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**RADIOLOGICAL ENGINEERING EVALUATION OF THE DELAY LINE
AIR SCRUBBER LOCATED AT THE CLINTON P. ANDERSON
MESON PHYSICS FACILITY (LAMPF)**

A Thesis

by

SCOTT EDWARD HUNEYCUTT

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

MASTER

May 1996

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Major Subject: Health Physics

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Approved as to style and content by:

Milton E. McLain, Jr.
(Co-Chair of Committee)

Warren D. Reece
(Co-Chair of Committee)

Gerald A. Schlapper
(Member)

Michael A. Walker
(Member)

John W. Poston, Sr.
(Head of Department)

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ABSTRACT

Radiological Engineering Evaluation of the Delay Line

Air Scrubber Located at the Clinton P. Anderson

Meson Physics Facility (LAMPF).

(May 1996)

Scott Edward Huneycutt, B.S., University of Texas at Arlington

Co-Chairs of Advisory Committee: Dr. Milton E. McLain, Jr.
Dr. Warren D. Reece

The purpose of this study was to determine the effects of the addition of an air scrubber to an already existing delay line and whether it would scrub $^{11}\text{CO}_2$. There were three main objectives of this study. The first objective was to determine the scrubbing efficiency of the scrubber. The scrubbing efficiency was then used to predict the dose rates in the scrubber area and compare those values with measurements from radiological surveys. The third objective was to determine if the shield blocks were effective in reducing the dose rates in the scrubber area.

The activities were measured before and during scrubber operation and this information was used to calculate the scrubbing efficiency and the efficiency of $^{11}\text{CO}_2$ removal was determined to be around 50%. Microshield[®] was then used to predict dose rates and compared those values with measurements from radiological surveys. This was also used to determine that the shield blocks around the scrubber were effective in reducing the dose rates from the radiation field produced by the radionuclides in the scrubber.

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TABLE OF CONTENTS

	Page
ABSTRACT	iii
ACKNOWLEDGMENTS	iv
TABLE OF CONTENTS.....	v
LIST OF FIGURES	vii
LIST OF TABLES	x
INTRODUCTION.....	1
BACKGROUND	3
THEORY.....	7
Air Scrubber	7
Prediction Spreadsheet.....	14
Removal Efficiency Calculation	15
Water Diagnostic Line.....	15
Air Sample Line	16
HRS dome Air Sample Line.....	16
Source Term Calculation	17
Dose Rate Calculations	18
MATERIALS	19
Delay Line Air Scrubber.....	19
Water Diagnostic Line.....	20
Air Sample Line	25
HRS dome Air Sample Line.....	28
METHODS.....	31
RESULTS.....	38
Water Diagnostic Line Results.....	38
Air Sample Line Results.....	40
HRS dome Air Sample Line Results	42
Radiological Survey Results	43

	Page
DISCUSSION.....	49
CONCLUSION.....	55
FUTURE WORK	57
REFERENCES	58
APPENDIX A: ANALOG DATA	60
APPENDIX B: PREDICTION SPREADSHEET.....	64
APPENDIX C: MICROSIELD [®] MODEL.....	72
VITA.....	160

LIST OF FIGURES

	Page
Figure 1: Diagram of LAMPF showing the five major areas of the linac	3
Figure 2: Layout of the LAMPF Switchyard and experimental areas showing the location of the beam stop with respect to the experimental areas and HRS dome	4
Figure 3: A cutaway diagram of the LAMPF beam stop showing the major components and materials	5
Figure 4: Stage one vertical column showing the position of the shower head, acid-resistant filler, and recirculated water	11
Figure 5: Direction of the air flow through the scrubber	12
Figure 6: Location of the scrubber with respect to the drip pan in Area A East	20
Figure 7: Location of the diagnostic line with respect to the scrubber and shield blocks	21
Figure 8: Diagram of the Diagnostic Station with a cutaway to show the position of the scintillator with respect to the water volume	22
Figure 9: Plumbing diagram showing the valving system and the sampling lines to and from the diagnostic station	23
Figure 10: Diagram of the counting electronics used to monitor the dose rates in the water diagnostic line	24
Figure 11: Diagram of the air sampling lines and the valves used to control where the sample is taken from and to close the sample canister for a decay series	25
Figure 12: The air sample detector geometry with the NaI detector and the sample container axially in-line and the dimensions of the sample container	26
Figure 13: Diagram of the air sample counting electronics used to record the decay series of the airstream samples	27

	Page
Figure 14: The geometry of the detector in the HRS dome used to monitor the activity of the ^{11}C and ^{41}Ar in the Kanne chamber	29
Figure 15: Diagram of the counting electronics use in the HRS dome to measure the activities of the ^{11}C and ^{41}Ar in the Kanne chamber and to record the output of the Kanne chamber	29
Figure 16: Prediction software printout showing the scrubber response to rates of flow of NaOH and distilled water	33
Figure 17: Dose rate response recorded from the scintillator in the water diagnostic station	39
Figure 18: Dose rate response (during the first four hours) recorded from the scintillator in the water diagnostic station	39
Figure 19: Decay curve for sample number one	40
Figure 20: Decay curve for sample number two	41
Figure 21: Decay curve for sample number three	41
Figure 22: Levels of activity in the HRS Kanne chamber as more ^{11}C is being removed by the air scrubber	42
Figure 23: Results of the radiological survey of the scrubber performed on September 22, 1995. The dose rates are recorded in mR/hr	44
Figure 24: Radiological survey of A6 North on August 3, 1995, (values in mR/hr)	45
Figure 25: Radiological survey of A6 North on August 4, 1995, (values in mR/hr)	45
Figure 26: Radiological survey of A6 North on August 6, 1995, (values in mR/hr)	46
Figure 27: Radiological survey of A6 North on August 10, 1995, (values in mR/hr)	46

	Page
Figure 28: Radiological survey of A6 North on August 13, 1995, (values in mR/hr)	47
Figure 29: Radiological survey of A6 North on September 22, 1995, (values in mR/hr)	47
Figure 30: Predicted dose rates with scrubber not operating, (values in mR/hr)	48
Figure 31: Predicted dose rates when scrubber is operating, (values in mR/hr)	48
Figure 32: Comparison of the three decay curves taken from the three air samples	50
Figure 33: Graph of the scrubber removal efficiency of ^{11}C with respect to time taken from the ratios recorded in the HRS dome	52

LIST OF TABLES

	Page
Table 1: Most abundant nuclides in the atmosphere	7
Table 2: Radionuclides with half-life greater than 1 minute produced in air at proton accelerators	8
Table 3: Expected air activation reactions at linear accelerators	9
Table 4: Stack gas composition for calendar year 1991 at LAMPF	10
Table 5: List of components used for the water diagnostic line counting electronics	24
Table 6: List of components used for the air sample line counting electronics	27
Table 7: List of the HRS dome air sample line counting electronics	30
Table 8: The following equations were used in the prediction software to determine the response of the scrubber system to the input flow rates	32
Table 9: HRS dome ^{11}C and ^{41}Ar count rates and ratios	43
Table 10: Results of a linear regression analysis of each air sample which shows the partial fractions of ^{15}O , ^{13}N , and ^{11}C	50
Table 11: ^{11}C removal efficiency calculated from the $^{11}\text{C}/^{41}\text{Ar}$ ratios as a function of time	52

INTRODUCTION

The Clinton P. Anderson Meson Physics Facility, also known as the Los Alamos Meson Physics Facility (LAMPF), is located at Technical Area 53 (TA-53) of Los Alamos National Laboratory (LANL). In 1989, the National Emission Standards for Hazardous Air Pollutants (NESHAPS), Title 40 of the Code of Federal Regulations, Chapter 61, subpart H, established an effective dose equivalent of 0.10 millisievert (10 millirem) as the maximum allowable annual dose to be received by a member of the public as a result of operation of a Department of Energy facility (USEPA, 1992).

This federal regulation is important due to the close proximity of LAMPF to the neighboring Los Alamos town-site. Even short-lived activated air products from LAMPF, such as ^{11}C , can cause a measurable off-site dose (Jacobson, 1994). To help reduce the dose to the surrounding population, a delay-line was added to the primary exhaust stack in 1994 to allow time for many of the short-lived radionuclides to decay before being released. This delay-line provides approximately 100 minutes of delay before sending the activated air out the stack. This delay is approximately five times the half-life of ^{11}C (20.3 minutes).

In 1995, an air scrubber was added to the delay line. This air scrubber was built to remove acids from the air stream, as well as tritiated water (HTO),

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carbon dioxide (CO_2), and other pollutants (Gonzales, 1995). The scrubber was constructed and ready for operation for the 1995 LAMPF run-cycle which began August 2, 1995. The research described here was primarily performed to determine how scrubbing ^{11}C from the delay line airstream will affect the dose rates in the scrubber area.

To determine how the dose rates are effected by the addition of the scrubber to the delay line, the research was broken down into three objectives. The first objective was to determine the removal efficiency of ^{11}C in the scrubber system. The second objective was to factor the measured efficiency of the scrubber into a calculation of the source term for the scrubber as well as the dose rates at various locations around the scrubber. The third objective was to analyze the effectiveness of the shield blocks used to shield the scrubber.

BACKGROUND

LAMPF is an 800 meter long linear accelerator (linac) constructed in the early 1970's. It is capable of accelerating positively or negatively charged hydrogen ions to energies of 800 million electron-volts (MeV) at an average current of one milliampere (mA). The accelerator is composed of three stages which includes the injectors, a 62 meter long drift-tube linac, and the 731 meter long side-coupled-cavity linac (Fig. 1). After the beam passing through each stage and reaching its maximum energy, the beam is then separated in the switchyard and directed down three main beam lines to as many as ten experimental areas (Allred and Talley, 1987) (Fig. 2).

Fig. 1. Diagram of LAMPF showing the five major areas of the linac.

Fig. 2. Layout of the LAMPF Switchyard and experimental areas showing the location of the beam stop with respect to the experimental areas and HRS dome.

The beam-stop, A6, is located within the doghouse in Area A-East and is the focus of this study. The doghouse is the steel containment box, surrounded by cement shielding blocks, which houses the beam stop (Fig. 3). At the beam stop, the beam exits the vacuum pipe through a vacuum window, travels through approximately one meter of air and several beam line components before it is stopped; as the beam passes through the air, the air becomes activated by direct interaction with the beam. Interactions with the beam line components and the beam stop produce secondary particles which also activate the air.

Fig. 3. A cutaway diagram of the LAMPF beam stop showing the major components and materials.

The radioactive air in the doghouse is collected by a ventilation system and is eventually exhausted through an emissions stack (FE-3). This ventilation system maintains a negative pressure within the doghouse to reduce the probability that radioactive gases escape from the doghouse into Area A. Before the radioactive air is released through FE-3, it passes through a delay line. The air delay line consists of PVC piping, shielded high-efficiency particulate air (HEPA) filters, PVC delivery tube, fan, and 1230 meters (4000 ft) of 0.55 meter (1.8 ft) diameter polyethylene tubing. With an air flow rate of 1000 cfm, the radioactive air is delayed 100 minutes. This time is sufficient for radionuclides with short half-lives to decay away leaving the longer lived radionuclides such as ^{11}C and ^{41}Ar . During the 1994 delay line

operations, August through November, FE-3 stack emissions were reduced by 25 percent and off site dose from emissions was reduced by one third (Paciotti, 1995).

The delay line design, however, allows tritiated water vapor to enter the line. The tritiated water vapor is formed in the high temperature area of the doghouse. As the vapor enters the cooler delay line, it cools and condenses leaving puddles of tritiated water in the delay line tubing (Paciotti, 1995). The delay line design also has to be very long to allow for enough time for the longer lived ^{11}C to decay through five half-lives. The addition of the delay line air scrubber will help eliminate these problems and possibly allow the delay line to be moved to another location (Gonzales, 1995).

THEORY

Air Scrubber

The radioactive gases to be scrubbed are produced as a result of the atmospheric gases which are naturally present in the doghouse and target areas. Atmospheric gas abundance is shown in Table 1 (IAEA, 1988). As the proton beam passes through the atmosphere in the doghouse it activates the gases by direct interaction.

Table 1. Most abundant nuclides in the atmosphere.

Isotope	Percent by volume in atmosphere
^{14}N	78.10
^{16}O	21.20
^{40}Ar	0.46
^{15}N	0.28
^{18}O	0.04

Table 2 shows a partial list of the radioactive gases with half-lives greater than one minute that can be produced in a proton accelerator (IAEA, 1988). The activated air products that can be expected at LAMPF, and the activation reactions that produced them, can be seen in Table 3 (Shire, et al., 1994).

Table 2. Radionuclides with half-lives greater than 1 minute produced in air at proton accelerators.

Radionuclide	Half-life	Emission	Parent Element
^3H	12.2 years	β^-	N
			O
^7Be	53.0 days	γ, EC	N
			O
			Ar
^{11}C	20.5 minutes	β^+	N
			O
			Ar
^{14}C	5370.0 years	β^-	N
^{13}N	10.0 minutes	β^+	N
			N
			O
			Ar
^{14}O	74.0 seconds	β^+, γ	O
			Ar
^{15}O	2.1 minutes	β^+	O
			O
			Ar
^{18}Fe	1.9 hours	β^+, EC	Ar
^{22}Na	2.6 years	β^+, γ	Ar
^{24}Mg	15.0 hours	β^-	Ar
^{28}Al	2.3 hours	β^-, γ	Ar
^{31}Si	2.6 hours	β^-, γ	Ar
^{30}P	2.5 minutes	β^+, γ	Ar
^{32}P	14.3 days	β^-	Ar
^{35}S	87.0 days	β^-	Ar
^{39}Cl	55.0 minutes	β^-, γ	Ar
^{41}Ar	1.8 hours	β^-, γ	Ar

The actual FE-3 stack effluent composition and activity measured during the 1991 run season can be seen in Table 4 (Shire, et al., 1994; Montgomery, 1993). The ^{11}C which is produced is normally in the form of carbon dioxide (CO_2) (Endo, et al., 1995).

Table 3. Expected air activation reactions at linear accelerators.

Parent	Reaction	Daughter	Half-life
^{16}O	(n,p)	^{16}N	7.1 sec
^{16}O	(p,p' α 2n)	^{10}C	19.3 sec
^{14}N	(p,p' α 3n)		
^{16}O	(p,p'2n)	^{14}O	1.2 min
^{14}N	(p,n)		
^{16}O	(p,p'n)	^{15}O	2.0 min
^{16}O	(n,2n')		
^{16}O	(γ ,n)		
^{14}N	(p, γ)		
^{16}O	(p, α)	^{13}N	10.0 min
^{14}N	(p,p'n)		
^{14}N	(n,2n')		
^{14}N	(γ ,n)		
^{16}O	(p,p' α n)	^{11}C	20.3 min
^{14}N	(p, α)		
^{40}Ar	(n, γ)	^{41}Ar	110.0 min

Table 4. Stack gas composition for calendar year 1991 at LAMPF.

Nuclide	Half-life	Percent abundance in stack effluent (%)	Measured annual activity (Ci)
¹⁶ N	7.1 sec	1.8	1070
¹⁰ C	19.3 sec	4.5	2676
¹⁴ O	1.2 min	2.0	1189
¹⁵ O	2.0 min	59.6	35443
¹³ N	10.0 min	14.9	8861
¹¹ C	20.3 min	16.8	9991
⁴¹ Ar	110.0 min	0.5	268

The scrubber works by passing the radioactive air through two vertical columns where it interacts with a shower of a basic solution of water and sodium hydroxide (NaOH) (Fig. 4). The two stage design is more efficient than a one stage scrubber. The first stage is used remove the majority of contaminants from the airstream, while the second stage removes what is left. Each stage, or column, of the scrubber holds 36 gallons of water/NaOH solution. The airstream passes over a packed bed of acid-resistant filler of polypropylene that is continuously flooded with the recirculated water/ NaOH solution. In these two columns, nitric acid is neutralized, carbon dioxide is absorbed, and tritiated water vapor is removed from the airstream before it returns to the air delay line (Fig. 5).

Fig. 4. Stage one vertical column showing the position of the shower head, acid-resistant filler, and recirculated water.

Fig. 5. Direction of the air flow through the scrubber.

The water/NaOH solution is added to a surge tank where it mixes with distilled water being added to the scrubber. From the surge tank, the solution flows into the second stage of the scrubber and is pumped to the top of the column where it passes through a shower head. This shower head allows the solution to be more fully dispersed as it passes through the filler. The filler allows more surface area for the

solution to react with the airstream. The solution is then recirculated continuously through this stage. The solution is purged at a rate of 10 gallons per hour by allowing the solution to flow from stage two to stage one of the scrubber.

In stage one of the scrubber, the solution is continuously recirculated in the same fashion as stage two. The solution in stage one flows into a delay line and drain at 10 gallons per hour. This constant flow of the solution allows fresh NaOH solution to be continuously added to the scrubber. This keeps the system clean and allows the pH to be maintained at the proper level. The solution being purged from stage one flows down a water delay line to a drain which leads to sump pumps designated for handling radioactive waste. The length of the water delay line allows the ^{11}C in the purged solution to decay for over 200 minutes before being discharged to the sump pumps. This reduces the amount of radioactive waste being sent to the storage lagoons (Gonzales, 1995).

Maintaining a proper pH is essential for scrubbing CO_2 from the airstream. Carbon dioxide is absorbed into water through a reversible reaction shown in equation 1. This chemical equation shows how CO_2 reacts with water to form HCO_3^- (Quagliano, 1963). This carbonic acid drives the water to an acidic state. This chemical reaction is affected by pH.

Under normal standard temperature and pressure (STP), water and CO_2 reach an equilibrium pH of 5.5 due to the carbonic acids produced in equation 1 (Quagliano, 1963). Once equilibrium is met, the absorption of CO_2 would cease until the equilibrium is upset by the addition of distilled water or NaOH. More CO_2 can then be absorbed by increasing the pH with the addition of NaOH. Therefore, by keeping the scrubber at a basic pH by adding NaOH, the scrubber is able to absorb more CO_2 before it reaches equilibrium. The preferred level of the scrubber solution would be a pH of 12. A pH 12 is the preferred level, even though a higher pH would remove even more CO_2 , due to restrictions on the pH of waste streams drained to the holding tanks. The pH of the scrubber solution is maintained by changing the flow rates of distilled water and NaOH to the surge tank and stage two of the scrubber.

Most of the acid vapor, acid in solution, mist or droplets are removed. The HNO_3 vapor is neutralized by the NaOH in the solution. The HTO vapor condenses and exchanges with water in the scrubber and lowers the concentration in the airstream. The remainder of the water vapor is removed by baffles in the scrubber before the airstream returns to the delay-line (Gonzales, 1995).

Prediction Spreadsheet

A spreadsheet was developed to help predict the response of the scrubber to various inputs. Inputs on the spreadsheet include the input flow rates for water and NaOH. The spreadsheet also includes factors such as the respective volumes of the different components of the scrubber system.

The flow of the water and NaOH through the scrubber system was assumed to be in one direction, from one component to the next, for ease of calculation.

Calculations were made for each component of the system including percent NaOH, pH, and the percent CO₂ removed from the airstream.

Removal Efficiency Calculation

Three methods are used to calculate the removal efficiency of ¹¹C. The removal efficiency can be determined from monitoring the activity of the water solution in the scrubber system. The efficiency can also be determined by taking air samples from the delay-line before and after it enters the air-scrubber. Finally, the efficiency can be determined by measuring the ¹¹C activity in the delay line 100 minutes downstream from the air-scrubber.

Water Diagnostic Line

As the CO₂ is absorbed into the scrubber solution, the amount of ¹¹C in the scrubber solution is increased. By measuring the increase in activity of ¹¹C in the water solution, the overall removal efficiency may be calculated.

The water diagnostic line can only sample one stage of the scrubber at a time. Therefore, the efficiency found by using the water diagnostic line is only applicable to one stage of a two-stage system. The water diagnostic line can be used to closely watch effectiveness of the scrubber in removing ¹¹C as the distilled water and NaOH flow rates vary. It also gives a quick reading to determine the magnitude of dose rates from the scrubber. The dose rates measured with the water diagnostic line

while the scrubber is in operation can be compared to dose rates recorded while the scrubber is not in operation and from past data.

Air Sample Line

The removal efficiency can be determined by comparing the activated air composition in air samples taken from the delay line before and after the scrubber. By taking air samples from the delay line, the relative concentration of activated gases can be determined from analysis of the decay curve.

A linear regression analysis performed on the decay curves recorded from the air samples before and after the scrubber yields the concentration of ^{11}C , and other gases in each sample. By comparing the concentration of ^{11}C in the airstream before and after the scrubber, the overall efficiency can be determined.

HRS dome Air Sample Line

The air sampling point in the HRS dome is 100 minutes downstream from the scrubber. By the time the airstream reaches the sampling point, all the activated air components have had time to decay through 10 half-lives except ^{11}C and ^{41}Ar . It is therefore assumed that any activity in the airstream is due to the ^{11}C and ^{41}Ar .

Being a noble gas, it is assumed that the amount of ^{41}Ar in the airstream is unaffected by the operation of the scrubber. The concentration of ^{11}C in the airstream, however, depends on the efficiency of the scrubber. The relationship between the ^{11}C and ^{41}Ar activity can be used to determine the ^{11}C removal efficiency. Since the activity of the ^{41}Ar in the airstream should remain constant, the

activity of the ^{11}C for each sample will give a relative activity that is independent of the count time. Then by comparing the relative activities of the ^{11}C from each sample, the ^{11}C removal efficiency may be found.

The relative activities of ^{11}C and ^{41}Ar can be determined in the delay line using a HPGe scintillator to measure the photon spectrum. Taking the ratio of the ^{11}C activity to the ^{41}Ar activity gives a value that is independent of the data collection time; therefore, the $^{11}\text{C}/^{41}\text{Ar}$ ratios will be compared rather than just the ^{11}C activity. The efficiency of ^{11}C removal can be determined by taking the ratio of the normal $^{11}\text{C}/^{41}\text{Ar}$ ratio to the $^{11}\text{C}/^{41}\text{Ar}$ ratio when the scrubber is in operation.

Source Term Calculation

Once the efficiency of the scrubber is determined, the gamma field from the captured ^{11}C can be calculated assuming that the production rate of ^{11}C is 8 Ci per hour (Gonzales, 1995), assuming that there is no loss of ^{11}C in the system and that all the ^{11}C that is absorbed into the scrubber system is allowed time decay; the flow rate of the water in the scrubber is such that the ^{11}C is equally distributed throughout the scrubber. Using these assumptions, the source term for the scrubber can then be calculated from equation 2 (Faw and Shultis, 1993).

$$\text{Activity} = P(1 - \exp(-kt))/k \quad (2)$$

where $k = 0.693/20.69 \text{ min}$
and $P = \text{production rate.}$

Dose Rate Calculations

The scrubber was modeled as two vertical cylinders. Each cylinder is 5.33 meters (17.5 feet) tall and contains 137 liters (36 gallons) of water. Microshield[®], a modeling program developed by Grove Engineering, was used to calculate the dose rates from the scrubber. The model is explained in Appendix C.

Concrete shield blocks were installed around the scrubber system to lower the radiation field. To determine the effect of these shield blocks, the Microshield[®] model was changed to include the shield blocks and the dose rates were recalculated. These dose rate calculations were then compared to the actual dose rates recorded during a survey around the scrubber system.

MATERIALS

Analysis of the scrubber was performed using three separate measurement or sampling methods. A water sampling line was used to monitor the activity in the water solution in the air-scrubber system. Air sampling lines were used to take samples before and after the scrubber. Another air-sampling line was installed in the High Resolution Spectrometer (HRS) dome 100 minutes downstream from the scrubber. Each of these methods was used to calculate ^{11}C the removal efficiency.

Delay Line Air Scrubber

The scrubber was constructed during the summer of 1995 and added to the delay line for use during the 1995 LAMPF operations. The scrubber was constructed from 16-inch PVC pipe and installed in a drip pan designed to contain any water spills or leaks. The location of the scrubber in the drip pan in Area A East can be seen in Fig. 6.

The air drawn from the doghouse first passes through a high efficiency particulate filter (HEPA) which removes 99.9 % of particulates from the airstream (ASTM, 1993) as is tested by engineers at LANL. The air then passes through the scrubber and then through a section of the line that heats the air to reduce condensation of any water vapor in the airstream. After being heated, the airstream passes through a dual HEPA filter before it is finally returned to the delay-line.

Fig. 6. Location of the scrubber with respect to the drip pan in Area A East.

Water Diagnostic Line

A water diagnostic line was constructed to analyze the activity of the NaOH solution in the scrubber. One-inch PVC water lines were added to the scrubber system to remove water samples from the two stages. The water was piped to a diagnostic point where the water would be analyzed. The water filled the space between two concentric lengths of PVC pipe. The detector was placed in the center of the water diagnostic line. This design would approximate a $4\text{-}\pi$ geometry, and the water would help act as shielding from the nearby scrubber components (Fig. 7).

Fig. 7. Location of the diagnostic line with respect to the scrubber and shield blocks.

The diagnostic station is 63 inches long. It was constructed with a 6-inch diameter PVC pipe containing a 4-inch diameter PVC pipe inside running the length of the 6-inch pipe. The ends of the diagnostic line are capped to enclose the space between the 6-inch and 4-inch pipes while leaving the inside of the 4-inch pipe open to the air. Inside the space between the two pipes is the flow stream for the water to be analyzed. The water enters the diagnostic line through a coupling on one end of the 6 inch pipe and leaves from the other end of the 6-inch pipe through another coupling (Fig. 8).

Fig. 8. Diagram of the Diagnostic Station with a cutaway to show the position of the scintillator with respect to the water volume.

The water diagnostic line was designed to test one stage at a time. A valve at each stage could be opened to allow water from that stage to flow through the diagnostic line (Fig. 9). The water was then returned to the scrubber in one-inch PVC pipe. Care had to be taken to ensure the water in the diagnostic line was returned to the correct stage of the scrubber. If the water in the diagnostic line was returned to the wrong stage, it would contaminate the stage receiving the water sample and drain the water from one stage into the other affecting the efficiency of the scrubber and potentially burning the water pump on that stage.

Fig. 9. Plumbing diagram showing the valving system and the sampling lines to and from the water diagnostic station.

The inside diameter of 4-inch PVC pipe in the diagnostic line is large enough to accept a variety of instruments. A NMC GA-6 was used to monitor the radiation levels produced by the water in the diagnostic line. The GA-6 is a dose-rate meter that uses a 2 inch plastic scintillator connected to a self-contained rate-meter via a 50-foot cable. This allowed the scintillator to be inserted into the diagnostic station while the rate-meter was located behind the concrete shield blocks surrounding the scrubber system.

The electronics for the GA-6 has a built-in log-scale rate-meter connected to a paper strip chart recorder. The log scale allows dose rate measurement over many orders of magnitude. The data being recorded by the strip chart were also recorded by computer for more thorough examination (Fig. 10). The components used in the water diagnostic line electronics are listed in Table 5.

Fig. 10. Diagram of the counting electronics used to monitor the dose rates in the water diagnostic line.

Table 5. List of components used for the water diagnostic line counting electronics.

make	model	description	serial number
NMC	GD-6B	plastic scintillator	9-1576-27-56
NMC	GA-6	Gamma Radiation Monitor	LANL # 843351
Yokogawa	436001\A1	micro R chart recorder	C933CA863

Air Sample Line

The air sample lines were constructed using flexible one-inch tubing. One air sampling line was connected to the delay-line before the airstream enters the first stage of the scrubber. Another air sampling line was connected to the delay-line after the airstream leaves the scrubber. This air line sampled the airstream after it leaves the second stage of the system. A third air line was connected to the delay line as a return for the two air sampling lines (Fig 11).

The air samples were analyzed at a sampling station approximately 100 feet from the scrubber. This allowed the sampling station to be behind the concrete shield blocks which surround the scrubber system. This location reduced the background and reduced dose to persons working with the air sampling lines.

Fig. 11. Diagram of the air sampling lines and the valves used to control where the sample is taken from and to close the sample canister for a decay series.

Using an air pump, air samples were drawn from the delay-line to the sampling station through a canister where they were analyzed using a NaI detector. The air sampling line could be chosen by opening the associated valves at the canister and at the delay-line. The geometry of the detector and sample canister can be seen in Fig. 12. The output from the NaI detector was then sent to its associated counting electronics (Fig. 13) and was also recorded by computer (Table 6). Lead bricks were also used to shield the detector and canister from the scrubber and the high background in the area.

Fig. 12. The air sample detector geometry with the NaI detector and the sample container axially in-line and the dimensions of the sample container.

Fig. 13. Diagram of the air sample counting electronics used to record the decay series of the airstream samples.

Table 6. List of components used for the air sample line counting electronics.

make	model	description	serial number
Bicron	2MT 1/2	2 1/4" NaI and PMT	BI-758
Bicron	P-14	preamplifier	AA-474
Power Designs	2K20	HV DC power supply	108062
Tennelec	MB-1	portable NIM bin	1370
Tennelec	TC909	power supply	1407
Ortec	450	research amplifier	263
Ortec	124	preamplifier	454
Tennelec	TC 205A	Linear Amplifier	284
Ortec	455	timing SCA	2556211
Ortec	661	Ratemeter	
Graphtec	Microserver SR6421	chart recorder	
Canberra	1457	delay amplifier	261739
Ortec	401 A	NIM bin	102866
Tektronix	475 A	oscilloscope	
sample chamber			

HRS dome Air Sample Line

An air line was installed to sample the airstream in the delay-line in the HRS dome. The air sample was pumped through a 50-liter Kanne chamber outside the dome and returned to the delay-line at a point downstream from the sampling point. The Kanne chamber voltage was monitored using a Keithley voltmeter and recorded on a strip-chart.

A high-purity germanium detector (HPGe) detector was used to measure the gamma rays emanating from the air sample in the Kanne chamber (Fig. 14). The output of the HPGe detector was sent to the associated counting electronics and multi-channel analyzer (MCA) (Fig. 15 and Table 7). At this point, after being delayed 100 minutes by the delay-line, most of the radioactive components of the airstream have already decayed. The main components remaining are ^{11}C and ^{41}Ar . The 511-keV gamma rays emitted by the ^{11}C and the 1293-keV photons from the ^{41}Ar were counted by adjusting the discriminators on the counting electronics and by peak analysis on the MCA. The efficiency of ^{11}C removal could then be obtained by taking the ratio of the ^{11}C to ^{41}Ar before and after scrubber operation.

Fig. 14. The geometry of the detector in the HRS dome used to monitor the activity of the ^{11}C and ^{41}Ar in the Kanne chamber.

Fig. 15. Diagram of the counting electronics used in the HRS dome to measure the activities of the ^{11}C and ^{41}Ar in the Kanne chamber and to record the output of the Kanne chamber.

Table 7. List of the HRS dome air sample line counting electronics.

make	model	description
<u>Kanne Chamber</u>		
Keithley	485	picoammeter
Yokogawa	914435	chart recorder
<u>HPGe detector</u>		
<u>Canberra HPGe</u>		
detector	GC2018	scintillator and PMT
cryostat	7500SL	cryostat
preamplifier	2002CSL	preamplifier
Ortec	656	5K HV power supply
Tennelec	TC205A	linear amplifier
LEEP	NIM bin	NIM bin
Nucleus	Spectrum 88	MCA

METHODS

After construction of all the components to analyze the scrubber response, a spreadsheet was developed to predict the outcome of the scrubber response. This spreadsheet was developed by Mike Paciotti, Dave Fuehne, and myself. Using the initial values of the pH in each section of the scrubber, the water volumes in each, section and the rates of flow for the water and the NaOH into the system, the pH in each section could be predicted as a function of time. As the removal of CO₂ from the airstream is directly related to the pH of the solution (Paciotti, 1995), the percent of CO₂ remaining in the emissions airstream could be predicted. The governing equations for predicting the scrubber response can be seen in Table 8. A printout of the prediction results can be seen in Appendix B.

The spreadsheet values were used to set the initial settings for the flow rates for the water and NaOH into the scrubber. A graph of the predicted change in pH and CO₂ removal can be seen in Fig. 16. Flow rates for the water and NaOH had to be chosen which would result in a rapid increase in the pH. This was followed with a change in the flow rates which would result in a long period in which the pH was at a plateau. This combination would result in a rapid increase in the removal of CO₂ followed by a steady removal at this same rate. When the values of the proper flow rates were determined, the study could begin.

Table 8. The following equations were used in the prediction software to determine the response of the scrubber system to the input flow rates.

Surge tank NaOH concentration

(previous surge tank NaOH concentration * surge tank volume +
water flow rate * $^{\circ}\text{OH}$ concentration in pure water * change in time +
NaOH flow rate * $^{\circ}\text{OH}$ concentration in NaOH * change in time -
previous surge tank NaOH concentration * (water flow rate + NaOH flow rate) * change in time)/
surge tank volume

Surge tank pH

$-\log((1 * 10^{-14}) / (\text{surge tank NaOH concentration}))$

Stage 2 NaOH concentration

(previous stage 2 NaOH concentration * stage 2 volume +
surge tank NaOH concentration * (water flow rate + NaOH flow rate) * change in time -
previous stage 2 NaOH concentration * (water flow rate + NaOH flow rate) * change in time)/
stage 2 volume

Percent of CO_2 remaining in the airstream leaving stage 2

$\exp((- \text{moles } \text{CO}_2 \text{ scrubbed} / (\text{mole NaOH/liter}) \text{ in a stage}) * \text{stage 2 NaOH concentration}) * \text{\%CO}_2 \text{ leaving stage 1}$

Stage 2 pH

$-\log((1 * 10^{-14}) / (\text{stage 2 NaOH concentration}))$

Stage 1 NaOH concentration

(previous stage 1 NaOH concentration * stage 1 volume *
stage 2 NaOH concentration * (water flow rate + NaOH flow rate) * change in time -
previous stage 1 NaOH concentration * (water flow rate + NaOH flow rate) * change in time)/
stage 1 volume

Percent of CO_2 remaining in the airstream leaving stage 1

$\exp((- \text{moles } \text{CO}_2 \text{ scrubbed} / (\text{mole NaOH/liter}) \text{ in a stage}) * \text{stage 1 NaOH concentration})$

Stage 1 pH

$-\log((1 * 10^{-14}) / (\text{stage 1 NaOH concentration}))$

Neutralization tank NaOH concentration

(previous neutralization tank NaOH concentration * neutralization tank volume +
stage 1 NaOH concentration * (water flow rate + NaOH flow rate) * change in time -
previous tank NaOH concentration * (water flow rate + NaOH flow rate) * change in time)/
neutralization tank volume

Neutralization tank pH

$-\log((1 * 10^{-14}) / (\text{neutralization tank NaOH concentration}))$

Fig. 16. Prediction software printout showing the scrubber response to rates of flow of NaOH and distilled water. The lines representing NaOH-S.T., NaOH-S2, and NaOH-S1 represent the concentration of NaOH in the surge tank, stage 2 of the scrubber and stage one of the scrubber respectively. The lines representing CO₂-total and CO₂-S1 show the amount of CO₂ being removed from combined stages 1 and 2, and from stage 1 respectively.

Due to the high dose rates around the scrubber while the beam is on, the water diagnostic line was turned on prior to this study at a time when the H^+ beam had been turned off for a period of several hours. This allowed the dose rates around the scrubber to drop low enough to allow entry to turn the valves to monitor stage one of the scrubber. The stage one water diagnostic line stayed on for the entire period of the experiment. Data from the GA-6 scintillator in the water diagnostic line was recorded on strip chart and on computer.

An initial air sample, sample #1, was taken from the airstream leaving the second stage of the scrubber before the addition of NaOH to the system. This would act as a baseline and give a basis for comparison to determine the efficiency of CO_2 removal by the scrubber. The air sample line was run for approximately five minutes to flush out the ambient air from the sample chamber. Then the air pump for the sample line was turned off and the sample chamber was isolated by closing the valves on either side. Having secured the sample, the activity of the air was recorded as a function of time for future analysis. Data were recorded for a period of about two and one-half hours.

After establishing the initial conditions of the air leaving the second stage of the scrubber recorded, the NaOH solution was added to the system. The NaOH had an initial flow rate of 2 liters per hour and the initial flow rate of the water was 11 liters per hour. These values were chosen from the prediction spreadsheet to cause a

rapid increase in the pH of the scrubber system to quickly increase the amount of CO₂ being scrubbed.

After a period of 4 hours and 15 minutes, the NaOH flow was stopped and the water flow rate was increased to 45 liters per hour. The increased water flow rate, and cessation of NaOH solution, was predicted to bring the scrubber to an equilibrium, ceasing the rapid increase in pH. Immediately after the change in the flow rates, another sample, sample #2, of the air leaving the second stage of the scrubber was taken in the same manner as stated above and the air activity was recorded for a period of over two hours. This sample will be used to determine the scrubbing efficiency at this time in the experiment.

Using the half-lives of ¹⁵O, ¹³N, and ¹¹C, a linear regression analysis performed on the decay curves will yield the relative percent fractions of these radionuclides in the samples. These fractions can be used to determine the removal efficiency of ¹¹C by the scrubber.

When the system had been running for 6 hours and 15 minutes, 2 hours after the flow of the NaOH solution had been stopped, the flow rate of the water was reduced to 11 liters per hour. This regime was predicted to have the maximum CO₂ removal by the scrubber. The NaOH has evenly mixed throughout the scrubber system, and the water flow is slow enough to allow the pH to stay relatively level. A fast flow rate, or a continued flow rate of 45 liters per hour, would have resulted in flushing the NaOH from the system too quickly. This slower NaOH flow rate

allowed the system to remain at a relatively level pH for a longer period of time. A third air sample, sample #3, from the second stage was taken at this time using the same technique as the first two times and the activity recorded for a period of over two hours. This sample should show the maximum scrubbing efficiency.

Eight hours from experiment initiation, a radiological survey was performed to determine the dose rates at various points around the air-scrubber. According to the model, the maximum amount of CO_2 was being removed from the airstream due to the high concentration of NaOH throughout the system and the slow water flush rate. The locations of the survey points were recorded to allow for later dose rate calculations and comparisons.

The survey was conducted by a Radiological Control Technician (RCT) from the Health Physics group in ESH-1 at LANL using a RO-2 ion chamber to measure dose rates outside the scrubber drip-pan and a Teletector ion chamber to measure dose rates close to the scrubber. These detectors are part of the ESH-1 instrument pool and are checked for calibration before each use.

The activity of the airstream flowing through the HRS dome was monitored by a Kanne chamber and the microamperage from the chamber recorded on a strip chart. Any decrease in the ^{11}C in the air sample would result in a decrease in the microamperage. It was assumed that ^{41}Ar was unaffected by the operation of the scrubber and therefore the activity of the ^{41}Ar in the airstream would remain constant throughout the experiment.

The HPGe detector in the HRS dome monitored the activity of the air samples in the HRS dome Kanne chamber. At discreet times, the output of the HPGe detector was analyzed with the MCA to determine the activity of the ^{11}C and ^{41}Ar in the air sample. The relative activities of the ^{11}C and ^{41}Ar will be used to determine the percent removal of ^{11}C from the airstream by the scrubber.

RESULTS

Water Diagnostic Line Results

The water diagnostic line was monitored by a NMC GA-6 dose rate meter. This rate meter was attached to a strip chart recorder and also a personal computer for data storage. A portion of the strip from the first 12 hours of the experiment can be seen in Appendix A. Figures 17 and 18 show the results from the values recorded by the computer; Figure 17 is for all 25 hours of the experiment, while Fig. 18 shows only the first four hours.

Figure 17 shows the steady dose rates from the water diagnostic line as the scrubber began operation and also shows how the rate increases as the system began scrubbing the airstream. There are several dips in the line before the scrubber began operation. There are also some dips in the line as the dose rate increases which make the line appear to be notched. These dips in the line are from when the proton beam was turned off for brief periods of time. These dips can also be seen in Fig. 17 which is a computer record of the same data recorded on the strip chart.

Figure 18 shows how the dose rates measured in the water diagnostic line changed over the first four hours of scrubber operation. This expanded time view allows a closer look at how the dose rates changed as the NaOH solution entered the system and spread from stage two to stage one.

Fig. 17. Dose rate response recorded from the scintillator in the water diagnostic station.

Fig. 18. Dose rate response (during the first four hours) recorded from the scintillator in the water diagnostic station.

Air Sample Line Results

Air samples were taken before and during the experiment. These air samples were allowed to decay and their decay curves recorded. The decay curve for the air sample taken before scrubber operation can be seen in Fig. 19. The air sample decay curves recorded during the experiment when the scrubber was operating can be seen in Figures 20 and 21. The two samples taken during the experiment were acquired while the maximum amount of CO₂ was being scrubbed as determined from the prediction chart and from monitoring the water diagnostic station.

Fig. 19. Decay curve for sample number one.

Fig. 20. Decay curve for sample number two.

Fig. 21. Decay curve for sample number three.

HRS dome Air Sample Line Results

The activity of the effluent in the delay line was measured with an air sample line in the HRS dome. A Kanne chamber hooked up to a picoammeter and strip chart recorder measured the overall activity of the air samples. Figure 22 shows the Kanne chamber data. The dips in the line are from brief periods of time where the beam was turned off. Appendix A shows a portion of the analog strip chart from the Kanne chamber.

Fig. 22. Levels of activity in the HRS Kanne chamber as more ^{11}C is being removed by the air scrubber.

A germanium detector was used to perform gamma spectrometry of the effluent gases in the Kanne chamber. Relative peaks for the ^{11}C and ^{41}Ar are recorded in Table 9. This table also contains the ratio of ^{11}C to ^{41}Ar which is used to determine the removal efficiency of the scrubber.

Table 9. HRS dome ^{11}C and ^{41}Ar count rates and ratios.

time	Carbon-11 511 keV peak		Argon-41 1293 keV peak		ratio ($^{11}\text{C} / ^{41}\text{Ar}$)
	(net counts/sec)	(% error)	(net counts/sec)	(% error)	
1247	479.51		7.78		61.6
1510	362.70	0.12	5.64	0.79	64.3
1515	367.50	0.06	5.70	0.50	64.4
1615	417.11	0.16	7.78	1.16	53.6
1715	369.46	0.08	7.77	0.57	47.5
1730	325.33	0.25	8.07	1.56	40.3
2245	261.19	0.34	7.59	2.06	34.4
2250	260.70	0.29	7.63	1.69	34.2
2257	260.07	0.41	8.26	2.28	31.5

Radiological Survey Results

Figure 23 shows the results of the survey of the scrubber itself during operation. Figures 24 through 28 show the results of a series of radiological surveys taken over a period of several days before the scrubber began operation. The results of the radiological survey of the A6 North area taken during the scrubber operation can be seen in Fig. 29. The predicted dose rates for the scrubber area can be seen in

Figures 30 and 31. These figures show the predicted values for the dose rates with and without the shielding in place around the scrubber. The printouts for the dose rate calculations can be seen in Appendix C.

Fig. 23. Results of the radiological survey of the scrubber performed on September 22, 1995. The dose rates are recorded in mR/hr.

Fig. 24. Radiological survey of A6 North on August 3, 1995, (values in mR/hr).

Fig. 25. Radiological survey of A6 North on August 4, 1995, (values in mR/hr).

Fig. 26. Radiological survey of A6 North on August 6, 1995, (values in mR/hr).

Fig. 27. Radiological survey of A6 North on August 10, 1995, (values in mR/hr).

Fig. 28. Radiological survey of A6 North on August 13, 1995, (values in mR/hr).

Fig. 29. Radiological survey of A6 North on September 22, 1995, (values in mR/hr).

Fig. 30. Predicted dose rates with scrubber not operating, (values in mR/hr).

Fig. 31. Predicted dose rates when scrubber is operating, (values in mR/hr).

DISCUSSION

The efficiency of the scrubber was determined from the data collected from the air sample lines and the HRS dome. The decay curves from the air sample lines were analyzed for the fraction of ^{15}O , ^{13}N , and ^{11}C . These fractions were compared to determine the efficiency of ^{11}C removal. The ratios of the relative activities of ^{11}C to ^{41}Ar measured in the HRS dome were compared to determine the efficiency of ^{11}C removal.

A comparison of the three decay curves taken from the air sample lines is shown in Fig. 32. A reduction in the radioactive air components of the effluent in the delay line after the scrubber began operation is apparent from these curves. By performing a linear regression analysis on each decay curve the percentages of ^{11}C , ^{15}O , and ^{13}N can be inferred. The results of the linear regression analysis are shown in Table 10. Once the fractions of the radionuclides in the airstream were determined, the change in those fractions were used to calculate the ^{11}C removal efficiency.

Fig. 32. Comparison of the three decay curves taken from the three air samples

Table 10. Results of a linear regression analysis of each air sample which shows the partial fractions of ^{15}O , ^{13}N , and ^{11}C .

sample	partial fractions			r^2
	^{15}O	^{13}N	^{11}C	
sample 1	0.4688	0.0785	0.4526	0.99932
standard error	0.656	0.856	0.572	
sample 2	0.5516	0.1778	0.2706	0.99913
standard error	0.579	0.755	0.504	
sample 3	0.5677	0.1818	0.2505	0.99916
standard error	0.593	0.798	0.545	

The efficiency of ^{11}C removal can be determined by comparing the results of the analyses of the three samples. The results of the linear regression analysis of the first air sample shows that 45.3 % of the activity in the airstream comes from ^{11}C . Results from the second and third air samples show that ^{11}C produces 27.1 % and 25.1 % of the activity in the airstream respectively. Using these values gives an efficiency of removal of 41.2 % from the second sample and 45.6 % from the third sample.

An inspection of the strip chart recording the Kanne chamber line current shows the reduction of ^{11}C shows decrease in activity in the airstream as scrubbing efficiency increases. The reduction in current as the efficiency increased can be seen in Fig. 22. A more quantitative value for the scrubbing efficiency can be determined by comparing the ^{11}C to ^{41}Ar ratios recorded in Table 8 in the Results section. A comparison of these ratios and the calculated efficiencies can be seen in Table 11. Figure 33 illustrates the scrubbing efficiency with respect to time.

Table 11. ^{11}C removal efficiency calculated from the $^{11}\text{C}/^{41}\text{Ar}$ ratios as a function of time.

time	ratio	percent reduction	error (%)
1510	64.3	0.00	9.01
1515	64.4	-0.16	5.65
1615	53.6	16.64	7.99
1715	47.5	26.13	3.48
1730	40.3	37.33	7.79
2245	34.4	46.50	9.34
2250	34.2	46.81	7.58
2257	34.4	46.50	9.50

Fig. 33. Graph of the scrubber removal efficiency of ^{11}C with respect to time taken from the ratios recorded in the HRS dome.

The radiological surveys show a relatively high background radiation in the scrubber area compared to the field induced by the scrubbed radionuclides. This background radiation is due to activated air components leaking from the beam-stop doghouse and from the target areas. This background radiation makes it difficult to compare calculated dose rates to those that are measured in the area, except in close proximity to the scrubber.

The background radiation remains fairly constant during the series of radiological surveys performed prior to operating the scrubber. However, there is an increase in the background on the survey recorded on August 13, 1995. In closer proximity to the scrubber, a gradual increase in the dose rates can be seen during the series of surveys. This increase in the dose rates may have been the result of a water leak in the water damper around the beam stop. This water leak sprayed water directly into the proton beam.

The dose rates measured during the scrubber operation were also probably elevated by the same effect. The dose rates measured in the scrubber area was even higher than that measured on August 13, 1995. This higher background is probably due to more activated air products leaking from the doghouse and is probably not a higher dose rate as a result of the scrubber operation.

The dose rates measured in close proximity to the scrubber showed a dramatic increase when the scrubber began operation going from 200 mR/hr to 1000 mR/hr. This is likely due to the removal of $^{11}\text{CO}_2$ into the scrubber solution. The calculated

dose rates close to the scrubber closely match those values actually measured. The calculated dose rates in the area around the scrubber behind the shield blocks is harder to compare to the measured values. Figures 32 and 33 show the calculated dose rates at several points. Figure 32 shows the predicted values using only the activated air products passing through the scrubber as the source term. Figure 33 shows the predicted dose rates using the activated air products plus the ^{11}C which has been removed by the scrubber as the source term.

The dose rates for both cases were calculated with and without shielding. This prediction shows that the shielding around the scrubber is very effective at reducing the dose rates in the working area around the scrubber area. However, due to the background radiation, these predictions cannot be compared to dose rates from the scrubber.

The data from the water diagnostic line was not used to calculate the removal efficiency of ^{11}C . It could not be determined how much the ^{15}O or ^{13}N that may have been scrubbed contributed to the dose rates. The water line was used to determine when the CO_2 removal had reached a plateau. This line was also as a tool to measure the dose rates from the water in the scrubber so the RCT crew could determine when it was safe to enter the scrubber area. The water diagnostic line was used to determine whether or not the scrubber was working.

CONCLUSION

This study was conducted as a proof of concept. There were several areas of interest concerning the addition of an air scrubber to the existing delay line. The efficiency of ^{11}C removal was of interest due to its relatively long half-life. The dose rates from the scrubber as the source term was important because LANL employees need to perform maintenance operations while the scrubber is in operation. This dose rate is also important to understand the effectiveness of the shield blocks used to reduce the dose rates from the scrubber. This study showed that there was no real increase in the dose rates from the scrubber measured outside the shield blocks.

The efficiency of ^{11}C removal was determined to be approximately 51 %. The removal efficiency from the air samples taken from the scrubber gave a removal efficiency of $45.6 \pm 0.015\%$. The removal efficiency determined from the HRS dome sample line gave a value of $51 \pm 0.24 \%$. These values are very similar considering the different methods used to determine the efficiency. The errors seem very small, but do not include any error that may have produced from varying production ^{41}Ar and how it was affected by the scrubber. The error also did not include other factors such as the reliability of the air pumps and other equipment.

The method used in the HRS dome has the least inherent error. The samples from the air sample lines at the scrubber gave the fractions of the activity of the radionuclides in each air sample. The main error in this method is from how the fractions of the ^{13}N , ^{15}O and ^{11}C change to produce the overall activity in each air

sample as the amount of ^{11}C in the airstream is reduced. The Amounts of ^{15}O and ^{13}N in the airstream should have also been reduced. The method used in the HRS dome depends only on the comparison of the activities of ^{41}Ar ^{11}C .

The water diagnostic line was not used to find the efficiency of ^{11}C removal. This method needed more information than what was gathered for this study. Not only was ^{11}C removed from the airstream, but also ^{15}O and ^{13}N in the forms of HNO_3 (nitric acid) and CO_2 . The percentages removed were not able to be predicted due to the lack of control of the pH of the system.

The dose rates were calculated for when the scrubber was in operation and when the scrubber was not in operation. These rates were compared to the actual values measured. For points close to the scrubber, the calculated and measured values were within a factor of two. For points far from the scrubber, or behind shield blocks, the calculated values could not be compared to the measured rates due to the high radiation background. Therefore, the predicted values could not be confirmed.

The dose rates while the scrubber was not in operation were calculated to be reduced by a factor of almost 200 with the addition of the shield blocks. While the scrubber was in operation, the dose rates were calculated to be 500 to 600 times less with the addition of the shield blocks. These calculations show that the shield blocks in place effectively reduce the dose rates from the scrubber to well below the 0.5mR/hr level due to the scrubbed ^{11}C and the radionuclides in the airstream.

FUTURE WORK

Future work on the LAMPF scrubber can be conducted in several areas to expand on this research. This was only a proof of concept study, the scrubber was not fully operational. Future work could involve an analysis of the scrubber system while the system is operating under normal conditions. Under normal operating conditions, with the scrubber operating for long periods of time, many measurements could be taken to ensure the validity of the data.

During this study, the pH meters in the scrubber system did not respond properly. This limited the ability to finely monitor the pH of the scrubber system. Future work could be performed with more control of the pH levels in the scrubber. This would enable the system to work under optimal conditions and could vary the removal efficiency of CO₂.

Finally, This study was performed while a leak was spraying water into the proton beam. Future work could be planned so an analysis of the scrubber system could be performed under normal linac operation.

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APPENDIX A
ANALOG DATA

This appendix contains the analog strip chart data taken from the water diagnostic line and the HRS dome air sample line. The first strip chart is from the water diagnostic line. The second strip chart is from the HRS dome Kanne chamber.

The water daignostic line strip chart had a feed rate of 2 cm per hour. Each line is one centimeter apart, therefore each line represents 30 minutes change in time. The strip chart was also calibrated for a full scale equal to 46.9 mV. This gave a total range of 0 mV to 46.9 mV which represented a dose rate range from 0 mR/hr to 10 R/hr at full range.

The second chart is a recording of the HRS dome Kanne chamber response. This chart was also fed at a rate of 2 cm per hour. The scale was set for a range from 0 to 9.75 mV. This chart differs also from the water diagnostic line in that this chart has a linear scale as opposed to a log scale.

Figure 17

APPENDIX B
PREDICTION SPREADSHEET

This appendix contains a printout of the flow rate prediction software. This spreadsheet was used to help what distilled water and NaOH flow rates were required for the correct response from the scrubber. By changing the flow rates at particular times, it was possible to predict what the NaOH concentration would be in each stage of the scrubber system. This also allowed the amount of CO₂ being scrubbed in each component to be estimated. With this information, it was possible to plan when to take samples to be analyzed.

PLot out transient response of scrubber

Water flow	11 liters/hr	Moles CO2 scrubbed		1.020		
NaOH rate	2 liters/hr	per mole NaOH/l in a stage.			neut. tank	hold tank
Volume surge tank	120 liters				capacity	capacity
Vol of each stage (1&2)	170 liters	OH conc (pure water)	1.00E-07 mol/L		liters	liters
Vol of neutralization tank	756 liters	OH conc (NaOH soln)	19.4 mol/L			
Vol of holding tank	9450 liters	XO2 Water flow	151.200 L/hr			
Delta-t	0.1 hrs	XO2 Water OH conc	1E-09 mol/L		756	9450
	Water	NaOH	c(NaOH)	c(CO2)		
	flow	flow	surge	c(NaOH)	c(CO2)	
	rate	rate	tank	stage 2	exit fraction	
	L/hr	L/hr	mol/L	mol/L	of nat. conc.	
					% S2	
Time						
hr						
0	11	0	1.000E-07	0.000	1.000	7.000
0.1	11	2	3.233E-02	0.000	1.000	12.510
0.2	11	2	6.432E-02	0.001	0.999	12.808
0.3	11	2	9.595E-02	0.001	0.998	12.982
0.4	11	2	1.272E-01	0.002	0.997	13.105
0.5	11	2	1.582E-01	0.004	0.996	13.199
0.6	11	2	1.888E-01	0.005	0.995	13.276
0.7	11	2	2.191E-01	0.007	0.993	13.341
0.8	11	2	2.491E-01	0.009	0.991	13.396
0.9	11	2	2.787E-01	0.011	0.989	13.445
1	11	2	3.080E-01	0.013	0.987	13.489
1.1	11	2	3.370E-01	0.015	0.984	13.528
1.2	11	2	3.657E-01	0.018	0.981	13.563
1.3	11	2	3.941E-01	0.021	0.978	13.596
1.4	11	2	4.221E-01	0.024	0.975	13.625
1.5	11	2	4.499E-01	0.027	0.971	13.653
1.6	11	2	4.774E-01	0.031	0.968	13.679
1.7	11	2	5.045E-01	0.034	0.964	13.703
1.8	11	2	5.314E-01	0.038	0.960	13.725
1.9	11	2	5.580E-01	0.042	0.956	13.747
2	11	2	5.842E-01	0.046	0.951	13.767
2.1	11	2	6.103E-01	0.050	0.947	13.786
2.2	11	2	6.360E-01	0.055	0.942	13.803
2.3	11	2	6.614E-01	0.060	0.937	13.820
2.4	11	2	6.866E-01	0.064	0.932	13.837
2.5	11	2	7.115E-01	0.069	0.927	13.852
2.6	11	2	7.361E-01	0.074	0.922	13.867
2.7	11	2	7.605E-01	0.080	0.916	13.881
2.8	11	2	7.846E-01	0.085	0.911	13.895
2.9	11	2	8.084E-01	0.091	0.905	13.908
3	11	2	8.320E-01	0.096	0.899	13.920
3.1	11	2	8.553E-01	0.102	0.893	13.932
3.2	11	2	8.784E-01	0.108	0.887	13.944
3.3	11	2	9.012E-01	0.114	0.881	13.955

3.4	11	2	9.237E-01	0.120	0.875	13.966	13.080	0.011	0.989	12.037	1.79E-04	10.252	4.60E-06	8.663
3.5	11	2	9.461E-01	0.127	0.868	13.976	13.102	0.012	0.988	12.071	1.99E-04	10.298	5.09E-06	8.706
3.6	11	2	9.682E-01	0.133	0.862	13.986	13.124	0.013	0.987	12.104	2.20E-04	10.343	5.61E-06	8.749
3.7	11	2	9.900E-01	0.140	0.855	13.996	13.145	0.014	0.986	12.135	2.43E-04	10.386	6.18E-06	8.791
3.8	11	2	1.012E+00	0.146	0.849	14.005	13.165	0.015	0.985	12.167	2.68E-04	10.428	6.78E-06	8.831
3.9	11	2	1.033E+00	0.153	0.842	14.014	13.185	0.016	0.984	12.197	2.95E-04	10.469	7.43E-06	8.871
4	11	2	1.054E+00	0.160	0.835	14.023	13.204	0.017	0.983	12.226	3.23E-04	10.509	8.13E-06	8.910
4.1	11	2	1.075E+00	0.167	0.828	14.031	13.222	0.018	0.982	12.255	3.53E-04	10.548	8.87E-06	8.948
4.2	11	2	1.096E+00	0.174	0.821	14.040	13.240	0.019	0.981	12.283	3.86E-04	10.586	9.66E-06	8.985
4.3	45	0	1.055E+00	0.197	0.798	14.023	13.295	0.024	0.976	12.378	5.26E-04	10.721	1.33E-05	9.124
4.4	45	0	1.015E+00	0.219	0.777	14.007	13.340	0.029	0.971	12.463	6.95E-04	10.842	1.80E-05	9.255
4.5	45	0	9.770E-01	0.239	0.757	13.990	13.378	0.035	0.965	12.539	8.97E-04	10.953	2.39E-05	9.379
4.6	45	0	9.404E-01	0.258	0.738	13.973	13.411	0.040	0.960	12.607	1.13E-03	11.054	3.13E-05	9.495
4.7	45	0	9.051E-01	0.275	0.721	13.957	13.439	0.047	0.953	12.669	1.40E-03	11.147	4.02E-05	9.604
4.8	45	0	8.712E-01	0.290	0.704	13.940	13.463	0.053	0.947	12.725	1.71E-03	11.234	5.08E-05	9.706
4.9	45	0	8.385E-01	0.305	0.689	13.924	13.484	0.060	0.941	12.777	2.06E-03	11.313	6.33E-05	9.801
5	45	0	8.071E-01	0.318	0.675	13.907	13.503	0.067	0.934	12.824	2.44E-03	11.388	7.78E-05	9.891
5.1	45	0	7.768E-01	0.330	0.662	13.890	13.519	0.074	0.928	12.867	2.87E-03	11.457	9.45E-05	9.976
5.2	45	0	7.477E-01	0.341	0.650	13.874	13.533	0.081	0.921	12.907	3.33E-03	11.522	1.14E-04	10.055
5.3	45	0	7.196E-01	0.351	0.639	13.857	13.546	0.088	0.914	12.944	3.83E-03	11.583	1.35E-04	10.131
5.4	45	0	6.926E-01	0.360	0.628	13.841	13.557	0.095	0.908	12.978	4.38E-03	11.641	1.59E-04	10.202
5.5	45	0	6.667E-01	0.369	0.619	13.824	13.566	0.102	0.901	13.010	4.96E-03	11.695	1.86E-04	10.270
5.6	45	0	6.417E-01	0.376	0.610	13.807	13.575	0.110	0.894	13.040	5.58E-03	11.747	2.16E-04	10.334
5.7	45	0	6.176E-01	0.382	0.601	13.791	13.582	0.117	0.888	13.067	6.24E-03	11.795	2.48E-04	10.395
5.8	45	0	5.944E-01	0.388	0.593	13.774	13.589	0.124	0.881	13.093	6.94E-03	11.842	2.84E-04	10.453
5.9	45	0	5.722E-01	0.393	0.586	13.758	13.594	0.131	0.875	13.117	7.68E-03	11.885	3.23E-04	10.509
6	45	0	5.507E-01	0.397	0.580	13.741	13.599	0.138	0.869	13.140	8.46E-03	11.927	3.65E-04	10.562
6.1	45	0	5.300E-01	0.400	0.573	13.724	13.602	0.145	0.863	13.161	9.27E-03	11.967	4.10E-04	10.613
6.2	45	0	5.102E-01	0.403	0.568	13.708	13.606	0.152	0.857	13.181	1.01E-02	12.005	4.58E-04	10.661
6.3	11	0	5.055E-01	0.404	0.566	13.704	13.606	0.153	0.855	13.186	1.03E-02	12.014	4.70E-04	10.672
6.4	11	0	5.009E-01	0.405	0.565	13.700	13.607	0.155	0.854	13.191	1.05E-02	12.023	4.82E-04	10.683
6.5	11	0	4.963E-01	0.405	0.564	13.696	13.608	0.157	0.852	13.195	1.08E-02	12.031	4.94E-04	10.694
6.6	11	0	4.917E-01	0.406	0.563	13.692	13.608	0.158	0.851	13.200	1.10E-02	12.040	5.06E-04	10.705
6.7	11	0	4.872E-01	0.406	0.561	13.688	13.609	0.160	0.849	13.204	1.12E-02	12.049	5.19E-04	10.715
6.8	11	0	4.827E-01	0.407	0.560	13.684	13.609	0.162	0.848	13.208	1.14E-02	12.057	5.31E-04	10.725
6.9	11	0	4.783E-01	0.407	0.559	13.680	13.610	0.163	0.847	13.212	1.16E-02	12.065	5.43E-04	10.735
7	11	0	4.739E-01	0.408	0.558	13.676	13.610	0.165	0.845	13.217	1.18E-02	12.073	5.55E-04	10.745
7.1	11	0	4.696E-01	0.408	0.557	13.672	13.611	0.166	0.844	13.221	1.21E-02	12.082	5.68E-04	10.754
7.2	11	0	4.653E-01	0.408	0.556	13.668	13.611	0.168	0.843	13.225	1.23E-02	12.090	5.80E-04	10.764
7.3	11	0	4.610E-01	0.409	0.555	13.664	13.611	0.169	0.841	13.229	1.25E-02	12.098	5.93E-04	10.773
7.4	11	0	4.568E-01	0.409	0.553	13.660	13.612	0.171	0.840	13.233	1.28E-02	12.106	6.05E-04	10.782
7.5	11	0	4.526E-01	0.409	0.552	13.656	13.612	0.172	0.839	13.237	1.30E-02	12.113	6.18E-04	10.791
7.6	11	0	4.485E-01	0.410	0.551	13.652	13.612	0.174	0.837	13.241	1.32E-02	12.121	6.30E-04	10.800
7.7	11	0	4.444E-01	0.410	0.550	13.648	13.613	0.176	0.836	13.244	1.35E-02	12.129	6.43E-04	10.808
7.8	11	0	4.403E-01	0.410	0.549	13.644	13.613	0.177	0.835	13.248	1.37E-02	12.137	6.56E-04	10.817
7.9	11	0	4.362E-01	0.410	0.549	13.640	13.613	0.179	0.834	13.252	1.39E-02	12.144	6.69E-04	10.825
8	11	0	4.322E-01	0.410	0.548	13.636	13.613	0.180	0.832	13.255	1.42E-02	12.152	6.82E-04	10.834
8.1	11	0	4.283E-01	0.410	0.547	13.632	13.613	0.182	0.831	13.259	1.44E-02	12.159	6.95E-04	10.842

8.2	11	0	4.244E-01	0.411	0.546	13.628	13.613	0.183	0.830	13.262	1.47E-02	12.166	7.08E-04	10.850
8.3	11	0	4.205E-01	0.411	0.545	13.624	13.613	0.184	0.828	13.266	1.49E-02	12.174	7.21E-04	10.858
8.4	11	0	4.166E-01	0.411	0.544	13.620	13.613	0.186	0.827	13.269	1.52E-02	12.181	7.34E-04	10.866
8.5	11	0	4.128E-01	0.411	0.543	13.616	13.613	0.187	0.826	13.273	1.54E-02	12.188	7.47E-04	10.873
8.6	11	0	4.090E-01	0.411	0.543	13.612	13.613	0.189	0.825	13.276	1.57E-02	12.195	7.60E-04	10.881
8.7	11	0	4.053E-01	0.411	0.542	13.608	13.613	0.190	0.824	13.279	1.59E-02	12.202	7.74E-04	10.888
8.8	11	0	4.015E-01	0.411	0.541	13.604	13.613	0.192	0.822	13.283	1.62E-02	12.209	7.87E-04	10.896
8.9	11	0	3.979E-01	0.410	0.540	13.600	13.613	0.193	0.821	13.286	1.64E-02	12.216	8.00E-04	10.903
9	11	0	3.942E-01	0.410	0.540	13.596	13.613	0.195	0.820	13.289	1.67E-02	12.222	8.14E-04	10.911
9.1	11	0	3.906E-01	0.410	0.539	13.592	13.613	0.196	0.819	13.292	1.70E-02	12.229	8.27E-04	10.918
9.2	11	0	3.870E-01	0.410	0.538	13.588	13.613	0.197	0.818	13.295	1.72E-02	12.236	8.41E-04	10.925
9.3	11	0	3.835E-01	0.410	0.538	13.584	13.613	0.199	0.817	13.298	1.75E-02	12.242	8.55E-04	10.932
9.4	11	0	3.800E-01	0.410	0.537	13.580	13.612	0.200	0.815	13.301	1.77E-02	12.249	8.68E-04	10.939
9.5	11	0	3.765E-01	0.409	0.536	13.576	13.612	0.201	0.814	13.304	1.80E-02	12.256	8.82E-04	10.946
9.6	11	0	3.730E-01	0.409	0.536	13.572	13.612	0.203	0.813	13.307	1.83E-02	12.262	8.96E-04	10.952
9.7	11	0	3.696E-01	0.409	0.535	13.568	13.612	0.204	0.812	13.310	1.86E-02	12.268	9.10E-04	10.959
9.8	11	0	3.662E-01	0.409	0.535	13.564	13.611	0.205	0.811	13.313	1.88E-02	12.275	9.24E-04	10.966
9.9	11	0	3.629E-01	0.408	0.534	13.560	13.611	0.207	0.810	13.315	1.91E-02	12.281	9.38E-04	10.972
10	11	0	3.595E-01	0.408	0.533	13.556	13.611	0.208	0.809	13.318	1.94E-02	12.287	9.52E-04	10.979
10.1	11	0	3.562E-01	0.408	0.533	13.552	13.610	0.209	0.808	13.321	1.96E-02	12.293	9.66E-04	10.985
10.2	11	0	3.530E-01	0.407	0.532	13.548	13.610	0.211	0.807	13.323	1.99E-02	12.299	9.80E-04	10.991
10.3	11	0	3.497E-01	0.407	0.532	13.544	13.610	0.212	0.806	13.326	2.02E-02	12.305	9.95E-04	10.998
10.4	11	0	3.465E-01	0.407	0.531	13.540	13.609	0.213	0.805	13.329	2.05E-02	12.311	1.01E-03	11.004
10.5	11	0	3.434E-01	0.406	0.531	13.536	13.609	0.214	0.804	13.331	2.08E-02	12.317	1.02E-03	11.010
10.6	11	0	3.402E-01	0.406	0.531	13.532	13.608	0.216	0.803	13.334	2.10E-02	12.323	1.04E-03	11.016
10.7	11	0	3.371E-01	0.405	0.530	13.528	13.608	0.217	0.802	13.336	2.13E-02	12.329	1.05E-03	11.022
10.8	11	0	3.340E-01	0.405	0.530	13.524	13.607	0.218	0.801	13.339	2.16E-02	12.335	1.07E-03	11.028
10.9	11	0	3.309E-01	0.404	0.529	13.520	13.607	0.219	0.800	13.341	2.19E-02	12.341	1.08E-03	11.034
11	11	0	3.279E-01	0.404	0.529	13.516	13.606	0.220	0.799	13.343	2.22E-02	12.346	1.10E-03	11.040
11.1	11	0	3.249E-01	0.403	0.529	13.512	13.606	0.222	0.798	13.346	2.25E-02	12.352	1.11E-03	11.046
11.2	11	0	3.219E-01	0.403	0.528	13.508	13.605	0.223	0.797	13.348	2.28E-02	12.358	1.13E-03	11.051
11.3	11	0	3.190E-01	0.402	0.528	13.504	13.605	0.224	0.796	13.350	2.31E-02	12.363	1.14E-03	11.057
11.4	11	0	3.160E-01	0.402	0.528	13.500	13.604	0.225	0.795	13.352	2.34E-02	12.369	1.16E-03	11.063
11.5	11	0	3.131E-01	0.401	0.527	13.496	13.603	0.226	0.794	13.355	2.37E-02	12.374	1.17E-03	11.068
11.6	11	0	3.103E-01	0.401	0.527	13.492	13.603	0.227	0.793	13.357	2.40E-02	12.379	1.19E-03	11.074
11.7	11	0	3.074E-01	0.400	0.527	13.488	13.602	0.228	0.792	13.359	2.43E-02	12.385	1.20E-03	11.079
11.8	11	0	3.046E-01	0.399	0.526	13.484	13.601	0.230	0.791	13.361	2.46E-02	12.390	1.22E-03	11.085
11.9	11	0	3.018E-01	0.399	0.526	13.480	13.601	0.231	0.790	13.363	2.49E-02	12.395	1.23E-03	11.090
12	11	0	2.991E-01	0.398	0.526	13.476	13.600	0.232	0.789	13.365	2.52E-02	12.401	1.25E-03	11.096
12.1	11	0	2.963E-01	0.397	0.526	13.472	13.599	0.233	0.789	13.367	2.55E-02	12.406	1.26E-03	11.101
12.2	11	0	2.936E-01	0.397	0.526	13.468	13.599	0.234	0.788	13.369	2.58E-02	12.411	1.28E-03	11.106
12.3	11	0	2.909E-01	0.396	0.525	13.464	13.598	0.235	0.787	13.371	2.61E-02	12.416	1.29E-03	11.111
12.4	11	0	2.882E-01	0.395	0.525	13.460	13.597	0.236	0.786	13.373	2.64E-02	12.421	1.31E-03	11.117
12.5	11	0	2.856E-01	0.395	0.525	13.456	13.596	0.237	0.785	13.375	2.67E-02	12.426	1.32E-03	11.122
12.6	11	0	2.830E-01	0.394	0.525	13.452	13.595	0.238	0.784	13.377	2.70E-02	12.431	1.34E-03	11.127
12.7	11	0	2.804E-01	0.393	0.525	13.448	13.595	0.239	0.784	13.378	2.73E-02	12.436	1.35E-03	11.132
12.8	11	0	2.778E-01	0.393	0.525	13.444	13.594	0.240	0.783	13.380	2.76E-02	12.441	1.37E-03	11.137
12.9	11	0	2.753E-01	0.392	0.524	13.440	13.593	0.241	0.782	13.382	2.79E-02	12.446	1.39E-03	11.142

13	11	0	2.727E-01	0.391	0.524	13.436	13.592	0.242	0.781	13.384	2.82E-02	12.451	1.40E-03	11.147
13.1	11	0	2.702E-01	0.390	0.524	13.432	13.591	0.243	0.781	13.386	2.85E-02	12.455	1.42E-03	11.152
13.2	11	0	2.678E-01	0.389	0.524	13.428	13.590	0.244	0.780	13.387	2.88E-02	12.460	1.43E-03	11.156
13.3	11	0	2.653E-01	0.389	0.524	13.424	13.590	0.245	0.779	13.389	2.92E-02	12.465	1.45E-03	11.161
13.4	11	0	2.629E-01	0.388	0.524	13.420	13.589	0.246	0.778	13.390	2.95E-02	12.470	1.47E-03	11.166
13.5	11	0	2.605E-01	0.387	0.524	13.416	13.588	0.247	0.778	13.392	2.98E-02	12.474	1.48E-03	11.171
13.6	11	0	2.581E-01	0.386	0.524	13.412	13.587	0.248	0.777	13.394	3.01E-02	12.479	1.50E-03	11.175
13.7	11	0	2.557E-01	0.385	0.524	13.408	13.586	0.248	0.776	13.395	3.04E-02	12.483	1.51E-03	11.180
13.8	11	0	2.534E-01	0.384	0.524	13.404	13.585	0.249	0.775	13.397	3.07E-02	12.488	1.53E-03	11.185
13.9	11	0	2.511E-01	0.384	0.524	13.400	13.584	0.250	0.775	13.398	3.11E-02	12.492	1.55E-03	11.189
14	11	0	2.488E-01	0.383	0.524	13.396	13.583	0.251	0.774	13.400	3.14E-02	12.497	1.56E-03	11.194
14.1	11	0	2.465E-01	0.382	0.524	13.392	13.582	0.252	0.773	13.401	3.17E-02	12.501	1.58E-03	11.198
14.2	11	0	2.442E-01	0.381	0.524	13.388	13.581	0.253	0.773	13.403	3.20E-02	12.506	1.60E-03	11.203
14.3	11	0	2.420E-01	0.380	0.524	13.384	13.580	0.254	0.772	13.404	3.24E-02	12.510	1.61E-03	11.207
14.4	11	0	2.398E-01	0.379	0.524	13.380	13.579	0.254	0.771	13.405	3.27E-02	12.514	1.63E-03	11.212
14.5	11	0	2.376E-01	0.378	0.524	13.376	13.578	0.255	0.771	13.407	3.30E-02	12.519	1.64E-03	11.216
14.6	11	0	2.354E-01	0.377	0.524	13.372	13.577	0.256	0.770	13.408	3.33E-02	12.523	1.66E-03	11.220
14.7	11	0	2.332E-01	0.376	0.524	13.368	13.576	0.257	0.770	13.409	3.36E-02	12.527	1.68E-03	11.225
14.8	11	0	2.311E-01	0.375	0.524	13.364	13.575	0.258	0.769	13.411	3.40E-02	12.531	1.69E-03	11.229
14.9	11	0	2.290E-01	0.374	0.524	13.360	13.573	0.258	0.768	13.412	3.43E-02	12.535	1.71E-03	11.233
15	11	0	2.269E-01	0.374	0.525	13.356	13.572	0.259	0.768	13.413	3.46E-02	12.539	1.73E-03	11.238
15.1	11	0	2.248E-01	0.373	0.525	13.352	13.571	0.260	0.767	13.415	3.50E-02	12.544	1.75E-03	11.242
15.2	11	0	2.227E-01	0.372	0.525	13.348	13.570	0.260	0.767	13.416	3.53E-02	12.548	1.76E-03	11.246
15.3	11	0	2.207E-01	0.371	0.525	13.344	13.569	0.261	0.766	13.417	3.56E-02	12.552	1.78E-03	11.250
15.4	11	0	2.187E-01	0.370	0.525	13.340	13.568	0.262	0.766	13.418	3.59E-02	12.556	1.80E-03	11.254
15.5	11	0	2.167E-01	0.369	0.525	13.336	13.567	0.263	0.765	13.419	3.63E-02	12.560	1.81E-03	11.258
15.6	11	0	2.147E-01	0.368	0.525	13.332	13.565	0.263	0.765	13.420	3.66E-02	12.564	1.83E-03	11.262
15.7	11	0	2.127E-01	0.367	0.526	13.328	13.564	0.264	0.764	13.421	3.69E-02	12.567	1.85E-03	11.267
15.8	11	0	2.108E-01	0.366	0.526	13.324	13.563	0.265	0.763	13.423	3.73E-02	12.571	1.86E-03	11.271
15.9	11	0	2.088E-01	0.365	0.526	13.320	13.562	0.265	0.763	13.424	3.76E-02	12.575	1.88E-03	11.275
16	11	0	2.069E-01	0.364	0.526	13.316	13.561	0.266	0.762	13.425	3.79E-02	12.579	1.90E-03	11.278
16.1	11	0	2.050E-01	0.363	0.526	13.312	13.559	0.266	0.762	13.426	3.83E-02	12.583	1.92E-03	11.282
16.2	11	0	2.031E-01	0.362	0.527	13.308	13.558	0.267	0.762	13.427	3.86E-02	12.587	1.93E-03	11.286
16.3	11	0	2.013E-01	0.361	0.527	13.304	13.557	0.268	0.761	13.428	3.89E-02	12.590	1.95E-03	11.290
16.4	11	0	1.994E-01	0.359	0.527	13.300	13.556	0.268	0.761	13.429	3.93E-02	12.594	1.97E-03	11.294
16.5	11	0	1.976E-01	0.358	0.527	13.296	13.554	0.269	0.760	13.430	3.96E-02	12.598	1.99E-03	11.298
16.6	11	0	1.958E-01	0.357	0.528	13.292	13.553	0.269	0.760	13.430	3.99E-02	12.601	2.00E-03	11.302
16.7	11	0	1.940E-01	0.356	0.528	13.288	13.552	0.270	0.759	13.431	4.03E-02	12.605	2.02E-03	11.305
16.8	11	0	1.922E-01	0.355	0.528	13.284	13.551	0.271	0.759	13.432	4.06E-02	12.609	2.04E-03	11.309
16.9	11	0	1.905E-01	0.354	0.528	13.280	13.549	0.271	0.758	13.433	4.09E-02	12.612	2.06E-03	11.313
17	11	0	1.887E-01	0.353	0.529	13.276	13.548	0.272	0.758	13.434	4.13E-02	12.616	2.07E-03	11.317
17.1	11	0	1.870E-01	0.352	0.529	13.272	13.547	0.272	0.758	13.435	4.16E-02	12.619	2.09E-03	11.320
17.2	11	0	1.853E-01	0.351	0.529	13.268	13.545	0.273	0.757	13.436	4.19E-02	12.623	2.11E-03	11.324
17.3	11	0	1.836E-01	0.350	0.530	13.264	13.544	0.273	0.757	13.436	4.23E-02	12.626	2.13E-03	11.328
17.4	11	0	1.819E-01	0.349	0.530	13.260	13.543	0.274	0.756	13.437	4.26E-02	12.630	2.14E-03	11.331
17.5	11	0	1.802E-01	0.348	0.530	13.256	13.541	0.274	0.756	13.438	4.30E-02	12.633	2.16E-03	11.335
17.6	11	0	1.786E-01	0.347	0.531	13.252	13.540	0.275	0.756	13.439	4.33E-02	12.636	2.18E-03	11.339
17.7	11	0	1.769E-01	0.346	0.531	13.248	13.538	0.275	0.755	13.439	4.36E-02	12.640	2.20E-03	11.342

17.8	11	0	1.753E-01	0.344	0.531	13.244	13.537	0.276	0.755	13.440	4.40E-02	12.643	2.22E-03	11.346
17.9	11	0	1.737E-01	0.343	0.532	13.240	13.536	0.276	0.755	13.441	4.43E-02	12.646	2.23E-03	11.349
18	11	0	1.721E-01	0.342	0.532	13.236	13.534	0.276	0.754	13.442	4.46E-02	12.650	2.25E-03	11.353
18.1	11	0	1.705E-01	0.341	0.532	13.232	13.533	0.277	0.754	13.442	4.50E-02	12.653	2.27E-03	11.356
18.2	11	0	1.690E-01	0.340	0.533	13.228	13.531	0.277	0.754	13.443	4.53E-02	12.656	2.29E-03	11.360
18.3	11	0	1.674E-01	0.339	0.533	13.224	13.530	0.278	0.753	13.443	4.57E-02	12.659	2.31E-03	11.363
18.4	11	0	1.659E-01	0.338	0.534	13.220	13.529	0.278	0.753	13.444	4.60E-02	12.663	2.32E-03	11.366
18.5	11	0	1.644E-01	0.337	0.534	13.216	13.527	0.278	0.753	13.445	4.63E-02	12.666	2.34E-03	11.370
18.6	11	0	1.629E-01	0.335	0.534	13.212	13.526	0.279	0.753	13.445	4.67E-02	12.669	2.36E-03	11.373
18.7	11	0	1.614E-01	0.334	0.535	13.208	13.524	0.279	0.752	13.446	4.70E-02	12.672	2.38E-03	11.376
18.8	11	0	1.599E-01	0.333	0.535	13.204	13.523	0.279	0.752	13.446	4.73E-02	12.675	2.40E-03	11.380
18.9	11	0	1.584E-01	0.332	0.536	13.200	13.521	0.280	0.752	13.447	4.77E-02	12.678	2.42E-03	11.383
19	11	0	1.570E-01	0.331	0.536	13.196	13.520	0.280	0.751	13.447	4.80E-02	12.681	2.43E-03	11.386
19.1	11	0	1.555E-01	0.330	0.537	13.192	13.518	0.280	0.751	13.448	4.84E-02	12.684	2.45E-03	11.390
19.2	11	0	1.541E-01	0.329	0.537	13.188	13.517	0.281	0.751	13.448	4.87E-02	12.687	2.47E-03	11.393
19.3	11	0	1.527E-01	0.328	0.538	13.184	13.515	0.281	0.751	13.449	4.90E-02	12.690	2.49E-03	11.396
19.4	11	0	1.513E-01	0.326	0.538	13.180	13.514	0.281	0.751	13.449	4.94E-02	12.693	2.51E-03	11.399
19.5	11	0	1.499E-01	0.325	0.538	13.176	13.512	0.282	0.750	13.450	4.97E-02	12.696	2.53E-03	11.403
19.6	11	0	1.485E-01	0.324	0.539	13.172	13.511	0.282	0.750	13.450	5.00E-02	12.699	2.55E-03	11.406
19.7	11	0	1.472E-01	0.323	0.539	13.168	13.509	0.282	0.750	13.451	5.04E-02	12.702	2.56E-03	11.409
19.8	11	0	1.458E-01	0.322	0.540	13.164	13.508	0.282	0.750	13.451	5.07E-02	12.705	2.58E-03	11.412
19.9	11	0	1.445E-01	0.321	0.540	13.160	13.506	0.283	0.750	13.451	5.11E-02	12.708	2.60E-03	11.415
20	11	0	1.432E-01	0.320	0.541	13.156	13.505	0.283	0.749	13.452	5.14E-02	12.711	2.62E-03	11.418
20.1	11	0	1.418E-01	0.318	0.541	13.152	13.503	0.283	0.749	13.452	5.17E-02	12.714	2.64E-03	11.421
20.2	11	0	1.405E-01	0.317	0.542	13.148	13.501	0.283	0.749	13.452	5.21E-02	12.717	2.66E-03	11.425
20.3	11	0	1.393E-01	0.316	0.542	13.144	13.500	0.284	0.749	13.453	5.24E-02	12.719	2.68E-03	11.428
20.4	11	0	1.380E-01	0.315	0.543	13.140	13.498	0.284	0.749	13.453	5.27E-02	12.722	2.70E-03	11.431
20.5	11	0	1.367E-01	0.314	0.543	13.136	13.497	0.284	0.749	13.453	5.31E-02	12.725	2.71E-03	11.434
20.6	11	0	1.355E-01	0.313	0.544	13.132	13.495	0.284	0.748	13.454	5.34E-02	12.728	2.73E-03	11.437
20.7	11	0	1.342E-01	0.311	0.545	13.128	13.493	0.284	0.748	13.454	5.38E-02	12.730	2.75E-03	11.440
20.8	11	0	1.330E-01	0.310	0.545	13.124	13.492	0.285	0.748	13.454	5.41E-02	12.733	2.77E-03	11.443
20.9	11	0	1.318E-01	0.309	0.546	13.120	13.490	0.285	0.748	13.454	5.44E-02	12.736	2.79E-03	11.446
21	11	0	1.306E-01	0.308	0.546	13.116	13.489	0.285	0.748	13.455	5.48E-02	12.738	2.81E-03	11.449
21.1	11	0	1.294E-01	0.307	0.547	13.112	13.487	0.285	0.748	13.455	5.51E-02	12.741	2.83E-03	11.451
21.2	11	0	1.282E-01	0.306	0.547	13.108	13.485	0.285	0.748	13.455	5.54E-02	12.744	2.85E-03	11.454
21.3	11	0	1.270E-01	0.305	0.548	13.104	13.484	0.285	0.748	13.455	5.58E-02	12.746	2.87E-03	11.457
21.4	11	0	1.258E-01	0.303	0.549	13.100	13.482	0.285	0.747	13.455	5.61E-02	12.749	2.88E-03	11.460
21.5	11	0	1.247E-01	0.302	0.549	13.096	13.480	0.285	0.747	13.456	5.64E-02	12.752	2.90E-03	11.463
21.6	11	0	1.235E-01	0.301	0.550	13.092	13.479	0.286	0.747	13.456	5.68E-02	12.754	2.92E-03	11.466
21.7	11	0	1.224E-01	0.300	0.550	13.088	13.477	0.286	0.747	13.456	5.71E-02	12.757	2.94E-03	11.469
21.8	11	0	1.213E-01	0.299	0.551	13.084	13.475	0.286	0.747	13.456	5.74E-02	12.759	2.96E-03	11.471
21.9	11	0	1.202E-01	0.298	0.552	13.080	13.474	0.286	0.747	13.456	5.78E-02	12.762	2.98E-03	11.474
22	11	0	1.191E-01	0.296	0.552	13.076	13.472	0.286	0.747	13.456	5.81E-02	12.764	3.00E-03	11.477
22.1	11	0	1.180E-01	0.295	0.553	13.072	13.470	0.286	0.747	13.456	5.84E-02	12.767	3.02E-03	11.480
22.2	11	0	1.169E-01	0.294	0.553	13.068	13.469	0.286	0.747	13.456	5.88E-02	12.769	3.04E-03	11.483
22.3	11	0	1.158E-01	0.293	0.554	13.064	13.467	0.286	0.747	13.456	5.91E-02	12.772	3.06E-03	11.485
22.4	11	0	1.148E-01	0.292	0.555	13.060	13.465	0.286	0.747	13.456	5.94E-02	12.774	3.08E-03	11.488
22.5	11	0	1.137E-01	0.291	0.555	13.056	13.463	0.286	0.747	13.457	5.97E-02	12.776	3.10E-03	11.491

22.6	11	0	1.127E-01	0.290	0.556	13.052	13.462	0.286	0.747	13.457	6.01E-02	12.779	3.12E-03	11.494
22.7	11	0	1.116E-01	0.288	0.557	13.048	13.460	0.286	0.747	13.457	6.04E-02	12.781	3.13E-03	11.496
22.8	11	0	1.106E-01	0.287	0.557	13.044	13.458	0.286	0.747	13.457	6.07E-02	12.783	3.15E-03	11.499
22.9	11	0	1.096E-01	0.286	0.558	13.040	13.457	0.286	0.747	13.457	6.11E-02	12.786	3.17E-03	11.502
23	11	0	1.086E-01	0.285	0.558	13.036	13.455	0.286	0.747	13.457	6.14E-02	12.788	3.19E-03	11.504
23.1	11	0	1.076E-01	0.284	0.559	13.032	13.453	0.286	0.747	13.457	6.17E-02	12.790	3.21E-03	11.507
23.2	11	0	1.066E-01	0.283	0.560	13.028	13.451	0.286	0.747	13.457	6.20E-02	12.793	3.23E-03	11.509
23.3	11	0	1.056E-01	0.282	0.560	13.024	13.450	0.286	0.747	13.456	6.24E-02	12.795	3.25E-03	11.512
23.4	11	0	1.047E-01	0.280	0.561	13.020	13.448	0.286	0.747	13.456	6.27E-02	12.797	3.27E-03	11.515
23.5	11	0	1.037E-01	0.279	0.562	13.016	13.446	0.286	0.747	13.456	6.30E-02	12.799	3.29E-03	11.517
23.6	11	0	1.028E-01	0.278	0.563	13.012	13.444	0.286	0.747	13.456	6.33E-02	12.802	3.31E-03	11.520
23.7	11	0	1.018E-01	0.277	0.563	13.008	13.442	0.286	0.747	13.456	6.37E-02	12.804	3.33E-03	11.522
23.8	11	0	1.009E-01	0.276	0.564	13.004	13.441	0.286	0.747	13.456	6.40E-02	12.806	3.35E-03	11.525
23.9	11	0	9.996E-02	0.275	0.565	13.000	13.439	0.286	0.747	13.456	6.43E-02	12.808	3.37E-03	11.527
24	11	0	9.904E-02	0.274	0.565	12.996	13.437	0.286	0.747	13.456	6.46E-02	12.810	3.39E-03	11.530
24.1	11	0	9.814E-02	0.272	0.566	12.992	13.435	0.286	0.747	13.456	6.50E-02	12.813	3.41E-03	11.532
24.2	11	0	9.724E-02	0.271	0.567	12.988	13.433	0.285	0.747	13.456	6.53E-02	12.815	3.43E-03	11.535
24.3	11	0	9.634E-02	0.270	0.567	12.984	13.432	0.285	0.747	13.455	6.56E-02	12.817	3.45E-03	11.537
24.4	11	0	9.546E-02	0.269	0.568	12.980	13.430	0.285	0.748	13.455	6.59E-02	12.819	3.47E-03	11.540
24.5	11	0	9.459E-02	0.268	0.569	12.976	13.428	0.285	0.748	13.455	6.62E-02	12.821	3.49E-03	11.542
24.6	11	0	9.372E-02	0.267	0.570	12.972	13.426	0.285	0.748	13.455	6.66E-02	12.823	3.51E-03	11.545
24.7	11	0	9.286E-02	0.266	0.570	12.968	13.424	0.285	0.748	13.455	6.69E-02	12.825	3.53E-03	11.547
24.8	11	0	9.201E-02	0.265	0.571	12.964	13.422	0.285	0.748	13.455	6.72E-02	12.827	3.55E-03	11.550
24.9	11	0	9.117E-02	0.263	0.572	12.960	13.421	0.285	0.748	13.454	6.75E-02	12.829	3.57E-03	11.552
25	11	0	9.033E-02	0.262	0.573	12.956	13.419	0.285	0.748	13.454	6.78E-02	12.831	3.58E-03	11.554
25.1	11	0	8.950E-02	0.261	0.573	12.952	13.417	0.284	0.748	13.454	6.81E-02	12.833	3.60E-03	11.557
25.2	11	0	8.868E-02	0.260	0.574	12.948	13.415	0.284	0.748	13.454	6.85E-02	12.835	3.62E-03	11.559
25.3	11	0	8.787E-02	0.259	0.575	12.944	13.413	0.284	0.748	13.453	6.88E-02	12.837	3.64E-03	11.562
25.4	11	0	8.706E-02	0.258	0.576	12.940	13.411	0.284	0.749	13.453	6.91E-02	12.839	3.66E-03	11.564
25.5	11	0	8.627E-02	0.257	0.576	12.936	13.409	0.284	0.749	13.453	6.94E-02	12.841	3.68E-03	11.566
25.6	11	0	8.547E-02	0.256	0.577	12.932	13.408	0.284	0.749	13.453	6.97E-02	12.843	3.70E-03	11.569
25.7	11	0	8.469E-02	0.254	0.578	12.928	13.406	0.283	0.749	13.452	7.00E-02	12.845	3.72E-03	11.571
25.8	11	0	8.391E-02	0.253	0.579	12.924	13.404	0.283	0.749	13.452	7.03E-02	12.847	3.74E-03	11.573
25.9	11	0	8.315E-02	0.252	0.579	12.920	13.402	0.283	0.749	13.452	7.06E-02	12.849	3.76E-03	11.576
26	11	0	8.238E-02	0.251	0.580	12.916	13.400	0.283	0.749	13.451	7.09E-02	12.851	3.78E-03	11.578
26.1	11	0	8.163E-02	0.250	0.581	12.912	13.398	0.283	0.750	13.451	7.13E-02	12.853	3.80E-03	11.580
26.2	11	0	8.088E-02	0.249	0.582	12.908	13.396	0.282	0.750	13.451	7.16E-02	12.855	3.82E-03	11.582
26.3	11	0	8.014E-02	0.248	0.582	12.904	13.394	0.282	0.750	13.450	7.19E-02	12.857	3.84E-03	11.585
26.4	11	0	7.940E-02	0.247	0.583	12.900	13.392	0.282	0.750	13.450	7.22E-02	12.858	3.86E-03	11.587
26.5	11	0	7.868E-02	0.246	0.584	12.896	13.390	0.282	0.750	13.450	7.25E-02	12.860	3.88E-03	11.589
26.6	11	0	7.795E-02	0.245	0.585	12.892	13.389	0.281	0.751	13.449	7.28E-02	12.862	3.90E-03	11.591
26.7	11	0	7.724E-02	0.244	0.586	12.888	13.387	0.281	0.751	13.449	7.31E-02	12.864	3.92E-03	11.594
26.8	11	0	7.653E-02	0.242	0.586	12.884	13.385	0.281	0.751	13.449	7.34E-02	12.866	3.94E-03	11.596
26.9	11	0	7.583E-02	0.241	0.587	12.880	13.383	0.281	0.751	13.448	7.37E-02	12.867	3.96E-03	11.598
27	11	0	7.514E-02	0.240	0.588	12.876	13.381	0.280	0.751	13.448	7.40E-02	12.869	3.98E-03	11.600
27.1	11	0	7.445E-02	0.239	0.589	12.872	13.379	0.280	0.751	13.447	7.43E-02	12.871	4.00E-03	11.602
27.2	11	0	7.376E-02	0.238	0.590	12.868	13.377	0.280	0.752	13.447	7.46E-02	12.873	4.02E-03	11.604
27.3	11	0	7.309E-02	0.237	0.590	12.864	13.375	0.280	0.752	13.446	7.49E-02	12.874	4.04E-03	11.607

APPENDIX C
MICROSHIELD[®] MODEL

This appendix contains the printouts of the model calculations used to predict the dose rates in the scrubber area. The model which was used can be described as two vertical line sources. Each line source was surrounded by a water jacket. The second line source acted as a shield for the first line source when calculating dose rates in that line. Calculations were made with and without cement block shielding.

Each calculation was actually the sum of two calculations. The dose rate was determined from the second line source. That value was added to the dose rate determined from the first line source, using the second source as another shield. These two values could be added due to the superposition principle.

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page	: 1	File Ref:	_____
File	: OFF01.MSH	Date:	____/____/____
Run date:	February 22, 1996	By:	_____
Run time:	9:45 p.m.	Checked:	_____

CASE: dose above block

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	91.440	cm.
Vertical displacement of dose point.....	Y	121.920	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	91.440	cm.

MATERIAL DENSITIES (g/cc):

Material	Shield 1
-----	-----
Air	.001220
Aluminum	
Carbon	
Concrete	
Hydrogen	
Iron	
Lead	
Lithium	
Nickel	
Tin	
Titanium	
Tungsten	
Urania	
Uranium	
Water	
Zirconium	

CASE: dose above block

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	5.0000e-04	C-11	3.0700e-02	N-13	1.3700e-01
N-16	4.2000e-03	O-15	5.0000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	7.770e+06	2.344e+02	2.456e-01
2	6.3359	2.497e+05	6.708e+00	7.266e-03
3	6.1328	1.072e+08	2.788e+03	3.048e+00
4	2.7422	1.181e+06	1.374e+01	2.024e-02
5	1.7578	2.020e+05	1.509e+00	2.559e-03
6	1.6797	9.620e+03	6.869e-02	1.178e-04
7	1.2891	1.834e+07	1.007e+02	1.833e-01
8	.5078	1.608e+10	3.527e+04	7.222e+01
9				
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19				
20				
TOTALS:		1.622e+10	3.842e+04	7.573e+01

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1
File : ON01.MSH
Run date: February 22, 1996
Run time: 9:47 p.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: above shield, on

GEOMETRY 2: Line source - slab shields

Distance to detector..... X	91.440	cm.
Vertical displacement of dose point..... Y	121.920	"
Source line length..... L	457.2	"
Angle of line with respect to shield base.... A	90.	degrees
Thickness of first shield..... T1	91.440	cm.

MATERIAL DENSITIES (g/cc):

Material	Shield 1
-----	-----
Air	.001220
Aluminum	
Carbon	
Concrete	
Hydrogen	
Iron	
Lead	
Lithium	
Nickel	
Tin	
Titanium	
Tungsten	
Urania	
Uranium	
Water	
Zirconium	

CASE: above shield, on

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	5.0000e-04	C-11	1.9200e+00	N-13	1.3700e-01
N-16	4.2000e-03	O-15	5.0000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	7.770e+06	2.344e+02	2.456e-01
2	6.3359	2.497e+05	6.708e+00	7.266e-03
3	6.1328	1.072e+08	2.788e+03	3.048e+00
4	2.7422	1.181e+06	1.374e+01	2.024e-02
5	1.7578	2.020e+05	1.509e+00	2.559e-03
6	1.6797	9.620e+03	6.869e-02	1.178e-04
7	1.2891	1.834e+07	1.007e+02	1.833e-01
8	.5078	1.556e+11	3.412e+05	6.987e+02
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20				
TOTALS:		1.557e+11	3.444e+05	7.022e+02

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1
 File : OFF02.MSH
 Run date: February 22, 1996
 Run time: 9:46 p.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: dose behind shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	121.920	cm.
Vertical displacement of dose point.....	Y	30.480	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	73.660	cm.
Thickness of second shield.....	T2	48.260	"
Microshield inserted air gap.....	air	0.	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Air gap
-----	-----	-----	-----
Air	.001220		.001220
Aluminum			
Carbon			
Concrete		2.350	
Hydrogen			
Iron			
Lead			
Lithium			
Nickel			
Tin			
Titanium			
Tungsten			
Urania			
Uranium			
Water			
Zirconium			

CASE: dose behind shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	5.0000e-04	C-11	3.0700e-02	N-13	1.3700e-01
N-16	4.2000e-03	O-15	5.0000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	7.770e+06	8.617e+00	9.030e-03
2	6.3359	2.497e+05	2.351e-01	2.547e-04
3	6.1328	1.072e+08	9.649e+01	1.055e-01
4	2.7422	1.181e+06	2.162e-01	3.185e-04
5	1.7578	2.020e+05	1.181e-02	2.003e-05
6	1.6797	9.620e+03	4.952e-04	8.490e-07
7	1.2891	1.834e+07	4.168e-01	7.584e-04
8	.5078	1.608e+10	1.652e+01	3.383e-02
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20				
TOTALS:		1.622e+10	1.225e+02	1.497e-01

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1
 File : ON02.MSH
 Run date: February 22, 1996
 Run time: 9:48 p.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: behind shield, on

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	121.920	cm.
Vertical displacement of dose point.....	Y	30.450	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	73.660	cm.
Thickness of second shield.....	T2	48.260	"
Microshield inserted air gap.....	air	0.	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Air gap
-----	-----	-----	-----
Air	.001220	.	.001220
Aluminum			
Carbon			
Concrete		2.350	
Hydrogen			
Iron			
Lead			
Lithium			
Nickel			
Tin			
Titanium			
Tungsten			
Urania			
Uranium			
Water			
Zirconium			

CASE: behind shield, on

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	5.0000e-04	C-11	1.9200e+00	N-13	1.3700e-01
N-16	4.2000e-03	O-15	5.0000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	7.770e+06	8.615e+00	9.027e-03
2	6.3359	2.497e+05	2.351e-01	2.546e-04
3	6.1328	1.072e+08	9.647e+01	1.055e-01
4	2.7422	1.181e+06	2.162e-01	3.184e-04
5	1.7578	2.020e+05	1.181e-02	2.003e-05
6	1.6797	9.620e+03	4.950e-04	8.488e-07
7	1.2891	1.834e+07	4.167e-01	7.582e-04
8	.5078	1.556e+11	1.598e+02	3.272e-01
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19				
20				
TOTALS:		1.557e+11	2.657e+02	4.430e-01

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page	: 1	File Ref:	_____
File	: ON02CON.MSH	Date:	____/____/____
Run date:	February 22, 1996	By:	_____
Run time:	9:49 p.m.	Checked:	_____

CASE: berger for concrete

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	121.920	cm.
Vertical displacement of dose point.....	Y	30.450	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	73.660	cm.
Thickness of second shield.....	T2	48.260	"
Microshield inserted air gap.....	air	0.	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Air gap
-----	-----	-----	-----
Air	.001220	.	.001220
Aluminum			
Carbon			
Concrete		2.350	
Hydrogen			
Iron			
Lead			
Lithium			
Nickel			
Tin			
Titanium			
Tungsten			
Urania			
Uranium			
Water			
Zirconium			

CASE: berger for concrete

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of concrete.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	5.0000e-04	C-11	1.9200e+00	N-13	1.3700e-01
N-16	4.2000e-03	O-15	5.0000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	7.770e+06	8.530e+00	8.938e-03
2	6.3359	2.497e+05	2.321e-01	2.514e-04
3	6.1328	1.072e+08	9.518e+01	1.041e-01
4	2.7422	1.181e+06	2.068e-01	3.046e-04
5	1.7578	2.020e+05	1.078e-02	1.828e-05
6	1.6797	9.620e+03	4.487e-04	7.694e-07
7	1.2891	1.834e+07	3.619e-01	6.584e-04
8	.5078	1.556e+11	1.084e+02	2.219e-01
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20				
TOTALS:		1.557e+11	2.129e+02	3.361e-01

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page	: 1	File Ref:	_____
File	: OFFMID.MSH	Date:	____/____/____
Run date:	February 22, 1996	By:	_____
Run time:	9:51 p.m.	Checked:	_____

CASE: off mid 1,2

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	60.960	cm.
Vertical displacement of dose point.....	Y	228.6	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	60.960	cm.

MATERIAL DENSITIES (g/cc):

Material	Shield 1
-----	-----
Air	.001220
Aluminum	
Carbon	
Concrete	
Hydrogen	
Iron	
Lead	
Lithium	
Nickel	
Tin	
Titanium	
Tungsten	
Urania	
Uranium	
Water	
Zirconium	

CASE: off mid 1,2

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	5.0000e-04	C-11	3.0700e-02	N-13	1.3700e-01
N-16	4.2000e-03	O-15	5.0000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	7.770e+06	4.131e+02	4.328e-01
2	6.3359	2.497e+05	1.182e+01	1.280e-02
3	6.1328	1.072e+08	4.912e+03	5.371e+00
4	2.7422	1.181e+06	2.421e+01	3.566e-02
5	1.7578	2.020e+05	2.658e+00	4.506e-03
6	1.6797	9.620e+03	1.210e-01	2.074e-04
7	1.2891	1.834e+07	1.773e+02	3.225e-01
8	.5078	1.608e+10	6.186e+04	1.267e+02
9				
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13				
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18				
19				
20				
TOTALS:		1.622e+10	6.740e+04	1.328e+02

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1

File : ONMIDDLE.MSH

Run date: February 22, 1996

Run time: 9:51 p.m.

File Ref: _____

Date: ____/____/____

By: _____

Checked: _____

CASE: between 1 and 2

GEOMETRY 2: Line source - slab shields

Distance to detector..... X	60.960	cm.
Vertical displacement of dose point..... Y	228.6	"
Source line length..... L	457.2	"
Angle of line with respect to shield base.... A	90.	degrees
Thickness of first shield..... T1	60.960	cm.

MATERIAL DENSITIES (g/cc):

Material	Shield 1
-----	-----
Air	.001220
Aluminum	
Carbon	
Concrete	
Hydrogen	
Iron	
Lead	
Lithium	
Nickel	
Tin	
Titanium	
Tungsten	
Uranium	
Water	
Zirconium	

CASE: between 1 and 2

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	5.0000e-04	C-11	1.9200e+00	N-13	1.3700e-01
N-16	4.2000e-03	O-15	5.0000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	7.770e+06	4.131e+02	4.328e-01
2	6.3359	2.497e+05	1.182e+01	1.280e-02
3	6.1328	1.072e+08	4.912e+03	5.371e+00
4	2.7422	1.181e+06	2.421e+01	3.566e-02
5	1.7578	2.020e+05	2.658e+00	4.506e-03
6	1.6797	9.620e+03	1.210e-01	2.074e-04
7	1.2891	1.834e+07	1.773e+02	3.225e-01
8	.5078	1.556e+11	5.984e+05	1.225e+03
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13				
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18				
19				
20				
TOTALS:		1.557e+11	6.040e+05	1.231e+03

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1
File : SIDOFF.MSH
Run date: February 22, 1996
Run time: 9:54 p.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: beside and on

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	20.320	cm.
Vertical displacement of dose point.....	Y	228.6	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	20.320	cm.

MATERIAL DENSITIES (g/cc):

Material	Shield 1
-----	-----
Air	
Aluminum	
Carbon	
Concrete	
Hydrogen	
Iron	
Lead	
Lithium	
Nickel	
Tin	
Titanium	
Tungsten	
Urania	
Uranium	
Water	1.0
Zirconium	

CASE: beside and on

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of water.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	5.0000e-04	C-11	3.0700e-02	N-13	1.3700e-01
N-16	4.2000e-03	O-15	5.0000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	7.770e+06	7.726e+02	8.095e-01
2	6.3359	2.497e+05	2.193e+01	2.375e-02
3	6.1328	1.072e+08	9.096e+03	9.945e+00
4	2.7422	1.181e+06	4.181e+01	6.158e-02
5	1.7578	2.020e+05	4.481e+00	7.597e-03
6	1.6797	9.620e+03	2.034e-01	3.487e-04
7	1.2891	1.834e+07	2.955e+02	5.377e-01
8	.5078	1.608e+10	1.034e+05	2.116e+02
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		1.622e+10	1.136e+05	2.230e+02

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page	: 1	File Ref:	_____
File	: SIDOFF2.MSH	Date:	____/____/____
Run date:	February 22, 1996	By:	_____
Run time:	9:54 p.m.	Checked:	_____

CASE: beside and on

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	142.240	cm.
Vertical displacement of dose point.....	Y	228.6	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	101.6	cm.
Thickness of second shield.....	T2	40.640	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2
-----	-----	-----
Air	.001220	
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water		1.0
Zirconium		

CASE: beside and on

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	5.0000e-04	C-11	3.0700e-02	N-13	1.3700e-01
N-16	4.2000e-03	O-15	5.0000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	7.770e+06	5.833e+01	6.112e-02
2	6.3359	2.497e+05	1.644e+00	1.781e-03
3	6.1328	1.072e+08	6.805e+02	7.441e-01
4	2.7422	1.181e+06	2.719e+00	4.005e-03
5	1.7578	2.020e+05	2.526e-01	4.284e-04
6	1.6797	9.620e+03	1.128e-02	1.933e-05
7	1.2891	1.834e+07	1.458e+01	2.653e-02
8	.5078	1.608e+10	3.094e+03	6.334e+00
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		1.622e+10	3.852e+03	7.172e+00

Microshield 3.12

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Page : 1
 File : SIDEON.MSH
 Run date: February 22, 1996
 Run time: 9:52 p.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: beside and on

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	20.320	cm.
Vertical displacement of dose point.....	Y	228.6	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	20.320	cm.

MATERIAL DENSITIES (g/cc):

Material	Shield 1
-----	-----
Air	
Aluminum	
Carbon	
Concrete	
Hydrogen	
Iron	
Lead	
Lithium	
Nickel	
Tin	
Titanium	
Tungsten	
Urania	
Uranium	
Water	1.0
Zirconium	

CASE: beside and on

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of water.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	5.0000e-04	C-11	1.9200e+00	N-13	1.3700e-01
N-16	4.2000e-03	O-15	5.0000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	7.770e+06	7.726e+02	8.095e-01
2	6.3359	2.497e+05	2.193e+01	2.375e-02
3	6.1328	1.072e+08	9.096e+03	9.945e+00
4	2.7422	1.181e+06	4.181e+01	6.158e-02
5	1.7578	2.020e+05	4.481e+00	7.597e-03
6	1.6797	9.620e+03	2.034e-01	3.487e-04
7	1.2891	1.834e+07	2.955e+02	5.377e-01
8	.5078	1.556e+11	9.998e+05	2.047e+03
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		1.557e+11	1.010e+06	2.058e+03

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1
 File : SIDEON2.MSH
 Run date: February 22, 1996
 Run time: 9:53 p.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: beside and on

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	142.240	cm.
Vertical displacement of dose point.....	Y	228.6	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	101.6	cm.
Thickness of second shield.....	T2	40.640	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2
-----	-----	-----
Air	.001220	
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water		1.0
Zirconium		

CASE: beside and on

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	5.0000e-04	C-11	1.9200e+00	N-13	1.3700e-01
N-16	4.2000e-03	O-15	5.0000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	7.770e+06	5.833e+01	6.112e-02
2	6.3359	2.497e+05	1.644e+00	1.781e-03
3	6.1328	1.072e+08	6.805e+02	7.441e-01
4	2.7422	1.181e+06	2.719e+00	4.005e-03
5	1.7578	2.020e+05	2.526e-01	4.284e-04
6	1.6797	9.620e+03	1.128e-02	1.933e-05
7	1.2891	1.834e+07	1.458e+01	2.653e-02
8	.5078	1.556e+11	2.993e+04	6.127e+01
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		1.557e+11	3.068e+04	6.211e+01

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1
 File : OFF04Y.MSH
 Run date: February 22, 1996
 Run time: 9:55 p.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: behind shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	504.4	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	111.760	cm.
Thickness of second shield.....	T2	40.640	"
Thickness of third shield.....	T3	304.	"
Thickness of fourth shield.....	T4	48.	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3	Shield 4
-----	-----	-----	-----	-----
Air	.001220		.001220	
Aluminum				
Carbon				
Concrete				2.350
Hydrogen				
Iron				
Lead				
Lithium				
Nickel				
Tin				
Titanium				
Tungsten				
Urania				
Uranium				
Water		1.0		
Zirconium				

CASE: behind shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	1.5350e-02	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	2.968e-01	3.110e-04
2	6.3359	1.249e+05	7.770e-03	8.417e-06
3	6.1328	5.361e+07	3.154e+00	3.449e-03
4	2.7422	5.905e+05	4.303e-03	6.338e-06
5	1.7578	1.010e+05	1.577e-04	2.674e-07
6	1.6797	4.810e+03	6.315e-06	1.083e-08
7	1.2891	9.172e+06	3.923e-03	7.138e-06
8	.5078	8.040e+09	4.965e-02	1.017e-04
9				
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11				
12				
13				
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16				
17				
18				
19				
20				
TOTALS:		8.108e+09	3.517e+00	3.884e-03

Microshield 3.12

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Page : 1
 File : OFF04Y2.MSH
 Run date: February 22, 1996
 Run time: 9:56 p.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: behind shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	360.	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	312.	cm.
Thickness of second shield.....	T2	48.	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2
-----	-----	-----
Air	.001220	
Aluminum		
Carbon		
Concrete		2.350
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water		
Zirconium		

CASE: behind shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	1.5350e-02	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	1.222e+00	1.280e-03
2	6.3359	1.249e+05	3.341e-02	3.619e-05
3	6.1328	5.361e+07	1.372e+01	1.500e-02
4	2.7422	5.905e+05	3.126e-02	4.604e-05
5	1.7578	1.010e+05	1.716e-03	2.910e-06
6	1.6797	4.810e+03	7.195e-05	1.234e-07
7	1.2891	9.172e+06	6.063e-02	1.103e-04
8	.5078	8.040e+09	2.404e+00	4.921e-03
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		8.108e+09	1.747e+01	2.140e-02

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page	: 1	File Ref:	_____
File	: ON04Y.MSH	Date:	____/____/____
Run date:	February 22, 1996	By:	_____
Run time:	9:58 p.m.	Checked:	_____

CASE: behind shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	504.4	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	111.760	cm.
Thickness of second shield.....	T2	40.640	"
Thickness of third shield.....	T3	304.	"
Thickness of fourth shield.....	T4	48.	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3	Shield 4
-----	-----	-----	-----	-----
Air	.001220		.001220	
Aluminum				
Carbon				
Concrete				2.350
Hydrogen				
Iron				
Lead				
Lithium				
Nickel				
Tin				
Titanium				
Tungsten				
Urania				
Uranium				
Water		1.0		
Zirconium				

CASE: behind shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	9.6000e-01	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	2.968e-01	3.110e-04
2	6.3359	1.249e+05	7.770e-03	8.417e-06
3	6.1328	5.361e+07	3.154e+00	3.449e-03
4	2.7422	5.905e+05	4.303e-03	6.338e-06
5	1.7578	1.010e+05	1.577e-04	2.674e-07
6	1.6797	4.810e+03	6.315e-06	1.083e-08
7	1.2891	9.172e+06	3.923e-03	7.138e-06
8	.5078	7.778e+10	4.803e-01	9.835e-04
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		7.785e+10	3.948e+00	4.765e-03

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page	: 1	File Ref:	_____
File	: ON04Y2.MSH	Date:	___/___/___
Run date:	February 22, 1996	By:	_____
Run time:	9:57 p.m.	Checked:	_____

CASE: behind shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	360.	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	312.	cm.
Thickness of second shield.....	T2	48.	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2
-----	-----	-----
Air	.001220	
Aluminum		
Carbon		
Concrete		2.350
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water		
Zirconium		

CASE: behind shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	9.6000e-01	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	1.222e+00	1.280e-03
2	6.3359	1.249e+05	3.341e-02	3.619e-05
3	6.1328	5.361e+07	1.372e+01	1.500e-02
4	2.7422	5.905e+05	3.126e-02	4.604e-05
5	1.7578	1.010e+05	1.716e-03	2.910e-06
6	1.6797	4.810e+03	7.195e-05	1.234e-07
7	1.2891	9.172e+06	6.063e-02	1.103e-04
8	.5078	7.778e+10	2.325e+01	4.761e-02
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		7.785e+10	3.832e+01	6.408e-02

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1
 File : OFF04N.MSH
 Run date: February 22, 1996
 Run time: 9:59 p.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: no shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	504.4	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	111.760	cm.
Thickness of second shield.....	T2	40.640	"
Thickness of third shield.....	T3	352.	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3
-----	-----	-----	-----
Air	.001220	.	.001220
Aluminum			
Carbon			
Concrete			
Hydrogen			
Iron			
Lead			
Lithium			
Nickel			
Tin			
Titanium			
Tungsten			
Urania			
Uranium			
Water		1.0	
Zirconium			

CASE: no shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	1.5350e-02	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	3.469e+00	3.635e-03
2	6.3359	1.249e+05	9.809e-02	1.063e-04
3	6.1328	5.361e+07	4.064e+01	4.444e-02
4	2.7422	5.905e+05	1.691e-01	2.491e-04
5	1.7578	1.010e+05	1.620e-02	2.746e-05
6	1.6797	4.810e+03	7.253e-04	1.244e-06
7	1.2891	9.172e+06	9.578e-01	1.743e-03
8	.5078	8.040e+09	2.165e+02	4.433e-01
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		8.108e+09	2.619e+02	4.935e-01

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page	: 1	File Ref:	_____
File	: OFF04N2.MSH	Date:	___/___/___
Run date:	February 22, 1996	By:	_____
Run time:	9:59 p.m.	Checked:	_____

CASE: no shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	360.	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	360.	cm.

MATERIAL DENSITIES (g/cc):

Material	Shield 1
-----	-----
Air	.001220
Aluminum	
Carbon	
Concrete	
Hydrogen	
Iron	
Lead	
Lithium	
Nickel	
Tin	
Titanium	
Tungsten	
Urania	
Uranium	
Water	
Zirconium	

CASE: no shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	1.5350e-02	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	1.300e+01	1.362e-02
2	6.3359	1.249e+05	3.719e-01	4.028e-04
3	6.1328	5.361e+07	1.546e+02	1.690e-01
4	2.7422	5.905e+05	7.634e-01	1.124e-03
5	1.7578	1.010e+05	8.412e-02	1.426e-04
6	1.6797	4.810e+03	3.831e-03	6.568e-06
7	1.2891	9.172e+06	5.640e+00	1.026e-02
8	.5078	8.040e+09	2.032e+03	4.161e+00
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		8.108e+09	2.206e+03	4.355e+00

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1
 File : ON04N1.MSH
 Run date: February 22, 1996
 Run time: 10:01 p.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: no shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	504.4	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	111.760	cm.
Thickness of second shield.....	T2	40.640	"
Thickness of third shield.....	T3	352.	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3
-----	-----	-----	-----
Air	.001220		.001220
Aluminum			
Carbon			
Concrete			
Hydrogen			
Iron			
Lead			
Lithium			
Nickel			
Tin			
Titanium			
Tungsten			
Urania			
Uranium			
Water		1.0	
Zirconium			

CASE: no shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	9.6000e-01	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	3.469e+00	3.635e-03
2	6.3359	1.249e+05	9.809e-02	1.063e-04
3	6.1328	5.361e+07	4.064e+01	4.444e-02
4	2.7422	5.905e+05	1.691e-01	2.491e-04
5	1.7578	1.010e+05	1.620e-02	2.746e-05
6	1.6797	4.810e+03	7.253e-04	1.244e-06
7	1.2891	9.172e+06	9.578e-01	1.743e-03
8	.5078	7.778e+10	2.095e+03	4.289e+00
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		7.785e+10	2.140e+03	4.339e+00

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page	: 1	File Ref:	_____
File	: ON04N.MSH	Date:	___/___/___
Run date:	February 22, 1996	By:	_____
Run time:	10:00 p.m.	Checked:	_____

CASE: no shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	360.	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	360.	cm.

MATERIAL DENSITIES (g/cc):

Material	Shield 1
-----	-----
Air	.001220
Aluminum	
Carbon	
Concrete	
Hydrogen	
Iron	
Lead	
Lithium	
Nickel	
Tin	
Titanium	
Tungsten	
Urania	
Uranium	
Water	
Zirconium	

CASE: no shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	9.6000e-01	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	1.300e+01	1.362e-02
2	6.3359	1.249e+05	3.719e-01	4.028e-04
3	6.1328	5.361e+07	1.546e+02	1.690e-01
4	2.7422	5.905e+05	7.634e-01	1.124e-03
5	1.7578	1.010e+05	8.412e-02	1.426e-04
6	1.6797	4.810e+03	3.831e-03	6.568e-06
7	1.2891	9.172e+06	5.640e+00	1.026e-02
8	.5078	7.778e+10	1.966e+04	4.025e+01
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		7.785e+10	1.983e+04	4.044e+01

Microshield 3.12

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Page : 1
 File : OFF05Y.MSH
 Run date: February 23, 1996
 Run time: 7:39 a.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: behind shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	1205.4	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	111.760	cm.
Thickness of second shield.....	T2	40.640	"
Thickness of third shield.....	T3	304.	"
Thickness of fourth shield.....	T4	48.	"
Thickness of fifth shield.....	T5	701.	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3	Shield 4	Shield 5
-----	-----	-----	-----	-----	-----
Air	.001220		.001220		.001220
Aluminum					
Carbon					
Concrete				2.350	
Hydrogen					
Iron					
Lead					
Lithium					
Nickel					
Tin					
Titanium					
Tungsten					
Urania					
Uranium					
Water		1.0			
Zirconium					

CASE: behind shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	1.5350e-02	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	6.875e-02	7.204e-05
2	6.3359	1.249e+05	1.809e-03	1.959e-06
3	6.1328	5.361e+07	7.351e-01	8.037e-04
4	2.7422	5.905e+05	1.059e-03	1.561e-06
5	1.7578	1.010e+05	4.026e-05	6.826e-08
6	1.6797	4.810e+03	1.618e-06	2.774e-09
7	1.2891	9.172e+06	1.028e-03	1.870e-06
8	.5078	8.040e+09	1.379e-02	2.823e-05
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		8.108e+09	8.216e-01	9.094e-04

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1
File : OFF05Y2.MSH
Run date: February 23, 1996
Run time: 7:42 a.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: behind shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	1061.	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	312.	cm.
Thickness of second shield.....	T2	48.	"
Thickness of third shield.....	T3	701.	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3
-----	-----	-----	-----
Air	.001220		.001220
Aluminum			
Carbon			
Concrete		2.350	
Hydrogen			
Iron			
Lead			
Lithium			
Nickel			
Tin			
Titanium			
Tungsten			
Urania			
Uranium			
Water			
Zirconium			

CASE: behind shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	1.5350e-02	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	2.120e-01	2.222e-04
2	6.3359	1.249e+05	5.826e-03	6.311e-06
3	6.1328	5.361e+07	2.395e+00	2.619e-03
4	2.7422	5.905e+05	5.790e-03	8.529e-06
5	1.7578	1.010e+05	3.307e-04	5.607e-07
6	1.6797	4.810e+03	1.392e-05	2.387e-08
7	1.2891	9.172e+06	1.203e-02	2.189e-05
8	.5078	8.040e+09	5.080e-01	1.040e-03
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		8.108e+09	3.139e+00	3.918e-03

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1
 File : ON05Y.MSH
 Run date: February 23, 1996
 Run time: 10:25 a.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: behind shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	1205.4	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	111.760	cm.
Thickness of second shield.....	T2	40.640	"
Thickness of third shield.....	T3	304.	"
Thickness of fourth shield.....	T4	48.	"
Thickness of fifth shield.....	T5	701.	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3	Shield 4	Shield 5
-----	-----	-----	-----	-----	-----
Air	.001220		.001220		.001220
Aluminum					
Carbon					
Concrete				2.350	
Hydrogen					
Iron					
Lead					
Lithium					
Nickel					
Tin					
Titanium					
Tungsten					
Urania					
Uranium					
Water		1.0			
Zirconium					

CASE: behind shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	9.6000e-01	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	6.875e-02	7.204e-05
2	6.3359	1.249e+05	1.809e-03	1.959e-06
3	6.1328	5.361e+07	7.351e-01	8.037e-04
4	2.7422	5.905e+05	1.059e-03	1.561e-06
5	1.7578	1.010e+05	4.026e-05	6.826e-08
6	1.6797	4.810e+03	1.618e-06	2.774e-09
7	1.2891	9.172e+06	1.028e-03	1.870e-06
8	.5078	7.778e+10	1.334e-01	2.731e-04
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		7.785e+10	9.412e-01	1.154e-03

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1
 File : ON05Y2.MSH
 Run date: February 23, 1996
 Run time: 7:50 a.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: behind shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	1061.	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	312.	cm.
Thickness of second shield.....	T2	48.	"
Thickness of third shield.....	T3	701.	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3
-----	-----	-----	-----
Air	.001220		.001220
Aluminum			
Carbon			
Concrete		2.350	
Hydrogen			
Iron			
Lead			
Lithium			
Nickel			
Tin			
Titanium			
Tungsten			
Urania			
Uranium			
Water			
Zirconium			

CASE: behind shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	9.6000e-01	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	2.120e-01	2.222e-04
2	6.3359	1.249e+05	5.826e-03	6.311e-06
3	6.1328	5.361e+07	2.395e+00	2.619e-03
4	2.7422	5.905e+05	5.790e-03	8.529e-06
5	1.7578	1.010e+05	3.307e-04	5.607e-07
6	1.6797	4.810e+03	1.392e-05	2.387e-08
7	1.2891	9.172e+06	1.203e-02	2.189e-05
8	.5078	7.778e+10	4.914e+00	1.006e-02
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		7.785e+10	7.545e+00	1.294e-02

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1
 File : OFF05N.MSH
 Run date: February 23, 1996
 Run time: 7:56 a.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: no shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	1205.4	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	111.760	cm.
Thickness of second shield.....	T2	40.640	"
Thickness of third shield.....	T3	1053.	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3
-----	-----	-----	-----
Air	.001220		.001220
Aluminum			
Carbon			
Concrete			
Hydrogen			
Iron			
Lead			
Lithium			
Nickel			
Tin			
Titanium			
Tungsten			
Urania			
Uranium			
Water		1.0	
Zirconium			

CASE: no shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	1.5350e-02	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	7.088e-01	7.427e-04
2	6.3359	1.249e+05	2.006e-02	2.173e-05
3	6.1328	5.361e+07	8.315e+00	9.091e-03
4	2.7422	5.905e+05	3.508e-02	5.168e-05
5	1.7578	1.010e+05	3.399e-03	5.763e-06
6	1.6797	4.810e+03	1.524e-04	2.613e-07
7	1.2891	9.172e+06	2.030e-01	3.694e-04
8	.5078	8.040e+09	4.732e+01	9.688e-02
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		8.108e+09	5.660e+01	1.072e-01

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1

File : OFF05N2.MSH

Run date: February 23, 1996

Run time: 8:00 a.m.

File Ref: _____

Date: ____/____/____

By: _____

Checked: _____

CASE: no shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	1061.	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	1061.	cm.

MATERIAL DENSITIES (g/cc):

Material	Shield 1
-----	-----
Air	.001220
Aluminum	
Carbon	
Concrete	
Hydrogen	
Iron	
Lead	
Lithium	
Nickel	
Tin	
Titanium	
Tungsten	
Urania	
Uranium	
Water	
Zirconium	

CASE: no shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	1.5350e-02	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	1.840e+00	1.928e-03
2	6.3359	1.249e+05	5.266e-02	5.704e-05
3	6.1328	5.361e+07	2.189e+01	2.393e-02
4	2.7422	5.905e+05	1.086e-01	1.599e-04
5	1.7578	1.010e+05	1.205e-02	2.044e-05
6	1.6797	4.810e+03	5.495e-04	9.421e-07
7	1.2891	9.172e+06	8.161e-01	1.485e-03
8	.5078	8.040e+09	3.114e+02	6.376e-01
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		8.108e+09	3.361e+02	6.652e-01

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1
 File : ON05N.MSH
 Run date: February 23, 1996
 Run time: 8:17 a.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: no shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	1205.4	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	111.760	cm.
Thickness of second shield.....	T2	40.640	"
Thickness of third shield.....	T3	1053.	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3
-----	-----	-----	-----
Air	.001220		.001220
Aluminum			
Carbon			
Concrete			
Hydrogen			
Iron			
Lead			
Lithium			
Nickel			
Tin			
Titanium			
Tungsten			
Urania			
Uranium			
Water		1.0	
Zirconium			

CASE: no shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	9.6000e-01	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	7.088e-01	7.427e-04
2	6.3359	1.249e+05	2.006e-02	2.173e-05
3	6.1328	5.361e+07	8.315e+00	9.091e-03
4	2.7422	5.905e+05	3.508e-02	5.168e-05
5	1.7578	1.010e+05	3.399e-03	5.763e-06
6	1.6797	4.810e+03	1.524e-04	2.613e-07
7	1.2891	9.172e+06	2.030e-01	3.694e-04
8	.5078	7.778e+10	4.577e+02	9.372e-01
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		7.785e+10	4.670e+02	9.475e-01

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page	: 1	File Ref:	_____
File	: ON05N2.MSH	Date:	____/____/____
Run date:	February 23, 1996	By:	_____
Run time:	8:19 a.m.	Checked:	_____

CASE: no shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	1061.	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	1061.	cm.

MATERIAL DENSITIES (g/cc):

Material	Shield 1
-----	-----
Air	.001220
Aluminum	
Carbon	
Concrete	
Hydrogen	
Iron	
Lead	
Lithium	
Nickel	
Tin	
Titanium	
Tungsten	
Urania	
Uranium	
Water	
Zirconium	

CASE: no shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	9.6000e-01	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	1.840e+00	1.928e-03
2	6.3359	1.249e+05	5.266e-02	5.704e-05
3	6.1328	5.361e+07	2.189e+01	2.393e-02
4	2.7422	5.905e+05	1.086e-01	1.599e-04
5	1.7578	1.010e+05	1.205e-02	2.044e-05
6	1.6797	4.810e+03	5.495e-04	9.421e-07
7	1.2891	9.172e+06	8.161e-01	1.485e-03
8	.5078	7.778e+10	3.012e+03	6.168e+00
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		7.785e+10	3.037e+03	6.195e+00

Microshield 3.12

(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1 File Ref: _____
 File : OFF06Y.MSH Date: ____/____/____
 Run date: February 23, 1996 By: _____
 Run time: 8:30 a.m. Checked: _____

CASE: behind shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	1662.6	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	111.760	cm.
Thickness of second shield.....	T2	40.640	"
Thickness of third shield.....	T3	304.	"
Thickness of fourth shield.....	T4	48.	"
Thickness of fifth shield.....	T5	1158.2	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3	Shield 4	Shield 5
Air	.001220		.001220		.001220
Aluminum					
Carbon					
Concrete				2.350	
Hydrogen					
Iron					
Lead					
Lithium					
Nickel					
Tin					
Titanium					
Tungsten					
Urania					
Uranium					
Water		1.0			
Zirconium					

CASE: behind shield

File: OFF06Y.MSH

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	1.5350e-02	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	3.720e-02	3.897e-05
2	6.3359	1.249e+05	9.789e-04	1.060e-06
3	6.1328	5.361e+07	3.979e-01	4.351e-04
4	2.7422	5.905e+05	5.766e-04	8.492e-07
5	1.7578	1.010e+05	2.200e-05	3.730e-08
6	1.6797	4.810e+03	8.845e-07	1.516e-09
7	1.2891	9.172e+06	5.637e-04	1.026e-06
8	.5078	8.040e+09	7.633e-03	1.563e-05
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		8.108e+09	4.449e-01	4.926e-04

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page	: 1	File Ref:	_____
File	: OFF06Y2.MSH	Date:	___/___/___
Run date:	February 23, 1996	By:	_____
Run time:	8:32 a.m.	Checked:	_____

CASE: behind shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	1518.2	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	312.	cm.
Thickness of second shield.....	T2	48.	"
Thickness of third shield.....	T3	1158.2	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3
-----	-----	-----	-----
Air	.001220		.001220
Aluminum			
Carbon			
Concrete		2.350	
Hydrogen			
Iron			
Lead			
Lithium			
Nickel			
Tin			
Titanium			
Tungsten			
Urania			
Uranium			
Water			
Zirconium			

CASE: behind shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	1.5350e-02	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	1.072e-01	1.123e-04
2	6.3359	1.249e+05	2.945e-03	3.190e-06
3	6.1328	5.361e+07	1.211e+00	1.324e-03
4	2.7422	5.905e+05	2.941e-03	4.332e-06
5	1.7578	1.010e+05	1.686e-04	2.859e-07
6	1.6797	4.810e+03	7.102e-06	1.218e-08
7	1.2891	9.172e+06	6.154e-03	1.120e-05
8	.5078	8.040e+09	2.624e-01	5.374e-04
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		8.108e+09	1.593e+00	1.993e-03

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1 File Ref: _____
 File : ON06Y.MSH Date: ____/____/____
 Run date: February 23, 1996 By: _____
 Run time: 8:36 a.m. Checked: _____

CASE: behind shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	1662.6	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	111.760	cm.
Thickness of second shield.....	T2	40.640	"
Thickness of third shield.....	T3	304.	"
Thickness of fourth shield.....	T4	48.	"
Thickness of fifth shield.....	T5	1158.2	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3	Shield 4	Shield 5
-----	-----	-----	-----	-----	-----
Air	.001220		.001220		.001220
Aluminum					
Carbon					
Concrete				2.350	
Hydrogen					
Iron					
Lead					
Lithium					
Nickel					
Tin					
Titanium					
Tungsten					
Urania					
Uranium					
Water		1.0			
Zirconium					

CASE: behind shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	9.6000e-01	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	3.720e-02	3.897e-05
2	6.3359	1.249e+05	9.789e-04	1.060e-06
3	6.1328	5.361e+07	3.979e-01	4.351e-04
4	2.7422	5.905e+05	5.766e-04	8.492e-07
5	1.7578	1.010e+05	2.200e-05	3.730e-08
6	1.6797	4.810e+03	8.845e-07	1.516e-09
7	1.2891	9.172e+06	5.637e-04	1.026e-06
8	.5078	7.778e+10	7.383e-02	1.512e-04
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		7.785e+10	5.111e-01	6.282e-04

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1
 File : ON06Y2.MSH
 Run date: February 23, 1996
 Run time: 8:38 a.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: behind shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	1518.2	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	312.	cm.
Thickness of second shield.....	T2	48.	"
Thickness of third shield.....	T3	1158.2	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3
-----	-----	-----	-----
Air	.001220		.001220
Aluminum			
Carbon			
Concrete		2.350	
Hydrogen			
Iron			
Lead			
Lithium			
Nickel			
Tin			
Titanium			
Tungsten			
Urania			
Uranium			
Water			
Zirconium			

CASE: behind shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	9.6000e-01	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	1.072e-01	1.123e-04
2	6.3359	1.249e+05	2.945e-03	3.190e-06
3	6.1328	5.361e+07	1.211e+00	1.324e-03
4	2.7422	5.905e+05	2.941e-03	4.332e-06
5	1.7578	1.010e+05	1.686e-04	2.859e-07
6	1.6797	4.810e+03	7.102e-06	1.218e-08
7	1.2891	9.172e+06	6.154e-03	1.120e-05
8	.5078	7.778e+10	2.539e+00	5.198e-03
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		7.785e+10	3.869e+00	6.653e-03

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1
 File : OFF06N.MSH
 Run date: February 23, 1996
 Run time: 8:48 a.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: no shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	1662.6	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	111.760	cm.
Thickness of second shield.....	T2	40.640	"
Thickness of third shield.....	T3	1510.	"
Microshield inserted air gap.....	air	0.2	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3	Air gap
-----	-----	-----	-----	-----
Air	.001220		.001220	.001220
Aluminum				
Carbon				
Concrete				
Hydrogen				
Iron				
Lead				
Lithium				
Nickel				
Tin				
Titanium				
Tungsten				
Urania				
Uranium				
Water		1.0		
Zirconium				

CASE: no shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	1.5350e-02	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	3.770e-01	3.950e-04
2	6.3359	1.249e+05	1.067e-02	1.156e-05
3	6.1328	5.361e+07	4.422e+00	4.834e-03
4	2.7422	5.905e+05	1.863e-02	2.744e-05
5	1.7578	1.010e+05	1.802e-03	3.055e-06
6	1.6797	4.810e+03	8.079e-05	1.385e-07
7	1.2891	9.172e+06	1.075e-01	1.956e-04
8	.5078	8.040e+09	2.492e+01	5.102e-02
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		8.108e+09	2.986e+01	5.649e-02

Microshield 3.12

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Page : 1
File : OFF06N2.MSH
Run date: February 23, 1996
Run time: 8:52 a.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: no shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	1518.2	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	1518.2	cm.

MATERIAL DENSITIES (g/cc):

Material	Shield 1
-----	-----
Air	.001220
Aluminum	
Carbon	
Concrete	
Hydrogen	
Iron	
Lead	
Lithium	
Nickel	
Tin	
Titanium	
Tungsten	
Urania	
Uranium	
Water	
Zirconium	

CASE: no shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	1.5350e-02	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	9.105e-01	9.540e-04
2	6.3359	1.249e+05	2.606e-02	2.823e-05
3	6.1328	5.361e+07	1.083e+01	1.185e-02
4	2.7422	5.905e+05	5.389e-02	7.938e-05
5	1.7578	1.010e+05	6.009e-03	1.019e-05
6	1.6797	4.810e-03	2.741e-04	4.700e-07
7	1.2891	9.172e+06	4.092e-01	7.446e-04
8	.5078	8.040e+09	1.610e+02	3.297e-01
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		8.108e+09	1.733e+02	3.433e-01

Microshield 3.12

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Page : 1
File : ON06N.MSH
Run date: February 23, 1996
Run time: 8:55 a.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: no shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	1662.6	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	111.760	cm.
Thickness of second shield.....	T2	40.640	"
Thickness of third shield.....	T3	1510.	"
Microshield inserted air gap.....	air	0.2	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3	Air gap
-----	-----	-----	-----	-----
Air	.001220		.001220	.001220
Aluminum				
Carbon				
Concrete				
Hydrogen				
Iron				
Lead				
Lithium				
Nickel				
Tin				
Titanium				
Tungsten				
Uranium				
Water		1.0		
Zirconium				

CASE: no shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	9.6000e-01	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	3.770e-01	3.950e-04
2	6.3359	1.249e+05	1.067e-02	1.156e-05
3	6.1328	5.361e+07	4.422e+00	4.834e-03
4	2.7422	5.905e+05	1.863e-02	2.744e-05
5	1.7578	1.010e+05	1.802e-03	3.056e-06
6	1.6797	4.810e+03	8.079e-05	1.385e-07
7	1.2891	9.172e+06	1.075e-01	1.956e-04
8	.5078	7.778e+10	2.411e+02	4.936e-01
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		7.785e+10	2.460e+02	4.991e-01

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1
File : ON06N2.MSH
Run date: February 23, 1996
Run time: 8:56 a.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: no shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	1518.2	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	1518.2	cm.

MATERIAL DENSITIES (g/cc):

Material	Shield 1
-----	-----
Air	.001220
Aluminum	
Carbon	
Concrete	
Hydrogen	
Iron	
Lead	
Lithium	
Nickel	
Tin	
Titanium	
Tungsten	
Urania	
Uranium	
Water	
Zirconium	

CASE: no shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	9.6000e-01	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	9.105e-01	9.540e-04
2	6.3359	1.249e+05	2.606e-02	2.823e-05
3	6.1328	5.361e+07	1.083e+01	1.185e-02
4	2.7422	5.905e+05	5.389e-02	7.938e-05
5	1.7578	1.010e+05	6.009e-03	1.019e-05
6	1.6797	4.810e+03	2.741e-04	4.700e-07
7	1.2891	9.172e+06	4.092e-01	7.446e-04
8	.5078	7.778e+10	1.558e+03	3.189e+00
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		7.785e+10	1.570e+03	3.203e+00

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page	: 1	File Ref:	_____
File	: OFF07Y.MSH	Date:	____/____/____
Run date:	February 23, 1996	By:	_____
Run time:	9:11 a.m.	Checked:	_____

CASE: behind shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	2775.260	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	111.760	cm.
Thickness of second shield.....	T2	40.640	"
Thickness of third shield.....	T3	304.	"
Thickness of fourth shield.....	T4	48.	"
Thickness of fifth shield.....	T5	2270.760	"
Microshield inserted air gap.....	air	0.1	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3	Shield 4	Shield 5	Air gap
-----	-----	-----	-----	-----	-----	-----
Air	.001220		.001220		.001220	.001220
Aluminum						
Carbon						
Concrete				2.350		
Hydrogen						
Iron						
Lead						
Lithium						
Nickel						
Tin						
Titanium						
Tungsten						
Urania						
Uranium						
Water		1.0				
Zirconium						

CASE: behind shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	1.5350e-02	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	1.339e-02	1.403e-05
2	6.3359	1.249e+05	3.521e-04	3.814e-07
3	6.1328	5.361e+07	1.431e-01	1.565e-04
4	2.7422	5.905e+05	2.061e-04	3.035e-07
5	1.7578	1.010e+05	7.825e-06	1.327e-08
6	1.6797	4.810e+03	3.144e-07	5.391e-10
7	1.2891	9.172e+06	1.997e-04	3.633e-07
8	.5078	8.040e+09	2.666e-03	5.458e-06
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		8.108e+09	1.599e-01	1.770e-04

Microshield 3.12

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Page : 1
File : OFF07Y2.MSH
Run date: February 23, 1996
Run time: 9:14 a.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: behind shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	2630.760	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	312.	cm.
Thickness of second shield.....	T2	48.	"
Thickness of third shield.....	T3	2270.760	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3
-----	-----	-----	-----
Air	.001220		.001220
Aluminum			
Carbon			
Concrete		2.350	
Hydrogen			
Iron			
Lead			
Lithium			
Nickel			
Tin			
Titanium			
Tungsten			
Urania			
Uranium			
Water			
Zirconium			

CASE: behind shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	1.5350e-02	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	3.584e-02	3.756e-05
2	6.3359	1.249e+05	9.846e-04	1.066e-06
3	6.1328	5.361e+07	4.047e-01	4.425e-04
4	2.7422	5.905e+05	9.760e-04	1.438e-06
5	1.7578	1.010e+05	5.566e-05	9.438e-08
6	1.6797	4.810e+03	2.343e-06	4.017e-09
7	1.2891	9.172e+06	2.022e-03	3.678e-06
8	.5078	8.040e+09	8.488e-02	1.738e-04
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18				
19				
20				
TOTALS:		8.108e+09	5.295e-01	6.602e-04

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1
 File : ON07Y.MSH
 Run date: February 23, 1996
 Run time: 9:18 a.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: behind shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	2775.260	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	111.760	cm.
Thickness of second shield.....	T2	40.640	"
Thickness of third shield.....	T3	304.	"
Thickness of fourth shield.....	T4	48.	"
Thickness of fifth shield.....	T5	2270.760	"
Microshield inserted air gap.....	air	0.1	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3	Shield 4	Shield 5	Air gap
-----	-----	-----	-----	-----	-----	-----
Air	.001220		.001220		.001220	.001220
Aluminum						
Carbon						
Concrete				2.350		
Hydrogen						
Iron						
Lead						
Lithium						
Nickel						
Tin						
Titanium						
Tungsten						
Urania						
Uranium						
Water		1.0				
Zirconium						

CASE: behind shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	9.6000e-01	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	1.339e-02	1.403e-05
2	6.3359	1.249e+05	3.521e-04	3.814e-07
3	6.1328	5.361e+07	1.431e-01	1.565e-04
4	2.7422	5.905e+05	2.061e-04	3.035e-07
5	1.7578	1.010e+05	7.825e-06	1.327e-08
6	1.6797	4.810e+03	3.144e-07	5.391e-10
7	1.2891	9.172e+06	1.997e-04	3.633e-07
8	.5078	7.778e+10	2.579e-02	5.280e-05
9				
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18				
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20				
TOTALS:		7.785e+10	1.831e-01	2.244e-04

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1
File : ON07Y2.MSH
Run date: February 23, 1996
Run time: 9:16 a.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: behind shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	2630.760	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	312.	cm.
Thickness of second shield.....	T2	48.	"
Thickness of third shield.....	T3	2270.760	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3
-----	-----	-----	-----
Air	.001220		.001220
Aluminum			
Carbon			
Concrete		2.350	
Hydrogen			
Iron			
Lead			
Lithium			
Nickel			
Tin			
Titanium			
Tungsten			
Urania			
Uranium			
Water			
Zirconium			

CASE: behind shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	9.6000e-01	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	3.584e-02	3.756e-05
2	6.3359	1.249e+05	9.846e-04	1.066e-06
3	6.1328	5.361e+07	4.047e-01	4.425e-04
4	2.7422	5.905e+05	9.760e-04	1.438e-06
5	1.7578	1.010e+05	5.566e-05	9.438e-08
6	1.6797	4.810e+03	2.343e-06	4.017e-09
7	1.2891	9.172e+06	2.022e-03	3.679e-06
8	.5078	7.778e+10	8.210e-01	1.681e-03
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18				
19				
20				
TOTALS:		7.785e+10	1.266e+00	2.167e-03

Microshield 3.12

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Page : 1
File : OFF07N.MSH
Run date: February 23, 1996
Run time: 9:25 a.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: no shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	2775.160	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	111.760	cm.
Thickness of second shield.....	T2	40.640	"
Thickness of third shield.....	T3	2622.	"
Microshield inserted air gap.....	air	0.760	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3	Air gap
-----	-----	-----	-----	-----
Air	.001220		.001220	.001220
Aluminum				
Carbon				
Concrete				
Hydrogen				
Iron				
Lead				
Lithium				
Nickel				
Tin				
Titanium				
Tungsten				
Urania				
Uranium				
Water		1.0		
Zirconium				

CASE: no shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	1.5350e-02	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	1.343e-01	1.408e-04
2	6.3359	1.249e+05	3.799e-03	4.115e-06
3	6.1328	5.361e+07	1.574e+00	1.721e-03
4	2.7422	5.905e+05	6.576e-03	9.687e-06
5	1.7578	1.010e+05	6.313e-04	1.070e-06
6	1.6797	4.810e+03	2.828e-05	4.848e-08
7	1.2891	9.172e+06	3.738e-02	6.802e-05
8	.5078	8.040e+09	8.450e+00	1.730e-02
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20				
TOTALS:		8.108e+09	1.021e+01	1.925e-02

Microshield 3.12
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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1

File : OFF07N2.MSH

Run date: February 23, 1996

Run time: 9:27 a.m.

File Ref: _____

Date: ____/____/____

By: _____

Checked: _____

CASE: no shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	2630.760	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	2630.760	cm.

MATERIAL DENSITIES (g/cc):

Material	Shield 1
-----	-----
Air	.001220
Aluminum	
Carbon	
Concrete	
Hydrogen	
Iron	
Lead	
Lithium	
Nickel	
Tin	
Titanium	
Tungsten	
Urania	
Uranium	
Water	
Zirconium	

CASE: no shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	1.5350e-02	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	3.018e-01	3.162e-04
2	6.3359	1.249e+05	8.641e-03	9.360e-06
3	6.1328	5.361e+07	3.592e+00	3.927e-03
4	2.7422	5.905e+05	1.797e-02	2.647e-05
5	1.7578	1.010e+05	2.022e-03	3.429e-06
6	1.6797	4.810e+03	9.237e-05	1.584e-07
7	1.2891	9.172e+06	1.393e-01	2.535e-04
8	.5078	8.040e+09	5.802e+01	1.188e-01
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20				
TOTALS:		8.108e+09	6.208e+01	1.233e-01

Microshield 3.12

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{PENNSYLVANIA POWER & LIGHT - #138}

Page	: 1	File Ref:	_____
File	: ON07N.MSH	Date:	____/____/____
Run date:	February 23, 1996	By:	_____
Run time:	9:32 a.m.	Checked:	_____

CASE: no shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	2775.160	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	111.760	cm.
Thickness of second shield.....	T2	40.640	"
Thickness of third shield.....	T3	2622.	"
Microshield inserted air gap.....	air	0.760	"

MATERIAL DENSITIES (g/cc):

Material	Shield 1	Shield 2	Shield 3	Air gap
-----	-----	-----	-----	-----
Air	.001220		.001220	.001220
Aluminum				
Carbon				
Concrete				
Hydrogen				
Iron				
Lead				
Lithium				
Nickel				
Tin				
Titanium				
Tungsten				
Uranium				
Water		1.0		
Zirconium				

CASE: no shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	9.6000e-01	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	1.343e-01	1.408e-04
2	6.3359	1.249e+05	3.799e-03	4.115e-06
3	6.1328	5.361e+07	1.574e+00	1.721e-03
4	2.7422	5.905e+05	6.576e-03	9.687e-06
5	1.7578	1.010e+05	6.313e-04	1.070e-06
6	1.6797	4.810e+03	2.828e-05	4.848e-08
7	1.2891	9.172e+06	3.738e-02	6.802e-05
8	.5078	7.778e+10	8.175e+01	1.674e-01
9				
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20				
TOTALS:		7.785e+10	8.350e+01	1.693e-01

Microshield 3.12

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(PENNSYLVANIA POWER & LIGHT - #138)

Page : 1
File : ON07N2.MSH
Run date: February 23, 1996
Run time: 9:30 a.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: no shield

GEOMETRY 2: Line source - slab shields

Distance to detector.....	X	2630.760	cm.
Vertical displacement of dose point.....	Y	46.	"
Source line length.....	L	457.2	"
Angle of line with respect to shield base....	A	90.	degrees
Thickness of first shield.....	T1	2630.760	cm.

MATERIAL DENSITIES (g/cc):

Material	Shield 1
-----	-----
Air	.001220
Aluminum	
Carbon	
Concrete	
Hydrogen	
Iron	
Lead	
Lithium	
Nickel	
Tin	
Titanium	
Tungsten	
Urania	
Uranium	
Water	
Zirconium	

CASE: no shield

BUILDUP FACTOR: based on BERGER method.
Using the characteristics of air.

INTEGRATION PARAMETERS:

None - integrated with Simpson's rule with a convergence of .001

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ar-41	2.5000e-04	C-11	9.6000e-01	N-13	6.8500e-02
N-16	2.1000e-03	O-15	2.5000e-02		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	7.1172	3.885e+06	3.018e-01	3.162e-04
2	6.3359	1.249e+05	8.641e-03	9.360e-06
3	6.1328	5.361e+07	3.592e+00	3.927e-03
4	2.7422	5.905e+05	1.797e-02	2.647e-05
5	1.7578	1.010e+05	2.022e-03	3.429e-06
6	1.6797	4.810e+03	9.237e-05	1.584e-07
7	1.2891	9.172e+06	1.393e-01	2.535e-04
8	.5078	7.778e+10	5.613e+02	1.149e+00
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17				
18				
19				
20				
TOTALS:		7.785e+10	5.653e+02	1.154e+00

VITA

Scott Edward Huneycutt
19328 CR 4108
Lindale, Texas 75771

Education

- 1995 HPS Summer School, Reactor Health Physics
- 1991 University of North Texas, Denton, TX, Certification, Education
- 1986 University of Texas at Arlington, Arlington, TX, B.S., Physics

Experience

- 1995 Health Physicist, (as a practicum assignment for the DOE Fellowship for Nuclear Engineering/Health Physics), Los Alamos National Laboratory, Los Alamos, NM.
- 1993-1994 Teacher, Calvert ISD, Calvert, TX.
- 1992-1993 Teacher, Midland ISD, Midland, TX.
- 1991-1992 Teacher, Cleburne ISD, Cleburne, TX.
- 1988-1991 Engineer, General Dynamics, Fort Worth, TX.
- 1987-1988 Prototype Engineer, Fresnel Technologies, Fort Worth, TX.