Aspects Expected be included in the Installers' Critical Examination Reports, C Farmery, October 2010
5- Prior Risk Assessment - SERCO/P8612/TR001, N J Reeves, December 2010
6- The Basic Safety Standard Directive, 96/29/EURATOM
7- Radioactive Substances Act 1993, Certificate of Authorisation, RSA/A/1078880