Irradiation Stability of Syringe and Valve Controllers of RadioGenix™ System

Chemical Sciences and Engineering Division

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IRRADIATION STABILITY OF SYRINGE AND VALVE CONTROLLERS OF RADIOGENIX™ SYSTEM

1 INTRODUCTION

NorthStar Medical Technologies has developed the RadioGenix™ (formerly known as TechneGen) Generator System, which allows nuclear pharmacies to provide ^{99m}Tc for critical medical procedures using low-specific-activity molybdenum-99 (Mo-99) as source material. Molybdenum-99 is the parent isotope of technetium-99m (Tc-99m), an element used in approximately 85% of diagnostic imaging procedures. The RadioGenix™ System allows for the efficient separation and dose preparation of Tc-99m from Mo-99. There is an interest in determining the lifetime of the components that are used in the system, in particular, the controllers used for the syringe and valves. We performed (1) Monte Carlo N-Particle Transport (MCNPX) calculations to predict the dose rates these components would receive during operation and (2) an experimental study to measure the radiation stability of these controllers using a 3 MeV Van de Graaff electron accelerator. A tungsten photon converter was attached to the beam window so that the electronic components were irradiated with photons rather than electrons.

2 CALCULATION OF DOSE RATES

We performed MCNPX modeling to determine dose rates and total doses to the syringe and valve controllers of the RadioGenix™ system. The source was modeled as consisting of 3 Ci ^{99}Mo (in equilibrium with $^{99\text{m}}\text{Tc}$) in a 5 M, 3 mL KOH solution. Photon fluxes at the controller locations were converted to dose rates using built-in flux-to-dose conversion coefficients (ICRP-21, 1973). The hot syringe was assumed to have up to 6 Ci of ^{99}Mo , while 3 Ci was considered as an average ^{99}Mo activity throughout the operation of the generator. Dose rates at the valve controller locations are presented in Table 1. The syringe controller receives much higher dose rates than the valve controllers due to its proximity to the source valve and the lack of shielding. Dose rate distribution plots in horizontal and vertical planes are shown in Figures 1 and 2, respectively.

TABLE 1 Dose Rate Results for a 3 Ci ^{99}Mo Source Calculated with MCNPX

	Dose Rate(rad/hr)
Syringe controller	114
Valve controller – bottom	0.029
Valve controller – top	0.011

FIGURE 1 Dose Rate Distribution in the Horizontal Plane

FIGURE 2 Dose Rate Distribution in the Vertical Plane

We estimated that in 2 years of operation the total exposure time to the controllers would be around 515 hours. The total gamma doses to the controllers in this time are summarized in Table 2.

TABLE 2 Total Doses in 515 Hours for a 3 Ci ^{99}Mo Source

	Dose (krad)
Syringe controller	58.72
Valve controller – bottom	0.015
Valve controller – top	0.006

3 EXPERIMENTAL

Based on the above calculations, the initial guidelines for the experiments were:

Test Valve and Syringe: Irradiate in 5 kGy increments up to 25 kGy, and then in 10 kGy increments up to 50 kGy and then 20 kGy increments until failure.

Pressure Sensor: Irradiate at average dose rate of 10 kGy/hr for total dose of 60 kGy.

CPC Connectors: Irradiate to 80 kGy and remove connector #1, repeat and remove connector #2, repeat and remove connector #3, and repeat and remove connector #4.

The dose rates for the controller experiments were determined with a Radcal 9010 Dosimeter. Figure 3 shows the relationship between beam current and dose rate at 12 in. from the convertor. Figure 4 is a photograph of the irradiation setup.

FIGURE 3 Current on the Converter and Radical Dose Rate (in R/h)

FIGURE 4 Setup for the Irradiation of the Syringe Controllers

4 RESULTS AND DISCUSSION

Syringe and valve controllers that are being used in the RadioGenix™ were sent to Argonne for irradiation at the Van de Graaff accelerator. The initial target was to irradiate the controllers to 50 kGy. When the first controller failed at 2 kGy, we developed a new experimental plan. As the irradiations progressed, many changes were made to the controllers to determine how to extend their life expectancy. The controllers used for samples #4 and #5 had the circuit boards removed and distanced from the source. Samples #8 and #9 had ½-in. lead shielding installed between the syringe and the circuit boards. Test conditions and stability results are reported in Table 3.

These components were all irradiated using the electron beam at 25 in. from the window. Oxalic acid dosimetry was used to determine the dose (Figure 5). The current profile moving perpendicularly from the center of the beam is reported in Figure 6.

Colder Products Company (CPC) tubing connectors are being used on the RadioGenix™ to transfer solutions. We thus irradiated four connectors to 80 kGy, removing one and continuing in 80 kGy increments until the target dose was reached. Each irradiated connector looked unaffected, but they all leaked. A pressure switch was irradiated to 60 kGy, and it still functioned. Integrated circuit (IC) chips were irradiated to 50 kGy, and at this time, we do not know if they are still functioning. Results are presented in Table 4.

TABLE 3 Controller Test Conditions and Results

Sample	Controller Type	Dose Rate (Gy/min)	Total Dose (Gy)	Failure (Y/N)	Comment
1	Valve	15	2160	Y	
2	Syringe PSD3	15	195	Y	
3	Syringe PSD3	0.45	20.4	Y	
4	Syringe PSD3	15	1181	No	Circuit board 17 in. from syringe
5	Syringe PSD3	15	295	Y	Circuit board 6 in. from syringe
6	Syringe PSD4	15	502	Y	
7	Syringe PSD4	15	443	Y	
8	Syringe	7.35	353	Y	½-in. lead in front
9	Syringe	7.35	360	Y	½-in. lead in front

FIGURE 5 Linear Relationship between the Time and Dose Determined from the Irradiations of 90-100 mL of 0.6 M Oxalic Acid at 20- μ A Shutter Electron Beam and 25 in. from the Window

FIGURE 6 Profile of 10 μ A Shutter Current Beam at 25 in. from Window and Various Distances from Center Line

TABLE 4 Radiation Stability of CPC Connectors, IC Chip, and Pressure Sensor

Sample	Dose Rate (Gy/min)	Total Dose (Gy)	Results
CPC connector#1	2471	80.3k	All CPC connectors leaked at 50 psi and at 20 psi. The connector shell became brittle.
CPC connector#2	2471	160.6k	
CPC connector#3	2471	240.9k	
CPC connector#4	2471	321k	No leakage detected.
CPC connector#5	2471	50k	
Pressure Sensor MS85F	2471	60k	
CPC connector #6	2471	50k	Leaks detected.
Fujitsu MB89R118	2471	50k	?

Chips= Chip Fujitsu MB89R118

Pressure sensor= Measurement Specialties, Model 85 Flush Mount

5 SUMMARY

Equipment used in the RadioGenix™ dispensing units was irradiated at Argonne's Van de Graaff generator facility. Dose rate calculations for individual components were provided by modeling the system with MCNPX. The syringe and valve controllers were operated during the irradiation to determine the dose at which failure occurred. CPC connectors, a pressure switch, and computer chips were also irradiated and evaluated upon completion of the irradiations. NorthStar has determined from this work that some of this equipment will need to be modified. This study will be helpful in future equipment design.

6 REFERENCE

International Commission on Radiological Protection (ICRP), *Data for Protection against Ionizing from External Sources*, Vol. 21 (1973).

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