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Application of the Computer Program GENMOD for Modeling the
Behaviour of Radionuclides in the Human Body and for
Performing Calculations of Internal Dose

By

William Kassing, Roy Eckart, and Henry Spitz

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Introduction to GENMOD

GENMOD is a computer program for modeling the behavior of radionuclides in the human body, and for performing various internal dosimetry calculations using the results obtained from the modeling. The program employs seven different mathematical models in describing the behavior of a wide variety of radionuclides in the body. These models are the following:

General Model	-	for radionuclides not listed below.
Alkaline Earth Model	-	for barium, calcium, radium, strontium.
Iodine Model	-	for iodine.
Tellurium-Iodine
Decay Model	-	for the case of tellurium parent and
iodine daughter.
HTO Model	-	for tritiated water.
HT Model	-	for tritium gas.
MIRD-Iron Model	-	for iron.

Exposure to a radionuclide in these models can be by inhalation, ingestion, or injection, and can be an acute one time exposure or a chronic exposure occurring over a period of time.

The mathematical models are systems of first order differential equations that describe the time rate of change of the activity of a radionuclide in the organs of the body. If the activity in the organs is known at any particular instant of time, then the equations can be solved to give the activity at any other time. These necessary initial conditions are given by the activity deposited in the body at the time of exposure. For inhalation exposure this is activity deposited in the lung. for ingestion

exposure this is activity deposited in the stomach, and for injection exposure this is activity deposited directly into the blood and body fluids (i.e., into the transfer compartment). The fundamental information that the mathematical models provide is that which the solution of the differential equations gives, which is the instantaneous activity (also called instantaneous retention) of the radionuclide at any instant of time in the various organs of the body. From this information one other piece of information can be obtained. By integrating the instantaneous activity in a given organ over any period of time, the integrated activity in this organ (also called integrated retention or cumulated activity) is obtained over this period of time. These two pieces of information (instantaneous activity and integrated activity) are then used in dosimetry calculations.

In order to perform the dosimetry calculations, GENMOD contains large data files of dose conversion factors for converting activity into dose. S_{ij} factors convert instantaneous activity in source organs into dose equivalent rate in target organs (and also integrated activity in source organs into dose equivalent in target organs). S' factors convert instantaneous activity in source organs into effective dose equivalent rate in the whole body (and also integrated activity in source organs into effective dose equivalent in the whole body).

The essence of the GENMOD program follows from these concepts. The solution of the differential equations that make up a particular mathematical model provides, following an exposure to a radionuclide, the instantaneous activity and the integrated activity in the various organs of the body. The dose conversion factors are then used to convert these activities into dose rates at particular times and into dose over a period of time, in the organs of the body and in the body as a whole. This information is used in a variety of ways to form the output of the program.

The information generated by GENMOD is placed in seven different output files. These output files are summarized here and examined

in more detail later in this report.

ANDOSETABS File (Annual Dose Tables)

This file gives the dose equivalent incurred between the time periods in the user's time array. If the time array is in consecutive years, then this file gives the annual doses. The doses given are those to the organs and to the whole body.

DINVLTABS File (Derived Investigational Levels Tables)

This file gives the annual limit on intake and the investigational levels on intake; it also gives derived investigational levels in urine, feces, lung, and total body at various times (depending on the user's time array).

DOSERTS File (Dose Rates)

This file gives the dose equivalent rates and the dose equivalent to the organs and to the whole body, at the times in the user's time array. It also gives the effective committed dose equivalent, the committed dose equivalent to the critical organ, and it indicates whether the stochastic or the non-stochastic effect is limiting.

ICRP30_DFS File (ICRP 30 Dose Factors)

This file gives the dose equivalent to the organs per unit radionuclide intake at the times in the user's time array.

INGRETTABS File (Integrated Retention Tables)

This file gives the integrated retentions in the organs at the times in the user's time array. As options, the user can have the dose conversion factor table (Sij factors) printed in this file, and can have a dose summary table printed in this file.

RETEXCRRTS File (Retention and Excretion Rates)

This file gives the instantaneous retention in lung and total body at the times in the user's time array; it also gives urinary and fecal excretion rates at these times.

RETTABS File (Retention Tables)

This file gives the instantaneous retention in the various organs at the times in the user's time array; it also gives urinary and fecal excretion rates at these times.

To run the GENMOD program, the user must first supply some necessary information to the program (radionuclide involved, half-life of the radionuclide, etc.). An interactive front end program called GMIAF assists the user in this regard. GMIAF prompts the user for all the necessary information that GENMOD requires, and it also allows the user the opportunity to make changes to the way in which the program runs. Through GMIAF the user can specify the type of exposure involved, can make modifications to any of the model parameters, can specify which of the output files will be generated, and can specify the time array of the output files (i.e., the times at which output information is generated). The ease with which the user can interact with and make modifications to the GENMOD program makes it a very valuable educational and investigational tool.

The General Model

The general model used in the GENMOD program combines, with slight modifications, the respiratory and gastrointestinal models of ICRP 30 and a compartmental organ model. The schematic diagram of the general model is shown on page 9.

The best way to get a thorough understanding of the general model is to study the differential equations that define it. These equations are displayed on pages 10 through 22. Although the system of equations is large, each individual equation is conceptually very simple and thus the system as a whole is easy to understand. It is assumed that the reader is familiar with first order differential equations and can understand the physical meaning of each individual equation. Therefore, only some general comments will be made concerning the model.

Each compartment of the model has three equations associated with it. One equation is for the parent radionuclide, one is for its daughter, and one is for its granddaughter. If the daughter and/or granddaughter radionuclides are not significant to the case being investigated, the user can choose not to include these in the model.

The model can accommodate either an acute or a chronic exposure. For acute exposure, the activity deposited in the body defines the initial conditions of the system at time zero. This initial activity is assigned to the appropriate $Y(i,1)$ variables, depending on the type of exposure (inhalation, ingestion, or injection). The variables $Y(i,1)$ represent the activity of the parent radionuclide in the various compartments of the model ($i = 1$ through 33). For inhalation exposure the initial activity will be distributed in compartments 1 through 9, for ingestion exposure the initial activity will be in compartment 13, and for injection exposure the initial activity will be in compartment 17. The variables $DEPOSIT(i)$, which are used in the chronic exposure case,

are all set equal to zero in the acute exposure case.

For chronic exposure, the variables $Y(i,1)$ are all set equal to zero at time zero (i.e., the initial conditions are all zero), and the variables $DEPOSIT(i)$ are now set equal to some constant, depending on the type of exposure. This defines the constant intake into the system. Here again, for inhalation exposure compartments 1 through 9 are involved, and for ingestion exposure compartment 13 is involved. The model does not accommodate the chronic injection case.

The individual components making up the general model are now discussed.

Respiratory System Model (Lung Model)

Compartments 1 and 2 represent the nasopharyngeal region. Radionuclide in compartment 1 is absorbed into the transfer compartment. Radionuclide in compartment 2 is transported to the stomach (by ciliary movement to the oropharyngeal region and then by swallowing).

Compartments 3, 4, and 12 represent the tracheobronchial region. Radionuclide in compartment 3 is absorbed into the transfer compartment. Radionuclide in compartment 4 is transported to the stomach. Compartment 12 represents the path through which radionuclide is transported from the pulmonary region to the stomach (again by ciliary movement and then swallowing). This compartment is considered part of the tracheobronchial region and is separated from the other tracheobronchial compartments so that a unique rate constant can be assigned to it, and also because no initial activity is deposited here.

Compartments 5 through 9 represent the pulmonary region. Radionuclide in compartment 5 is absorbed into the transfer compartment. Radionuclide in compartments 6 and 7 is transported

through compartment 12 into the stomach. Radionuclide in compartment 8 is transported to compartment 10 of the pulmonary lymph nodes and then from this compartment is absorbed into the transfer compartment. Radionuclide in compartment 9 is transported to compartment 11 of the pulmonary lymph nodes where it remains.

Gastrointestinal Model

Compartment 13 represents the stomach. Radionuclide is transported out of the stomach either to the small intestine or to the transfer compartment, depending on the value of F1. If F1 is equal to one, then the radionuclide is directly absorbed from the stomach into the transfer compartment and bypasses the intestines completely. If F1 is not equal to one, then the radionuclide is transported into the small intestine (compartment 14). From the small intestine a portion of the radionuclide is absorbed into the transfer compartment and the remainder is transported through the rest of gastrointestinal system and excreted in feces. RT(11) is defined in terms of RT(14) and F1 as follows: $RT(11) = RT(14) * (F1 / (1 - F1))$.

Transfer Compartment

The transfer compartment (compartment 17) represents the blood and body fluids and is the central compartment through which radionuclides from the respiratory and gastrointestinal models are transported to the organs. Once in the transfer compartment, the radionuclide is transferred out at a constant rate. This rate constant is represented as RT(17) in the model and is also known as TCOU by the program. The radionuclide leaves the transfer compartment by various paths represented by the TCOMP paths to the organs and by TCEX for direct excretion in urine and feces. The TCOMP and TCEX variables are fractions that sum to unity (i.e., the sum of the 16 TCOMP variables plus TCEX is unity). The rate constants along these paths are given by the product of RT(17) and

the respective fractions (e.g., the rate constant for the path from the transfer compartment to compartment 18 is $RT(17)$ times $TCOMP(1)$). The variables UEX (urinary excretion) and FEX (fecal excretion) are also fractions and they also sum to unity.

Organ Model

The general model accommodates four additional organs (other than those of the respiratory and gastrointestinal systems). These organs are those that are significant for the radionuclide involved and the program automatically selects the correct organs to use from the radionuclide that is involved. All four organs are not used in every case. Each organ is made up of four compartments. These compartments account for the fact that because of anatomical, physiological, or biochemical reasons the radionuclide may be transported into and out of an organ at varying rates, and therefore the compartments making up an organ can have different rate constants associated with them. All four compartments are not used in every case. When transported out of the organ, the radionuclide is excreted in urine and feces. ORGUEx is the fraction from a compartment that is excreted in urine, and ORGFEX is the fraction from a compartment that is excreted in feces. ORGUEx and ORGFEX sum to unity for each compartment.

Integrated Activities

Included in the differential equations are those equations necessary for calculating integrated activities in the various organs.

Excretion Equations

Included in the differential equations are those equations necessary for calculating urine and fecal excretion rates.

GENERAL MODEL

The Differential Equations of the General Model

The differential equations of the general model are shown on the following pages. The equations are shown as they appear in the program (in Fortran format). The major variables of the system are described below; other variables are described on the following pages with reference to the equations they pertain to.

$Y(i,j)$ = the instantaneous activity (Bq) of a radionuclide in a particular compartment, where:

i = the compartment number

$j = 1$ for parent radionuclide

2 for daughter radionuclide

3 for granddaughter radionuclide

Note: the variable $Y(i,j)$ has a different meaning for
 $i > 33$ (see the integrated retention equations).

$RT(i)$ = the biological rate constant (d^{-1}) for compartment i .

$RR(j)$ = the physical decay constant (d^{-1}) for radionuclide j ,
where j is 1,2, or 3 as explained above for $Y(i,j)$.

$DEPOSIT(i)$ = in the chronic case this represents the rate of intake (Bq/day) of the parent radionuclide into compartment i . For the acute case, $DEPOSIT(i) = 0$ for all i .

----- RESPIRATORY SYSTEM MODEL (LUNG MODEL) -----

Compartments 1 through 12

$$\begin{aligned}\frac{d}{dt}Y(1,1) &= \text{DEPOSIT}(1) - [RT(1) + RR(1)] * Y(1,1) \\ \frac{d}{dt}Y(1,2) &= - [RT(1) + RR(2)] * Y(1,2) + RR(1) * Y(1,1) \\ \frac{d}{dt}Y(1,3) &= - [RT(1) + RR(3)] * Y(1,3) + RR(2) * Y(1,2)\end{aligned}$$

$$\begin{aligned}\frac{d}{dt}Y(2,1) &= \text{DEPOSIT}(2) - [RT(2) + RR(1)] * Y(2,1) \\ \frac{d}{dt}Y(2,2) &= - [RT(2) + RR(2)] * Y(2,2) + RR(1) * Y(2,1) \\ \frac{d}{dt}Y(2,3) &= - [RT(2) + RR(3)] * Y(2,3) + RR(2) * Y(2,2)\end{aligned}$$

$$\begin{aligned}\frac{d}{dt}Y(3,1) &= \text{DEPOSIT}(3) - [RT(3) + RR(1)] * Y(3,1) \\ \frac{d}{dt}Y(3,2) &= - [RT(3) + RR(2)] * Y(3,2) + RR(1) * Y(3,1) \\ \frac{d}{dt}Y(3,3) &= - [RT(3) + RR(3)] * Y(3,3) + RR(2) * Y(3,2)\end{aligned}$$

$$\begin{aligned}\frac{d}{dt}Y(4,1) &= \text{DEPOSIT}(4) - [RT(4) + RR(1)] * Y(4,1) \\ \frac{d}{dt}Y(4,2) &= - [RT(4) + RR(2)] * Y(4,2) + RR(1) * Y(4,1) \\ \frac{d}{dt}Y(4,3) &= - [RT(4) + RR(3)] * Y(4,3) + RR(2) * Y(4,2)\end{aligned}$$

$$\begin{aligned}\frac{d}{dt}Y(5,1) &= \text{DEPOSIT}(5) - [RT(5) + RR(1)] * Y(5,1) \\ \frac{d}{dt}Y(5,2) &= - [RT(5) + RR(2)] * Y(5,2) + RR(1) * Y(5,1) \\ \frac{d}{dt}Y(5,3) &= - [RT(5) + RR(3)] * Y(5,3) + RR(2) * Y(5,2)\end{aligned}$$

$$\begin{aligned}\frac{d}{dt}Y(6,1) &= \text{DEPOSIT}(6) - [RT(6) + RR(1)] * Y(6,1) \\ \frac{d}{dt}Y(6,2) &= - [RT(6) + RR(2)] * Y(6,2) + RR(1) * Y(6,1) \\ \frac{d}{dt}Y(6,3) &= - [RT(6) + RR(3)] * Y(6,3) + RR(2) * Y(6,2)\end{aligned}$$

$$\frac{d}{dt}Y(7,1) = \text{DEPOSIT}(7) - [RT(7) + RR(1)] * Y(7,1)$$

$$\frac{d}{dt}Y(7,2) = -[RT(7) + RR(2)] * Y(7,2) + RR(1) * Y(7,1)$$

$$\frac{d}{dt}Y(7,3) = -[RT(7) + RR(3)] * Y(7,3) + RR(2) * Y(7,2)$$

$$\frac{d}{dt}Y(8,1) = \text{DEPOSIT}(8) - [RT(8) + RR(1)] * Y(8,1)$$

$$\frac{d}{dt}Y(8,2) = -[RT(8) + RR(2)] * Y(8,2) + RR(1) * Y(8,1)$$

$$\frac{d}{dt}Y(8,3) = -[RT(8) + RR(3)] * Y(8,3) + RR(2) * Y(8,2)$$

$$\frac{d}{dt}Y(9,1) = \text{DEPOSIT}(9) - [RT(9) + RR(1)] * Y(9,1)$$

$$\frac{d}{dt}Y(9,2) = -[RT(9) + RR(2)] * Y(9,2) + RR(1) * Y(9,1)$$

$$\frac{d}{dt}Y(9,3) = -[RT(9) + RR(3)] * Y(9,3) + RR(2) * Y(9,2)$$

$$\frac{d}{dt}Y(10,1) = RT(8) * Y(8,1) - [RT(10) + RR(1)] * Y(10,1)$$

$$\frac{d}{dt}Y(10,2) = RT(8) * Y(8,2) - [RT(10) + RR(2)] * Y(10,2) + RR(1) * Y(10,1)$$

$$\frac{d}{dt}Y(10,3) = RT(8) * Y(8,3) - [RT(10) + RR(3)] * Y(10,3) + RR(2) * Y(10,2)$$

$$\frac{d}{dt}Y(11,1) = RT(9) * Y(9,1) - RR(1) * Y(11,1)$$

$$\frac{d}{dt}Y(11,2) = RT(9) * Y(9,2) - RR(2) * Y(11,2) + RR(1) * Y(11,1)$$

$$\frac{d}{dt}Y(11,3) = RT(9) * Y(9,3) - RR(3) * Y(11,3) + RR(2) * Y(11,2)$$

$$\frac{d}{dt}Y(12,1) = RT(6) * Y(6,1) + RT(7) * Y(7,1) - [RT(12) + RR(1)] * Y(12,1)$$

$$\begin{aligned} \frac{d}{dt}Y(12,2) = & RT(6) * Y(6,2) + RT(7) * Y(7,2) - [RT(12) + RR(2)] * Y(12,2) \\ & + RR(1) * Y(12,1) \end{aligned}$$

$$\begin{aligned} \frac{d}{dt}Y(12,3) = & RT(6) * Y(6,3) + RT(7) * Y(7,3) - [RT(12) + RR(3)] * Y(12,3) \\ & + RR(2) * Y(12,2) \end{aligned}$$

----- GASTROINTESTINAL MODEL (GUT MODEL) -----

Compartments 13 through 16

The variable FGUT2SI is set to either 0 or 1 depending on the value of F1. If F1 = 1, then FGUT2SI = 0; if F1 ≠ 1, then FGUT2SI = 1. This is because if F1 = 1, the radionuclide is absorbed from the gastrointestinal tract so rapidly that it is assumed to be completely absorbed from the stomach, and therefore bypasses the remainder of the gastrointestinal tract completely.

$$\frac{d}{dt}Y(13,1) = \text{DEPOSIT}(13) + \text{RT}(2) * Y(2,1) + \text{RT}(4) * Y(4,1) + \text{RT}(12) * Y(12,1) \\ - [\text{RT}(13) + \text{RR}(1)] * Y(13,1)$$

$$\frac{d}{dt}Y(13,2) = \text{RT}(2) * Y(2,2) + \text{RT}(4) * Y(4,2) + \text{RT}(12) * Y(12,2) \\ - [\text{RT}(13) + \text{RR}(2)] * Y(13,2) + \text{RT}(1) * Y(13,1)$$

$$\frac{d}{dt}Y(13,3) = \text{RT}(2) * Y(2,3) + \text{RT}(4) * Y(4,3) + \text{RT}(12) * Y(12,3) \\ - [\text{RT}(13) + \text{RR}(3)] * Y(13,3) + \text{RT}(2) * Y(13,2)$$

$$\frac{d}{dt}Y(14,1) = \text{FGUT2SI} * \text{RT}(13) * Y(13,1) - [\text{RT}(11) + \text{RT}(14) + \text{RR}(1)] * Y(14,1)$$

$$\frac{d}{dt}Y(14,2) = \text{FGUT2SI} * \text{RT}(13) * Y(13,2) - [\text{RT}(11) + \text{RT}(14) + \text{RR}(2)] * Y(14,2) \\ + \text{RR}(1) * Y(14,1)$$

$$\frac{d}{dt}Y(14,3) = \text{FGUT2SI} * \text{RT}(13) * Y(13,3) - [\text{RT}(11) + \text{RT}(14) + \text{RR}(3)] * Y(14,3) \\ + \text{RR}(2) * Y(14,2)$$

$$\frac{d}{dt}Y(15,1) = \text{RT}(14) * Y(14,1) - [\text{RT}(15) + \text{RR}(1)] * Y(15,1)$$

$$\frac{d}{dt}Y(15,2) = \text{RT}(14) * Y(14,2) - [\text{RT}(15) + \text{RR}(2)] * Y(15,2) + \text{RR}(1) * Y(15,1)$$

$$\frac{d}{dt}Y(15,3) = \text{RT}(14) * Y(14,3) - [\text{RT}(15) + \text{RR}(3)] * Y(15,3) + \text{RR}(2) * Y(15,2)$$

$$\frac{d}{dt}Y(16,1) = \text{RT}(15) * Y(15,1) - [\text{RT}(16) + \text{RR}(1)] * Y(16,1)$$

$$\frac{d}{dt}Y(16,2) = \text{RT}(15) * Y(15,2) - [\text{RT}(16) + \text{RR}(2)] * Y(16,2) + \text{RR}(1) * Y(16,1)$$

$$\frac{d}{dt}Y(16,3) = \text{RT}(15) * Y(15,3) - [\text{RT}(16) + \text{RR}(3)] * Y(16,3) + \text{RR}(2) * Y(16,2)$$

-----TRANSFER COMPARTMENT (BLOOD AND BODY FLUIDS) -----

Compartment 17

The variable FGUT2TC is set to either 0 or 1 depending on the value of F1. If F1 = 1, then FGUT2TC = 1; if F1 ≠ 1, then FGUT2TC = 0. If F1 ≠ 1, then absorption from the gastrointestinal tract into the transfer compartment is assumed to occur only in the small intestine (cf., FGUT2SI of the gastrointestinal model).

RT(17) is also known as TCOU and represents the total biological rate constant for removal of the radionuclide from the transfer compartment. The radionuclide leaves the transfer compartment in various directions at various fractions of this rate constant.

$$\begin{aligned} \frac{d}{dt}Y(17,1) = & RT(1) * Y(1,1) + RT(3) * Y(3,1) + RT(5) * Y(5,1) + RT(10) * Y(10,1) \\ & + RT(11) * Y(14,1) + FGUT2TC * RT(13) * Y(13,1) \\ & - [RT(17) + RR(1)] * Y(17,1) \end{aligned}$$

$$\begin{aligned} \frac{d}{dt}Y(17,2) = & RT(1) * Y(1,2) + RT(3) * Y(3,2) + RT(5) * Y(5,2) + RT(10) * Y(10,2) \\ & + RT(11) * Y(14,2) + FGUT2TC * RT(13) * Y(13,2) \\ & - [RT(17) + RR(2)] * Y(17,2) + RR(1) * Y(17,1) \end{aligned}$$

$$\begin{aligned} \frac{d}{dt}Y(17,3) = & RT(1) * Y(1,3) + RT(3) * Y(3,3) + RT(5) * Y(5,3) + RT(10) * Y(10,3) \\ & + RT(11) * Y(14,3) + FGUT2TC * RT(13) * Y(13,3) \\ & - [RT(17) + RR(3)] * Y(17,3) + RR(2) * Y(17,2) \end{aligned}$$

----- ORGAN MODEL -----

Compartments 18 through 33

The variable TCOMP is the fraction of the radionuclide that is transferred out of the transfer compartment along a particular path to the organs.

$$\frac{d}{dt}Y(18,1) = RT(17) * TCOMP(1) * Y(17,1) - [RT(18) + RR(1)] * Y(18,1)$$

$$\begin{aligned} \frac{d}{dt}Y(18,2) &= RT(17) * TCOMP(1) * Y(17,2) - [RT(18) + RR(2)] * Y(18,2) \\ &\quad + RR(1) * Y(18,1) \end{aligned}$$

$$\begin{aligned} \frac{d}{dt}Y(18,3) &= RT(17) * TCOMP(1) * Y(17,3) - [RT(18) + RR(3)] * Y(18,3) \\ &\quad + RR(2) * Y(18,2) \end{aligned}$$

$$\frac{d}{dt}Y(19,1) = RT(17) * TCOMP(2) * Y(17,1) - [RT(19) + RR(1)] * Y(19,1)$$

$$\begin{aligned} \frac{d}{dt}Y(19,2) &= RT(17) * TCOMP(2) * Y(17,2) - [RT(19) + RR(2)] * Y(19,2) \\ &\quad + RR(1) * Y(19,1) \end{aligned}$$

$$\begin{aligned} \frac{d}{dt}Y(19,3) &= RT(17) * TCOMP(2) * Y(17,3) - [RT(19) + RR(3)] * Y(19,3) \\ &\quad + RR(2) * Y(19,2) \end{aligned}$$

$$\frac{d}{dt}Y(20,1) = RT(17) * TCOMP(3) * Y(17,1) - [RT(20) + RR(1)] * Y(20,1)$$

$$\begin{aligned} \frac{d}{dt}Y(20,2) &= RT(17) * TCOMP(3) * Y(17,2) - [RT(20) + RR(2)] * Y(20,2) \\ &\quad + RR(1) * Y(20,1) \end{aligned}$$

$$\begin{aligned} \frac{d}{dt}Y(20,3) &= RT(17) * TCOMP(3) * Y(17,3) - [RT(20) + RR(3)] * Y(20,3) \\ &\quad + RR(2) * Y(20,2) \end{aligned}$$

$$\frac{d}{dt}Y(21,1) = RT(17) * TCOMP(4) * Y(17,1) - [RT(21) + RR(1)] * Y(21,1)$$

$$\begin{aligned} \frac{d}{dt}Y(21,2) &= RT(17) * TCOMP(4) * Y(17,2) - [RT(21) + RR(2)] * Y(21,2) \\ &\quad + RR(1) * Y(21,1) \end{aligned}$$

$$\begin{aligned} \frac{d}{dt}Y(21,3) &= RT(17) * TCOMP(4) * Y(17,3) - [RT(21) + RR(3)] * Y(21,3) \\ &\quad + RR(2) * Y(21,2) \end{aligned}$$

$$\begin{aligned}
\frac{d}{dt}Y(22,1) &= RT(17) * TCOMP(5) * Y(17,1) - [RT(22) + RR(1)] * Y(22,1) \\
\frac{d}{dt}Y(22,2) &= RT(17) * TCOMP(5) * Y(17,2) - [RT(22) + RR(2)] * Y(22,2) \\
&\quad + RR(1) * Y(22,1) \\
\frac{d}{dt}Y(22,3) &= RT(17) * TCOMP(5) * Y(17,3) - [RT(22) + RR(3)] * Y(22,3) \\
&\quad + RR(2) * Y(22,2) \\
\\
\frac{d}{dt}Y(23,1) &= RT(17) * TCOMP(6) * Y(17,1) - [RT(23) + RR(1)] * Y(23,1) \\
\frac{d}{dt}Y(23,2) &= RT(17) * TCOMP(6) * Y(17,2) - [RT(23) + RR(2)] * Y(23,2) \\
&\quad + RR(1) * Y(23,1) \\
\frac{d}{dt}Y(23,3) &= RT(17) * TCOMP(6) * Y(17,3) - [RT(23) + RR(3)] * Y(23,3) \\
&\quad + RR(2) * Y(23,2) \\
\\
\frac{d}{dt}Y(24,1) &= RT(17) * TCOMP(7) * Y(17,1) - [RT(24) + RR(1)] * Y(24,1) \\
\frac{d}{dt}Y(24,2) &= RT(17) * TCOMP(7) * Y(17,2) - [RT(24) + RR(2)] * Y(24,2) \\
&\quad + RR(1) * Y(24,1) \\
\frac{d}{dt}Y(24,3) &= RT(17) * TCOMP(7) * Y(17,3) - [RT(24) + RR(3)] * Y(24,3) \\
&\quad + RR(2) * Y(24,2) \\
\\
\frac{d}{dt}Y(25,1) &= RT(17) * TCOMP(8) * Y(17,1) - [RT(25) + RR(1)] * Y(25,1) \\
\frac{d}{dt}Y(25,2) &= RT(17) * TCOMP(8) * Y(17,2) - [RT(25) + RR(2)] * Y(25,2) \\
&\quad + RR(1) * Y(25,1) \\
\frac{d}{dt}Y(25,3) &= RT(17) * TCOMP(8) * Y(17,3) - [RT(25) + RR(3)] * Y(25,3) \\
&\quad + RR(2) * Y(25,2) \\
\\
\frac{d}{dt}Y(26,1) &= RT(17) * TCOMP(9) * Y(17,1) - [RT(26) + RR(1)] * Y(26,1) \\
\frac{d}{dt}Y(26,2) &= RT(17) * TCOMP(9) * Y(17,2) - [RT(26) + RR(2)] * Y(26,2) \\
&\quad + RR(1) * Y(26,1) \\
\frac{d}{dt}Y(26,3) &= RT(17) * TCOMP(9) * Y(17,3) - [RT(26) + RR(3)] * Y(26,3) \\
&\quad + RR(2) * Y(26,2)
\end{aligned}$$

$$\begin{aligned}
\frac{d}{dt}Y(27,1) &= RT(17) * TCOMP(10) * Y(17,1) - [RT(27) + RR(1)] * Y(27,1) \\
\frac{d}{dt}Y(27,2) &= RT(17) * TCOMP(10) * Y(17,2) - [RT(27) + RR(2)] * Y(27,2) \\
&\quad + RR(1) * Y(27,1) \\
\frac{d}{dt}Y(27,3) &= RT(17) * TCOMP(10) * Y(17,3) - [RT(27) + RR(3)] * Y(27,3) \\
&\quad + RR(2) * Y(27,2) \\
\\
\frac{d}{dt}Y(28,1) &= RT(17) * TCOMP(11) * Y(17,1) - [RT(28) + RR(1)] * Y(28,1) \\
\frac{d}{dt}Y(28,2) &= RT(17) * TCOMP(11) * Y(17,2) - [RT(28) + RR(2)] * Y(28,2) \\
&\quad + RR(1) * Y(28,1) \\
\frac{d}{dt}Y(28,3) &= RT(17) * TCOMP(11) * Y(17,3) - [RT(28) + RR(3)] * Y(28,3) \\
&\quad + RR(2) * Y(28,2) \\
\\
\frac{d}{dt}Y(29,1) &= RT(17) * TCOMP(12) * Y(17,1) - [RT(29) + RR(1)] * Y(29,1) \\
\frac{d}{dt}Y(29,2) &= RT(17) * TCOMP(12) * Y(17,2) - [RT(29) + RR(2)] * Y(29,2) \\
&\quad + RR(1) * Y(29,1) \\
\frac{d}{dt}Y(29,3) &= RT(17) * TCOMP(12) * Y(17,3) - [RT(29) + RR(3)] * Y(29,3) \\
&\quad + RR(2) * Y(29,2) \\
\\
\frac{d}{dt}Y(30,1) &= RT(17) * TCOMP(13) * Y(17,1) - [RT(30) + RR(1)] * Y(30,1) \\
\frac{d}{dt}Y(30,2) &= RT(17) * TCOMP(13) * Y(17,2) - [RT(30) + RR(2)] * Y(30,2) \\
&\quad + RR(1) * Y(30,1) \\
\frac{d}{dt}Y(30,3) &= RT(17) * TCOMP(13) * Y(17,3) - [RT(30) + RR(3)] * Y(30,3) \\
&\quad + RR(2) * Y(30,2) \\
\\
\frac{d}{dt}Y(31,1) &= RT(17) * TCOMP(14) * Y(17,1) - [RT(31) + RR(1)] * Y(31,1) \\
\frac{d}{dt}Y(31,2) &= RT(17) * TCOMP(14) * Y(17,2) - [RT(31) + RR(2)] * Y(31,2) \\
&\quad + RR(1) * Y(31,1) \\
\frac{d}{dt}Y(31,3) &= RT(17) * TCOMP(14) * Y(17,3) - [RT(31) + RR(3)] * Y(31,3) \\
&\quad + RR(2) * Y(31,2)
\end{aligned}$$

$$\frac{d}{dt}Y(32,1) = RT(17) * TCOMP(15) * Y(17,1) - [RT(32) + RR(1)] * Y(32,1)$$

$$\begin{aligned} \frac{d}{dt}Y(32,2) = & RT(17) * TCOMP(15) * Y(17,2) - [RT(32) + RR(2)] * Y(32,2) \\ & + RR(1) * Y(32,1) \end{aligned}$$

$$\begin{aligned} \frac{d}{dt}Y(32,3) = & RT(17) * TCOMP(15) * Y(17,3) - [RT(32) + RR(3)] * Y(32,3) \\ & + RR(2) * Y(32,2) \end{aligned}$$

$$\frac{d}{dt}Y(33,1) = RT(17) * TCOMP(16) * Y(17,1) - [RT(33) + RR(1)] * Y(33,1)$$

$$\begin{aligned} \frac{d}{dt}Y(33,2) = & RT(17) * TCOMP(16) * Y(17,2) - [RT(33) + RR(2)] * Y(33,2) \\ & + RR(2) * Y(33,2) \end{aligned}$$

$$\begin{aligned} \frac{d}{dt}Y(33,3) = & RT(17) * TCOMP(16) * Y(17,3) - [RT(33) + RR(3)] * Y(33,3) \\ & + RR(1) * Y(33,1) \end{aligned}$$

----- INTEGRATED RETENTIONS -----

The variable $Y(i,j)$ no longer represents the activity of the radionuclide in compartment i ; for $i > 33$, it represents integrated activity and has units of Bq-days.

$i = 34$	Integrated activity in Lung
35	Integrated activity in Pulmonary Lymph Nodes
36	Integrated activity in Stomach
37	Integrated activity in Small Intestine
38	Integrated activity in Upper Large Intestine
39	Integrated activity in Lower Large Intestine
40	Integrated activity in Organ #1
41	Integrated activity in Organ #2
42	Integrated activity in Organ #3
43	Integrated activity in Organ #4

$$\frac{d}{dt}Y(34,1) = Y(3,1) + Y(4,1) + Y(5,1) + Y(6,1) + Y(7,1) + Y(8,1) + Y(9,1) + Y(12,1)$$

$$\frac{d}{dt}Y(34,2) = Y(3,2) + Y(4,2) + Y(5,2) + Y(6,2) + Y(7,2) + Y(8,2) + Y(9,2) + Y(12,2)$$

$$\frac{d}{dt}Y(34,3) = Y(3,3) + Y(4,3) + Y(5,3) + Y(6,3) + Y(7,3) + Y(8,3) + Y(9,3) + Y(12,3)$$

$$\frac{d}{dt}Y(35,1) = Y(10,1) + Y(11,1)$$

$$\frac{d}{dt}Y(35,2) = Y(10,2) + Y(11,2)$$

$$\frac{d}{dt}Y(35,3) = Y(10,3) + Y(11,3)$$

$$\frac{d}{dt}Y(36,1) = Y(13,1)$$

$$\frac{d}{dt}Y(36,2) = Y(13,2)$$

$$\frac{d}{dt}Y(36,3) = Y(13,3)$$

$$\frac{d}{dt}Y(37,1) = Y(14,1)$$

$$\frac{d}{dt}Y(37,2) = Y(14,2)$$

$$\frac{d}{dt}Y(37,3) = Y(14,3)$$

$$\begin{aligned}\frac{d}{dt}Y(38,1) &= Y(15,1) \\ \frac{d}{dt}Y(38,2) &= Y(15,2) \\ \frac{d}{dt}Y(38,3) &= Y(15,3)\end{aligned}$$

$$\begin{aligned}\frac{d}{dt}Y(39,1) &= Y(16,1) \\ \frac{d}{dt}Y(39,2) &= Y(16,2) \\ \frac{d}{dt}Y(39,3) &= Y(16,3)\end{aligned}$$

$$\begin{aligned}\frac{d}{dt}Y(40,1) &= Y(18,1) + Y(19,1) + Y(20,1) + Y(21,1) \\ \frac{d}{dt}Y(40,2) &= Y(18,2) + Y(19,2) + Y(20,2) + Y(21,2) \\ \frac{d}{dt}Y(40,3) &= Y(18,3) + Y(19,3) + Y(20,3) + Y(21,3)\end{aligned}$$

$$\begin{aligned}\frac{d}{dt}Y(41,1) &= Y(22,1) + Y(23,1) + Y(24,1) + Y(25,1) \\ \frac{d}{dt}Y(41,2) &= Y(22,2) + Y(23,2) + Y(24,2) + Y(25,2) \\ \frac{d}{dt}Y(41,3) &= Y(22,3) + Y(23,3) + Y(24,3) + Y(25,3)\end{aligned}$$

$$\begin{aligned}\frac{d}{dt}Y(42,1) &= Y(26,1) + Y(27,1) + Y(28,1) + Y(29,1) \\ \frac{d}{dt}Y(42,2) &= Y(26,2) + Y(27,2) + Y(28,2) + Y(29,2) \\ \frac{d}{dt}Y(42,3) &= Y(26,3) + Y(27,3) + Y(28,3) + Y(29,3)\end{aligned}$$

$$\begin{aligned}\frac{d}{dt}Y(43,1) &= Y(30,1) + Y(31,1) + Y(32,1) + Y(33,1) \\ \frac{d}{dt}Y(43,2) &= Y(30,2) + Y(31,2) + Y(32,2) + Y(33,2) \\ \frac{d}{dt}Y(43,3) &= Y(30,3) + Y(31,3) + Y(32,3) + Y(33,3)\end{aligned}$$

----- URINE AND FECAL EXCRETION RATES -----

URINE(j) is the instantaneous urinary excretion rate (Bq/day) of radionuclide j.

FECES(j) is the instantaneous fecal excretion rate (Bq/day) of radionuclide j.

FROMTC is the sum of all the TCOMPs; therefore (1-FROMTC) is the fraction of the radionuclide leaving the transfer compartment directly and not via the organs; it is represented as TCEX in the model schematic.

UEX is the fraction of (1-FROMTC) that is excreted in urine.

FEX is the fraction of (1-FROMTC) that is excreted in feces.

ORGUEX(M) is the fraction of the radionuclide leaving organ compartment M (for M = 18 through 33) via urine excretion.

ORGFEX(M) is the fraction of the radionuclide leaving organ compartment M (for M = 18 through 33) via fecal excretion.

$$\text{URINE}(1) = \text{UEX} * \text{RT}(17) * (1 - \text{FROMTC}) * \text{Y}(17,1) \\ + \sum_{M=18}^{33} \text{ORGUEX}(M) * \text{RT}(M) * \text{Y}(M,1)$$

$$\text{URINE}(2) = \text{UEX} * \text{RT}(17) * (1 - \text{FROMTC}) * \text{Y}(17,2) \\ + \sum_{M=18}^{33} \text{ORGUEX}(M) * \text{RT}(M) * \text{Y}(M,2)$$

$$\text{URINE}(3) = \text{UEX} * \text{RT}(17) * (1 - \text{FROMTC}) * \text{Y}(17,3) \\ + \sum_{M=18}^{33} \text{ORGUEX}(M) * \text{RT}(M) * \text{Y}(M,3)$$

$$\text{FECES}(1) = \text{FEX} * \text{RT}(17) * (1 - \text{FROMTC}) * \text{Y}(17,1) + \text{RT}(16) * \text{Y}(16,1) \\ + \sum_{M=18}^{33} \text{ORGFEX}(M) * \text{RT}(M) * \text{Y}(M,1)$$

$$\text{FECES}(2) = \text{FEX} * \text{RT}(17) * (1 - \text{FROMTC}) * \text{Y}(17,2) + \text{RT}(16) * \text{Y}(16,2) \\ + \sum_{M=18}^{33} \text{ORGFEX}(M) * \text{RT}(M) * \text{Y}(M,2)$$

$$\begin{aligned}
 \text{FECES}(3) = & \text{FEX} * \text{RT}(17) * (1 - \text{FROMTC}) * \text{Y}(17,3) + \text{RT}(16) * \text{Y}(16,3) \\
 & + \sum_{M=18}^{33} \text{ORGFEX}(M) * \text{RT}(M) * \text{Y}(M,3)
 \end{aligned}$$

Running GENMOD

To run the GENMOD program, the user must first set up an input file containing information that is needed by the program. GENMOD then accesses the information in this file as it runs. The interactive program GMIAF sets up this input file for the user; to do so it queries the user for the necessary information needed by GENMOD, and also for any optional changes the user might wish to make to the program.

The simplest case of running GENMOD is that where the user simply specifies the radionuclide involved, its half-life, and whether the exposed individual is an adult or an infant. This is the minimum information the program needs in order to run. GENMOD then selects the correct mathematical model to use (from the radionuclide involved), and supplies all other necessary data from information contained in various files. The program contains data for all necessary model parameters (biological rate constants, excretion fractions, etc.) for the various solubility classes of compounds in which the radionuclide may occur. For every radionuclide that the program accommodates, there is data for: three solubility classes for inhalation exposure (D, W, and Y), two solubility classes for ingestion exposure (less water soluble and more water soluble), and a single class for injection exposure. (This is for the most general case; some radionuclides are not known to exist in compounds for some of the solubility classes, and in these cases the program does not contain any data. For example, plutonium does not occur in a D class compound and thus the program does not contain data for this solubility class).

Once the radionuclide, its half-life, and the age group of the exposed individual is specified, then GENMOD can be run and output generated. The default conditions of the program are set for acute inhalation and acute ingestion exposure. Under these conditions, the output files generated will contain information for the three solubility classes for inhalation exposure, and for the two solubility classes for ingestion exposure. That is, each output

file generated will, in general, contain results for five radionuclide exposure scenarios: D class acute inhalation, W class acute inhalation, Y class acute inhalation, less water soluble material acute ingestion, and more water soluble material acute ingestion. The output files that are generated, under the default conditions, are the INGRETABS file (integrated retention tables), the RETABS file (retention tables), and the RETEXCRTS file (retention and excretion rates). Two other files are also generated, as they are every time GENMOD is run. These are the IN file (the input file created by GMIAF) and the SYSOUT file (the system output file which contains information about the case that has just been run). All of these files will be listed in the user's directory after GENMOD is run; the IN file is also listed in the directory after GMIAF is run.

Beyond this simple case of running GENMOD under default conditions, the real utility of the program is that the user has a great deal of control over all aspects of the program. The user can specify exactly the type of exposure (acute, chronic, inhalation, ingestion, injection, and specific solubility class), can change any of the model parameters, can specify the time array used in the output files, can determine which of the output files are generated, and more. All of this can be done through GMIAF. GMIAF is examined in the next section of this report, and the best way to gain an understanding of all of the control and flexibility that the user has with GENMOD is to study the prompts making up GMIAF, for everything that the user can accomplish with GENMOD can be done through GMIAF.

The information contained in the GENMOD output files is all in terms of a unit exposure (1 Bq) to the radionuclide (e.g., dose per Bq, retention per Bq, excretion per Bq, etc.). To obtain results for exposure to any other amount of the radionuclide, the user need simply multiply the output results by the desired factor (e.g., to obtain the results for a 10 Bq exposure, multiply all of the output information by a factor of 10). This is justified because all of the systems of differential equations used in the program are linear (recall the fundamental definition of a linear

system, $L(cx) = cL(x)$, where L is a linear operator). Note that since the user has much control over the program, he could, for example, place 10 Bq directly into the system as initial conditions for an exposure case, and the computer would generate the correct results for this case. However, this is tedious and nothing is gained, for the results obtained are identical to those for the case of a unit exposure, with all of the output being multiplied by 10.

GMIAF

GMIAF is an interactive program that sets up the input file which is needed to run the GENMOD program. GMIAF was written specifically for the general model, but the user may also use it to set up the input files for the other models, provided that he understands that the variables used in the general model may have different meanings or may not apply in the other models.

If GENMOD is being used for investigational work, where the user makes repeated minor changes to the system, then it is often easiest (and timesaving) to use GMIAF only to set up the initial input file, and thereafter to edit this file manually to make the minor changes required (instead of going through GMIAF each time a minor change is made).

Listed here are all of the prompts which may appear during a session with GMIAF along with some general comments concerning these prompts. The prompts are shown in bold regular sized print, comments appear in smaller italicized print. The actual prompts that appear during a session and the order in which they appear depend on the user's responses during the session.

DO YOU WISH SIJ AND S-PRIME FILES ATTACHED <Y/N>

This prompt is a puzzle that needs further investigation. The input file set up by GMIAF is unaffected by what is entered here, and no change could be observed in any of the output files generated by GENMOD whether a Y or a N is entered. In the GMIAF program the result entered (a Y or N) toggles a logical flag on or off, but this flag doesn't appear to be used anywhere else. It may be that this prompt was necessary for the computer system that GENMOD was originally written for, where it appears that the SIJ and S-Prime files were stored on tape. If you were doing dosimetry calculations where these files were needed (as opposed to retention and excretion calculations), then the

tapes would have to be accessed. Until this prompt is further investigated, typing a Y is the safe response.

ENTER AGE OF SUBJECTS <A=ADULT, I=INFANT>

Type A if an adult is involved; type I if an infant is involved. This information is needed because different data is used for adults and infants in the program.

ENTER THE TITLE OR COMMENT FOR THIS CASE

ENTER <CR> TO END:

This is optional. If desired, a title or comment can appear at the top of the SYSOUT file; it can be up to 80 characters long.

ENTER THE PARENT FOR THIS CASE <Z#/ELEMENT/A#/MS>

The parent radionuclide is specified in the format shown. Examples:

For plutonium-239 : Type 94/PLUTONIUM/239

For technetium-99m : Type 43/TECHNETIUM/99/M

(an M is typed as shown to specify a metastable state)

ENTER THE HALF LIFE (IN DAYS) OF THE PARENT

TYPE 0.0 IF THE PARENT IS IN ERROR

Type the half-life of the parent in days. If a mistake was made in typing the parent radionuclide, typing 0.0 allows you to correct this by bringing up the previous prompt again.

ENTER DAUGHTER 1 FOR THIS CASE

<Z#/ELEMENT/A#/MS> OR <CR> IF NO DAUGHTER

If the daughter radionuclide is also of interest, you can specify it here in the same format as for the parent, otherwise press return and the daughter will be ignored.

ENTER THE HALF LIFE (IN DAYS) OF THE DAUGHTER

TYPE 0.0 IF THE DAUGHTER IS IN ERROR

If a daughter is specified, then its half-life in days must be entered.

ENTER DAUGHTER 2 FOR THIS CASE

<Z#/ELEMENT/A#/MS> OR <CR> IF NO DAUGHTER

A granddaughter can also be included if desired.

ENTER THE HALF LIFE (IN DAYS) OF THE DAUGHTER

TYPE 0.0 IF THE DAUGHTER IS IN ERROR

If a granddaughter is specified, then its half-life in days must be entered.

VOLUME OR SURFACE SEEKER <V,S,<CR>>

For bone seeking radionuclides, enter V if it is a volume seeker, enter S if it is a surface seeker. If this doesn't apply to your case, press return.

Deposition fraction:

for nasal-pharynx region - ZNP
for tracheo-bronchial region - ZTB
for pulmonary region - ZP

ZNP, ZTB, ZP = 0.3000000, 7.9999999E-02, 0.2500000

Do you wish to change these values (Y/N)?

Shown are the default settings for particle size 1 AMAD. If you wish to change these type Y; you will then be prompted for new values which you enter in the order shown, separated by commas. By properly selecting these fractions, you can change to a different AMAD.

----- CASE IDENTIFIER -----

ACUTE CHRONIC INHALATION INGESTION

1 0 1 1

NOTE: USE 0000 FOR INJECTION

CHRONIC MUST BE 1 FOR CHRONIC-ACUTE CASE

Do you wish to change these values (Y/N)?

The default setting is for acute inhalation and acute ingestion; i.e., the program generates tables for both of these cases. If you wish to change to some other case, type Y. You will then be prompted for input; for example, if you want just the acute inhalation case you would type 1010.

0 = STANDARD; 1 = AECL-7919; 2 = IAEA

ENTER FORMAT CODE

This allows you to select the form of the D50 table (a dose summary table) which appears in the INGRETABS file as an option. Type 0 for standard format in the D50 table. type 1 for Atomic Energy of Canada Limited format, or type 2

for International Atomic Energy Association format in the D50 table. This needs some further investigation.

DEFAULT SHOWN IN <>; CURRENT SHOWN IN []

1 T = OVERRIDE METADATA VALUES	<F>	[F]
2 T = CHRONIC-ACUTE CASE	<F>	[F]
3 T = PAS *** MANUAL USE ONLY ***	<F>	[F]
4 T = OVERRIDE RATES AND AMOUNTS	<F>	[F]
5 T = PRINT D50 TABLE	<F>	[F]
6 T = PRINT RETENT. & EXCRET. TABLE	<F>	[F]
7 T = PRINT SIJ TABLE	<F>	[F]
8 T = USE LUNG S-PRIME FACTOR	<F>	[F]
9 T = PRINT DOSE TABLE	<F>	[F]
10 T = USE CONSECUTIVE TIME CASE	<F>	[F]
11 T = MIRD-IRON RATE CONSTANT MODEL	<F>	[F]
12 T = PRINT DIL TABLE	<F>	[F]
13 T = PRINT ANNUAL DOSE TABLE	<F>	[F]

[0=DISPLAY LIST, 98=RESET TO DEFAULT]

ENTER # OF OPTION TO BE TOGGLED OR 99 TO STOP

This is where you select the options you want. To toggle the option, type the number of the option and press return; when you have selected every option you wish to turn on or off type 99 and press return.

Although it does not appear so (this needs to be corrected), options 5, 6, and 7 are set true by default. So selecting these options will turn them off.

There are two additional options not shown:

19 T = DSFCT file is to be output in Ci/yr	<F>	[F]
20 T = DSFCT file is to be generated	<F>	[F]

Some of the options interact. That is in some cases when you select one of

the options it will turn some of the other options on or off. This interaction was not investigated very thoroughly.

The options are now discussed:

OPTION 1 *Override Metadata Values*

Setting this option true allows you to change the values of many of the variables in the METDATA namelist. These variables are the following:

F1
XDIV
RT(18) through RT(33)
TCOUT
UEX
FEX
TCOMP
ORGFEX
ORGUEX

OPTION 2 *Chronic-Acute Case*

If this option is set true, both chronic and acute output will be generated. This needs further investigation.

OPTION 3 *PAS *** Manual Use Only ****

This option is for use with a personal air sampler. This option was not investigated.

OPTION 4 *Override Rates and Amounts*

Setting this option true allows you to change the values of the variables in

the AMOUNT namelist. These variables are YDUM and RTDUM.

OPTION 5 Print D50 Table

If this option is set true, the D50 table (a dose summary table) is included in the INGRETABS file.

OPTION 6 Print Retent. & Excretion Table

If this option is set true, the RETEXCRRTS output file is generated.

OPTION 7 Print Sij Table

If this option is set true, the SIJ table used for the dosimetry calculations is included in the INGRETABS output file.

OPTION 8 Use Lung S-Prime Factor

This option was not investigated very thoroughly. It allows you to vary the lung S-Prime values by a given factor.

OPTION 9 Print Dose Table

If this option is set true, the DOSERTS output file is generated.

OPTION 10 Use Consecutive Time Case

If this option is set true, a unique method for generating the time array is enabled. You will be prompted for an initial time, a final time, and the increment value for the times between these.

OPTION 11 Mird-Iron Rate Constant Model

This option is for the Mird-Iron Model and was not investigated.

OPTION 12 Print DIL Table

If this option is set true, the DINVLVL TABS output file is generated.

OPTION 13 Print Annual Dose Table

If this option is set true, the ANDOSETABS output file is generated.

OPTION 19 DSFCT file is to be output in Ci/yr

If this option is set true, the DSFCT file is generated in Ci/yr. This needs further investigation (it is very questionable).

OPTION 20 DSFCT file is to be generated

If this option is set true, the DSFCT file is generated.

If Option 1 was selected, the following 15 prompts will appear:

ENTER F1 VALUE FOR CLASS D OR (-1 TO SKIP)

If you wish to change the F1 value for the class D inhalation case, specify it here, otherwise type -1 and the default value will be used. Typing a zero will cause this solubility class to be ignored; i.e., if you do not want D class information generated, you can turn it off in this manner.

ENTER F1 VALUE FOR CLASS W OR (-1 TO SKIP)

If you wish to change the F1 value for the class W inhalation case, specify it here, otherwise type -1 and the default value will be used. Typing a zero will cause this solubility class to be ignored.

ENTER F1 VALUE FOR CLASS Y OR (-1 TO SKIP)

If you wish to change the F1 value for the class Y inhalation case, specify it here, otherwise type -1 and the default value will be used. Typing a zero will cause this solubility class to be ignored.

ENTER F1 VALUE FOR INGESTION OR (-1 TO SKIP)

If you wish to change the F1 value for the more water soluble material ingestion case, specify it here, otherwise type -1 and the default value will be used. Typing a zero will cause this solubility class to be ignored.

ENTER F1 VALUE FOR INGESTION OR (-1 TO SKIP)

If you wish to change the F1 value for the less water soluble material ingestion case, specify it here, otherwise type -1 and the default value will be used. Typing in a zero here will cause this solubility class to be ignored.

ENTER CLASS D BIO. HALF LIFE (-1 TO SKIP)

If you wish to change the XDIV value for the class D inhalation case, specify it here (in days), otherwise type -1 and the default value will be used. See appendix 1 for the definition of XDIV

ENTER CLASS W BIO. HALF LIFE (-1 TO SKIP)

If you wish to change the XDIV value for the class W inhalation case, specify it here (in days), otherwise type -1 and the default value will be used.

ENTER CLASS Y BIO. HALF LIFE (-1 TO SKIP)

If you wish to change the XDIV value for the class Y inhalation case, specify it here (in days), otherwise type -1 and the default value will be used.

ENTER TOTAL RATE LEAVING BLOOD (-1 TO SKIP)

If you wish to change the TCOUT value, specify it here, otherwise type -1 and the default value will be used. Note that since $RT(17) = TCOUT$, this value can be changed either here or below in the prompt for the rate constants.

ENTER BLOOD URINE EXCRETION FRACTION (-1 TO SKIP)

If you wish to change the UEX value, specify it here, otherwise type -1 and the default value will be used.

ENTER BLOOD FECES EXCRETION FRACTION (-1 TO SKIP)

If you wish to change the FEX value, specify it here, otherwise type -1 and the default value will be used.

ENTER INDEX <1-16>, NEW VALUE FOR TCOMP (0,0 TO END)

The values of the TCOMP variables can be changed here. If you wish to change any of these, type the compartment number and the new TCOMP value separated by a comma, and then press return. For example 1,.3 would assign the value of .3 to TCOMP 1. When you have made all the changes you wish to make, type 0,0 and press return. Those values you did not change will be assigned default values.

ENTER INDEX <18-33>, NEW ORGAN HALF LIFE OR (0,0 TO END)

The values for the biological half-lives associated with the organ compartments can be changed here. If you wish to change any of these, type the compartment number and the new half-life value (in days) separated by a comma, and then press return. For example 18,100 would assign the half life value of 100 days to compartment 18. When you have made all the changes you wish to make, type 0,0 and press return. Those values you did not change will be assigned default values.

Note: In the input file set up by GMIAF these half-life values are assigned to their respective rate constants. For example, if you input 100 days for the biological half life of compartment 18, then the input file will contain the statement $RT18 = 100$. This is incorrect, but GENMOD corrects the problem before using it in calculations by making the assignment $RT(i) = \ln 2 / RT(i)$ for $i = 18$ through 33. This is important to know if you edit the input file manually.

ENTER INDEX <18-33>, NEW ORGAN URINE FRACTION OR (0,0 TO END)

The values of the ORGUEx variables can be changed here. If you wish to change any of these, type the compartment number and the new ORGUEx value separated by a comma, and then press return. For example 18,.3 would assign the value of .3 to ORGUEx 18. When you have made all the changes you wish to make, type 0,0

and press return. Those values you did not change will be assigned default values.

ENTER INDEX <18-33>, NEW ORGAN FECES FRACTION OR (0,0 TO END)

The values of the ORGFEX variables can be changed here. If you wish to change any of these, type the compartment number and the new ORGFEX value separated by a comma, and then press return. For example 18,.3 would assign the value of .3 to ORGFEX 18. When you have made all the changes you wish to make, type 0,0 and press return. Those values you did not change will be assigned default values.

If Option 4 was selected, the following 2 prompts will appear:

ENTER INDEX <1-33>, NEW AMOUNT FOR COMP (0,0 TO END)

This allows you to change the initial conditions for the amount of parent radionuclide in a given compartment at time 0. Note that although you can change the initial conditions for all 33 compartments, only the lung compartments (inhalation), the stomach (ingestion), or the transfer compartment (injection) have physical significance, under normal circumstances. The changes made here are assigned to the variable YDUM in the input file. To make a change, type the compartment number and the new YDUM value (Bq) separated by a comma, and then press return. For example 1,.3 would assign the value of .3 Bq to YDUM 1. When you have made all the changes you wish to make, type 0,0 and press return. Those values you did not change will be assigned default values.

ENTER INDEX <1-17>, NEW LUNG RATE (0,0 TO END)

The values of rate constants 1 through 17 can be changed here (note that the prompt says lung rate, but you can also change the rates for compartments 14 through 17). The changes made here are assigned to the variable RTDUM in the

input file. If you wish to change any of these, type the compartment number and the new RT value separated by a comma, and then press return. For example 1,.3 would assign the value of .3 to RT 1. When you have made all the changes you wish to make, type 0,0 and press return. Those values you did not change will be assigned default values. Note that since $RT(17) = TCOUT$, this value can be changed either here or in the previously discussed prompt for TCOUT.

If Option 2 was selected, the following 3 prompts will appear:

ENTER # WORK HOURS, # NON-WORKING HOURS
(0,0 FOR DEFAULT):

This allows you to specify the working and non-working hours during a day for the chronic case. The default values are 8 hours working, 16 hours non-working.

ENTER # WORK DAYS, # NON-WORKING DAYS
(0,0 FOR DEFAULT):

This allows you to specify the working and non-working days during a week for the chronic case. The default values are 5 days working, 2 days non-working.

ENTER # DAYS TO RUN (0 FOR DEFAULT):

This allows you to specify the number of days the individual was exposed for the chronic case. The default value is 30 days.

If Option 10 was selected, the following prompt will appear:

ENTER START, END AND STEP TIMES

This allows you to specify the time array in a unique way. You enter the start time, the end time, and the step time. For example 1,50,1 would give you a time array of every day from day 1 to day 50. This is a good way to generate consecutive years; e.g., 0,18250,365 would give a time array of consecutive years from day 0 to day 18250 (50 years).

If Option 10 was not selected, the following prompt will appear:

DO YOU WISH A NEW TIME ARRAY <Y/N>

If you wish to specify a specific time array, type Y and you will be prompted for the new time array. The default time array is the following :

0 days
.1
.2
.5
1
2
5
7
14
30
60
90
180
365
730
1825
3650
7300
18250

If you had requested a new time array, the following prompt will appear:

ENTER PRINT TIMES ; 1 PER LINE, -1 TO STOP

This allows you to add a specific time array. The array can have up to 100 times. Input each time in days followed by return. When you are done, type -1.

If the chronic case is involved (but not option 2), the following prompt will appear:

TSTOP is the time intake stops in a chronic case (days)

ENTER TSTOP:

Specify the number of days of exposure for the chronic case.

GENMOD Output Files

Shown on the following pages (in Tables 1 through 8) are examples of the output files generated by GENMOD. The files shown are for the case of acute inhalation exposure to plutonium-239 in a W class compound. The time array used to generate these files is the following (in days): 0, 1, 365, 3650, 18250.

This is a simple exposure case, but if the user can understand the information in these output files he should have no difficulty in interpreting any other output files, for the files will always be in this same format.

The headers at the top of most of the files indicate that the output information is in terms of unit exposure. This is per Bq for acute cases and per Bq/day for chronic cases. As explained earlier the user can multiply the output information by a factor to obtain results for a different level of exposure.

The following are common to most of the files shown:

94- Plutonium -239: the radionuclide involved.

ACUTE INHALATION CLASS W: the nature of the exposure.

XDIV: the biological half-life in the pulmonary region (see appendix 1).

F1: the F1 value used.

NP: the nasopharyngeal deposition fraction.

TB: the tracheobronchial deposition fraction.

P: the pulmonary deposition fraction.

ANDOSETABS File (Annual Dose Tables)

See Table 1 on the following page.

This file gives the dose equivalent (rem) incurred between the times in the user's time array. Dose is given to the organs and also to the whole body (effective dose equivalent, $H(E)$).

For time 1.0 (days), the doses given are those incurred between times 0.0 and 1.0; for time 365.0, the doses given are those incurred between times 1.0 and 365.0; and so on.

If the user's time array is in consecutive years, this file will give annual doses.

Table 1. ANDOSETABS File

INTERVAL DOSE : Dose Incurred from T(n-1) to T(n).

[Rem per Bq Intake (Acute) * or * Rem per Bq/day Intake (CHRONIC)]

94 PLUTONIUM -239 ACUTE INHALATION CLASS W NP: 3.0E-01 TB: 8.0E0E-02 P: 2.5E-01 XDIV: 5.0E+01

TIME	LUNG	GUT	S INT.	UL INT.	LL INT.	BONE SUR	R MARROW	LIVER	TESTES	-H(E)
1.0	3.54E-05	3.52E-08	7.90E-08	2.58E-07	2.15E-07	6.08E-06	4.86E-07	1.65E-06	6.60E-08	4.68E-06
365.0	1.68E-03	2.57E-08	7.30E-08	6.48E-07	2.49E-06	5.23E-03	4.18E-04	1.41E-03	5.67E-05	5.14E-04
3650.0	1.50E-05	3.44E-10	4.36E-10	1.52E-09	3.74E-09	5.08E-02	4.06E-03	1.31E-02	5.50E-04	2.97E-03
18250.0	3.38E-09	8.52E-10	8.06E-10	1.19E-09	1.01E-09	1.91E-01	1.53E-02	3.91E-02	2.07E-03	1.06E-02

DINVLTABS File (Derived Investigational Levels Tables)

See Table 2 on the following page.

This file gives the following:

- 1) The annual limit on intake (in Bq). The algorithm used to calculate ALI is:

$$ALI = .5/D50, \text{ if } D50 > 10 \cdot H50$$

$$ALI = .05/H50, \text{ if } D50 < 10 \cdot H50$$

where: D50 = committed dose equivalent to the critical organ.

H50 = effective committed dose equivalent.

- 2) The investigational levels on intake (in Bq). These are given at the times in the user's time array during year 1 (except day 0). The algorithm used to calculate the investigational levels on intake is:

$$ILI = .3ALI/(365/\text{time}).$$

- 3) The derived investigational levels in total lung, total body, urine, and feces. These are obtained by multiplying the ILI by the corresponding entry in the RETEXCRRTS file. For example, the derived investigational level on day 1 in urine is $(1.66E-01) \cdot (6.57E-04) = 1.09E-04$ Bq/day. This is the urinary excretion seen on day 1 from .166 Bq inhaled at time zero.

Table 2. DINVLVLTABS File

DERIVED INVESTIGATIONAL LEVELS
FOLLOWING AN ACUTE IHALATION EXPOSURE
TO CLASS W MATERIAL

94 -PLUTONIUM -239

TIME	TOTAL LUNG	TOTAL BODY	URINARY	FECAL	ILI
1.0	3.60E-02	9.70E-02	1.09E-04	1.75E-02	1.66E-01
365.0	8.26E-02	6.54E+00	1.32E-04	6.82E-04	6.08E+01

ANNUAL LIMIT ON INTAKE: 2.03E+02

DOSERTS File (Dose Rates)

See Table 3 on the following page.

In this file are:

- 1) Instantaneous dose equivalent rates (rem/day) at the times in the user's time array, to the organs and to the whole body (effective dose equivalent rate, $H(E)$). These dose rates are listed in the D. rows.
- 2) Cumulative dose equivalent (rem) delivered from time zero through the times in the user's time array, to the organs and to the whole body ($H(E)$). These doses are listed in the D rows.
- 3) In the bottom row of the file are the following:

The radionuclide and solubility class are listed.

F11: this indicates the F1 value used.

H50: this is the effective committed dose equivalent.

D50: this is the committed dose equivalent to the critical organ.

ORGAN: this is the critical organ (the organ receiving the largest dose).

S: this indicates that the stochastic effect is limiting.
NS would appear if the non-stochastic effect were limiting. The algorithm used in determining this is:

If $H50 < (1000 \times D50)$ then: S
If $H50 \geq (1000 \times D50)$ then: NS

(this is a questionable calculation and it needs further investigation. See ICRP 30, page 6.)

Table 3. DOSERTS File

INSTANTANEOUS (D.) AND CUMULATIVE (D) DOSE

[D.(t) = rem/day at t per Bq (ACUTE) or Bq/day (CHRONIC) Intake]

[D(t) = rem through time, t, per Bq (ACUTE) or Bq/day (CHRONIC) Intake]

91	-PLUTONIUM	-239	ACUTE	INHALATION	CLASS W	NP: 3.0E-01	TB: 8.0E-02	P: 2.5E-01	XDIV: 5.0E+01		
		LUNG	GUT	S INT.	UL INT.	LL INT.	BONE SUR	R MARROW	LIVER	TESTES	H.(E) H(E)
D (	0.0)	4.79E-05	7.56E-13	1.99E-14	2.55E-14	6.73E-15	7.16E-13	8.15E-13	1.49E-12	1.12E-15	5.78E-06
D (	0.0)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
D (	1.0)	3.07E-05	1.64E-08	5.33E-08	3.84E-07	5.54E-07	8.79E-06	7.03E-07	2.38E-06	9.53E-08	4.29E-06
D (	1.0)	3.54E-05	3.52E-08	7.90E-08	2.58E-07	2.15E-07	6.08E-06	4.86E-07	1.65E-06	6.59E-08	4.68E-06
D (	365.0)	1.97E-07	1.11E-12	2.66E-12	1.59E-11	4.84E-11	1.58E-05	1.27E-06	4.26E-06	1.72E-07	9.63E-07
D (	365.0)	1.72E-03	6.10E-08	1.52E-07	9.06E-07	2.70E-06	5.24E-03	4.19E-04	1.41E-03	5.68E-05	5.18E-04
D (	3650.0)	4.60E-13	7.63E-14	7.03E-14	1.06E-13	7.86E-14	1.50E-05	1.20E-06	3.68E-06	1.62E-07	8.66E-07
D (	3650.0)	1.73E-03	6.13E-08	1.52E-07	9.07E-07	2.71E-06	5.60E-02	4.48E-03	1.45E-02	6.07E-04	3.49E-03
D (	18250.0)	1.68E-13	4.38E-14	4.27E-14	6.17E-14	5.94E-14	1.13E-05	9.07E-07	1.87E-06	1.23E-07	5.99E-07
D (	18250.0)	1.73E-03	6.22E-08	1.53E-07	9.08E-07	2.71E-06	2.47E-01	1.97E-02	5.35E-02	2.68E-03	1.40E-02
94	-PLUTONIUM	-239	CLASS: W	F11: 1.0E-04	H50: 1.40E-02	D50: 2.47E-01	ORGAN: BONE SUR	S			

ICRP30_DFS File (ICRP 30 Dose Factors)

See Table 4 on the following page.

Shown in this file are dose factors for the organs, in Sv/Bq (acute) or Sv/(Bq/day)* (chronic). These factors give the dose equivalent (Sv) delivered to the organs through the times in the user's time array, per Bq (acute) or per Bq/day (chronic).

The numbers listed near the top of the file (9 8 ...) are not important to the user. The 9 indicates how many organs are involved. The remaining numbers are the code numbers used in the program for the organs (8 = lung; 20 = gut; etc).

The "Inh" in front of the times stands for inhalation exposure. If the ingestion case was included, an "Ing" would appear in front of a similar group of times representing ingestion exposure.

* Note: Sv/Bq-day at the top of the file should read Sv/(Bq/day).

Table 4. ICRP30_DFS File

ICRP-30 Inhalation & Ingestion DFs in Sv/Bq, Sv/Bq-day GENMOD created on 1-AUG-88 at 14:55:39										
	9	8	20	21	22	23	6	24	4	10
Class W		LUNG	GUT	S INT.	UL INT.	LL INT.	BONE SUR	R MARROW	LIVER	TESTES
Inh 0		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inh 1		3.54E-07	3.52E-10	7.90E-10	2.58E-09	2.15E-09	6.08E-08	4.86E-09	1.65E-08	6.59E-10
Inh 365		1.72E-05	6.10E-10	1.52E-09	9.06E-09	2.70E-08	5.24E-05	4.19E-06	1.41E-05	5.68E-07
Inh 3650		1.73E-05	6.13E-10	1.52E-09	9.07E-09	2.71E-08	5.60E-04	4.48E-05	1.45E-04	6.07E-06
Inh 18250		1.73E-05	6.22E-10	1.53E-09	9.08E-09	2.71E-08	2.47E-03	1.97E-04	5.35E-04	2.68E-05

INGRETTABS File (Integrated Retention Tables)

See Table 5 on the following two pages.

This file gives:

- 1) The S_{ij} table (Dose Conversion Factors Table) that is used in calculating the doses to the organs. This appears if option 7 is selected.
- 2) The integrated retention table. Listed in this table are the integrated retentions (integrated activities) in the organs through the times in the user's time array.
- 3) At the bottom of the integrated retention table is listed the following information from left to right: the radionuclide, the solubility class, the F1 factor, H50, D50, and the critical organ (cf., similar information at the bottom of the DOSERTS file). This information is included if option 5 is selected; it is called the D50 table, and the user can select the form of it (i.e., standard form as shown here, or AECL form, or IAEA form).

Table 5. INGRETTABS File

Dose Conversion Factors

[Rem(target) per Bq-day(source) * or * rem/day(target) per Bq(source)]

PARENT : 94 -PLUTONIUM -239

TARGET ORGANS	S O U R C E O R G A N S								
	LUNG	LYMPH	GUT	S INT.	UL INT.	LL INT.	BONE SUR	LIVER	TESTES
LUNG	1.45E-06	1.45E-06	1.68E-14	7.26E-16	8.25E-16	2.35E-16	8.31E-15	5.79E-14	2.35E-17
GUT	2.29E-14	2.29E-14	2.87E-08	5.01E-14	7.06E-14	9.17E-15	3.98E-15	1.23E-14	1.58E-16
S INT.	6.03E-16	6.03E-16	1.51E-14	1.79E-08	7.31E-13	3.88E-13	5.51E-15	9.31E-15	1.18E-15
UL INT.	7.73E-16	7.73E-16	3.90E-14	4.08E-12	3.20E-08	2.44E-13	6.23E-15	1.63E-14	9.08E-16
LL INT.	2.04E-16	2.04E-16	4.96E-15	5.43E-13	7.10E-14	5.31E-08	1.51E-14	7.03E-16	1.23E-14
BONE SUR	2.17E-14	2.17E-14	5.62E-15	1.43E-14	1.01E-14	3.28E-14	2.97E-06	1.40E-14	3.00E-15
BONE MARROW	2.47E-14	2.47E-14	7.87E-15	5.66E-14	3.89E-14	1.32E-13	2.38E-07	1.49E-14	2.31E-15
LIVER	4.53E-14	4.53E-14	9.98E-15	1.25E-14	1.67E-14	7.82E-16	4.86E-15	8.05E-07	9.93E-17
TESTES	3.40E-17	3.40E-17	1.48E-16	9.04E-16	9.57E-16	7.20E-15	1.98E-15	2.05E-16	4.14E-05

Table 5. (Continued) INGRETTABS File

INTEGRATED RETENTION TABLE: Bq-days per Bq intake (acute) or Bq/day intake (chronic)

4 -PLUTONIUM -239

ACUTE INHALATION CLASS W XDIV: 5.000E+01 F1 FACTOR: 1.000E-04 NP: 3.00E-01 TB: 8.00E-02 P: 2.50E-01

Days	LUNG	LYMPH	GUT	S INT.	UL INT.	LL INT.	BONE SUR	LIVER	TESTES
0.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.0	2.44E-01	8058E-05	1.23E-02	4.41E-02	8.05E-02	4.04E-02	2.05E-02	2.05E-02	1.59E-05
365.0	1.10E+01	8.67E-01	2.12E-02	8.49E-02	2.83E-01	5.09E-01	1.76E+01	1.76E+01	1.37E-02
3650.0	1.10E+01	9.02E-01	2.12E-02	8.50E-02	2.83E-01	5.10E-01	1.89E+02	1.80E+02	1.47E-01
18250.0	1.10E+01	9.02E-01	2.12E-02	8.50E-02	2.83E-01	5.10E-01	8.31E+02	6.65E+02	6.47E-01

4 -PLUTONIUM -239 W 1.000E-04 1.405E-04 2.47E-03 BONE SUR

RETEXCRRTS File (Retention and Excretion Rates)

See Table 6 on the following page.

This file gives:

- 1) The instantaneous retention (instantaneous activity) in the total lung and in the total body, at the times in the user's time array.
- 2) The instantaneous excretion rates in urine and feces at the times in the user's time array.

Note: total lung = the tracheobronchial and pulmonary regions and the pulmonary lymph nodes (i.e., compartments 3 through 12).

Table 6. RETEXCRRTS File

RETENTION AND EXCRETION RATES
 FOLLOWING AN ACUTE INHALATION EXPOSURE TO CLASS W MATERIAL
 OF 1 Bq (acute) or 1 Bq/day (chronic)

PARENT				

94 -PLUTONIUM -239				

	Bq		Bq/day	
	=====		=====	
TIME	TOTAL	TOTAL	URINARY	FECAL
	LUNG	BODY		
0.0	3.30E-01	6.30E-01	0.00E+00	0.00E+00
1.0	2.16E-01	5.83E-01	6.57E-04	1.05E-01
365.0	1.36E-03	1.08E-01	2.17E-06	1.12E-05
3650.0	0.00E+00	9.62E-02	1.54E-06	1.54E-06
18250.0	0.00E+00	6.15E-02	9.00E-07	9.00E-07

RETTABS File (Retention Tables)

See Table 7 on the following page.

This file gives:

- 1) The instantaneous retention (instantaneous activity) in the organs at the times in the user's time array.
- 2) The instantaneous excretion rates in urine and feces at the times in the user's time array.

Note: lung = tracheobronchial and pulmonary regions (i.e., compartments 3 through 9, and 12).

Table . RETTABS File

RETENT ON TABLE: Instantaneous quantity of material in organ (Bq) at time t per Bq intake (acute) or Bq/day intake (chronic)

94 -PLUTONIUM -239

ACUTE INHALATION CLASS W XDIV: 5.000E+01 F1 FACTOR: 1.000E-04 NP: 3.00E-01 TB: 8.00E-02 P: 2.50E-01

Days	LUNG	LYMPH	GUT	S INT.	UL INT.	LL INT.	BONE	SUR	LIVER	TESTES	URINARY	FECAL
0.0	3.30E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.0	2.11E-01	1.71E-04	5.71E-03	2.98E-02	1.20E-01	1.04E-01	2.96E-02	2.96E-02	2.30E-05	6.57E-04	1.05E-01	
365.0	9.55E-04	4.01E-04	3.58E-07	1.48E-06	4.96E-06	9.05E-06	5.34E-02	5.29E-02	4.15E-05	2.17E-06	1.12E-05	
3650.0	2.84E-11	4.48E-12	1.10E-14	4.42E-14	1.50E-13	2.77E-13	5.04E-02	4.57E-02	3.92E-05	1.54E-06	1.54E-06	
18250.0	4.84E-12	1.37E-12	2.07E-15	8.28E-15	2.78E-14	5.06E-14	3.82E-02	2.33E-02	2.97E-05	9.00E-07	9.00E-07	

SYSOUT File (System Output)

See Table 8.

The SYSOUT file is generated every time GENMOD is run, and it gives information about the case that was run. Use the information below as a guide in interpreting Table 8.

TITLE: this is where the user's title or comment appears, if one is included.

PARENT: listed is the radionuclide involved, and its half-life.

GENERAL MODEL FOR THE ADULT CASE 1010 ACUTE INHALATION: this indicates the nature of the case that was run.

***** TRANSFER RATES *****				
	TC-ORGAN	ORGAN-EXC	URINE-EXC	FECES-EXC
ORGANS	*****			
ORGAN #1	TCOMP(1)	HL(18)	ORGUEX(18)	ORGFEX(18)
	TCOMP(2)	HL(19)	ORGUEX(19)	ORGFEX(19)
	TCOMP(3)	HL(20)	ORGUEX(20)	ORGFEX(20)
	TCOMP(4)	HL(21)	ORGUEX(21)	ORGFEX(21)
ORGAN #2	TCOMP(5)	HL(22)	ORGUEX(22)	ORGFEX(22)
	TCOMP(6)	HL(23)	ORGUEX(23)	ORGFEX(23)
	TCOMP(7)	HL(24)	ORGUEX(24)	ORGFEX(24)
	TCOMP(8)	HL(25)	ORGUEX(25)	ORGFEX(25)
ORGAN #3	TCOMP(9)	HL(26)	ORGUEX(26)	ORGFEX(26)
	TCOMP(10)	HL(27)	ORGUEX(27)	ORGFEX(27)
	TCOMP(11)	HL(28)	ORGUEX(28)	ORGFEX(28)
	TCOMP(12)	HL(29)	ORGUEX(29)	ORGFEX(29)

Organ #4 was not involved in this particular case: if it had been involved, it would also be listed here in the same format.

TC EXC RATE: TOTAL: listed is the TCOUT value.

URINE FRACTION: listed is the UEX value.

FECES FRACTION: listed is the FEX value.

F11 VALUES USED: listed are the five F1 values; from left to right these are for D class inhalation, W class inhalation, Y class inhalation, more water soluble material ingestion, and less water soluble material ingestion.

LUNG DEPOSITION: listed are the values of the nasopharyngeal, tracheobronchial, and pulmonary deposition fractions.

DECAY RATES: listed are the values of the physical decay constants; from left to right: parent, daughter, and granddaughter.

PRINT TIMES: listed are the times in the user's time array.

***** RUN DATA *****

ACUTE INHALATION CLASS W: indicates the case that was run.

XDIV: the XDIV value (see appendix 1 for description).

F1 FACTOR: the F1 value for this case.

EXPOSURE STOP AT: the final time in the user's time array.

LUNG ADJ: listed are the lung adjustment fractions for compartments 1 through 9. For example, 10% of the radionuclide deposited in the nasopharyngeal region is deposited in compartment 1, and the remaining 90% is deposited in compartment 2, and so on.

RATES: listed are the biological rate constants for compartments 1 through 10.

DEPOSITS: for the chronic case, listed are the values of the DEPOSIT variables.

ADJUSTED INITIAL AMOUNTS ARE: listed here are the initial conditions used in the differential equations of the model; i.e.,

the values of $Y(i,1)$ at time zero. Note that the values listed are obtained by multiplying the lung deposition fractions times the lung adjustment fractions. The sum of the initial conditions in this case is .63, as we would expect for one becquerel inhaled (the remaining .37 was exhaled). Note that there are places for 45 possible values for initial conditions. The program was written to accommodate a system with a maximum of 45 compartments. The general model uses 43 compartments: the 33 physical compartments and 10 integrated activity "compartments". Other models used in GENMOD may use less or more compartments.

Table 8. SYSOUT File

 GENMOD - A PROGRAM FOR INTERNAL DOSIMETRY CALCULATIONS - DOSIMETRIC RESEARCH BRANCH, CHALK RIVER NUCLEAR LABORATORIES

TITLE

Executed on: 1-AUG-88 at: 17:47:18

PARENT : 94 -PLUTONIUM -239 WITH HALFLIFE: 8.80E+06 DAYS

GENERAL MODEL FOR THE ADULT CASE 1010 ACUTE INHALTION

***** TRANSFER RATES *****

TC-ORGAN ORGAN-EXC URINE-EXC FECES-EXC

ORGAN:

BONE SUR	4.500E-01	3.650E+04	5.000E-01	5.000E-01
	0.000E+00	0.000E+00	0.000E+00	0.000E+00
	0.000E+00	0.000E+00	0.000E+00	0.000E+00
	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LIVER	4.500E-01	1.500E+04	5.000E-01	5.000E-01
	0.000E+00	0.000E+00	0.000E+00	0.000E+00
	0.000E+00	0.000E+00	0.000E+00	0.000E+00
	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TESTES	3.500E-04	3.650E+04	5.000E-01	5.000E-01
	0.000E+00	0.000E+00	0.000E+00	0.000E+00
	0.000E+00	0.000E+00	0.000E+00	0.000E+00
	0.000E+00	0.000E+00	0.000E+00	0.000E+00

```

TC EXCRETES      :      TOTAL:  2.770E+00  URINE FRACTION: 0.500  FECES FRACTION: 0.500
F11 VALUES USED:      0.000E+00  1.000E-04  1.000E-05  1.000E-04  1.000E-05
LUNG DEPOSITION:      NP = 3.00E-01  TB = 8.00E-02  P = 2.50E-01
DECAY RATES       :      7.872E-08  0.000E+00  0.000E+00

```

```
***** RUN DATA *****
```

[illegible][illegible]

APPENDICES

Appendices 1 and 2 on the following pages are copies of the appendices that were in the original GENMOD documentation. I have made a few modifications to these, and am still working on them. I plan to clarify some of the variable definitions, and also list where the user can find the default values for these variables in the program.

VARIABLE	TYPE	DESCRIPTIONS	NAMELIST
ISOTOPE	char*40 (3)	<p>Name(s) of the radioisotope(s) Form: Z#/Element/A#/M where M indicates that a metastable state is involved.</p> <p>examples: 92/URANIUM/235 43/TECHNETIUM/95/M</p>	SETUP
AGE	char*1	<p>Age of the subject A = adult (default) I = infant</p>	SETUP
HL	real (3)	<p>Half-life(s) of isotope(s) in days</p>	SETUP
FORMAT	integer	<p>Flag for form of output for D50 table:</p> <p>0 = standard (default) 1 = as in AECL-7919 2 = IAEA (inhalation only)</p>	SETUP
OPTION	logic (20)	<p>logic flags for options, see appendix 2 for descriptions</p>	SETUP
TIMER	CHAR*80	<p>Flag for printout time array</p> <p>< 0 = use existing user default times</p> <p>0 = default times</p> <p>> 0 = read new print times</p>	SETUP

VARIABLE	TYPE	DESCRIPTIONS	NAMELIST
RBC	REAL	<p>Flag for printout times in MIRD-Iron Model</p> <p>< 0 = print each time setup</p> <p>0 = print at normal printout times (default)</p> <p>> 0 = print at multiples of this time. e.g., 5 would print at 5, 10, 15,...</p>	SETUP
TITLE	Char*80	Comment for this run	SETUP
BONE	Char*1	<p>Flag for bone volume or surface seeker.</p> <p>V = volume seeker</p> <p>S = surface seeker</p>	SETUP
ZNP	REAL	Deposition fraction for nasopharyngeal region. Default value is .30 (1 AMAD)	SETUP
ZTB	REAL	Deposition fraction for tracheobronchial region. Default value is .08 (1 AMAD)	SETUP
ZP	REAL	Deposition fraction for pulmonary region. Default value is .25 (1 AMAD)	SETUP

VARIABLE	TYPE	DESCRIPTIONS	NAMELIST
CASES	CHAR*4	<p>Character flags for case to run. Each of the four positions controls a case</p> <p>Position 1 = Acute Position 2 = Chronic Position 3 = Inhalation Position 4 = Ingestion</p> <p>A case may be turned on by setting this position to 1, off by setting to 0. Default = 1011, i.e. acute, inhalation and ingestion. Note: 0000 signifies the injection case.</p>	SETUP
TSTOP	REAL	TSTOP is the time intake stops in the chronic case.	SETUP
LUNGF	REAL	<p>Multiplication factor for lung and lymph S' factors. Default = 1.0</p> <p>Note: Option (8) must be on.</p>	SETUP
TCOUT	REAL	Total rate leaving transfer compartment	METDATA
TCOMP	REAL(16)	Fraction of TCOUT which is transferred to organ compartment i.	METDATA
UEX	REAL	Fraction of excreted material from blood via urine.	METDATA
FEX	REAL	Fraction of excreted material from blood via feces.	METDATA

VARIABLE	TYPE	DESCRIPTIONS	NAMELIST
CLASS	CHAR*1(3)	The three inhalation classes (D,W,Y)	METDATA
F11	REAL(5)	Fraction of material absorbed into blood from gut. Note: if set to zero, this case will be ignored.	METDATA
ORGANS	CHAR*8(12)	The names of the organs involved in the case.	METDATA
ORGUEX	REAL(16)	Fraction of excreted material from organ i via urine.	METDATA
ORGFEX	REAL(16)	Fraction of excreted material from organ i via feces.	METDATA
XDIV	REAL(3)	Biological half-life for the major compartments in the pulmonary region of the lung in each class (D,W,Y)	METDATA
RT	REAL(18:33)	Half-life for compartment i	METDATA
L	REAL(10)	Rate of transfer in tellurium-iodine model.	METDATA
HOURL	INTEGER(2)	Number of hours worked, number of hours not worked in chronic-acute case.	CHROAC

VARIABLE	TYPE	DESCRIPTIONS	NAMELIST
DAY	INTEGER(2)	Number of days worked, number of days not worked in the chronic-acute case	CHROAC
NDAYS	INTEGER	Number of days to run the chronic-acute case.	CHROAC
TIMES	REAL(100)	Printout times	TGRID
T2	REAL	Start time in consecutive time printout case.	TGRID
T3	REAL	End time in consecutive time printout case.	TGRID
T4	REAL	Time increment in consecutive time printout case, e.g. if T2 = 0, T3 = 10, T4 = 1 then printout times would be 0, 1, 2, ... 10.	TGRID
YDUM	REAL(33)	Initial amount to be placed in compartment i.	AMOUNT
RTDUM	REAL(17)	Rate of transfer for compartment i in lung, gut model in general model.	AMOUNT

APPENDIX 2 OPTIONS

OPTION	DESCRIPTION	DEFAULT
1	Flag to override metabolic data base values and therefore read namelist METDATA TRUE = Override	FALSE
2	Flag to set for chronic-acute case and therefore read namelist CHROAC TRUE = Chronic-Acute Case	FALSE
3	Flag to set for Personnel Air Sampler/Measured Intake case TRUE = PASMI Case	FALSE
4	Flag to override initial amounts and rates for lung and GI tract model and therefore read namelist AMOUNT TRUE = Override	FALSE
5	Print D50 summary table TRUE = Print Table	TRUE
6	Print Retention and Excretion Table TRUE = Print Table	TRUE
7	Print Sij Table TRUE = Print Table	TRUE
8	S' (lung) factor is to be adjusted TRUE = Adjust Factor	FALSE

APPENDIX 2 OPTIONS

OPTION	DESCRIPTION	DEFAULT
9	Print Committed Effective Dose Equivalent, Effective Dose Equivalent, and Dose Rate Table TRUE = Print Table	FALSE
10	Use consecutive time values TRUE = Use consecutive time and therefore read namelist TGRID	FALSE
11	Rate constant version of MIRD-Iron model TRUE = use rate constant version	FALSE
12	Print Derived Investigational Levels Table TRUE = Print Table	FALSE
13	Print Annual Dose Table TRUE = Print Table	FALSE
14-18	Not used (for future expansion)	
19	DSFCT File is to be output in Ci/yr TRUE = Generate DSFCT File in Ci/yr	FALSE
20	DSFCT File is to be generated TRUE = Generate DSFCT File	FALSE

GENMOD References

Listed below are the primary references containing information about the models used in the GENMOD program.

GENERAL MODEL

Johnson, J.R. and Carver, M.B. "A General Model for Use in Internal Dosimetry", Health Physics 41, 341 - 348, 1981. (AECL-7225)

ALKALINE EARTH MODEL

Johnson, J.R. and Myers, R.C. "Alkaline Earth Metabolism: A Model Useful in Calculating Organ Burdens, Excretion Rates and Committed Effective Dose Equivalent Conversion Factors", Radiation Protection Dosimetry 1, (2), 87-95, 1981. (AECL-7289)

IODINE MODEL

Johnson, J.R. "Radioiodine Dosimetry", Journal of Radioanalytical Chemistry 65, 223 - 238, 1981. (AECL-7381)

Johnson, J.R. "Fetal Thyroid Dose from Intakes of Radioiodine by the Mother", Health Physics 43, (4), 573 - 582, 1982. (AECL-7694)

TELLURIUM-IODINE MODEL

Johnson, J.R. and Barwell, V.K. "A Mathematical Model to Assess Radiological Doses from the Tellurium-Iodine Decay Chain", Presentation at the SIAM Fall Meeting, Houston, Texas, Nov. 80.

HTO MODEL

Johnson, J.R. "The Estimation of the Effective Dose Equivalent from Tritiated Water Exposures using Tritium Concentrations in Urine", Radiation Protection Dosimetry 2, (4), 245 - 247, 1982. (AECL-7744)

HT MODEL

Peterman, B.F. "Computer Modeling of HT Gas Metabolism in Humans" Radiation Protection Dosimetry 3, (3), 129 - 133, 1982. (AECL-7896)

MIRD-IRON MODEL

Robertson, J.S., Price, R.R., Budinger, T.F., et.al. "Radiation Absorbed Doses from Iron-52, Iron-55, and Iron-59 used to Study Ferrokinetics", MIRD Dose Estimate Report No. 11, The Journal of Nuclear Medicine 24, 339 - 348, 1983.

Johnson, J.R. and Dunford, D.W. Letter to the Editor, "Radiation Absorbed Doses from Iron-52, Iron-55, and Iron-59 used to Study Ferrokinetics", The Journal of Nuclear Medicine 25, (4), 530 - 531, 1984. (AECL-8280)