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**A Combined Methodology for
Estimating Dose Rates and
Health Effects from
Exposure to Radioactive
Pollutants**

D. E. Dunning, Jr.
R. W. Leggett
M. G. Yalcintas

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Health and Safety Research Division

A COMBINED METHODOLOGY FOR ESTIMATING DOSE RATES AND HEALTH EFFECTS
FROM EXPOSURE TO RADIOACTIVE POLLUTANTS

D. E. Dunning, Jr.
R. W. Leggett
M. G. Yalcintas

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Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
Department of Energy

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HIGHLIGHTS

The work described in the report is basically a synthesis of two previously existing computer codes: INREM II, developed at the Oak Ridge National Laboratory (ORNL); and CAIRD, developed by the Environmental Protection Agency (EPA). The INREM II code uses contemporary dosimetric methods to estimate doses to specified reference organs due to inhalation or ingestion of a radionuclide. The CAIRD code employs actuarial life tables to account for competing risks in estimating numbers of health effects resulting from exposure of a cohort to some incremental risk. The combined computer code, referred to as RADRISK, estimates numbers of health effects in a hypothetical cohort of 100,000 persons due to continuous lifetime inhalation or ingestion of a radionuclide. Also briefly discussed in this report is a method of estimating numbers of health effects in a hypothetical cohort due to continuous lifetime exposure to external radiation. This method employs the CAIRD methodology together with dose conversion factors generated by the computer code DOSFACTOR, developed at ORNL; these dose conversion factors are used to estimate dose rates to persons due to radionuclides in the air or on the ground surface. The combination of the life table and dosimetric methods was performed at the request of the EPA as an aid in determining guidelines for the release of radioactive pollutants to the atmosphere, as required by the Clean Air Act Amendments of 1977.

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ACKNOWLEDGMENT

The work described in this report is basically a synthesis of the INREM II computer code, developed at Oak Ridge National Laboratory, and the CAIRD computer code, developed by the Environmental Protection Agency. The authors wish to express their debt to the authors of these original programs: G. G. Killough, J. C. Pleasant, J. R. Cook, B. M. Bunger, and M. K. Barrick.

1. INTRODUCTION

This report describes a methodology designed to yield estimates of health effects to a hypothetical cohort of 100,000 persons, assuming constant, lifetime exposure to a given radionuclide. The exposure pathways considered are inhalation, ingestion, and external exposure. For the cases of inhalation and ingestion, the methodology is essentially a combination of the dosimetric methods represented by the computer code INREM II (ref. 1), developed at the Oak Ridge National Laboratory (ORNL), and the life table methodology represented by the computer code CAIRD (ref. 2), developed by the Environmental Protection Agency (EPA). Numbers of health effects from external exposure are estimated using CAIRD together with dose rates generated by the computer code DOSFACTER (ref. 3). The combination of the dosimetric and life table methodologies was performed at the request of the EPA as an aid in determining guidelines for the release of airborne radioactive pollutants. The determination of these guidelines is required by the Clean Air Act Amendments of 1977.⁴

2. AN OVERVIEW OF THE METHODOLOGY

The following general approach is used to estimate the number of health effects from inhalation or ingestion of a radionuclide. It is assumed that each member of the exposed cohort continually inhales or ingests, over an entire lifetime, 1 pCi/year of a given parent radionuclide. Dosimetric and metabolic information about the radionuclides in the subchain beginning with the parent nuclide is entered into a computer code referred to as RADRISK, which is a modified version of the INREM II computer code containing as a subroutine a suitably adapted version of the computer code CAIRD. The RADRISK code implements contemporary dosimetric models to estimate the dose rates as a function of time to specified reference organs in the body. Estimates concerning the deposition and retention of inhaled particulates in the lung and their absorption into the blood and clearance into the gastrointestinal (GI) tract are made using the ICRP Task Group Lung Model.⁵ Residence

times of radionuclides in the GI tract and assimilation times from that site are estimated using a four segment model of the GI tract that involves first-order mass transport and absorption of activity. Retention functions for activity in other organs are approximated by linear combinations of exponential functions. The use of dosimetric factors (S-factors, in units of rad/ μ Ci-day) together with estimates of activity in the various organs permits an estimate of dose rates from cross-irradiation when penetrating radiations are present. The RADRISK code permits the consideration of the different absorption and retention properties of the various radionuclides in a decay chain.

For each reference organ, the instantaneous dose rates (rad/year) at specified times are sent by RADRISK to a subroutine which is, in essence, the CAIRD code. This subroutine uses average yearly doses corresponding to the transmitted dose rates to estimate the number of incremental fatalities in the cohort due to radiation-induced cancer of the reference organ. The calculation of the incremental fatalities is based on estimated annual incremental risks, computed from annual doses to the organ, together with radiation risk factors provided by the EPA. (These risk factors are based on an average of absolute and relative risks from the BEIR report; typical risk factors from the BEIR study⁸ are shown in Table 1.) An important feature of the CAIRD code is that it employs actuarial life tables to allow for competing risks of death in its estimate of risk due to radiation exposure.

A life table is essentially a table of data describing age-specific mortality rates from all causes of death for a given population. This information is derived from data obtained on actual mortality within a real population. The use of life tables in the study of risk due to exposure to low-level radiation is important because of the delay inherent in radiation risk. During or after exposure to radiation, a potential cancer victim may experience years of life in which he/she is continually exposed to risks of death from normal daily activities. Hence, some fraction of the individuals who would eventually die from radiation-induced cancer will die earlier from competing causes of death. If the latent period (period after exposure in which there is no risk of radiation-induced cancer death) and plateau period (period in which the

Table 1. Typical radiation risk factors as given in the BEIR document

Age at irradiation	Type of cancer	Duration of latent period (years)	Duration of plateau region ^a (years)	Risk estimate	
				Absolute risk ^b (deaths/10 ⁶ persons per year/rad) ^c	Relative risk (% incr. in deaths/rad) ^c
In Utero	Leukemia	0	10	25	50
	All other cancer	0	10	25	50
0-9 years	Leukemia	2	25	2.0	5.0
	All other cancer	15	(a)30 (b)Life	1.0	2.0
10+ years	Leukemia	2	25	1.0	2.0
	All other cancer	15	(a)30 (b)Life	5.0	0.2

^aPlateau region = interval following latent period during which risk remains elevated.

^bThe absolute risk for those aged 10 or more at the time of irradiation for all cancer excluding leukemia can be broken down into the respective sites as follows:

Type of cancer	Deaths/10 ⁶ persons per year/rad ^c
Breast	1.5*
Lung	1.3
GI incl. stomach	1.0
Bone	0.2
All other cancer	1.0
Total	5.0

^cRisk factors in the BEIR document are actually given in terms of rem rather than rad. The risk factors given in this table apply to low-LET radiation only.

*This is derived from the value of 6.0 quoted in Appendix II, Section A 1 e (of the BEIR document) corrected for a 50% cure rate and the inclusion of males as well as females in the population.

risk of radiation-induced cancer death persists) are known, the life tables can be used to estimate the number of individuals who will die from radiation-induced cancer, excluding those who might have died from radiation-induced cancer but die earlier from other causes.

Numbers of health effects from external exposure to a radionuclide are estimated in the following general manner. It is assumed that each member of the cohort is continually exposed to external radiation resulting from a specified concentration of a given radionuclide in the air and/or a specified concentration of the same radionuclide on the ground surface. The dose rate to the total body is calculated for a person who is assumed to remain standing on the ground surface. These dose rates are estimated from conversion factors generated by the methods of Kocher,³ which employ standard formulas to convert photon and electron radiation exposure to dose rates. The dose rates (rad/year) are entered into the computer code CAIRD, which calculates risk to the cohort as described earlier.

For expository purposes, we first consider the life table approach as applied in the present methodology. The dosimetric approach used in this methodology is described in a later section.

Throughout this report the term "incremental" is reserved for reference to increased risk of dying from cancer (of a given organ) during a specified time period, as a result of the specified exposure to radiation. Thus, the phrase "incremental risk for the k th year" is a short-hand way of saying "increased probability of dying, during the k th year of life, as a result of cancer (of the given organ) induced by the specified exposure to radiation."

3. THE LIFE TABLE APPROACH FOR ESTIMATING INCREMENTAL RISK, AS APPLIED IN THE PRESENT METHODOLOGY

3.1 Basic Concepts of the Life Table Approach

It is assumed that each member of the hypothetical cohort is continuously exposed to a fixed activity of a given radionuclide. The exposure pathways considered are inhalation, ingestion, and external

exposure. Thus it may be assumed, for example, that each member of the cohort inhales 1 pCi/year of a given nuclide, or ingests 1 pCi/year of that nuclide, or is exposed externally to air and ground surface concentrations of 1 pCi/cm³ and 1 pCi/cm², respectively, of that nuclide. The cohort consists of an initial population of 100,000 persons, all of whom are simultaneously liveborn. The inhalation, ingestion, or external exposure begins at birth and continues throughout the entire lifetime of each member of the cohort.

It is assumed that no member of the cohort lives more than 110 years. The span from 0 to 110 years is divided into as many as nine age intervals (usually 0-2, 2-4, 4-8, 8-16, 16-24, 24-36, 36-48, 48-64, 64-110 years). The dose rates (rad/year) at the midpoints of the age intervals to specified reference organs due to the continuous exposure are estimated as discussed later. In addition, dose rates at 50 and at 70 years of age are calculated. The dose rate at the midpoint of each age interval is used as an estimate of the average dose rate during each year of that age interval. For a given organ, the incremental probability of death due to radiation-induced cancer is estimated for each year using (1) risk factors described in Section 2 and (2) the estimated doses during that year and relevant preceding years. The calculation of these incremental probabilities of death for each year is explained in a subsequent section. The incremental probabilities of death are used in conjunction with actuarial life tables to estimate the incremental number of (radiation-induced) deaths each year. Although the method can be used with any set of age-specific probabilities of death, the life tables used for our calculations are those based on the 1969-71 U.S. population data, as reported by the National Center for Health Statistics (NCHS).⁷ The use of life tables in risk analysis provides a reference for the risk of death from all causes for any given age and thus allows the consideration of competing risks of death.

The estimates of the number of premature deaths proceeds as follows. At the beginning of the first year (the year following the birth of the 100,000 persons) there is a probability $P(1)$ of dying during that year, as calculated from the NCHS life table data, and an estimated incremental probability $R(1)$ of dying during that year due to radiation-induced

cancer of the given organ. The total number of deaths during the first year is assumed to be

$$D(1) = [P(1) + R(1)] \times 100,000 , \quad (3.1)$$

and the incremental number of (radiation-induced) deaths is estimated to be

$$Q(1) = R(1) \times 100,000 . \quad (3.2)$$

The number of survivors at the beginning of the second year is calculated to be

$$N(2) = N(1) - D(1) , \quad (3.3)$$

where $N(1) = 100,000$. In general, for the i th year, the calculations are

$$D(i) = [P(i) + R(i)] \times N(i) , \quad (3.4)$$

$$Q(i) = R(i) \times N(i) , \quad (3.5)$$

and

$$N(i + 1) = N(i) - D(i) , \quad (3.6)$$

where

$D(i)$ = total number of deaths in cohort during i th year,

$Q(i)$ = incremental number of (radiation-induced) deaths during i th year due to cancer of a given organ,

$N(i)$ = number of survivors at the beginning of the i th year,

$P(i)$ = probability of death at the beginning of the i th year taken from life table data,

$R(i)$ = incremental probability of death at the beginning of the i th year due to radiation-induced cancer of a given organ.

The total number of premature deaths for the cohort is then

$$Q = \sum_{i=1}^{110} Q(i) , \quad (3.7)$$

since it is assumed that no member of the cohort lives more than 110 years.

In addition to providing an estimate of the incremental number of (radiation-induced) deaths, the life table methodology can be used to estimate the total number of years of life lost to those dying prematurely, the average number of years of life lost for those dying prematurely, and the decrease in the population's life expectancy. The total number T of years of life lost to those dying prematurely is simply the difference between the total number of years of life T_1 lived by the cohort, assuming no incremental radiation risk (T_1 is taken from the NCHS life table) and the total number of years of life T_2 lived by the same cohort assuming the incremental risk from radiation. The average number of years of life lost to those dying prematurely is then

$$T/Q = (T_1 - T_2)/Q . \quad (3.8)$$

The decrease E in the population's life expectancy can be calculated from the formula

$$E = (T_1 - T_2) \times 10^{-5} . \quad (3.9)$$

3.2 Calculation of the Annual Incremental Probability of Death Due to Radiation Exposure

Either absolute or relative risk factors can be used with this method. Absolute risk factors, given in terms of deaths per 10^6 rad-person-years at risk (sometimes expressed as deaths/ 10^6 persons per rad/year), are based on the assumption that there is some absolute number of deaths in a population per unit of dose. Relative risk factors, given in terms of a percentage increase in cancer deaths per rad, are based on the assumption that the number of radiation-induced cancer deaths associated with a given type of cancer depends on the total number of fatal cancers of that type. Both absolute and relative risk factors are assumed to apply uniformly during a plateau period, beginning at the end of a latent period; this latent period follows the beginning of exposure, and during this latent period there is assumed to be no risk. It is often the case that different risk factors are used for adult, child, and in utero exposures. (With the present treatment, in utero exposures are not considered.)

The incremental probability of death due to a particular type of radiation-induced cancer is calculated from the risk factor(s) in the following way. We first consider absolute risk factors. Assume that the risk factor for a child is A_1 deaths/ 10^6 persons per mrad/year, with latent and plateau periods of L_1 and P_1 years, respectively, and that the risk factor for an adult is A_2 deaths/ 10^6 persons per mrad/year, with latent and plateau periods of L_2 and P_2 years, respectively.

Let year E be the ending year of the child stage (E is usually taken to be 10) and assume that each individual in the cohort receives a dose of $Z(i)$ rad during the i th year, $i = 1, 2, \dots, 110$. It follows from the definitions of the latent and plateau periods that dose during the child stage (years 1 through E) contributes to the incremental risk during each of the years $L_1 + 1, L_1 + 2, \dots, L_1 + P_1 + E$. Furthermore, it can be seen that the incremental risk contributed to the i th year, $L_1 + 1 \leq i \leq L_1 + P_1 + E$, by the dose during the j th year of the child stage, $1 \leq j \leq E$, is

$$\begin{aligned} Z(j) \times A_1 \times 0.5 & \quad \text{if } j = i - L_1, \\ Z(j) \times A_1 & \quad \text{if } i - L_1 - P_1 + 1 \leq j < i - L_1, \\ Z(j) \times A_1 \times 0.5 & \quad \text{if } j = i - L_1 - P_1, \\ 0 & \quad \text{otherwise.} \end{aligned}$$

Similarly, it can be seen that the incremental risk contributed to the i th year, $L_2 + E + 1 \leq i \leq 110$, by the dose during the j th year of the adult stage, $E < j \leq 110$, is

$$\begin{aligned} Z(j) \times A_2 \times 0.5 & \quad \text{if } j = i - L_2, \\ Z(j) \times A_2 & \quad \text{if } i - L_2 - P_2 + 1 \leq j < i - L_2, \\ Z(j) \times A_2 \times 0.5 & \quad \text{if } j = i - L_2 - P_2, \\ 0 & \quad \text{otherwise.} \end{aligned}$$

The factors 0.5 in the cases $j = i - L_k$, $k = 1, 2$, and $j = i - L_k - P_k$, $k = 1, 2$, are reflective of the fact that times during the i th year are, on the average, L_k (respectively, $L_k + P_k$) years later than only half the exposure times during the j th year.

As an example, let $L_i = 2$, $P_i = 25$ ($i = 1, 2$), and $E = 10$. Then the incremental risk during the fourth year of life, for example, is

$$[Z(1) \times A_1] + [Z(2) \times A_1 \times 0.5] ;$$

the incremental risk during the fifteenth year of life is

$$\sum_{j=1}^{10} [Z(j) \times A_1] + \sum_{j=11}^{12} [Z(j) \times A_2] + [Z(13) \times A_2 \times 0.5] ;$$

and the incremental risk during the thirtieth year of life is

$$[Z(3) \times A_1 \times 0.5] + \sum_{j=4}^{10} [Z(j) \times A_1] + \sum_{j=11}^{27} [Z(j) \times A_2] \\ + [Z(28) \times A_2 \times 0.5] .$$

Calculations made for the situation in which relative risk factors are used are analogous to the preceding calculations. The only difference is that the numbers A_1 and A_2 are replaced by year-specific numbers $A(i)$, which are the relative risk factors multiplied by the cancer mortality rates taken from NCHS mortality tables.

4. THE ESTIMATION OF DOSE RATES TO REFERENCE ORGANS

The calculation of dose rates to specified reference organs due to the constant inhalation or ingestion of a given activity of a radio-nuclide is performed by a portion of the RADRISK code which is adapted from the INREM II code.¹ The dosimetric methods in RADRISK are, in most respects, identical to those in INREM II. The principal qualitative differences are that (1) RADRISK calculates dose rates (rad/year) to specified organs separately for high and low linear energy transfer (LET) radiation, whereas INREM II calculates total dose equivalent commitments (rem) to specified organs; and (2) RADRISK calculates dose rates to the nasal-pharynx, tracheo-bronchial tree, and pulmonary regions, as well as to the entire lung, whereas INREM II calculates dose commitment to the entire lung but not to the three subcompartments.

The description of the dosimetric portion of RADRISK which follows applies equally well to the code INREM II except where explicitly stated

to the contrary. In fact, the notation and equations that follow are generally identical to those in the INREM II document,¹ and the description that follows is in many places paraphrased from the description of INREM II in ref. 1.

4.1 Sources of Dose to an Organ after Intake of a Radionuclide

In all dosimetric calculations performed with RADRISK, it is assumed that only the first nuclide in a chain of N radioactive species ($N \geq 1$) is taken into the body. As described later, calculations made by the code consider the formation and dynamics of daughters in the chain.

Throughout, $A_{ik}(t)$ denotes the activity (μCi) of the i th species of the chain ($1 \leq i \leq N$) in an organ indexed by subscript k ; the time t is measured from the initial intake of species 1 into the body. The activity $A_{ik}(t)$ is a measure of the energy being emitted by the i th species in the k th organ at time t . Thus, the activities in all organs of the i th species at time t can be directly related to the dose rate to the k th organ at time t . The problem is to estimate the fraction of the energy emitted by the decay of the i th species in each organ that is absorbed by the k th organ. This specific absorbed fraction is incorporated into the calculation through the use of dosimetric S-factors.^{8,9} The S-factor $S_i(X \leftarrow Y)$ ($\text{rad}/\mu\text{Ci-day}$) is defined, for use in RADRISK, as the average dose rate to target organ X due to 1 μCi of the radionuclide species i uniformly distributed in source organ Y . Methods for calculating S-factors are described in Section 4.4. It should be pointed out that the definition and use of "S-factor" here differ slightly from the definition and use for INREM II. Furthermore, the S-factors used here are conceptually similar but numerically distinct from the SEE values used by the ICRP,¹⁰ as noted in Section 4.4. For use in RADRISK, S-factors do not include quality or modifying factors. For use in INREM II, S-factors do include quality factors and are defined in terms of average dose equivalent rates to a target organ.

The dose rate $[DR_i(X)](t)$ to target organ X at time t due to radionuclide species i in source organs $Y_1, Y_2, \dots, Y_M$ is estimated to be

$$[DR_i(X)](t) = \sum_{k=1}^M [DR_i(X \leftarrow Y_k)](t) \text{ rad/day} , \quad (4.1)$$

where

$$[DR_i(X \leftarrow Y_k)](t) = S_i(X \leftarrow Y_k) A_{ik}(t) \text{ rad/day} .$$

Recall that $A_{ik}(t)$ is the activity, at time t , of species i in source organ Y_k . Implicit in the definitions is the assumption of uniform distribution of activity of species i in each source organ (with an exception noted below), as is the assumption of averaging of the dose rate over the tissue of the target organ. Generally, for particle radiations, $[DR_i(X \leftarrow X)](t)$ will contribute the principal dose to organ X .

An exception to the assumption of uniform distribution of activity in source organs occurs for alpha-emitting radionuclides deposited in bone. Radionuclides may be assumed to deposit primarily on bone surfaces (e.g., actinide elements) or to be distributed uniformly throughout the bone volume (e.g., ^{226}Ra), depending on the characteristics of the particular radionuclide. The distribution of daughter isotopes produced in bone is assumed to depend on that of the parent nuclide originally deposited. Special absorbed fractions are calculated for irradiation of endosteal cells and red bone marrow from activity in bone, based on methods of Thorne¹¹ and the assumed deposition pattern in bone.

4.2 Retention and Translocation of Radioactivity

The time rate of change of activity in the body is modeled by a system of ordinary differential equations, with each differential equation describing the rate of change of activity in a conceptual compartment of the body. The pathways in the body by which the activity is assumed to move are illustrated in Fig. 1. In each compartment there may be formation of radioactive daughters, which may have different chemical and physical properties from those of the parent. If the entire chain consists of N species, indexed $i = 1, \dots, N$, then each species has associated with a given compartment a retention function $R_i(t)$, which is the fraction of activity in the compartment at time zero

Fig. 1. Schematic representation of radioactivity movement in the body as modeled by RADRISK.

that survives the compartment's removal processes and radioactive decay t days later.

The activity $A_i(t)$ of the i th species may be expressed in terms of the retention function as follows:

$$A_i(t) = A_i(0) R_i(t) + \int_0^t \left[p_i(\tau) + \lambda_i^R \sum_{j=1}^{i-1} B_{ij} A_j(\tau) \right] \times R_i(t - \tau) d\tau \quad \mu\text{Ci} , \quad (4.2)$$

where

$\lambda_i^R = (\ln 2)/T_i^R$, where T_i^R = radioactive half-life (days) of species i ,

B_{ij} = radioactive branching ratio from species j to species i ,
 $j < i$,

$p_i(t)$ = rate ($\mu\text{Ci/day}$) at which activity of species i enters the compartment at time t .

Each retention function $R_i(t)$ is assumed to be of the form

$$R_i(t) = \sum_{s=1}^{L_i} c_{is} \exp[-(\lambda_i^R + \lambda_{is}^B)t] , \quad (4.3)$$

where

λ_{is}^B = rate coefficient (day^{-1}) for biological removal of species i from the compartment.

The coefficients c_{is} can be thought of as "pathway fractions." For example, one retention function given for uranium in bone is

$$R(t) = 0.9 \exp[-(\ln 2/20) + (\ln 2/T^R)] \\ + 0.1 \exp[-(\ln 2/5000) + (\ln 2/T^R)] ,$$

where T^R denotes the radiological half-life.¹⁰ Thus, in this case, it is assumed that bone consists of two compartments. Ninety percent of the uranium in bone is assumed to clear from compartment 1 with a biological half-time of 20 days, and 10% is assumed to clear from compartment 2 with a biological half-time of 5000 days. In Eq. (4.3) it is required that

$$\sum_{s=1}^{L_i} c_{is} = 1, \quad (4.4)$$

that is, $R_i(0) = 1$.

4.2.1 The respiratory tract

The model used in RADRISK for particulate deposition and retention in the respiratory tract is based on the ICRP Task Group Lung Model,⁴ with parameters given in ICRP Publication 19.¹² With this model (which is shown schematically in Fig. 2) there are assumed to be four major respiratory regions: nasal-pharynx (N-P), tracheo-bronchial tree (T-B), pulmonary region (P), and lymphatic tissue (L). The regions N-P, T-B, and P are assumed to receive fractions D_3 , D_4 , and D_5 of inhaled particulates, where $D_3 + D_4 + D_5 < 1$ (since some particulates are assumed to be removed by prompt exhalation). The values D_3 , D_4 , and D_5 depend on the activity median aerodynamic diameter (AMAD) of the inspired particles. A functional relationship between D_3 , D_4 , and D_5 and AMAD for $0.1 \mu\text{m} \leq \text{AMAD} \leq 20 \mu\text{m}$ suggested in ref. 13 is used in RADRISK. The lung model employs three clearance classes, D , W , and Y , corresponding to rapid, intermediate, and slow clearance, respectively, of material deposited in the respiratory passages. The clearance class depends on chemical properties of the species.

The retention function used in RADRISK for the nasal-pharynx is

$$R_i^{N-P}(t) = \underbrace{F_{a,i} e^{-\lambda_{a,i} t}}_{\text{to blood}} + \underbrace{F_{b,i} e^{-\lambda_{b,i} t}}_{\text{to GI}}, \quad (4.5)$$

where the first term is assigned to pathway a , that is, clearance to the blood, and the second term is assigned to pathway b , that is, mechanical removal to the stomach. In this equation, as in the equations which follow, $\lambda_{v,i}$ is the sum of the radiological decay constant and the biological removal constant $\lambda_{v,i}^B = (\ln 2)/T_{v,i}^B$, where $T_{v,i}^B$ is the biological half-time associated with clearance pathway v ($= a, b, \dots, i$ in Fig. 2). The pathway fractions, $F_{v,i}$, are given in Fig. 2 for the three clearance classes D , W , and Y .

COMPARTMENT		CLASS					
		D		W		Y	
		T	F	T	F	T	F
N-P ($D_3 = 0.30$)	a	0.01	0.5	0.01	0.1	0.01	0.01
	b	0.01	0.5	0.4	0.9	0.4	0.99
T-B ($D_4 = 0.08$)	c	0.01	0.95	0.01	0.5	0.01	0.01
	d	0.2	0.05	0.2	0.5	0.2	0.99
P ($D_5 = 0.25$)	e	0.5	0.8	50	0.15	500	0.05
	f	n.a.	n.a.	1.0	0.4	1.0	0.4
	g	n.a.	n.a.	50	0.4	500	0.4
	h	0.5	0.2	50	0.05	500	0.15
L	i	0.5	1.0	50	1.0	1000	0.9

Fig. 2. The ICRP Task Group Lung Model for particulates (Ref's. 5 and 12). The columns labeled D, W, and Y correspond, respectively, to rapid, intermediate, and slow clearance of the inspired material. The symbols T and F denote the biological half-time (days) and coefficient, respectively, of a term in the appropriate retention function [Eq. (4.5) through (4.9)]. The values shown for D_3 , D_4 , and D_5 correspond to activity median aerodynamic diameter $AMAD = 1 \mu m$. Differential equations for pathways a , b , ..., i are (4.10) through (4.21).

The retention function describing activity deposited directly in the tracheo-bronchial tree takes the form

$$R_{1,i}^{T-B}(t) = \underbrace{F_{c,i} e^{-\lambda_{c,i} t}}_{\text{to blood}} + \underbrace{F_{d,i} e^{-\lambda_{d,i} t}}_{\text{to GI}}, \quad (4.6)$$

where the first term is assigned to pathway c (clearance to the blood) and the second term is assigned to pathway d (removal to the stomach). Activity in the tracheo-bronchial tree can also result from recirculation from the pulmonary region. The clearance of the activity in transit from the pulmonary pathways f and g to the stomach via pathways k and l , respectively, is described by the retention function

$$R_{2,i}^{T-B}(t) = \underbrace{e^{-\lambda_{d,i} t}}_{\text{to GI}} \quad (4.7)$$

The clearance of activity from the pulmonary and respiratory lymph regions through pathways e , f , g , h , and i is represented by the equations

$$R_i^F(t) = \underbrace{F_{e,i} e^{-\lambda_{e,i} t}}_{\text{to blood}} + \underbrace{F_{f,i} e^{-\lambda_{f,i} t} + F_{g,i} e^{-\lambda_{g,i} t}}_{\text{to T-B}} + \underbrace{F_{h,i} e^{-\lambda_{h,i} t}}_{\text{to lymph}} \quad (4.8)$$

and

$$R_i^L(t) = \underbrace{F_{i,i} e^{-\lambda_{i,i} t}}_{\text{to blood}} + \underbrace{(1 - F_{i,i}) e^{-\lambda_{i,i}^R t}}_{\substack{\text{remains in lymph} \\ \text{(class Y materials)}}} \quad (4.9)$$

The activities $A_{a,i}$, ..., $A_{l,i}$ cleared by pathways a , ..., l , respectively, are represented by the following differential equations:

$$\begin{aligned} \dot{A}_{a,i} = & -\lambda_{a,i} A_{a,i} + F_{a,i} \lambda_i^R \sum_{j=1}^{i-1} B_{ij} (A_{a,j} + A_{b,j}) \\ & + F_{a,i} D_3 H_i(t), \end{aligned} \quad (4.10)$$

$$\begin{aligned}\dot{A}_{b,i} = & -\lambda_{b,i} A_{b,i} + F_{b,i} \lambda_i^R \sum_{j=1}^{i-1} B_{ij} (A_{a,j} + A_{b,j}) \\ & + F_{b,i} D_3 H_i(t) ,\end{aligned}\quad (4.11)$$

$$\begin{aligned}\dot{A}_{c,i} = & -\lambda_{c,i} A_{c,i} + F_{c,i} \lambda_i^R \sum_{j=1}^{i-1} B_{ij} (A_{c,j} + A_{d,j}) \\ & + F_{c,i} D_4 H_i(t) ,\end{aligned}\quad (4.12)$$

$$\begin{aligned}\dot{A}_{d,i} = & -\lambda_{d,i} A_{d,i} + F_{d,i} \lambda_i^R \sum_{j=1}^{i-1} B_{ij} (A_{c,j} + A_{d,j}) \\ & + F_{d,i} D_4 H_i(t) ,\end{aligned}\quad (4.13)$$

$$\begin{aligned}\dot{A}_{e,i} = & -\lambda_{e,i} A_{e,i} + F_{e,i} \lambda_i^R \sum_{j=1}^{i-1} B_{ij} (A_{e,j} + A_{f,j} + A_{g,j} + A_{h,j}) \\ & + F_{e,i} D_5 H_i(t) ,\end{aligned}\quad (4.14)$$

$$\begin{aligned}\dot{A}_{f,i} = & -\lambda_{f,i} A_{f,i} + F_{f,i} \lambda_i^R \sum_{j=1}^{i-1} B_{ij} (A_{e,j} + A_{f,j} + A_{g,j} + A_{h,j}) \\ & + F_{f,i} D_5 H_i(t) ,\end{aligned}\quad (4.15)$$

$$\begin{aligned}\dot{A}_{g,i} = & -\lambda_{g,i} A_{g,i} + F_{g,i} \lambda_i^R \sum_{j=1}^{i-1} B_{ij} (A_{e,j} + A_{f,j} + A_{g,j} + A_{h,j}) \\ & + F_{g,i} D_5 H_i(t) ,\end{aligned}\quad (4.16)$$

$$\begin{aligned}\dot{A}_{h,i} = & -\lambda_{h,i} A_{h,i} + F_{h,i} \lambda_i^R \sum_{j=1}^{i-1} B_{ij} (A_{e,j} + A_{f,j} + A_{g,j} + A_{h,j}) \\ & + F_{h,i} D_5 H_i(t) ,\end{aligned}\quad (4.17)$$

$$\dot{A}_{i,i} = -\lambda_{i,i}^R A_{i,i} + F_{i,i} \left\{ \lambda_i^R \sum_{j=1}^{i-1} B_{ij} (A_{i,j} + A_{j,j}) + \lambda_{h,i}^B A_{h,i} \right\}, \quad (4.18)$$

$$\dot{A}_{j,i} = -\lambda_{j,i}^R A_{j,i} + (1 - F_{i,i}) \left\{ \lambda_i^R \sum_{j=1}^{i-1} B_{ij} (A_{i,j} + A_{j,j}) + \lambda_{h,i}^B A_{h,i} \right\}, \quad (4.19)$$

$$\dot{A}_{k,i} = -\lambda_{d,i} A_{k,i} + \lambda_i^R \sum_{j=1}^{i-1} B_{ij} A_{k,j} + \lambda_{f,i}^B A_{f,i}, \quad (4.20)$$

$$\dot{A}_{l,i} = -\lambda_{d,i} A_{l,i} + \lambda_i^R \sum_{j=1}^{i-1} B_{ij} A_{l,j} + \lambda_{g,i}^B A_{g,i}. \quad (4.21)$$

Here $H_i(t)$ is the rate ($\mu\text{Ci/day}$) at which species i is inhaled at time t . It is assumed that no daughters of species i are inhaled. [The inhalation of daughters of species i must be treated in a separate run of RADRISK; however, the formation of daughters of species i in the body after inhalation (or ingestion) of species i is considered in the calculation of dose rates due to intake of species i .] Initial conditions for all species and compartments are zero:

$$A_{v,i}(0) = 0, \quad v = a, \dots, l, \quad i = 1, \dots, N. \quad (4.22)$$

The rate of absorption of activity from the respiratory tract into the blood is described by the equation

$$\dot{A}_{LB,i} = \lambda_{a,i}^F A_{a,i} + \lambda_{c,i}^B A_{c,i} + \lambda_{e,i}^B A_{e,i} + \lambda_{i,i}^B A_{i,i}. \quad (4.23)$$

The cumulative activity of species i absorbed into the blood, $A_{LB,i}$, is used to determine the uptake of species i by other organs. Recall that $\lambda_{v,i}^B$ is the rate coefficient for biological removal of species i from the respiratory tract by pathway v .

The rate at which activity of species i is transmitted from the respiratory tract to the GI tract is estimated from the equation

$$\dot{A}_{LG,i} = \lambda_{b,i}^B A_{b,i} + \lambda_{d,i}^B A_{d,i} + \lambda_{k,i}^B A_{k,i} + \lambda_{\ell,i}^B A_{\ell,i}, \quad (4.24)$$

where $A_{LG,i}$ is the cumulative activity of species i entering the GI tract from the respiratory tract. This transmitted activity of species i is assumed to behave exactly as activity which reaches the GI tract directly by ingestion. In the next section the behavior of radioactive particles deposited in the GI tract, following either ingestion or transmission from the respiratory tract, is discussed.

4.2.2 The gastrointestinal tract

The model used in RADRISK to describe movement of activity through the GI tract is illustrated schematically in Fig. 3. This model, which is equivalent to that described in ref. 14, consists of four segments: stomach, small intestine, upper large intestine, and lower large intestine. Exponential outflow of activity from each segment into the next or out of the system is assumed. Outflow rates calculated from transit times suggested in ref. 15 are shown in the figure. It is usually assumed that activity is absorbed into the blood only from the small intestine; however, the user may specify absorption from any combination of four segments.

The differential equations describing the rate of change of activity in the stomach (S), small intestine (SI), upper large intestine (ULI), and lower large intestine (LLI), are

$$\begin{aligned} \dot{A}_{S,i} = & -(\lambda_S + \lambda_i^R + \lambda_{S,i}^{ab}) A_{S,i} + \lambda_i^R \sum_{j=1}^{i-1} B_{ij} A_{S,j} + (1 - \theta) G_i(t) \\ & + \theta (\lambda_{b,i}^B A_{b,i} + \lambda_{d,i}^B A_{d,i} + \lambda_{k,i}^B A_{k,i} + \lambda_{\ell,i}^B A_{\ell,i}), \end{aligned} \quad (4.25)$$

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Fig. 3. Schematic representation of radioactivity movement among respiratory tract, GI tract, and blood.

$$\begin{aligned} \dot{A}_{SI,i} = & -(\lambda_{SI} + \lambda_i^R + \lambda_{SI,i}^{ab}) A_{SI,i} + \lambda_S A_{S,i} \\ & + \lambda_i^R \sum_{j=1}^{i-1} B_{ij} A_{SI,j} , \end{aligned} \quad (4.26)$$

$$\begin{aligned} \dot{A}_{ULI,i} = & -(\lambda_{ULI} + \lambda_i^R + \lambda_{ULI,i}^{ab}) A_{ULI,i} + \lambda_{SI} A_{SI,i} \\ & + \lambda_i^R \sum_{j=1}^{i-1} B_{ij} A_{ULI,j} , \end{aligned} \quad (4.27)$$

$$\begin{aligned} \dot{A}_{LLI,i} = & -(\lambda_{LLI} + \lambda_i^R + \lambda_{LLI,i}^{ab}) A_{LLI,i} + \lambda_{ULI} A_{ULI,i} \\ & + \lambda_i^R \sum_{j=1}^{i-1} B_{ij} A_{LLI,j} , \end{aligned} \quad (4.28)$$

where

$A_{\sigma,i}$ = activity (μCi) of species i in the segment σ ($= S, SI, ULI$, or LLI) of the GI tract,

λ_{σ} = outflow rate coefficient (day^{-1}) for activity in segment σ of the GI tract (calculated from transit times of Eve (see Fig. 1.2 of ref. 13),

λ_i^R = radioactive decay rate coefficient (day^{-1}) for nuclide species i ,

$\lambda_{\sigma,i}^{ab}$ = rate coefficient (day^{-1}) for absorption of nuclide species i from segment σ ($= S, SI, ULI$, or LLI) into the blood,

B_{ij} = branching ratio of nuclide species j to species i ,

$\theta = 0$ or 1 according as intake of the parent nuclide occurs by ingestion or inhalation,

$G_i(t)$ = ingestion rate ($\mu\text{Ci/day}$) of species i at time t .

All initial conditions are zero:

$$A_{S,i}(0) = A_{SI,i}(0) = A_{ULI,i}(0) = A_{LLI,i}(0) = 0 . \quad (4.29)$$

The coefficient $\lambda_{\sigma,i}^{ab}$ for the rate of absorption of species i into the blood from the GI tract is derived from an absorption fraction $f_{\sigma,i}$ by the equation

$$\lambda_{\sigma,i}^{ab} = \lambda_{\sigma} f_{\sigma,i} / (1 - f_{\sigma,i}) . \quad (4.30)$$

The equation describing the rate of absorption of species i from the GI tract into the blood is

$$\begin{aligned} \dot{A}_{GB,i} = & \lambda_{S,i}^{ab} A_{S,i} + \lambda_{SI,i}^{ab} A_{SI,i} + \lambda_{ULI,i}^{ab} A_{ULI,i} \\ & + \lambda_{LLI,i}^{ab} A_{LLI,i} . \end{aligned} \quad (4.31)$$

4.2.3 Other organs

For the case of ingestion, Eq. (4.31) is used to describe the availability of the radionuclide to those organs that receive activity only from the blood. For intake by inhalation, Eq. (4.24) is also used to compute the availability of activity to those organs.

The activity that enters the blood is assumed to be distributed immediately to various compartments within other specified source organs. The distribution of activity to the source organs is specified in the input data. The list of source organs is element-dependent, and may include such organs as bone or liver where sufficient metabolic data are available. This list is complemented by an additional source denoted as "OTHER," which accounts for that activity not distributed among the explicit source organs; uniform distribution of this remaining activity within "OTHER" is assumed.

For each source organ, the fraction of the initial activity of a radionuclide which remains after time t is assumed to be described by a fractional retention function of the form of Eq. (4.3). In Eq. (4.2), the fraction of the activity surviving at time t is convoluted with the rate of formation of species i from the decay of parent radionuclides in the organ plus the flow of activity into the organ from other parts of the system.

In order to remain consistent with ref. 1, we denote by $f_{2,i}'$ the fractional allocation of species i to an organ. We note that the

fraction $f_{2,i}^*$ often may be included implicitly within retention equations found in the literature; this is, for example, the approach used by the ICRP in recent publications.¹⁰ We rewrite Eq. (4.2) as

$$A_i(t) = \int_0^t \left\{ f_{2,i}^* [\theta \dot{A}_{LB,i}(\tau) + \dot{A}_{GB,i}(\tau)] + \lambda_i^R \sum_{j=1}^{i-1} B_{ij} A_j(\tau) \right\} \times R_i(t - \tau) d\tau \quad \mu\text{Ci} , \quad (4.32)$$

where $\theta = 1$ for the inhalation case and $\theta = 0$ for the ingestion case. The initial level in the organ is assumed to be zero, and the fraction $f_{2,i}^*$ of activity is assumed to flow into the organ without delay.

The differential equations corresponding to Eq. (4.32) are

$$\dot{A}_{is} = -(\lambda_i^R + \lambda_{is}^B) A_{is} + c_{is} \left\{ \lambda_i^R \sum_{j=1}^{i-1} B_{ij} \sum_{r=1}^{L_j} A_{jr} + f_{2,i}^* [\theta \dot{A}_{LB,i} + \dot{A}_{GB,i}] \right\} , \quad s = 1, \dots, L_i , \quad (4.33)$$

with initial conditions

$$A_{is}(0) = 0, \quad s = 1, \dots, L_i .$$

where the coefficients c_{is} are those in the expression for R_i (Eq. 4.3). It should be pointed out that this formulation does not explicitly assume recirculation to the blood of daughters formed in organs other than the respiratory or GI tract.

4.3 Solution of the Differential Equations

Each of the differential equations (4.10) through (4.21), (4.25) through (4.28), and (4.33) is a special case of the equation

$$\dot{A}_{ik} = -(\lambda_i^R + \lambda_{ik}^B) A_{ik} + c_{ik} \left(\lambda_i^R \sum_{j=1}^{i-1} B_{ij} \sum_{r=1}^{L_j} A_{jr} + p_i \right) , \quad (4.34)$$

$$k = 1, \dots, L_i ,$$

where

- A_{ik} = activity (μCi) of species i in the organ,
 $\lambda_i^R = (\ln 2)/T_i^R$, where T_i^R = radioactive half-life (days) of species i ,
 λ_i^B = rate coefficient (day^{-1}) for biological removal of species i from the compartment,
 L_j = number of exponential terms in the retention function for species j ,
 B_{ij} = branching ratio of nuclide j to species i ,
 p_i = inflow rate of i th species.

The subsystem described by each of these equations can be interpreted as a biological compartment in which the fractional retention of species i is governed by the function

$$R_i(t) = \sum_{k=1}^{L_i} c_{ik} \exp[-(\lambda_i^R + \lambda_{ik}^B)(t)] . \quad (4.35)$$

The subscript k in Eq. (4.34) represents the k th term of the retention function, and the coefficients c_{ik} can be considered as "pathway fractions."

If the inflow rates p_i in Eq. (4.34) remain constant, then the explicit solutions $A_{ik}(t)$, of Eq. (4.34) are

$$A_{ik}(t) = \begin{cases} n_{1k} + H_{1k} \exp(-\lambda_{1k} t) & \text{if } i = 1 , \\ D_{ik} + H_{ik} \exp(-\lambda_{ik} t) + \sum_{j=1}^{i-1} \sum_{m=1}^{L_j} G_{ikjm} \exp(-\lambda_{jm} t) & \text{if } i > 1 , \end{cases} \quad (4.36)$$

where the coefficients D_{ik} , H_{ik} , and G_{ikjm} may be calculated from the following recursions:

$$D_{ik} = \begin{cases} c_{1k} p_1 / \lambda_{1k} & \text{if } i = 1 , \\ (c_{ik} / \lambda_{ik}) \left[\lambda_i^R \sum_{j=1}^{i-1} B_{ij} \sum_{m=1}^{L_j} D_{jm} + p_i \right] & \text{if } i > 1 , \end{cases} \quad (4.37)$$

$$H_{ik} = \begin{cases} A_{1k}(0) - D_{1k} & \text{if } i = 1, \\ A_{ik}(0) - D_{ik} - c_{ik} \lambda_i^R \sum_{j=1}^{i-1} \sum_{m=1}^{L_j} (E_{ijm} + B_{ij} H_{jm}) \\ \quad \times (\lambda_{ik} - \lambda_{jm})^{-1} & \text{if } i > 1, \end{cases} \quad (4.38)$$

and

$$G_{ikjm} = c_{ik} \lambda_i^R (E_{ijm} + B_{ij} H_{jm}) (\lambda_{ik} - \lambda_{jm})^{-1}, \quad i > 1, \quad (4.39)$$

where

$$E_{ijm} = \begin{cases} \sum_{r=j+1}^{i-1} B_{ir} \sum_{\mu=1}^{L_r} G_{r\mu jm} & \text{if } j \leq i - 2 \\ 0 & \text{if } j = i - 1. \end{cases} \quad (4.40)$$

The following recursion is used to calculate the E_{ijm} :

$$E_{ijm} = \begin{cases} 0 & \text{if } i = 2 \\ \sum_{r=j+1}^{i-1} B_{ir} \lambda_r^R \sum_{\mu=1}^{L_r} c_{r\mu} (E_{rjm} + B_{rj} H_{jm}) (\lambda_{r\mu} - \lambda_{jm})^{-1}, \\ \text{for } j = 1, \dots, i - 2, \text{ and } i > 2. \end{cases} \quad (4.41)$$

To reduce computer storage requirements, only the D_{ik} , H_{ik} , and E_{ijm} are retained, and the G_{ikjm} are generated as needed. The order of computation is with increasing i , in the order D_{ik} , E_{ijm} , H_{ik} .

One obvious problem is presented in using Eq. (4.34) as a model of the rate of change of activity of a radionuclide in a compartment: in many cases it is unlikely that the inflow, p_i , of species i into the compartment, especially from another compartment, would be at a constant rate over a long period of time. The way that this problem is handled in RADRISK is somewhat different from the way it is handled in INREM II. In both codes, the time interval over which the dose is to be considered (e.g., 110 years) is divided into relatively small subintervals (e.g., of length 1 year). In INREM II, for those cases in which the inflow p_i

may be expected to be nonconstant, p_i is set equal to zero, and the assumed continuous inflow rate over the entire subinterval is accounted for as an initial pulse, which takes the form of an initial condition of the differential equation on that subinterval. This approach yields a conservative estimate of the dose commitment over the time period of interest but cannot be used to estimate instantaneous dose rates that result from continuous inhalation or ingestion of a radionuclide.

Since our use of the computer code CAIRD required the input of doses numerically equivalent to dose rates at specified times after the beginning of the continuous intake, it was necessary to modify the approach used in INREM II to handle the situations where the inflow rate, p_i , could be expected to be nonconstant. In RADRISK, the inflow rate p_i on each subinterval is taken to be that constant inflow rate which would yield the total activity of the radionuclide which flows out of the preceding compartment(s) during the same subinterval. For example, the inflow p to the small intestine from the stomach during a subinterval of length 365 days is taken to be $\lambda_S \bar{A}_S / 365$ where λ_S is the outflow rate coefficient (day⁻¹) from the stomach to the small intestine, and $\bar{A}_S$ is the integrated activity of the radionuclide in the stomach during the same time interval. (The integrated activities in the preceding compartments are computed in previous steps.) Thus, while INREM II solves a given differential equation with different initial conditions on each subinterval, RADRISK solves a new differential equation on each subinterval.

4.4 Calculation of the S-Factors

The dose rate to a target organ X from a source organ Y due to an emission of type m may be calculated from the expression

$$S_m(X \leftarrow Y) = 51.15 \sum f_m E_m \phi_m(X \leftarrow Y) \quad (\text{rad}/\mu\text{Ci-day}), \quad (4.42)$$

where

$$51.15 = 0.01 \text{ g-rad/erg} \times (3.2 \times 10^9) \text{ disintegrations}/\mu\text{Ci-day} \\ \times (1.6 \times 10^{-6}) \text{ erg/MeV},$$

$$f_m = \text{intensity of decay event (number per disintegration),}$$

E_m = average energy of decay event (MeV),
 $\phi_m(X \leftarrow Y)$ = specific absorbed fraction = fraction of emitted energy from source organ Y absorbed by target organ X per gram of X (g^{-1}),

and where the summation is taken over all events of type m . In the following sections we discuss briefly the estimation of the absorbed fractions $\phi_m(X \leftarrow Y)$ for photon emissions, beta, positron, electron, and alpha decays. More complete descriptions can be found in refs. 8 and 9. The SFACTOR computer code⁸ is used to compute the S-factors for RADRISK, excluding all quality and modifying factors.

The S-factor is similar in concept to the SEE factor (specific effective energy) used by ICRP Committee 2 in the recent Publication 30.¹⁰ The SEE factor has units of $\text{MeV}\cdot\text{g}^{-1}\cdot\text{transformation}^{-1}$ or $\text{MeV}\cdot\text{g}^{-1}\cdot\text{Bq}^{-1}\cdot\text{sec}^{-1}$, and includes a quality factor for the radiation emitted during the transformation. The S-factor as used in the RADRISK analysis does not include consideration of the quality factor, and is expressed in units of $\text{rad}/\mu\text{Ci}\cdot\text{day}$. The two quantities are related as

$$SEE(X \leftarrow Y)_m = k \sum_m Q_m S_m(X \leftarrow Y) \quad (4.43)$$

where

Q_m = the appropriate quality factor for the m th radiation type, and
 $k = (100 \text{ erg/g}\cdot\text{rad}) \times (\text{day}/86400 \text{ sec}) \times (\mu\text{Ci}/(3.7 \times 10^4 \text{ Bq}))$
 $\times (\text{MeV}/(1.6 \times 10^{-6} \text{ erg})) = 0.0196 \text{ MeV/g}\cdot\text{Bq}\cdot\text{sec per rad}/\mu\text{Ci}\cdot\text{day}.$

4.4.1 Photon emissions

For photon emissions, specified absorbed fractions $\phi_m(X \leftarrow Y)$ are interpolated from a basic set of absorbed fractions compiled in ref. 9 which were computed by Monte Carlo methods for all combinations of source organs and target organs and 12 photon energies. The Monte Carlo method is essentially a computerized approach to estimate the probability of a photon interaction within organ X after emission from organ Y . This method proceeds basically as follows. The body is represented by an idealized phantom in which the internal organs are assigned masses, shapes, positions, and attenuation coefficients based on their chemical composition. A mass attenuation coefficient μ_o is chosen, where μ_o is

greater than or equal to the mass attenuation coefficients for any region of the body. The photon begins its course from organ Y in a randomly chosen direction, and a potential site of an interaction is chosen by taking the distance traveled as $-\ln r/\mu_0$, where r is a random number distributed between 0 and 1. The point on the line at this distance from the photon's starting point and in the direction of the photon's path is tested to determine the region of the body containing this point. The computer randomly selects either a favorable or an unfavorable outcome; the probability of a favorable outcome is μ_i/μ_0 , where μ_i is the total mass attenuation coefficient for the i th region. If the outcome is unfavorable, then it is assumed that no interaction occurs, and the photon proceeds another randomly chosen distance along the same line of flight and the game is repeated. If the outcome is favorable, then it is assumed that an interaction occurs. With each interaction, an artificial "weight" of the photon (initially set at unity) is reduced by an amount equal to the expectation of absorption which the photon would have in the actual physical processes. The flight of the photon is terminated (1) if it escapes the body; (2) if its energy falls below a cutoff value--typically 4 keV; or (3) if its weight falls below 10^{-5} ; in the latter two cases, the energy is considered to be totally absorbed. The energy deposition for an interaction is determined according to a standard equation (see ref. 9).

4.4.2 Beta, positron, and electron decay

Beta particles, positrons, and discrete electrons are usually not sufficiently energetic to contribute significantly to cross-irradiation doses of targets separated from a source organ. Thus, it is generally assumed that $\phi_m(X \leftarrow X)$ is just the inverse of the mass of organ X , and if source and target are separated, $\phi_m(X \leftarrow Y) = 0$. Exceptions occur when the source and target are in close proximity, which is the case, for example, with various skeletal tissues. Absorbed fractions for cross irradiations among skeletal tissues are computed as a function of energy, from data of Spiers as described by Snyder et al.⁹ This approach differs somewhat from recently proposed methods of the ICRP,¹⁰ where the functional dependence of absorbed fractions on the beta energy is reduced

to a two-stage step function for nuclides depositing on bone surfaces and eliminated entirely for nuclides with a uniform volume deposition. However, in our calculations to date, no distinction is made between volume and surface deposition patterns for beta decay; all beta activity is assumed to be uniformly distributed in the mineral bone volume. The reader is referred to refs. 9 and 10 for further discussion of these exceptional cases.

4.4.3 Alpha particle decay

The energy of alpha particles and their associated recoil nuclei is generally assumed to be absorbed in the source organ. Therefore, $\Phi_{\alpha}(X \leftarrow X)$ is taken to be the inverse of the organ mass, and $\Phi_{\alpha}(X \leftarrow Y) = 0$ if X and Y are separated. In addition to the special cases noted previously, special calculations are performed for red marrow and endosteal cells in bone, based on the method of Thorne.¹¹ The equation for S_{α} is

$$S_{\alpha}(X \leftarrow Y) = 51.15 [(KE) + (RE)] \Phi_{\alpha}(X \leftarrow Y) \text{ (rad/}\mu\text{Ci-day)}, \quad (4.44)$$

where (KE) and (RE) denote the kinetic and recoil energy, respectively; these values are given by

$$(KE) = \sum f_{\alpha} E_{\alpha}, \quad (4.45)$$

$$(RE) = \frac{4}{A - 4} \sum f_{\alpha} E_{\alpha}, \quad (4.46)$$

where A is the mass number of the radionuclide, and the summations are taken over all alpha particles for the given radionuclide. A more complete discussion of S-Factors for alpha particle decay can be found in refs. 8 and 9.

5. THE ESTIMATION OF DOSE RATES TO REFERENCE ORGANS DUE TO EXTERNAL EXPOSURE TO A RADIONUCLIDE IN AIR OR ON THE GROUND SURFACE

The dose rates to reference organs of an individual immersed in contaminated air or exposed to a contaminated ground surface are estimated from the equation

$$R(t) = Q(t) \times D . \quad (5.1)$$

Here $R(t)$ is the dose rate at time t , $Q(t)$ is the radionuclide concentration in the air or on the ground surface at time t , and D is a dose rate conversion factor calculated by Kocher.³ The dose rate conversion factor is defined as the dose rate per unit radionuclide concentration and is uniquely specified by the radiation type, exposure mode, and organ of the exposed individual. In calculations to date, only dose rate factors for photon radiations are utilized. Since skin is not specified as a target tissue of concern in the present calculations, no consideration of beta dose rate factors is required. The calculations in ref. 3 assume that the contaminated air or ground surface is infinite in extent and that the radionuclide concentration is uniform throughout the medium. It is assumed that the exposed individual remains standing on the ground surface.

The equations used by Kocher to calculate the particular dose rate conversion factors are shown below. The derivation of each equation is outlined in ref. 3.

The dose rate factor D_γ (in millirad/year per $\mu\text{Ci}/\text{cm}^3$) for photons (γ) for the body surface of an individual immersed in contaminated air is

$$D_\gamma = 0.5(1.87 \times 10^7) \frac{1}{\rho_a} \sum_i f_{i\gamma} E_{i\gamma} \left[\frac{(\mu_{en}/\rho)_t}{(\mu_{en}/\rho)_a} \right]_i \quad (5.2)$$

where

- ρ_a = density of air in g/cm^3
- $f_{i\gamma}$ = intensity of i th discrete photon in number per disintegration
- $E_{i\gamma}$ = energy in MeV for i th photon,
- μ_{en}/ρ = photon mass energy-absorption coefficient in cm^2/g , with subscripts t and a denoting tissue and air, respectively.

The factor 1.87×10^7 is the end product of several changes of unit:
 $(3.7 \times 10^{-4} \text{ dis/sec-}\mu\text{Ci}) \times (0.01 \text{ g-rad/erg}) \times (1.60 \times 10^{-6} \text{ erg/MeV}) \times$
 $(1000 \text{ millirad/rad}) \times (3.1536 \times 10^7 \text{ sec/year}) = 1.87 \times 10^7 \text{ (units)}.$

The factor of 0.5 reflects consideration of the half space containing no radionuclide concentration, i.e., the half space occupied by the ground.

The dose rate factor D_Y (in millirad/year per $\mu\text{Ci}/\text{cm}^2$) for photons for the body surface of an individual exposed to a contaminated ground surface is

$$D_Y(z) = 0.5(1.87 \times 10^7) \sum_i f_{iY} E_{iY} \left[(\mu_{en}/\rho)_t \right]_i \left[\tilde{E}_1(\mu_{a,i} z) - \frac{C_{a,i}}{(D_{a,i} - 1)} \exp \left[(D_{a,i} - 1) \mu_{a,i} z \right] \right] , \quad (5.3)$$

where

$\mu_{a,i}$ = mass attenuation coefficient in air in cm^{-1} for the i th discrete photon

$$\tilde{E}_1(\mu_{a,i} z) = \int_{\mu_{a,i} z}^{\infty} \frac{1}{r} \exp(-\mu_{a,i} r) dr$$

z = height of reference position above ground surface in centimeters (usually taken to be 100 cm).

The quantities $C_{a,i}$ and $D_{a,i}$ are functions of the photon energy — they are the coefficients of the Berger form of the buildup factor — and the remaining quantities are as given earlier.

The organ dose rate factors for immersion in contaminated air are obtained from Eq. (5.2) by multiplying the i th term by a factor $G^k(E_{iY})$, which is the ratio of absorbed dose rate in body organ k to absorbed dose rate at the body surface for the i th photon. (Electrons are not considered in calculating dose rates to internal organs from external exposure). More specifically,

$$\begin{aligned} D_Y^k &= \text{photon dose-rate factor in millirads/year per } \mu\text{Ci}/\text{cm}^3 \\ &\quad \text{for body organ } k \text{ from immersion in contaminated air} \\ &= 0.5(1.87 \times 10^7) \frac{1}{\rho_a} \sum_i f_{iY} E_{iY} \left[\frac{(\mu_{en}/\rho)_t}{(\mu_{en}/\rho)_a} \right]_i G^k(E_{iY}) . \quad (5.4) \end{aligned}$$

In a similar fashion the organ dose rate factors for exposure to a contaminated ground surface are obtained from Eq. (5.4) by multiplying the i th term by $G^k(E_{i\gamma})$. Thus,

$$\begin{aligned}
 D_Y^k(z) &= \text{photon dose-rate factor in millirads/year per } \mu\text{Ci/cm}^2 \\
 &\quad \text{for body organ } k \text{ from exposure at } z \text{ cm to contaminated} \\
 &\quad \text{ground surface} \\
 &= 0.5(1.87 \times 10^7) \sum_i f_{i\gamma} E_{i\gamma} \left[(\mu_{en}/\rho)_t \right]_i \left[\frac{\gamma}{E} \right]_i (\mu_{a,i} z) \\
 &\quad - \frac{C_{a,i}}{D_{a,i}-1} \exp[(D_{a,i}-1)\mu_{a,i} z] \left] G^k(E_{i\gamma}) . \quad (5.5)
 \end{aligned}$$

6. LIMITATIONS OF THE LIFE TABLE APPROACH

The life table methodology, in its present form, does not consider a real population. Rather, it considers a hypothetical population whose probabilities of death correspond to those of the U.S. population during the years 1969-71. The use of the 1969-71 U.S. population census has the advantage of representing the most complete U.S. population data available. However, there is the obvious disadvantage that mortality rates, particularly cancer mortality rates, may change significantly with time.

Even if present mortality rates were available in the detail necessary for application of this method, the life table methodology could not be interpreted as predicting future effects in a real population, since such effects are dependent on several unknown quantities, including future death probabilities. The results from the life table analysis should be viewed as if the cohort lives its entire existence during a period when mortality rates are not changing.

The life table methodology is to some extent nonlinear, in the sense that the number of premature deaths predicted from high exposure rates cannot be used in a linear fashion to estimate the number of premature deaths from lower exposure rates. This nonlinearity stems from the fact that the methods of CAIRD are based on the assumption that the

number of incremental, radiation-induced deaths is extremely small compared with the total number of deaths (cf. Eq. 3.4). If the number of premature deaths predicted for an inhalation rate of 100 $\mu\text{Ci}/\text{year}$ of ^{239}Pu were 20,000, for example, it should not be concluded that an inhalation rate of 0.01 $\mu\text{Ci}/\text{year}$ would yield 2 premature deaths. This type of extrapolation should be made only at exposure rates low enough that the number of premature deaths each year is very small compared with the number of deaths from competing causes.

Recall that the methodology assumes that the cohort is exposed to the radionuclide from birth to death, and that no added risk is considered for dose to the fetus. Although the CAIRD code includes an option allowing consideration of risk due to fetal dose, it was felt that large uncertainties are associated with present dosimetric methods concerning the fetus. In a real population, continuous ingestion or inhalation of some radionuclides might actually result in significant doses to the fetus; hence the cohort analysis performed here may differ from a real population analysis in this respect.

Additional problems arise in applying the CAIRD methodology to a real population if the population is relatively small. The CAIRD approach is based on average mortality rates and risk factors which are meaningful only for large numbers of persons. In addition, the code computes fractional numbers of deaths in the cohort each year, and while it may not present serious difficulties to consider 10.1 deaths in a cohort of size 100,000 to be essentially the same as 10 deaths, very basic difficulties are encountered in the interpretation of 0.1 death, for example, in a cohort of size 1,000.

In the calculation of dose rates, there is assumed to be no age dependence in the metabolism of the radionuclide. All dose rates are calculated for reference organs whose weights are typical for an adult weighing 70 kg. Since the methodology considers dose rates to individuals inhaling or ingesting a radionuclide from birth to death, the assumption of age independence in the dosimetry methods may be undesirable in many respects. However, the uncertainty involved in computing age-dependent estimates of dose at the present level of knowledge was deemed unacceptably great.

The largest uncertainties in estimating radiation risk using the present methodology probably arise from uncertainties in the dosimetric methods and in the risk factors. It should be kept in mind that estimates of risk made using this methodology can be no more reliable than the metabolic data or risk factors used to generate the estimated risks. The RADRISK methodology is intended only as a framework for assessing risk from radiation; if this framework has been constructed adequately, then the RADRISK code will produce increasingly reliable estimates of risk as more reliable input data are incorporated.

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APPENDIX I

Illustrative Examples of RADRISK Output

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Output from the computer code RADRISK is illustrated in Figs. I-1 through I-4. For this example, it is assumed that an individual inhales or ingests ^{210}Pb at a constant rate of 2.74×10^{-9} $\mu\text{Ci/day}$ (1 pCi/year).

Dose rates to 20 reference tissues at specified times after the beginning of continuous ^{210}Pb inhalation are shown in Fig. I-1, along with half-lives, gastrointestinal uptake factors, respiratory clearance classifications, and other pertinent data for each radionuclide in the decay chain. Dose rates resulting from chronic ^{210}Pb ingestion are shown in Fig. I-2. Note that dose rates are given separately for high and low linear energy transfer (LET) radiations. In addition to dose rates used in the calculation of somatic risks to the exposed cohort, 30-year dose commitments to the testes and ovaries are calculated for potential use in evaluating genetic risks.

Risks from cancers of specified tissues, in terms of numbers of incremental deaths in the exposed cohort, decrease in population life expectancy, total years of life lost to the cohort, and average years of life lost to those dying prematurely, are tabulated in Figs. I-3 and I-4 for the inhalation and ingestion cases, respectively. In addition to the risk to the cohort described above, these tables also contain other pertinent information, such as the 70-year dose equivalent rate and "risk equivalent factors." The risk equivalent factor is defined as the number of premature deaths in the cohort resulting from the given exposure (in this case, inhalation or ingestion of ^{210}Pb at the rate of 1 pCi/year) divided by the number of deaths in the cohort which would result from a continuous dose rate to the given organ of 1 millirad/year.

RADIOISOTOPE: PB-210

PHYSICAL AND METABOLIC PARAMETERS FOR DOSIMETRICALLY SIGNIFICANT PROGENY:

NUCLIDE	RADIOACTIVE HALF-LIFE (DAYS)
PB-210	8140.
BI-210	5.310
PO-210	138.0

BRANCHING RATIOS:	FROM	TO	FRACTION
	PB-210	BI-210	1.000
	BI-210	PO-210	1.000

CASE 1.. INHALATION

INHALATION INTAKE RATE FUNCTION (MICROCURI/DAY)			
FROM (DAYS)	TO (DAYS)	RATE	
0.0	3.175E 04	2.740E-09	

ANAD (MICRON)...	1.30	02 =0.310	04 =1.000E-02	05 =0.249
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G.I. UPTAKE FRACTIONS				
SOLUBILITY CLASS	STOMACH	S INT	U L INT	L L INT
PB-210	W	0.0	0.200	0.0
BI-210	W	0.0	5.000E-02	0.0
PO-210	W	0.0	1.000E-01	0.0

LOW-LET DOSE RATE (MRAD/YEAR)

TIME (YEARS)	1.	3.	6.	12.	20.	30.	42.	50.	56.	70.	87.
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TARGET											
S WALL	8.49E-07	1.03E-05	1.03E-06	1.05E-06	1.05E-06	1.06E-06	1.06E-06	1.07E-06	1.07E-06	1.07E-06	1.07E-06
SI WALL	1.90E-06	2.38E-05	2.39E-06	2.40E-06	2.41E-06	2.42E-06	2.43E-06	2.43E-06	2.43E-06	2.43E-06	2.44E-06
ULI WALL	1.14E-05	1.37E-05	1.37E-05	1.38E-05	1.38E-05	1.38E-05	1.38E-05	1.38E-05	1.38E-05	1.38E-05	1.38E-05
LLI WALL	3.39E-05	4.03E-05	4.03E-05	4.03E-05	4.04E-05	4.04E-05	4.04E-05	4.04E-05	4.04E-05	4.04E-05	4.04E-05
BL WALL	2.36E-07	2.55E-07	2.55E-07	2.55E-07	2.55E-07	2.55E-07	2.55E-07	2.55E-07	2.55E-07	2.55E-07	2.55E-07
KIDNEYS	7.80E-06	1.13E-05	1.13E-05	1.13E-05	1.13E-05	1.13E-05	1.13E-05	1.13E-05	1.13E-05	1.13E-05	1.13E-05
LIVER	1.16E-05	1.75E-05	1.75E-05	1.75E-05	1.75E-05	1.75E-05	1.75E-05	1.75E-05	1.75E-05	1.75E-05	1.75E-05
MUSCLE	4.86E-07	1.28E-07	1.28E-07	1.28E-07	1.28E-07	1.28E-07	1.28E-07	1.28E-07	1.28E-07	1.28E-07	1.28E-07
OVARIES	4.93E-07	1.28E-07	1.28E-07	1.28E-07	1.28E-07	1.28E-07	1.28E-07	1.28E-07	1.28E-07	1.28E-07	1.28E-07
PANCREAS	4.98E-07	1.45E-07	1.45E-07	1.45E-07	1.45E-07	1.45E-07	1.45E-07	1.45E-07	1.45E-07	1.45E-07	1.45E-07
R MAR	4.91E-06	1.10E-05	1.10E-05	1.10E-05	1.10E-05	1.10E-05	1.10E-05	1.10E-05	1.10E-05	1.10E-05	1.10E-05
ENDOST	1.27E-05	2.91E-05	2.91E-05	2.91E-05	2.91E-05	2.91E-05	2.91E-05	2.91E-05	2.91E-05	2.91E-05	2.91E-05
SPLEEN	4.64E-07	6.94E-07	6.94E-07	6.94E-07	6.94E-07	6.94E-07	6.94E-07	6.94E-07	6.94E-07	6.94E-07	6.94E-07
TESTES	4.68E-07	7.04E-07	7.04E-07	7.04E-07	7.04E-07	7.04E-07	7.04E-07	7.04E-07	7.04E-07	7.04E-07	7.04E-07
THYMUS	4.95E-07	1.36E-07	1.36E-07	1.36E-07	1.36E-07	1.36E-07	1.36E-07	1.36E-07	1.36E-07	1.36E-07	1.36E-07
THYROID	4.72E-07	1.12E-07	1.12E-07	1.12E-07	1.12E-07	1.12E-07	1.12E-07	1.12E-07	1.12E-07	1.12E-07	1.12E-07
UTERUS	4.74E-07	7.13E-07	7.13E-07	7.13E-07	7.13E-07	7.13E-07	7.13E-07	7.13E-07	7.13E-07	7.13E-07	7.13E-07
N-P	1.62E-05	1.62E-05	1.62E-05	1.62E-05	1.62E-05	1.62E-05	1.62E-05	1.62E-05	1.62E-05	1.62E-05	1.62E-05
T-B	6.57E-05	6.12E-05	6.12E-05	6.12E-05	6.12E-05	6.12E-05	6.12E-05	6.12E-05	6.12E-05	6.12E-05	6.12E-05
PUL	2.92E-04	3.01E-04	3.01E-04	3.01E-04	3.01E-04	3.01E-04	3.01E-04	3.01E-04	3.01E-04	3.01E-04	3.01E-04

HIGH-LET DOSE RATE (MRAD/YEAR)

TIME (YEARS)	1.	3.	6.	12.	20.	30.	42.	50.	56.	70.	87.
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TARGET											
S WALL	3.97E-09	5.42E-09	5.42E-09	5.42E-09	5.42E-09	5.42E-09	5.42E-09	5.42E-09	5.42E-09	5.42E-09	5.42E-09
SI WALL	9.09E-09	1.24E-08	1.24E-08	1.24E-08	1.24E-08	1.24E-08	1.24E-08	1.24E-08	1.24E-08	1.24E-08	1.24E-08
ULI WALL	5.75E-08	7.79E-08	7.79E-08	7.79E-08	7.79E-08	7.79E-08	7.79E-08	7.79E-08	7.79E-08	7.79E-08	7.79E-08
LLI WALL	1.94E-07	2.60E-07	2.60E-07	2.60E-07	2.60E-07	2.60E-07	2.60E-07	2.60E-07	2.60E-07	2.60E-07	2.60E-07
BL WALL	1.43E-06	2.29E-06	2.29E-06	2.29E-06	2.29E-06	2.29E-06	2.29E-06	2.29E-06	2.29E-06	2.29E-06	2.29E-06
KIDNEYS	5.23E-05	6.12E-05	6.12E-05	6.12E-05	6.12E-05	6.12E-05	6.12E-05	6.12E-05	6.12E-05	6.12E-05	6.12E-05
LIVER	3.44E-05	5.53E-05	5.53E-05	5.53E-05	5.53E-05	5.53E-05	5.53E-05	5.53E-05	5.53E-05	5.53E-05	5.53E-05
MUSCLE	2.87E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06
OVARIES	2.87E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06
PANCREAS	2.87E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06
R MAR	3.50E-06	6.15E-06	6.15E-06	6.15E-06	6.15E-06	6.15E-06	6.15E-06	6.15E-06	6.15E-06	6.15E-06	6.15E-06
ENDOST	2.28E-05	5.65E-05	5.65E-05	5.65E-05	5.65E-05	5.65E-05	5.65E-05	5.65E-05	5.65E-05	5.65E-05	5.65E-05
SPLEEN	5.27E-05	8.46E-05	8.46E-05	8.46E-05	8.46E-05	8.46E-05	8.46E-05	8.46E-05	8.46E-05	8.46E-05	8.46E-05
TESTES	2.87E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06
THYMUS	2.87E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06
THYROID	2.87E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06
UTERUS	2.87E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06	4.58E-06
N-P	2.43E-07	2.43E-07	2.43E-07	2.43E-07	2.43E-07	2.43E-07	2.43E-07	2.43E-07	2.43E-07	2.43E-07	2.43E-07
T-B	3.48E-05	4.76E-05	4.76E-05	4.76E-05	4.76E-05	4.76E-05	4.76E-05	4.76E-05	4.76E-05	4.76E-05	4.76E-05
PUL	5.13E-04	5.25E-04	5.25E-04	5.25E-04	5.25E-04	5.25E-04	5.25E-04	5.25E-04	5.25E-04	5.25E-04	5.25E-04

30-YEAR GENETIC DOSE COMMITMENT (MRAD)...

	TESTES	OVARIES	AVERAGE
LOW	3.37E-05	3.48E-05	3.43E-05
HIGH	1.69E-04	1.69E-04	1.69E-04

Fig. I-1. Estimated dose rates to reference tissues at specified times after the beginning of continuous ²¹⁰Pb inhalation.

CASE 2.. INGESTION

INGESTION INTAKE RATE FUNCTION (MICROCURIES/DAY)
FROM (DAYS) TO (DAYS) RATE
0.0 3.176E 04 2.740E-09

INGESTION TRANSFER FRACTIONS (G. I. TRACT TO BLOOD)

	PB-210	BI-210	FO-210
STOMACH	0.0	0.0	0.0
S INT	0.200	5.000E-02	1.000E-01
U L INT	0.0	0.0	0.0
L L INT	0.0	0.0	0.0

LOW-LET DOSE RATE (MRAD/YEAR)

TIME (YEARS)	1.	3.	6.	12.	20.	30.	42.	50.	56.	70.	87.
TARGET											
S WALL	1.69E-07	1.73E-07	1.78E-07	1.85E-07	1.92E-07	1.97E-07	2.01E-07	2.02E-07	2.03E-07	2.04E-07	2.05E-07
SI WALL	4.22E-07	4.28E-07	4.35E-07	4.45E-07	4.55E-07	4.63E-07	4.68E-07	4.70E-07	4.71E-07	4.73E-07	4.74E-07
ULI WALL	3.07E-06	3.68E-06	3.69E-06	3.70E-06	3.71E-06	3.72E-06	3.72E-06	3.73E-06	3.73E-06	3.73E-06	3.73E-06
LLI WALL	1.74E-05	1.75E-05	1.75E-05	1.75E-05	1.75E-05	1.75E-05	1.75E-05	1.75E-05	1.75E-05	1.75E-05	1.75E-05
BL WALL	2.15E-07	3.05E-07	3.75E-07	4.93E-07	5.83E-07	6.61E-07	7.14E-07	7.35E-07	7.46E-07	7.61E-07	7.69E-07
KIDNEYS	5.22E-06	7.40E-06	9.07E-06	1.16E-05	1.40E-05	1.59E-05	1.71E-05	1.76E-05	1.79E-05	1.82E-05	1.84E-05
LIVER	1.11E-05	1.57E-05	1.93E-05	2.48E-05	2.99E-05	3.39E-05	3.66E-05	3.76E-05	3.82E-05	3.90E-05	3.94E-05
MUSCLE	4.26E-07	6.10E-07	7.53E-07	9.73E-07	1.18E-06	1.34E-06	1.45E-06	1.49E-06	1.51E-06	1.54E-06	1.56E-06
OVARIES	4.47E-07	6.31E-07	7.74E-07	9.93E-07	1.20E-06	1.36E-06	1.46E-06	1.51E-06	1.53E-06	1.56E-06	1.58E-06
PANCREAS	4.35E-07	6.27E-07	7.74E-07	9.98E-07	1.21E-06	1.37E-06	1.48E-06	1.52E-06	1.55E-06	1.58E-06	1.60E-06
R MAR	4.67E-06	1.00E-05	1.64E-05	2.66E-05	3.60E-05	4.34E-05	4.84E-05	5.03E-05	5.14E-05	5.28E-05	5.36E-05
ENDOST	1.21E-05	2.64E-05	4.38E-05	7.12E-05	9.66E-05	1.17E-04	1.30E-04	1.36E-04	1.38E-04	1.42E-04	1.44E-04
SPLEEN	4.08E-07	5.83E-07	7.19E-07	9.29E-07	1.12E-06	1.28E-06	1.38E-06	1.42E-06	1.44E-06	1.47E-06	1.49E-06
TESTES	4.23E-07	6.03E-07	7.41E-07	9.53E-07	1.15E-06	1.30E-06	1.41E-06	1.45E-06	1.47E-06	1.50E-06	1.52E-06
THYMUS	4.27E-07	6.10E-07	7.50E-07	9.66E-07	1.17E-06	1.32E-06	1.43E-06	1.47E-06	1.49E-06	1.52E-06	1.54E-06
THYROID	4.25E-07	6.08E-07	7.49E-07	9.65E-07	1.17E-06	1.32E-06	1.43E-06	1.47E-06	1.50E-06	1.53E-06	1.54E-06
UTERUS	4.31E-07	6.13E-07	7.53E-07	9.67E-07	1.17E-06	1.32E-06	1.43E-06	1.47E-06	1.49E-06	1.52E-06	1.54E-06
PUL	1.23E-08	2.18E-08	3.22E-08	4.84E-08	6.35E-08	7.54E-08	8.34E-08	8.65E-08	8.92E-08	9.05E-08	9.18E-08

HIGH-LET DOSE RATE (MRAD/YEAR)

TIME (YEARS)	1.	3.	6.	12.	20.	30.	42.	50.	56.	70.	87.
TARGET											
S WALL	2.71E-13	2.71E-13	2.71E-13	2.71E-13	2.71E-13	2.71E-13	2.71E-13	2.71E-13	2.71E-13	2.71E-13	2.71E-13
SI WALL	1.02E-11	1.02E-11	1.02E-11	1.02E-11	1.02E-11	1.02E-11	1.02E-11	1.02E-11	1.02E-11	1.02E-11	1.02E-11
ULI WALL	7.55E-10	7.55E-10	7.55E-10	7.55E-10	7.55E-10	7.55E-10	7.55E-10	7.55E-10	7.55E-10	7.55E-10	7.55E-10
LLI WALL	1.06E-08	1.06E-08	1.06E-08	1.06E-08	1.06E-08	1.06E-08	1.06E-08	1.06E-08	1.06E-08	1.06E-08	1.06E-08
BL WALL	5.30E-07	8.00E-07	9.87E-07	1.27E-06	1.53E-06	1.74E-06	1.88E-06	1.94E-06	1.96E-06	2.00E-06	2.03E-06
KIDNEYS	1.32E-05	1.98E-05	2.44E-05	3.13E-05	3.78E-05	4.28E-05	4.63E-05	4.76E-05	4.83E-05	4.93E-05	4.98E-05
LIVER	2.79E-05	4.22E-05	5.21E-05	6.71E-05	8.10E-05	9.19E-05	9.93E-05	1.02E-04	1.04E-04	1.06E-04	1.07E-04
MUSCLE	1.06E-06	1.60E-06	1.97E-06	2.54E-06	3.07E-06	3.48E-06	3.76E-06	3.87E-06	3.93E-06	4.01E-06	4.05E-06
OVARIES	1.06E-06	1.60E-06	1.97E-06	2.54E-06	3.07E-06	3.48E-06	3.76E-06	3.87E-06	3.93E-06	4.01E-06	4.05E-06
PANCREAS	1.06E-06	1.60E-06	1.97E-06	2.54E-06	3.07E-06	3.48E-06	3.76E-06	3.87E-06	3.93E-06	4.01E-06	4.05E-06
R MAR	1.65E-06	3.00E-06	4.34E-06	6.44E-06	8.38E-06	9.91E-06	1.09E-05	1.14E-05	1.16E-05	1.19E-05	1.20E-05
ENDOST	2.11E-05	5.03E-05	8.52E-05	1.40E-04	1.91E-04	2.31E-04	2.59E-04	2.69E-04	2.75E-04	2.83E-04	2.87E-04
SPLEEN	1.02E-06	1.53E-06	1.89E-06	2.42E-06	2.92E-06	3.31E-06	3.58E-06	3.68E-06	3.74E-06	3.81E-06	3.85E-06
TESTES	1.06E-06	1.60E-06	1.97E-06	2.54E-06	3.07E-06	3.48E-06	3.76E-06	3.87E-06	3.93E-06	4.01E-06	4.05E-06
THYMUS	1.06E-06	1.60E-06	1.97E-06	2.54E-06	3.07E-06	3.48E-06	3.76E-06	3.87E-06	3.93E-06	4.01E-06	4.05E-06
THYROID	1.06E-06	1.60E-06	1.97E-06	2.54E-06	3.07E-06	3.48E-06	3.76E-06	3.87E-06	3.93E-06	4.01E-06	4.05E-06
UTERUS	1.06E-06	1.60E-06	1.97E-06	2.54E-06	3.07E-06	3.48E-06	3.76E-06	3.87E-06	3.93E-06	4.01E-06	4.05E-06
PUL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

30-YEAR GENETIC DOSE COMMITMENT (MRAD)...

LET	TESTES	OVARIES	AVERAGE
LOW	2.93E-05	3.05E-05	2.99E-05
HIGH	7.79E-05	7.79E-05	7.79E-05

Fig. I-2. Estimated dose rates to reference tissues at specified times after the beginning of continuous ²¹⁰Pb ingestion.

TOTAL COHORT (1.0F+E PERSONS) CANCER FATALITIES FROM LIFETIME PB-210 INHALATION
 AMAD = 1.00 , RESP CLEARANCE CLASS = W , FI = 0.200E 00
 FOR 1.00E 00 PCI/YR INTAKE

SUMMARY TABLE

CANCER	ADULT LATENCY PERIOD (YEARS)	ADULT PLATEAU PERIOD (YEARS)	RISK	LET	ADULT DEATH RATE (DTHS/ 1E6/MYR)/YR	70-YEAR DOSE RATE (MRAD/YR)	NUMBER OF PREMATURE DEATHS IN COHORT	AVERAGE YEARS OF LIFE LOST (YEARS)	TOTAL YEARS OF LIFE LOST (YEARS)	DECREASE IN LIFE EXPECTANCY (YEARS)	70-YEAR DOSE EQUIV- ALENT RATE (MREM/YR)	RISK EQUIVALENT FACTOR
P LUNG	2	25	AES	LOW	2.300-03	5.92E-05	1.410-05	2.660 01	3.750-04	3.750-04	3.82E-04	2.98E-04
				HIGH	4.400-02	1.61E-05	8.320-05	2.800 01	2.330-03	2.330-03		
ENDOST	5	30	AES	LOW	2.000-04	1.59E-04	3.470-06	2.460 01	8.550-05	8.550-10	6.52E-03	2.36E-03
				HIGH	2.000-03	3.18E-04	6.910-05	2.460 01	1.700-03	1.700-08		
PULMONARY	10	110	AES	LOW	3.000-03	3.01E-04	1.830-04	2.300 01	4.200-03	4.200-08	1.08E-02	5.54E-03
				HIGH	3.000-02	5.25E-04	3.190-03	2.300 01	7.330-02	7.330-07		
BREAST	15	110	AES	LOW	2.300-03	1.78E-06	5.060-07	1.980 01	1.000-05	1.000-10	1.48E-04	7.19E-06
				HIGH	2.300-03	7.29E-06	2.360-06	2.040 01	4.810-05	4.310-10		
LIVER	15	110	AES	LOW	9.000-04	4.37E-05	4.840-06	1.970 01	5.550-05	9.550-10	2.58E-03	9.51E-04
				HIGH	9.000-03	1.27E-04	1.440-04	1.980 01	2.850-03	2.350-08		
ST WALL	15	110	AES	LOW	5.000-04	1.07E-06	9.020-08	2.130 01	1.920-06	1.920-11	1.18E-06	1.09E-06
				HIGH	5.000-03	5.42E-09	4.630-09	2.120 01	5.830-08	9.330-13		
PANCREAS	15	110	AES	LOW	7.000-04	1.82E-06	1.570-07	1.980 01	3.110-06	3.110-11	1.48E-04	6.06E-05
				HIGH	7.000-03	7.29E-06	7.170-06	2.040 01	1.460-04	1.460-09		
LLI WALL	15	110	AES	LOW	4.000-04	4.04E-05	2.770-06	2.140 01	5.930-05	5.930-10	4.56E-05	4.25E-05
				HIGH	4.000-03	2.60E-07	1.780-07	2.130 01	3.790-06	3.790-11		
KIDNEYS	15	110	AES	LOW	2.000-04	2.35E-05	6.080-07	2.000 01	1.220-05	1.220-10	2.31E-03	9.87E-04
				HIGH	2.000-03	1.14E-04	3.360-05	2.060 01	6.950-04	6.950-09		
BL WALL	15	110	AES	LOW	2.000-04	8.68E-07	2.150-08	1.970 01	4.230-07	4.230-12	7.38E-05	3.02E-05
				HIGH	2.000-03	3.65E-06	1.020-06	2.040 01	2.090-05	2.090-10		
ULI WALL	15	110	AES	LOW	2.000-04	1.38E-05	4.730-07	2.140 01	1.010-05	1.010-10	1.53E-05	1.44E-05
				HIGH	2.000-03	7.79E-08	2.660-08	2.140 01	5.680-07	5.680-12		
SI WALL	15	110	AES	LOW	1.000-04	2.43E-06	4.140-08	2.130 01	8.810-07	8.810-12	2.68E-06	2.50E-06
				HIGH	1.000-03	1.24E-08	2.120-09	1.940 01	4.100-08	4.100-13		
OVARIES	15	110	AES	LOW	1.000-04	1.77E-06	2.190-08	1.960 01	4.310-07	4.310-12	1.49E-04	6.02E-05
				HIGH	1.000-03	7.29E-06	1.020-06	2.040 01	2.090-05	2.090-10		
TESTES	15	110	AES	LOW	1.000-04	1.72E-06	2.130-08	1.970 01	4.190-07	4.190-12	1.48E-04	6.01E-05
				HIGH	1.000-03	7.29E-06	1.020-06	2.040 01	2.090-05	2.090-10		
SPLEEN	15	110	AES	LOW	1.000-04	1.69E-06	2.100-08	1.960 01	4.110-07	4.110-12	1.75E-03	8.39E-04
				HIGH	1.000-03	8.72E-05	1.460-05	2.120 01	3.090-04	3.090-09		
UTERUS	15	110	AES	LOW	1.000-04	1.74E-06	2.150-08	1.970 01	4.240-07	4.240-12	1.48E-04	6.01E-05
				HIGH	1.000-03	7.29E-06	1.020-06	2.040 01	2.090-05	2.090-10		
THYMUS	15	110	AES	LOW	1.000-04	1.77E-06	2.200-08	1.960 01	4.310-07	4.310-12	1.48E-04	6.02E-05
				HIGH	1.000-03	7.29E-06	1.020-06	2.040 01	2.090-05	2.090-10		
THYROID	2	45	AES	LOW	4.000-04	1.75E-06	1.150-07	2.540 01	2.920-06	2.920-11	1.48E-04	7.58E-06
				HIGH	4.000-04	7.29E-06	5.270-07	2.650 01	1.390-05	1.390-10		
TOTAL (SOMATIC)							3.76E-03	2.30E 01	8.64E-02	8.64E-07		1.80E-03

30-YEAR GENETIC DOSE COMMITMENTS (MRAD):

LET	TESTES	OVARIES	AVERAGE
LOW	3.37E-05	3.48E-05	3.43E-05
HIGH	1.69E-04	1.69E-04	1.69E-04

Fig. I-3. Estimated risk due to continuous inhalation of ²¹⁰Pb.

TOTAL COHORT (1.0E+5 PERSONS) CANCER FATALITIES FROM LIFETIME PB-210 FI = 0.200E 00 FOR 1.00E 00 PCI/YR INTAKE												
SUMMARY TABLE												
CANCER	ADULT LATENCY PERIOD (YEARS)	ADULT PLATEAU PERIOD (YEARS)	RISK	LET	ADULT DEATH RATE (DTHS/ 1E6/MPAD/YR)	70-YEAR DOSE RATE (MPAD/YR)	NUMBER OF PREMATURE DEATHS IN COHORT	AVERAGE YEARS OF LIFE LOST (YEARS)	TOTAL YEARS OF LIFE LOST (YEARS)	DECREASE IN LIFE EXPECTANCY (YEARS)	70-YEAR DOSE EQUIV- ALENT RATE (MREM/YR)	RISK EQUIVALENT FACTOR
B MARROW	2	25	ABS	LOW	2.30D-03	5.28E-05	1.26D-05	2.66D 01	3.35D-04	3.35D-09	2.90E-04	2.17E-04
				HIGH	4.50D-02	1.19E-05	5.81D-05	2.71D 01	1.58D-03	1.58D-08		
ENDOST	5	30	ABS	LOW	2.00D-04	1.42E-04	3.11D-06	2.47D 01	7.66D-05	7.66D-10	5.80E-03	2.10E-03
				HIGH	2.00D-03	2.83E-04	6.15D-05	2.46D 01	1.51D-03	1.51D-08		
PULMONARY	10	110	ABS	LOW	3.00D-03	9.05E-08	3.59D-08	2.04D 01	7.32D-07	7.32D-12	9.05E-08	5.91E-08
				HIGH	0.0	0.0	0.0	0.0	0.0	0.0		
BREAST	15	110	ABS	LOW	2.30D-03	1.54E-06	4.36D-07	1.97D 01	6.59D-06	8.59D-11	8.17E-05	3.93E-06
				HIGH	2.30D-03	4.01E-06	1.13D-06	1.97D 01	2.24D-05	2.24D-10		
LIVER	15	110	ABS	LOW	9.00D-04	3.90E-05	4.33D-06	1.97D 01	6.55D-05	8.55D-10	2.16E-03	7.79E-04
				HIGH	9.00D-03	1.06E-04	1.17D-04	1.97D 01	2.31D-03	2.31D-08		
ST WALL	15	110	ABS	LOW	5.00D-04	2.04E-07	1.64D-08	2.09D 01	3.44D-07	3.44D-12	2.04E-07	1.89E-07
				HIGH	5.00D-03	2.71E-13	2.35D-13	2.15D 01	5.06D-12	5.06D-17		
PANCREAS	15	110	ABS	LOW	7.00D-04	1.58E-06	1.36D-07	1.97D 01	2.68D-06	2.68D-11	8.18E-05	2.96E-05
				HIGH	7.00D-03	4.01E-06	3.45D-06	1.97D 01	6.80D-05	6.80D-10		
LLI WALL	15	110	ABS	LOW	4.00D-04	1.75E-05	1.22D-06	2.15D 01	2.61D-05	2.61D-10	1.78E-05	1.76E-05
				HIGH	4.00D-03	1.06E-08	7.34D-09	2.14D 01	1.57D-07	1.57D-12		
KIDNEYS	15	110	ABS	LOW	2.00D-04	1.82E-05	4.51D-07	1.97D 01	8.91D-06	8.91D-11	1.00E-03	3.63E-04
				HIGH	2.00D-03	4.93E-05	1.21D-05	1.97D 01	2.39D-04	2.39D-09		
BL WALL	15	110	ABS	LOW	2.00D-04	7.61E-07	1.88D-08	1.95D 01	3.67D-07	3.67D-12	4.09E-05	1.48E-05
				HIGH	2.00D-03	2.00E-06	4.93D-07	1.97D 01	6.72D-06	9.72D-11		
ULT WALL	15	110	ABS	LOW	2.00D-04	3.73E-06	1.29D-07	2.14D 01	2.76D-06	2.76D-11	3.74E-06	3.71E-06
				HIGH	2.00D-03	7.55E-10	2.62D-10	1.24D 01	3.26D-09	3.26D-14		
SI WALL	15	110	ABS	LOW	1.00D-04	4.73E-07	7.83D-09	2.10D 01	1.65D-07	1.65D-12	4.73E-07	4.50E-07
				HIGH	1.00D-03	1.02E-11	1.76D-12	2.15D 01	3.79D-11	3.79D-16		
OVARIES	15	110	ABS	LOW	1.00D-04	1.56E-06	1.93D-08	1.96D 01	3.78D-07	3.78D-12	8.18E-05	2.94E-05
				HIGH	1.00D-03	4.01E-06	4.93D-07	1.97D 01	9.72D-06	9.72D-11		
TESTES	15	110	ABS	LOW	1.00D-04	1.50E-06	1.85D-08	1.96D 01	3.63D-07	3.63D-12	8.17E-05	2.94E-05
				HIGH	1.00D-03	4.01E-06	4.93D-07	1.97D 01	9.72D-06	9.72D-11		
SPLEEN	15	110	ABS	LOW	1.00D-04	1.47E-06	1.81D-08	1.96D 01	3.55D-07	3.55D-12	7.77E-05	2.80E-05
				HIGH	1.00D-03	3.81E-06	4.70D-07	1.97D 01	9.26D-06	9.26D-11		
UTERUS	15	110	ABS	LOW	1.00D-04	1.52E-06	1.88D-08	1.95D 01	3.67D-07	3.67D-12	8.17E-05	2.94E-05
				HIGH	1.00D-03	4.01E-06	4.93D-07	1.97D 01	9.72D-06	9.72D-11		
THYMUS	15	110	ABS	LOW	1.00D-04	1.52E-06	1.88D-08	1.95D 01	3.67D-07	3.67D-12	8.17E-05	2.94E-05
				HIGH	1.00D-03	4.01E-06	4.93D-07	1.97D 01	9.72D-06	9.72D-11		
THYROID	2	45	ABS	LOW	4.00D-04	1.53E-06	9.99D-08	2.54D 01	2.53D-06	2.53D-11	8.17E-05	4.28E-06
				HIGH	4.00D-04	4.01E-06	2.63D-07	2.54D 01	6.66D-06	6.66D-11		
TOTAL (SOMATIC)							2.79E-04	2.27E 01	6.35E-03	6.35E-08		1.34E-04
30-YEAR GENETIC DOSE COMMITMENTS (MPAD):												
LET	TESTES	OVARIES	AVERAGE									
LOW	2.93E-05	3.05E-05	2.99E-05									
HIGH	7.79E-05	7.79E-05	7.79E-05									

Fig. I-4. Estimated risk due to continuous ingestion of ^{210}Pb .

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APPENDIX II

RADRISK Source Code Listing

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C RADRISK

C-----
 C THE RADRISK CODE FOR ANALYSIS OF DOSIMETRY AND HEALTH EFFECTS
 C ASSOCIATED WITH INTERNALLY DEPOSITED RADIONUCLIDES IS BASICALLY A
 C SYNTHESIS OF ORNL'S INREM II (ORNL/NUREG/TM-84; KILLOUGH ET AL., 1978)
 C COMPUTER PROGRAM AND THE CAIRD (EPA 520/4-78-012; COOK ET AL., 1978)
 C CODE DEVELOPED BY THE EPA.

C RADRISK PROGRAM AUTHORS..

C D. E. DUNNING, JR., R. W. LEGGETT, AND M. G. YALCINTAS
 C HEALTH AND SAFETY RESEARCH DIVISION
 C OAK RIDGE NATIONAL LABORATORY
 C OAK RIDGE, TENNESSEE 37830

C INREM II PROGRAM AUTHORS..

C G. G. KILLOUGH, D. E. DUNNING, JR., AND J. C. PLEASANT
 C HEALTH AND SAFETY RESEARCH DIVISION
 C OAK RIDGE NATIONAL LABORATORY
 C OAK RIDGE, TENNESSEE 37830

C CAIRD PROGRAM AUTHORS..

C J. R. COOK, B. M. BUNGER, AND M. K. BARRICK
 C U. S. ENVIRONMENTAL PROTECTION AGENCY
 C OFFICE OF RADIATION PROGRAMS
 C CRITERIA AND STANDARDS DIVISION
 C WASHINGTON, D. C.

C-----
 C DOUBLE PRECISION NAMNUC,NAMSOU,NAMTRG
 C LOGICAL DEFAULT, LAST
 C REAL LMA,LMB,LMC,LMD,LME,LMF,LMG,LMH,LMI
 C COMMON /CASES/ NCASES,MODE(6),TEND(6),NINT(6),T(6,30),P(6,30),
 C \$ ISOL(6,20),AMAD(6),DEFAULT(6),FLUNG(6,9,20),TBLUNG(6,9,20),
 C \$ F1(6,20),GIFRAC(6,20,4)
 C COMMON /RADAT/ TP(20),BRANCH(20,20)
 C COMMON /NUMBRS/ NSPEC,NSOU,NTRG
 C COMMON /TGLM/ LMA(20),LMB(20),LMC(20),LMD(20),LME(20),
 C \$ LMF(20),LMG(20),LMH(20),LMI(20),
 C \$ FA(20),FB(20),FC(20),FD(20),FE(20),FF(20),FG(20),FH(20),FI(20)
 C COMMON /TGLMDF/ DLMA(3),DLMB(3),DLMC(3),DLMD(3),DLME(3),DLMF(3),
 C \$ DLMG(3),DLMH(3),DLMI(3),
 C \$ DFA(3),DFB(3),DFC(3),DFD(3),DFE(3),DFF(3),DFG(3),
 C \$ DFH(3),DFI(3)
 C COMMON /ORGDAT/ NCOMP(20,16),C(20,5,16),TB(20,5,16),
 C \$ F2PRIM(20,16)
 C COMMON /LIFTBL/ INLIFE

C INITIALIZE INDICATOR FOR INPUT OF REFERENCE LIFE TABLE DATA IN
 C SUBROUTINE RISK.
 C INLIFE=0

C SET LAST CARD INDICATOR.
 C LAST=.FALSE.

C USE ASSEMBLER SUBROUTINE PGMMASK TO SET PROGRAM MASK WHICH WILL
 C IGNORE UNDERFLOWS AND LOSS OF SIGNIFICANCE.
 C CALL PGMMASK(1,1,0,0)

C THE FOLLOWING ITERATION (INDEX IPAPNT) (1) READS DATA FOR
 C A PARENT RADIONUCLIDE AND ITS DAUGHTERS AND USER SPECIFICATIONS
 C FOR ONE OR MORE CASES (A CASE CONSISTS OF CALCULATING THE
 C DOSES RESULTING FROM AN INTAKE HISTORY OF THE PARENT, EITHER
 C BY INHALATION OR INGESTION), (2) PRINTS OUT THE PHYSICAL AND
 C METABOLIC DATA, AND (3) PERFORMS THE DOSE INTEGRATION AND
 C PRINTS OUT THE CASE INFORMATION AND THE RESULTS.

C *** EXIT FROM THE IPAPNT LOOP OCCURS WHEN SUBROUTINE INPUT DETECTS
 C THE END-OF-FILE AND RETURNS LAST=.TRUE.

C DO 100 IPAPNT=1,10000
 C

```

C CALL SUBROUTINE INPUT TO READ DATA AND CASES FOR THE NEXT CHAIN.
  CALL INPUT(LAST)
  IF(LAST) GO TO 200
C
C INVOKE SUBROUTINE OUTDAT TO PRINT PHYSICAL AND METABOLIC DATA
C FOR THE CHAIN.
  CALL OUTDAT
C
C CONVERT RADIOACTIVE HALF-LIVES TO DECAY RATE COEFFICIENTS AND
C CONVERT BIOLOGICAL HALF-TIMES TO REMOVAL COEFFICIENTS (1/DAYS)..
  DO 10 ISPEC=1,NSPEC
    IF(TR(ISPEC) .GT. 0.0) TR(ISPEC)=0.6931472/TR(ISPEC)
    NS=NSOU-6
    IF(NS.EQ.0) GO TO 10
    DO 10 IS=1,NS
      NC=NCOMP(ISPEC,IS)
      DO 10 IC=1,NC
        TEMP=TB(ISPEC,IC,IS)
        IF(TEMP .GT. 0.0) TB(ISPEC,IC,IS)=0.6931472/TEMP
    10 CONTINUE
C
C THE FOLLOWING LOOP HANDLES THE SEVERAL CASES.
  DO 70 ICASE=1,NCASES
C
C DETERMINE WHETHER THIS IS AN INHALATION CASE.
  IF(MODE(ICASE) .NE. 1) GO TO 60
C
C -----
C INHALATION CASE.
C -----
C
C THE FOLLOWING LOOP INDEXED BY ISPEC MOVES TO COMMON
C BLOCK /TGLM/ THE APPROPRIATE LUNG PARAMETERS FOR
C THE CURRENT CASE, WHERE SUBROUTINE DIFFUN WILL OBTAIN
C THEM. IN THE DEFAULT CASE, ARRAY ISOL CONTAINS
C CODES FOR THE SOLUBILITIES (D,W,Y), AND THE PARAMETERS
C WILL BE TAKEN FROM COMMON BLOCK /TGLMDF/, WHERE THEY
C WERE INITIALIZED IN A BLOCK DATA SUBROUTINE. IN THE
C NON-DEFAULT CASE, THE USER HAS SUPPLIED PARAMETERS.
C AND THESE ARE IN THE ARRAYS TBLUNG (HALF-TIMES IN DAYS)
C AND FLUNG. FIRST, HALF TIMES ARE CONVERTED TO REMOVAL COEFFICIENTS.
  DO 50 ISPEC=1,NSPEC
    IF(ISOL(ICASE,ISPEC) .LT. 4) GO TO 40
    DO 20 IPATH=1,9
      IF(TBLUNG(ICASE,IPATH,ISPEC) .GT. 0.0)
        TBLUNG(ICASE,IPATH,ISPEC)=0.6931472
        /TBLUNG(ICASE,IPATH,ISPEC)
    20 CONTINUE
C MOVE LUNG PARAMETERS TO COMMON BLOCK /TGLM/..
C NON-DEFAULT CASE..
    LMA(ISPEC)=TBLUNG(ICASE,1,ISPEC)
    FA(ISPEC)=FLUNG(ICASE,1,ISPEC)
    LMB(ISPEC)=TBLUNG(ICASE,2,ISPEC)
    FB(ISPEC)=FLUNG(ICASE,2,ISPEC)
    LMC(ISPEC)=TBLUNG(ICASE,3,ISPEC)
    FC(ISPEC)=FLUNG(ICASE,3,ISPEC)
    LMD(ISPEC)=TBLUNG(ICASE,4,ISPEC)
    FD(ISPEC)=FLUNG(ICASE,4,ISPEC)
    LME(ISPEC)=TBLUNG(ICASE,5,ISPEC)
    FE(ISPEC)=FLUNG(ICASE,5,ISPEC)
    LMF(ISPEC)=TBLUNG(ICASE,6,ISPEC)
    FF(ISPEC)=FLUNG(ICASE,6,ISPEC)
    LMG(ISPEC)=TBLUNG(ICASE,7,ISPEC)
    FG(ISPEC)=FLUNG(ICASE,7,ISPEC)
    LMH(ISPEC)=TBLUNG(ICASE,8,ISPEC)
    FH(ISPEC)=FLUNG(ICASE,8,ISPEC)
    LMI(ISPEC)=TBLUNG(ICASE,9,ISPEC)
    FI(ISPEC)=FLUNG(ICASE,9,ISPEC)
C
C BRANCH AROUND DEFAULT CASE.
  GO TO 60
C
C MOVE LUNG PARAMETERS TO COMMON BLOCK /TGLM/..
C DEFAULT CASE..
  40 CONTINUE
    IS=ISOL(ICASE,ISPEC)
    LMA(ISPEC)=DLMA(IS)

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      FA(ISPEC)=DFA(IS)
      LMB(ISPEC)=DLMB(IS)
      FB(ISPEC)=DFB(IS)
      LMC(ISPEC)=DLMC(IS)
      FC(ISPEC)=DFC(IS)
      LMD(ISPEC)=DLMD(IS)
      FD(ISPEC)=DFD(IS)
      LME(ISPEC)=DLME(IS)
      FE(ISPEC)=DFE(IS)
      LMF(ISPEC)=DLMF(IS)
      FF(ISPEC)=DFF(IS)
      LMG(ISPEC)=DLMG(IS)
      FG(ISPEC)=DFG(IS)
      LMH(ISPEC)=DLMH(IS)
      FH(ISPEC)=DFH(IS)
      LMI(ISPEC)=DLMI(IS)
      FI(ISPEC)=DFI(IS)
50      CONTINUE
C
C CALL INTERPOLATION SUBROUTINE INTP TO COMPUTE LUNG DEPOSITION
C FRACTIONS D3,D4,D5 IN /RESDP/ FROM AMAD(ICASE).
      55      CALL INTP(AMAD(ICASE),ICASE)
C-----
C END INHALATION CASE.
C-----
60      CONTINUE
C
C INVOKE SUBROUTINE DOSRUN TO PERFORM DOSE CALCULATIONS FOR
C THIS CASE. THE DOSE TO TARGET ORGAN ITRG FROM SOURCE ORGAN
C ISOU WILL BE STORED IN DOSE(ICASE,ITRG,ISOU) (REMS).
C FOR ISOU=NSOU+1, THE DOSES RESULT FROM THE 'REST OF BODY'
C COMPARTMENT. DOSE(ICASE,ITRG,NSOU+2) IS THE TOTAL DOSE TO
C TARGET ITRG.
      CALL DOSRUN(ICASE)
C
C END ICASE LOOP.
      70      CONTINUE
C
C USE SUBROUTINE OUTPUT TO PRINT OUT CASE INFORMATION AND
C RESULTS.
      CALL OUTPUT
C
C LOOK FOR COMMENTS AFTER NUCLIDE DATA GROUP. IF THERE
C ARE ANY, PRINT THEM. A CARD WITH 'S' IN COLUMN 1 ENDS
C THE DATA GROUP PLUS COMMENTS.
      CALL CMMNTS
C
C COMPUTE RISK ESTIMATES WITH SUBROUTINE CAIRD.
      CALL RISK
      INLIFE=INLIFE + 1
C
C END OF IPARNT LOOP.
      100      CONTINUE
C-----
C END OF INREM II.
C-----
200      CALL EXIT
      END
      BLOCK DATA

C
C THE FOLLOWING QUANTITIES ARE MASSES (G) OF THE
C
C SOURCE ORGANS.. LUNGS, RES. LYMPH, S CONT, SI CONT,
C ULI CONT, AND LLI CONT
C
C TARGET ORGANS.. LUNGS, RES. LYMPH, S WALL, SI WALL,
C ULI WALL, AND LLI WALL
C
      COMMON /MASSES/ SMASS(24),TMASS(27)
      DATA SMASS/1000., 15., 250., 400., 220., 135., 18*0.0/,
      $ TMASS/1000., 15., 150., 640., 210., 160., 21*0.0/
C
C THE NAMES OF THESE SPECIAL SOURCE AND TARGET TISSUES ARE
C INITIALIZED NEXT.

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C
  DOUBLE PRECISION NAMNUC,NAMSOU,NAMTRG
  COMMON /NAMES/ NAMNUC(20),NAMSOU(24),NAMTRG(27)
  DATA NAMSOU/8HLUNGS , 8HRES LYM , 8HS CONT ,
$ 8HSI CONT , 8HULI CONT, 8HLLI CONT, 18*8H /,
$ NAMTRG/8HLUNGS , 8HRES LYM , 8HS WALL ,
$ 8HSI WALL , 8HULI WALL, 8HLLI WALL, 21*8H /

C
C THE FOLLOWING QUANTITIES LMGI ARE TURNOVER RATES FOR THE
C G. I. TRACT SEGMENTS S, SI, ULI, LLI. THEY ARE BASED ON
C THE DOLPHIN AND EVE TRANSIT TIMES (HEALTH PHYS. 12, PP. 163-172
C (1966)). UNITS ARE RECIPROCAL DAYS.
C
  REAL LMGI, LMAB
  COMMON /GI/ LMGI(4), LMAB(20,4)
  DATA LMGI/24., 6., 1.846134, 1./

C
C NEXT ARE DEFAULT DATA FOR THE TASK GROUP LUNG MODEL.
C THE QUANTITIES LMA-LMI (RECIPROCAL DAYS) ARE CLEARANCE
C COEFFICIENTS FOR THE PATHWAYS A-I. FA-FI ARE DEPOSITION
C FRACTIONS ASSOCIATED WITH THESE PATHWAYS. THE INDEXING
C CORRESPONDS TO D=1, W=2, Y=3. THESE VALUES ARE USED WHEN
C DEFAULT IS SPECIFIED.
C
  REAL LMA, LMB, LMC, LMD, LME, LMF, LMG, LMH, LMI
  COMMON /TGLMDF/ LMA(3), LMB(3), LMC(3), LMD(3), LME(3), LMF(3),
$ LMG(3), LMH(3), LMI(3),
$ FA(3), FB(3), FC(3), FD(3), FE(3), FF(3), FG(3), FH(3), FI(3)
  DATA LMA/3*69.31472/,
$ FA/0.5, 0.1, 0.01/,
$ LMB/69.31472, 2*1.732868/,
$ FB/0.5, 0.9, 0.99/,
$ LMC/3*69.31472/,
$ FC/0.95, 0.5, 0.01/,
$ LMD/3*3.465736/,
$ FD/0.05, 0.5, 0.99/,
$ LME/1.386294, 1.386294E-2, 1.386294E-3/,
$ FE/0.8, 0.15, 0.05/,
$ LMF/0.0, 2*0.6931472/,
$ FF/0.0, 2*0.4/,
$ LMG/0.0, 1.386294E-2, 1.386294E-3/,
$ FG/0.0, 2*0.4/,
$ LMH/1.386294, 1.386294E-2, 1.386294E-3/,
$ FH/0.2, 0.05, 0.15/,
$ LMI/1.386294, 1.386294E-2, 6.931472E-4/,
$ FI/2*1.0, 0.9/
  END

  SUBROUTINE INPUT(LAST)
  DOUBLE PRECISION NAMNUC,NAMSOU,NAMTRG,NTOTAL,NAMEXC
  LOGICAL DEFAULT, LAST, EXFLAG
  DIMENSION DUMMY(3), F2PEX(20), CEX(20,5), TBEX(20,5), NCOEX(20)
  COMMON /RADAT/ TR(20), BRANCH(20,20)
  COMMON /ORGDAT/ NCOMP(20,16), C(20,5,16), TB(20,5,16),
$ F2PRIM(20,16)
  COMMON /NAMES/ NAMNUC(20), NAMSOU(24), NAMTRG(27)
  COMMON /MASSES/ SMASS(24), TMASS(27)
  COMMON /NUMBRS/ NSPEC, NSOU, NTRG
  COMMON /SFACT/ S(2,20,24,15)
  COMMON /LET/ NLET
  COMMON /CASES/ NCASES, NUDE(6), TEND(6), NINT(6), T(6,30), P(6,30),
$ ISOL(6,20), AMAD(6), DEFAULT(6), FLUNG(6,9,20), TBLUNG(6,9,20),
$ FI(6,20), GIPAC(6,20,4)
  COMMON /TYME/ TSTEP(6)
  COMMON /STEPS/ NSTEPS(6)
  COMMON /BONDEP/ INDBON
C INPUT CHANNEL
  DATA IN /5/
  DATA NTOTAL/8HTOTAL /
  DATA NAMEXC/8HEXCRET. /
C READ NUMBER OF NUCLIDES IN THE CHAIN, AND FOR EACH THE NAME
C AND PHYSICAL HALF-LIFE (DAYS).
  READ(IN,1000,END=80) NSPEC,NLET,INDBON,(NAMNUC(ISPEC),TR(ISPEC),
$ ISPEC=1,NSPEC)

```

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C NLET IS A FLAG TO INDICATE THE PRESENCE OF HIGH-LET RADIATION:
C NLET .LE. 1 INDICATES ONLY LOW-LET RADIATIONS ARE PRESENT.
C NLET .EQ. 2 INDICATES THE PRESENCE OF HIGH-LET.
  IF (NLET .LT. 1) NLET=1
C INDBON IS AN INDICATOR AS TO WHETHER THE NUCLIDE IS A SURFACE
C OR VOLUME DEPOSITOR IN BONE (USED FOR HIGH-LET DOSES ONLY).
C INDBON = 2 INDICATES SURFACE DEPOSITION;
C INDBON = 0 INDICATES VOLUME DEPOSITION.
C INITIALIZE MATRIX OF BRANCHING RATIOS TO ZERO.
  DO 10 ISPEC=1,NSPEC
    DO 10 JSPEC=1,NSPEC
      BRANCH(ISPEC,JSPEC)=0.0
  10 CONTINUE
  IF(NSPEC .EQ. 1) GO TO 20
C
C READ THE NUMBER NBR OF NON-ZERO BRANCHING RATIOS TO FOLLOW.
  READ(IN,1010) NBR
  DO 15 K=1,NBR
    READ(IN,1020) JSPEC,ISPEC,BRANCH(ISPEC,JSPEC)
  15 CONTINUE
C
C READ NUMBER NS OF SOURCE ORGANS OTHER THAN LUNGS, RES. LYMPH,
C S CONT, SI CONT, ULI CONT, AND LLI CONT. TOTAL BODY (ABSORBED) MUST
C BE THE FIRST OF THESE AND OTHER MUST BE THE LAST.
C THEN READ THE NAMES AND MASSES (G) OF EACH.
C THE CHARACTERS IN CARD COLUMNS 11-22 ARE READ INTO THE ARRAY
C DUMMY. IF THESE ARE NON-BLANK, A PROMPT EXCRETION FUNCTION
C IS ASSUMED TO BE INCLUDED FOR EACH SPECIES BUT NOT COUNTED IN THE
C INDICATED NUMBER OF SOURCE ORGANS.
  20 CONTINUE
  READ(IN,1030) NS,DUMMY,(NAMSOU(ISOU+6),SMASS(ISOU+6),ISOU=1,NS)
  EXFLAG=.FALSE.
  IF(ICOMPA(DUMMY,12H ,12) .NE. 0) EXFLAG=.TRUE.
C
C READ NUMBER NT OF TARGET ORGANS OTHER THAN LUNGS, RES. LYMPH,
C S WALL, SI WALL, ULI WALL, AND LLI WALL. TOTAL BODY MUST BE
C THE FIRST OF THESE. THEN READ THE NAMES AND MASSES (G).
  READ(IN,1030) NT,DUMMY,(NAMTRG(ITRG+6),TMASS(ITRG+6),ITRG=1,NT)
  NSOU=NS+6
  NTRG=NT+6
  NSOU1=NSOU+1
  NAMSOU(NSOU1)=NTOTAL
C
C FOR EACH SPECIES IN THE CHAIN, READ S-FACTORS AND METABOLIC
C DATA FOR ORGANS OTHER THAN RESPIRATORY.
  DO 40 ISPEC=1,NSPEC
C
C FOR EACH SOURCE ORGAN (OTHER THAN RESPIRATORY OR G. I. TRACT)
C READ (1) FRACTIONAL TRANSFER F2-PRIME FROM BLOOD TO THE ORGAN, AND
C (2) NUMBER OF EXPONENTIAL COMPARTMENTS, AND FOR EACH A
C FRACTIONAL DEPOSITION COEFFICIENT AND A BIOLOGICAL HALF-TIME
C (DAYS).
    DO 30 ISOU=1,NS
      READ(IN,1050) F2PRIM(ISPEC,ISOU),NC,(C(ISPEC,IC,ISOU),
      $ TB(ISPEC,IC,ISOU),IC=1,NC)
      NCOMP(ISPEC,ISOU)=NC
      IF(ISOU .EQ. 1 .AND. EXFLAG)
      $ READ(IN,1050) F2PEX(ISPEC),NC,(CEX(ISPEC,IC),
      $ TBEX(ISPEC,IC),IC=1,NC)
      IF(ISOU .EQ. 1 .AND. EXFLAG) NCOEX(ISPEC)=NC
C THE TWO PRECEDING STATEMENTS READ DATA FOR PROMPT EXCRETION FUNCTIONS
C WHEN THESE ARE PRESENT. SUCH DATA ARE INSERTED IN THE DECK
C IMMEDIATELY AFTER THE TOTAL BODY (ABSORBED) RETENTION FUNCTIONS
C IN THE SAME FORMAT.
    30 CONTINUE
C
C READ MATRIX OF S-FACTORS FOR THE CURRENT SOURCES AND TARGETS.
C REQUIRED INDEXING FOR SPECIAL ORGANS IS SHOWN BELOW..
C
C INDEX SOURCE INDEX TARGET
C 1 LUNGS 1 LUNGS
C 2 RES LYM 2 RES LYM
C 3 S CONT 3 S WALL
C 4 SI CONT 4 SI WALL
C 5 ULI CONT 5 ULI WALL
C 6 LLI CONT 6 LLI WALL
C 7 TOT BODY 7 TOT BODY
C NSOU+1 OTHER

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C
DO 36 ILET=1,NLET
DO 35 ITRG=1,NTRG
  READ(IN,1040)(S(ILET,ISPEC,ITRG,ISOU),ISOU=1,NSOU)
35  CONTINUE
36  CONTINUE
C
C END OF ISPEC LOOP.
40  CONTINUE
  IF(.NOT. EXFLAG) GO TO 5200
-----
C THE FOLLOWING BLOCK OF STATEMENTS (WITH NUMBERS IN 5000S) IS
C EXECUTED IF AND ONLY IF PROMPT EXCRETION DATA HAVE BEEN READ IN.
C THESE STATEMENTS REARRANGE THE ARRAYS SO THAT THE EXCRETION
C FUNCTIONS WILL BE DISPLAYED BEFORE THE ORGAN RETENTION FUNCTIONS
C (SOURCE INDEX 8). S-FACTORS FOR TOTAL BODY AS SOURCE ARE USED
C FOR THESE EXCRETION FUNCTIONS.
  NAMSOU(NSOU+2)=NAMSOU(NSOU+1)
  IF(NS .EQ. 1) GO TO 5035
DO 5030 IS=2,NS
  K=NS-IS+2
  NAMSOU(K+7)=NAMSOU(K+6)
  SMASS(K+7)=SMASS(K+6)
DO 5020 ISPEC=1,NSPEC
  F2PRIM(ISPEC,K+1)=F2PRIM(ISPEC,K)
  NCOMP(ISPEC,K+1)=NCOMP(ISPEC,K)
  NC=NCOMP(ISPEC,K)
DO 5015 IC=1,NC
  C(ISPEC,IC,K+1)=C(ISPEC,IC,K)
  TB(ISPEC,IC,K+1)=TB(ISPEC,IC,K)
5015  CONTINUE
5020  CONTINUE
5030  CONTINUE
5035  CONTINUE
DO 5061 ILET=1,NLET
DO 5060 IS=8,NSOU
  K=NSOU-IS+8
DO 5050 ISPEC=1,NSPEC
DO 5040 ITRG=1,NTRG
  S(ILET,ISPEC,ITRG,K+1)=S(ILET,ISPEC,ITRG,K)
5040  CONTINUE
5050  CONTINUE
5060  CONTINUE
5061  CONTINUE
  NAMSOU(8)=NAMEXC
DO 5100 ISPEC=1,NSPEC
  F2PRIM(ISPEC,2)=F2PEX(ISPEC)
  NCOMP(ISPEC,2)=NCOEX(ISPEC)
  NC=NCOMP(ISPEC,2)
DO 5070 IC=1,NC
  C(ISPEC,IC,2)=CEX(ISPEC,IC)
  TB(ISPEC,IC,2)=TBEX(ISPEC,IC)
5070  CONTINUE
DO 5081 ILET=1,NLET
DO 5080 ITRG=1,NTRG
  S(ILET,ISPEC,ITRG,8)=S(ILET,ISPEC,ITRG,7)
5080  CONTINUE
5081  CONTINUE
5100  CONTINUE
  NS=NS+1
  NSOU=NSOU+1
  NSOU1=NSOU1+1
C
C END OF SPECIAL SECTION FOR PROMPT EXCRETION.
-----
5200 CONTINUE
C
C READ CONTROL INFORMATION. FIRST THE NUMBER OF CASES. THEN FOR
C EACH CASE (1) THE EXPOSURE MODE (G FOR INGESTION, H FOR INHALATION),
C (2) THE TIME (DAYS) FOR ENDING INTEGRATION, (3) THE INTAKE RATE
C FUNCTION (MICROCURIES/DAY), AND (4) OTHER INFORMATION SPECIFIC TO
C THE MODE OF INTAKE.
  READ(IN,1010) NCASES
DO 70 ICASE=1,NCASES
  READ(IN,1080) MODE(ICASE),TEND(ICASE),TSTEP(ICASE),NSTEPS(ICASE)
  IF(TSTEP(ICASE) .EQ. 0.0) TSTEP(ICASE)=365.0
  IF(NSTEPS(ICASE) .EQ. 0) NSTEPS(ICASE)=50
  IF(ICOMPA(MODE(ICASE),1HH,1) .EQ. 0) GO TO 41

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      MODE(ICASE)=2
      GO TO 42
41     MODE(ICASE)=1
42     CONTINUE
C
C READ NUMBER OF TIME INTERVALS FOR INTAKE FUNCTION. THEN FOR
C EACH INTERVAL READ THE LEFT ENDPOINT (DAYS) AND THE INTAKE
C RATE (MICROCURIES/DAY) DURING THAT INTERVAL. THE FIRST TIME
C SHOULD BE ZERO. THE ENDPOINT OF THE LAST INTERVAL IS THE
C END OF THE INTEGRATION INTERVAL.
      READ(IN,1090) NI,(T(ICASE,INT),P(ICASE,INT),INT=1,NI)
      NINT(ICASE)=NI
C
C IF EXPOSURE MODE IS INGESTION, BRANCH AROUND LUNG PARAMETER
C INPUTS.
      IF(MODE(ICASE) .EQ. 2) GO TO 66
C
C INPUT INHALATION PARAMETERS..
C
C READ PARTICLE SIZE (MICROMETERS).
      READ(IN,1040) AMAD(ICASE)
C
C DETERMINATION OF LUNG CLEARANCE PARAMETERS AND G. I. UPTAKE
C FRACTIONS. FOR EACH SPECIES, A LITERAL FLAG IS READ INTO
C ISOL. IF IT IS 'D', 'W', OR 'Y', THE APPROPRIATE DEFAULT
C LUNG PARAMETERS ARE USED FOR THE SPECIES. OTHERWISE, SPECIAL
C PARAMETERS FOR THE LUNG ARE READ. THE FLAG VALUES ARE STORED
C IN ARRAY ISOL AS FOLLOWS..
C
C     ISOL(ICASE,ISPEC) = 1 FOR 'D'
C                       = 2 FOR 'W'
C                       = 3 FOR 'Y'
C                       = 4 FOR 'SPECIAL CASE'
C
      DO 60 ISPEC=1,NSPEC
      READ(IN,1080) ISOL(ICASE,ISPEC)
C
C CONVERT LITERAL TO NUMERIC CODE.
      IF(ICOMPA(ISOL(ICASE,ISPEC),IHD,1) .EQ. 0)
      $     GO TO 45
      IF(ICOMPA(ISOL(ICASE,ISPEC),IHW,1) .EQ. 0)
      $     GO TO 46
      IF(ICOMPA(ISOL(ICASE,ISPEC),IHY,1) .EQ. 0)
      $     GO TO 47
C OTHERWISE..
      GO TO 48
45     ISOL(ICASE,ISPEC)=1
      GO TO 50
46     ISOL(ICASE,ISPEC)=2
      GO TO 50
47     ISOL(ICASE,ISPEC)=3
      GO TO 50
48     ISOL(ICASE,ISPEC)=4
50     CONTINUE
C
C IF SPECIAL LUNG PARAMETERS ARE TO BE READ, READ THEM.
      IF(ISOL(ICASE,ISPEC) .LT. 4) GO TO 55
      READ(IN,1040)(TBLUNG(ICASE,IPATH,ISPEC),
      $     FLUNG(ICASE,IPATH,ISPEC),IPATH=1,9)
C
C READ G. I. UPTAKE FRACTION F1.
55     CONTINUE
      READ(IN,1040) F1(ICASE,ISPEC),(GIFRAC(ICASE,ISPEC,ISEG),
      $     ISEG=1,4)
      DO 56 ISEG=1,4
      IF(GIFRAC(ICASE,ISPEC,ISEG) .NE. 0.0) GO TO 60
56     CONTINUE
      GIFRAC(ICASE,ISPEC,2)=F1(ICASE,ISPEC)
60     CONTINUE
C
C END OF INPUT FOR INHALATION CASE. BRANCH AROUND
C INGESTION-CASE INPUTS. TO END OF ICASE LOOP.
      GO TO 70
C
C READ G. I. UPTAKE FRACTIONS F1 FOR INGESTION CASE.
66     DO 69 ISPEC=1,NSPEC
      READ(IN,1040) F1(ICASE,ISPEC),(GIFRAC(ICASE,ISPEC,ISEG),

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      $      ISEG=1,4)
      DO 67 ISEG=1,4
      IF(GIFRAC(ICASE,ISPEC,ISEG) .NE. 0.0) GO TO 69
67      CONTINUE
      GIFRAC(ICASE,ISPEC,2)=F1(ICASE,ISPEC)
69      CONTINUE
C
C END OF ICASE LOOP.
70      CONTINUE
      RETURN
C
C SIGNAL EXIT IN CASE END-OF-FILE CARD IS DETECTED BY FIRST READ
C STATEMENT.
80      LAST=.TRUE.
      RETURN
C
C FORMAT STATEMENTS..
1000      FORMAT(3I2/(A8,2X,E10.0))
1010      FORMAT(I2)
1020      FORMAT(2I2,E10.0)
1030      FORMAT(12,8X,3A4/(4(A8,2X,E10.0)))
1040      FORMAT(8E10.0)
1050      FORMAT(E10.0,I2/(8E10.0))
1080      FORMAT(A2,2E10.0,I4)
1090      FORMAT(I2/(8E10.0))
1100      FORMAT(20A2)
      END

SUBROUTINE OUTDAT
C PRINTS THE FOLLOWING INPUT DATA:
C (1) PHYSICAL AND METABOLIC PARAMETERS FOR DOSIMETRICALLY SIGNIFICANT
C PROGENY FOR THE GIVEN NUCLIDE
C (2) S FACTORS FOR ALL SOURCE AND TARGET ORGANS FOR EACH SPECIES IN
C THE NUCLIDE CHAIN
      INTEGER OUT,OUT3
      DOUBLE PRECISION NAMNUC,NAMSOU,NAMTRG
      COMMON /RADAT/ TR(20),BRANCH(20,20)
      COMMON /ORGDAT/ NCOMP(20,16),C(20,5,16),TB(20,5,16),
      $      F2PRIM(20,16)
      COMMON /NAMES/ NAMNUC(20),NAMSOU(24),NAMTRG(27)
      COMMON /NUMBERS/ NSPEC,NSOU,NTRG
      COMMON /SFACT/ S(2,20,24,15)
      COMMON /LET/ NLET
C OUTPUT CHANNEL
      DATA OUT /6/
      DATA OUT3 /16/
C
C PRINT HEADING
      WRITE(OUT,2000) NAMNUC(1)
C FOR EACH NUCLIDE IN THE CHAIN, PRINT ITS NAME AND RADIOACTIVE HALF-
C LIFE
      DO 100 ISPEC=1,NSPEC
      100      WRITE (OUT,2010) NAMNUC(ISPEC),TR(ISPEC)
      IF (NSPEC.EQ.1) GO TO 110
C PRINT HEADING FOR BRANCHING RATIOS
      WRITE (OUT,2020)
C PRINT NONZERO BRANCHING RATIOS
      DO 110 JSPEC=1,NSPEC
      DO 110 ISPEC=1,NSPEC
      IF (BRANCH(ISPEC,JSPEC) .NE. 0.0)
      $      WRITE (OUT,2030) NAMNUC(JSPEC),NAMNUC(ISPEC),
      $      BRANCH(ISPEC,JSPEC)
      110      CONTINUE
C
C PRINT HEADING FOR BLOOD TRANSFER FRACTIONS, COMPARTMENT DEPOSITION
C FRACTIONS, AND COMPARTMENT BIOLOGICAL HALF-TIMES.
      WRITE (OUT3,2040)
C
C FOR EACH SOURCE ORGAN AND FOR EACH NUCLIDE IN THE CHAIN,
C PRINT BLOOD TRANSFER FRACTIONS, COMPARTMENTAL DEPOSITION FRACTIONS,
C AND COMPARTMENTAL BIOLOGICAL HALF-TIMES.
      NS=NSOU-6
      DO 120 ISOU=1,NS
      WRITE (OUT3,2050) NAMSOU(ISOU+6),NAMNUC(1),F2PRIM(1,ISOU),

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$ C(1,1,ISOU),TB(1,1,ISCU)
NCOM=NCOMP(1,ISOU)
IF (NCOM.EQ.1) GO TO 121
DO 122 IC=2,NCOM
122 WRITE (OUT3,2060) C(1,IC,ISOU),TB(1,IC,ISOU)
121 IF (NSPEC.EQ.1) GO TO 120
DO 123 ISPEC=2,NSPEC
WRITE (OUT3,2070) NAMNUC(ISPEC),F2PRIM(ISPEC,ISOU),
$ C(ISPEC,1,ISOU), TB(ISPEC,1,ISOU)
NCOMPA=NCOMP(ISPEC,ISOU)
IF (NCOMPA.EQ.1) GO TO 123
DO 124 ICOM=2,NCOMPA
124 WRITE (OUT3,2080) C(ISPEC,ICOM,ISOU),TB(ISPEC,ICOM,ISOU)
123 CONTINUE
120 CONTINUE
C
C PRINT S FACTORS FOR ALL SOURCES, TARGETS, AND NUCLIDES IN THE CHAIN
C
DO 131 ISPEC=1,NSPEC
DO 130 ILET=1,NLET
IFIRST=1
LAST=11
IF (NSOU .LT. LAST) LAST=NSOU
ISPEC1=ISPEC
CALL PRINTS(ILET,IFIRST,LAST,ISPEC1)
IF (LAST .EQ. NSOU) GO TO 130
IFIRST=12
LAST=21
IF (NSOU .LT. LAST) LAST=NSOU
CALL PRINTS(ILET,IFIRST,LAST,ISPEC1)
IF (LAST .EQ. NSOU) GO TO 130
IFIRST=22
LAST=24
IF (NSOU .LT. LAST) LAST=NSOU
CALL PRINTS(ILET,IFIRST,LAST,ISPEC1)
130 CONTINUE
131 CONTINUE
C
RETURN
C FORMAT STATEMENTS
C
2000 FORMAT('1RADIONUCLIDE: ',A8,' ',130(' ')/' PHYSICAL AND METABOLI',
$ 'C PARAMETERS FOR DOSIMETRICALLY SIGNIFICANT PROGENY: '///' ',
$ T15,'RADIOACTIVE'/' ',T16,'HALF-LIFE'/' NUCLIDE',T17,
$ '(DAYS)')
2010 FORMAT(' ',A8,T15,1PG10.4)
2020 FORMAT('0BRANCHING RATICS:',T21,'FROM',T31,'TO',T41,
$ 'FRACTION')
2030 FORMAT(' ',T21,A8,T31,A8,T40,1PG10.4)
2040 FORMAT('0',T25,'BLOOD',T59,'COMPARTMENT'/' ',T25,'TRANSFER',
$ T41,'COMPARTMENT',T59,'BIOLOGICAL'/' ',T25,'FRACTION',
$ T41,'DEPOSITION',T59,'HALF-TIME'/' ORGAN',T14,'NUCLIDE',
$ T25,'F2-PRIME',T41,'FRACTION',T60,'(DAYS)')
2050 FORMAT(' ',A8,T14,A8,T25,1PG9.3,T41,1PG10.3,T60,1PG9.3)
2060 FORMAT(' ',T41,1PG10.3,T60,1PG9.3)
2070 FORMAT(' ',T14,A8,T25,1PG9.3,T41,1PG10.3,T60,1PG9.3)
2080 FORMAT(' ',T41,1PG10.3,T60,1PG9.3)
END
C
C
SUBROUTINE PRINTS(ILET,IFIRST,LAST,ISPEC)
C AFTER PRINTING A HEADING AND THE NAMES OF SOURCES (IFIRST TO LAST)
C THIS SUBROUTINE PRINTS S-FACTORS FOR ALL TARGET ORGANS FOR
C THESE SOURCES.
C
C ILET INDICATES HIGH OR LOW LET RADIATION: ILET=1 DENOTES LOW LET
C RADIATION, ILET=2 DENOTES HIGH LET.
C
INTEGER OUT,OUT3
DOUBLE PRECISION NAMNUC,NAMSOU,NAMTRG
COMMON /NAMES/ NAMNUC(20),NAMSOU(24),NAMTRG(27)
COMMON /NUMBR/ NSPEC,NSOU,NTRG
COMMON /SFACT/ S(2,20,24,15)
C OUTPUT CHANNEL
DATA OUT /6/
DATA OUT3/16/
C PRINT HEADING

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      IF (ILET .EQ. 1) WRITE (OUT3,1000) NAMNUC(ISPEC)
      IF (ILET .EQ. 2) WRITE (OUT3,1001) NAMNUC(ISPEC)
C
C PRINT NAMES OF SOURCES
      IF(IFIRST .EQ. 1) GO TO 110
      WRITE(OUT3,1010) (NAMSOU(ISOU),ISOU=IFIRST, LAST)
C
C PRINT S-FACTORS FOR THIS SPECIES FOR SOURCE ORGANS IFIRST TO LAST
C AND FOR ALL TARGET ORGANS
      DO 100 ITRG=1,NTRG
      WRITE(OUT3,1020)NAMTRG(ITRG),(S(ILET,ISPEC,ITRG,ISOU),ISOU=IFIRST,
      $ LAST)
      100 CONTINUE
      GO TO 120
      110 WRITE(OUT3,1010)(NAMSOU(ISOU),ISOU=1,6),(NAMSOU(ISOU),ISOU=8,LAST)
      DO 120 ITRG=1,NTRG
      WRITE(OUT3,1020) NAMTRG(ITRG),(S(ILET,ISPEC,ITRG,ISOU),ISOU=1,6),
      $ (S(ILET,ISPEC,ITRG,ISCU),ISOU=8,LAST)
      120 CONTINUE
C
      RETURN
C
C FORMAT STATEMENTS
C
1000 FORMAT(//',T37,'LOW-LET S FACTORS (RAD/MICROCURIE-DAY) FOR ',A8/
      $ '0TARGET',T55,'SOURCE ORGANS',// 'ORGANS')
1001 FORMAT(//',T37,'HIGH-LET S FACTORS (RAD/MICROCURIE-DAY) FOR ',
      $ A8/'0TARGET',T55,'SOURCE ORGANS',// 'ORGANS')
1010 FORMAT('0',T14,A8,9(3X,A8))
1020 FORMAT(' ',A8,T13,E10.3,9(X,E10.3))
C
      END

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      SUBROUTINE INTP(AMAD,ICASE)
C
C COMPUTES LUNG DEPOSITION FRACTIONS D3, D4, AND D5 AS A FUNCTION
C OF AMAD (ACTIVITY MEDIAN AERODYNAMIC DIAMETER)(MICRONS).
C THE FUNCTIONS EXPRESSING THE RELATIONSHIPS BETWEEN THE LUNG
C FRACTIONS AND AMAD VALUES ARE THOSE PRESENTED IN WASH-1400.
C
      LOGICAL FLAG
      COMMON /RESPD/ D3,D4,D5
      COMMON /ALERT/ FLAG(6)
      P(T)=1.0-0.5*( (((0.015527*T+.000344)*T+.115194)*T+.196854)*T
      $ +1.0)**(-4)
      PPT(W)=-((W-((.010328*W+.802853)*W+2.515517)/(((.001308*W
      $ +.189269)*W+1.432788)*W+1.0))
      WW(X)=SQRT(-2.0*ALOG(X))
      DO 1 J=1,6
      1 FLAG(J)=.FALSE.
C FLAG IS A WARNING INDICATOR TO SIGNAL THAT THE GIVEN VALUE OF
C AMAD EXCEEDS THE RANGE FOR WHICH THE FUNCTIONAL RELATIONSHIP IS KNOWN.
C IN SUCH A CASE, THE BOUNDARY VALUE IS SUBSTITUTED FOR THE GIVEN
C AMAD.
      IF(AMAD .GT. 0.0) GO TO 2
      D3=0.02
      D4=0.04
      D5=0.94
      RETURN
      2 DO 100 I=1,3
      IF(I .GT. 1) GO TO 15
C NASAL-PHARYNX
      IF(AMAD .LT. 0.2) GO TO 5
      GO TO 10
      5 U0=-0.698970
      U1=-1.000
      T0=PPT(WW(0.05))
      T1=PPT(WW(0.10))
      IF(AMAD .GE. 0.1) GO TO 50
      AMAD=.1
      FLAG(ICASE)=.TRUE.
      GO TO 50
      10 U0=-0.698970
      U1=0.301030
      T0=PPT(WW(0.05))

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      T1=PPT(WW(0.50))
      IF(AMAD .LE. 20.0) GO TO 50
      AMAD=20.0
      FLAG(ICASE)=.TRUE.
      GO TO 50
15  CONTINUE
      IF(I .GT. 2) GO TO 35
C   TRACHEO-BRONCHIAL REGION
      IF(AMAD .LT. 0.2) GO TO 20
      IF(AMAD .GT. 10.0) GO TO 30
      D4=0.08
      GO TO 100
20  U0=-0.698970
      U1=-1.0
      T0=PPT(WW(0.08))
      T1=PPT(WW(0.17))
      IF(AMAD .GE. 0.1) GO TO 50
      AMAD=0.1
      FLAG(ICASE)=.TRUE.
      GO TO 50
30  U0=1.0
      U1=1.30130
      T0=PPT(WW(0.08))
      T1=PPT(WW(0.03))
      IF(AMAD .LE. 20.0) GO TO 50
      AMAD=20.0
      FLAG(ICASE)=.TRUE.
      GO TO 50
35  CONTINUE
C   PULMONARY REGION
      IF(AMAD .LT. 10.) GO TO 40
      GO TO 45
40  U0=1.0
      U1=-0.698970
      T0=PPT(WW(0.05))
      T1=PPT(WW(0.5))
      IF(AMAD .GE. 0.1) GO TO 50
      AMAD=0.1
      FLAG(ICASE)=.TRUE.
      GO TO 50
45  U0=1.0
      U1=1.301030
      T0=PPT(WW(0.05))
      T1=PPT(WW(0.02))
      IF(AMAD .LE. 20.0) GO TO 50
      AMAD=20.0
      FLAG(ICASE)=.TRUE.
50  T=T0+(T1-T0)/(U1-U0)*(ALOG10(AMAD)-U0)
      IF(T .GE. 0.0) X=P(T)
      IF(T .LT. 0.0) X=1.0-P(-T)
      IF(I .EQ. 1) D3=X
      IF(I .EQ. 2) D4=X
      IF(I .EQ. 3) D5=X
100 CONTINUE
      RETURN
      END

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      SUBROUTINE DOSPUN(ICASE)
      DOUBLE PRECISION NAMNUC,NAMSOU,NAMTRG
      REAL AWIGL(20,27),ALEVEL(20,27),LMR,TIME(11),REGMAS(3)
      REAL LMA,LMB,LMC,LMD,LME,LMF,LMG,LMH,LMI
      REAL LMLUNG,LMRI,LMBAB,LMBDAB
      REAL LUNDOS
      REAL AGENET(20,27)
C*****
      REAL AW(20,12)
C*****
      LOGICAL SNP,STB1,SP,SL,STB2,SGI,SEND,STEADY
      COMMON /GENETC/ DOSTES(2,6),DOSOV(2,6),DOSGON(2,6)
      COMMON /PERCNT/ PCTDOS(2,6,27,13),PCTDRT(2,6,27,13)
      COMMON /TGLM/ LMA(20),LMB(20),LMC(20),LMD(20),LME(20),
      $ LMF(20),LMG(20),LMH(20),LMI(20),
      $ FA(20),FB(20),FC(20),FD(20),FE(20),FF(20),FG(20),
      $ FH(20),FI(20)

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COMMON /PADAT/ LMP(20),ERANCH(20,20)
COMMON /SWITCH/ SNP,STB1,SP,SL(2),STB2(2),SG1
COMMON /LEVELS/ YNP(20,2),Y1TB(20,2),Y2TB(20,2),
$ YP(20,4),YL(20,2),YS(20),YSI(20),YULI(20),
$ YLLI(20),YORG(20,5,16)
COMMON /CUMACT/ YNPW(20,2),Y1TBW(20,2),Y2TBW(20,2),
$ YPW(20,4),YLW(20,2),YSW(20),YSIW(20),YULIW(20),
$ YLLIW(20),YORGW(20,5,16)
COMMON /NUMBRS/ NSPEC,NSOU,NTRG
COMMON /NAMES/ NAMNUC(20),NAMSOU(24),NAMTRG(27)
COMMON /CASES/ NCASES,MODE(6),TEND(6),NINT(6),TI(6,30),
$ P(6,30),ISOL(6,20),AMAD(6),DEFAULT(6),FLUNG(6,9,20),
$ LMLUNG(6,9,20),F1(6,20),GIFRAC(6,20,4)
COMMON /TYME/ TSTEP(6)
COMMON /HALGES/ JCASE
COMMON /ORGDAT/ NCOMP(20,16),C(20,5,16),LMBDAB(20,5,16),
$ F2PRIM(20,16)
COMMON /DOSES/ DOSE(2,6,24,15),DOSRAT(2,11,6,27),DOSTIM(11)
COMMON /SFACT/ S(2,20,24,15)
COMMON /LET/ NLET
COMMON /NUMTIM/ NTIMFS
COMMON /STEPS/ NSTEPS(6)
COMMON /GI/ LMG1(4),LMAB(20,4)
COMMON /LUNGRG/ LUNDOS(2,6,3)
DATA TIME/365.0,1095.0,2190.0,4380.0,7300.0,10950.0,15330.0,
$ 18250.0,20440.0,22550.0,31755.0/
DATA REGMAS/32.0,40.0,570.0/

C
C NOTIFY SUBROUTINES HAL AND GES WHICH CASE IS CURRENT
C THROUGH COMMON BLOCK /HALGES/ (HAL RETURNS THE INTAKE
C RATE BY INHALATION, GES BY INGESTION).
C JCASE=ICASE

C
C COMPUTE NUMBER OF TIME STEPS (NSTEPS) INTO WHICH THE INTEGRATION
C INTERVAL IS TO BE SUBDIVIDED.
C
C NUMBER OF STEPS IS FIXED FOR THIS VERSION OF DOSRUN (EPA) BY THE
C VARIABLE NSTEPS(ICASE).
C
C NTIMES IS THE NUMBER OF TIMES FOR WHICH DOSE RATES ARE TO BE
C COMPUTED. THE TIMES ARE SPECIFIED IN THE ARRAY TIME(NTIMES).
C THE EPA CAIRD PROGRAM ACCEPTS A MAXIMUM OF 9 DOSE RATES. IN
C ADDITION TO THE 9 DOSE RATES SELECTED FOR USE IN THAT PROGRAM,
C WE WILL CALCULATE THE DOSE RATES AT 60 AND 70 YEARS.
C NTIMES=11

C
C INITIAL CONDITIONS.. SET TO ZERO ALL ARRAYS IN /LEVELS/
C BLOCK AND AWIGL.
NS=NSOU - 6
NS5=NSOU + 5
NS3=NSOU + 3
DO 30 ISPEC=1,NSPEC
YS(ISPEC)=0.0
YSI(ISPEC)=0.0
YULI(ISPEC)=0.0
YLLI(ISPEC)=0.0
DO 5 J=1,2
YNP(ISPEC,J)=0.0
Y1TB(ISPEC,J)=0.0
Y2TB(ISPEC,J)=0.0
YL(ISPEC,J)=0.0
5 CONTINUE
DO 10 J=1,4
YP(ISPEC,J)=0.0
10 CONTINUE
DO 15 J=1,NS3
AWIGL(ISPEC,J)=0.0
15 CONTINUE
DO 17 J=1,NS3
ALEVFI(ISPEC,J)=0.0
AGENEI(ISPEC,J)=0.0
17 CONTINUE
C*****
DO 16 J=1,12
AW(ISPEC,J)=0.0
16 CONTINUE
C*****
DO 25 K=1,NS

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      NC=NCOMP(ISPEC,K)
      DO 20 J=1,NC
        YORG(ISPEC,J,K)=0.0
20    CONTINUE
25    CONTINUE
30    CONTINUE
C
C SWITCHES SNP,....,SGI INDICATE EXHAUSTION OF THEIR RESPECTIVE
C COMPARTMENTS. SEND INDICATES FINAL EXHAUSTION OF ALL FEEDER
C COMPARTMENTS AND HENCE THE INTEGRATION FOR OTHER ORGANS MAY
C BE COMPLETED IN ONE FINAL STEP. SET ALL OF THESE SWITCHES
C INITIALLY TO .FALSE..
      SNP=.FALSE.
      STB1=.FALSE.
      SP=.FALSE.
      SL(1)=.FALSE.
      SL(2)=.FALSE.
      STB2(1)=.FALSE.
      STB2(2)=.FALSE.
      IF(MODE(ICASE).EQ. 1) GO TO 31
      SNP=.TRUE.
      STB1=.TRUE.
      SP=.TRUE.
      SL(1)=.TRUE.
      SL(2)=.TRUE.
      STB2(1)=.TRUE.
      STB2(2)=.TRUE.
31  SGI=.FALSE.
      SEND=.FALSE.
C
C SET G.I. ABSORPTION RATE PARAMETER LMAB..
      DO 35 ISPEC=1,NSPEC
        DO 35 ISEG=1,4
          TEMP=AMIN1(0.95,GIFRAC(ICASE,ISPEC,ISEG))
          LMAB(ISPEC,ISEG)=LMGI(ISEG)*TEMP/(1.0-TEMP)
35  CONTINUE
      INDEX=1
      NSTPS=NSTEPS(ICASE)
      DO 75 INTERV=1,NSTPS
        T1=FLOAT(INTERV-1)*TSTEP(ICASE)
        T2=FLOAT(INTERV)*TSTEP(ICASE)
        IF(SEND) T2=TEND(ICASE)
C-----
C INVOKE STEP TO ADVANCE THE INTEGRATION FROM T1 TO T2.
C-----
        CALL STEP(T1,T2,MODE(ICASE))
C-----
C ACCUMULATE CUMULATIVE ACTIVITY AWIGL IN SOURCE TISSUES.
C-----
        DO 70 ISPEC=1,NSPEC
C
C OMIT RESPIRATORY CONTRIBUTIONS IF THIS IS AN INGESTION CASE.
        IF(MODE(ICASE).NE. 1) GO TO 55
C
C MICROCURIE-DAYS IN LUNGS (NP + TB + P)..
        AWIGL(ISPEC,1)=AWIGL(ISPEC,1)+YNPW(ISPEC,1)+YNPW(ISPEC,2)
        $      +Y1TBW(ISPEC,1)+Y1TBW(ISPEC,2)
        $      +Y2TBW(ISPEC,1)+Y2TBW(ISPEC,2)
        $      +YPW(ISPEC,1)+YPW(ISPEC,2)+YPW(ISPEC,3)
        $      +YPW(ISPEC,4)
C MICROCURIES IN LUNGS (NP + TB + P)..
        ALEVEL(ISPEC,1)=YNP(ISPEC,1)+YNP(ISPEC,2)
        $      +Y1TB(ISPEC,1)+Y1TB(ISPEC,2)
        $      +Y2TB(ISPEC,1)+Y2TB(ISPEC,2)
        $      +YP(ISPEC,1)+YP(ISPEC,2)+YP(ISPEC,3)
        $      +YP(ISPEC,4)
C
C MICROCURIE-DAYS IN NP, TB, AND P REGIONS..
        AWIGL(ISPEC,NSOU+1)=AWIGL(ISPEC,NSOU+1) + YNPW(ISPEC,1) +
        $      YNPW(ISPEC,2)
        AWIGL(ISPEC,NSOU+2)=AWIGL(ISPEC,NSOU+2) + Y1TBW(ISPEC,1) +
        $      Y1TBW(ISPEC,2)+Y2TBW(ISPEC,1)+Y2TBW(ISPEC,2)
        AWIGL(ISPEC,NSOU+3)=AWIGL(ISPEC,NSOU+3) + YPW(ISPEC,1) +
        $      YPW(ISPEC,2)+YPW(ISPEC,3)+YPW(ISPEC,4)
C MICROCURIES IN NP, TB, AND P REGIONS..
        ALEVEL(ISPEC,NSOU+1)=YNP(ISPEC,1) + YNP(ISPEC,2)
        ALEVEL(ISPEC,NSOU+2)=Y1TB(ISPEC,1) + Y1TB(ISPEC,2) +

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$          Y2TB(ISPEC,1) + Y2TB(ISPEC,2)
$ ALEVEL(ISPEC,NSOU+3)=YP(ISPEC,1) + YP(ISPEC,2) + YP(ISPEC,3) +
$          YP(ISPEC,4)
C MICRODURIE-DAYS IN LYMPH (L)..
$      AWIGL(ISPEC,2)=AWIGL(ISPEC,2)+YLW(ISPEC,1)+YLW(ISPEC,2)
C MICROCURIES IN LYMPH (L)..
$      ALEVEL(ISPEC,2)=YL(ISPEC,1)+YL(ISPEC,2)
55      CONTINUE
C MICROCURIE-DAYS IN G.I. SEGMENTS (S,SI,ULI,LLI)..
$      AWIGL(ISPEC,3)=AWIGL(ISPEC,3)+YSW(ISPEC)
$      AWIGL(ISPEC,4)=AWIGL(ISPEC,4)+YSIW(ISPEC)
$      AWIGL(ISPEC,5)=AWIGL(ISPEC,5)+YULIW(ISPEC)
$      AWIGL(ISPEC,6)=AWIGL(ISPEC,6)+YLLIW(ISPEC)
C MICROCURIES IN G.I. SEGMENTS (S,SI,ULI,LLI)..
$      ALEVEL(ISPEC,3)=YS(ISPEC)
$      ALEVEL(ISPEC,4)=YSI(ISPEC)
$      ALEVEL(ISPEC,5)=YULI(ISPEC)
$      ALEVEL(ISPEC,6)=YLLI(ISPEC)
C
C MICROCURIE-DAYS IN OTHER SOURCE ORGANS..
$      DO 65 ISOU=7,NSOU
$      NC=NCOMP(ISPEC,ISOU-6)
$      DO 63 IC=1,NC
$      AWIGL(ISPEC,ISOU)=AWIGL(ISPEC,ISOU)
$      +YORGW(ISPEC,IC,ISOU-6)
63      CONTINUE
65      CONTINUE
C MICROCURIES IN OTHER SOURCE ORGANS..
$      DO 67 ISOU=7,NSOU
$      ALEVEL(ISPEC,ISOU)=0.0
$      NC=NCOMP(ISPEC,ISOU-6)
$      DO 66 IC=1,NC
$      ALEVEL(ISPEC,ISOU)=ALEVEL(ISPEC,ISOU)
$      +YORG(ISPEC,IC,ISOU-6)
66      CONTINUE
67      CONTINUE
C*****
C ACCUMULATED ACTIVITY FOR PATHWAYS A THROUGH L..
$      IF(MODE(ICASE) .NE. 1) GO TO 71
$      AW(ISPEC,1)=AW(ISPEC,1)+YNPW(ISPEC,1)
$      AW(ISPEC,2)=AW(ISPEC,2)+YNPW(ISPEC,2)
$      AW(ISPEC,3)=AW(ISPEC,3)+Y1TBW(ISPEC,1)
$      AW(ISPEC,4)=AW(ISPEC,4)+Y1TBW(ISPEC,2)
$      AW(ISPEC,5)=AW(ISPEC,5)+YPW(ISPEC,1)
$      AW(ISPEC,6)=AW(ISPEC,6)+YPW(ISPEC,2)
$      AW(ISPEC,7)=AW(ISPEC,7)+YPW(ISPEC,3)
$      AW(ISPEC,8)=AW(ISPEC,8)+YPW(ISPEC,4)
$      AW(ISPEC,9)=AW(ISPEC,9)+YLW(ISPEC,1)
$      AW(ISPEC,10)=AW(ISPEC,10)+YLW(ISPEC,2)
$      AW(ISPEC,11)=AW(ISPEC,11)+Y2TBW(ISPEC,1)
$      AW(ISPEC,12)=AW(ISPEC,12)+Y2TBW(ISPEC,2)
71      CONTINUE
C*****
C
C IF T2 IS 30 YEARS, STORE ACCUMULATED ACTIVITIES FOR CALCULATION OF
C GENETIC DOSE COMMITMENT..
$      IF (T2 .NE. 10950.) GO TO 70
$      DO 68 ISOU=1,NSOU
$      AGENET(ISPEC,ISOU)=AWIGL(ISPEC,ISOU)
68      CONTINUE
70      CONTINUE
C
C-----
C DETERMINE IF T2 IS ONE OF THE SELECTED TIMES AT WHICH DOSE
C RATES SHOULD BE CALCULATED. IF SO, COMPUTE A MATRIX OF DOSE
C RATES TO ALL TARGET ORGANS AT T2.
C-----
$      IF (T2 .NE. TIME(INDEX)) GO TO 75
$      DO 76 ITRG=1,NTRG
$      DOSRAT(1,INDEX,ICASE,ITRG)=0.0
$      DOSRAT(2,INDEX,ICASE,ITRG)=0.0
$      DO 77 ISPEC=1,NSPEC
$      DO 76 ISOU=1,NSOU
$      IF (ISOU .EQ. 7) GO TO 76
$      DOSRAT(1,INDEX,ICASE,ITRG)=DOSPAT(1,INDEX,ICASE,ITRG)+

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$      S(1,ISPEC,ITRG,ISOU)*ALEVEL(ISPEC,ISOU)
$      IF (NLET.EQ. 2)
$          DOSRAT(2,INDEX,ICASE,ITRG)=DOSRAT(2,INDEX,ICASE,ITRG)+
$          S(2,ISPEC,ITRG,ISOU)*ALEVEL(ISPEC,ISOU)
76      CONTINUE
77      CONTINUE
$      DOSRAT(1,INDEX,ICASE,ITRG)=DOSRAT(1,INDEX,ICASE,ITRG)*3.65E+05
$      DOSRAT(2,INDEX,ICASE,ITRG)=DOSRAT(2,INDEX,ICASE,ITRG)*3.65E+05
78      CONTINUE
C-----
C COMPUTE DOSE RATES FOR REGIONS OF THE RESPIRATORY TRACT.
C-----
$      IF (MODE(ICASE).NE. 1) GO TO 81
$      DO 81 ILET=1,NLET
$      DO 80 IREG=1,3
$          NTRGP=NTRG + IREG
$          NSOUP=NSOU + IREG
$          DOSPAT(ILET,INDEX,ICASE,NTRGP)=0.0
$      DO 79 ISPEC=1,NSPEC
$          DOSRAT(ILET,INDEX,ICASE,NTRGP)=DOSRAT(ILET,INDEX,ICASE,NTRGP)
$          +ALEVEL(ISPEC,NSOUP)*S(ILET,ISPEC,1,1)*1000.0/REGMAS(IREG)
$          IF (IREG.NE. 3) GO TO 79
$          DOSRAT(ILET,INDEX,ICASE,NTRGP)=DOSRAT(ILET,INDEX,ICASE,NTRGP)
$          + ALEVEL(ISPEC,2)*S(ILET,ISPEC,1,2)*1000.0/REGMAS(IREG)
$      DO 82 ISOU=3,NSOU
$          IF (ISOU.EQ. 7) GO TO 82
$          DOSPAT(ILET,INDEX,ICASE,NTRGP)=DOSPAT(ILET,INDEX,ICASE,NTRGP)
$          + ALEVEL(ISPEC,ISOU)*S(ILET,ISPEC,1,ISOU)
82      CONTINUE
79      CONTINUE
$      DOSRAT(ILET,INDEX,ICASE,NTRGP)=DOSPAT(ILET,INDEX,ICASE,NTRGP)
$          *3.65E+05
80      CONTINUE
81      CONTINUE
$      DOSTIM(INDEX)=T2/365.
C-----
C IF NSPEC > 1, COMPUTE PERCENT OF TOTAL DOSE RATE IN THE 70TH YEAR
C TO EACH ORGAN DUE TO EACH SPECIES IN THE CHAIN.
C-----
$      IF (DOSTIM(INDEX).NE. 70.0) GO TO 508
$      IF (NSPEC.EQ. 1) GO TO 508
$      DO 504 ITRG=1,NTRG
$      DO 503 ISPEC=1,NSPEC
$      DO 502 ILET=1,NLET
$          PCTDRT(ILET,ICASE,ITRG,ISPEC)=0.0
$      DO 501 ISOU=1,NSOU
$          IF (ISOU.EQ. 7) GO TO 501
$          PCTDRT(ILET,ICASE,ITRG,ISPEC)=PCTDRT(ILET,ICASE,ITRG,ISPEC)
$          + S(ILET,ISPEC,ITRG,ISOU)*ALEVEL(ISPEC,ISOU)
501      CONTINUE
$          IF (DOSRAT(ILET,INDEX,ICASE,ITRG).EQ. 0.0)
$          PCTDRT(ILET,ICASE,ITRG,ISPEC)=0.0
$          IF (DOSRAT(ILET,INDEX,ICASE,ITRG).EQ. 0.0) GO TO 502
$          PCTDRT(ILET,ICASE,ITRG,ISPEC)=PCTDRT(ILET,ICASE,ITRG,ISPEC)
$          *100.0/DOSPAT(ILET,INDEX,ICASE,ITRG)*3.65E+05
502      CONTINUE
503      CONTINUE
504      CONTINUE
C PERCENT DOSE RATE TO NP, TB, AND PULMONARY REGIONS..
$      IF (MODE(ICASE).NE. 1) GO TO 508
$      DO 508 IREG=1,3
$          NTRGP=NTRG + IREG
$          NSOUP=NSOU + IREG
$      DO 507 ISPEC=1,NSPEC
$      DO 506 ILET=1,NLET
$          PCTDRT(ILET,ICASE,NTRGP,ISPEC)=(ALEVEL(ISPEC,NSOUP)
$          *S(ILET,ISPEC,1,1)*1000.0/REGMAS(IREG)) * 100.0
$          /DOSPAT(ILET,INDEX,ICASE,NTRGP)*3.65E+05
$          IF (IREG.NE. 3) GO TO 506
$          PCTDRT(ILET,ICASE,NTRGP,ISPEC)=PCTDRT(ILET,ICASE,NTRGP,ISPEC)
$          +ALEVEL(ISPEC,2)*S(ILET,ISPEC,1,2)*1000.0/REGMAS(IREG)
$          *100.0/DOSPAT(ILET,INDEX,ICASE,NTRGP)*3.65E+05
$      DO 505 ISOU=3,NSOU
$          IF (ISOU.EQ. 7) GO TO 505
$          PCTDRT(ILET,ICASE,NTRGP,ISPEC)=
$          PCTDRT(ILET,ICASE,NTRGP,ISPEC) + ALEVEL(ISPEC,ISOU)
$          *S(ILET,ISPEC,1,ISOU)*100.0/DOSPAT(ILET,INDEX,ICASE,NTRGP)
$          *3.65E+05

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505     CONTINUE
506     CONTINUE
507     CONTINUE
508 CONTINUE
C*****
C OUTPUT ACTIVITIES IN ALL SOURCE COMPARTMENTS TO PERMIT FUTURE MANUAL
C AGE-DEPENDENT CALCULATIONS (BY VARYING THE S-FACTOR) IF DESIRED..
C*****
      WRITE(17,310) NAMNUC(1),DOSTIM(INDEX),ICASE,TSTEP(ICASE)
      IF (NSOU .GT. 12) GO TO 302
      WRITE(17,320) (NAMSOU(ISOU),ISOU=1,NSOU)
      DO 301 ISPEC=1,NSPEC
        WRITE(17,330) NAMNUC(ISPEC),(ALEVEL(ISPEC,ISOU),ISOU=1,NSOU)
301    CONTINUE
      GO TO 304
302    WRITE(17,320) (NAMSOU(ISOU),ISOU=1,12)
      DO 303 ISPEC=1,NSPEC
        WRITE(17,330) NAMNUC(ISPEC),(ALEVEL(ISPEC,ISOU),ISOU=1,12)
303    CONTINUE
      WRITE(17,320) (NAMSOU(ISOU),ISOU=13,NSOU)
      DO 304 ISPEC=1,NSPEC
        WRITE(17,330) NAMNUC(ISPEC),(ALEVEL(ISPEC,ISOU),ISOU=13,NSOU)
304    CONTINUE
      IF (MODE(ICASE) .NE. 1) GO TO 305
      WRITE(17,340)
      NSOU1=NSOU + 1
      NSOU3=NSOU + 3
      DO 305 ISPEC=1,NSPEC
        WRITE(17,330) NAMNUC(ISPEC),(ALEVEL(ISPEC,JSOU),JSOU=NSOU1,NSOU3)
305    CONTINUE
310    FORMAT('0',60X,A8,/,46X,'MICROCURIES AT',F4.0,' YEARS FOR ',
$         'CASE',I2,/,51X,'(TIME STEP =',F6.0,' DAYS)')
320    FORMAT('0','NUCLIDE',12(A8,2X))
330    FORMAT('0',A8,1X,1P12E10.3)
340    FORMAT('0','NUCLIDE',3X,'N-P',7X,'T-B',7X,'PULMINARY')
C*****
C
      INDEX=INDEX+1
75    CONTINUE
C
C-----
C CALCULATE THE ACCUMULATED DOSE TO TESTES AND OVARIES TO AGE 30
C FOR GENETIC CALCULATIONS..
C-----
      DO 155 ILET=1,NLET
        DOSTES(ILET,ICASE)=0.0
        DOSOVR(ILET,ICASE)=0.0
        DO 154 ISOU=1,NSOU
          IF (ISOU .EQ. 7) GO TO 154
          DO 153 ISPEC=1,NSPEC
            DOSTES(ILET,ICASE)=DOSTES(ILET,ICASE) +
$              S(ILET,ISPEC,21,ISOU) * AGENET(ISPEC,ISOU)
            DOSOVR(ILET,ICASE)=DOSOVR(ILET,ICASE) +
$              S(ILET,ISPEC,13,ISOU) * AGENET(ISPEC,ISOU)
153        CONTINUE
154        CONTINUE
        DOSTES(ILET,ICASE)=DOSTES(ILET,ICASE) * 1.0E+03
        DOSOVR(ILET,ICASE)=DOSOVR(ILET,ICASE) * 1.0E+03
        DOSGON(ILET,ICASE)=(DOSTES(ILET,ICASE) + DOSOVR(ILET,ICASE))/2.0
155    CONTINUE
C
C-----
C FOR EPA CALCULATIONS, THE ACCUMULATED DOSE IS NOT OF INTEREST SINCE
C WE ARE CONCERNED WITH THE DOSE RATES AT VARIOUS TIMES. THEREFORE,
C WE WILL BYPASS THIS CALCULATION FOR THIS APPLICATION.
C-----
      GO TO 410
C
C-----
C COMPUTE THE TARGET-SOURCE DOSE MATRIX FOR THE CURRENT CASE.
C-----
      DO 100 ILET=1,NLET
        DO 95 ISOU=1,NSOU
          DO 90 ITRG=1,NTRG
            DOSE(ILET,ICASE,ITRG,ISOU)=0.0
            DO 89 ISPEC=1,NSPEC
              DOSE(ILET,ICASE,ITRG,ISOU)=DOSE(ILET,ICASE,ITRG,ISOU)

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$          +S(ILET,ISPEC,ITRG,ISOU)*AWIGL(ISPEC,ISOU)
89      CONTINUE
90      CONTINUE
95      CONTINUE
100     CONTINUE
C DOSE TO INDIVIDUAL REGIONS OF THE LUNG..
  IF (MODE(ICASE) .NE. 1) GO TO 103
  DO 103 ILET=1,NLET
    DO 102 IREG=1,3
      NSOUP=NSOU + IREG
      LUNDOS(ILET,ICASE,IREG)=0.0
      DO 101 ISPEC=1,NSPEC
        LUNDOS(ILET,ICASE,IREG)=LUNDOS(ILET,ICASE,IREG) +
$          AWIGL(ISPEC,NSOUP)*S(ILET,ISPEC,1,1)*1000.0/REGMAS(IREG)
        IF (IREG .NE. 3) GO TO 101
        LUNDOS(ILET,ICASE,IREG)=LUNDOS(ILET,ICASE,IREG) +
$          AWIGL(ISPEC,2)*S(ILET,ISPEC,1,2)*1000.0/REGMAS(IREG)
      DO 105 ISOU=3,NSOU
        IF (ISOU .EQ. 7) GO TO 105
        LUNDOS(ILET,ICASE,IREG)=LUNDOS(ILET,ICASE,IREG) +
$          AWIGL(ISPEC,ISOU)*S(ILET,ISPEC,1,ISOU)
105     CONTINUE
101     CONTINUE
102     CONTINUE
103     CONTINUE
-----
C COMPUTE TOTAL DOSE TO EACH TARGET ORGAN.
C-----
      NSOU1=NSOU+1
      DO 380 ILET=1,NLET
        DO 374 ITRG=1,NTRG
          DOSE(ILET,ICASE,ITRG,NSOU1)=0.0
          DO 375 ISOU=1,NSOU
            IF (ISOU .EQ. 7) GO TO 375
            DOSE(ILET,ICASE,ITRG,NSOU1)=DOSE(ILET,ICASE,ITRG,NSOU1)
$            +DOSE(ILET,ICASE,ITRG,ISOU)
375     CONTINUE
374     CONTINUE
380     CONTINUE
-----
C IF NSPEC IS GREATER THAN 1, COMPUTE PERCENT OF TOTAL DOSE TO EACH
C TARGET ORGAN DUE TO EACH SPECIES OF THE CHAIN.
C-----
      IF (NSPEC .EQ. 1) GO TO 210
      DO 203 ITRG=1,NTRG
        DO 202 ISPEC=1,NSPEC
          DO 201 ILET=1,NLET
            PCTDOS(ILET,ICASE,ITRG,ISPEC)=0.0
            DO 200 ISOU=1,NSOU
              IF (ISOU .EQ. 7) GO TO 200
              PCTDOS(ILET,ICASE,ITRG,ISPEC)=PCTDOS(ILET,ICASE,ITRG,ISPEC)+
$              S(ILET,ISPEC,ITRG,ISOU)*AWIGL(ISPEC,ISOU)
200     CONTINUE
            IF (DOSE(ILET,ICASE,ITRG,NSOU1) .EQ. 0.0)
$              PCTDOS(ILET,ICASE,ITRG,ISPEC)=0.0
            IF (DOSE(ILET,ICASE,ITRG,NSOU1) .EQ. 0.0) GO TO 201
            PCTDOS(ILET,ICASE,ITRG,ISPEC)=PCTDOS(ILET,ICASE,ITRG,ISPEC)
$              *100.0/DOSE(ILET,ICASE,ITRG,NSOU1)
201     CONTINUE
202     CONTINUE
203     CONTINUE
C PERCENT DOSE TO NP, TB, AND PULMONARY REGIONS..
  IF (MODE(ICASE) .NE. 1) GO TO 206
  DO 206 IREG=1,3
    NTRGP=NTRG + IREG
    NSOUP=NSOU + IREG
    DO 205 ISPEC=1,NSPEC
      DO 204 ILET=1,NLET
        PCTDOS(ILET,ICASE,NTRGP,ISPEC)=(AWIGL(ISPEC,NSOUP)
$          *S(ILET,ISPEC,1,1)*1000.0/REGMAS(IREG)) * 100.0
$          /LUNDOS(ILET,ICASE,IREG)
        IF (IREG .NE. 3) GO TO 204
        PCTDOS(ILET,ICASE,NTRGP,ISPEC)=PCTDOS(ILET,ICASE,NTRGP,ISPEC)
$          +AWIGL(ISPEC,2)*S(ILET,ISPEC,1,2)*1000.0/REGMAS(IREG)
$          *100.0/LUNDOS(ILET,ICASE,IREG)
      DO 207 ISOU=3,NSOU
        IF (ISOU .EQ. 7) GO TO 207

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          PCTDOS(ILET,ICASE,NTRGP,ISPEC)=
$          PCTDOS(ILET,ICASE,NTRGP,ISPEC) + AWIGL(ISPEC,ISOU)
$          *S(ILET,ISPEC,1,ISOU)*100.0/LUNDOS(ILET,ICASE,IREG)
207      CONTINUE
204      CONTINUE
205      CONTINUE
206      CONTINUE
C*****
C OUTPUT ACCUMULATED ACTIVITIES ON UNIT 16 FOR LATER REFERENCE.
C*****
210      WRITE (16,9991) NAMNUC(I),ICASE, TSTEP(ICASE)
      IF(NSOU.GT. 12) GO TO 9002
      WRITE(16,9992) (NAMSOU(I),I=1,NSOU)
      DO 9001 ISPEC=1,NSPEC
9001      WRITE(16,9993) NAMNUC(ISPEC),(AWIGL(ISPEC,I),I=1,NSOU)
      GO TO 9005
9002      WRITE(16,9992) (NAMSOU(I),I=1,12)
      DO 9003 ISPEC=1,NSPEC
9003      WRITE(16,9993) NAMNUC(ISPEC),(AWIGL(ISPEC,I),I=1,12)
      WRITE(16,9992) (NAMSOU(I),I=13,NSOU)
      DO 9004 ISPEC=1,NSPEC
9004      WRITE(16,9993) NAMNUC(ISPEC),(AWIGL(ISPEC,I),I=13,NSOU)
9005      WRITE(16,9994)
      DO 9006 ISPEC=1,NSPEC
9006      WRITE(16,9993) NAMNUC(ISPEC),(AWIGL(ISPEC,I),I=1,12)
9991      FORMAT(1H0,/,60X,A8,/,50X,'MICROCURIE-DAYS FOR CASE ',I2,/,45X,
$ ' (TIME STEP FOR INTEGRATION =',F6.0,' DAYS)')
9992      FORMAT(1H0,'NUCLIDE ',I2(A8,2X))
9993      FORMAT(1H,A8,1X,1P12E10,3)
9994      FORMAT(1H0,39X,'ACCUMULATED ACTIVITY FOR TGLM PATHWAYS A ',
$ ' THROUGH L',/,12X,'A',9X,'B',9X,'C',9X,'D',9X,'E',9X,'F',9X,'G',
$ ' 9X,'H',9X,'I',9X,'J',9X,'K',9X,'L')
C*****
410      RETURN
C-----
C END OF DOSRUN
C-----
      END

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      SUBROUTINE STEP(T1,T2,MCDE)
C
C ADVANCES THE RESIDENCE TIME INTEGRATION FROM TIME T1 TO T2 (DAYS).
C MODE = 1 FOR INHALATION, = 2 FOR INGESTION.
      INTEGER NCTEMP(20)
      REAL LMGI(4),LMAB(20,4),LMR(20),BRANCH(20,20)
      REAL G(20),H(20)
      REAL LMBDAB
      REAL LB(20,5),CTEMP(20,5),PTEMP(20,5),YTEMPO(20,5),YTEMP(20,5),
$ YTEMPW(20,5)
      REAL LMA,LMB,LMC,LMD,LME,LMF,LMG,LMH,LMI
      DOUBLE PRECISION T
      LOGICAL SNP,STB1,SP,SL,STB2,SGI
      COMMON /SWITCH/ SNP,STD1,SP,SL(2),STB2(2),SGI
      COMMON /LEVELS/ YNP(20,2),Y1TB(20,2),Y2TB(20,2),
$ YP(20,4),YL(20,2),YS(20),YSI(20),YULI(20),
$ YLLI(20),YORG(20,5,16)
      COMMON /CUMACT/ YNPW(20,2),Y1TBW(20,2),Y2TBW(20,2),
$ YPW(20,4),YLW(20,2),YSW(20),YSIW(20),YULIW(20),
$ YLLIW(20),YORGW(20,5,16)
      COMMON /ORGDAT/ NCOMP(20,16),C(20,5,16),LMBDAB(20,5,16),
$ F2PRIM(20,16)
      COMMON /NUMBRS/ NSPEC,NSOU,NTRG
      COMMON /GI/ LMGI,LMAB
      COMMON /RADAT/ LMR,BRANCH
      COMMON /TGLM/ LMA(20),LMB(20),LMC(20),LMD(20),LME(20),LMF(20),
$ LMG(20),LMH(20),LMI(20),
$ FA(20),FB(20),FC(20),FD(20),FE(20),FF(20),FG(20),FH(20),
$ FI(20)
      COMMON /RESDP/ D3,D4,D5
      DELT=T2-T1
      T=DBLE(0.5*(T1+T2))
C
C IF THIS CASE IS NOT INHALATION, BRANCH TO INGESTION.
      IF(MODE.NE. 1) GO TO 130
C-----
C RESPIRATORY TRACT (TASK GROUP LUNG MODEL FOR AEROSOLS)
C-----
      CALL HAL(T,H)

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      IF(SNP) GO TO 21
C
C   NASOPHARYNGEAL REGION (A,B)
C   -----
C   IPATH=1 FOR A
C   =2 FOR B
C   DO 10 ISPEC=1,NSPEC
C
C   INFLOW-RATE VECTOR PTEMP.. INITIALIZE TO ZERO.
C   DO 4 IPATH=1,2
C     PTEMP(ISPEC,IPATH)=0.0
C   4   CONTINUE
C
C   NUMBER OF SUBCOMPARTMENTS..
C   NCTEMP(ISPEC)=2
C
C   SUBCOMPARTMENT FRACTIONS..
C   CTEMP(ISPEC,1)=FA(ISPEC)
C   CTEMP(ISPEC,2)=FB(ISPEC)
C
C   BIOLOGICAL CLEARANCE COEFFICIENTS..
C   LB(ISPEC,1)=LMA(ISPEC)
C   LB(ISPEC,2)=LMB(ISPEC)
C
C   INITIAL CONDITIONS..
C   DO 5 IPATH=1,2
C     YTEMP0(ISPEC,IPATH)=YNP(ISPEC,IPATH)
C   5   CONTINUE
C   10  CONTINUE
C
C   FIRST COMPONENT OF INTAKE VECTOR..
C   DO 14 IPATH=1,2
C     PTEMP(1,IPATH)=D3*H(1)
C   14  CONTINUE
C   (ALL OTHER COMPONENTS OF H ARE ZERO).
C   CALL MULCOM(DELTA,NSPEC,LMR,LB,CTEMP,NCTEMP,BRANCH,
C   $   PTEMP,YTEMP0,YTEMP,YTEMPW)
C
C   MOVE OUTPUTS FOR A,B PATHWAYS..
C   DO 20 ISPEC=1,NSPEC
C     DO 15 IPATH=1,2
C       YNP(ISPEC,IPATH)=YTEMP(ISPEC,IPATH)
C       YNPW(ISPEC,IPATH)=YTEMPW(ISPEC,IPATH)
C     15  CONTINUE
C   20  CONTINUE
C   21  CONTINUE
C   IF(STB1) GO TO 41
C
C   TRACHEOBRONCHIAL REGION (C,D)
C   -----
C   IPATH=1 FOR C
C   =2 FOR D
C   DO 30 ISPEC=1,NSPEC
C
C   INFLOW RATE VECTOR..
C   DO 24 IPATH=1,2
C     PTEMP(ISPEC,IPATH)=C.0
C   24  CONTINUE
C
C   COMPARTMENT FRACTIONS..
C   CTEMP(ISPEC,1)=FC(ISPEC)
C   CTEMP(ISPEC,2)=FD(ISPEC)
C
C   BIOLOGICAL CLEARANCE COEFFICIENTS..
C   LB(ISPEC,1)=LMC(ISPEC)
C   LB(ISPEC,2)=LMD(ISPEC)
C
C   INITIAL CONDITIONS..
C   DO 25 IPATH=1,2
C     YTEMP0(ISPEC,IPATH)=Y1TB(ISPEC,IPATH)
C   25  CONTINUE
C   30  CONTINUE
C
C   FIRST COMPONENT OF INTAKE VECTOR..
C   DO 34 IPATH=1,2
C     PTEMP(1,IPATH)=D4*H(1)
C   34  CONTINUE
C   CALL MULCOM(DELTA,NSPEC,LMR,LB,CTEMP,NCTEMP,BRANCH,

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      $ PTEMP,YTEMP0,YTEMP,YTEMPW)
C
C MOVE OUTPUTS FOR C,D PATHWAYS..
  DO 40 ISPEC=1,NSPEC
    DO 35 IPATH=1,2
      Y1TB(ISPEC,IPATH)=YTEMP(ISPEC,IPATH)
      Y1TBW(ISPEC,IPATH)=YTEMPW(ISPEC,IPATH)
    35 CONTINUE
  40 CONTINUE
  41 CONTINUE
    IF(SP) GO TO 61
C
C PULMONARY REGION (E,F,G,H)
C -----
C   IPATH=1 FOR E
C   =2 FOR F
C   =3 FOR G
C   =4 FOR H
C   DO 50 ISPEC=1,NSPEC
C
C INFLOW RATE VECTOR..
  DO 44 IPATH=1,4
    PTEMP(ISPEC,IPATH)=C.0
  44 CONTINUE
C
C NUMBER OF SUBCOMPARTMENTS..
  NCTEMP(ISPEC)=4
C
C SUBCOMPARTMENT FRACTIONS..
  CTEMP(ISPEC,1)=FE(ISPEC)
  CTEMP(ISPEC,2)=FF(ISPEC)
  CTEMP(ISPEC,3)=FG(ISPEC)
  CTEMP(ISPEC,4)=FH(ISPEC)
C
C BIOLOGICAL CLEARANCE COEFFICIENTS..
  LB(ISPEC,1)=LME(ISPEC)
  LB(ISPEC,2)=LMF(ISPEC)
  LB(ISPEC,3)=LMG(ISPEC)
  LB(ISPEC,4)=LMH(ISPEC)
C
C INITIAL CONDITIONS..
  DO 45 IPATH=1,4
    YTEMP0(ISPEC,IPATH)=YP(ISPEC,IPATH)
  45 CONTINUE
  50 CONTINUE
C
C FIRST COMPONENT OF INFLOW VECTOR..
  DO 54 IPATH=1,4
    PTEMP(1,IPATH)=D5*H(1)
  54 CONTINUE
  CALL MULCOM(DELT,NSPEC,LMR,LB,CTEMP,NCTEMP,BRANCH,
    $ PTEMP,YTEMP0,YTEMP,YTEMPW)
C
C MOVE OUTPUTS FOR E,F,G,H PATHWAYS..
  DO 60 ISPEC=1,NSPEC
    DO 55 IPATH=1,4
      YP(ISPEC,IPATH)=YTEMP(ISPEC,IPATH)
      YPW(ISPEC,IPATH)=YTEMPW(ISPEC,IPATH)
    55 CONTINUE
  60 CONTINUE
  61 CONTINUE
    IF(SL(1).AND. SL(2)) GO TO 81
C
C LYMPHATIC TISSUE (I,J)
C -----
C   IPATH=1 FOR I
C   =2 FOR J
C   DO 70 ISPEC=1,NSPEC
C
C INFLOW RATE.. TOTAL OUTFLOW OF PATHWAY H.
  DO 64 IPATH=1,2
    PTEMP(ISPEC,IPATH)=LMH(ISPEC)*YPW(ISPEC,4)/DELT
  64 CONTINUE
C
C NUMBER OF SUBCOMPARTMENTS..
  NCTEMP(ISPEC)=2
C
C SUBCOMPARTMENT FRACTIONS..

```

```

      CTEMP(ISPEC,1)=FI(ISPEC)
      CTEMP(ISPEC,2)=1.0-FI(ISPEC)
C
C BIOLOGICAL CLEARANCE COEFFICIENTS..
      LB(ISPEC,1)=LMI(ISPEC)
      LB(ISPEC,2)=0.0
C (THE J SUBCOMPARTMENT IS SUBJECT ONLY TO RADIOACTIVE DECAY).
C
C INITIAL CONDITIONS..
      DO 65 IPATH=1,2
        YTEMP0(ISPEC,IPATH)=YL(ISPEC,IPATH)
      65 CONTINUE
      70 CONTINUE
      CALL MULCOM(DELTA,NSPEC,LMR,LB,CTEMP,NCTEMP,BRANCH,
        $ PTEMP,YTEMP0,YTEMP,YTEMPW)
C
C MOVE OUTPUTS FOR (I,J) PATHWAYS..
      DO 80 ISPEC=1,NSPEC
        DO 75 IPATH=1,2
          YL(ISPEC,IPATH)=YTEMP(ISPEC,IPATH)
          YLW(ISPEC,IPATH)=YTEMPW(ISPEC,IPATH)
        75 CONTINUE
      80 CONTINUE
      81 CONTINUE
      IF(STB2(1)) GO TO 101
C
C TRACHEOBRONCHIAL FEEDBACK (K,L)
C -----
C THIS WILL REQUIRE TWO CALLS TO MULCOM..
C (1) INPUT FROM F, OUTPUT K
C (2) INPUT FROM G, OUTPUT L
C PATHWAYS K AND L ARE INDEPENDENT SUBCOMPARTMENTS.
C
C PATHWAY K
C -----
      DO 90 ISPEC=1,NSPEC
C
C INFLOW VECTOR.. OUTFLOW OF PATHWAY F.
      PTEMP(ISPEC,1)=LMF(ISPEC)*YPW(ISPEC,2)/DELTA
C
C NUMBER OF SUBCOMPARTMENTS..
      NCTEMP(ISPEC)=1
C
C SUBCOMPARTMENT FRACTIONS (=UNITY)..
      CTEMP(ISPEC,1)=1.0
C
C BIOLOGICAL CLEARANCE COEFFICIENTS..
      LB(ISPEC,1)=LMD(ISPEC)
C (REMOVAL IS REGULATED BY TRACHEOBRONCHIAL CLEARANCE TO G.I.).
C
C INITIAL CONDITIONS..
      YTEMP0(ISPEC,1)=Y2TB(ISPEC,1)
      90 CONTINUE
      CALL MULCOM(DELTA,NSPEC,LMR,LB,CTEMP,NCTEMP,BRANCH,
        $ PTEMP,YTEMP0,YTEMP,YTEMPW)
C
C MOVE OUTPUT FOR K PATHWAY..
      DO 100 ISPEC=1,NSPEC
        Y2TB(ISPEC,1)=YTEMP(ISPEC,1)
        Y2TBW(ISPEC,1)=YTEMPW(ISPEC,1)
      100 CONTINUE
      101 CONTINUE
      IF(STB2(2)) GO TO 130
C
C PATHWAY L
C -----
      DO 110 ISPEC=1,NSPEC
C
C INFLOW VECTOR.. OUTFLOW FROM PATHWAY G.
      PTEMP(ISPEC,1)=LMG(ISPEC)*YPW(ISPEC,3)/DELTA
C
C NCTEMP, CTEMP, AND LB..
      NCTEMP(ISPEC)=1
      CTEMP(ISPEC,1)=1.0
      LB(ISPEC,1)=LMD(ISPEC)
C
C INITIAL CONDITIONS..
      YTEMP0(ISPEC,1)=Y2TB(ISPEC,2)

```



```

110 CONTINUE
  CALL MULCOM(DELT, NSPEC, LMP, LB, CTEMP, NCTEMP, BRANCH,
    $ PTEMP, YTEMPO, YTEMP, YTEMPW)
C
C MOVE OUTPUT FOR L PATHWAY..
  DO 120 ISPEC=1, NSPEC
    Y2TB(ISPEC, 2)=YTEMP(ISPEC, 1)
    Y2TBW(ISPEC, 2)=YTEMPW(ISPEC, 1)
  120 CONTINUE
C-----
C END OF RESPIRATORY SEGMENT
C-----
  130 CONTINUE
    IF(SGI) GO TO 220
C-----
C G. I. TRACT
C-----
C
C STOMACH (S)
C-----
  IF(MODE .EQ. 2) CALL GES(T, G)
  DO 140 ISPEC=1, NSPEC
C
C INFLOW RATE VECTOR..
  IF(MODE .EQ. 2) PTEMP(ISPEC, 1)=G(ISPEC)
  IF(MODE .EQ. 1) PTEMP(ISPEC, 1)=(LMB(ISPEC)*YNPW(ISPEC, 2) +
    $ LMD(ISPEC)+(Y1TBW(ISPEC, 2)+Y2TBW(ISPEC, 1)+Y2TBW(ISPEC, 2)))/DELT
C
C NUMBER OF SUBCOMPARTMENTS, COEFFICIENTS, AND BIOLOGICAL REMOVAL
C COEFFICIENTS.
  NCTEMP(ISPEC)=1
  CTEMP(ISPEC, 1)=1.0
  LB(ISPEC, 1)=LMGI(1)+LMAB(ISPEC, 1)
C
C INITIAL CONDITIONS..
  YTEMPO(ISPEC, 1)=YS(ISPEC)
  140 CONTINUE
    CALL MULCOM(DELT, NSPEC, LMP, LB, CTEMP, NCTEMP, BRANCH,
      $ PTEMP, YTEMPO, YTEMP, YTEMPW)
C
C MOVE OUTPUTS FOR S..
  DO 150 ISPEC=1, NSPEC
    YS(ISPEC)=YTEMP(ISPEC, 1)
    YSW(ISPEC)=YTEMPW(ISPEC, 1)
  150 CONTINUE
C
C SMALL INTESTINE (SI)
C-----
  DO 160 ISPEC=1, NSPEC
C
C BIOLOGICAL REMOVAL RATES (ABSORPTION PLUS EMPTYING)..
  LB(ISPEC, 1)=LMAB(ISPEC, 2)+LMGI(2)
C
C INFLOW RATE VECTOR.. OUTFLEW FROM STOMACH.
  PTEMP(ISPEC, 1)=LMGI(1)*YSW(ISPEC)/DELT
C
C NCTEMP AND CTEMP ARE AS FOR THE STOMACH.
C
C INITIAL CONDITIONS..
  YTEMPO(ISPEC, 1)=YSI(ISPEC)
  160 CONTINUE
    CALL MULCOM(DELT, NSPEC, LMP, LB, CTEMP, NCTEMP, BRANCH,
      $ PTEMP, YTEMPO, YTEMP, YTEMPW)
C
C MOVE OUTPUTS FOR SI..
  DO 170 ISPEC=1, NSPEC
    YSI(ISPEC)=YTEMP(ISPEC, 1)
    YSIW(ISPEC)=YTEMPW(ISPEC, 1)
  170 CONTINUE
C

```

```

C  UPPER LARGE INTESTINE (ULI)
C  -----
C  DO 180 ISPEC=1, NSPEC
C  BIOLOGICAL REMOVAL RATES (ABSORPTION PLUS EMPTYING)..
C  LB(ISPEC,1)=LMAB(ISPEC,3)+LMGI(3)
C  INFLOW VECTOR.. OUTFLOW FROM SMALL INTESTINE.
C  PTEMP(ISPEC,1)=LMGI(2)*YSIW(ISPEC)/DELT
C  NCTEMP AND CTEMP ARE AS FOR SI. EMPTYING RATES..
C  INITIAL CONDITIONS..
C  YTEMP0(ISPEC,1)=YULI(ISPEC)
180  CONTINUE
C  CALL MULCOM(DELT, NSPEC, LMR, LB, CTEMP, NCTEMP, BRANCH,
C  $ PTEMP, YTEMP0, YTEMP, YTEMPW)
C  MOVE ULI OUTPUTS..
C  DO 190 ISPEC=1, NSPEC
C  YULI(ISPEC)=YTEMP(ISPEC,1)
C  YULIW(ISPEC)=YTEMPW(ISPEC,1)
190  CONTINUE
C  LOWER LARGE INTESTINE (LLI)
C  -----
C  DO 200 ISPEC=1, NSPEC
C  BIOLOGICAL REMOVAL RATES (ABSORPTION PLUS EMPTYING)..
C  LB(ISPEC,1)=LMGI(4)+LMAB(ISPEC,4)
C  INFLOW VECTOR.. OUTFLOW FROM UPPER LARGE INTESTINE.
C  PTEMP(ISPEC,1)=LMGI(3)*YULIW(ISPEC)/DELT
C  NCTEMP AND CTEMP ARE AS FOR ULI.
C  INITIAL CONDITIONS..
C  YTEMP0(ISPEC,1)=YLLI(ISPEC)
200  CONTINUE
C  CALL MULCOM(DELT, NSPEC, LMR, LB, CTEMP, NCTEMP, BRANCH,
C  $ PTEMP, YTEMP0, YTEMP, YTEMPW)
C  MOVE OUTPUTS FOR LLI..
C  DO 210 ISPEC=1, NSPEC
C  YLLI(ISPEC)=YTEMP(ISPEC,1)
C  YLLIW(ISPEC)=YTEMPW(ISPEC,1)
210  CONTINUE
C  -----
C  END OF G.I. TRACT CALCULATION.
C  -----
220  CONTINUE
C  -----
C  OTHER ORGANS
C  -----
C  NORG=NSOU-6
C  DO 250 IORG=1, NORG
C  DO 230 ISPEC=1, NSPEC
C  NUMBER OF SUBCOMPARTMENTS, INTAKE RATE, COEFFICIENTS, REMOVAL RATES,
C  AND INITIAL CONDITIONS..
C  NCTEMP(ISPEC)=NCOMP(ISPEC, IORG)
C  NC=NCOMP(ISPEC, IORG)
C  DO 225 IC=1, NC
C  CTEMP(ISPEC, IC)=C(ISPEC, IC, IORG)
C  LB(ISPEC, IC)=LMBOAB(ISPEC, IC, IORG)
C  PTEMP(ISPEC, IC)=(LMAB(ISPEC,1)
C  $ *YSW(ISPEC)+LMAB(ISPEC,2)*YSIW(ISPEC)
C  $ +LMAB(ISPEC,3)*YULIW(ISPEC)
C  $ +LMAB(ISPEC,4)*YLLIW(ISPEC))
C  $ *F2PR IM(ISPEC, IORG))/DELT
C  IF(MODE .EQ. 1) PTEMP(ISPEC, IC)=PTEMP(ISPEC, IC)
C  $ +((LMA(ISPEC)*YNPW(ISPEC,1)+LMC(ISPEC)*Y1TBW(ISPEC,1)
C  $ +LME(ISPEC)*YPW(ISPEC,1)+LMI(ISPEC)*YLW(ISPEC,1))
C  $ *F2PR IM(ISPEC, IORG))/DELT
C  YTEMP0(ISPEC, IC)=YORG(ISPEC, IC, IORG)
225  CONTINUE
230  CONTINUE
C  CALL MULCOM(DELT, NSPEC, LMR, LB, CTEMP, NCTEMP, BRANCH,

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      $      PTEMP,YTEMP0,YTEMP,YTEMPW)
C
C MOVE OUTPUTS FROM ORGAN IORG..
      DO 240 ISPEC=1,NSPEC
          NC=NCOMP(ISPEC,IORG)
          DO 235 IC=1,NC
              YORG(ISPEC,IC,IORG)=YTEMP(ISPEC,IC)
              YORGW(ISPEC,IC,IORG)=YTEMPW(ISPEC,IC)
          235      CONTINUE
      240      CONTINUE
C
C END OF IORG LOOP..
      250 CONTINUE
C-----
C END OF OTHER ORGANS
C-----
      RETURN
      END
      SUBROUTINE MULCOM(T,N,LMR,LMB,C,NCOMP,BRANCH,P,A0,A,AW)
      REAL T,LMR(20),LMB(20,5),C(20,5),BRANCH(20,20),P(20,5),
      $ A0(20,5),A(20,5),AW(20,5)
      DOUBLE PRECISION TA1,TA2,TAW1,TAW2,TERM
      INTEGER NCOMP(20)
      DOUBLE PRECISION E(950),H(20,5),D(20,5),G
      DOUBLE PRECISION LM(20,5),LX(100)
      DOUBLE PRECISION EXPFUN,EXPP1,ELX1,EXILI,
      $ TEMP,TEMP1
C THE FOLLOWING INTEGER-VALUED STATEMENT FUNCTION COMPUTES THE INDEX
C OF THE (I,J,M)-TH ENTRY IN THE ARRAY E.
      INDXE(I,J,M)=J+(I-1)*(I-2)/2+(M-1)*NN2
      NN2=N*(N-1)/2
      IF(T.GT. 0.0) GO TO 20
      DO 10 I=1,N
          NCI=NCOMP(I)
          DO 5 M=1,NCI
              A(I,M)=A0(I,M)
              AW(I,M)=0.0
          5      CONTINUE
      10      CONTINUE
      GO TO 300
      20 CONTINUE
C
C COMPUTE TOTAL LAMBDA'S AND STORE IN LINEAR ARRAY LX FOR SEPARATION.
      KOUNT=0
      DO 40 I=1,N
          NCI=NCOMP(I)
          DO 30 M=1,NCI
              KOUNT=KOUNT+1
              LX(KOUNT)=LMR(I)+LME(I,M)
              IF (I.EQ. 1 .AND. LX(KOUNT) .LT. 6.93E-07)
                  $ LX(KOUNT)=6.93E-07
          30      CONTINUE
      40      CONTINUE
C
C IF TWO LX(I) ARE NEARLY EQUAL . SEPARATE THEM.
C
C SKIP SEPARATION ROUTINE IF N=1.
      IF(N.EQ. 1) GO TO 65
C
C BEGINNING OF SEPARATION ROUTINE. KOUNT=NO. ELEMENTS IN LX.
      KOUNT1=KOUNT-1
C CODE IS A SWITCH FOR WHICH THE VALUE 1 MEANS ANOTHER
C PASS SHOULD BE MADE.
      KODE=1
      45 IF(KODE.NE. 1) GO TO 65
      KODE=0
C BEGIN PASS.
      DO 60 K=1,KOUNT1
          K1=K+1
          DO 55 L=K1,KOUNT1
C IF LX(L) AND LX(K) ARE NEARLY EQUAL, SEPARATE THEM.
              IF(DABS(LX(L)/LX(K)-1.000) .GE. 1.00-6) GO TO 55
              LX(L)=LX(K)*1.00001D0
              KODE=1
          55      CONTINUE
      60      CONTINUE
      65      CONTINUE

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55     CONTINUE
60     CONTINUE
C RETURN FOR (POSSIBLY) ANOTHER PASS BY MEANS OF BACKWARD-POINTING
C GO TO STATEMENT.
    GO TO 45
C END OF SEPARATION ROUTINE.
65     CONTINUE
C
C MOVE SEPARATED RATE COEFFICIENTS FROM LX TO LM.
    KOUNT=0
    DO 80 I=1,N
        NCI=NCOMP(I)
        DO 70 M=1,NCI
            KOUNT=KOUNT+1
            LM(I,M)=LX(KOUNT)
        70     CONTINUE
    80     CONTINUE
C
C BEGIN MAIN CALCULATION. I=1 IS HANDLED AS A SPECIAL CASE.
    I=1
    NCI=NCOMP(I)
    DO 90 K=1,NCI
        D(I,K)=DBLE(C(I,K)*P(I,K))/LM(I,K)
        H(I,K)=DBLE(A0(I,K))-D(I,K)
        A(I,K)=SNGL(D(I,K)+H(I,K)*EXPFUN(-DBLE(T)*LM(I,K)))
        AW(I,K)=SNGL(D(I,K)*DBLE(T)+H(I,K)*EXPF1(LM(I,K),
        $ DBLE(T)))
    90     CONTINUE
    IF(I.EQ.N) GO TO 300
    DO 200 I=2,N
        I1=I-1
        NCI=NCOMP(I)
        DO 110 K=1,NCI
            TEMP=0.0D0
            DO 93 J=1,I1
                TEMP1=0.0D0
                NCJ=NCOMP(J)
                DO 91 M=1,NCJ
                    TEMP1=TEMP1+D(J,M)
            91     CONTINUE
            TEMP=TEMP+DBLE(BRANCH(I,J))*TEMP1
        93     CONTINUE
        D(I,K)=DBLE(C(I,K))/LM(I,K)*(DBLE(LMP(I))*TEMP+P(I,K))
        TEMP=0.0D0
    110     CONTINUE
        DO 150 J=1,I1
            NCJ=NCOMP(J)
            DO 140 M=1,NCJ
                IJM=INDXE(I,J,M)
                E(IJM)=0.0D0
                IF(J.GT.I-2) GO TO 140
                J1=J+1
                DO 130 IR=J1,I1
                    TEMP1=0.0D0
                    NCIR=NCOMP(IR)
                    DO 120 MU=1,NCIR
                        IRJM=INDXE(IR,J,M)
                        TEMP1=TEMP1+DBLE(C(IR,MU)*LMR(IR))/(LM(IR,MU)-LM(J,M))
                        $ *(E(IRJM)+DBLE(BRANCH(IR,J))*H(J,M))
                    120     CONTINUE
                    E(IJM)=E(IJM)+DBLE(BRANCH(I,IR))*TEMP1
                130     CONTINUE
            140     CONTINUE
        150     CONTINUE
C
C COMPUTE H(I,K), K=1,...,NCOMP(I).
    DO 180 K=1,NCI
        TEMP=0.0D0
        DO 175 J=1,I1
            NCJ=NCOMP(J)
            DO 170 M=1,NCJ
                IJM=INDXE(I,J,M)
                TEMP=TEMP+DBLE(LMR(I))/(LM(I,K)-LM(J,M))
                $ *(E(IJM)+DBLE(BRANCH(I,J))*H(J,M))
            170     CONTINUE
        175     CONTINUE
        H(I,K)=DBLE(A0(I,K))-D(I,K)-DBLE(C(I,K))*TEMP
    180     CONTINUE

```



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C
DOUBLE PRECISION TIME
LOGICAL DEFAULT
DIMENSION H(20)
COMMON /CASES/ NCASES,MODE(6),TEND(6),NINT(6),T(6,30),P(6,30),
$ ISOL(6,20),AMAD(6),DEFAULT(6),FLUNG(6,9,20),TBLUNG(6,9,20),
$ F1(6,20),GIFRAC(6,20,4)
COMMON /HALGES/ ICASE
COMMON /NUMBRS/ NSPEC,NSOU,NTRG
DO 10 ISPEC=1,NSPEC
  H(ISPEC)=0.0
10 CONTINUE
  IF (MODE(ICASE).NE.1) GO TO 40
  NI1=NINT(ICASE)-1
  IF (NI1.EQ.0) GO TO 30
  DO 20 I=1,NI1
    IF (SNGI(TIME).GE.T(ICASE,I+1)) GO TO 20
    H(I)=P(ICASE,I)
  GO TO 40
20 CONTINUE
30 H(1)=P(ICASE,NI1+1)
40 RETURN
END

```

```

SUBROUTINE GES(TIME,G)
C
C CALCULATES THE INTAKE RATE BY INGESTION
C
DOUBLE PRECISION TIME
LOGICAL DEFAULT
DIMENSION G(20)
COMMON /CASES/ NCASES,MODE(6),TEND(6),NINT(6),T(6,30),P(6,30),
$ ISOL(6,20),AMAD(6),DEFAULT(6),FLUNG(6,9,20),TBLUNG(6,9,20),
$ F1(6,20),GIFRAC(6,20,4)
COMMON /HALGES/ ICASE
COMMON /NUMBRS/ NSPEC,NSOU,NTRG
DO 10 ISPEC=1,NSPEC
  G(ISPEC)=0.0
10 CONTINUE
  IF (MODE(ICASE).NE.2) GO TO 40
  NI1=NINT(ICASE)-1
  IF (NI1.EQ.0) GO TO 30
  DO 20 I=1,NI1
    IF (SNGI(TIME).GE.T(ICASE,I+1)) GO TO 20
    G(I)=P(ICASE,I)
  GO TO 40
20 CONTINUE
30 G(1)=P(ICASE,NI1+1)
40 RETURN
END

```

```

SUBROUTINE OUTPUT
C
C PRINTS SPECIFICATION INFORMATION AND OUTPUT FOR EACH
C OF THE CASES.
DOUBLE PRECISION NAMNUC,NAMSOU,NAMTRG,NAMTOT,GISEG,NAMSEC
LOGICAL DEFAULT,ERFLAG
INTEGER OUT,OUT2,OUT3,NDICAT(2)
REAL LUNDOS,CLASS(4),NMLET(2)
DIMENSION FOUT(9),TOUT(5),GISEG(4),NAMSEC(3)
COMMON /GENETC/ DOSTES(2,6),DOSOV(2,6),DOSGON(2,6)
COMMON /PERCNT/ PCTDOS(2,6,27,13),PCTORT(2,6,27,13)
COMMON /NAMES/ NAMNUC(20),NAMSOU(24),NAMTRG(27)
COMMON /NUMBRS/ NSPEC,NSOU,NTRG
COMMON /DOSES/ DOSE(2,6,24,15),DOSRAT(2,11,6,27),DOSTIM(11)
COMMON /CASES/ NCASES,MODE(6),TEND(6),NINT(6),T(6,30),
$ P(6,30),ISOL(6,20),AMAD(6),DEFAULT(6),FLUNG(6,9,20),
$ TBLUNG(6,9,20),F1(6,20),GIFRAC(6,20,4)
COMMON /RESDP/ D3,D4,D5
COMMON /ALERT/ ERFLAG(6)
COMMON /LET/ NLET
COMMON /NUMTIM/ NTIMES
COMMON /LUNGRG/ LUNDOS(2,6,3)
DATA NMLET/4HLOW ,4HHIGH/

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DATA GISEG/8HSTOMACH ,8HS INT ,8HU L INT ,8HL L INT /
DATA OUT/6/
DATA OUT2/6/
DATA OUT3/16/
DATA NAMTOT/8HTOTAL /
DATA DLIT,WLIT,YLIT,STAR/4HD ,4HW ,4HY ,4H* /
DATA NAMSEC/8H*N-P* ,8H*T-B* ,8H*PUL* /
DATA NDICAT/3,2/
DATA CLASS/4HD ,4HW ,4HY ,4H* /
C STORE HEADING FOR 'TOTAL' C COLUMN OF DOSE MATRIX.
  NAMSOU(NSOU+1)=NAMTOT
C STORE HEADINGS FOR RESPIRATORY TRACT SECTIONS
  NAMTRG(NTRG+1)=NAMSEC(1)
  NAMTRG(NTRG+2)=NAMSEC(2)
  NAMTRG(NTRG+3)=NAMSEC(3)
C
C FOR EACH OF THE SEVERAL CASES, PRINT OUTPUT.
  DO 75 ICASE=1,NCASES
C
C DETERMINE EXPOSURE MODE FOR THE CURRENT CASE.
  IF (MODE(ICASE).EQ.1) GO TO 30
C -----
C INGESTION CASE
C -----
  NI=NINT(ICASE)
  WRITE(OUT,1000) ICASE
  INT=NI+1
  T(ICASE,INT)=TEND(ICASE)
  WRITE(OUT,1010)(T(ICASE,INT),T(ICASE,INT+1),P(ICASE,INT),
    $ INT=1,NI)
  NS=NSPEC
  IF(NSPEC.GT.12) NS=12
  WRITE(OUT,1020)
  WRITE(OUT,1030) (NAMNUC(ISPEC),ISPEC=1,NS)
  DO 5 ISEG=1,4
5 WRITE(OUT,1040) GISEG(ISEG),(GIFRAC(ICASE,ISPEC,ISEG),
    $ ISPEC=1,NS)
  IF(NS.FQ.NSPEC) GO TO 10
  NS1=NS+1
  WRITE(OUT,1030) (NAMNUC(ISPEC),ISPEC=NS1,NSPEC)
  DO 6 ISEG=1,4
6 WRITE(OUT,1040) GISEG(ISEG),(GIFRAC(ICASE,ISPEC,ISEG),
    $ ISPEC=1,NS)
10 CONTINUE
C
C BRANCH TO SEGMENT WHICH PRINTS DOSE MATRIX.
  GO TO 64
C -----
C END OF CASE INFORMATION FOR INGESTION.
C -----
30 CONTINUE
C -----
C INHALATION CASE.
C -----
  NI=NINT(ICASE)
  WRITE(OUT,1050) ICASE
  INT=NI+1
  T(ICASE,INT)=TEND(ICASE)
  WRITE(OUT,1060)(T(ICASE,INT),T(ICASE,INT+1),P(ICASE,INT),
    $ INT=1,NI)
C CHECK FOR WARNING CONDITION FROM SUBROUTINE INTP.
  IF (ERFLAG(ICASE)) WRITE(OUT,1100)
  WRITE(OUT,1070) AMAD(ICASE),D3,D4,D6
C
C NSC COUNTS SPECIES FOR WHICH SPECIAL LUNG PARAMETERS
C HAVE BEEN ENTERED FOR THE CURRENT CASE.
  NSC=0
C
C PRINT A TABLE OF SOLUBILITY CLASSES AND G. I. UPTAKE
C FRACTIONS F1. IF THE USER HAS PROVIDED SPECIAL LUNG
C PARAMETERS, THIS IS INDICATED BY AN ASTERISK.
  WRITE(OUT,1075)
  DO 40 ISPEC=1,NSPEC
    IF(ISOL(ICASE,ISPEC).EQ.1) GO TO 31
    IF(ISOL(ICASE,ISPEC).EQ.2) GO TO 32
    IF(ISOL(ICASE,ISPEC).EQ.3) GO TO 33

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      GO TO 34
31  FLAG=DLIT
      GO TO 35
32  FLAG=WLIT
      GO TO 35
33  FLAG=YLIT
      GO TO 35
34  FLAG=STAR
      NSC=NSC+1
35  WRITE(OUT,1080) NAMNUC(ISPEC),FLAG,(GIFRAC(ICASE,ISPEC,ISEG),
      $      ISEG=1,4)
40  CONTINUE
C
C IF THERE ARE NO SPECIAL LUNG PARAMETERS, PROCEED TO SEGMENT
C WHICH PRINTS DOSE MATRIX.
      IF(NSC .EQ. 0) GO TO 64
C
C OTHERWISE, WRITE OUT SPECIAL LUNG PARAMETERS.
      WRITE(OUT,1085)
      DO 50 ISPEC=1,NSPEC
        IF(ISOL(ICASE,ISPEC) .LT. 4) GO TO 50
        DO 45 IPATH=1,9
          FOUT(IPATH)=FLUNG(ICASE,IPATH,ISPEC)
          TOUT(IPATH)=TBLUNG(ICASE,IPATH,ISPEC)
          IF(TOUT(IPATH) .GT. 0.0) TOUT(IPATH)=0.6931472
        $      /TOUT(IPATH)
45  CONTINUE
      WRITE(OUT,1090) NAMNUC(ISPEC),FOUT,TOUT
50  CONTINUE
C-----
C PRINT DOSE MATRIX
C-----
64  CONTINUE
C
C+++++
C FOR EPA CALCULATIONS, THE ACCUMULATED DOSE IS NOT OF INTEREST SINCE
C WE ARE CONCERNED WITH THE DOSE RATES AT VARIOUS TIMES. THEREFORE,
C WE WILL BYPASS THIS OUTPUT FOR THIS APPLICATION.
C+++++
C
      GO TO 81
C
C
C IF INGESTION CASE, DOSE FROM LUNGS AND RES. LYMPH IS ZERO AND IS
C NOT PRINTED.
C BRANCH TO INGESTION CASE IN THIS EVENT.
      IF (MODE(ICASE).EQ.2) GO TO 65
C-----
C INHALATION CASE
C-----
      DO 63 ILET=1,NLET
        IFIRST=1
        NSOU2=NSOU+1
        ILAST=NSOU+1
        IF (NSOU2.GT.12) ILAST=12
        CALL PRINTD(ILET,IFIRST,ILAST,ICASE)
        IF (ILAST.EQ.NSOU2) GO TO 62
        IFIRST=13
        ILAST=NSOU2
        IF (NSOU2.GT.23) ILAST=23
        CALL PRINTD(ILET,IFIRST,ILAST,ICASE)
        IF (ILAST.EQ.NSOU2) GO TO 62
        IFIRST=24
        ILAST=NSOU2
        CALL PRINTD(ILET,IFIRST,ILAST,ICASE)
62  IF (ILET .EQ. 1) WRITE(CUT,1200)
        IF (ILET .EQ. 2) WRITE(CUT,1201)
        WRITE(OUT,1210) (NAMSEC(J),LUNDOS(ILET,ICASE,J),J=1,3)
63  CONTINUE
      GO TO 70
C-----
C INGESTION CASE
C-----
65  DO 66 ILET=1,NLET
        IFIRST=3
        NSOU2=NSOU+1
        ILAST=NSOU+1
        IF (NSOU2.GT.14) ILAST=14

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      CALL PRINTD(ILET,IFIRST,ILAST,ICASE)
      IF (ILAST.EQ.NSOU2) GO TO 66
      IFIRST=15
      ILAST=NSOU2
      IF (NSOU2.GT.24) ILAST=24
      CALL PRINTD(ILET,IFIRST,ILAST,ICASE)
66  CONTINUE
C-----
C PUNCH DOSES ON CARDS FOR LATER TABULATIONS.
C-----
      71 WRITE(7,2002) NAMNUC(1),ICASE,MODE(ICASE),F1(ICASE,1),
      $ (DOSE(NLET,ICASE,JTARG,NSOU2),JTARG=1,NTRG)
2002 FORMAT(A8,I4,I4,I4,X,5E10.3/ 7E10.3,9X,'2'/ 7E10.3,9X,'3'/ 4E10.3,
      $ 39X,'4')
      GO TO 72
      70 WRITE(7,2000) NAMNUC(1),ICASE,MODE(ICASE),ISOL(ICASE,1),
      $ AMAD(ICASE),
      $ F1(ICASE,1),(DOSE(NLET,ICASE,JTARG,NSOU2),JTARG=1,NTRG)
2000 FORMAT(A8,I4,I4,I4,I4,6E10.3/ 7E10.3,9X,'2'/ 7E10.3,9X,'3'/ 4E10.3,
      $ 39X,'4')
      72 CONTINUE
C-----
C IF NSPEC IS GREATER THAN 1, PRINT TABLE CONTAINING PERCENT OF TOTAL
C DOSE TO EACH TARGET ORGAN DUE TO EACH SPECIES OF THE CHAIN.
C-----
999  CONTINUE
      IF(NSPEC.EQ. 1) GO TO 81
      NTRGP=NTRG
      IF (MODE(ICASE).EQ. 1) NTRGP=NTRG + 3
      DO 81 ILET=1,NLET
        IF(ILET.EQ. 1) WRITE(OUT,100)
        IF(ILET.EQ. 2) WRITE(OUT,104)
        WRITE(OUT,101) (NAMNUC(ISPEC),ISPEC=1,NSPEC)
        WRITE(OUT,102)
        DO 80 ITRG=1,NTRGP
          WRITE(OUT,103) NAMTRG(ITRG),(PCTDOS(ILET,ICASE,ITRG,ISPEC),
          $ ISPEC=1,NSPEC)
      80  CONTINUE
      81 CONTINUE
C+++++
C PRINT MATRIX OF DOSE RATES
C+++++
      DO 91 ILET=1,NLET
C PRINT HEADING
        IF (ILET.EQ. 1) WRITE(OUT2,200)
        IF (ILET.EQ. 2) WRITE(OUT2,210)
        WRITE(OUT2,220) (DOSTIM(I),I=1,NTIMES)
        WRITE(OUT2,230)
        NTRGP=NTRG
        IF (MODE(ICASE).EQ. 1) NTRGP=NTRG+3
        DO 90 ITRG=3,NTRGP
          IF (ITRG.EQ. 7 .OR. ITRG.EQ. 8 .OR. ITRG.EQ. 15 .OR.
          $ ITRG.EQ. 17 .OR. ITRG.EQ. 19) GO TO 90
          WRITE(OUT2,240) NAMTRG(ITRG),(DOSRAT(ILET,ITIME,ICASE,ITRG),
          $ ITIME=1,NTIMES)
      90 CONTINUE
        IF (MODE(ICASE).EQ. 2) WRITE(OUT2,245) (DOSRAT(ILET,ITIME,ICASE,1),
        $ ITIME=1,NTIMES)
C+++++
C IF NSPEC > 1, PRINT PERCENT DOSE RATE TABLE.
C+++++
      IF(NSPEC.EQ. 1) GO TO 91
      NTRGP=NTRG
      IF (MODE(ICASE).EQ. 1) NTRGP=NTRG + 3
      IF (ILET.EQ. 1) WRITE(OUT3,270)
      IF (ILET.EQ. 2) WRITE(OUT3,280)
      WRITE(OUT3,101) (NAMNUC(ISPEC),ISPEC=1,NSPEC)
      WRITE(OUT3,102)
      DO 94 ITRG=1,NTRGP
        IF (ITRG.EQ. 7 .OR. ITRG.EQ. 8 .OR. ITRG.EQ. 15 .OR.
        $ ITRG.EQ. 17 .OR. ITRG.EQ. 19) GO TO 94
        WRITE(OUT3,103) NAMTRG(ITRG),(PCTDRT(ILET,ICASE,ITRG,ISPEC),
        $ ISPEC=1,NSPEC)
      94  CONTINUE
      91 CONTINUE

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C+++++
C OUTPUT 30-YEAR GENETIC DOSE COMMITMENTS FOR TESTES, OVARIES, AND
C AN AVERAGE.
C+++++
      WRITE(OUT2,105)
      DO 96 ILET=1,NLET
        WRITE(OUT2,106) NMLET(ILET),DOSTES(ILET,ICASE),
          $ DOSOVR(ILET,ICASE),DOSGON(ILET,ICASE)
      96 CONTINUE
C+++++
C OUTPUT DOSE RATES TO PUNCHED CARDS FOR LATER REFERENCE.
C+++++
      IF (MODE(ICASE).EQ. 1) WRITE(27,250) NAMNUC(1),MODE(ICASE),
        $ ISOL(ICASE,1),AMAD(ICASE), F1(ICASE,1),NLET,NTIMES
      IF (MODE(ICASE).EQ. 2) WRITE(27,255) NAMNUC(1),MODE(ICASE),
        $ F1(ICASE,1),NLET,NTIMES
      NTRGP=NTRG
      IF (MODE(ICASE).EQ. 1) NTRGP=NTRG + 3
      DO 93 ITRG=1,NTRGP
      DO 92 ILET=1,NLET
        WRITE(27,260) NAMTRG(ITRG),(DOSRAT(ILET,ITIME,ICASE,ITRG),
          $ ITIME=1,NTIMES)
      92 CONTINUE
      93 CONTINUE
      WRITE(27,290) (DOSTES(ILET,ICASE),DOSOVR(ILET,ICASE),
        $ DOSGON(ILET,ICASE),ILET=1,NLET)
C+++++
C UNFORMATTED OUTPUT TO DISK FOR USE IN DARTAB PROGRAM.
C+++++
      DUMMY=0.0
      NUMTRG=NTRG
      IF (MODE(ICASE).EQ. 1) NUMTRG=NTRG+3
      DO 95 ITIME=1,NTIMES
        IF (MODE(ICASE).EQ. 1) WRITE(25) NAMNUC(1),AMAD(ICASE),
          $ CLASS(ISOL(ICASE,1)),(GIFRAC(ICASE,1,I),I=1,4),DOSTIM(ITIME),
          $ NDICAT(MODE(ICASE)))
        IF (MODE(ICASE).EQ. 2) WRITE(25) NAMNUC(1),DUMMY,DUMMY,
          $ (GIFRAC(ICASE,1,I),I=1,4),DOSTIM(ITIME),NDICAT(MODE(ICASE)))
        WRITE(25) NUMTRG,NLET,(NAMTRG(ITRG),ITRG=1,NUMTRG)
        WRITE(25) ((DOSRAT(ILET,ITIME,ICASE,ITRG),ILET=1,NLET),
          $ ITRG=1,NUMTRG)
      95 CONTINUE
      75 CONTINUE
      RETURN

C
C FORMAT STATEMENTS
100 FORMAT('0PERCENT DOSE (LOW-LET)..')
104 FORMAT('0PERCENT DOSE (HIGH-LET)..')
101 FORMAT('0NUCLIDE',T13,14A8,A7)
102 FORMAT('0TARGET')
103 FORMAT(' ',A8,T12,14(F5.1,3X),F5.1)
105 FORMAT('// 30-YEAR GENETIC DOSE COMMITMENT (MRAD)../'0LET',T11,
  $ 'TESTES',T26,'OVARIES',T41,'AVERAGE')
106 FORMAT(' ',A4,T10,1PE9.2,T25,1PE9.2,T40,1PE9.2)
200 FORMAT('0LOW-LET DOSE RATE (MRAD/YEAR)')
210 FORMAT('0HIGH-LET DOSE RATE (MRAD/YEAR)')
220 FORMAT('0TIME (YEARS)',11(F5.0,5X))
230 FORMAT('0TARGET')
240 FORMAT(' ',A8,T12,11(1PE9.2,1X))
245 FORMAT(' *PUL*',T12,11(1PE9.2,1X))
250 FORMAT(A8,2I4,4X,2E10.3,2I4)
255 FORMAT(A8,T4,18X,E10.3,2I4)
260 FORMAT(' A8,7E10.3/8E10.3)
270 FORMAT('0PERCENT DOSE RATE IN THE 70TH YEAR (LOW-LET)..')
280 FORMAT('0PERCENT DOSE RATE IN THE 70TH YEAR (HIGH-LET)..')
290 FORMAT('TESTES ',E10.3,'OVARIES ',E10.3,'AVERAGE ',E10.3)
1000 FORMAT('// CASE',I2,'.. INGESTION'/' ',19('-'))
1010 FORMAT('// INGESTION INTAKE RATE FUNCTION (MICROCURI/DAAY)'/
  $ ' ',T6,' FROM (DAYS)',T20,' TO (DAYS)',T33,' RATE'/'
  $ (' ',1P3G13.3))
1020 FORMAT('// INGESTION TRANSFER FRACTIONS (G. I. TRACT TO BLOOD)
  $ ')
1030 FORMAT('// ',T9,12(2X,A8))
1040 FORMAT(' ',A8,T10,1P12G10.3)
1050 FORMAT('// CASE',I2,'.. INHALATION'/' ',20('-'))
1060 FORMAT('// INHALATION INTAKE RATE FUNCTION (MICROCURI/DAAY)'/
  $ ' ',T6,' FROM (DAYS)',T20,' TO (DAYS)',T33,' RATE'/'

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$ (' ',1P3G13.3))
1070 FORMAT('O AMAD (MICRON).. ',1PG9.3,5X,'D3 =',G9.3,
$ 5X,'D4 =',G9.3,5X,'D5 =',G9.3)
1075 FORMAT('O',T34,'G.1. UPTAKE FRACTIONS'/' ',T13,'SOLUBILITY',T26,
$ 37(' ')/' ',T15,'CLASS',T26,'STOMACH',T36,'S INT',
$ T46,'U L INT',T56,'L L INT'/)
1080 FORMAT(' ',A8,T17,A1,T25,1P4G10.3)
1085 FORMAT('O*SPECIAL LUNG CLEARANCE PARAMETERS. T=HALF-TIME (DAYS),
$F=DEPOSITION FRACTION.'/' ' CLEARANCE'/' ' PATHWAY..' ',
$ T16,'A',T26,'B',T36,'C',T46,'D',T56,'E',T66,'F',T76,'G',
$ T86,'H',T96,'I'/)
1090 FORMAT(' ',A8,2X,'F',9(1X,1PG9.2)/' ',T12,'T',9(1X,1PG9.2))
1100 FORMAT('OWARNING: AMAD EXCEEDS THE RANGE OF AVAILABLE DATA ',
$ 'FOR D3,D4 AND D5 FUNCTIONS')
1200 FORMAT('O', 'LOW-LET RESPIRATORY DOSE DISTRIBUTION (RAD)'/
$ ' (CROSS IRRADIATION CONSIDERED FOR PULMONARY REGION ONLY)'/
$ 'OREGION',T14,'DOSE'/)
1201 FORMAT('O', 'HIGH-LET RESPIRATORY DOSE DISTRIBUTION (RAD)'/
$ ' (CROSS IRRADIATION CONSIDERED FOR PULMONARY REGION ONLY)'/
$ 'OREGION',T14,'DOSE'/)
1210 FORMAT(' ',A8,T12,1PG10.3)
END

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SUBROUTINE PRINTD(ILET,IFIRST,I LAST,JCASE)
C
C PRINTS A HEADING AND THEN PRINTS COLUMNS IFIRST THROUGH I LAST OF THE DOSE
C MATRIX WHEN CALLED BY THE OUTPUT SUBROUTINE
DOUBLE PRECISION NAMNUC, NAMSOU, NAMTRG
INTEGER OUT
COMMON /NAMES/ NAMNUC(20),NAMSOU(24),NAMTRG(27)
COMMON /NUMBRS/ NSPEC,NSOU,NTRG
COMMON /DOSES/ DOSE(2,6,24,15),DOSRAT(2,11,6,27),DOSTIM(11)
COMMON /CASES/ NCASES,MODE(6),TEND(6),NINT(6),T(6,30),P(6,30),
$ ISOL(6,20),AMAD(6),DEFAULT(6),FLUNG(6,9,20),TBLUNG(6,9,20),
$ F1(6,20),GIFRAC(6,20,4)
DATA OUT/6/
C PRINT HEADING
IF (ILET .EQ. 1) WRITE(CUT,100)
IF (ILET .EQ. 2) WRITE(CUT,101)
C PRINT NAMES OF SOURCES
IF(IFIRST .LT. 7) GO TO 20
WRITE(OUT,110)(NAMSOU(ISOU),ISOU=IFIRST,I LAST)
C PRINT LABEL
WRITE(OUT,120)
C PRINT NAMES OF TARGETS AND DOSES
DO 10 ITRG=1,NTRG
WRITE(OUT,130) NAMTRG(ITRG),(DOSE(ILET,JCASE,ITRG,ISOU),ISOU=
$ IFIRST,I LAST)
10 CONTINUE
GO TO 30
20 WRITE(OUT,110) (NAMSOU(ISOU),ISOU=IFIRST,6),(NAMSOU(ISOU),ISOU=8,
$ I LAST)
WRITE(OUT,120)
DO 30 ITRG=1,NTRG
WRITE(OUT,130) NAMTRG(ITRG),(DOSE(ILET,JCASE,ITRG,ISOU),
$ ISOU=IFIRST,6),(DOSE(ILET,JCASE,ITRG,ISOU),ISOU=8,I LAST)
30 CONTINUE
C
RETURN
C
C FORMAT STATEMENTS
100 FORMAT('OLOW-LET DOSE EQUIVALENT (RAD)')
101 FORMAT('OHIGH-LET DOSE EQUIVALENT (RAD)')
110 FORMAT('OSOURCE',T13,11(A8,3X))
120 FORMAT('OTARGET')
130 FORMAT(' ',A8,T12,11(1PG10.3,1X))
END

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SUBROUTINE RISK
DOUBLE PRECISION NAMNUC,NAMSOU,NAMTRG,TITLE1(3),TITLE2(2),
$ TITLE3(3),REFTBL,CANCER(20),DEAD(20,2),AYEARS(20,2),
$ DECRLE(20,2),DRATE(20,2),NAMLET(2),NAMPUL,NAMBN,
$ NAMGEN(3)

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LOGICAL DEFAULT
REAL DOSE(9),NAMCLS(4),BASORG(20),HELFAC(20),NMRISK(3),
$ Q(2),PEMDOS(20),TDEAD(20),NMLET(2),NFAC,DEAD2(20,2),TYRS2(20,2)
INTEGER SWITCH(7),INDTRG(20),NDICAT(2,3),IPLATO(20),LATNCY(20),
$ SWITCH3(20),SW3,INDEX1(2)
COMMON /LIFTBL/ INLIFE
COMMON /REFLIF/ REFTBL(11,3,3)
COMMON /DOSES/ DOSCOM(2,6,24,15),DOSPAT(2,11,6,27),DOSTIM(11)
COMMON /GENETC/ DOSTES(2,6),DOSOV(2,6),DOSGON(2,6)
COMMON /NAMES/ NAMNUC(20),NAMSOU(24),NAMTRG(27)
COMMON /NUMBPS/ NSPEC,NSOU,NTRG
COMMON /LET/ NLET
COMMON /CASES/ NCASES,MCDE(6),TEND(6),NINT(6),T(6,30),P(6,30),
$ ISOL(6,20),AMAD(6),DEFAULT(6),FLUNG(6,9,20),TBLUNG(6,9,20),
$ F1(6,20),GIFRAC(6,20,4)
COMMON /NUMTIM/ NTIMES
DATA SWITCH/3,2,2,1,4,1,9/
DATA SWITCH3/20*2/
DATA TITLE1/8H MALE ,8H FEMALE ,8H TOTAL /
DATA TITLE2/8H INHALA ,8H INGES/
DATA TITLE3/8H NO ,8H ABSOLUTE ,8H RELATIVE/
DATA NMRISK/4HNO ,4HABS ,4HREL /
DATA CANCER/8HR MARROW ,8HENDOST ,8HPULMINARY ,8HBPEAST ,
$ 8HLIVER ,8HST WALL ,8HPANCREAS ,8HLLI WALL ,
$ 8HKIDNEYS ,8HBL WALL ,8HULI WALL ,8HSI WALL ,
$ 8HOVARIES ,8HTESTES ,8HSPLEEN ,8HUTERUS ,
$ 8HTHYMUS ,8HTHYROID ,2*8H /
DATA BLANK/4H /
DATA NAMCLS/4HD ,4HW ,4HY ,4H* /
DATA NAMLET/8H LOW LET ,8HHIGH LET/
DATA NMLET/4HLOW ,4HHIGH/
DATA NAMPUL/8HPULMINARY/
DATA NAMBON/8HBONE /
DATA NAMGEN/8HTESTES ,8HOVARIES ,8HAVERAGE /
DATA Q/1.0,20.0/
DATA INDTRG/16,18,27,12,11,3,14,6,10,9,5,4,13,21,20,24,22,23,1,1/
DATA NDICAT/13,12,23,22,0,0/
DATA INDEX1/3,2/
DATA NUMCAN/18/
DATA BASORG/3,26E-01,3,08E-02,6,08E-01,3,99E-01,1,56E-01,8,68E-02,
$ 1,21E-01,6,94E-02,3,47E-02,3,47E-02,3,47E-02,1,74E-02,1,74E-02,
$ 1,74E-02,1,74E-02,1,74E-02,1,74E-02,8,47E-02,2,09E+00,1,0/
C READ REFERENCE LIFE TABLE DATA IF THIS IS THE FIRST CALL TO RISK..
IF (INLIFE .EQ. 0)
$ READ(5,100)((REFTBL(IAGE,IREF,IPOP),IREF=1,3),IAGE=1,111),
$ IPOP=1,3)
C INITIALIZE PARAMETEPS..
RISTIM=110.0
NUMCN1=NUMCAN + 1
ONE=1.0
DO 40 ICASE=1,NCASES
RADINT=P(ICASE,1)*1.0E+06*365.0
HELFAC(NUMCN1)=0.0
TDEAD(NUMCN1)=0.0
TOTYRS=0.0
DO 9 ILET=1,NLET
DEAD(NUMCN1,ILET)=0.0D0
TYEARS(NUMCN1,ILET)=0.0D0
DECRLE(NUMCN1,ILET)=0.0D0
9 CONTINUE
C COMPUTE RISK FOR EACH CANCER..
DO 20 KAN=1,NUMCAN
HELFAC(KAN)=0.0
TDEAD(KAN)=0.0
REMDOS(KAN)=0.0
SW3=SWITCH3(KAN)
DO 15 ILET=1,NLET
ACTIVT=0.0
DRATE(KAN,ILET)=0.0D0
DEAD(KAN,ILET)=0.0D0
DEAD2(KAN,ILET)=0.0
AYEARS(KAN,ILET)=0.0D0
TYEAPS(KAN,ILET)=0.0D0
TYRS2(KAN,ILET)=0.0
DECRLE(KAN,ILET)=0.0D0
C DEFINE DOSE RATE FOR EACH CASE, ORGAN, AND TIME..
INDEX=INDTRG(KAN)
IF (MODE(ICASE) .EQ. 2 .AND. CANCER(KAN) .EQ. NAMPUL) INDEX=1

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      DO 10 ITIME=1,7
        DOSE(ITIME)=DOSRAT(ILET,ITIME,ICASE,INDEX)
10      CONTINUE
        DOSE(8)=DOSRAT(ILET,9,ICASE,INDEX)
        DOSE(9)=DOSRAT(ILET,11,ICASE,INDEX)
C CONVERT TO MRAD/YR..
      DO 16 ITIME=1,9
        DOSE(ITIME)=DOSE(ITIME) * 1.0
16      CONTINUE
C COMPUTE DOSE EQUIVALENT IN THE 70TH YEAR FOR REFERENCE TABULATION..
      NFAC=1.0
      IF (ILET.EQ. 2 .AND. CANCER(KAN) .EQ. NAMBON) NFAC=1.0
      RDOS=DOSRAT(ILET,10,ICASE,INDEX)
      REMDOS(KAN)=REMDOS(KAN) + RDOS * Q(ILET) * NFAC * 1.0
C
      IF (DOSE(1) .EQ. 0.0) GO TO 15
C ADJUST DOSE RATE TO FALL WITHIN CAIRD'S LINEAR RANGE..
      ACTIVT=RADINT
      CONV=1.0
      SMALL=DOSE(1)
      BIG=DOSE(9)
14      IF (SMALL .LT. 1.0E-10) CONV=CONV*1.0E+06
      IF (SMALL .LT. 1.0E-10) SMALL=SMALL*1.0E+06
      IF (BIG .GT. 1.0E+03) CONV=CONV*1.0E-06
      IF (BIG .GT. 1.0E+03) BIG=BIG*1.0E-06
      IF (SMALL .LT. 1.0E-10 .AND. BIG .GT. 1.0E+03) GO TO 18
      IF (SMALL .LT. 1.0E-10 .OR. BIG .GT. 1.0E+03) GO TO 14
      DO 17 ITIME=1,9
        DOSE(ITIME)=DOSE(ITIME) * CONV
17      CONTINUE
      ACTIVT=ACTIVT * CONV
C OUTPUT TITLE FOR CURRENT CAIRD CALL..
18      WRITE(26,200)TITLE1(SWITCH(1)),CANCER(KAN),NAMNUC(1),
$      TITLE2(MODE(ICASE)),TITLE3(SW3)
      IF (MODE(ICASE) .EQ. 1) WRITE(26,210) AMAD(ICASE),
$      NAMCLS(ISOL(ICASE,1)),F1(ICASE,1),NAMLET(ILET),ACTIVT
      IF (MODE(ICASE) .EQ. 2) WRITE(26,220) F1(ICASE,1),
$      NAMLET(ILET),ACTIVT
C INVOKE SUBROUTINE CAIRD TO COMPUTE RISK..
      ICAN=KAN
      CALL CAIRD(DOSE,ILET,ICAN,SW3,IPLATO(ICAN),
$      LATNCY(ICAN),DRATE(ICAN,ILET),DEAD(ICAN,ILET),
$      AYEARS(ICAN,ILET),TYEARS(ICAN,ILET),DECRLE(ICAN,ILET))
      DEAD(KAN,ILET)=DEAD(KAN,ILET) / CONV
      DEAD2(KAN,ILET)=SNGL(DEAD(KAN,ILET))
      TYEARS(KAN,ILET)=TYEARS(KAN,ILET) / CONV
      TYRS2(KAN,ILET)=SNGL(TYEARS(KAN,ILET))
      DECRLE(KAN,ILET)=DECRLE(KAN,ILET) / CONV
      DEAD(NUMCN1,ILET)=DEAD(NUMCN1,ILET) + DEAD(ICAN,ILET)
      TYEARS(NUMCN1,ILET)=TYEARS(NUMCN1,ILET) + TYEARS(ICAN,ILET)
      DECRLE(NUMCN1,ILET)=DECRLE(NUMCN1,ILET) + DECRLE(ICAN,ILET)
      TDEAD(KAN)=TDEAD(KAN) + DEAD(KAN,ILET)
      TDEAD(NUMCN1)=TDEAD(NUMCN1) + DEAD(KAN,ILET)
      TOTYRS=TOTYRS + TYEARS(KAN,ILET)
      IF (ACTIVT.NE. RADINT) WRITE(26,225)RADINT,DEAD(KAN,ILET),
$      TYEARS(KAN,ILET),DECRLE(KAN,ILET)
15      CONTINUE
C COMPUTE RISK EQUIVALENT FACTOR FOR ORGAN KAN..
      HELFAC(KAN)=TDEAD(KAN) / BASORG(KAN)
20      CONTINUE
C COMPUTE TOTAL RISK EQUIVALENT FACTOR..
      HELFAC(NUMCN1)=TDEAD(NUMCN1) / BASORG(NUMCN1)
C PRINT SUMMARY TABLE FOR THE CURRENT CASE..
      WRITE(6,230) TITLE1(SWITCH(1)),NAMNUC(1),TITLE2(MODE(ICASE))
      IF (MODE(ICASE) .EQ. 1) WRITE(6,211) AMAD(ICASE),
$      NAMCLS(ISOL(ICASE,1)),F1(ICASE,1),RADINT
      IF (MODE(ICASE) .EQ. 2) WRITE(6,221) F1(ICASE,1),RADINT
      WRITE(6,290)
      WRITE(6,235)
      DO 30 KAN=1,NUMCAN
        INDEX=INDTRG(KAN)
        IF (MODE(ICASE) .EQ. 2 .AND. CANCER(KAN) .EQ. NAMPUL) INDEX=1
        SW3=SWTCH3(KAN)
        RADDOS=DOSRAT(1,10,ICASE,INDEX) * 1.0
        WRITE(6,240) CANCER(KAN),LATNCY(KAN),IPLATO(KAN),
$      NMRISK(SW3),NMLET(1),DRATE(KAN,1),RADDOS,DEAD(KAN,1),
$      AYEARS(KAN,1),TYEARS(KAN,1),DECRLE(KAN,1),REMDOS(KAN),
$      HELFAC(KAN)

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      RADDOS=DOSRAT(2,10,ICASE,INDEX) * 1.0
      IF (NLET .EQ. 2) WRITE(6,245) NMLET(2),DRATE(KAN,2),RADDOS,
$      DEAD(KAN,2),AYEAPS(KAN,2),TYEAPS(KAN,2),DECPLE(KAN,2)
30  CONTINUE
      TOTAYR=TOTYRS / TDEAD(NUMCN1)
      DECRES=TOTYRS / 100000.
      WRITE(6,250) TDEAD(NUMCN1),TOTAYR,TOTYRS,DECRES,HELFAC(NUMCN1)
C  OUTPUT GENETIC 30-YEAR DOSE COMMITMENTS..
      WRITE(6,255)
      DO 31 ILET=1,NLET
        WRITE(6,256) NMLET(ILET),DOSTES(ILET,ICASE),DOSOVR(ILET,ICASE),
$        DOSGON(ILET,ICASE)
31  CONTINUE
      WRITE(6,257)
C
C  OUTPUT TO CARDS FOR LATER REFERENCE..
      IF (MODE(ICASE) .EQ. 1) WRITE(37,260) NAMNUC(1),MODE(ICASE),
$      ISOL(ICASE,1),AMAD(ICASE),F1(ICASE,1),PADINT,NUMCAN,ILET
      IF (MODE(ICASE) .EQ. 2) WRITE(37,270) NAMNUC(1),MODE(ICASE),
$      F1(ICASE,1),RADINT,NUMCAN,ILET
      DO 36 ILET=1,NLET
      DO 35 KAN=1,NUMCAN
        INDEX=INDTRG(KAN)
        IF (MODE(ICASE) .EQ. 2 .AND. CANCER(KAN) .EQ. NAMPUL) INDEX=1
        RADDOS=DOSRAT(ILET,10,ICASE,INDEX) * 1.0
        WRITE(37,280) CANCER(KAN),LATNCY(KAN),IPLATO(KAN),
$        DRATE(KAN,ILET),RADDOS,DEAD(KAN,ILET),AYEAPS(KAN,ILET),
$        TYEAPS(KAN,ILET),HELFAC(KAN)
35  CONTINUE
36  CONTINUE
      WRITE(37,285) (DOSTES(ILET,ICASE),DOSOVR(ILET,ICASE),
$      DOSGON(ILET,ICASE),ILET=1,NLET)
C
C  UNFORMATTED OUTPUT TO DISK FOR USE BY DARTAB PROGRAM..
      DUMMY=0.0
C  ..DOSE RATES..
      NUMTRG=NTRG
      IF (MODE(ICASE) .EQ. 1) NUMTRG=NTRG + 3
C*  NMTRG1=NUMTRG + 1
      DO 37 ITIME=1,NTIMES
        IF (MODE(ICASE) .EQ. 1) WRITE(25) NAMNUC(1),AMAD(ICASE),
$      NAMCLS(ISOL(ICASE,1)),(GIFRAC(ICASE,1,I),I=1,4),
$      DOSTIM(ITIME),INDEX1(MODE(ICASE))
        IF (MODE(ICASE) .EQ. 2) WRITE(25) NAMNUC(1),DUMMY,BLANK,
$      (GIFRAC(ICASE,1,I),I=1,4),DOSTIM(ITIME),INDEX1(MODE(ICASE))
        WRITE(25) NUMTRG,NLET,(NAMTRG(ITRG),ITRG=1,NUMTRG)
        WRITE(25) ((DOSRAT(ILET,ITIME,ICASE,ITRG),ILET=1,NLET),
$      ITRG=1,NUMTRG)
37  CONTINUE
C  ..GENETIC DOSE..
      THIRTY=30.
      ITHREE=3
      IF (MODE(ICASE) .EQ. 1) INDEXG=98
      IF (MODE(ICASE) .EQ. 2) INDEXG=99
      IF (MODE(ICASE) .EQ. 1) WRITE(25) NAMNUC(1),AMAD(ICASE),
$      NAMCLS(ISOL(ICASE,1)),(GIFRAC(ICASE,1,I),I=1,4),
$      THIRTY,INDEXG
      IF (MODE(ICASE) .EQ. 2) WRITE(25) NAMNUC(1),DUMMY,DUMMY,
$      (GIFRAC(ICASE,1,I),I=1,4),THIRTY,INDEXG
      WRITE(25) ITHREE,NLET,(NANGEN(IGEN),IGEN=1,3)
      WRITE(25) (DOSTES(ILET,ICASE),ILET=1,NLET),(DOSOVR(ILET,ICASE),
$      ILET=1,NLET),(DOSGON(ILET,ICASE),ILET=1,NLET)
C  ..RISK ESTIMATES..
      IRISK=SWITCH(3) - 1
      IF (MODE(ICASE) .EQ. 1) WRITE(25) NAMNUC(1),AMAD(ICASE),
$      NAMCLS(ISOL(ICASE,1)),(GIFRAC(ICASE,1,I),I=1,4),RISTIM,
$      NOICAT(MODE(ICASE),IRISK)
      IF (MODE(ICASE) .EQ. 2) WRITE(25) NAMNUC(1),DUMMY,DUMMY,
$      (GIFRAC(ICASE,1,I),I=1,4),RISTIM,NOICAT(MODE(ICASE),IRISK)
      WRITE(25) NUMCAN,NLET,(CANCER(JCAN),JCAN=1,NUMCAN)
      WRITE(25) ((DEAD2(JCAN,JLET),JLET=1,NLET),JCAN=1,NUMCAN)
      WRITE(25) ((TYRS2(JCAN,JLET),JLET=1,NLET),JCAN=1,NUMCAN)
      WRITE(25) (HELFAC(JCAN),JCAN=1,NUMCAN)
40  CONTINUE
C
100 FORMAT(3F20.10)
200 FORMAT('1'.T2.'|-----',

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$-----|,/,T2,|,T133,|,/,
$ T2,|,T15,A8,COHORT (1.0E+5 PERSONS) A8,
$ FATALITIES FROM LIFETIME 2A8,TION: A8,RISK,T133,|)
210 FORMAT(' T2,|,T40,AMAD =,F5.2, , RESP CLEARANCE CLASS =,
$ A4, F1 =,E10.3,T133,|/,T2,|,T133,|/,T2,|,
$ T50,A8, : 1PE9.2, PCI/YR INTAKE,T133,|)
211 FORMAT(' T2,|,T40,AMAD =,F5.2, , RESP CLEARANCE CLASS =,
$ A4, F1 =,E10.3,T133,|/,T2,|,T133,|/,T2,|,
$ T54,FOR T58,1PE9.2, PCI/YR INTAKE,T133,|)
220 FORMAT(' T2,|,T59,F1 =,E10.3,T133,|/,T2,|,T133,|/,
$ T2,|,T50,A8, : 1PE9.2, PCI/YR INTAKE,T133,|)
221 FORMAT(' T2,|,T59,F1 =,E10.3,T133,|/,T2,|,T133,
$ |/,T2,|,T54,FCR T58,1PE9.2, PCI/YR INTAKE,T133,|)
225 FORMAT('0,NORMALIZATION TO 1PE9.2, PCI/YR YIELDS: 1PE9.2,
$ PREMATURE DEATHS/,T44,1PE9.2, YEARS OF LIFE LOST/,
$ T44,1PE9.2, YEARS DECREASE IN LIFE EXPECTANCY)
230 FORMAT('1,T2,|-----|,/,
$-----|,/,T2,|,T133,|,/,
$ T2,|,T22,A8,COHORT (1.0E+5 PERSONS) CANCER FATALITIES ,
$ FROM LIFETIME 2A8,TION: T133,|)
235 FORMAT(' T2,|,T133,|/,T2,|,T62,SUMMARY TABLE,
$ T133,|/,T2,|,T133,|/,T2,|,T14,ADULT,T22,ADULT,
$ T41,ADULT,T65,NUMBER OF,T76,AVERAGE,T87,TOTAL,T98,
$ DECREASE,T110,70-YEAR,T122,RISK,T133,|/,T2,|,T14,
$ LATENCY,T22,PLATEAU,T41,DEATH,T54,70-YEAR,T65,
$ PREMATURE,T76,YEARS OF,T87,YEARS OF,T98,IN LIFE,
$ T110,DOSE EQUIV-T122,EQUIVALENT,T133,|/,
$ T2,|,T5,CANCER,T14,PERIOD,T22,PERIOD,T30,RISK,
$ T36,LET,T41,RATE (CTHS/,
$ T54,DOSE RATE,T65,DEATHS,T76,LIFE LOST,T87,LIFE LOST,
$ T98,EXPECTANCY,
$ T110,ALENT RATE,T122,FACTOR,T133,|/,T2,|,T14,
$ (YEARS) T22,(YEARS) T41,1E6/MRAD/YR) T54,(MRAD/YR) T65,
$ IN COHORT T76,(YEARS) T87,(YEARS) T98,(YEARS) T110,
$ (MREM/YR) T133,|/,T2,|,T133,|)
240 FORMAT(' T2,|,T5,A8,T15,I4,T23,I4,T30,A4,T36,A4,T41,1PE9.2,
$ T53,1PE9.2,T64,1PE9.2,T75,1PE9.2,T86,1PE9.2,T97,1PE9.2,T109,
$ 1PE9.2,T121,1PE9.2,T133,|)
245 FORMAT(' T2,|,T36,A4,T41,1PE9.2,T53,1PE9.2,T64,1PE9.2,
$ T75,1PE9.2,T86,1PE9.2,T97,1PE9.2,T133,|)
250 FORMAT(' T2,|,T133,|/,T2,|,T5,TOTAL (SOMATIC) T64,
$ 1PE9.2,T75,1PE9.2,T86,1PE9.2,T97,1PE9.2,T121,1PE9.2,T133,|)
255 FORMAT(' T2,|,T133,|/,T2,|,T133,|/,T2,|,
$ T5,30-YEAR GENETIC DCSE COMMITMENTS (MPAD): T133,|/,
$ T2,|,T133,|/,T2,|,T5,LET,T15,TESTES,T30,OVARIES,
$ T45,AVERAGE,T133,|)
256 FORMAT(' T2,|,T5,A4,T14,1PE9.2,T29,1PE9.2,T44,1PE9.2,T133,|)
257 FORMAT(' T2,|,T133,
$ |/,T2,|-----|,/,
$-----|,/,
$-----|)
260 FORMAT(A8,2I4,4X,3E10.3,2I4)
270 FORMAT(A8,I4,18X,2E10.3,2I4)
280 FORMAT(A8,2I4,4X,6E10.3)
285 FORMAT(6E10.3)
290 FORMAT(' T2,|,T133,|/,T2,|-----|,/,
$-----|,/,
$-----|)
RETURN
END

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SUBROUTINE CAIRD(DOSE,ILET,CAN,ISW3,IPLATO,LATNCY,DRATE,
$ AUDEAU,AVGYLL,YLL,DLE)

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*** COHORT ANALYSIS FOR INCREASED RISK OF DEATH ***

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FOR USE IN RADRISK, THE CAIRD CODE HAS BEEN ADAPTED TO SUBROUTINE FORM. WE NOTE THAT CAIRD HAS PROVISIONS FOR PRODUCING A VARIETY OF OUTPUT TABLES, WHICH ARE NOT USED IN THIS APPLICATION. SWITCH SETTINGS ARE FIXED IN THE 'SWITCH' DATA STATEMENT TO PRINT ONLY THE TABLES OF INTEREST. THIS APPROACH HAS BEEN DEEMED PREFERABLE TO THAT OF ELIMINATING ALL NONFUNCTIONAL (IN THE PRESENT APPLICATION) SECTIONS OF THE CODE, AND SHOULD FACILITATE LATER EXPANSION OF THE

C RADRISK CODE. IN THE PRESENT APPLICATION SUBROUTINES LTHEAD, STHEAD,
 C AND CTHEAD ARE NOT USED.
 C ALSO, IN THIS APPLICATION THE CAIRD ROUTINE TREATS ONLY A SINGLE CANCER
 C TYPE AT A TIME AS IT IS CALLED BY SUBROUTINE RISK, SUCH THAT 'NOCAN'
 C ALWAYS EQUALS 1; THIS ALSO RESULTS IN A DIFFERENT INTERPRETATION
 C OF THE VARIABLE 'CAN' THAN THAT OF THE ORIGINAL CCAIRD CODE.
 C SIMILARLY, ACCIDENTAL (NON-RADIATION) RISKS ARE NOT ROUTINELY CONSIDERED
 C IN THE RADRISK CODE, SO THAT SUBROUTINE ACCRSK IS NOT USED.

...DECLARATION, DIMENSION AND INITIALIZATION OF SCALARS AND ARRAYS

REAL*8 REFTBL(111,3,3),MORT(22,3,11)/726*0D0/,ALLCAN
 1(111,4,11)/4884*0D0/,GLTABL(111,9)/999*0D0/,APCO(111)/111*0D0/,
 2NOARCO(111)/111*0D0/,TDEAD(111)/111*0D0/,FETAL(111)/111*0D0/,
 3CHILD(111)/111*0D0/,ADULT(111)/111*0D0/,MORTAL(22),
 4CANMOP(111,10)/1110*1.0/,FDEATH(2),CDEATH(20,2),ADEATH(20,2),
 SINC MOR,REFMOR

REAL*8 LSW1(3)/'MALE','FEMALE','GENERAL'/,LSW2(2)/'DISK','CARDS'/,
 1LSW3(3)/'NONE','ABSOLUTE','RELATIVE'/,LSW4(4,5)/'NONE',,
 2',,'ACCIDENT',,'(SINGLE',,)',,,'ACCIDENT',,'MULTIP',,'LE',,)',,)',
 3'CANCER C',,'OMMITTME',,'NT (SING',,'LE)',,'CANCER C',,'OMMITTME',,
 4'NT (MULT',,'IPLE)',,/,LSW5(2,4)/'NONE',,)',,'STAGES',,)',,'CANCERS',,
 5',,'STAGES &',,'CANCERS'/,LSW6(3,4)/'NONE',,)',,)',,'LIFE TAB'
 6',,'LE',,)',,'COMPONEN',,'T ANALYS',,'IS',,'LIFE TAB',,'LE & ANA',,
 7'LYSIS'/,LSW7(10)/'NONE',,'ONE',,'TWO',,'THREE',,'FOUR',,'FIVE',,'SIX',,
 8'SEVEN',,'EIGHT',,'NINE'/'

REAL*4 TITLE(20),CANCER(3,20),DOSE(9)

INTEGER*4 INTAGE(110,2),BEGAGE(9),ENDAGE(9),STRTAG(9),CLTN CY(20),
 1CPLATO(20),ALTN CY(20),AFLATO(20),KIDEXP(9),ADEXP(9),SWITCH(7),
 2AGE,CAN,POP,REF,STG,SEPAGE,STATRF,TOTCAN,CANNO,BEGSTG,BEGCAN,
 3SW1,SW2,SW3,SW4,SW5,SW6,SW7,CASREP,CANREP,SWZ,FLTN CY

EQUIVALENCE (SW1,SWITCH(1)),(SW2,SWITCH(2)),(SW3,SWITCH(3)),
 1(SW4,SWITCH(4)),(SW5,SWITCH(5)),(SW6,SWITCH(6)),(SW7,SWITCH(7))

COMMON /REFLIF/ REFTBL(111,3,3)
 COMMON /BONDEP/ INOBON

DATA SEPAGE/10/
 DATA NORMAG/0/
 DATA BEGAGE/0,2,4,8,16,24,36,48,64/
 DATA ENDAGE/2,4,8,16,24,36,48,64,110/
 DATA NOCAN/1/
 DATA CANNO/1/
 DATA FLTN CY/0/
 DATA CPLATO/0/
 DATA FDEATH/0.0,0.0,0/
 DATA CLTN CY/2,5,10,14*15,2/
 DATA CPLATO/25,30,15*11C,45/
 DATA CDEATH/2.3E-03,2.0E-04,3.0E-03,2.3E-03,9.0E-04,5.0E-04,
 \$ 7.0E-04,4.0E-04,2.0E-04,2.0E-04,2.0E-04,6*1.0E-04,4.0E-04,2*0.0,
 \$ 4.6E-02,2.0E-03,3.0E-02,2.3E-03,9.0E-03,5.0E-03,7.0E-03,
 \$ 4.0E-03,2.0E-03,2.0E-03,2.0E-03,6*1.0E-03,4.0E-04,2*0.0/
 DATA ALTN CY/2,5,10,14*15,2/
 DATA AFLATO/25,30,15*11C,45/
 DATA ADEATH/2.3E-03,2.0E-04,3.0E-03,2.3E-03,9.0E-04,5.0E-04,
 \$ 7.0E-04,4.0E-04,2.0E-04,2.0E-04,2.0E-04,6*1.0E-04,4.0E-04,2*0.0,
 \$ 4.6E-02,2.0E-03,3.0E-02,2.3E-03,9.0E-03,5.0E-03,7.0E-03,
 \$ 4.0E-03,2.0E-03,2.0E-03,2.0E-03,6*1.0E-03,4.0E-04,2*0.0/
 DATA MORTAL/1.56E-6,2.44E-7,3.41E-7,5.96E-7,9.51E-7,9.11E-7,
 \$ 1.61E-6,2.16E-6,4.14E-6,9.45E-6,1.69E-5,2.89E-5,3.83E-5,5.15E-5,
 \$ 6.04E-5,6.69E-5,6.83E-5,7.14E-5,7.14E-5,7.14E-5,7.14E-5,7.14E-5/
 DATA SWITCH/3,2,2,1,4,1,9/
 DATA JCAN/1/
 DATA CANCER/4HRED ,4HMARR,4HOW ,4HENDO,4HSTEA,4HHL ,
 \$ 4HPULM,4HONAR,4HY ,4HBREA,4HST ,4H ,
 \$ 4HLIVE,4HR ,4H ,4HSTOM,4HACH ,4HWALL ,
 \$ 4HPANC,4HREAS,4H ,4HLLI ,4HWALL,4H ,
 \$ 4HKIDN,4HEYS ,4H ,4HBLAD,4HDER ,4HWALL ,
 \$ 4HULI ,4HWALL,4H ,4HSI W,4HALL ,4H ,
 \$ 4HOVAR,4HIES ,4H ,4HTEST,4HES ,4H ,
 \$ 4HSPLE,4HEN ,4H ,4HUTER,4HUS ,4H ,
 \$ 4HTHYM,4HUS ,4H ,4HTHYR,4HOLD ,4H ,6*4H /


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C DETERMINE CORRECT RISK ESTIMATOR FOR HIGH-LET IN BONE..
C   IF (INDBON .LE. 1) CDEATH(4,2)=4.0E-03
C   IF (INDBON .LE. 1) ADEATH(4,2)=4.0E-03
C REDEFINE PARAMETERS AS RECEIVED FROM SUBROUTINE RISK...
C   SWITCH(3)=ISW3
C   SW3=ISW3
C   IPLATO=APLATO(CAN)
C   LATNCY=ALTNCY(CAN)
C   DRATE=ADEATH(CAN,ILET)
C   TOTCAN = NOCAN + 1
C   IF(SW3.NE.3)GO TO 55
C
C   ...EXPAND ABRIDGED CANCER MORTALITY DATA TO LIFE TABLE FORMAT
C
C   DO 20 L=1,22
C     AGE = 5 * (L-1) + 1
65     CANMOR(AGE,JCAN) = MORTAL(L)
C     IF(AGE.EQ.5*L)GO TO 20
C     AGE = AGE + 1
C     GO TO 65
20  CONTINUE
C
C   ...CALCULATE RADIATION RISK DISTRIBUTION FOR ALL CASE DOSES
C
55  DO 30 J=1,SW7
C     IF(BEGAGE(J).NE.-1)GO TO 75
C     CALL FETRSK(SWITCH(3),PLTNCY,FPLATO,DOSE(1),FDEATH(ILET),FETAL)
C     GO TO 30
75  IF(BEGAGE(J).LT.SEPAGE)GO TO 85
C     STRTAG(J) = BEGAGE(J)
C     ADEXP(J) = ENDAGE(J) - STRTAG(J)
C     CALL CARSK(SWITCH(3),STRTAG(J),ADEXP(J),DOSE(J),ALTNCY(CAN),
1     APLATO(CAN),ADEATH(CAN,ILET),ADULT)
C     GO TO 30
85  IF(ENDAGE(J).LE.SEPAGE)GO TO 95
C     KIDEXP(J) = SEPAGE - BEGAGE(J)
C     CALL CARSK(SWITCH(3),BEGAGE(J),KIDEXP(J),DOSE(J),CLTNCY(CAN),
1     CPLATO(CAN),CDEATH(CAN,ILET),CHILD)
C     STRTAG(J) = SEPAGE
C     ADEXP(J) = ENDAGE(J) - SEPAGE
C     CALL CARSK(SWITCH(3),STRTAG(J),ADEXP(J),DOSE(J),ALTNCY(CAN),
1     APLATO(CAN),ADEATH(CAN,ILET),ADULT)
C     GO TO 30
95  KIDEXP(J) = ENDAGE(J) - BEGAGE(J)
C     CALL CARSK(SWITCH(3),BEGAGE(J),KIDEXP(J),DOSE(J),CLTNCY(CAN),
1     CPLATO(CAN),CDEATH(CAN,ILET),CHILD)
30  CONTINUE
C
C   ...STORE FETAL, CHILD, ADULT AND SUMMED RISKS FOR ALL AGES
C   = CALCULATE RADIATION MORTALITY FOR RELATIVE RISK CASES
C
C   DO 40 AGE=1,110
C     ALLCAN(AGE,1,JCAN) = ALLCAN(AGE,1,JCAN) + FETAL(AGE) *
1     CANMOR(AGE,JCAN)
C     ALLCAN(AGE,2,JCAN) = ALLCAN(AGE,2,JCAN) + CHILD(AGE) *
1     CANMOR(AGE,JCAN)
C     ALLCAN(AGE,3,JCAN) = ALLCAN(AGE,3,JCAN) + ADULT(AGE) *
1     CANMOR(AGE,JCAN)
C     ALLCAN(AGE,4,JCAN) = ALLCAN(AGE,4,JCAN) + (FETAL(AGE) +
1     CHILD(AGE) + ADULT(AGE)) * CANMOR(AGE,JCAN)
C
C   ...STORE TOTAL RADIATION RISK FOR ALL AGES
C
C   DO 50 STG=1,4
C     ALLCAN(AGE,STG,TOTCAN) = ALLCAN(AGE,STG,TOTCAN) +
1     ALLCAN(AGE,STG,JCAN)
50  CONTINUE
40  CONTINUE
C
C   ...INITIALIZE STAGE VECTORS FOR NEXT CANCER
C
C   DO 60 AGE=1,111
C     CANMOR(AGE,JCAN)=1.0
C     FETAL(AGE) = 0.0
C     CHILD(AGE) = 0.0
C     ADULT(AGE) = 0.0
60  CONTINUE

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10  CONTINUE
C
C    ...DETERMINE TYPE AND FORMAT OF ADDITIONAL RISK
C
45  GO TO(105,115,115,125,125),SW4
C
C    ...INPUT NON-RADIATION RISK VALUES - THESE RISKS ARE NOT SUBJECT
C    MORTALITY CONVERSION
C
115 CALL ACCRSK(SW4,BEGAGE(1),ENDAGE(1),CASREP,NOARCO)
    GO TO 105
C
C    ...INPUT NON-RADIATION RISK VALUES - THESE RISKS ARE SUBJECT TO
C    MORTALITY CONVERSION
C
125 CALL ACCRSK(SW4,BEGAGE(1),ENDAGE(1),CASREP,ARCO)
C
C    ...GENERATE LIFE TABLE
C
105 STATRF = NORMAG + 1
    GLTABL(STATRF,4) = REFTBL(STATRF,2,SW1)
    ADDEAD = 0.0
    DO 70 AGE=STATRF,110
        INTAGE(AGE,2) = AGE
        INTAGE(AGE,1) = INTAGE(AGE,2) - 1
        REFMOR = REFTBL(AGE,1,SW1) / (1.0-0.5*REFTBL(AGE,1,SW1))
        GLTABL(AGE,2) = ARCO(AGE)
        GLTABL(AGE,2) = GLTABL(AGE,2) / (1.0-0.5*GLTABL(AGE,2))
        INCMOR = GLTABL(AGE,2) + ALLCAN(AGE,4,TOTCAN) + NOARCO(AGE)
        GLTABL(AGE,1) = REFMOR / (1.0+0.5*(REFMOR + INCMOR))
        GLTABL(AGE,2) = INCMOR / (1.0+0.5*(REFMOR + INCMOR))
        GLTABL(AGE,3) = GLTABL(AGE,1) + GLTABL(AGE,2)
        GLTABL(AGE,5) = GLTABL(AGE,3) * GLTABL(AGE,4)
        GLTABL(AGE+1,4) = GLTABL(AGE,4) - GLTABL(AGE,5)
        GLTABL(AGE,6) = (GLTABL(AGE,4)+GLTABL(AGE+1,4)) / 2.
        GLTABL(AGE,9) = GLTABL(AGE,2) * GLTABL(AGE,4)
        ADDEAD = ADDEAD + GLTABL(AGE,9)
    70 CONTINUE
    ADDEAD = ADDEAD * (100000.0/REFTBL(STATRF,2,SW1))
    AGE = 110
    GLTABL(AGE,7) = GLTABL(AGE,6) + REFTBL(111,3,SW1)
    GLTABL(AGE,8) = GLTABL(AGE,7) / GLTABL(AGE,4)
135 AGE = AGE - 1
    GLTABL(AGE,7) = GLTABL(AGE,6) + GLTABL(AGE+1,7)
    GLTABL(AGE,8) = GLTABL(AGE,7) / GLTABL(AGE,4)
    IF(AGE.GT.STATRF)GO TO 135
C
C    ...DETERMINE TYPE OF ADDITIONAL ANALYSIS AND ASSIGN ORGAN AND STAG
C
    GO TO(145,155,165,175),SW5
155 BEGCAN = TOTCAN
    BEGSTG = 1
    GO TO 145
165 BEGCAN = 1
    BEGSTG = 4
    GO TO 145
175 BEGCAN = 1
    BEGSTG = 1
C
C    ...CALCULATE FRACTION OF TOTAL DEATHS FOR ALL AGES
C
145 DO 80 AGE=STATRF,111
    IF(GLTABL(AGE,9).EQ.0.0)GO TO 80
    GO TO(185,195,195,205,205),SW4
185 TDEAD(AGE) = GLTABL(AGE,9)
    GO TO 215
195 NOARCO(AGE) = NOARCO(AGE) * GLTABL(AGE,4)
    NOARCO(111) = NOARCO(111) + NOARCO(AGE)
    TDEAD(AGE) = GLTABL(AGE,9) - NOARCO(AGE)
    GO TO 215
205 ARCO(AGE) = (ARCO(AGE)*GLTABL(AGE,9)) / (ALLCAN(AGE,4,TOTCAN)+
1 ARCO(AGE))
    ARCO(111) = ARCO(111) + ARCO(AGE)
    TDEAD(AGE) = GLTABL(AGE,9) - ARCO(AGE)
C
C    ...CALCULATE AND STORE FRACTION OF TOTAL DEATHS FOR EACH CANCER
C

```

```

215 IF(SW3.EQ.1)GO TO 80
    DO 90 KCAN=BEGCAN.TOTCAN
C
C      ...CALCULATE AND STORE FRACTION OF TOTAL DEATHS FOR EACH STAGE
C
      DO 100 STG=BEGSTG,4
        ALLCAN(AGE,STG,KCAN) = (ALLCAN(AGE,STG,KCAN)*TDEAD(AGE) /
1      ALLCAN(AGE,4,TOTCAN))
        ALLCAN(111,STG,KCAN) = ALLCAN(111,STG,KCAN) +
1      ALLCAN(AGE,STG,KCAN)
100  CONTINUE
90  CONTINUE
80  CONTINUE
C
C      ...CALCULATE YEARS OF LIFE LOST AND DECREASE IN LIFE EXPECTANCY
C
      YLL = (REFTBL(STATRF,3,SW1)-GLTABL(STATRF,7)) * (100000.0/
1      REFTBL(STATRF,2,SW1))
      AVGYLL = YLL / ADDEAD
      DLE = YLL / 100000.0
C
C      ..CONTINUE OUTPUT OF INDIVIDUAL CANCER RISK TABLE FROM SUBROUTINE RISK
C
      WRITE(26,16)
16  FORMAT(1H ,T2,'|',T133,'|')
      WRITE(26,36)LSW1(SW1)
36  FORMAT(1H ,T2,'|',T94,'POPULATION AT RISK: ',A8,T133,'|')
      WRITE(26,46)LSW7(SW7+1),LSW2(SW2)
46  FORMAT(1H ,T2,'|',T7,'NUMBER OF DOSE RATES: ',A8,T79,'REFERENCE ',
1  'TABLE INPUT SOURCE: ',A8,T133,'|')
      WRITE(26,56)LSW3(SW3),(LSW5(L,SW5),L=1,2)
56  FORMAT(1H ,T2,'|',T7,'RADIATION RISK MODEL: ',A8,T88,'ADDITION',
1  'AL ANALYSIS: ',2A8,T133,'|')
      WRITE(26,66)(LSW4(L,SW4),L=1,4),(LSW6(L,SW6),L=1,3)
66  FORMAT(1H ,T2,'|',T12,'ADDITIONAL RISK: ',4A8,T90,'ADDITIONAL ',
1  'OUTPUT: ',3A8,T133,'|')
      WRITE(26,16)
      WRITE(26,6)
6  FORMAT(1H ,T2,'|-----|',
1  '-----|',
2  '-----|')
      WRITE(26,386)
386 FORMAT(1H ,T2,'|',T67,'|',T133,'|')
      WRITE(26,76)
76  FORMAT(1H ,T2,'|',T23,'*** INPUT DATA ***',T67,'|',T90,'****',
1  'OUTPUT DATA ***',T133,'|')
      WRITE(26,386)
C
C      ...OUTPUT CASE VARIABLES AND STATISTICS
C
      WRITE(26,86)
86  FORMAT(1H ,T2,'|',T13,'DOSE (MRAD/YR)',T46,'AGE INTERVAL' ,
1  T67,'|',T133,'|')
      DO 120 M=1,SW7
        WRITE(26,96)DOSE(M),BEGAGE(M),ENDAGE(M)
96  FORMAT(1H ,T2,'|',T12,E10.3,T47,I3,T51,'-',T53,I3,T67,'|',T133,
1  '|')
120 CONTINUE
      WRITE(26,106)SEPAGE,ADDEAD
106 FORMAT(1H ,T2,'|',T11,'CHILD AGE INTERVAL =',T49,'0 -',T53,I3,T67,
1  '|',T71,'NUMBER OF PREMATURE DEATHS = ',T121,E10.3,T133,'|')
      WRITE(26,116)SEPAGE,DLE
116 FORMAT(1H ,T2,'|',T11,'ADULT AGE INTERVAL =',T47,I3,' - 110',
1  T67,'|',T71,'DECREASE IN POPULATION LIFE EXPECTANCY =',T121,E10.3,
2  T133,'|')
      WRITE(26,126)NORMAG,YLL
126 FORMAT(1H ,T2,'|',T11,'OUTPUT DATA BASED ON AGE INTERVAL =',T47,
1  I3,' - 110',T67,'|',T71,'TOTAL YEARS OF LIFE LOST TO PREMATURE ',
2  'DEATHS = ',E11.3,T133,'|')
      WRITE(26,136)AVGYLL
136 FORMAT(1H ,T2,'|',T67,'|',T71,'AVERAGE YEARS OF LIFE LOST PER',
1  'PREMATURE DEATH = ',E11.3,T133,'|')
      WRITE(26,146)
146 FORMAT(1H ,T2,'|',T67,'|',T133,'|')
      WRITE(26,6)
      WRITE(26,16)
      IF(SW3.EQ.1)GO TO 485

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C
C      ...OUTPUT CANCER VARIABLES
C
      WRITE(26,16)
      WRITE(26,156)
156  FORMAT(1H ,T2,'|',T9,'CANCER ',T42,'FETAL',T75,'CHILD',T108,
1    'ADULT',T133,'|')
      WRITE(26,166)
166  FORMAT(1H ,T2,'|',T31,'LATENCY PLATEAU DEATH RATE',T64,'LATENCY'
1    ' PLATEAU DEATH RATE',T97,'LATENCY PLATEAU DEATH RATE',T133,
2    '|',T2,'|',T31,'(YEARS) (YEARS) (DTHS/1E6/',T64,'(YEARS)',
3    '(YEARS) (DTHS/1E6/',T97,'(YEARS) (YEARS) (DTHS/1E6/',
4    T133,'|',T2,'|',T50,'MRAD/YR)',T83,'MRAD/YR)',T116,'MRAD/YR)',
5    T133,'|')
      WRITE(26,16)
      WRITE(26,176) (CANCER(K,CAN),K=1,3),FLTNCY,FPLATO,FDEATH(ILET),
1    CLTNCY(CAN),CPLATO(CAN),CDEATH(CAN,ILET),ALTNCY(CAN),APLATO(CAN),
2    ADEATH(CAN,ILET)
176  FORMAT(1H ,T2,'|',T9,3A4,T31,I5,T40,I5,T46,F10,3,T64,I5,T73,I5,
1    T79,E13,3,T97,I5,T108,I5,T114,E11,3,T133,'|')
      WRITE(26,16)
      WRITE(26,6)
      WRITE(26,16)

C
C      ...OUTPUT CANCER DEATHS FOR ALL STAGES
C
      WRITE(26,186)
186  FORMAT(1H ,T2,'|',T27,'CANCER',T54,'FETAL',T69,'CHILD',T84,
1    'ADULT',T104,'TOTAL',T133,'|')
      WRITE(26,16)
      GO TO(485,535,255,265),SW5
      IF(SW5.NE.1)GO TO 255
535  CONTINUE
      WRITE(26,196) (CANCER(K,CAN),K=1,3)
196  FORMAT(1H ,T2,'|',T27,3A4,T133,'|')
      WRITE(26,206) (ALLCAN(111,STG,TOTCAN),STG=1,4)
206  FORMAT(1H ,T2,'|',T27,'TOTAL',T52,F5,2,T67,F5,2,T82,F5,2,T102,
1    F5,2,T133,'|')
      GO TO 245
255  IF(SW5.NE.2)GO TO 265
      WRITE(26,216) (CANCER(K,CAN),K=1,3), ALLCAN(111,4,CAN)
216  FORMAT(1H ,T2,'|',T27,3A4,T102,F5,2,T133,'|')
      WRITE(26,226) ALLCAN(111,4,TOTCAN)
226  FORMAT(1H ,T2,'|',T27,'TOTAL',T102,F5,2,T133,'|')
      GO TO 245
265  CONTINUE
      WRITE(26,236) (CANCER(K,CAN),K=1,3), (ALLCAN(111,I,JCAN),I=1,4)
236  FORMAT(1H ,T2,'|',T27,3A4,T52,E10,3,T67,E10,3,T82,E10,3,T102,
1    E10,3,T133,'|')
      WRITE(26,246) (ALLCAN(111,STG,TOTCAN),STG=1,4)
246  FORMAT(1H ,T2,'|',T27,'TOTAL',T52,E10,3,T67,E10,3,T82,E10,3,T102,
1    E10,3,T133,'|')
245  WRITE(26,16)
      WRITE(26,6)
      WRITE(26,16)

C
C      ...OUTPUT ADDITIONAL RISK
C
485  GO TO(295,275,275,285,285),SW4
275  WRITE(26,256) NOARCO(111)
256  FORMAT(1H ,T2,'|',T27,'NUMBER OF DEATHS CAUSED BY ',
1    'NON-RADIATION RISKS',T104,F11,5,T133,'|')
      WRITE(26,16)
      WRITE(26,6)
      WRITE(26,16)
      GO TO 295
285  WRITE(26,256) ARCO(111)
      WRITE(26,16)
      WRITE(26,6)
      WRITE(26,16)

C
C      ...OUTPUT TOTAL NUMBER OF INCREMENTAL DEATHS
C
295  WRITE(26,266) ADDEAD
266  FORMAT(1H ,T2,'|',T27,'TOTAL NUMBER OF INCREMENTAL DEATHS',T104,
1    E10,3,T133,'|')
      WRITE(26,16)
      WRITE(26,6)

```

```

C
C      ...OUTPUT GENERATED LIFE TABLE
C
505  GO TO(345,505,515,505),SW6
      CALL LTHEAD(SW1)
      INTBLK = (STATRF + 4) / 5
      DO 170 AGE=STATRF,110
        WRITE(26,276)(INTAGE(AGE,J),J=1,2),(GLTABL(AGE,N),N=1,9)
276  FORMAT(1H,T2,'|',T4,I3,'-',I3,'|',F12.10,'|',F12.10,'|',
1    F12.10,'|',F11.4,'|',F9.4,'|',F10.4,'|',F12.4,'|',
2    F9.6,'|',F8.4,T133,'|')
      LINE = MOD(AGE-1,5) + 1
      IF(LINE.EQ.5)GO TO 315
170  CONTINUE
      GO TO 325
315  WRITE(26,286)
286  FORMAT(1H,T2,'|',T12,'|',T27,'|',T42,'|',T57,'|',T71,'|',T83,'|',
1    T96,'|',T111,'|',T123,'|',T133,'|')
      NOWBLK = (AGE + 4)/5
      IF(NOWBLK-INTBLK.EQ.7)GO TO 335
      GO TO 170
335  CALL LTHEAD(SW1)
      INTBLK = NOWBLK + 1
      GO TO 170
325  WRITE(26,6)
      WRITE(26,6)
C
C      ...DETERMINE TYPE OF ADDITIONAL OUTPUT
C
515  GO TO(345,345,355,365,355),SW6
C
C      ...OUTPUT STAGE TABLE
C
355  CALL STHEAD
      STATRF = 1
      INTBLK = (STATRF+4) / 5
      DO 190 AGE=STATRF,110
        WRITE(26,336)(INTAGE(AGE,J),J=1,2),
1    (ALLCAN(AGE,STG,TOTCAN),STG=1,4)
336  FORMAT(1H,T28,'|',T36,I3,'-',I3,T50,'|',T55,F5.2,T63,'|',T66,
1    F5.2,T73,'|',T77,F5.2,T86,'|',T93,F5.2,T105,'|')
      LINE = MOD(AGE-1,5) + 1
      IF(LINE.EQ.5) GO TO 375
190  CONTINUE
      GO TO 405
375  WRITE(26,316)
316  FORMAT(1H,T28,'|',T50,'|',T63,'|',T73,'|',T86,'|',T105,'|')
      NOWBLK = (AGE+4) / 5
      IF(NOWBLK-INTBLK.EQ.7) GO TO 395
      GO TO 190
395  CALL STHEAD
      INTBLK = NOWBLK + 1
      INTBLK = NOWBLK + 1
      GO TO 190
405  WRITE(26,306)
306  FORMAT(1H,T28,'|-----|',
1    '-----|')
      WRITE(26,306)
C
C      ...OUTPUT CANCER TABLE
C
365  IF(SW5.EQ.3)GO TO 345
445  CALL CTHEAD(CANCER)
      STATRF = 1
      INTBLK = (STATRF+4) / 5
      DO 200 AGE=STATRF,110
        WRITE(26,346)(INTAGE(AGE,J),J=1,2),ALLCAN(AGE,4,TOTCAN),
1    (ALLCAN(AGE,4,ICAN),ICAN=1,NOCAN)
346  FORMAT(1H,T2,'|',T7,I3,'-',I3,T123,'|',T125,F5.2,T133,'|',T18,
1    T23,F5.2,T33,'|',T38,F5.2,T48,'|',T53,F5.2,T63,'|',T68,F5.2,
2    T78,'|',T83,F5.2,T93,'|',T98,F5.2,T108,'|',T113,F5.2)
      LINE = MOD(AGE-1,5) + 1
      IF(LINE.EQ.5) GO TO 415
200  CONTINUE
      GO TO 425
415  WRITE(26,366)
366  FORMAT(1H,T2,'|',T18,'|',T33,'|',T48,'|',T63,'|',T78,'|',T93,'|',

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1T108,'|',T123,'|',T133,'|')
NOWBLK = (AGE+4) / 5
IF(NOWBLK - INTBLK.EQ.7) GO TO 435
GO TO 200
435 CALL CTHEAD(CANCER)
    INTBLK = NOWBLK + 1
    GO TO 200
425 WRITE(26,366)
    WRITE(26,6)
    WRITE(26,366)
    WRITE(26,356)ALLCAN(111,4,TOTCAN),(ALLCAN(111,4,I),I=1,NOCAN)
356 FORMAT(1H,T2,'|',T7,'|',TCTAL,T125,F7.2,T133,'|',T18,'|',T23,F6.2,
1T33,'|',T38,F6.2,T48,'|',T53,F6.2,T63,'|',T68,F6.2,T78,'|',T83,
2F6.2,T93,'|',T98,F6.2,T108,'|',T113,F6.2,T123,'|')
    WRITE(26,366)
    WRITE(26,6)
    WRITE(26,6)
C
C    ...INITIALIZE MATRICES FOR NEXT CASE
C
345 CONTINUE
    DO 210 AGE=1,111
        TDEAD(AGE) = 0.0
        ARCO(AGE) = 0.0
        NOARCO(AGE) = 0.0
        DO 220 N=1,9
            GLTABL(AGE,N) = 0.0
            DO 230 STG=1,4
                ALLCAN(AGE,STG,N) = 0.0
230         CONTINUE
220     CONTINUE
210 CONTINUE
    RETURN
    END
C

```

```

C    *** NON-RADIATION RISK SUBROUTINE ***
C
SUBROUTINE ACCRSK(SW4,BEGAGE,ENDAGE,CASREP,ADDRSK)
REAL*8 ADDRSK(1),SINRSK
INTEGER SW4,AGE,BEGAGE,ENDAGE,CASREP
GO TO(5,15,25,15,25),SW4
15 READ(5,7)CASREP,SINRSK
7  FORMAT(15,F10.9)
DO 10 AGE=BEGAGE,ENDAGE
    ADDRSK(AGE) = SINRSK
10 CONTINUE
GO TO 5
25 READ(5,17)CASREP,(ADDRSK(AGE),AGE=1,110)
17 FORMAT(15/14(8F10.9/))
5  RETURN
    END
...C

```

```

C    *** FETAL RADIATION RISK SUBROUTINE ***
C
SUBROUTINE FETRSK(SW3,FLTNCY,FPLATO,DOSE,DEATHS,IXP)
REAL*8 IXP(1),DEATHS
INTEGER SW3,START,END,FLTNCY,FPLATO
IF(SW3.EQ.3)GO TO 5
RISK = DOSE * (DEATHS/1000000.0)
GO TO 15
5  RISK = DOSE * DEATHS
15 START = FLTNCY + 1
    END = FLTNCY + FPLATO
    DO 10 I=START,END
        IXP(I) = RISK
10 CONTINUE
    RETURN
    END
C

```

```

C *** CHILD & ADULT RADIATION RISK SUBROUTINE ***
C
SUBROUTINE CARSK(SW3,BEGAGE,YRSEXP,DOSE,LATNCY,PLATOE,DEATHS,IXR)
REAL*8 IXP(1)
INTEGER BEGAGE,YRSEXP,PLATOE,SW3,YR,AGE,BEGHLF,STRTAG,ENDAG
GO TO (5,5,15),SW3
5 RISK = DOSE * (DEATHS/1000000.0)
GO TO 25
15 RISK = DOSE * DEATHS
25 BEGHLF = BEGAGE + LATNCY + 1
DO 10 YR=1,YRSEXP
    IXP(BEGHLF) = IXP(BEGHLF) + 0.5 * RISK
    STRTAG = BEGHLF + 1
    ENDAG = BEGHLF + PLATOE - 1
    IF(ENDAG.LE.110)GO TO 35
    IF(ENDAG-PLATOE.GE.110)GO TO 45
    ENDAG = 110
35 DO 20 AGE=STRTAG,ENDAG
    IXP(AGE) = IXP(AGE) + RISK
20 CONTINUE
    BEGHLF = BEGHLF + 1
    IF(ENDAG.EQ.110)GO TO 10
    IXP(ENDAG+1) = IXP(ENDAG+1) + 0.5 * RISK
10 CONTINUE
45 DO 30 AGE=1,110
    IXP(111) = IXP(111) + IXP(AGE)
30 CONTINUE
RETURN
END
C

```

```

C *** LIFE TABLE HEADING SUBROUTINE ***
C
SUBROUTINE LTHEAD(SW1)
INTEGER SW1
WRITE(26,63)
63 FORMAT(1H1,' ')
WRITE(26,61)
IF(SW1.EQ.1) GO TO 125
IF(SW1.EQ.2) GO TO 135
WRITE(26,83)
83 FORMAT(' ',T2,'|',T27,'GENERATED LIFE TABLE FOR THE GENERAL ',
1 ' POPULATION: UNITED STATES, 1969-71',T133,'|')
GO TO 145
125 WRITE(26,60)
60 FORMAT(' ',T2,'|',T36,'GENERATED LIFE TABLE FOR MALES: UNITED ',
1 ' STATES 1969-71',T133,'|')
GO TO 145
135 WRITE(26,84)
84 FORMAT(' ',T2,'|',T35,'GENERATED LIFE TABLE FOR FEMALES: UNITED ',
1 ' STATES 1969-71',T133,'|')
145 WRITE(26,61)
61 FORMAT(' ',T2,'|-----|',
1 '-----|',
2 '-----|')
WRITE(26,62)
62 FORMAT(1H ,T2,'|',T12,'|',T27,'|',T42,'|',T57,'|',T71,'|',T83,
1 '|',T96,'|',T111,'|',T123,'|',T133,'|')
WRITE(26,70)
70 FORMAT(1H ,T2,'|',T3,'X TO X+T 1',T18,'TOX',T27,'|',T33,'IXR',
1 T42,'|',T48,'TOXR',T57,'|',T63,'LXR',T71,'|',T76,'DXR',T83,'|',
2 T88,'TLXR',T96,'|',T102,'TXR',T111,'|',T116,'EXR',T123,'|',T126,
3 'IXRLXR',T133,'|')
WRITE(26,62)
WRITE(26,61)
WRITE(26,62)
WRITE(26,71)
71 FORMAT(1H ,T2,'|',T4,'YEARS',T12,'|',T27,'|',T42,'|',T57,'|',T71,
1 '|',T83,'|',T96,'|',T111,'|',T123,'|',T133,'|')
WRITE(26,62)
RETURN
END
C

```

```

SUBROUTINE STHEAD
WRITE(26,6)
6  FORMAT(1H1,' ')
WRITE(26,16)
16 FORMAT(1H ,T28,'|-----|')
1  WRITE(26,26)
26 FORMAT(1H ,T28,'|',T33,'AGE DISTRIBUTION OF RADIATION ',
1  ' DEATHS BY STAGE FOR ALL CANCERS COMBINED',T105,'|')
WRITE(26,16)
WRITE(26,36)
36 FORMAT(1H ,T28,'|',T50,'|',T63,'|',T73,'|',T86,'|',T105,'|')
WRITE(26,46)
46 FORMAT(1H ,T28,'|',T38,'AGES',T50,'|',T55,'FETAL',T63,'|',T66,
1  'CHILD',T73,'|',T77,'ADULT',T86,'|',T93,'TOTAL',T105,'|')
WRITE(26,36)
WRITE(26,16)
WRITE(26,36)
RETURN
END

```

```

C  ***  CANCER TABLE HEADING SUBROUTINE  ***
C
SUBROUTINE CTHEAD(CANCER)
REAL*4 CANCER(3,10)
INTEGER CAN
WRITE(26,6)
6  FORMAT(1H1,' ')
WRITE(26,16)
16 FORMAT(1H ,T2,'|-----|')
1  WRITE(26,26)
26 FORMAT(1H ,T2,'|',T37,'AGE DISTRIBUTION OF RADIATION',
1  ' DEATHS BY CANCER TYPE FOR ALL STAGES COMBINED',T133,'|')
WRITE(26,16)
WRITE(26,36)
36 FORMAT(1H ,T2,'|',T18,'|',T33,'|',T48,'|',T63,'|',T78,'|',
1  T108,'|',T123,'|',T133,'|')
WRITE(26,46)((CANCER(K,CAN),K=1,3),CAN=1,7)
46 FORMAT(1H ,T2,'|',T9,'AGES',T18,'|',T33,'|',T48,'|',T63,'|',T78,
1  '|',T93,'|',T108,'|',T123,'|',T126,'TOTAL',T133,'|',T20,3A4,T35,
23A4,T50,3A4,T65,3A4,T80,3A4,T95,3A4,T110,3A4)
WRITE(26,36)
WRITE(26,16)
WRITE(26,36)
RETURN
END

```

```

SUBROUTINE CMMNTS
INTEGER*4 LINE(20),IN,OUT,DOLLAR
DATA OUT/6/, IN/5/
DATA DOLLAR/'$'/
C READ THE NEXT CARD. IF THE FIRST CHARACTER IS '$', RETURN.
C OTHERWISE PRINT THE CARD AND REPEAT.
10 READ(IN,4010,END=20) LINE
4010 FORMAT(20A4)
IF(ICOMP(LINE,DOLLAR,1).EQ.0) RETURN
WRITE(OUT,4020) LINE
4020 FORMAT(' ',20A4)
GO TO 10
20 STOP
END

```

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