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**THE ACT AND ACTIVE CODES
FOR CALCULATING NEUTRON-INDUCED ACTIVATION**

R. M. Lessler
W. E. Alley
J. B. Green

April 10, 1973

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THE ACT AND ACTIVE CODES FOR CALCULATING NEUTRON-INDUCED ACTIVATION

Abstract

ACT and ACTIVE are two computer programs that were written to calculate the neutron-induced radioactive products produced by a nuclear explosion. ACT calculates the products in high-flux regions where multiple-order reactions occur, as in the explosive itself; ACTIVE

calculates the products in relatively low-flux regions where only first-order reactions are important, as in the materials around the explosive. This report explains how the codes operate and describes their input and output.

Introduction

The ACT and ACTIVE codes were written to calculate the neutron-induced radioactive products produced by a nuclear explosion. ACT is used to calculate the products from the explosive itself; ACTIVE is used to calculate the products from the materials surrounding the explosive. It is necessary to employ different codes for these two cases because the neutronics conditions are different. Within the explosive, there are very high neutron-flux levels; this requires that time-dependent multiple-order reactions, as well as material depletion, be calculated. External to the explosive, the flux levels are normally low enough so that multiple-order reactions are not important; thus a single

calculation based upon the integrated flux can be used.

Each of the codes is linked to a source code which computes the neutron flux in the regions of the problem. ACT is linked to the geometrically one-dimensional MEG^{1,2} code, while ACTIVE is linked to the two-dimensional TART³ code. ACT and ACTIVE will then compute the neutron-induced radioactive products and provide decay information.

The cross sections employed by the codes come from the Semiempirical Neutron Induced Reaction Cross Section Library described in Ref. 4. The accuracy of the calculations depends directly on the reliability of the cross sections as well as on the flux calculations.

ACT

The ACT code is normally linked to the MEG hydrodynamic and neutronic

code. The Monte Carlo option of MEG is normally employed. MEG will write

a flux edit tape as a function of time and energy; the fluxes must be regional fluxes to be processed by ACT. A region is a series of one or more zones containing the same material. Since ACT will compute multiple-order reactions and material depletion, one must be careful to select the edit frequency of MEG that will produce a sufficient number of flux edits during the period of high flux levels when most of the activation occurs.

It is also possible to input the flux information from cards. The fluxes may be put in as actual fluxes or as total integrated fluxes as a function of time. Using cards would eliminate the necessity of linking with the MEG source code; this option is usually not employed, however, because of the tedious procedure required to calculate the flux information and then prepare the appropriate cards. Further discussion here is based on the MEG-to-ACT link.

ACTIVATION AND DEPLETION

MEG will write an incremental integrated flux for each region. In order to prevent large changes in material depletion without sufficient multiple-order reactions when the flux level is high, ACT divides up the fluxes so that no more than 2% (or some other specified amount) of an element in a region is activated in any one step. Since

$$\frac{A}{A_0} = \sigma \phi,$$

where

A = the number of atoms of produced isotope,

A_0 = the number of atoms of initial isotope at time zero (t_0),

σ = the cross section in barns, and

ϕ = the fluence in neutrons/cm²,

this requires that

$$\sum_i (\sigma_i \phi_i),$$

where the sum is over all isotopes of element i , be less than 0.02. When this condition is not met, the flux is divided appropriately. The value of 0.02, which was chosen on the basis of extensive testing of the activation process, optimizes the accuracy of the calculation while keeping the number of calculational steps to a minimum.

Once the first activation step for a flux increment has been completed, the depletion is calculated by simply subtracting the amount of activation products from the original amount of that isotope. Isomers are treated in a similar manner, considering the ratio of the isomer to the ground-state abundance. This process is continued until all isotopes and all reactions have been calculated for that flux increment. The next flux increment will then be calculated, repeating the activation-depletion loop. This is continued until all the fluxes have been processed for all the regions.

NEUTRON CROSS SECTIONS

There are eleven possible reactions that ACT will calculate for any isotope. These are (n,3n), (n,2n), (n, γ), (n,p),

(n,α) , $(n,3n^*)$, $(n,2n^*)$, (n,n^*) , (n,γ^*) , (n,p^*) , and (n,α^*) , where the asterisk refers to an isomeric product. Not all of the cross sections for each of these reactions for every isotope have been measured or calculated. As a result, an extrapolation routine is employed by the code in selecting the cross sections for each energy group which will be used when one is not available. The method of selection is as follows:

1. If a cross section is available for a particular reaction for that isotope, it is used.

2. If a cross section for the element is not available, then this procedure is followed:

- a. If a first-order activation product is being considered, the activation will not be calculated.

- b. If a multiple-order activation product is being calculated, cross sections for the next heavier element are used.

3. If a cross section for an isotope is not available, then this procedure is followed:

- a. All lighter isotopes in question of the same element are assumed to have the same cross section as the element's lightest isotope whose cross section is known.

- b. All heavier isotopes in question of the same element are assumed to have the same cross section as the element's heaviest isotope whose cross section is known.

- c. All isotopes in question that fall between isotopes of known cross section are assumed to have the same cross section as the closest lighter isotope whose cross section is known.

The cross-section library that ACT uses⁴ contains approximately 800 neutron-induced reactions. Because such a large number of reactions have been measured or calculated and are contained in the library, there are cross sections for most first-order reactions, especially those of common materials such as the metals used as structural materials and the normal constituents of rock. The extrapolation procedure applies primarily when one is selecting cross sections to be used for multiple-order reactions.

The cross sections used are actually in histogram form as a function of neutron energy. The energy groups employed must correspond to the groups used by the MEG code for the flux edits. The Monte Carlo version of MEG uses 20 groups, and the diffusion-theory version uses 10 groups. The group limits used for each of these cases are shown in Table 1; a cross section is considered constant within a group.

RADIOACTIVE DECAY

Once the initial radioactive products have been calculated, ACT will follow each of the radioactive decay schemes and compute the decay products as a function of time. The values can be printed for up to six different edit times. Since the neutron activation takes place over such a short time, decay during activation is not considered. Time zero is taken as the completion of the neutron activation.

The correct differential equation to use in calculating the growth and decay products of the decay chain depends on the number of steps in the chain. Decay

Table 1. Energy groups used by the Monte Carlo and diffusion-theory versions of the MEG code.

Monte Carlo			
1.	0.025-0.05 eV	15.	0.261-0.429 MeV
2.	0.05-0.2 eV	16.	0.429-0.638 MeV
3.	0.2-0.8 eV	17.	0.638-0.888 MeV
4.	0.8-3.2 eV	18.	0.888-1.18 MeV
5.	3.2-12.8 eV	19.	1.18-1.72 MeV
6.	12.8-51.1 eV	20.	1.72-2.55 MeV
7.	51.1-204 eV	21.	2.55-3.56 MeV
8.	0.204-0.817 keV	22.	3.56-4.73 MeV
9.	0.817-3.27 keV	23.	4.73-6.07 MeV
10.	3.27-13.1 keV	24.	6.07-7.57 MeV
11.	13.1-34.0 keV	25.	7.57-9.24 MeV
12.	34.0-65.4 keV	26.	9.24-11.08 MeV
13.	65.4-136 keV	27.	11.08-13.09 MeV
14.	0.136-0.261 MeV	28.	13.09-14.1 MeV

Diffusion Theory			
1.	0.025-3000 eV	6.	2.2-4.8 MeV
2.	3-30 keV	7.	4.8-7.24 MeV
3.	30-150 keV	8.	7.24-10.0 MeV
4.	0.15-0.5 MeV	9.	10.0-14.0 MeV
5.	0.5-2.2 MeV	10.	14.0-14.1 MeV

information for each isotope is taken from the Table of Isotopes⁵ and stored in the cross-section file. The chain decay may then be calculated by following the decay of each isotope. Only a single mode of decay is allowed for any specific isotope (i.e., no branching). Up to six decay steps are allowed for any chain, and the appropriate decay equations for these are indicated below.

For a decay chain having only one radioactive nuclide (i.e., $A \rightarrow \text{stable}$),

$$\frac{dN_a}{dt} = -\lambda_a N_a,$$

where λ_a is the decay constant of nuclide A and N_a is the number of atoms of nuclide A present at time t. Solving for N,

$$N = N_0 e^{-\lambda_a t},$$

where N_0 is the number of atoms of nuclide A at $t = 0$.

For any decay chain having two or more radioactive nuclides (i.e., $A \rightarrow B \rightarrow \dots \rightarrow X$, where X is the stable isotope into which the radioactive chain decays),

$$\frac{dN_x}{dt} = \lambda_{x-1} N_{x-1} - \lambda_x N_x,$$

and

$$\frac{dN_{x-1}}{dt} = -\lambda_{x-1} N_{x-1} + \lambda_{x-2} N_{x-2}.$$

The solutions to these equations are somewhat complex, but they are standard in form.

When the appropriate equation is employed for a specific decay chain, all of the decay products for that decay chain can be calculated. ACT calculates the decay products by this method for each of the radionuclides present following activation.

In addition to calculating the number of atoms present as a function of time, the code will calculate the radionuclide activities in either disintegrations per second or curies, and the gamma MeV per hour. The total integrated gamma MeV remaining for a specific decay chain is also provided as a function of time. The average gamma MeV per disintegration is obtained from the Table of Isotopes; this value does not include any contribution from x rays resulting from electron capture or the β^+ annihilation energy. In most cases, any x-ray contribution is negligible. For some heavy metals, where the gamma decay energy is small, the x rays cannot

be ignored. Tungsten 181 is a good example, where the average decay gamma has an energy of about 2 keV per disintegration. The x ray emitted upon electron capture has an energy of about 60 keV.

Branching decay of an isotope cannot be handled by ACT, since there are provisions for only one mode of decay for any specific isotope. In the case where there is branching decay, the decay mode corresponding to the largest branching ratio is assumed for all decay. However, if this decay mode goes to a stable isotope, the decay mode going to the radioactive product is used.

CODE DESCRIPTION

ACT is written as a controllee for the CDC 7600 computer. In order to run, the code requires either a flux edit tape written by the MEG code or a card flux input with all the fluxes being regional. The code can handle up to 75 fluxes for up to 15 regions. If there are more than 75 flux edits on the tape, the code will sum fluxes, first two at a time, then three at a time, etc., until there are fewer than 75. The code also requires the cross-section and decay information.

The cross sections are in point form as a function of neutron energy, within the energy range of 2.5×10^{-8} to 14.6 MeV. ACT will average the cross sections required over each group and create the corresponding 28 group cross sections. Where insufficient data points are available to generate the 28 group cross sections, an interpolation process must be employed. All (n, γ) cross sections and other cross sections with nonzero ther-

mal values are logarithmically interpolated to simulate the characteristic energy dependence. All other cross sections are interpolated linearly.

The activation is computed region by region. After the final region of the problem has been calculated, the regional products are summed to give the total activation products. The code then calculates decay information, using the total activation products.

The code consists of a MAIN and six subroutines: READ, AMAIN, XSECS, GROUP, MERGE, and DECAY. MAIN and READ read the flux edit tape or cards, process the fluxes, and store them in the appropriate array. XSECS, GROUP, and MERGE compute the cross sections when required during activation. AMAIN computes the zero-time activation products. DECAY provides decay information for all of the activation products.

The code will respond to Sense Switch 1 (SW1); however, a restart tape is not written. When SW1 has been set, the code will complete the flux on which it is currently working and provide decay information for the activation products already completed. Running time for the code can vary from less than 1 minute to about 30 minutes, depending on the number of regions and materials and the flux levels.

It is not required that all regions for which there are fluxes be calculated, nor is it required that all materials in a region be specified. The code will calculate the products for only those materials and regions specified in the input data deck.

CODE INPUT DESCRIPTION FOR ACT DATA DECK

	<u>Columns</u>	<u>Format</u>	<u>Variable name</u>	<u>Description</u>
<u>Card 1</u>	1-7	A7	IBOX	Output box number
	11-20	A10	INAME	Problem name
	26-30	A5	NF1L16	Flux dump tape vault number
<u>Card 2</u>	1-12	E12,6	P	a. Set P=1. if fluxes to be read from tape vault specified on card 1. b. Set P=0. if fluxes are to be read from cards (see card 2A). c. Set P=-1. if total integrated fluxes are to be read from cards (see card 2A).
	13-24	E12,6	Q	Flux tape multiplication factor. All fluxes on tape will be multiplied by factor. 1. must be entered to have fluxes unchanged.
	25-29	I5	IK	Problem mode a. Set IK=0 for problem to run only. b. Set IK=1 for an edit of the cross section file only. The problem will not run and no further data is required. In this mode it is not necessary to specify tape vault number on card 1.
<u>Card 2A</u>	(If P=1 on card 2, cards 2A and 2B are to be omitted)			
	1-6	I6	NR	Region number
	7-12	I6	NF	Number of fluxes in that region (maximum of 75 allowed).
<u>Card 2B</u>	1-60	5E12,6	FL	Fluxes for region specified on card 2A. Five flux values per card. Each flux must have 10 or 28 values corresponding to the energy groups, low to high energy. There will be 2 or 6 2B cards for each of the fluxes listed on card 2A for that region.
Cards 2A and 2B are to be repeated for each region desired.				
<u>Card 3</u>	1	I1	NTIMES	Number of decay times (maximum of 6), a. Set NTIMES=0 if only time zero activation is desired, and omit card 4. b. Set NTIMES= number of decay times specified on card 4.

	<u>Columns</u>	<u>Format</u>	<u>Variable name</u>	<u>Description</u>
<u>Card 3</u> (contd)	2-3	I2	NCUR	a. Set NCUR=0 for decay information printed in DPS. b. Set NCUR=1 for curies.
	4-15	E12,6	TIM	Integration limit. Set TIM= time (in seconds) desired for limit of γ -MeV integration. If TIM=0, 50 years will be used.
If NTIMES on card 3 is 0, omit card 4.				
<u>Card 4</u>	1-72	4(A6,E12,6)	Time,S	Decay times. "A" formats are labels for the following "E" format. Decay time in seconds.
	There can be four decay times per card. For six decay times, two cards 4 will be required.			
<u>Card 5</u>	1-6	I6	NR	Set NR equal to region number to be calculated.
	6-18	E12,6	P	Set P equal to maximum depletion per cycle. If P=0, 0.02 is used.

Material Description Cards for Regions

<u>Card 6</u>	1-2	I2	I	Isotope atomic number (Z)
	3-5	I3	M	Isotope atomic weight (A)
	6-15	E10,6	W	Grams of isotope
	16-25	E10,6	B	End of region indicator. When B=0, another isotope card to follow. On card for last isotope in region set B=1. If cross section printout desired for materials in that region set B=-1.
	Cards 6 are repeated for all isotopes in that region. Following last isotope card for a region, begin next region with a card 5.			
	The code can process a maximum of 25 different elements and 20 isotopes per element for a region.			

Card 7 Place a blank card at the end of the deck.

CODE OUTPUT DESCRIPTION FOR ACT

The first portion of the output provides information on the regional fluxes. The time, hydrodynamic-cycle number, and neutronic-cycle number are provided for each flux edit. This is followed by the actual flux edits. Each edit lists the flux in each region for each of the energy

groups (either 28 or 10). The last flux is the total flux for each region as a function of energy.

Regional input and activation information is provided next. The cross sections used for that region are also provided if requested. The mass in grams of each isotope is listed, followed by the activation of each element. A sample activation block is shown below for potassium.

K ACTIVATION

K	AT.WT. LESS THAN	37	3.254E+08	MORE THAN	47	4.366E+04				
1.688E+12	2.737E+15	8.020E+18	2.842E+17	7.213E+17	3.154E+16	6.901E+14	1.006E+11	1.007E+11	9.552E+08	
6.902E+06										
2.273E+15	0.0.	0.0.		0.0.	0.0.					
A	AT.WT. LESS THAN	35	1.300E+02	MORE THAN	42	5.773E+13				
1.303E+06	1.079E+10	7.171E+13	3.680E+17	3.317E+18	1.703E+17	5.908E+16	2.479E+15			
0.0.	0.0.	0.0.		0.0.	0.0.					
CL	AT.WT. LESS THAN	32	2.684E+11	MORE THAN	40	2.564E+15				
0.877E+12	2.606E+14	6.011E+15	1.033E+17	1.125E+18	6.913E+16	3.446E+16	1.371E+17	1.795E+15		
3.4.065E+15	7.3.446E+16	0.0.		0.0.	0.0.					
S	AT.WT. LESS THAN	29	0.	MORE THAN	36	5.403E+14				
0.0.	0.	0.	2.270E+11	0.219E+12	2.308E+14	2.192E+16	1.631E+17	1.941E+15	1.007E+13	
0.0.	0.0.	0.0.	0.0.	0.0.	0.0.					
P	AT.WT. LESS THAN	28	0.	MORE THAN	34	5.140E+15				
0.	1.642E+11	6.038E+12	1.852E+14	4.532E+15	8.462E+16	2.951E+15				
0.0.	0.0.	0.0.	0.0.	0.0.	0.0.					

NO CROSS-SECTIONS ON TAPE FOR NE

NA CROSS-SECTIONS WERE USED FOR NE

The first line lists the total number of atoms of all isotopes lower than ^{37}K and higher than ^{47}K . The next line lists the number of atoms of each isotope beginning with ^{37}K and going through ^{47}K . The next line lists the isomer production. There is only one potassium isomer, ^{38m}K . This same type of information is provided for each element which results from potassium activation.

Following the activation blocks for each element, the total activation products for that region are listed. After all regions have been completed, the total in atoms of each isotope for all regions is provided along with the disintegrations per second, curies, gamma-MeV per disintegration, and half-life for that isotope.

Decay information is provided next. The decay chain of each of the isotopes is listed along with the decay edit times. The total gamma MeV per disintegration is listed along with the total integrated gamma MeV remaining as a function of time. Activation in atoms as a function of time is next provided. This is followed by the activity in either disintegrations per second or curies, as specified.

The final edit is the gamma MeV per hour for each isotope as a function of time.

The problem running time is the last entry on the output printout.

OPERATION OF THE ACT CODE

To operate the code, one must have access to the controller ACT. This file is stored in ELEPHANT library. It must be placed on disc by means of the ELF routine, since it is not part of the public library.

To operate ACT from the Teletype, type:

1. ELF RDS .526900 : ACT / TV
2. ACT DATA1 / TV

The ACT code will now be running, reading the input data file named DATA1.

As the code runs, messages will be sent to the teletype as the activation of each region is completed. There will also be a final message indicating the amount of time the problem took on the machine.

SYSTEM RESPONSE: ALL DONE.

The problem is now completed. Subsequent problems can be run without again reading the file ACT onto disc.

ACTIVE

The ACTIVE code is linked to the TART Monte Carlo neutron-transport code.* TART will calculate and write an edit tape or disc file of the neutron path length per zone as a function of energy in 50 energy groups. ACTIVE will convert the path length to a total integrated flux from which the neutron-induced activation can be calculated. ACTIVE can process more than one edit tape or disc file and can sum the contributions from each to obtain a total flux.

GEOMETRY AND THERMAL TEMPERATURES

Since TART is a static neutron-transport code, ACTIVE should not be used to calculate the activation products in problems where large hydrodynamic or temperature changes are taking place. If it is necessary to use ACTIVE for problems of this type, the geometry chosen for the TART-ACTIVE calculation should reflect the conditions at the time when the neutron flux within the changing zones is at its greatest. Since most collisions (and hence captures) take place at the "thermal" temperature of a zone, accurately assigning the minimum energy of a zone in the TART calculation is very important; this is especially true when the neutron cross sections for the particular material are strongly energy dependent. Since TART can have two-dimensional geometry, the ACTIVE calculations can be two-dimensional, in

contrast to the one-dimensional MEG-ACT calculation.

ACTIVATION

Since ACTIVE was written to calculate activation products external to the nuclear device, where the neutron flux levels are relatively low, multiple-order reactions and material depletion are not important considerations, and so they are not included in the calculation. As a result, the total integrated flux can be used, and the complication of time dependence is eliminated.

TART will write the neutron path length in a zone. The path length can be converted to a total integrated flux by:

$$\phi \text{ (neutrons/cm}^2\text{)} = \frac{\text{path length (cm)}}{\text{volume (cm}^3\text{)}} \times \text{neutrons}$$

Once the flux has been computed for each zone, the activation products can be computed by simply multiplying the flux by the appropriate cross sections for the materials in each zone.

NEUTRON CROSS SECTIONS

Since there are no multiple-order reactions calculated by ACTIVE, only cross sections leading to radioactive products are needed in the ACTIVE cross-section library. ACTIVE will compute the products for any reaction for which a cross section exists in the library. The cross-section library used by ACTIVE is the same as that used by ACT (see p. 3).

* ACTIVE was originally written for linking to the 66-energy-group SORS code described in Ref. 6.

The cross sections are in point form as a function of neutron energy. The TART edit tape or file contains the structure of the 50 output tally groups used during the calculation. ACTIVE will average the cross sections required over each group and create the corresponding 50 group cross sections. Where insufficient data points are available to generate the 50 group cross sections, an interpolation process must be employed. All (n,γ) cross sections and other cross sections with nonzero thermal values are logarithmically interpolated to simulate the characteristic energy dependence. All other cross sections are interpolated linearly. This allows the flexibility of changing the energy groups from one problem to another. The cross-section data are available within the energy range of 2.5×10^{-8} to 14.6 MeV. If any of the output tally groups do not fall within this range, ACTIVE will adjust them so that they do fall within this range. This means that any energy groups greater than 14.6 MeV will use the cross sections for 14.6 MeV. The same principle applies to groups lower in energy than 2.5×10^{-8} MeV.

RADIOACTIVE DECAY

Once the initial radioactive products have been calculated, ACTIVE will follow each of the radioactive decay schemes and compute the decay products as a function of time. The values can be printed for up to eight different edit times.

Up to three radioactive products in any decay chain can be calculated. The differential equations for a two step chain decay are shown below:

If

$A \rightarrow B \rightarrow \text{stable}$,

and

A_0 atoms of nuclide A are present at time zero,

then

$$A = A_0 e^{-\lambda_a t}$$

is the amount of nuclide A present at time t.

The net rate of change of nuclide B with time is

$$\frac{dB}{dt} = \lambda_b B + \lambda_a A.$$

Solving for B,

$$B = \frac{\lambda_a A_0}{\lambda_b - \lambda_a} \left(e^{-\lambda_a t} - e^{-\lambda_b t} \right),$$

where B is the number of atoms of nuclide B at time t when $\lambda_b \neq \lambda_a$. The solutions to the more complicated decay schemes are similar to the above.

In addition to calculating the number of atoms present as a function of time, ACTIVE will calculate and print the corresponding activity in curies for each of the radionuclides. It will also calculate and print the total integrated decay energy and gamma MeV from edit time to 50 years, and the total decay energy and gamma MeV per hour.

Although ACTIVE cannot calculate branching decay of an isotope as such, provisions have been made for properly treating this situation. The decay information for the products of a particular

reaction is stored with each reaction in the cross-section library. Therefore, when branching occurs, a second reaction and the alternate decay scheme and branching fraction can be included in the cross-section library, so that all of the decay products are properly calculated. When a branch leads to a stable isotope, however, only the radioactive branch is calculated.

CODE DESCRIPTION

ACTIVE is written as a controller for the CDC 7600 computer. The code requires an output edit tape or disc file written by the TART code, which provides the neutron path length per zone as a function of energy. The code also requires cross-section and decay information; this is stored in an array as raw data in large core memory.

The preferred method of operation is to use the TART disc file; this speeds the operation of the code and eliminates the requirement for any tape input and output.

The activation is computed isotope by isotope, commencing with lightest element in any of the materials in the problem. Once all of the isotopes have been calculated, the code calculates decay information, using the total of the activation products for all of the zones.

The code consists of a MAIN and four subroutines. All calculations of the activation and decay are performed in MAIN, with two of the subroutines providing only indexing parameters and conversion factors for constants. The other two subroutines calculate the 50 group cross sections as required. Normal running time for the code is less than one minute, even for complicated problems with a large number of zones. Because of the short running time, the code will not respond to SW1, nor is there any restart capability.

It is not required that all zones for which there are fluxes be calculated, nor is it required that all elements within a zone be specified. The code will calculate the products for only those materials and zones specified in the input deck.

CODE INPUT DESCRIPTION FOR ACTIVE DATA DECK

	<u>Columns</u>	<u>Format</u>	<u>Variable name</u>	<u>Description</u>
Card 1	1-7	A7	IBOXJ	Output box number
	11-20	A10	NAME	Problem name
Card 2	1-6	I6	NT	Number of TART edit tapes or files
Card 3	1	I1	NED	Number of TART edit times
	2-13	E12,6	STAT	Number of source moles of neutrons
	14-23	R10	NFILB	Tape vault number or disc file name

<u>Columns</u>	<u>Format</u>	<u>Variable name</u>	<u>Description</u>
30	I1	IOLOGU	Set equal to 1 if NFILB is on tape. Leave blank if NFILB is on disc.

Note: There will be as many cards 3 as there are TART tapes or files to be processed.

Card 4	1-10	I10	IZONE	Zone number
	11-20	I10	MA	Material number in zone. Leave blank.
	21-30			Leave blank.
	31-40	E10.3	COM	Compression over TART. If blank, 1.0 is used.

Note: There should be one card 4 for each zone to be calculated.

Follow the last zone card with a blank card.

Card 5	1-6	I6	IS	Integer decay time in units specified in next field.
	7-9	A3	TNAME	Either sec, min, hrs, dys, or yrs as applicable for preceding value.

Note: This sequence can be repeated for up to 8 decay times (through column 72). If the card is blank, only zero-time information will be provided.

Card 6	1-5	I5	J	Material number
	6-10	I5	III	Number of elements in material. (Maximum of 80 per material)
	11-20	E10.3	DDD	Density of material
	21-30	E10.3	AAA	Atoms/cm-barn for that material (obtain from TART)

Card 7	1-2	A2	EEL	Element symbol (left adjusted)
	3-12	E10.3	PATOM	Atom fraction of element in zone
	13-22	E10.3	GRAMS	Grams of element in zone
	23-32	E10.3	PWT	Weight fraction of element in zone

Note: Enter only one of these for each element

Note: Repeat card 7 for each element of that material as specified on card 6. The sequence of card 6 and cards 7 will be repeated for each material to be calculated.

Place a blank card at the end of the deck.

CODE OUTPUT DESCRIPTION FOR ACTIVE

The first portion of the output describes the flux information for the problem. The number of moles is listed, followed by the flux in 50 energy groups for each zone. The density, atom density, volume, and compression are also listed for each zone.

The activation products are next listed. These are computed element by element. The element, the amount in each zone, the reaction, the product, the number of atoms of the product, and half-life are all provided. The next edit provides the initial decay information. It lists the atoms remaining as a function of time in the order of production. Following this edit, the total number of radioactive atoms is provided, as well as the total decay MeV and total gamma MeV, integrated to 50 years and per hour as a function of time.

The last two edits provide the total activation for all zones in atoms as a

function of time and the total activity for all zones in curies as a function of time.

OPERATION OF THE ACTIVE CODE

To operate the code, one must have access to the controllee ACTIVE. This file is stored in ELEPHANT library. It must be placed on disc by means of the ELF routine, since it is not part of the public library.

To operate ACTIVE from the Teletype, type:

1. ELF RDS .526900 : ACTIVE / TV
2. ACTIVE DATA1 / TV

The ACTIVE code will now be running, reading the input data file named DATA1.
SYSTEM RESPONSE: ALL DONE.

The problem is now completed. Subsequent problems can be run without again reading the files ACTIVE onto disc.

Acknowledgment

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