STATUS REPORT OF THE CYCLOTRONS C-30, CS-30 AND RDS-111 AT KFSHRC, SAUDI ARABIA

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Abstract

Experience gained since the commissioning of the IBA C-30 Cyclotron at the King Faisal Specialist Hospital and Research Centre (KFSHRC) in 2010, has shown this facility to be viable entity. In addition to the C-30 Cyclotron, the facility includes two other Cyclotrons, namely: the RDS-111 and the CS-30 Cyclotrons. The latter has dual responsibilities; while it is kept as a backup for the other Cyclotrons for radioisotopes production, it's also used for proton therapy researches and Bragg Peak measurements at that particular energy. Facility operating history, usage and radiopharmaceuticals productions are described.

INTRODUCTION

The production of radioisotopes for use in medical applications such as diagnostic imaging and therapeutic treatment is achieved through nuclear reactions using accelerated charged particles. The latter is accelerated using medical cyclotron which increases its energy to a range of 30 MeV or so. The accelerated charged particles are used to produce radioisotopes that can be used later in nuclear medicine in the form of radiopharmaceuticals. At KFSHRC, there are three medical cyclotrons, the CS-30, the C-30 and the RDS-111. Each of these cyclotrons will be described below.

CYCLOTRONS OPERATIONS

The CS-30 was assembled and tested at TCC in USA before being shipped to Saudi Arabia. Beam tests at the factory started in 1977 and ended in October [1, 2]. The CS-30 can accelerate four different particles with different energy levels [2]. Values are shown in Table 1. Target stations are available on seven beam lines as well as on an internal target. Beam lines #1 and #2 are reserved for FDG production. Beam line #3 terminates in gas target and processing system, which was designed for production of the positron-emitters ^{11}C and ^{15}O. Beam line # 4 consists of two end segments. The 101 degree dipole magnets are used for stack foils experiments. Presently mounted on beam line #5 is production of Krypton-81m generators. Beam line #6 goes to the "isocentric" neutron therapy system. Beam line #7 is used once a week for ^{13}N. A TCC model 4010 internal target system, with isorabbit transfer to the hot cells, is fitted to the cyclotron but has been substantially modified. The cold cathode internal ion source is quite reliable. The life time of tantalum is greater than 100 hours when producing proton [3]. However, this number drops massively when helium beams are accelerated. The C-30 cyclotron, on the other hands, was assembled and tested at IBA in Belgium before being shipped to Saudi Arabia. The Cyclone 30 is 30 MeV, negative ion machine, deep valley magnet and uses cryopumps technology. It has the advantage of simultaneous extraction of two beams rated 350 uA each. The RF system can deliver up to 45 kW of power to accelerate its particles. The C-30 delivers a stable dual beam current up to 750 µA. Maximum efficiency is obtained through the simultaneous bombardment of two different targets for two different isotopes production.

The Cyclone C-30 has three beam lines; beam line #1.1 is connected to five ports through a switching magnet. In each port there is a different target being selected by changing the magnetic field in the switching magnet, they are F-18, N-13, Kr-81m and two as spare for future development. Beam line #2.1 is dedicated for solid target (Thallium, Gallium, etc.) and beam line #2.2 is dedicated for ^{123}I through the well-known nuclear reaction of protons with highly enriched ^{124}Xe.

The RDS-111 cyclotron is a compact machine, installed in 2006. It has the ability to deliver dual beam at 11 MeV with a maximum beam current of 60 µA. It has six ports; three in each line and occupied as follows: two ports are reserved for faraday cup for measuring the beam, two ^{18}F and two ^{13}N targets.

Table 1: Cyclotrons' Characteristics at KFSHRC

Cyclotron Type	Particles	Energy (MeV)	I_{Beam} (µA)
C-30	P	30	750
CS-30	P	26.5	100
RDS-111	P	11	60

Figure 1 shows photos of the three cyclotrons at KFSHRC. Unlike the CS-30 and RDS-111, the C-30 has an advantage of varying its energy smoothly using the radial extraction system. This gives the operator the ability to select between different radioisotopes easily. However, the CS-30 is unique in terms of the number of particles that it can accelerate. Table 1 show the characteristics of these machines.

Figure 1: Photos of KFSHRC cyclotrons. From left to right: the CS-30 (1981), the RDS-111 (2006), and the C-30 (2010).

SAFETY SYSTEMS OF THE CYCLOTRONS FACILITY

In addition to the self-safety system which operates the PLC-technology included in each cyclotron, the facility is equipped with a radiation monitoring system supplied by LabImpex [2, 3]. The system monitors various room and corridors within the facility for gamma radiation. The C-30 cyclotron vault and its three targets along with the RDS vaults are monitored for gamma radiation. When the cyclotron is active, the detector within the vault is powered down to prolong its life. Two other types of detectors are used within the facility: PET stack and iodine stack. The latter is monitored for flow by an averaging Pitot connected to DP2001 differential Pressure meter. Air is sampled from the stack, pumped through a lead shielded iodine gas detector. Figure 2 shows a layout for the facility and locations of radiation detectors.

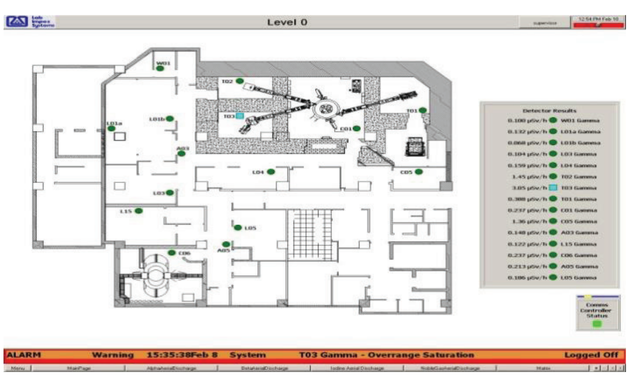

Figure 2: Plan view of KFSHRC cyclotron facility.

RADIOPHARMACEUTICLES PRODUCTION

Routine production of radiopharmaceuticals at KFSHRC started as early as 1983 with a limited number of batches. However, in 2012, 1329 batches were delivered from the department to different nuclear medicine centers in Saudi Arabia. Every batch of radiopharmaceutical products manufactured in the C&R Department is tested according to the established protocols and procedures, and released for human use only upon conformity to the predetermined level of quality. The Quality Control Section (QC) is responsible for testing the radiopharmaceuticals batches, whereas the quality assurance section has the authority to approve or reject the radiopharmaceutical products. This section is also charged with the authority to review production batch records.

Table 2 shows the common radiopharmaceuticals that the three cyclotrons produce with the energy level needed and required amount of activity per batch.

Table 2: Radiopharmaceuticals Produced at KFSHRC in 2012

Products	Cyclotron Energy (MeV)	Number of batches	Required Activity (mCi)
FDG	18	450	1800
N-13	14	46	50
Tl-201	29	51	200
Ga-67	26	54	200
I-123	30	382	25
Kr-81m	26.5	202	25

CURRENT RESEARCH PROJECTS AND FUTURE PLAN

Currently, most of the isotopes distributed around the Kingdom are produced in both the C-30 and the RDS-111 Cyclotron except for Krypton, which is under development, and soon beam testing using one of the C-30 beam lines will be established. Right now, the CS-30 is used to produce Krypton and other non-standard isotopes such as ^{124}I and ^{64}Cu. Moreover, the proton beam of the CS-30 is used as proton therapy of some tumour tissues. Having higher mass, protons deposit energy along straight tracks that end forming a Bragg peak and hence depositing only a minimal dose in regions right behind the Bragg peak.

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In the future, a comprehensive plan will take place to refurbish and upgrade the old parts of CS-30. This includes reconnecting the deuteron line which is needed for some interested deuteron-produced isotopes. However, there is still debate whether to connect and run the cyclotron using other particles (He-3 and He-4) or not.

CONCLUSION

The Cyclotron facility at KFSHRC is fully operational and most of the radioisotopes used in nuclear medicine are produced on a weekly basis using both C-30 and RDS-111. A scheduled plan was initiated to refurbish and upgrade the CS-30 power supplies and control system and to be ready for research projects in 2015.

REFERENCES

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