



UNIVERSITY OF MARYLAND AT COLLEGE PARK

NUCLEAR ENGINEERING  
MATERIALS AND NUCLEAR ENGINEERING

November 3, 1993.

Section 50.4 Distribution  
Document Control Desk  
U.S. Nuclear Regulatory Commission  
Washington, D.C. 20555

SUBJECT: ANNUAL REPORT

Dear Sir/Madam:

Enclosed is the Annual Report for the MUTR in accordance with requirements set forth in the Technical Specifications. This report covers the time period from July 1, 1992 to June 30, 1993.

Sincerely,

Dr. Walter J. Chappas  
Maryland University Training Reactor

cc: Dr. Aris Christou, Chairman, Materials and Nuclear Engineering

Mr. Allan Adams  
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M.S. 11-B-20  
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Reactor Files

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11

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**MARYLAND UNIVERSITY TRAINING REACTOR (MUTR)**

License # R-70  
Facility Docket # 50-166

**ANNUAL OPERATING REPORT**

for the period

**July 1, 1992 - June 30, 1993**

**Department of Materials and Nuclear Engineering  
University of Maryland  
College Park, Md 20742-2115**

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## I. INTRODUCTION

The Maryland University Training Reactor is an open-pool type, TRIGA fueled reactor.

The core is cooled by natural convection of the pool water with auxiliary coolers provided for protection of filters and ion exchange equipment associated with the reactor support piping.

The MUTR is used for academic instruction and operator training, performing neutron and gamma irradiations, neutron activation analysis experiments, and tours and demonstrations for internal and outside groups. Operator training includes qualification training for student and staff operators as well as for visiting nuclear power plant trainees.

## II. REACTOR USAGE

During the past year the MUTR operated a total of 149 runs, which can be broken down into the following categories.

Operator training	80 runs
Tours, Labs & Demonstrations	35 runs
Calibration and Maintenance	5 runs
Nuclear Engineering Classes	20 runs
Irradiations and Activations*	9 runs

\* Many of the Engineering classes involved activations and are not counted in the total runs under activations.

To perform these runs, the core produced 31.5 MWh, with a corresponding burn-up of 1.64 grams of Uranium-235.

Operator training was undertaken for facility operator qualification and visiting power plant trainees. Three operators were granted licenses by the NRC; two being issued instant Senior Reactor Operator certificates, and one issued a Reactor Operator certificate. Power plant trainees from the Baltimore Gas and Electric Calvert Cliffs

Plant also participated in several two week long training sessions to give them some operational reactor training time.

A substantial number of the runs were conducted for tours and demonstrations.

These involved high school, university, and visiting University of Maryland students. In these group tours a total of 847 students visited the MUTR. Individual tours were also conducted with a total of 564 students.

Many of these groups account for more than one visit, as it was common for a high school to return with groups from different classes.

### III. SURVEILLANCE TESTS AND INSPECTIONS

The following calibration and maintenance operations were performed on the indicated dates.

WATER SAMPLE TEST	monthly
AIR SAMPLE TEST	monthly
AT POWER SURVEY	quarterly
ALARM SYSTEM CHECK <sup>1</sup>	continuous
POWER CALIBRATION	8/05/92
REPLACED ION EXCHANGER RESIN*	9/10/92
REPLACED PARTICULATE FILTER *	1/14/93
REPLACED ION EXCHANGER RESIN*	2/19/93
CONTROL ROD DROP TEST	3/31/93
RADIATION SURVEY	4/15/93
INSTALLED NEW HEAT EXCHANGER*	4/30/93
RAM CALIBRATION	6/15/93
INSTALLED NEW UPPER CONTROL CONSOLE**	6/30/93

<sup>1</sup>The Facility's alarm system was replaced by a new digital system , Moose Products inc., Model Z1100 (2/28/93). This system continuously monitors all points of the facility installation as well as phone line connections to Campus Police, giving an alarm should a fault occur. The alarm is both audible and visual ( SUPERVISORY TROUBLE being displayed at all control terminals), and will not clear until the fault is rectified.

Most of the maintenance performed during this reporting period were routine consisting of fine tuning or adjusting of operating equipment. Various items from Section III of the report fall under the categories of Maintenance Operations Performed and Changes to the Facility. The above items accompanied with a (\*) are considered maintenance operations and the above operations designated (\*\*) are considered changes to the facility.

No other major maintenance was performed during this reporting period.

All maintenance and Facility changes were performed in accordance with 10 CFR 50.59.



#### IV. CHANGES TO THE FACILITY

The most significant change to the reactor involved the addition of a vertical extension to the existing console. The extension was placed in the chosen position to allow the radiation area monitors to be placed at eye-level for the operator. This work was completed after approval was obtained from the Reactor Safety Committee under the provisions of Section 10 of the Code of Federal Regulations Section 50.59. Approval was granted on June 10, 1993. The console extension is now being used to house two ultrasonic level detectors which monitor the levels of the biological shield as well as the level of the storage sump in the water handling room. An additional fuel temperature monitor has also been added in the extended console. The mass flow computer that was purchased in FY '92 has been installed and is operational.

All maintenance and facility changes were performed in accordance with 10 CFR 50.59.

## V. ENVIRONMENTAL SURVEYS OF SURROUNDING AREAS

Reactor surveys taken with portable neutron and beta/gamma detectors while at power indicate no changes in shielding requirements or a need to redesignate restricted areas.

All continuous monitoring for this year (reported under personnel exposure as internal building monitoring) was accomplished using fixed mounted film badges throughout the interior of the reactor building itself.

## VI. RADIOACTIVE RELEASE AND DISCHARGE TO THE ENVIRONMENT

Airborne releases by the MUTR were in the form of  $^{41}\text{Ar}$  originating from dissolved air in the pool tank and air activated inside of the sample ports. Calculations done for the SER show that  $^{41}\text{Ar}$  releases from the pool tank do not exceed 10CFR20 requirements. Further calculations done for power operations with a sample port open show that the additional release of  $^{41}\text{Ar}$  is insignificant. Attachment 1: "Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements" documents these calculations.

The Reactor Storage Sump was dumped via the city sewer system after sampling under the supervision of the Radiation Safety Office showed that concentrations of dissolved and suspended radioisotopes were below MPC levels. Discharge dates were 11/26/92 and 1/25/93

## VII. FACILITY PERSONNEL AND VISITOR EXPOSURE SUMMARY

For this reporting period, all badged facility personnel and students received less than 10 mrem. The Reactor Building fixed mounted film badges recorded the following exposures:

<u>Monitor</u>	<u>Location</u>	<u>Dose</u>
1	Control Room	<10 mrem
2	Pool Surface	1230 mrem
3	Hot Room	170 mrem
4	Prep Room	170 mrem
5	S. Wall Upper	10 mrem
6	S. Wall Lower	60 mrem
7	E. Wall Lower	30 mrem
8	Pump Room	870 mrem
9	N. Wall Lower	300 mrem
10	W. Wall Lower	<10 mrem

The Pocket Dosimeters recorded minimal exposure for all guests and service personnel. Calibrations of these self-reading dosimeters were performed at six month intervals by our Radiation Safety Department.

## VIII. UNSCHEDULED REACTOR SHUTDOWNS/REPORTABLE OCCURRENCES

No Reportable Occurrences took place during this reporting period.

There were two unscheduled reactor shutdowns during the reporting period.

The first unscheduled shutdown occurred September 30, 1992, when the up button for the regulating control rod apparently stuck in the up position (as reported by the RO trainee operating at the time) leading to a period scram. Subsequently, the duty SRO was unable to duplicate this fault. To date, the up button for the regulating control rod has yet to fault again in this manner.

The second unscheduled shutdown occurred January 6, 1993. During an extended high power operation, the reactor operator determined it necessary to shutdown the reactor after the discovery of a hairline fracture in the PVC piping of the primary water system. No significant loss of primary water occurred. The primary water system has since been repaired as part of the new particulate filter installation (Section III) using metal piping in place of PVC.

## IX. CHANGES IN THE FACILITY ORGANIZATION

No special experiments were performed during this reporting period.

Dr. Walter J. Chappas was approved by the University to be the permanent Reactor Director. The University also approved Dr. Aristos Cristou to be the permanent Chairman, Materials and Nuclear Engineering.

During the reporting period three individuals earned NRC licenses on the MUTR. Michael Scalingi and Matthew Goodman qualified Senior Reactor Operators, and Troy Martz qualified Reactor Operator.

**Dr. Aristos Christou**  
Chairman  
Materials and Nuclear Engineering

**Mr. Allan Adams**  
U.S. Nuclear Regulatory Commission  
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# MARYLAND UNIVERSITY TRAINING REACTOR

## CALCULATION FILE COVER SHEET

TITLE: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

PREPARED BY: J. E. Floyd Date: 2 Nov 93

J. E. Floyd  
Reactor Operator

REVIEWED BY: [Signature] Date: 11/3/93

Dr. W. J. Chappas  
Reactor Director



# MARYLAND UNIVERSITY TRAINING REACTOR

Sheet No 1 of 22

Project: \_\_\_\_\_ Task: \_\_\_\_\_ Prepared by: J. E. Floyd Date: 10/30/93

Calc File No: \_\_\_\_\_ Reviewed by: W. J. Chappas Date: \_\_\_\_\_

Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

## 1.0 INTRODUCTION

This calculation file documents work done to determine the release of  $^{41}\text{Ar}$  by the Maryland University Training Reactor (MUTR), Docket # 50-166, during the operational period beginning July 1, 1992, and ending June 30, 1993. Assumptions made for this calculation are documented herein. These calculations were performed for inclusion in the Annual Operating Report.

# MARYLAND UNIVERSITY TRAINING REACTOR

Sheet No 2 of 22

Project: \_\_\_\_\_ Task: \_\_\_\_\_ Prepared by: J. E. Floyd Date: 10/30/93

Calc File No: \_\_\_\_\_ Reviewed by: W. J. Chappas Date: \_\_\_\_\_

Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

## 2.0 10CFR20 REQUIREMENTS

10CFR20 [20.1001 - 20.2402] Appendix B, Table 2 documents the maximum permissible effluent concentrations of radionuclides.  $^{41}\text{Ar}$  has a maximum effluent concentration of  $1 \times 10^{-8}$   $\mu\text{Ci/ml}$  in air. The calculations contained in this document will show that in the worst case scenario, the  $^{41}\text{Ar}$  released by MUTR is well below the requirement stated above.

# MARYLAND UNIVERSITY TRAINING REACTOR

Sheet No 3 of 22

Project: \_\_\_\_\_ Task: \_\_\_\_\_ Prepared by: J. E. Floyd Date: 10/30/93

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Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

## 3.0 SOURCES OF $^{41}\text{Ar}$

There are five possible sources of  $^{41}\text{Ar}$  at the MUTR. The sources and their contribution to  $^{41}\text{Ar}$  production and release are as follows:

1. Pneumatic Transfer System: This system has an air hose which extends down into the fueled region of the core. However, the system is pressurized with  $\text{CO}_2$  during operation and its overall volume is small. Thus when the system is idle the amount of  $^{41}\text{Ar}$  produced is limited to the amount of  $^{40}\text{Ar}$  that manages to diffuse into the system when it is not in use. Furthermore any  $^{41}\text{Ar}$  that is created by activation of  $^{40}\text{Ar}$  must diffuse through over 50 feet of hose before it can enter the reactor building. The time required for such diffusion combined with the negligible amounts of production means that the Pneumatic Transfer System does not contribute to  $^{41}\text{Ar}$  production and release.
2. Pool Tank: A small amount of air is dissolved in the pool tank. The  $^{40}\text{Ar}$  contained in this air can be activated and diffuse back into the reactor building at the pool surface. This amount is not insignificant.
3. Thermal Column:  $^{40}\text{Ar}$  contained in the small amounts of air trapped in the Thermal Column can be activated. However, this air is assumed not to diffuse out into the reactor building. The Thermal Column is not a source of  $^{41}\text{Ar}$ .
4. Beam Tubes: When plugged there is no mechanism via which  $^{41}\text{Ar}$  produced inside the Beam Tubes can leave the pool tank region. However, if the plugs are removed during operation  $^{41}\text{Ar}$  will diffuse through the tube and reach the reactor building. The Beam Tubes are only source of  $^{41}\text{Ar}$  if they are unplugged during operation.
5. Through Tube: As for the Beam Tubes it is not a source of  $^{41}\text{Ar}$  when the tube is plugged. When unplugged, however, it is a source.

For the operational period covered by the annual report, only items 2 and 5 must be accounted for, see sections 4 and 5. Items 1 and 3 are not a source, and the Beam Tubes were never unplugged during operation.

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Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

## 4.0 POOL TANK <sup>41</sup>Ar PRODUCTION AND RELEASE

The SER, page 11-2, states that the <sup>41</sup>Ar release into the reactor building during an operational year of 30 MWh is less than 0.1 Ci. During the time period covered by the annual report the reactor was operated for 31.5 MWh. Thus <sup>41</sup>Ar release from the pool tank is 0.1 Ci. It was also determined in the SER that such a release amounts to less than 1 mrem of dose to the general public. If the MUTR were operated for 400 MWh the dose to the general public would still be less than 1 mrem.

A 0.1 Ci release over a continuous run of 31.5 MWh would correspond to an equilibrium value of approximately 1 mCi of <sup>41</sup>Ar in the reactor building or a concentration of  $6 \times 10^{-7}$   $\mu$ Ci/ml. When exhausted by the exhaust fans through the upper portion of the reactor building, the <sup>41</sup>Ar levels will be well below 10CFR20 requirements by the time the <sup>41</sup>Ar diffuses down to unrestricted areas.

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Project: \_\_\_\_\_ Task: \_\_\_\_\_ Prepared by: J. E. Floyd Date: 10/30/93

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Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

## 5.0 THROUGH TUBE <sup>41</sup>Ar PRODUCTION AND RELEASE

<sup>41</sup>Ar in the Through Tube is produced by activation of <sup>40</sup>Ar by the Through Tube flux. The flux in the through tube can be considered a cosine shaped flux whose amplitude is equal to the peak flux seen in the Through Tube. Once produced the <sup>41</sup>Ar will only be released in to the reactor building if it diffuses through the tube to the open end before it decays.

The flux in the Through Tube at any one cross sectional location can be considered constant, the air in the tube is a vacuum to the neutron flux. Thus the production and diffusion in the tube can be handled with a 1D approximation. The 1D values at any point in the tube when multiplied by the cross sectional area will then yield the total value for that portion of the tube. The equation governing <sup>41</sup>Ar concentration in one dimension is:

$$\frac{dN_{41}(x, t)}{dt} = \Sigma_a^{40} \phi(x, t) + D \frac{d^2 N_{41}(x, t)}{dx^2} - \lambda_{41} N_{41}(x, t)$$

Transforming the equation into a form suitable for a finite difference analysis yields:

$$\frac{N_{41}(x_i, t+1) - N_{41}(x_i, t)}{\Delta t} = \Sigma_a^{40} \phi_{\max} \cos\left(\frac{\pi x_i}{2a}\right) + D \frac{N_{41}(x_{i+1}, t) - 2N_{41}(x_i, t) + N_{41}(x_{i-1}, t)}{\Delta x^2} - \lambda_{41} N_{41}(x_i, t)$$

Rearranging terms gives:

$$N_{41}(x_i, t+1) = \Delta t \Sigma_a^{40} \phi_{\max} \cos\left(\frac{\pi x_i}{2a}\right) + \frac{D \Delta t}{\Delta x^2} [N_{41}(x_{i+1}, t) + N_{41}(x_{i-1}, t)] + N_{41}(x_i, t) \left[ 1 - \Delta t \left( \lambda_{41} + \frac{2D}{\Delta x^2} \right) \right]$$

By segmenting the Through tube into a equal number of nodes the <sup>41</sup>Ar released into the building can be calculated. There are three conditions required for this problem, an initial and two boundary conditions. The initial condition is that  $N_{41}(x, 0) = 0$ . The first boundary condition is that  $N_{41}(x_0, t) = 0$ , where  $x_0$  is an extrapolated boundary at the open end of the tube. The second boundary condition is  $dN_{41}(x_n, t)/dt = 0$ , where  $x_n$  is the final node position at the closed end of the tube. It was also assumed that any <sup>41</sup>Ar that makes it to the open end of the tube is instantaneously diffused through out the reactor building free air volume. A FORTRAN program called AR41CAL was written to do this calculation. The program listing can be found in Appendix A of this document.

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Sheet No 6 of 22

Project: \_\_\_\_\_ Task: \_\_\_\_\_ Prepared by: J. E. Floyd Date: 10/30/93

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Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

Three cases were run using this code. The first case represents a typical reactor run of 1 hour at full power. The second case represents a 10 hour run at full power to represent an equilibrium activation of  $^{41}\text{Ar}$  in the through tube. The third case is a 100 hour run at full power. This run condition can not be reached at the MUTR do to the buildup of Xenon. Each case was run for 10 hours beyond the reactor run. This was done to account for the Through Tube plug not being replaced immediately at the end of a run. The value of 10 hours allows for 5  $^{41}\text{Ar}$  half-lives to pass; therefore, any  $^{41}\text{Ar}$  remaining in the Through Tube after 10 hours will be insignificant compared to the original levels and will not affect the end results. The case outputs are given in Appendix B. The following table shows the results of these three cases.

Case	Production (mCi)	Release (mCi)	Maximum Level (mCi/ml)
1 hour	2.408	0.014	$3.07 \times 10^{-12}$
10 hours	24.08	0.164	$8.33 \times 10^{-12}$
100 hours	240.8	1.705	$8.70 \times 10^{-12}$

From these cases it can be seen that less than 0.02 mCi of  $^{41}\text{Ar}$  are released into the reactor building for every hour of full power run with the Through Tube unplugged. Furthermore, the concentration levels inside the reactor building are well below 10CFR20 requirements.

# MARYLAND UNIV.,SITY TRAINING REACTC.,

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Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

## 6.0 CONCLUSIONS

During the worst case scenario, operating the reactor for over 10 hours at full power with the Through Tube unplugged, the  $^{41}\text{Ar}$  exhausted from the reactor building will be below 10CFR20 requirements in unrestricted areas. Even if the run time approached 100 hours of continuous operation, the  $^{41}\text{Ar}$  levels will still be below 10CFR20 requirements in unrestricted areas. Since it is unlikely that the reactor will ever be operated for a continuous period of time longer than 100 hours, it can be said that  $^{41}\text{Ar}$  releases from the MUTR will never be greater than 10CFR20 requirements in unrestricted areas.

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Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

## APPENDIX A

### AR41CAL FORTRAN LISTING

PROGRAM AR41CAL

```
C*****
C PROGRAM AR41CAL (Argon-41 Calculation)
C
C PURPOSE: This program calculates the Argon-41 production in the
C MUTR reactor building with one through tube plug open.
C The net results are given in mCi/ml in the building.
C The levels are given in 1/2 hour time steps from the
C begining of the run. Also the max level is given. The
C program calculates the level using a 1D diffusion calc
C assuming a cosine flux distribution across the active
C length of the through tube.
C
C AUTHOR Jason E. Floyd
C*****
COMMON/CASEINF/POWER, RTIME, DELT, DELX, OUTINT, MAXTIME
COMMON/TUBEDIM/TUBEEND, COREBEG, COREEND, MAXPOS, CORELEN, EXB
COMMON/ARCAL/NAR41, MAXFLUX, SIGMAAR, LAMBDA, DIFF, PI, PROD
DOUBLE PRECISION MAXFLUX, SIGMAAR, LAMBDA, POWER, PROD, RELEASE,
/ DELX, DELT, DIFF, RADIUS, VOLUME, BLEVEL, CI, MAXLEVEL, ACTVTY,
/ NAR41(402,2), CORELEN, EXB, PI
INTEGER TUBEEND, COREBEG, COREEND, MAXPOS, RTIME, MAXTIME,
/ OUTTIME, OUTINT, TIME, NTSTEP
C*****
C VARIABLE LIST FOR AR41CAL
C
C ACTVTY: ACTIVITY LEVEL IN mCi/ml
C BLEVEL: BUILDING AR-41 LEVELS IN ATOMS/ml
C CI: 1 CURIE
C COREBEG: NODE LOCATION OF BEGINNING OF ACTIVE TUBE LENGTH
C COREEND: NODE LOCATION OF END OF ACTIVE TUBE LENGTH
C CORELEN: ACTIVE CORE LENGHT
C DELX: NODE SPACING FOR 1D CALCULATION
C DELT: TIME STEP
C DIFF: AR-41 DIFFUSION COEFFICIENT
C EXB: EXTRAPOLATED CORE BOUNDARY
C LAMBDA: ARGON-41 DECAY CONSTANT
C MAXFLUX: PEAK THROUGH TUBE FLUX (n/cm^2 kw)
C MAXLEVEL: MAXIMUM AR-41 LEVELS IN BUILDING
C MAXPOS: MAXIMUM NODE POSITION
C MAXTIME: TIME TO END CALCULATION AT
C NAR41(X,T): ARGON-41 NUMBER DENSITY AT TUBE CENTERLINE FOR NODE X
C T = 1/2 CURRENT TIME STEP/NEXT TIME STEP
C NTSTEP: NUMBER OF TIME STEPS IN CASE
C OUTINT: TIME INTERVAL BETWEEN LEVEL OUTPUTS
C OUTTIME: TIME OF NEXT OUTPUT
C POSIT: CURRENT NODE
C POWER: CORE POWER LEVEL DURING RUN
C RADIUS: THROUGH TUBE RADIUS
C RTIME: RUN TIME
C SIGMAAR: MACROSCOPIC ABSORPTION CX FOR AR40
C TIME: CURRENT TIME
C TUBEEND: NODE POSITION OF OPEN TUBE END
C TUBEEND: NODE POSITION OF CLOSED TUBE END
C VOLUME: FREE AIR VOLUME OF BUILDING
C*****
C LOAD CONSTANTS AND INITIALIZE ARRAY
C
CI = 3.7E+10
```



# MARYLAND UNIVERSITY TRAINING REACTOR

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Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

```
DELX = 2.  
DELT = 4.  
DIFF = .25  
EXB = -306 - 1/DIFF  
LAMBDA = 0.000105  
MAXFLUX = 1.6E+09  
MAXPOS = 309  
OUTINT = 900  
OUTTIME = 900  
PROD = 0.  
RELEASE = 0.  
SIGMAAR = 1.6306E-07  
RADIUS = 7.62  
PI = 3.14159  
TIME = 0  
TUBEEND = 401  
TUBEEND = 401  
COREBEG = 136  
COREEND = 308  
CORELEN = 72  
VOLUME = 1.700E+09  
DO 100 POSIT = 1,MAXPOS  
  NAR41(POSIT,1)=0  
  NAR41(POSIT,2)=0
```

```
100 CONTINUE  
C*****  
C OBTAIN POWER LEVEL AND RUNTIME FROM USER. PREPARE OUTPUT HEADER  
C  
  CALL CASINIT  
C*****  
C CALCULATE NUMBER OF TIME STEPS AND BEGIN CALCULATION  
C  
  NTSTEP = INT(MAXTIME/DELT)  
  TIME = 0  
  DO 200 I = 1,NTSTEP  
    TIME = TIME + DELT  
C*****  
C CALL NUMCAL TO CALCULATE ARGON-41 FOR THE CURRENT TIME STEP  
C  
  CALL NUMCAL(TIME)  
C*****  
C CALCULATE BUILDING CONCENTRATION AND UPDATE RELEASE AND ALSO  
C MAX LEVEL IF NEEDED  
C  
  BLEVEL = BLEVEL * (1 - LAMBDA * BLEVEL * DELT)  
  BLEVEL = BLEVEL+NAR41(TUBEEND,1)*PI*RADIUS ** 2 / VOLUME  
  RELEASE = RELEASE+NAR41(TUBEEND,1)  
  IF (BLEVEL.GE.MAXLEVEL) THEN  
    MAXLEVEL = BLEVEL  
  ENDIF  
C*****  
C UPDATE OUTPUT FILE IF NEEDED  
C  
  IF (TIME.EQ.OUTTIME) THEN  
    OUTTIME = OUTTIME + OUTINT  
    ACTVTY = BLEVEL * LAMBDA / CI * 1000  
    WRITE(6,900) TIME,ACTVTY  
    WRITE(7,900) TIME,ACTVTY  
  ENDIF  
200 CONTINUE  
C*****  
C WRITE MAXLEVEL, TOTAL PRODUCTION, AND RELEASE TO OUTPUT FILE  
C
```

# MARYLAND UNIVERSITY TRAINING REACTOR

Sheet No 10 of 22

Project: \_\_\_\_\_ Task: \_\_\_\_\_ Prepared by: J. E. Floyd Date: 10/30/93

Calc File No: \_\_\_\_\_ Reviewed by: W. J. Chappas Date: \_\_\_\_\_

Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

```
ACTVTY = MAXLEVEL * LAMBDA / CI * 1000
RELEASE = RELEASE * PI * RADIUS**2 * LAMBDA / CI * 1000
PROD = PROD * PI * RADIUS**2 * LAMBDA / CI * 1000
WRITE(6,910) ACTVTY
WRITE(7,910) ACTVTY
WRITE(6,920) PROD
WRITE(7,920) PROD
WRITE(6,930) RELEASE
WRITE(7,930) RELEASE
CLOSE(7)
STOP
```

```
900 FORMAT(I7.7,10X,E18.10)
910 FORMAT('MAXIMUM AR-41 CONCENTRATION IS: ',E18.10,' mCi/ml')
920 FORMAT('TOTAL AR-41 PRODUCTION IS: ',E18.10,' mCi')
930 FORMAT('TOTAL AR-41 RELEASE: ',E18.10,' mCi')
END
```

## SUBROUTINE CASINIT

```
C*****
C ROUTINE CASEINT (CASE INITIALIZATION)
C
C PURPOSE Gets input data from user on runtime and power level.
C Opens output file and prints header.
C
C AUTHOR Jason E. Floyd
C*****
COMMON/CASEINF/POWER,RTIME,DELT,DELX,OUTINT,MAXTIME
DOUBLE PRECISION POWER,DELX,DELT
INTEGER RTIME,OUTINT,MAXTIME
C
C WRITE(6,900)
C READ(5,*) POWER
C WRITE(6,910)
C READ(5,*) RTIME
C*****
C DETERMINE TIME TO END CASE
C
C MAXTIME = 1800 + 1800 * INT((RTIME+36000)/1800)
C*****
C OPEN OUTPUT FILE AND WRITE CASE HEADER
C
C OPEN(7,FILE='ARGON41.OUT',STATUS='UNKNOWN')
C WRITE(6,920) POWER,RTIME
C WRITE(7,920) POWER,RTIME
C WRITE(6,930) MAXTIME
C WRITE(7,930) MAXTIME
C WRITE(6,940) DELX,DELT,OUTINT
C WRITE(7,940) DELX,DELT,OUTINT
C WRITE(6,950)
C WRITE(7,950)
C*****
C RETURN TO AR41CAL
C
C RETURN
900 FORMAT('CORE POWER LEVEL IN KW')
910 FORMAT('RUNTIME IN SECONDS')
920 FORMAT('ARGON-41 FOR POWER=',F10.5,' KW FOR ',I6.6,' SECONDS')
930 FORMAT('CASE WILL BE RUN UNTIL TIME ',I7.7,' SECONDS')
940 FORMAT('NODE SPACING=',F5.2,' CM, TIME STEP='F5.2' S, OUTPUT INTER
/VAL='I5.5' S')
950 FORMAT(' TIME ACTIVITY IN mCi/ml')
END
SUBROUTINE NUMCAL(TIME)
C*****
```

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Project: \_\_\_\_\_ Task: \_\_\_\_\_ Prepared by: J. E. Floyd Date: 10/30/93

Calc File No: \_\_\_\_\_ Reviewed by: W. J. Chappas Date: \_\_\_\_\_

Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

```
C ROUTINE NUMCAL (Number Density Calculation)
C
C PURPOSE This routine uses a 1D nodal diffusion calculation to
C determine Ar-41 concentraions in the through tube. A
C zero boundary condition is at the extrapolated boundary
C of the open end of the tube, and a reflection boundary
C condition is set at the open end of the tube.
C Production of Ar-41 assumes a cosine flux shape over
C the active length of the tube for the duration of the
C run.
C
C AUTHOR Jason E. Floyd
C*****
COMMON/CASEINF/POWER, RTIME, DELT, DELX, OUTINT, MAXTIME
COMMON/TUBEDIM/TUBEEND, TUBEEND, COREBEG, COREEND, MAXPOS, CORELEN, EXB
COMMON/AR41/NAR41, MAXFLUX, SIGMAAR, LAMBDA, DIFF, PI, PROD
DOUBLE PRECISION MAXFLUX, SIGMAAR, LAMBDA, POWER, PROD,
/ DELX, DELT, DIFF, RADIUS, VOLUME, BLEVEL, CI, MAXLEVEL, ACTVTY,
/ NAR41(402,2), CORELEN, EXB, PI
INTEGER TUBEEND, TUBEEND, COREBEG, COREEND, MAXPOS, RTIME, MAXTIME,
/ OUTTIME, OUTINT, TIME
C*****
C ZERO CONCENTRATION AT EXTRAPOLATED BOUNDARY CONDITION
C
NAR41(1,2) = 0
DO 100 POSIT = 2, TUBEEND
  NAR41(POSIT,2) = DELT / DELX**2 * DIFF * (NAR41(POSIT-1,1) +
/ NAR41(POSIT+1,1)) + NAR41(POSIT,1) * (1 - DELT *
/ (LAMBDA + 2 * DIFF / DELX**2))
C*****
C IF IN THE ACTIVE REGION OF THE THRU TUBE AND THE REACTOR IS AT
C POWER CALCULATE THE AR-41 PRODUCTION
C
  IF ((POSIT.GE.COREBEG).AND.(POSIT.LE.COREEND).AND.(TIME.LE.
/ RTIME)) THEN
    NAR41(POSIT,2) = NAR41(POSIT,2) + DELT * POWER * MAXFLUX *
/ SIGMAAR * COS(PI*(EXB+POSIT*DELX)/CORELEN)
    PROD = PROD + DELT * POWER * MAXFLUX * SIGMAAR *
/ COS(PI*(EXB+POSIT*DELX)/CORELEN)
  ENDIF
C*****
C MAKE THE NODE AFTER THE LAST NODE EQUAL TO THE NODE BEFORE THE
C LAST NODE TO MEET THE REFLECTION BOUNDARY CONDITION
C
  IF (POSIT.EQ.TUBEEND-1) THEN
    NAR41(MAXPOS,2) = NAR41(POSIT,2)
  ENDIF
100 CONTINUE
DO 200 POSIT = 1, TUBEEND
  NAR41(POSIT,1) = NAR41(POSIT,2)
200 CONTINUE
C*****
C RETURN TO AR41CAL
C
RETURN
END
```

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Project: \_\_\_\_\_ Task: \_\_\_\_\_ Prepared by: J. E. Floyd Date: 10/30/93

Calc File No: \_\_\_\_\_ Reviewed by: W. J. Chappas Date: \_\_\_\_\_

Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

## APPENDIX B

### AR41CAL CASE OUTPUTS

1 Hour at Full Power

ARGON-41 FOR POWER= 250.00000 KW FOR 003600 SECONDS  
CASE WILL BE RUN UNTIL TIME 0041400 SECONDS  
NODE SPACING= 2.00 CM, TIME STEP= 4.00 S, OUTPUT INTERVAL=00900 S

TIME	ACTIVITY IN mCi/ml
0000900	-0.1070969988E-51
0001800	0.5162039140E-32
0002700	0.1867650207E-24
0003600	0.7298393504E-21
0004500	0.1133527619E-18
0005400	0.3519077431E-17
0006300	0.4307693578E-16
0007200	0.2920954381E-15
0008100	0.1327047791E-14
0009000	0.4531208049E-14
0009900	0.1250763710E-13
0010800	0.2928986189E-13
0011700	0.6016728670E-13
0012600	0.1110881687E-12
0013500	0.1877688714E-12
0014400	0.2947226932E-12
0015300	0.4344135621E-12
0016200	0.6066857717E-12
0017100	0.8085598381E-12
0018000	0.1034426223E-11
0018900	0.1276607432E-11
0019800	0.1526194370E-11
0020700	0.1774008479E-11
0021600	0.2011518147E-11
0022500	0.2231559265E-11
0023400	0.2428769672E-11
0024300	0.2599722588E-11
0025200	0.2742808224E-11
0026100	0.2857948308E-11
0027000	0.2946233184E-11
0027900	0.3009554426E-11
0028800	0.3050280186E-11
0029700	0.3070995730E-11
0030600	0.3074313207E-11
0031500	0.3062743624E-11
0032400	0.3038619087E-11
0033300	0.3004052530E-11
0034200	0.2960923557E-11
0035100	0.2910881217E-11
0036000	0.2855356952E-11
0036900	0.2795582900E-11
0037800	0.2732612417E-11
0038700	0.2667340801E-11
0039600	0.2600525069E-11
0040500	0.2532802155E-11
0041400	0.2464705284E-11

MAXIMUM AR-41 CONCENTRATION IS: 0.3074992466E-11 mCi/ml  
TOTAL AR-41 PRODUCTION IS: 0.2408635586E+01 mCi  
TOTAL AR-41 RELEASE: 0.1463356457E-01 mCi

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Project: \_\_\_\_\_ Task: \_\_\_\_\_ Prepared by: J. E. Floyd Date: 10/30/93

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Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

10 Hours at Full Power

ARGON-41 FOR POWER= 250.00000 KW FOR 036000 SECONDS  
CASE WILL BE RUN UNTIL TIME 0073800 SECONDS  
NODE SPACING= 2.00 CM, TIME STEP= 4.00 S, OUTPUT INTERVAL=00900 S

TIME	ACTIVITY IN mCi/ml
0000900	-0.1070969988E-51
0001800	0.5162039140E-32
0002700	0.1867650207E-24
0003600	0.7298393504E-21
0004500	0.1133527619E-18
0005400	0.3519077431E-17
0006300	0.4307693597E-16
0007200	0.2920961679E-15
0008100	0.1327161142E-14
0009000	0.4534726880E-14
0009900	0.1255070334E-13
0010800	0.2958174648E-13
0011700	0.6149204934E-13
0012600	0.1156048686E-12
0013500	0.2002206799E-12
0014400	0.3238812076E-12
0015300	0.4944238875E-12
0016200	0.7178968866E-12
0017100	0.9974553735E-12
0018000	0.1332428969E-11
0018900	0.1717804008E-11
0019800	0.2144349318E-11
0020700	0.2599490629E-11
0021600	0.3068822342E-11
0022500	0.3537924044E-11
0023400	0.3994039746E-11
0024300	0.4427244412E-11
0025200	0.4830925919E-11
0026100	0.5201639490E-11
0027000	0.5538542944E-11
0027900	0.5842658081E-11
0028800	0.6116153837E-11
0029700	0.6361763149E-11
0030600	0.6582369770E-11
0031500	0.6780752161E-11
0032400	0.6959449287E-11
0033300	0.7120709432E-11
0034200	0.7266488972E-11
0035100	0.7398477059E-11
0036000	0.7518130600E-11
0036900	0.7626710530E-11
0037800	0.7725314848E-11
0038700	0.7814906703E-11
0039600	0.7896337291E-11
0040500	0.7970364016E-11
0041400	0.8037662377E-11
0042300	0.8098816191E-11
0043200	0.8154246718E-11
0044100	0.8204055517E-11
0045000	0.8247828825E-11
0045900	0.8284508465E-11
0046800	0.8312413768E-11
0047700	0.8329425020E-11
0048600	0.8333271506E-11
0049500	0.8321840202E-11

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Project: \_\_\_\_\_ Task: \_\_\_\_\_ Prepared by: J. E. Floyd Date: 10/30/93

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Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

0050400	0.8293433021E-11
0051300	0.8246932190E-11
0052200	0.8181865951E-11
0053100	0.8098389736E-11
0054000	0.7997208670E-11
0054900	0.7879468182E-11
0055800	0.7746634848E-11
0056700	0.7600382767E-11
0057600	0.7442494404E-11
0058500	0.7274779718E-11
0059400	0.7099014009E-11
0060300	0.6916892923E-11
0061200	0.6730002078E-11
0062100	0.6539798531E-11
0063000	0.6347601436E-11
0063900	0.6154589553E-11
0064800	0.5961803670E-11
0065700	0.5770152401E-11
0066600	0.5580420143E-11
0067500	0.5393276299E-11
0068400	0.5209285100E-11
0069300	0.5028915546E-11
0070200	0.4852551144E-11
0071100	0.4680499216E-11
0072000	0.4512999648E-11
0072900	0.4350233005E-11
0073800	0.4192327968E-11
MAXIMUM AR-41 CONCENTRATION IS:	0.8333668028E-11 mCi/ml
TOTAL AR-41 PRODUCTION IS:	0.2408635586E+02 mCi
TOTAL AR-41 RELEASE:	0.1636378986E+00 mCi

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Project: \_\_\_\_\_ Task: \_\_\_\_\_ Prepared by: J. E. Floyd Date: 10/30/93

Calc File No: \_\_\_\_\_ Reviewed by: W. J. Chappas Date: \_\_\_\_\_

Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

100 Hours at Full Power

ARGON-41 FOR POWER= 250.00000 KW FOR 360000 SECONDS.

CASE WILL BE RUN UNTIL TIME 0397800 SECONDS

NODE SPACING= 2.00 CM, TIME STEP= 4.00 S, OUTPUT INTERVAL=00900 S

TIME	ACTIVITY IN mCi/ml
0000900	-0.1070969988E-51
0001800	0.5162039140E-32
0002700	0.1867650207E-24
0003600	0.7298393504E-21
0004500	0.1133527619E-18
0005400	0.3519077431E-17
0006300	0.4307693597E-16
0007200	0.2920961679E-15
0008100	0.1327161142E-14
0009000	0.4534726880E-14
0009900	0.1255070334E-13
0010800	0.2958174648E-13
0011700	0.6149204934E-13
0012600	0.1156048686E-12
0013500	0.2002206799E-12
0014400	0.3238812076E-12
0015300	0.4944238875E-12
0016200	0.7178968866E-12
0017100	0.9974553735E-12
0018000	-0.1332428969E-11
0018900	0.1717804008E-11
0019800	0.2144349318E-11
0020700	0.2599490629E-11
0021600	0.3068822342E-11
0022500	0.3537924044E-11
0023400	0.3994039746E-11
0024300	0.4427244412E-11
0025200	0.4830925919E-11
0026100	0.5201639490E-11
0027000	0.5538542944E-11
0027900	0.5842658081E-11
0028800	0.6116153837E-11
0029700	0.6361763149E-11
0030600	0.6582369770E-11
0031500	0.6780752161E-11
0032400	0.6959449287E-11
0033300	0.7120709432E-11
0034200	0.7266488972E-11
0035100	0.7398477059E-11
0036000	0.7518130600E-11
0036900	0.7626710530E-11
0037800	0.7725314848E-11
0038700	0.7814906703E-11
0039600	0.7896337292E-11
0040500	0.7970364117E-11
0041400	0.8037665389E-11
0042300	0.8098851363E-11
0043200	0.8154473330E-11
0044100	0.8205030838E-11
0045000	0.8250977572E-11
0045900	0.8292726239E-11
0046800	0.8330652694E-11
0047700	0.8365099491E-11
0048600	0.8396378975E-11
0049500	0.8424776014E-11

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Project: \_\_\_\_\_ Task: \_\_\_\_\_ Prepared by: J. E. Floyd Date: 10/30/93

Calc File No: \_\_\_\_\_ Reviewed by: W. J. Chappas Date: \_\_\_\_\_

Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

0050400	0.8450550440E-11
0051300	0.8473939239E-11
0052200	0.8495158533E-11
0053100	0.8514405380E-11
0054000	0.8531859415E-11
0054900	0.8547684346E-11
0055800	0.8562029324E-11
0056700	0.8575030198E-11
0057600	0.8586810660E-11
0058500	0.8597483302E-11
0059400	0.8607150576E-11
0060300	0.8615905682E-11
0061200	0.8623833372E-11
0062100	0.8631010696E-11
0063000	0.8637507681E-11
0063900	0.8643387948E-11
0064800	0.8648709289E-11
0065700	0.8653524177E-11
0066600	0.8657880250E-11
0067500	0.8661820742E-11
0068400	0.8665384879E-11
0069300	0.8668608244E-11
0070200	0.8671523106E-11
0071100	0.8674158724E-11
0072000	0.8676541617E-11
0072900	0.8678695821E-11
0073800	0.8680643115E-11
0074700	0.8682403226E-11
0075600	0.8683994024E-11
0076500	0.8685431689E-11
0077400	0.8686730873E-11
0078300	0.8687904837E-11
0079200	0.8688965587E-11
0080100	0.8689923984E-11
0081000	0.8690789859E-11
0081900	0.8691572103E-11
0082800	0.8692278761E-11
0083700	0.8692917109E-11
0084600	0.8693493727E-11
0085500	0.8694014564E-11
0086400	0.8694485001E-11
0087300	0.8694909900E-11
0088200	0.8695293659E-11
0089100	0.8695640251E-11
0090000	0.8695953268E-11
0090900	0.8696235957E-11
0091800	0.8696491251E-11
0092700	0.8696721801E-11
0093600	0.8696930002E-11
0094500	0.8697118017E-11
0095400	0.8697287801E-11
0096300	0.8697441122E-11
0097200	0.8697579573E-11
0098100	0.8697704596E-11
0099000	0.8697817493E-11
0099900	0.8697919440E-11
0100800	0.8698011498E-11
0101700	0.8698094626E-11
0102600	0.8698169691E-11
0103500	0.8698237475E-11
0104400	0.8698298684E-11
0105300	0.8698353956E-11
0106200	0.8698403867E-11



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Project: \_\_\_\_\_ Task: \_\_\_\_\_ Prepared by: J. E. Floyd Date: 10/30/93

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Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

0107100	0.8698448937E-11
0108000	0.8698489636E-11
0108900	0.8698526389E-11
0109800	0.8698559577E-11
0110700	0.8698589547E-11
0111600	0.8698616612E-11
0112500	0.8698641053E-11
0113400	0.8698663124E-11
0114300	0.8698683056E-11
0115200	0.8698701056E-11
0116100	0.8698717312E-11
0117000	0.8698731993E-11
0117900	0.8698745251E-11
0118800	0.8698757225E-11
0119700	0.8698768039E-11
0120600	0.8698777806E-11
0121500	0.8698786627E-11
0122400	0.8698794593E-11
0123300	0.8698801789E-11
0124200	0.8698808287E-11
0125100	0.8698814157E-11
0126000	0.8698819459E-11
0126900	0.8698824248E-11
0127800	0.8698828573E-11
0128700	0.8698832480E-11
0129600	0.8698836009E-11
0130500	0.8698839197E-11
0131400	0.8698842076E-11
0132300	0.8698844678E-11
0133200	0.8698847027E-11
0134100	0.8698849150E-11
0135000	0.8698851067E-11
0135900	0.8698852799E-11
0136800	0.8698854364E-11
0137700	0.8698855778E-11
0138600	0.8698857055E-11
0139500	0.8698858209E-11
0140400	0.8698859251E-11
0141300	0.8698860193E-11
0142200	0.8698861044E-11
0143100	0.8698861812E-11
0144000	0.8698862507E-11
0144900	0.8698863134E-11
0145800	0.8698863701E-11
0146700	0.8698864214E-11
0147600	0.8698864676E-11
0148500	0.8698865095E-11
0149400	0.8698865473E-11
0150300	0.8698865814E-11
0151200	0.8698866123E-11
0152100	0.8698866401E-11
0153000	0.8698866653E-11
0153900	0.8698866881E-11
0154800	0.8698867087E-11
0155700	0.8698867273E-11
0156600	0.8698867441E-11
0157500	0.8698867592E-11
0158400	0.8698867730E-11
0159300	0.8698867854E-11
0160200	0.8698867966E-11
0161100	0.8698868067E-11
0162000	0.8698868158E-11
0162900	0.8698868241E-11

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Project: \_\_\_\_\_ Task: \_\_\_\_\_ Prepared by: J. E. Floyd Date: 10/30/93

Calc File No: \_\_\_\_\_ Reviewed by: W. J. Chappas Date: \_\_\_\_\_

Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

0163800	0.8698868316E-11
0164700	0.8698868383E-11
0165600	0.8698868445E-11
0166500	0.8698868500E-11
0167400	0.8698868550E-11
0168300	0.8698868595E-11
0169200	0.8698868635E-11
0170100	0.8698868672E-11
0171000	0.8698868706E-11
0171900	0.8698868736E-11
0172800	0.8698868763E-11
0173700	0.8698868787E-11
0174600	0.8698868810E-11
0175500	0.8698868830E-11
0176400	0.8698868848E-11
0177300	0.8698868864E-11
0178200	0.8698868879E-11
0179100	0.8698868892E-11
0180000	0.8698868905E-11
0180900	0.8698868916E-11
0181800	0.8698868925E-11
0182700	0.8698868934E-11
0183600	0.8698868943E-11
0184500	0.8698868950E-11
0185400	0.8698868956E-11
0186300	0.8698868962E-11
0187200	0.8698868968E-11
0188100	0.8698868973E-11
0189000	0.8698868977E-11
0189900	0.8698868981E-11
0190800	0.8698868985E-11
0191700	0.8698868988E-11
0192600	0.8698868991E-11
0193500	0.8698868994E-11
0194400	0.8698868996E-11
0195300	0.8698868998E-11
0196200	0.8698869000E-11
0197100	0.8698869002E-11
0198000	0.8698869004E-11
0198900	0.8698869005E-11
0199800	0.8698869006E-11
0200700	0.8698869008E-11
0201600	0.8698869009E-11
0202500	0.8698869010E-11
0203400	0.8698869010E-11
0204300	0.8698869011E-11
0205200	0.8698869012E-11
0206100	0.8698869013E-11
0207000	0.8698869013E-11
0207900	0.8698869014E-11
0208800	0.8698869014E-11
0209700	0.8698869015E-11
0210600	0.8698869015E-11
0211500	0.8698869015E-11
0212400	0.8698869016E-11
0213300	0.8698869016E-11
0214200	0.8698869016E-11
0215100	0.8698869017E-11
0216000	0.8698869017E-11
0216900	0.8698869017E-11
0217800	0.8698869017E-11
0218700	0.8698869017E-11
0219600	0.8698869017E-11

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Project: \_\_\_\_\_ Task: \_\_\_\_\_ Prepared by: J. E. Floyd Date: 10/30/93

Calc-File No: \_\_\_\_\_ Reviewed by: W. J. Chappas Date: \_\_\_\_\_

Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

0220500	0.8698869018E-11
0221400	0.8698869018E-11
0222300	0.8698869018E-11
0223200	0.8698869018E-11
0224100	0.8698869018E-11
0225000	0.8698869018E-11
0225900	0.8698869018E-11
0226800	0.8698869018E-11
0227700	0.8698869018E-11
0228600	0.8698869018E-11
0229500	0.8698869018E-11
0230400	0.8698869018E-11
0231300	0.8698869018E-11
0232200	0.8698869018E-11
0233100	0.8698869018E-11
0234000	0.8698869019E-11
0234900	0.8698869019E-11
0235800	0.8698869019E-11
0236700	0.8698869019E-11
0237600	0.8698869019E-11
0238500	0.8698869019E-11
0239400	0.8698869019E-11
0240300	0.8698869019E-11
0241200	0.8698869019E-11
0242100	0.8698869019E-11
0243000	0.8698869019E-11
0243900	0.8698869019E-11
0244800	0.8698869019E-11
0245700	0.8698869019E-11
0246600	0.8698869019E-11
0247500	0.8698869019E-11
0248400	0.8698869019E-11
0249300	0.8698869019E-11
0250200	0.8698869019E-11
0251100	0.8698869019E-11
0252000	0.8698869019E-11
0252900	0.8698869019E-11
0253800	0.8698869019E-11
0254700	0.8698869019E-11
0255600	0.8698869019E-11
0256500	0.8698869019E-11
0257400	0.8698869019E-11
0258300	0.8698869019E-11
0259200	0.8698869019E-11
0260100	0.8698869019E-11
0261000	0.8698869019E-11
0261900	0.8698869019E-11
0262800	0.8698869019E-11
0263700	0.8698869019E-11
0264600	0.8698869019E-11
0265500	0.8698869019E-11
0266400	0.8698869019E-11
0267300	0.8698869019E-11
0268200	0.8698869019E-11
0269100	0.8698869019E-11
0270000	0.8698869019E-11
0270900	0.8698869019E-11
0271800	0.8698869019E-11
0272700	0.8698869019E-11
0273600	0.8698869019E-11
0274500	0.8698869019E-11
0275400	0.8698869019E-11
0276300	0.8698869019E-11

# MARYLAND UNIVERSITY TRAINING REACTOR

Sheet No 20 of 22

Project: \_\_\_\_\_ Task: \_\_\_\_\_ Prepared by: J. E. Floyd Date: 10/30/93

Calc File No: \_\_\_\_\_ Reviewed by: W. J. Chappas Date: \_\_\_\_\_

Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

0277200	0.8698869019E-11
0278100	0.8698869019E-11
0279000	0.8698869019E-11
0279900	0.8698869019E-11
0280800	0.8698869019E-11
0281700	0.8698869019E-11
0282600	0.8698869019E-11
0283500	0.8698869019E-11
0284400	0.8698869019E-11
0285300	0.8698869019E-11
0286200	0.8698869019E-11
0287100	0.8698869019E-11
0288000	0.8698869019E-11
0288900	0.8698869019E-11
0289800	0.8698869019E-11
0290700	0.8698869019E-11
0291600	0.8698869019E-11
0292500	0.8698869019E-11
0293400	0.8698869019E-11
0294300	0.8698869019E-11
0295200	0.8698869019E-11
0296100	0.8698869019E-11
0297000	0.8698869019E-11
0297900	0.8698869019E-11
0298800	0.8698869019E-11
0299700	0.8698869019E-11
0300600	0.8698869019E-11
0301500	0.8698869019E-11
0302400	0.8698869019E-11
0303300	0.8698869019E-11
0304200	0.8698869019E-11
0305100	0.8698869019E-11
0306000	0.8698869019E-11
0306900	0.8698869019E-11
0307800	0.8698869019E-11
0308700	0.8698869019E-11
0309600	0.8698869019E-11
0310500	0.8698869019E-11
0311400	0.8698869019E-11
0312300	0.8698869019E-11
0313200	0.8698869019E-11
0314100	0.8698869019E-11
0315000	0.8698869019E-11
0315900	0.8698869019E-11
0316800	0.8698869019E-11
0317700	0.8698869019E-11
0318600	0.8698869019E-11
0319500	0.8698869019E-11
0320400	0.8698869019E-11
0321300	0.8698869019E-11
0322200	0.8698869019E-11
0323100	0.8698869019E-11
0324000	0.8698869019E-11
0324900	0.8698869019E-11
0325800	0.8698869019E-11
0326700	0.8698869019E-11
0327600	0.8698869019E-11
0328500	0.8698869019E-11
0329400	0.8698869019E-11
0330300	0.8698869019E-11
0331200	0.8698869019E-11
0332100	0.8698869019E-11
0333000	0.8698869019E-11

# MARYLAND UNIVERSITY TRAINING REACTOR

Sheet No 21 of 22

Project: \_\_\_\_\_ Task: \_\_\_\_\_ Prepared by: J. E. Floyd Date: 10/30/93

Calc File No: \_\_\_\_\_ Reviewed by: W. J. Chappas Date: \_\_\_\_\_

Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

0333900	0.8698869019E-11
0334800	0.8698869019E-11
0335700	0.8698869019E-11
0336600	0.8698869019E-11
0337500	0.8698869019E-11
0338400	0.8698869019E-11
0339300	0.8698869019E-11
0340200	0.8698869019E-11
0341100	0.8698869019E-11
0342000	0.8698869019E-11
0342900	0.8698869019E-11
0343800	0.8698869019E-11
0344700	0.8698869019E-11
0345600	0.8698869019E-11
0346500	0.8698869019E-11
0347400	0.8698869019E-11
0348300	0.8698869019E-11
0349200	0.8698869019E-11
0350100	0.8698869019E-11
0351000	0.8698869019E-11
0351900	0.8698869019E-11
0352800	0.8698869019E-11
0353700	0.8698869019E-11
0354600	0.8698869019E-11
0355500	0.8698869019E-11
0356400	0.8698869019E-11
0357300	0.8698869019E-11
0358200	0.8698869019E-11
0359100	0.8698869019E-11
0360000	0.8698869019E-11
0360900	0.8698869019E-11
0361800	0.8698869019E-11
0362700	0.8698869019E-11
0363600	0.8698869018E-11
0364500	0.8698868918E-11
0365400	0.8698866043E-11
0366300	0.8698834343E-11
0367200	0.8698645961E-11
0368100	0.8697910189E-11
0369000	0.8695776277E-11
0369900	0.8690802033E-11
0370800	0.8680969885E-11
0371700	0.8663860519E-11
0372600	0.8636929173E-11
0373500	0.8597803632E-11
0374400	0.8544534133E-11
0375300	0.8475755572E-11
0376200	0.8390753647E-11
0377100	0.8289448756E-11
0378000	0.8172322084E-11
0378900	0.8040309559E-11
0379800	0.7894685126E-11
0380700	0.7736948470E-11
0381600	0.7568726137E-11
0382500	0.7391690121E-11
0383400	0.7207494591E-11
0384300	0.7017729434E-11
0385200	0.6823888276E-11
0386100	0.6627348334E-11
0387000	0.6429359524E-11
0387900	0.6231040553E-11
0388800	0.6033380072E-11
0389700	0.5837211253E-11

# MARYLAND UNIVL. CITY TRAINING REACT.

Sheet No 22 of 22

Project: \_\_\_\_\_ Task: \_\_\_\_\_ Prepared by: J. E. Floya Date: 10/30/93

Calc File No: \_\_\_\_\_ Reviewed by: W. J. Chappas Date: \_\_\_\_\_

Title: Ar-41 Production Calculations for Annual Report and 10CFR20 Requirements

0390600	0.5643369274E-11
0391500	0.5452398711E-11
0392400	0.5264863641E-11
0393300	0.5081206474E-11
0394200	0.4901787279E-11
0395100	0.4726892648E-11
0396000	0.4556744077E-11
0396900	0.4391505762E-11
0397800	0.4231291772E-11
MAXIMUM AR-41 CONCENTRATION IS:	0.8698869019E-11 mCi/ml
TOTAL AR-41 PRODUCTION IS:	0.2408635586E+03 mCi
TOTAL AR-41 RELEASE:	0.1705623475E+01 mCi