

Irradiation Stability of Syringe and Valve Controllers of RadioGenix™ System

Chemical Sciences and Engineering Division

About Argonne National Laboratory

Argonne is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC under contract DE-AC02-06CH11357. The Laboratory's main facility is outside Chicago, at 9700 South Cass Avenue, Argonne, Illinois 60439. For information about Argonne and its pioneering science and technology programs, see www.anl.gov.

DOCUMENT AVAILABILITY

Online Access: U.S. Department of Energy (DOE) reports produced after 1991 and a growing number of pre-1991 documents are available free via DOE's SciTech Connect (<http://www.osti.gov/scitech/>)

Reports not in digital format may be purchased by the public from the National Technical Information Service (NTIS):

U.S. Department of Commerce
National Technical Information Service
5301 Shawnee Rd
Alexandria, VA 22312
www.ntis.gov
Phone: (800) 553-NTIS (6847) or (703) 605-6000
Fax: (703) 605-6900
Email: orders@ntis.gov

Reports not in digital format are available to DOE and DOE contractors from the Office of Scientific and Technical Information (OSTI):

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
www.osti.gov
Phone: (865) 576-8401
Fax: (865) 576-5728
Email: reports@osti.gov

Disclaimer

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor UChicago Argonne, LLC, nor any of their employees or officers, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of document authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof, Argonne National Laboratory, or UChicago Argonne, LLC.

Irradiation Stability of Syringe and Valve Controllers of RadioGenix™ System

by

Kevin Quigley, Vakhtang Makarashvili, Sergey Chemerisov, George F. Vandegrift, and Peter Tkac
Chemical Sciences and Engineering Division, Argonne National Laboratory

Ron Schluter and James Harvey
NorthStar Medical Technologies, LLC

prepared for

U.S. Department of Energy, National Nuclear Security Administration,
Office of Defense Nuclear Nonproliferation

July 2014

CONTENTS

1	INTRODUCTION	1
2	CALCULATION OF DOSE RATES	2
3	EXPERIMENTAL	4
4	RESULTS AND DISCUSSION	6
5	SUMMARY	9
6	REFERENCE.....	10

FIGURES

1	Dose Rate Distribution in the Horizontal Plane.....	2
2	Dose Rate Distribution in the Vertical Plane	3
3	Current on the Converter and Radical Dose Rate	4
4	Setup for the Irradiation of the Syringe Controllers	5
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	7
6	Profile of 10 μ A Shutter Current Beam at 25 in. from Window and Various Distances from Center Line	7

TABLES

1	Dose Rate Results for a 3 Ci ^{99}Mo Source Calculated with MCNPX	2
2	Total Doses in 515 Hours for a 3 Ci ^{99}Mo Source	3
3	Controller Test Conditions and Results	6
4	Radiation Stability of CPC Connectors, IC Chip, and Pressure Sensor	8

This page intentionally left blank

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

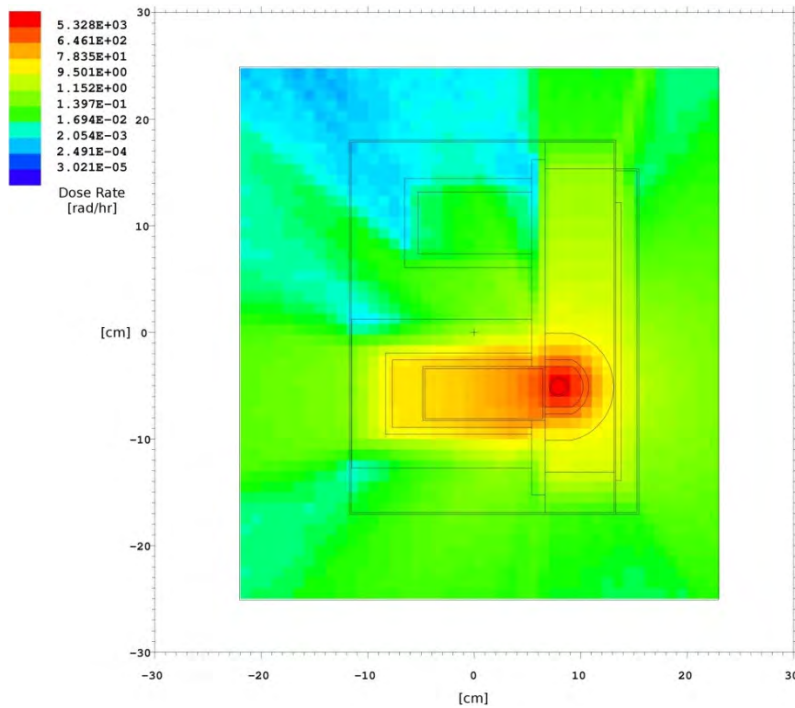


FIGURE 1 Dose Rate Distribution in the Horizontal Plane

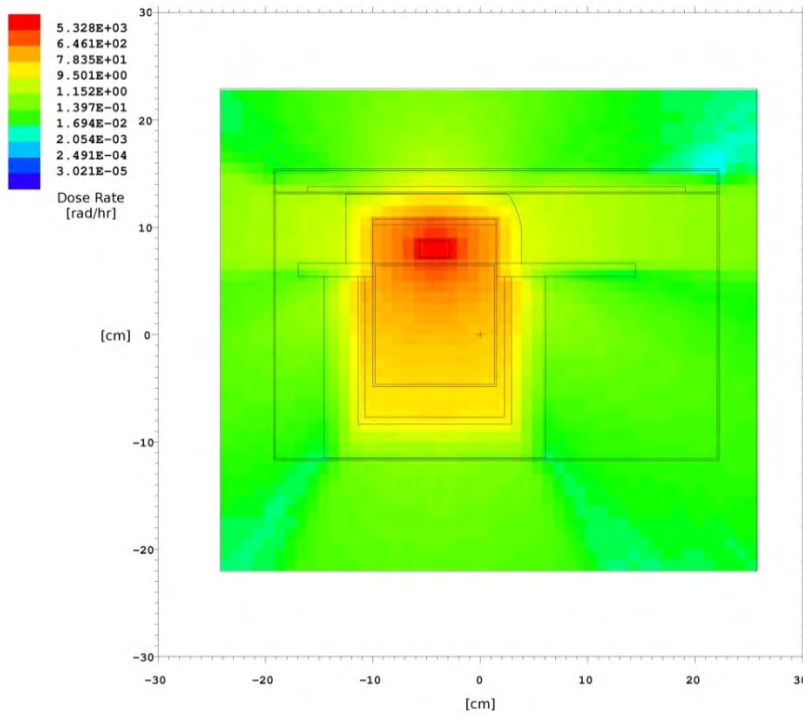


FIGURE 2 Dose Rate Distribution in the Vertical Plane

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.

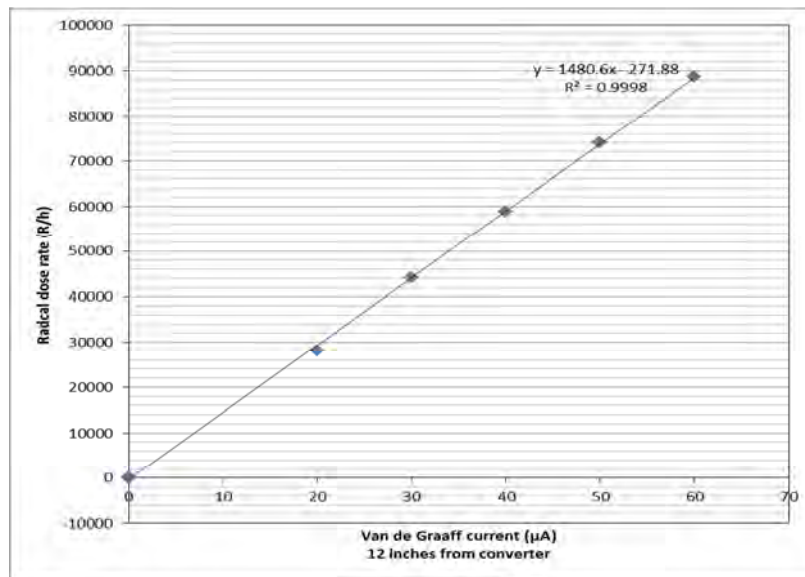


FIGURE 3 Current on the Converter and Radical Dose Rate (in R/h)



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

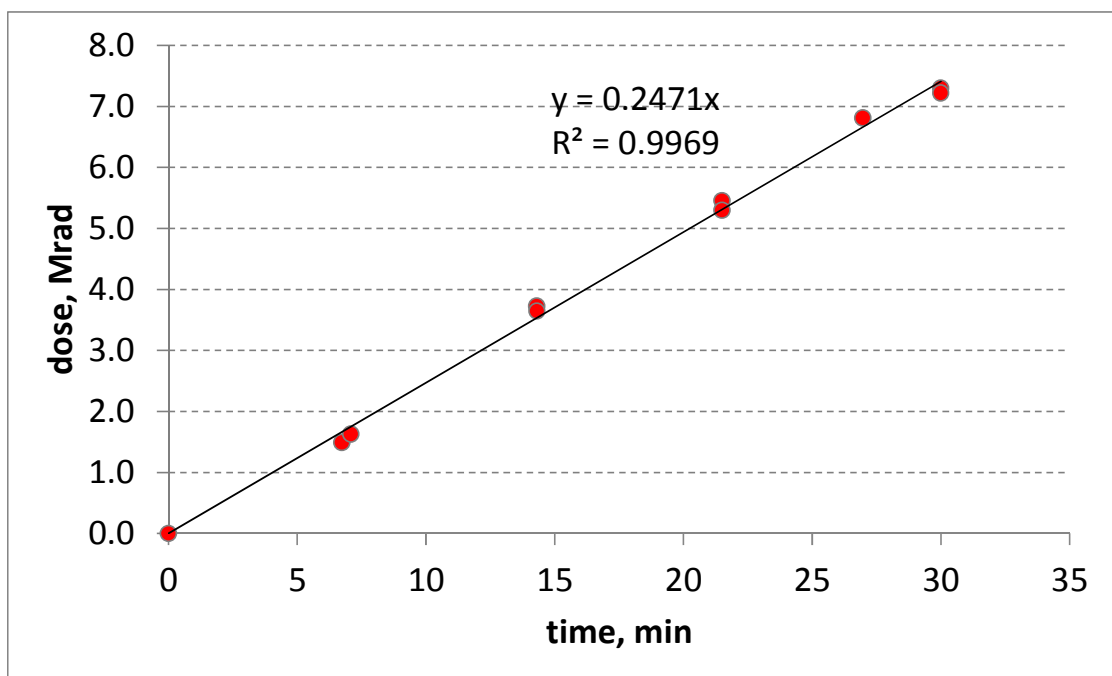


FIGURE 5 Linear Relationship between the Time and Dose Determined from the Irradiations of 90-100 mL of 0.6 M Oxalic Acid at 20- μ A Shutter Electron Beam and 25 in. from the Window

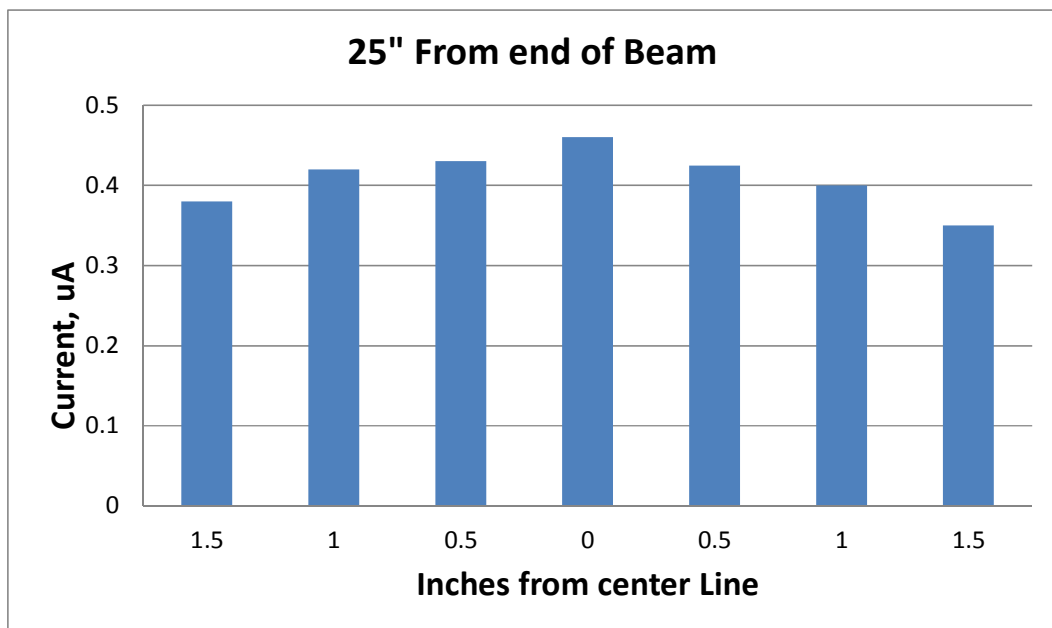


FIGURE 6 Profile of 10 μ A Shutter Current Beam at 25 in. from Window and Various Distances from Center Line

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).



Chemical Sciences and Engineering Division

Argonne National Laboratory

9700 South Cass Avenue, Bldg. 205

Argonne, IL 60439-4837

www.anl.gov



U.S. DEPARTMENT OF
ENERGY

Argonne National Laboratory is a U.S. Department of Energy
laboratory managed by UChicago Argonne, LLC