PRNC205

PRNC-205

: PUERTO RICO NUCLEAR CENTER

ENVIRONMENTAL MONITORING

oF

ARGON - 41

By

4 Carlos Andrew and Donald S. Sasscor

?OPERATED BY UNIVERSITY OF PUERTO NICO UNDER CONTRACT

NO. © (40.1}1839 FOR US ENERGY RESEARCH AN!) DEVELOPMENT ADMINISTRATION

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ENVIRONMENTAL MONITORING

oF

ARGON - 41

by

carlos Andreu *

and

Donald S. Sasscer

Work performed at the Puerto Rico Nuclear Center in partial

fulfillment of the requirenents for the degree of Master of

Science in Nuclear Engineering at the University of Puerto

Rico at Mayaguez.

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the Yearly Average Maximum Concentration... . - -

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assTRACT

?The objective of this work is to deteraine the yearly average
aximm concentration and dose of argon-A1 in unrestricted areas
adjacent to the Puerto Rico Nuclear Center, and to develop a sinple
and accurate procedure for seasuring argon-A1 concentration, in order
to verify the model used for calculation of the attenuation factor

between the off-gas stack outlet and ground levi. The model used is

the diffusion equation for average long-period concentration from a continuous point source. In addition, the Kanne Chander, which is che constant air nonitor of the reactor off-gas system, was calibrated s0 fas to enable an accurate and easy determination of the future concen= tration at any pover level. The Kanne chaaber wes satisfactorily calibrated, with a probable error of approxinately 5t.

?The systen used allows concentration at ground level to be measured

to a factor of 6.75 X 105 less than the concentration emitted by the

oft

ack, oF to approximately 1.6 X 10-10 uCi/ec, which is 20% of the allowable concentration of 8.0 X 10°10 yci/ee. (2).

?The average value of the ratio of the estimated to measured concen- tration is 1.1, This excellent agreement gives a high degree of

confidence in utilizing the model to calculate the yearly average

maximum concentration. The largest value of the yeerly average maximum

concentration occurred during one-ehift operation, dry season, at 125

meters from the stack in the ENE sectors and is 2.69 x 10-10 ci/meters3

which is 33.67 of the allowable concentration.

---Page Break---

The estimated dose corresponding to the largest yearly

average maximum concentration is 0.53 aren per year which is 5.3%

of the allowable dose of 10 arem per year. (1)

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1 rwrropucrioN

?The sampling of air and the seasurenent of its radioactive

content is often a difficult task due to variable sampling conditions,

the diversity of the radioactive substances being sampled, and the

fact that there are no standarzied air sampling instrusents or equipment

that can be used for all situation.

?The natural environment has alvays contained a certain anount of

radioactivity, With the discovery and application of radioactive sub-

stances and the incre:

ing use of research and power reactors, another

potential environmental contaminant has been created, thus necessitating a closer scrutiny of various environmental media, including air.

Discharges of radioactive waste to the enviconsent by the Puerto Rican Nuclear Center (PRNC) are regulated by the Energy Research and Development Administration.

?The FRNC, functioning as a training and research cencor, is

engaged in a wide variety of activities some of which involve the TRIGA~ FLIP reactor. Such operations invariably produce quantities of gascous wastes knovn to contain radioactive nitrogen, oxygen and argon. They ?are formed from the neutron bombardment of the air contained in the thermal coluan, beam tubes, gamma room, in-core and side core rabbit systen and from the water in the reactor pool.

The formation occurs according to

WALE LUE

as lglg

Mie a +e CB) 8 sec

376

Ps ay) 8 sec

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Bo

Ft Ow) on

so gh a Aa

aT 4 oh ?? ish ask + (ey) 10 min

?The half lives of the isotopes of nitrogen and oxygen which become

radioactive are so short that they decay before escaping from the reactor

building. Substantially all of the activity in the air or water under

normal opt

ating conditions {s due to argon-61.

During normal operation, pool water circulates through the reactor

by natural convection, thereby exposing the air which is dissolved in the

vater to the neutron flux of the core. AE the same tine that the argon in

this air is activated, a fraction of it is driven off from the water due

to the reduced air solubility as the vater temperature increases in its

passage through che core. Once the air is driven off, part of it re~

dissolves

it bubbles up through the water and part of it reaches ¢

pool surface and mixes with che building air. It is then exhausted through the normal 16000cfm ventilation system, 69 feet above the site boundary.

In addition, air is circulated through the thermal column: volume and the dry bean tubes and the tuo rabbit aysteas by the off-gas aysten blower. Of the six beam-tube positions, three contain neutron spectrometer colli ators and are not connected to the off-ges system. A fourth one is out of commission and renoved from the reactor. Of the remaining two, one is operated in the flooded condition so that only one bean tube is being

swept by the off-gas syste. The argon in this air and the air of the

rabbit system is therefore activated and dram off to the atmosphere by

the off-gas blower. This is @ 150cfm blover exhat

{ting to the atmosphere

at a level of 50 feet above the

ee boundary fence.

---Page Break---

Since radioactive argon is the main source of gaseous activity

produced by the PRNC TRIGA reactor during normal operation, the primary

objective of this work wa

to develop a simple and accurate procedure

for measuring argon-41 concentration at ground level, in order to verify

4iffusion equation for average long-period concentration fros a continuous

source. This model vas us

for calculating the attenuation factor b¢

tween the off-gas stack outlet and ground level. In addition, the Kanne chamber, which is the sir monitor of the reactor off-gas systen was calibrated go as to enable an accurate and easy determination of the concentration in the future at any power Level.

---Page Break---

TT REVIEW OF LITERATURE

rch has beén performed on this problem by Efigenio Rivera fron Health Physics Division in 1973 (2), This work included the rormination of the concentration of argon-41 bubbles emerging from the pool surface and all of the argon-41 through the off-gas system. Also, the Kanne chanber was calibrated utilizing the atgon-41 produced in the reactor core and energing through the pool vater as the calibrated source.

In addition, Pedro Cruz fron the Puerto Rico Nuclear Center Reactor

Division (3) includes the calibration of the Kanne chanber, using

kxypton-85 as the standas

?The experiment vas conducted statically

by f

{ing @ known concentration of krypton-85 into the chamber. For each concentration the meter readings in sy ap recorded and plotted fs a function of the known concentration in pCi/ce.

Other research related to the Kanne chy

ber refer to the efficiency

determination of a Kanne chanber for detection of radiogases by J. J.

Fitzgerald and B. W. Borelli (4). The inventor of the Kanne chasher,

W. R. Kanne, reported a device for the monitoring of gas for radioac~

tivity (5) and for the monitoring of gas for radioactive xenon (6)

These works describe in detai

1 the Kanne chanber and ite principle of

operation.

?The Literature survey revealed the existence of other vorks done

{in similar areas but not directly related or applicable to this

research.

---Page Break---

INSTRUMENTATION

A. FOR TRE EFFICIENCY DETERMINATION OF THE DETECTION SYSTEM

A four inch diameter by four inch height cylindrical sodium

iodide crystal activated with thalliom was used for the detection

of gamma rays

?he detector was connected to a preamplifier ané

Linear amplifier, Pulse height analysis was done by a multichannel

analyzer (Series 2200 Nuclear Data Analyzer) with the end result typed

or displayed on an oscilloscope. A high voltage power supply vas

utilized to provide a regulated voltage to the photomultiplier tube.

'B. FOR THE DETERMINATION OF THE ARGON=41 CONCENTRATION

1, In the off-gas system

2. At the surface of the reactor pool

The instruaentation described in

inmediately above, vas

used to determine the argon-41 concentration in both the off-gas

system and above the reactor pool.

3. At various ground level locations

The m

fenents of the argon-Al concentrations at various ground
Jevel locations required a high-sensitivity counting system. This high-sensitivity counting system was developed by: a) increasing the shielding to six inches of lead, b) connecting two sodiua iodide detectors in parallel, and c) obtaining samples of air by using a high pressure

pump to fill a scuba tank to a pre

sure of 2200 psi. The rate of air

entering the tank was found to be constant with time. (See Figure 1).

---Page Break---

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OF the ewo detectors used, one was the four inch by four inch

detector described above, and the one was a three inch by three

inch sodium iodide cryst

1. Each was connnected to a high voltage

supply, @ preamplifier and a linear amplifier, These two connections

were introduced to the multichannel analyzer (Series 2200 Nuclear

Data Analyzer) for che pulse height analysis, The results were shown

im an oscilloscope and typed.

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IV METHOD AND RESULTS

A. OVERALL EFFICIENCY DETERMINATION OF THE DETECTION SYSTEM

FOR THE 1.29 Mev CAMWA OF ARCON-A1

An efficiency calibration curve was made for the detection

systea of argon-t1. A sodiun-22 source (which (which emits 2 ganna

of 1.27 Mey 100% of the time) and a cesium-t137 source (which emits

1 gamna of 0.662 Mev 93.5% of the tine) were used as standird sources

for the determination of the efficiency, Each source was placed at

the same distance from the detector (7.88 ex) and the overall peak

efficiency for the count system at each energy vas found using

Equation 1

EFFICIENCY (2)

werviny) cProsasryiny * 1°

PROBABILITY = Probability of emitting a gana of that

energy per disintegration

ACTIVITY = Present activity of source (disintegration/sec)

AREA = Response of aystem to the source determined

using the Total Peak Ares Method (counts/sec)

wher

ara Ya Ata Gabty

Ag = Number of counts accumulated in channel i

1 = Channel number at left hand Limit oF photopeak

R = channel number at right hand Limit of photopeak

?The overall efficiency for the 1.27 Mev peak of Na-22 and the

0.662 Mev peak of Cs-137 vas determined to be 1,317 and 2.29%

respectively, for the detection system described in section III-A.

---Page Break---

Using the efficiency calibration curve of Figure 3, the overall

efficiency of the 1,29 Mev peak of argon~K was determined to be 1.3%.

An efficiency curve obtained from reference (7) tor 9 typical

four inch by four inch sodium iodide detector is also shown in Figure 2.

B. DETERMINATION OF THE ARGON=41. CONCENTRATION

1. In the off-gas system

Argon-41 concentration ia the off-gas system was determined bv

aking samples in a 1000 ce spherical #1

O88 container with a atopetork

valve, The container vas previously evacuated to a pressure of appsmsi~

mately 0.1 am of mercury for each sample. Each tine a sample was

collected, the cime of collects

jon, start counting tine, power Level

of the reactor, air flow through the stack and Kanne chamber readings were recorded. (See Table 1).

In order to apply the counting efficiency of the aysten as

obtained from point sources in Section IV-A to a much La

yt volume, a

Beometry factor is needed. Since this factor had already been obtained by Efigenio Rivers in his thesis (2) and the sane container and geometry

4 by Rivera was uscd in this work (7.88 om as the distance from the exact center of the 1000 cv sphere to the detector), it was possible

to use his geonetry factor for correcting the point source

sumption.

This correction factor is 0.950 for 1000 ce sphere.

Counts of 10000 second, live time, vere obtained for each sample.

---Page Break---

10

EFFICIENCY (2)

on

Figure 2.

n

Effictency Curve for a

Typical 4? by 4" Na T

Detector at 5 em fron

the source (7)

1.27 Mev Ganma

on 1.07 10

ENERGY (Nev) 1,29 Mew Gacena

of Ard

Overall Effictency as a Function of Energy of the Four Inch

Diameter by Four Inch High Cylindrical No I Detector, 7.88 cm

from the Souree.

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papaooay ered

cr sons seer imtoo ORE"? ggg

wn ES Soe oe

weashs se9-540 92 Uy YoyaeuTmI9s0q Wo}IEIzUeDNOD Ty-UORIY ?tT eTGeL

---Page Break---

BD

In order to keep the sane overall efficiency as was determined in

Section IV-A, the 1.29 Mev argon-41 peak was determined in the

same vay as the 1.27 Mev sodiun-22 peak. Total Peak Area Method

(explained in Section IV-A) was used to calculate the area under the

Peak. Since this area is not representative of the activity in the

off

system at the ins

int of collection, it had to be corrected

for decay time. (See Appendix).

Therefore, the argon-41 concentration in the off-gas system at

the instant of collection is given by

hp PAOD sca >

OT Ee WCF. xr HEC o

where

T.P.A, is the cotal peak ares in counts/sec per ce

oT is the time decay correction factor

c is the efficiency of the counting system

3.7 X 104 is the conversion factor from disintegration/sec to uCi

V.c.F, iw the volume correction factor for che 1000 ¢&

collection sphere

Results are presented on Table 1.

4, Kanne chanber calibration

Radioactive argon-41 concentration in the off sas system is

continuously monitored by a Kanne chamber. The Kanne chamber was

accurately calibrated in order to have confidence in future readings

The calibration was performed using the data obtained from the of gas

system concentration determination. (See Table 1). A Line to correlate

the recorded Kanne chamber reading and the determined argon-b1 concen

tration was drawn by Linear regrosion analysis. (See Figure 3.)

---Page Break---

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3

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; stope = 2.3.x 108 4 0.06 x 10

g yetle per sep

=

01x 10 5x 10d

Kanne Chander Reading

(emp)

Figure3 . Kanne Chamber Calibration Curve

---Page Break---

as

?These data gave a conversion factor between Kanne chamber reading

and concentration in nCi/ee of

Concentration (nCi/ec = (2.3 X 106 + 0.06 x 105) x

(Kame chamber Yeading) e

This indicated that the probable error io the conversion of Kanne

chanber to a concentration is approxinstely 57.

b, mission rate variation with power level

?The argon-41 emission rate should be proportional to the flux or

power level. Since the samples were taken at different power Levels,

(See Tabie 1) a Line was draun to check the Linearity of the activity

?of argon-é1 production as a function of power (See Figure 4). This ine gave an average emission rate of 543 nCi/min with a prubable

error of 6% at 1000 Ky.

2. At che surface of the reactor pool

Since the area where the argon-A1 emerged through the reactor pool water was Jarge, a sheet metal cone was placed on top of the water surface to collect some of the effluent gas. A polyethyelene

tube vas connected to the collector, and to one side of a th

way

lass valve. One valve outlet provided means for sample drawing at any tie, the other outlet was connected to another section of the tube with its end under two inches of water. (See Figure 5). ?This was done in order to determine the volune rate in cc/ain of argon-41 effluents, The area occupied by the collector on top of the pool surface was approximately one half of the total area

?through which the argon-41 effluent was emerging. Therefore, since

---Page Break---

the volume rate collected vas measured to be 133 ce/min, the total argon-41 effluent released into the reactor building was estinated to be 300 ce/min.

Using Equation 2 the concentration of argon-41 at the pool surface was obtained and is presented in Table 2.

3. At varfous ground level Locations

a. Sensitivity of counting system

The high sensitivity of the new countins ayatem (discussed in Section IT1-B-3), without taking into consideration the increased Pressure, vas determined before the system was used. This was done by taking «

ample of the off-gas in a scubs tank (previously evac-vated to @ pressure of 0.4 nm of mercury) at the stack. The tank was filled to atmospheric pres:

re. Activity for periods of 4000 seconds

were obtained for almost 24 hours. In all of the sixteen runs the

argon-41 peak was present even though the Last run wax counted 12.5 half Lives after the sample hal heen taken. This could be done becouse the background was reduced and the efficiency was increased by « factor of tuo.

A curve of the activity as a function of Lime wax obtained and the decay constant was found as 1,042% 10-4 gec-l vhich is very near to the accepted value of 1.052 X 10-4 sec-1,

The

rethod explained above gave the sensitivity of the counting

system taking into consideration only the increase in shieliing. and én

the efficiency, This gave an initial to final count ratio of approxi~

ately 4500, when the air in the tank vas at atnospheric pressure

---Page Break---

uv

600

500 Probable error = 61

400

300

Bntssion Rate (Ct /min)

200

100

° 250 300° «75040001250

Power Level (iu)

Figure 4. Entssion Rate of Argon

41 im the Off-Cas System as a Function

of Power Level.

---Page Break---

18

Glass sphere

Three Way Valve

Polyethylene

Tube

supple

collector

Gis

Graduated

cylinder

Diffuser

Jee

Reactor

Coxe

Reactor Pool

Figure 5+ Schenatic Diagram of the Experimental Sanple Collection set tps

---Page Break---

Table 2. Argons1 Concentration Determination

in the surface of the Reactor Poot

Foxe Ta Decay?

; * Emission

Level desintezracion, Tine $@Meentration Ale Tow MSSE

co) seeree (see) (WEEE) Cela) ctfnin)

1000 0.751999 22027 6.38x107) 300, 1,698

1000 310207 650 6.98x10" 300, 1.852

wate Recorded

---Page Break---

20

However, the

tivity was increased by a factor of 150 by collect-

ing air in e scuba tank a¢ a pressure of 2200 psi. Therefore, the

syaten can determine concentrations to approximately 150 tines 4500

© 6.75 X 105 times Less than the concentration leaving the off-pas

stack. The concentration in the off;

system is approximately

10.8 X 10°5 uci/ec at the 1000 Kw power Level, Therefore, the system

can determine concentrations to approximately 1.6 X 10-10 wci/ee, which

is less than 20% of che allovable concentration of 8 X 10-10 wei/ec (1).

b. Meagured value

ing the high sensitivity system described ahave, samples of air

at various ground level locations were obtaine! in a scubs tink which

was filled to a pres

ire of 2200 pounds per squnre inch. This pressure

vas obtained using @ scuba tank air compressor. thich tank was previously

evacuated toa

Fessure of 0.4 em of mercury. Counts of 404K) seconds

(ive time) were taken for each sample. For every sample the following

was recorded: Kanne chamber reading, air Flow coming out ol the stack,

@istance from the stack to the sampling location, wind spec. wind

direction, wind frequency to the sampling location, meteorological

conditions, time at start of collection, start counting tine, and prossur

of the tank after finishing the countings. AL1 of these parameters vere

needed. Sone to calculate the messi

8 valucs, others for the estimted

value

Using the Kanne chamber reading, the argon-4l concentration at the

stack could be determined from the calibration curve. Using Equation 3.

Concentration at the stack ~ (Kanne chanber) (Conversion factor)

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wae sesore 8

Sroes zeores oixtat y.omxi's cess craven one

asin sraotey ?oIxcror fsr9e?coreot neers HE JRE cL/EE/e stotetet

My (uyw/09) ean 08) von usw

ees ke>00 205 " wera gates oo

SOT EETEAOLS TY gg ay TEED Soastaed seed aurpucdssaz09

* ? Qianoy

wows 942 29 peansvoy worresauaci09 Ty-wo8y ?+ aTaeE

---Page Break---

2

10.3 X 10-5 = (4.5 x 10-11)(2,30 x 108).

Af the tank js filled with aryon-41 to atmuspheric pressure at

the stack, and counted with the same geometry sand of

feleney as the

fone filled at ground level, we can determine the arjwne41 concent

st ground Level using the following relation,

Concentration at ground level Activity at grown! level

eration at ground 1 at grout 1 f

?Concentration at th o

where appropriate corrections are made for counting ond devay tine

(See Appendix)

The activity at eround level (Table 4) and the activity at the

stack (Table 3), to which the yround meavurementss were compre, wre

obtained the same day in order to minimize the error determining the

attenuation factor between the stack and ground Level.

fe. Calculated value

?Taree meteorological factors are of significance in determining the

swount of mixing which will occur eo contaminnts in the event of dit=

fusion into the atmosphere. They are: the distribution of tomperature

With height, the surface wind direction and speed and the precipitation.

A complete mathematical

Lysis of diffusion processes vhich would

allow quantitative calculations of concentration is sliffivwlt becuse

instantaneous velocities exhibit irregular am! ramlon aetaut tones

Equations currently in use are based in part on xt

istieal analy

must necessarily include sone constants which are eapieiea! in natures

?These constants are functions of eddy Uitfusin

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2. | GEL fey E] 2 | GE : : a [Eye

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ee] ee] Py ay] Pye . i ?a

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2%

lepend on atnospheric «

bility. Determining suitable values for these

coefticients and paraneters is the ost important operation in their

application. Suggested diffusion coefficients for the PRNC, Nayaguer,

are shown in Table 5 and are obtained from Reference 8.

?The concentration of argon-él as a funetion of distance from a

continuous, Long term, point release of gas wis caleulated from Equat ion

3-143 or Reference 9 for the cross wind integrated concenteation

oe ee

where the standard deviation of the distribution of materia? in a plume

in the Z direction, 0,1 determined by the Sutton form (Sec 8-4) of (9)

to be

ag? = M2 C2 x(2-a)

TE the concentration is aver

ged over @ 22.5 section (1/16 of a circle),

then the long-term averaye concentration is given hy

q 2

2 oe a

= toy at @

4iffusion coefficient in che zplane (meters)®/?

X = distance from the source (meters)

?8 = nondimensional parameter associated with stability

{= percent of frequency with which the wind blows from a given sector

U = rate of material emission from a continwous point source (Ci/uwe)

b= mean vind speed (neter/sec)

h = height of source (meter)

2ex ts

TW * 18 the sector width for each of N sectors at the distance

XO = 16)

"concentration wi ariw-At (Ci/meeer2)

---Page Break---

25

Table 5. Diffusion Cocf ficients

Weak Lapse Rate

(Adiabatic) 0.25 0.26 0.36

Large Inversion,

Stable Conditions 0.50

---Page Break---

26

Table 6 presents the ostimated argon-41 concentration at ground

level and Figure 6 shows the relationship betwen the estimated and

measured argon-61 concentrations.

4. Yearly average maxiaum concentration

To deteraine the yearly average waxisus concentration of aryon~4l, the average velocity and frequency of wind in each 22.5? directional sector was obtained on an hourly basis for the dry and vet season from the climatology data of PRNC-37, Section IV, Appendix A, (8). The hourly values were averaged between 8:00 a.m. and 4:00 p.m. to obtain the average wind velocity and frequency per sector for one-shift operation. For the tvorshife operation, the hourly values were averaged between 8:00 a. and 6:00 p.m. (LL hours of day), and 7:00 pam. and 11:00 p.m. (5 hours of might). The division between night and day was necessary due to the fact that in Mayaguez the nights have 90% probability of large temperature inversion and the days a high probability of adiabatic conditions (8). Therefore, to determine the concentration, two sets of diffusion constants hhad to be used, one for the day and one for the nixht. (See Table 5)

For the dry season, during both one-shift and twishift operations,

the concentration ws greatest in the EXE sector. In th

rainy season

the greatest vatue of concentration for both operations was in the W sector. Although the SW sector and tho ENE sector have alwost the sane Frequency-to-velocity factor ducing the dry season, and W and SSW sectors

have algo almost the same frequency-to-velocity factor during the rainy

on, the ENE and the W sectors had the highest concentration due to the elevation of land in these sectors, giving a smaller effective stack heignt.

---Page Break---

The emission rate for the 1000 Kw power level vas assumed to be 9.0 (10°) Ci/see based on the emission rate as a function of pover level of Figure 4.

Subseituting the values of Table 7 for each separate condition in Equation 7, the concentrations as function of distance vere determined and are presented in Figure 7 and 8. The distance from the source, at which the yearly average maximum concentration occurs, was deternined from these figures.

?The 1000 Kw power level yearly avernge maximum concentration of ?argon-41 in uncontrolled areas, during one~shift und two-shift operations,

during the dry and the wet seasons, is shown in Table 7.

The locations of the maximum concentration are shown in Figure 9

C. YEARLY AVERAGE MAXTMUM DOSE CALCULATIONS

1. Internal dose

?The cumulative dose, from the besinning of exposure, due to a Finite

inhalation time vas calculated using Equation 7.101 of Reference 9.

5.92 (102),

mat

Bey Bt XC AL

Ae eae red)

here

E = energy absorbed in the organ from one disintegration (Mev)

Mm mass of the organ (gn)

fraction of radionuclide transferred to the organ retention factor

breathing cate (meters3/sec)

X= yearly average maximum concentrat ion (Ci/aeters3)

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28

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paposey eaey

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---Page Break---

@ Estimated (2/27/75)

AMeasuzed 2/27/75)

Concentration (aci/ee)

9200 am, 11:00 10

Tine of

Figure 6. [stinated and Measured Argon~

29

°

it

0 pam 9200

Day

41 Concentration st Ground Level.

---Page Break---

30

Allovable

Dry Season

Rainy Season

yo!

Yearly Aversge Maxioum Concentration

(ct/meters3)

sor??

400° 800 1209 1600 7000 2400-2800

Distance from the Source (meters)

Figure 7. Yearly average Maxirun Concentration at Gcound Level for Onee Shift Operation During the Dry and Rainy seasons as a function of Distance.

---Page Break---

au

Allowable

? Dry Season

Rainy Season

(ct/meters?)

or

Yearly Average Maximum Concentration

102? 4

400 1200 2000 2800

Distance from the Source

(meters)

Migure &. Yearly Average Maxtaum Concentration at Ground Level for

PrepShife Operation During the Dry and Kainy sonsoee

® Function of Distances

---Page Break---

yore?

1 Dry Season

2 Rainy Season ope)

2 at 02 os wes

Mg - Welt Locotions

SCALE

Meure 9. ap Of the Reactor Site shoving the Location of the Yearly

Average Maximun Concentration.

---Page Break---

3a

Ty = radioactive half Life (see)

Ty ~ biological half Life (sec)

f= time of exposure (see)

t= time folloving exposure (sec)

Dogt dose to the organ from internal radiation (rad)

When inhaled, argon is assumed co be distributed evenly throinsh

the lungs. The lungs are, therefore, the critical organs and M = 1000 ga

Using the standard man, (10).

The energy absorbed from the beta and gama radiation uf aryon=b1

?vas assumed to be one third of the end-point energy of the beta and to

be the anount of ganna energy absorbed when passing through 10 ca of lung

atter, as is given in Equation 7.89 of ().

ts

Pe Banas en

Ws the energy absorption coefficient of the lung for the ganna

photon Cea-1)

F = the effective diameter of the organ (cm)

BAe gauma energy per desintegration (Mev)

ge end point energy of the beta (ov)

The fraction of the radionuclide, transferred to the oryan by

inhalation,

far 48 assumed Lo be 0.10, a8 recommended by DE. Theodore

Agard. (11).

The breathing rai

+ for standard man was assured to be

2.78 X 10-4 meters3/sec.

?The biological half-life for argon-41 is short, but not well

Known. A value of 30 sec vas assumed, knowing that xenon, also a noble sas, has a biological half-life of less than 30 sec (11). Therefore,

the effective decay constant, 4, is 0.0232 sec-l,

---Page Break---

OFK00"9 OXY, orKsz"L

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?The exposure tine, t, equals eight hours for one shift operations

?and eleven hours for two-shife operations. The concentration of argor=$1

uring the last five hours of tworshift operation is more than ten orders

of magnitude Less than the concentration for the day-time operation and

is therefore neglected. The dose received after exposure has stopped

(t= 300 see). This i ten tine the assuned biological half life.

The results of the internal dose calculations for an average day

in aren are given in Table

To convert from rad to rea a relative biological effectiveness (REE)

factor is needed which for gannas and bet

is equal to one.

2. External dose calculations

calculated

?The external dose in a homogeneous infinite cloud we

by adding the contribution due to the beta and gama rat

tion. The

calculation was made using Equations 7.20 and 7.35a from Reference 9.

DY = (0,23 E+ 0.25 BE

where

Eg + end point energy of the beta (ev)

B, = gamaa energy per desincesration (ev)

?YX = yearly average maximua concentration (Ci/meters3)

DY = dose rate (rad/sec)

1 calculating the yearly average saxime dose, internal plus

cwtermal, the {aternal dose can be neglected since it fs a factor of «

thousand less than the external dose. (See Table 7).

---Page Break---

DISCUSSION OF RESULTS

?A. OVERALL EFFICIENCY DETERMINATION OF THE DETECTION SYSTEM FOR

THE 1,29 Mev GAMMA OF ARGON=61

ndix 11), (7) indicates that the total spectral efficiency of a

Standard four inch diameter by four inch deep sodium iodide detector

in response t0 a sodiun-22 point source, 7.88 cn above the detector should be 4.2%, In addition, this same reference gives the peak to total spectrum ratio for sodiun-22 in a three inch diameter by three inch deep detector a8 0.35. This implies that ve might expect our eysten to have an efficiency of 4.2% X 0.35 = 1.5% rather than 1.31%. This difference is possibly explained by : a) different techniques used in obtaining the Peak spectra (The Spectrum Catalogue does not discuss the technique used in obtaining the peak spectrum), b) a lover intrinsic efficiency of our detector due to detector fatigue or other reasons (our detector is eight years old) and c) lower efficiency of the electronic components of our system,

However, it should be noted that the accuracy of the measurement is not dependent upon determining the absolute efficiency of the system, but rather upon using # technique which assures that the ratio of counts of ?thie detector to activity of @ source is the same for argon-4l,

cesiun-137, and sodiun-22.

Thus the ratio

Counts under peak for

Known activity of Na-22 7 1-302

---Page Break---

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Using Figure 2 to extrapolate from the 1.27 Mev gamma peak of the

to the 1.29 Mev ganma peak of argon-41 ve obtain

Counts under peak for Anil

Known activity of azo ~ 130%

and this is the value we have used for the efficiency of the system,

XE should be noted that great care vas taken in determining the

efficiency of the system, since all succeeding work depends upon the

efficiency and since our value of 1.29% differs by 302 from the value

Of 1.8% obtained by Efigenio Rivera (2).

DETERMINATION OF THE ARGON=41 CONCENTRATION

1. In the off gas 53

The average argon-41 concentration and emission rate for 1000 kw Power level were found to be 10.80 X 10° + 0.37 X 10-3 wCt/ce and 543 417.5 MCi/min, respectively. The difference between these values and the ones used by Bfigenio Rivera (2), 2.7 X 10-5 wCi/ee and 116.1 ACi/min are due to the difference in the efficiency and Flow rate

measurements,

Kanne chamber calibration

4m estination of the accuracy of the Kanne chamber reading can be

obtained from Table 1 and Figure 3. At @ constant indicated power level

?of 1000 Kw, both the Kanne chamber reading and the concentration as

determined in the experinent show a variation of approximately 5% around

?the mean value. Wowever, it is not known which part of the variation

should be atributed to errors in the indicated pover level, the concontra~

---Page Break---

tion and the Kanne chamber res

ing. Tn addition, the Kanne chanber

can be read to only two significant figures, this in itself gives a

possible error of approximately 22.

The conversion factor of 2.3 X 10+6 + 0.06 x 1046 uci/ee per amp

found contains seven of the nine data points, as indicated in Figure 3.

1t is therefore concluded that the best estimate in error in converting

Kanne chamber reading to concentration is approxiaately 5t.

B, Eaission rate variation with power level

?The Linearity of the emission rate of argon-s1 production as a func~

tion of power level was determined with a 6% probable error.

2. At the surface of the reactor poo!

?The argon-41 concentration and the emission rate measured at the

Surface of the reactor pool are 6.383 x 10-3 wCi/ce and 1.7 Ci/min

respectively

3. Ae various ground level locations

8, Sensitivity of counting system

?As discussed in Section T1I-B-3, three modifications were made to

the standard system in order to improve the sensitivity of the system

for counting argon-él. They were: a) increasing the shiedling to six

inches of lead, 6) connecting two sodium iodide detectors in paralie ,

and ©) collecting air in a scuba rank at a pressure of 2200 pai.

?An indication of the accuracy of the system, with both detectors and

---Page Break---

39

increased shielding was obtained by determining the half life of

atgon-41 using che decay constant obtained as 1.042 x 1074 sec-1,

Lin 2

Decay Constane ~ 185 hours

Nae

?The half Life of argon-41 reported by Lederman (12) is 1.83 hours, however, he refers co three works which report 1.83 hours, one which reports 1.82 and the other which reports 1.85 hours. The initial to final count ratio of approximately 4500 indicates the sensitivity of

the counting system considering only the first two nodifications,

However, the sensitivity was increased by a factor of 150 by collecting air in a scuba tank at a pressure of 2200 psi. Therefore, uhen the three sodifications were combined, the argon-#1 concentration at ground level could be read to approximately 1.6 x 10-10 yci/ec., which is tess than

20% of the allowed concentration of 8.0 X 10-10 yci/ec with a probable

error of not sore than 10%.

b. and c. Measured and calculated values

?The average value of the ratio of the estimated to measured concen

tration is 1.1, The low frequency case (run No. 2 of Tables & and 6)

was not included in this average because the equation we used for

estinating the concentration is for long term average release, An

implicit assumption in this equation is that the percent of time the

Bas leaves the stack, in the direction of a given secto

is equal to

the percent of time the g:

is found in the sector at some distance x

from the stack. This will be true for both low and high frequency ia

---Page Break---

40

4 sector during a long period of tine such as a year since the cross "isd component is insignificant for the high frequency situation, and since for the low frequency case the cross vind components in a sector would be self compensating. However, for a short period of time, such a8 the half hour period, during which our samples were collected, this equation will only be applicable for the high frequency situations. For

the low frequency case and short collection tine the model does not

apply due to the fact that when the crosswind component is in a constant Sirection, very Little, if aay, of the gas entering @ sector of the stack

would still be in that sector a significant distance from the stack.

?The excellent agreement between the measured and estinat

?fons serves as a verification of the model used and gives a high degree

of confidence that the calculated yearly avera

4. Yearly average maxiaum concentration

?Tie previous value used for the yearly average maximum concentration, one-shift, dry season was 1.63 x 10-10 ci/aeters? (13), where the value obtained in this study is 2.69 x 10-10 Ci/seters?. Since the presently allowable value is 8.0 X 10-10 ci/meters3, which is 22 of the allovable

value specified in 10 CFR Part 20, appendix

Table 11, Column 1, (1)

the yearly average maximum concentration is 33.6% of the allovable.

©. YEARLY AVERAGE MAXIMUM DOSE CALCULATIONS

?The previous value used for the yearly average maxium dose one-shife,

?477 season was 0.45 aren (13), where the value obtained in this study is

---Page Break---

a

0.53 mrem, Since the presently allowable value {s 10 aren, the yearly average maximum dose is 5.32 of the allovable

Te can be noted that if a person is exposed to the daily average saximum dose, not for one-shift operation but rather for 24 hours day, seven days 4 week, then the dose would be 50z of the allovable. These

values seem to indicate a reasonable correlation betueen the concentra:

tion and dose.

---Page Break---

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ConciusroN

?The Kanne cha

"eF appears to be satisfactorily calibrated with

@ probable error of approxinately St,

The emission rate was found to be Linear as a function of power.

The average en:

ion rate for 1000 Ky, with all of the off-gas

facilities connected, was determined to be 543 pCi/min, with prob:

ble error of 6%.

The syst

using improved shielding, parallel detectors, and scuba

tank allows concentration at ground level to be measured to a factor of

6.75 X 105 Jess than the concentration emitted by the off-gas stack, or

to approximately 1.6 x 10-19 ci /ce.

The average value of the ratio of the estimated to measured concen-

tration is 1.1, This excellent agreement between the measured and

estimated concentrations gives a high degree of confidence in utilizing

the diffusion equation for average long-period concentration from a

contiauous point source to calculate the yearly average maximum concen

?The Largest value of the yearly average maximum concentration occured

during one-shift operation, dry season, at 125 meters from the stack in

the ENE

stor, This value was found to be 2.69 X 10-10 Ci/meters3, vhich

is 33.62 of the allowable value as proposed in June, 1974. (1)

?The dose corresponding to the largest yearly average maximum concen

tration is 0.53 mrem per year, which is 5.3% of the allowable value. Since the concentration and dose are 33.6% and 5.3% of the allowable values, respectively, argon-41 emission is not a limiting value for the

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a

PRNC TRIGA-FLIP reactor operating at 1000 Kw. Although for 2000 kw operation, the concentration and dose would double, the concentration would still be approximately 70% of the allovable and probably indicates a safe operating condition,

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4?

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APPENDIX

DECAY TINE

acTIVITY

a)

DECAY TIME

where

to 7 Activity at start counting tine

T's (ty + t,) = counting tise pertod

H = average activity for the counting tine pertod

T= time from start counting until average activity {s reached

?Therefore, it can be stated that

ven = 1" ?4 nat

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a?

then

but.

therefore

Teta Ge

now for

1 = 10000 seg

end

4,

tn 2_ (hour) | 1.052(10"

Decun "Tar he Woo see) = SE

we have the following

« 4 (4.052) (1074) (10000)

Terres SSR ita}

Th = 6566 sec

?The following is a table containing all the T* corresponding to the

counting periods used.

---Page Break---

48

|

Ti(seg) _T(see)

100 49.96

se ___1930

10K 4566

20K___ 8307

?The fact that time had passed from the sample collection tine to

the start counting tine vas taken Into consideration. So the total

decay tine ts

peter

where

1 = decay correction tine during counting

T= time between collection and start counting

In the case where the tank was filled up to a pressure of 2200 psi,
the pumping time mist also be consider. The pumping time was measured
and it was determined that the rate of air entering the tank ts a cons
tant function with time, therefore, T to determine decay tine {s equal to
half Of the pumping, plus the tine between the end of punping and the start

of counting.

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