A COMPUTER PROGRAM FOR INTERNAL DOSIMETRY ANALYSIS USING THE METHODS OF ICRP-30

by

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0.0 INTRODUCTION

Since the discovery of radioactivity, mankind has been confronted with the challenge of understanding biological effects of radiation. The domestication of nuclear power has heightened the need to fully comprehend the relation between radiation and human health for the safety of occupational workers and the public in general. During recent decades, the field of radiation protection has made tremendous strides from its infancy. The rapid growth of knowledge has made it possible to revise the mathematical models for accurate estimation of internal doses from radionuclides, and update the regulatory guidelines for control and management of radioactive materials. In view of this, the International Commission on Radiological Protection approved a new set of basic recommendations dealing with protection from ionizing radiation. These are detailed in the ICRP Publication 26 [IC77]. Further, the methods used to evaluate internal dose to comply with the limits in ICRP-26 along with the tables of specific committed dose equivalents, limits on annual intake, and air concentrations from specific radionuclides are shown in ICRP Publication 30 [IC79].

This report describes a computer program "DOSE" in FORTRAN-77 that generates internal dose factors of the type called for in ICRP-30. The constraints imposed by the ICRP on exposure of different organs and tissues of the body singly or together with other organs, in the case of intake of a radionuclide, are discussed in Chapter 1.0. The general principles, mathematical models, definitions, and calculational

procedures adopted by the ICRP-30 for calculation of specific committed dose equivalent are used in this program. Also, the models presented in Chapter 2.0 for the routes of entry of radionuclides into the body, namely, the respiratory system and the gastrointestinal tract, are the ones recommended by the ICRP-30. The metabolic data for the radioisotopes of different elements are also obtained from ICRP-30. In the case of iodine, the program follows the alternate model discussed in the ICRP-30. The specific committed dose equivalents are assumed to be received by a "reference man" of anatomical and physiological characteristics described in ICRP Publication [IC75]. The decay schemes of radionuclides are obtained from Kocher [K081]. The ICRP uses the decay schemes from its publication 38 [IC83]. This difference may reflect on the results for some of the radionuclides.

An important feature of this program is its flexibility. The data files on radiological and biological decay are written in such a manner that addition of new data on a radionuclide or amendment of the present data is easy. Also, as is explained in Chapter 3.0, most of the calculations for important quantities are done by separate, independent subroutines. This design makes future modifications in the program convenient and simple.

1.0 FUNDAMENTALS OF RADIATION PROTECTION

The concept of radiation protection centers around two possible effects in individuals. They are defined as "somatic" and "hereditary".

"Somatic" effects of radiation are limited to the exposed individual while **"hereditary"** effects are manifested in the individual's progeny. The quality of effect can be described as "stochastic" or "non-stochastic".

"Stochastic" effects involve probability of occurrence as opposed to severity, and are therefore considered a function of dose, without threshold. In contrast, **"non-stochastic"** effects vary in severity with dose, and hence may involve a threshold. Hereditary effects are considered stochastic at the dose range involved in radiation protection, while somatic effects may be stochastic or non-stochastic. An example of stochastic effects is carcinogenesis at low doses. Non-stochastic somatic effects may range from cataract of the lens to damage of the hematopoietic system.

To quantify health damage, the International Commission on Radiological Protection (ICRP) has proposed the concept of "detriment". **"Detriment"** in a population is described as the mathematical "expectation" of the deleterious effect from a radiation exposure, taking into account not only the probability of each type of damaging effect but also the severity of the effect. In other words, **"detriment"** to health G in a group of persons P is given as the summation over all effects i of the product of probability p_i of

suffering the effect and the severity of effect expressed by a weighting factor g_i, i.e.,

$$G = P \sum_i p_i \, g_i \, . \qquad (1.1)$$

1.1 DOSE EQUIVALENT, H

This quantity characterizes the severity and probability of the deleterious health effects of radiation. The dose equivalent H at a point in tissue is given by

$$H = D \, \bar{Q} \, N \, , \qquad (1.2)$$

where D is the absorbed dose,

$\bar{Q}$ is the effective quality factor, and

N is the product of all modifying factors such as absorbed dose rate and fractionation specified by ICRP. At present, it is assigned a value of 1.

The SI unit of dose equivalent is the sievert (Sv). 1 Sv ≡ 100 rem.

1.2 ABSORBED DOSE, D

This refers to the energy locally deposited (and ultimately dissipated as heat) per unit mass of the medium. It applies to both types of radiation, ionizing and non-ionizing. The SI unit of absorbed dose is the gray (Gy). 1 Gy = 1 J kg^{-1} (≡ 100 rad).

1.3 EFFECTIVE QUALITY FACTOR, $\bar{Q}$

Quality factor is introduced to allow for the effect on the detriment of the microscopic distribution of absorbed energy. It is a function of the collisional stopping power in water. For a spectrum of radiation, the ICRP [IC77] recommends an effective value $\bar{Q}$ to be used for both external and internal radiation:

X rays, γ rays, and electrons	1
Neutrons, protons and singly-charged particles of rest mass greater than one atomic mass unit of unknown energy	10
α particles and multiply-charged particles (and particles of unknown charge) of unknown energy	20

A graphic review of the relationship between these quantities is shown in Fig. 1.1.

1.4 COLLECTIVE DOSE EQUIVALENT, S

This concept approximates the relationship between detriment and the distribution of dose equivalent in an exposed population. It is expressed as:

$$S = \sum_i H_i \, P_i \, , \qquad (1.3)$$

where H_i is the dose equivalent to the whole body or a specific organ or tissue of an individual who is a member of the subgroup i in the exposed population, and

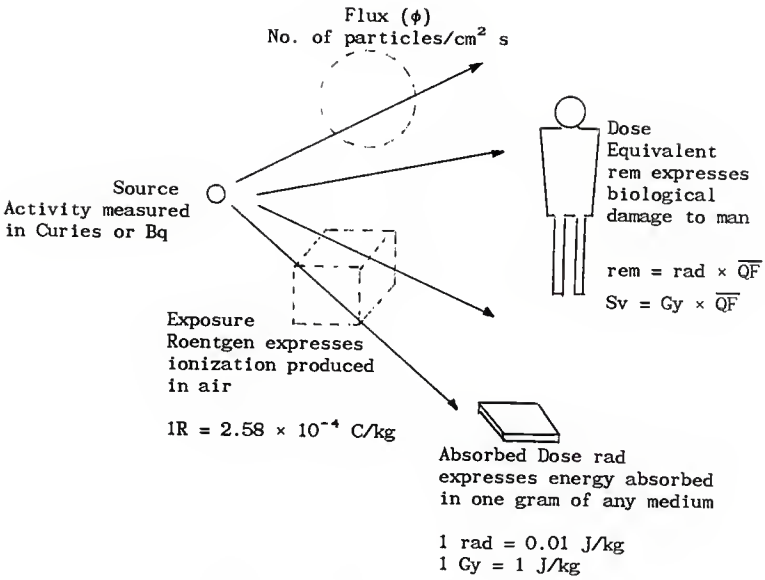


FIG. 1.1. Relationship of units.

P_i represents the number of members in this subgroup i.

The collective dose equivalent S_k from a practice or source (k) is given by

$$S_k = \int_0^\infty HP(H)dH \ , \qquad (1.4)$$

where P(H)dH is the number of individuals receiving a dose equivalent in the whole body or a specific organ or tissue in the range H to H + dH.

1.4.1 Radiobiological Assumption:

A simple summation over all subgroups of the population of doses to specific organs or tissues of a typical individual in a subgroup is used as a measure of detriment to estimate the collective dose equivalent in a population [IC77]. This process is based on an assumption regarding stochastic effects; namely, that within the usual range of radiation exposure a linear relationship without threshold exists between dose and the probability of an effect.

1.5 COMMITTED DOSE EQUIVALENT, H_{50}

This is defined as the total dose equivalent averaged throughout a tissue in the 50 years after intake of a radionuclide into the body. The 50 year period represents a working life. Mathematically, it can be expressed as:

$$H_{50} = \int_{t_o}^{t_o + 50y} \dot{H}(t)dt \ , \qquad (1.5)$$

where $\dot{H}(t)$ is the relevant dose-equivalent rate, and

t_o is the time of intake.

In view of the radiobiological assumption above, it is considered practical to conceptualize the term "dose equivalent" as a mean dose equivalent over all cells of uniform sensitivity in a particular tissue or organ for stochastic effects.

1.5.1 Non-homogeneous radiation:

If the doses to individual cells vary due to non-uniform irradiation then the relevance of the mean dose equivalent may be questioned. However, according to the Commission, based on theoretical concepts and epidemiological evidence, a series of "hot spots" in an organ or tissue is less likely to be damaging than a uniform distribution. High doses cause loss of reproductive capacity or death of cells, neither of which may contribute significantly to stochastic effects. Thus, for non-homogeneous irradiation, assessment of dose with the assumption of homogeneous distribution would probably be an overestimation. So far as non-stochastic effects are concerned, the limited amount of cell killing at moderate dose levels is thought not to be a major factor in perturbing the balance of organ function.

1.5.2 Unequal sensitivity of cells:

The problem of dose variance due to differing cell sensitivities of different organs is handled by the Commission by prescribing risk factors according to relative radiosensitivities of the irradiated tissues. A detailed explanation of these risk factors will follow later.

1.5.3 Rate of dose accumulation:

Based on assumptions and explanations summarized above, the Commission has found it unnecessary to recommend a maximum rate of dose accumulation as long as the annual dose equivalent limit is met. The only exception is the case of occupational exposure of women of reproductive potential and pregnant women.

1.5.4 Age, sex, and dose-dependency:

Risk factors for occurrence of malignant cancers are thought to be lessened in older persons due to long periods of latency needed for progression and expression of these effects. Also, development of breast cancer is much more common in females than in males. Such facts emphasize the importance of age, sex, and dose dependency. The Commission however, describes average risk levels based on anatomical and physiological characteristics of "reference man" because, for protection purposes, it is considered sufficiently prudent to use a single dose-equivalent limit for each organ or tissue for all workers regardless of age or sex.

1.6 DOSE EQUIVALENT LIMITS FOR OCCUPATIONAL EXPOSURE

The primary considerations of the Commission in establishing dose equivalent limits were:

i) For stochastic effects, a single value should not only limit uniform irradiation of the whole body but also ensure that the total risk from irradiation to parts of the body does not exceed the value.

ii) To preclude non-stochastic effects, a value should be proposed such that no single tissue receives more dose-equivalent than the value.

1.6.1 Recommended limit for non-stochastic effects:

To prevent non-stochastic effects in all tissues except the lens, the Commission has proposed a limit of 0.5 Sv (50 rem) in a year. The dose equivalent to the lens is limited to 0.15 Sv (15 rem) in a year.

1.6.2 Recommended limit for stochastic effects:

For whole-body uniform irradiation, the limit is

$$H_{wb} = 5 \text{ cSv } (5 \text{ rem}) \text{ in any year.} \qquad (1.6)$$

Non-uniform irradiation must adhere to the following condition:

$$\sum_{T} w_T H_T \leq H_{wb} \qquad (1.7)$$

where H_T is the dose equivalent received by tissue T, and

w_T is a weighting factor involving relative radiosensitivity of the tissue T.

The values of these weighting factors are given in Table 1.1.

TABLE 1.1. Weighting factors as proposed by the ICRP Publication 26.

Tissue	w_T
Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lung	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder	0.30

The "remainder" refers to five remaining organs or tissues receiving the highest dose equivalents, with $w_T = 0.06$ applied to each. All other tissues are neglected. Of course, lens and skin are not members of "remainder" because they are subject to non-stochastic effects. The gastrointestinal tract is treated as four separate organs: stomach, small intestine, upper large intestine, and lower large intestine.

1.6.3 External exposures to penetrating radiation:

In the absence of information on actual distribution of dose equivalent within the body, the maximum value of dose equivalent in a 30-cm spherical phantom when limited to the 0.5 Sv annual limit will permit a comparable level of protection.

1.6.4 Planned special exposures:

The limit under such situations should not exceed twice the relevant annual limit in any single event, and, in a lifetime, five times this annual limit. The exposures however, must be justified and permitted only when alternative techniques are impractical or unavailable.

1.6.5 Women of reproductive capacity:

Occupational exposure of such women should be restricted to insure that the embryo receives no more than 0.005 Sv during the first two months of pregnancy.

1.6.6 Occupational exposure of pregnant women:

Exposure should be minimized and not exceed 30% of the normal annual limits.

1.7 CONTROL OF INTERNAL DOSE

For control of internal dose for workers, the standards are derived from the general limits described in the previous section and are based on the parameters of the "reference man".

1.7.1 Annual limit on intake (ALI) [IC79]:

For a given radionuclide, if I is the annual intake (Bq) either by ingestion or inhalation, and $\hat{H}_{50,T}$ (Sv/Bq) is the specific (per unit intake) committed dose equivalent in tissue T from the intake by the

specified mode, weighted for its sensitivity by weighting factor w_T described in Table 1.1, then the annual limit on intake is defined as the greater value of I which satisfies both of the following inequalities

$$I \sum_T w_T \hat{H}_{50,T} \leq 0.05 \quad Sv \tag{1.8}$$

for stochastic effects, and

$$I \hat{H}_{50,T} \leq 0.5 \quad Sv \tag{1.9}$$

for non-stochastic effects.

The summation in the first inequality is over all tissues in Table 1.1, including of course the five "remaining tissues" in "remainder" which receive the greatest specific committed dose equivalents. A tissue is considered to be "significantly irradiated" only when it satisfies the following inequality

$$w_T \hat{H}_{50,T} \geq 0.1(w_T \hat{H}_{50,T})_{maximum} \tag{1.10}$$

1.7.2 Derived air concentration (DAC) [IC79]:

The DAC for any radionuclide is defined as that concentration in air (Bq/m^3) which, if received by "reference man" for a working year of 2000 h (50 weeks at 40 hours per week), would lead to the ALI for inhalation, i.e.,

$$DAC = ALI/(2000 \times 60 \times 0.02),$$

or

$$DAC = ALI/2.4 \times 10^3 \quad Bq/m^3, \tag{1.11}$$

where $0.02\ m^3$ is the volume of air breathed at work by "reference man" per minute under conditions of "light activity" as described by ICRP Publication 23.

For radioactive noble gases other than radon and thoron, DAC's are the concentrations which would lead to a cumulative weighted average dose of not more than 0.05 Sv, a dose to the lens of 0.15 Sv, or a dose to the skin of 0.5 Sv in a working year (2000 h).

2.0 EVALUATION OF SPECIFIC COMMITTED DOSE EQUIVALENT

Specific committed dose equivalent from a radionuclide to a target organ or tissue is defined as the committed dose equivalent to the organ or tissue as a result of ingestion or inhalation of *unit* activity of the nuclide.

Activity or decay rate A is mathematically expressed as

$$A = \lim_{\Delta t \to 0} \frac{\Delta N}{\Delta t} , \qquad (2.1)$$

where ΔN is the number of spontaneous nuclear transformations in a quantity of radionuclide, and

Δt is the time interval.

The unit of activity is the becquerel (Bq). 1 Bq = 1 s^{-1} ($\simeq 2.7 \times 10^{-11}$ Ci).

Committed dose equivalent, as explained in the previous chapter, is the total dose equivalent averaged throughout any tissue in the 50 years following intake of a radionuclide into the body, and hence can be written as

$$H_{50} = \sum_i \frac{\int^M D_{50,i}\ \bar{Q}_i\ N_i\ dm}{\int^M dm} , \qquad (2.2)$$

where i is an index for the type of radiation (α, β, γ, etc.) released by the radionuclide,

$D_{50,i}$ is the total absorbed dose in the element of mass dm of the specific organ or tissue during a 50 year period following intake of the radionuclide into the body,

$\bar{Q}_i$ is the effective quality factor for the radiation type i,

N_i is the product of all modifying factors such as dose rate, fractionation, etc., and

M is the mass of the organ or tissue under consideration.

A value of 1 is recommended for N by the ICRP (Publication 26) and the value of $\bar{Q}$ is constant for each type of radiation i; therefore, the above relation can be simplified to

$$H_{50} = \sum_i \bar{Q}_i \, \overline{D_{50,i}} \, . \qquad (2.3)$$

where $\overline{D_{50,i}}$ is the total absorbed dose during the 50 years after intake of the radionuclide into the body, *averaged* throughout the specified organ or tissue for each radiation type i.

When a radionuclide enters the body, it is distributed in various source organs or tissues where it may decay or be eliminated by normal metabolic processes. The committed dose equivalent in a target organ or tissue T due to the disintegration of a radionuclide j, releasing radiation of type i in source organ S, denoted by, $H_{50}(T \leftarrow S)_{i,j}$, is defined as a product of two factors:

i) the total number of transformations (decays) of radionuclide j in source organ S during the 50 year period following its entry into the body, and

ii) the energy absorbed per unit mass in the target organ T, modified for effective quality factor, from radiation of type i per transformation of radionuclide j in source organ S.

Mathematically, for each radiation type i from radionuclide j,

$$H_{50}(T \leftarrow S)_{i,j} = \overline{Q_i}\ \overline{D_{50}}(T \leftarrow S)_{i,j} ,$$

or

$$H_{50}(T \leftarrow S)_{i,j} = U_{s,j} \times 1.6 \times 10^{-13} \times SEE(T \leftarrow S)_{i,j} \times 10^{3} , \qquad (2.4)$$

where $U_{s,j}$ is the number of transformations (decays) of radionuclide j in organ S over 50 years following intake of the radionuclide,

1.6×10^{-13} is the number of joules in 1 MeV,

$SEE(T \leftarrow S)_{i,j}$ is the specific effective energy, modified by quality factor, for radiation type i absorbed in T from each transformation in S. The unit is MeV/g per transformation, and

10^{3} is the conversion factor from g^{-1} to kg^{-1}.

Thus, for all types of radiation emitted by radionuclide j,

$$H_{50}(T \leftarrow S)_{j} = 1.6 \times 10^{-10} \left[U_{s,j} \sum_{i} SEE(T \leftarrow S)_{i}\right]_{j} . \qquad (2.5)$$

If the radionuclide decays into a radioactive daughter j', then

$$H_{50}(T \leftarrow S)_{j+j'} = 1.6 \times 10^{-10} \left\{\left[U_{s,j} \sum_{i} SEE(T \leftarrow S)_{i}\right]_{j} + \left[U_{s,j'} \sum_{i} SEE(T \leftarrow S)_{i}\right]_{j'}\right\} . \qquad (2.6)$$

For a number of radioactive daughters, the committed dose equivalent in

target T from decays in source S can be generalized as

$$\sum_j H_{50}(T \leftarrow S)_j = 1.6 \times 10^{-10} \sum_j \left[U_{s,j} \sum_i SEE(T \leftarrow S)_i \right]_j \quad . \qquad (2.7)$$

Since the target organ T may receive dose from more than one source organ, the total value of H_{50} in target T is given by

$$H_{50,T} = 1.6 \times 10^{-10} \sum_s \sum_j \left[U_{s,j} \sum_i SEE(T \leftarrow S)_i \right]_j \quad . \qquad (2.8)$$

Since our interest is the specific committed dose equivalent, we express it per unit activity as

$$\hat{H}_{50,T} = 1.6 \times 10^{-10} \sum_s \sum_j \left[\hat{U}_{s,j} \sum_i SEE(T \leftarrow S)_i \right]_j \quad . \qquad (2.9)$$

where $\hat{U}_{s,j}$ is the number of transformations of radionuclide j in S over 50 years after intake of unit activity of the radionuclide.

2.1 SPECIFIC EFFECTIVE ENERGY

Let us denote the specific effective energy absorbed in target T per transformation of radionuclide j emitting all types of radiation i in source S as

$$SEE(T \leftarrow S)_j = \sum_i SEE(T \leftarrow S)_{i,j} \quad . \qquad (2.10)$$

As previously stated, each radionuclide may emit a range of different types and energies of radiation indicated by index i. But it is not necessary that every transformation (decay) of radionuclide j should result in emission of all the varied radiations. Hence the concept of yield. Associated with average or unique (as appropriate) energy E_i (in MeV) of every radiation type i is a yield Y_i. The yield provides the fraction of transformations that result in the release of radiation type i. Also, the amount of the energy absorbed in target T will vary significantly with the energy, kind of radiation, and location (source organ S) of release. This variance is accounted by introducing a quantity $AF(T \leftarrow S)_i$ which is defined as the fraction of energy absorbed in target organ T per emission of radiation i in source organ S. Of course, in accordance with the definition in the previous section, the product of all these quantities must be weighted for effective quality factors $\bar{Q}_i$ for each radiation type i, and, since we are interested in specific effective energy, the whole product must be taken per unit mass M_T (in g) of the target organ T. We can thus write, for each radionuclide j,

$$SEE(T \leftarrow S)_j = \sum_i \frac{Y_i E_i \, AF(T \leftarrow S)_i \, \bar{Q}_i}{M_T} . \qquad (2.11)$$

a) Decay Schemes [KO81]: The decay schemes of radionuclides used in this report were obtained from "Radioactive Decay Data Tables," by D. C. Kocher, DOE/TIC - 11026(1981). In case of positron emission, a photon of energy 0.511 MeV and yield twice that of the

positron is added to the decay scheme to account for the annihilation photons. The decay scheme used in the ICRP-30 results were from Publication 38 [IC83].

b) Absorbed fraction of energy in target organ: For most target organs, it is assumed that the energies from non-penetrating radiations such as alpha particles, beta particles, positrons, etc. are completely absorbed within the source organ. Hence, if target organ and source organ are the same, then the absorbed fraction is equal to 1, else it is equal to zero for non-penetrating radiation, except in the following cases [SN75]:

i) If the source organ is total body then, regardless of the target organ, the specific absorbed fraction $\hat{AF}$ (absorbed fraction per g of target) is given by

$$\hat{AF}(T \leftarrow \text{Total body}) = 1/69900,$$

where the denominator represents mass in grams of the total body of Reference Man.

ii) When the target organ is total body and the source organ is either bladder content, stomach content, SI content, ULI content, or LLI content, then

$$\hat{AF}(\text{Total body} \leftarrow \text{GI tract/Bladder content}) = M_w/(2 \times M_c \times 69900),$$

where M_w is the mass of the wall of the source organs, and

M_c is the mass of the contents of the source organs.

If the source is any other organ excluding the above and the target organ is total body then

$$\hat{AF}(\text{Total body} \leftarrow S) = 1/69900.$$

With the specific absorbed fraction, the value of specific effective energy is given by

$$SEE(T \leftarrow S)_j = \sum_i Y_i \, E_i \, \hat{AF}(T \leftarrow S)_i \, \bar{Q}_i \, . \qquad (2.12)$$

In case of penetrating radiations such as X-rays and γ rays, the absorbed fraction of energy from photons is estimated by the data in ICRP Publication 23 [IC75]. The tables in Publication 23 provide values for discrete energies from 0.01 MeV to 4.0 MeV. If the photon energy is within this range, then the value of absorbed fraction can be interpolated from the tables. However, if the energy of the photon is less than 0.01 MeV, specific absorbed fractions used in calculations are assumed to be the same as defined for non-penetrating radiations [SN78], i.e.,

i) $\hat{AF} = 1/M_T$ if the source and the target are the same, or

ii) $\hat{AF} = 0$ in general if the source and the target are different, except for the following conditions:

iii) $\hat{AF} = 1/69900$ if the source organ is total body.

iv) $\hat{AF} = M_w/(2 \times M_c \times 69900)$ if the target organ is total body and the source is either bladder content, stomach content, SI content, ULI content, or LLI content.

v) $\hat{AF} = 1/69900$ if the target organ is total body and the source is any organ other than the ones described in (iv).

This treatment in calculation of absorbed fractions or specific absorbed fractions is recommended for the majority of target organs. However, there are exceptions, notably the mineral bone, organs of the GI tract, and the bladder wall, which are explained below:

2.1.1 Target Organs of the GI Tract and Bladder Wall:

For non-penetrating radiations, if the source organ is different from a target organ of the GI tract or bladder wall, the specific absorbed fraction is zero except when the source is total body. In that case, $\hat{AF}$ = 1/69900. However, if the source is the content of the target organ in the GI tract or the bladder content, the only dose received is that by the mucosal layer ML of the wall of the organ. The specific absorbed fraction for the mucosal layer of the wall of the target organ is taken to be equal to $0.5\times\upsilon/M_T^c$, where M_T^c (in g) is the mass of the contents of that target organ, and υ is a factor between zero and unity representing the degree to which the radiation penetrates the mucus. The factor 0.5 is introduced because the absorbed dose rate at the interface between the contents and the mucus and mucosal layers is approximately half that deep within the contents. For β particles, υ is taken to be unity, and for α particles only 0.01 owing to attenuation in the mucus layer.

As far as photons are concerned, the fraction of their energy emitted in source S that is absorbed in the walls of the target T is obtained from the tables in ICRP Publication 23 by interpolating within the 0.01 to 4.0 MeV range. However, if the energy of the photon is less than 0.01 MeV, the specific absorbed fraction is extrapolated as:

i) $\hat{AF} = 1/(2 \times M_c)$ if the source and the target are the same, where M_c is the mass of contents of the organ, or

ii) $\hat{AF} = 0$ in general if the source and the target are different, except in the following case:

iii) if the source organ is total body, then $\hat{AF} = 1/69900$.

2.1.2 Target Organ in Bone:

In the case of mineral bone, the two target tissues are the cells near bone surfaces (BS) and the active red bone marrow (RM). The ICRP model describes source tissues as cortical and trabecular bone for all non-penetrating radiation. For photon emitters, S is any organ of the body containing the radionuclide and T is either the BS cells or RM. Cortical bone (CB) is the compact or dense material of the outside of the bone. Trabecular bone (TB) is the cancellous or spongy inner portion of the bone containing the marrow.

Absorbed fractions for non-penetrating radiation are governed by two major criteria:

i) Radionuclides with half lives of less than 15 days are considered to be distributed on bone surfaces, since they are unlikely to move far into the volume of bone before they decay,

ii) Isotopes of alkaline earth elements with half lives greater than 15 days and radionuclides ^{33}P, ^{93m}Nb, ^{94}Nb, ^{232}U, ^{233}U, ^{234}U, ^{235}U, ^{236}U, ^{238}U, Na, Cr, Rb, ^{65}Zn, ^{205}Pb, ^{210}Pb, ^{49}V, ^{7}Be, ^{10}Be, ^{103}Pd, ^{107}Pd, ^{113}Sn, ^{119m}Sn, ^{123}Sn, ^{126}Sn, ^{182}Ta,

^{181}W, ^{185}W, ^{188}W are assumed to be uniformly distributed throughout the volume of bone.

If the source organ is any other organ except total body, trabecular bone, or cortical bone, the specific absorbed fraction is taken to be zero. If the source is total body, $\hat{AF}$ = 1/69900. Recommended values of absorbed fractions for α and β particles in the cases of source tissues as TB and CB are given in Table 2.1. Masses of target organs BS and RM are taken to be 120 and 1500 g respectively.

TABLE 2.1 Absorbed fractions for dosimetry of radionuclides in bone as recommended by the ICRP 30.

Source Organ	Target Organ	α-emitter uniform in volume	α-emitter on bone surface	β-emitter uniform in volume	β-emitter on bone surface $\bar{E} \geq 0.2$ MeV	β-emitter on bone surface $\bar{E} < 0.2$ MeV
TB	BS	0.025	0.25	0.025	0.025	0.25
CB	BS	0.01	0.25	0.015	0.015	0.25
TB	RM	0.05	0.5	0.35	0.5	0.5
CB	RM	0.0	0.0	0.0	0.0	0.0

For photon emitters, if the energy is within 0.01 to 4.0 MeV, values of absorbed fraction can be interpolated from the tables in ICRP Publication 23 for any source organ. Values of absorbed fraction reported for skeleton in Publication 23 are taken as appropriate for BS cells. If the photon energy is less than 0.01 MeV and the source is TB or CB, absorbed fraction is taken to be $1/M_T$, where M_T is 1500 g for

target organ RM and 10500 g for BS cells. If however, the source is any other organ except total body, AF = 0. In the case of total body, specific absorbed fraction $\hat{AF}$ = 1/69900.

2.1.3 A note on daughters:

The metabolic behavior of daughters is assumed to be the same as that of the parent radionuclide which enters the body (see Section 2.2.1).

2.2 NUMBER OF TRANSFORMATIONS IN A SOURCE ORGAN OVER 50 YEARS

The number of transformations of a radionuclide in any source organ during a period of time is defined as the time integral of the activity of the radionuclide over that period of time.

After ingestion or inhalation of a radionuclide, its translocation to the body fluids is dependent upon the rate constants of the different compartments of the gastrointestinal and respiratory systems, and the decay constant of the radionuclide. A detailed account of the passage of radionuclides through the GI and respiratory system follows later. For now, let us examine the kinetics of a radionuclide after it reaches the body fluid compartment, and how it is deposited in, or passed for excretion from the different compartments of a tissue or organ. The mathematical model recommended by the ICRP is illustrated in Fig. 2.1. Transformations in the body fluid or transfer compartment are assumed to be uniformly distributed throughout the whole body of mass 70000 g. Each source organ or tissue may have one or more compartments where the radionuclide may be retained or translocated at

different rates. A maximum of three compartments per tissue is assumed. From each of these compartments, the radionuclide migrates at an appropriate rate to excretion pathways. In the interest of simplicity, no feedback to the transfer compartment either from the tissue compartments or from routes of excretion is assumed, although in reality the case is otherwise.

2.2.1 A note on daughters:

The immediate daughters and all subsequent progeny produced within the body are assumed to be associated with, and behave metabolically as the inhaled or ingested parent radionuclide. In general, there is little evidence to show whether the daughters behave metabolically like the parent or if, upon production, they exhibit their own metabolic behavior. When experimental evidence contrary to the assumption is available, separate models as shown later are used.

2.2.2 Transfer compartment, T:

Let us represent the radionuclides with an index j. If we suppose that an initial activity f_T^j, per unit intake, reaches the body fluid or transfer compartment from the GI tract and lungs, then for the parent (j = 1) a differential equation expressing the time-dependent behavior in accordance with the model in Fig. 2.1, can be written as

$$\frac{dq_{T1}(t)}{dt} = - \lambda_T \, q_{T1}(t) - \lambda_1 \, q_{T1}(t) \, , \qquad (2.13)$$

where q_{T1} is the activity of the parent in the transfer compartment,

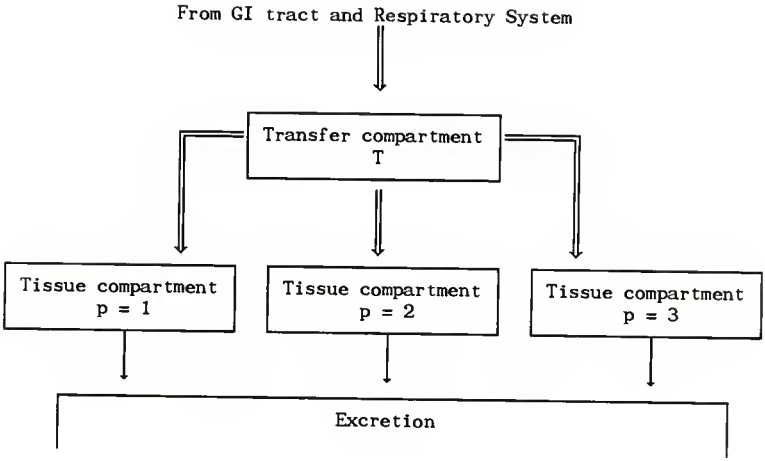


FIG 2.1 Mathematical model used by the ICRP-30 to describe the kinetics of radionuclides in the body.

λ_1 is the radiological decay constant for species 1, and

λ_T is the rate of loss of the stable element from the transfer compartment.

For most elements, λ_T is taken to be equal to ln2/0.25 days, i.e., the biological half life for translocation to the organs and tissues of deposition from the transfer compartment is taken to be 0.25 days. Following are the exceptions:

i) If the element is fluorine, potassium, gold, or thallium, the translocation is assumed to be instantaneous and the biological half life is zero.

ii) If the element is thorium, cobalt, chromium, or phosphorus, the biological half life is 0.5 days.

iii) If the element is technetium or rhenium, the biological half life is 0.02 days.

iv) If the element is ruthenium or rhodium, the biological half life is 0.3 days.

v) If the element is tellurium, the biological half life is 0.8 days.

vi) If the element is bismuth, the biological half life is 0.01 days.

Taking the Laplace transform of Eq. (2.13), we have

$$s\,\overline{q_{T1}}(s) - q_{T1}(0) = -\lambda_T\,\overline{q_{T1}}(s) - \lambda_1\,\overline{q_{T1}}(s) \ .$$

This can be written as

$$\overline{q}_{T1}(s) = \frac{q_{T1}(0)}{[s + (\lambda_T + \lambda_1)]} \ . \qquad (2.14)$$

Now for the daughters, a similar differential equation (see Fig. 2.1) can be written as

$$\frac{dq_{Tj}(t)}{dt} = \lambda_j\, q_{T,j-1}(t) - \lambda_T q_{Tj}(t) - \lambda_j\, q_{Tj}(t) \ ,$$

$$j = 2, \ldots, N \qquad (2.15)$$

where j is the index for the daughters,

q_{Tj} is the activity of the species j in the transfer compartment,

$q_{T,j-1}$ is the activity of the parent of species j in the transfer compartment, and

λ_j is the radiological decay constant for species j.

Specifically for j = 2 ,

$$\frac{dq_{T2}(t)}{dt} = \lambda_2 \, q_{T1}(t) - \lambda_T q_{T2}(t) - \lambda_2 \, q_{T2}(t) \; . \qquad (2.16)$$

The Laplace transform of Eq. (2.16) is

$$s \, \overline{q_{T2}}(s) - q_{T2}(0) = \lambda_2 \overline{q_{T1}}(s) - \lambda_T \, \overline{q_{T2}}(s) - \lambda_2 \, \overline{q_{T2}}(s),$$

or

$$\overline{q_{T2}}(s) = \frac{q_{T2}(0) + \lambda_2 \, \overline{q_{T1}}(s)}{[s + (\lambda_T + \lambda_2)]} \; . \qquad (2.17)$$

Substituting for $\overline{q_{T1}}(s)$ from Eq. (2.14) in Eq. (2.17), we obtain

$$\overline{q_{T2}}(s) = \frac{1}{[s + (\lambda_T + \lambda_2)]} \left\{ q_{T2}(0) + \frac{\lambda_2 \, q_{T1}(0)}{[s + (\lambda_T + \lambda_1)]} \right\} . \qquad (2.18)$$

In general form,

$$\overline{q_{Tj}}(s) = \sum_{i=1}^{j} \left\{ \frac{\left[\prod_{k=i+1}^{j} \lambda_k \right] q_{Ti}(0)}{\prod_{k=i}^{j} [s + (\lambda_T + \lambda_k)]} \right\} . \qquad (2.19)$$

Now,

$$\frac{1}{\prod_{k=i}^{j} [s + (\lambda_T + \lambda_k)]} = \frac{1}{[s + (\lambda_T + \lambda_1)]\,[s + (\lambda_T + \lambda_2)] \ldots} .$$

In partial fractions, this can be written as

$$\frac{1}{\prod_{k=i}^{j} [s + (\lambda_T+\lambda_k)]} = \frac{A_1}{s + (\lambda_T+\lambda_1)} + \frac{A_2}{s + (\lambda_T+\lambda_2)} + \cdots \frac{A_m}{s + (\lambda_T+ \lambda_m)} + \cdots .$$

Multiplying throughout by $[s + (\lambda_T+\lambda_m)]$, we have

$$\frac{s + (\lambda_T+\lambda_m)}{\prod_{k=i}^{j} [s + (\lambda_T+\lambda_K)]} = \frac{A_m\,[s + (\lambda_T+\lambda_m)]}{[s + (\lambda_T+\lambda_m)]} + [s + (\lambda_T+\lambda_m)] \sum_{\substack{k=1 \\ k\neq m}}^{j} \frac{A_k}{[s + (\lambda_T+\lambda_k)]} .$$

Hence,

$$\frac{1}{\prod_{\substack{k=i \\ k\neq m}}^{j} [s + (\lambda_T+\lambda_k)]} = A_m + [s + (\lambda_T+\lambda_m)] \sum_{\substack{k=1 \\ k\neq m}}^{j} \frac{A_k}{[s + (\lambda_T+\lambda_k)]} .$$

Let $s = -(\lambda_T+\lambda_m)$, then

$$A_m = \frac{1}{\prod_{\substack{k=i \\ k\neq m}}^{j} (\lambda_k-\lambda_m)} .$$

Thus,

$$\overline{q_{Tj}}(s) = \sum_{i=1}^{i} \left\{ \left[\prod_{k=i+1}^{j} \lambda_k \right] q_{Ti}(0) \left[\sum_{m=i}^{j} \frac{1}{\prod_{\substack{k=i \\ k\neq m}}^{j} (\lambda_k - \lambda_m)[s + (\lambda_T + \lambda_m)]} \right] \right\} .$$

We know that if $L(f) = 1/s+a$, then $f(t) = e^{-at}$.

Therefore,

$$q_{Tj}(t) = \sum_{i=1}^{j} \left\{ \left[\prod_{k=i+1}^{j} \lambda_k \right] q_{Ti}(0) \left[\sum_{m=i}^{j} \frac{e^{-(\lambda_T+\lambda_m)t}}{\prod_{\substack{k=i \\ k\neq m}}^{j} (\lambda_k - \lambda_m)} \right] \right\} . \qquad (2.20)$$

where $\prod_{i=m}^{n} a_i = a_m \times a_{m+1} \times \ldots a_n$ if $n \geq m$, and

$\prod_{i=m}^{n} a_i = 1$ if $m > n$.

Now by definition, the number of transformations in the transfer compartment U_{Tj} for species j is given by

$$U_{Tj} = B_j \times \int_0^T q_{Tj}(t)\, dt , \qquad (2.21)$$

where $T = 365.25 \times 50$ days, and

B_j is the branching ratio of radionuclide j. For the parent, $B_1 = 1$.

The result of the integral is

$$U_{Tj} = B_j \times \sum_{i=1}^{j} \left\{ \left[\prod_{k=i+1}^{j} \lambda_k \right] q_{Ti}(0) \left[\sum_{m=i}^{j} \frac{[1 - e^{-(\lambda_T+\lambda_m)T}]}{(\lambda_T+\lambda_m) \prod_{\substack{k=i \\ k\neq m}}^{j} (\lambda_k-\lambda_m)} \right] \right\}, \quad (2.22)$$

where $\prod_{i=m}^{n} a_i = a_m \times a_{m+1} \times \ldots a_n$ if $n \geq m$,

$\prod_{i=m}^{n} a_i = 1$ if $m > n$, and

$q_{Ti}(0)$ is the initial activity of species i in the transfer compartment which is assumed to be equal to f_T^i. Calculation of this quantity is shown later.

If λ values have units d^{-1}, then this formula for U_{Tj} must be multiplied by 86400 s/d to yield units Bq^{-1} for U_{Tj}.

2.2.3 Tissue compartment, p:

As mentioned earlier, each source organ or tissue can have a maximum of three compartments, i.e., p = 1, 2, 3. From the transfer compartment, a fraction f_2^p may reach each tissue compartment of a source organ. This fraction is biologically eliminated from the compartment with a half life of λ_p. Since the daughters are assumed to possess the same metabolic behavior as the parent, the same retention fractions f_2^p and biological half-lives λ_p are used for them. These retention fractions and biological half lives are obtained from the

metabolic data in ICRP Publication 30 for each nuclide taken in the body.

With the knowledge of f_2^p, the total activity of species j translocated from the transfer to the tissue compartment during the 50 year time period can be given by

$$Q_{pj} = f_2^p \lambda_T \int_0^T q_{Tj}(t)\, dt \quad . \tag{2.23}$$

But as shown before,

$$U_{Tj} = B_j \times \int_0^T q_{Tj}(t)\, dt \quad .$$

Hence,

$$Q_{pj} = \frac{f_2^p \lambda_T}{B_j} U_{Tj} \quad . \tag{2.24}$$

If we assume that this total activity is transferred instantaneously as a single intake to the tissue compartment at time t = 0, then the initial activity deposited in the tissue compartment $q_{pi}(0)$ for species i is equal to

$$q_{pi}(0) = \frac{f_2^p \lambda_T U_{Ti}}{B_i} \quad . \tag{2.25}$$

For the time dependent behavior of species j in the tissue compartment, differential equations similar to the ones described in

the transfer compartment can be written. By a similar treatment of solution, the number of transformations in a tissue compartment for species j can be written as

$$U_{pj} = B_j \times \sum_{i=i}^{j} \left\{ \left[\prod_{k=i+1}^{j} \lambda_k \right] q_{pi}(0) \left[\sum_{m=i}^{j} \frac{[1 - e^{-(\lambda_p+\lambda_m)T}]}{(\lambda_p+\lambda_m) \prod_{\substack{k=i \\ k\neq m}}^{j} (\lambda_k-\lambda_m)} \right] \right\} , \qquad (2.26)$$

where $q_{pi}(0)$ is given by Eq. (2.25).

Thus, for a source which may have a maximum of 3 compartments, the number of source-organ transformations for species j is

$$U_{sj} = \frac{M_s \times U_{Tj}}{70000} + \sum_{p=1}^{3} U_{pj} , \qquad (2.27)$$

where M_s is mass of the source organ, and

70000 is mass of the total body in grams.

2.2.4 Respiratory system:

When a radionuclide is inhaled, parts of the respiratory system are irradiated. As a consequence, other organs and tissues of the body may be irradiated either by translocation of the inhaled material from the respiratory system to the body tissues or by radiations originating from the lungs.

Analyses of the dynamics of radionuclide transport within the lung is essential for the evaluation of number of source-organ transformations.

The model representing the respiratory system is proposed by the ICRP Task Group on Lung Dynamics (1966) [IC66]. It is shown in Fig. 2.2. This model partitions the respiratory system into three regions -- the nasal passage (N-P), the trachea and bronchial tree (T-B), and the pulmonary parenchyma (P). Each region is further subdivided into two or four compartments. All three regions have pathways directly to the body fluid compartment. Only the P region translocates material to the lymphatic system (L). This pulmonary lymphatic system also serves to remove the dust from the lungs. A subcompartment of the lymphatic system releases material to the body fluids while the other subcompartment is assumed to retain the material indefinitely. The latter subcompartment is deemed appropriate only for a particular class Y of aerosols. Both T-B and N-P regions are involved with mucociliary transport which translocates material to the gastrointestinal tract. Connection between the P region and the GI tract is only through feedback via the T-B region.

a) Deposition and Retention of Inhaled Material: Deposition of inhaled material in the respiratory system is dependent upon the aerodynamic properties of the aerosol distribution. Three terms D_{N-p}, D_{T-B}, and D_p represent the fractions of inhaled material initially deposited in the N-P, T-B, and P regions respectively, the balance being the fraction exhaled. The pattern of aerosol distribution is characterized by the activity median aerodynamic diameter (AMAD). This quantity is closely approximated by the mass-median aerodynamic

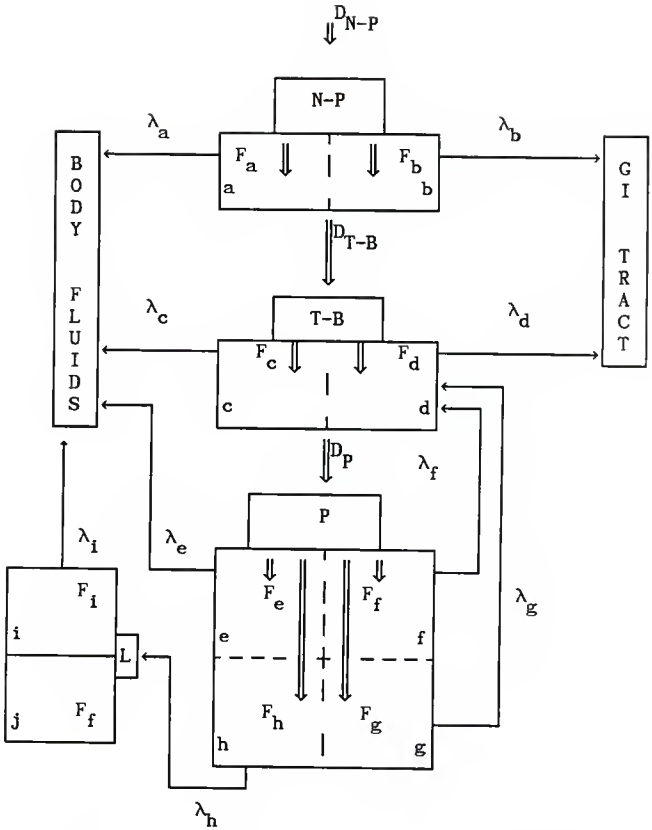


FIG. 2.2. Mathematical model used to describe clearance from respiratory system.

Source: ICRP Publication 30, Part I.

diameter, the aerodynamic diameter of a particle being the diameter of a spherical particle with the same settling velocity. The pattern of deposition is related to the AMAD of the aerosol according to Fig. 2.3.

To analyze the clearance of inhaled radioactive materials from the lung, the radionuclides are categorized as D, W, or Y. These categories refer to the retention in the pulmonary region. Class D reflects minimal retention, i.e., a rapid clearance within days while, class W material takes weeks for clearance, and class Y is cleared slowly in years. For elements and their compounds, retention classification is given in Fig. 2.4.

For each chemical classification, the sub-compartments have a half time of clearance T (days), and a fraction F that refers to the amount of material leaving each sub-compartment. These values are shown in Table 2.2. Note that the half lives are given in units of days. When converting these decay constants in units of s^{-1}, one must use the factor 86400 s/d.

b) Clearance Calculations: To calculate the source-organ transformations of a nuclide, we need to evaluate its time dependent activity in each subcompartment. Suppose we represent the subcompartments with an index ℓ such that ℓ = a, b, c, d, e, f, g, h, i, and j as shown in Fig. 2.2. Now, if a unit activity of nuclide is inhaled at time t = 0, then the initial activities in each of the subcompartments a - h of Fig. 2.2 can be given as the product of percent deposition in the compartment and the fraction of material entering the

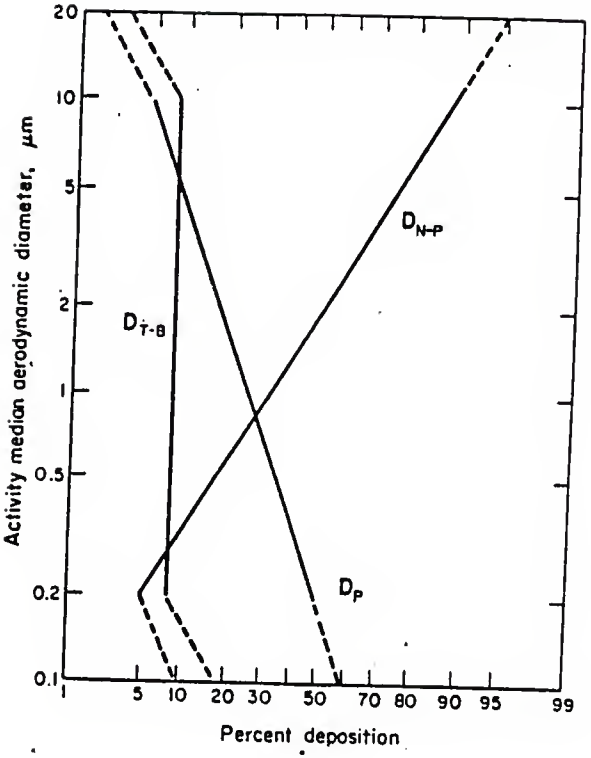


FIG. 2.3. Model of deposition of dust in the respiratory system as proposed by the ICRP-30. The model is intended for use with aerosols with AMAD between 0.2 and 10 μm and with geometric standard deviations of less than 4.5. Provisional estimates of deposition further extending the size range and given by dashed lines.

Class F—Avid retention: cleared slowly (years)
Carbides—actinides, lanthanides, Zr, Y, Mn
Sulfides—none
Sulfates—none
Carbonates—none
Phosphates—none
Oxides and hydroxides—lanthanides, actinides Groups 8 (V and VI), 1b, 2b (IV and V), 3b except Sc^{3+}, and 6b.
Halides—lanthanide fluorides
Nitrates—none

Class W—Moderate retention: intermediate clearance rates (weeks)
Carbides—Cations of all Class W hydroxides except those listed as Class Y carbides.
Sulfides—Groups 2a (V + VI), 4a (IV–VI), 3a (IV–VI), 1b, 2b and 6b (V + VI).
Sulfates—Groups 2a (IV–VII), and 3a (IV–VI)
Carbonates—lanthanides, Bi^{3+} and Group 2a (IV–VII)
Phosphates—Zn^{2+}, Sn^{2+}, Mg^{2+}, Fe^{3+}, Bi^{3+} and lanthanides
Oxides and hydroxides—Groups 2a (II–VII), 3a (III–VI), 4a (III–VI), 5a (IV–VI), 6a (IV–VI), 8, 2b (VI), 4b, 3b, and 7b Sc^{3+}
Halides—lanthanides (except fluorides), Groups 2a, 3a (III–VI), 4a (IV–VI), 5a (IV–VI), 8, 1b, 2b, 3b (IV–V), 4b, 3b, 6b and 7b
Nitrates—all cations whose hydroxides are Class Y and W

Class D—Minimal retention: rapid clearance (days)
Carbides—see hydroxides
Sulfides—all except Class W
Sulfates—all except Class W
Carbonates—all except Class W
Phosphates—all except Class W
Oxides and Hydroxides—Groups 1a, 3a (II), 4a (II), 3a (II, III), 6a (III).
Halides—Groups 1a and 7a
Nitrates—all except Class W
Noble Gases—Group 0

Note: Where reference is made from one chemical form to another, it implies that an *in vivo* conversion occurs, e.g. hydrolysis reaction.

The following periodic table of the elements is used with the foregoing classification.

Period	Group 1a	2a	3b	4b	5b	6b	7b	8			1b	2b	3a	4a	5a	6a	7a	0
I	H																	He
II	Li	Be											B	C	N	O	F	Ne
III	Na	Mg											Al	Si	P	S	Cl	Ar
IV	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
V	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
VI	Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
VII	Fr	Ra	Ac†															

* Lanthanides	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
† Actinides	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lw

FIG. 2.4. Pulmonary clearance classification of inorganic compounds as proposed by the ICRP.

Source: Report of ICRP Task Group on Lung Dynamics: Health Physics, 12, 173-207 (1966).

TABLE 2.2. The values of removal half times and compartmental fractions in the four respiratory regions as proposed in ICRP-30.

		Class					
		D		W		Y	
Region	Compartment	T day	F	T day	F	T day	F
N-P (D_{N-P} = 0.30)	a	0.01	0.5	0.01	0.1	0.01	0.01
	b	0.01	0.5	0.40	0.9	0.40	0.99
T-B (D_{T-B} = 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_P = 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
	j	n.a.	n.a.	n.a.	n.a.	∞	0.1

*n.a. = not applicable.

subcompartment. For example, the initial activity in subcompartment d is $q_d(0) = D_{T-B} F_d$. The clearance of the material from each of the subcompartments is assumed to be governed by first order kinetics, so that each subcompartment is associated with a biological decay constant, e.g., $\lambda_d(s^{-1}) = \ln 2/(86400\ T_d)$. Activities in each subcompartment may be found by solving the first order differential equations as follows:

For ℓ = a, b, c, e, f, g, and h ,

$$\frac{dq_\ell}{dt} = -(\lambda_R + \lambda_\ell)\, q_\ell \ . \tag{2.28}$$

Else,

$$\frac{dq_d}{dt} = \lambda_f\, q_f + \lambda_g\, q_g - (\lambda_R + \lambda_d)\, q_d \ , \tag{2.29}$$

$$\frac{dq_i}{dt} = -(\lambda_R + \lambda_i)\, q_i + F_i\, \lambda_h q_h \ , \tag{2.30}$$

$$\frac{dq_j}{dt} = -\lambda_R q_j + F_j \lambda_h q_h \ . \tag{2.31}$$

Since daughters are assumed to behave metabolically like the inhaled parent, similar systems of equations may be written for them using the partition fractions F and biological half lives as those of the parent.

The approximate expressions for the total number of transformations of the parent and the daughters in each subcompartment of the lung is given in Tables 2.3 and 2.4 respectively. These results are obtained by integrating the activities found from the solution of the above equations, in a pattern similar to that of the transfer compartment. All entries, except that for subcompartment j, are based on the approximation that the clearance times are much less than the 50-year dose evaluation period. In the entry for compartment j, the symbol η represents 50 years in units compatible with those of λ_R.

TABLE 2.3. Approximate expressions for the number of transformations in the subcompartments of lung following inhalation of unit Bq of activity.[a]

Compartment	Number of transformations	Compartment	Number of transformations
a	$\frac{D_{N-P}\, F_a}{\lambda_a + \lambda_R}$	b	$\frac{D_{N-P}\, F_b}{\lambda_b + \lambda_R}$
c	$\frac{D_{T-B}\, F_c}{\lambda_c + \lambda_R}$	d	$\left\{\frac{D_{T-B}\, F_d}{\lambda_d + \lambda_R} + \frac{D_p}{\lambda_d+\lambda_R}\left[\frac{\lambda_f\, F_f}{\lambda_f+\lambda_R} + \frac{\lambda_g\, F_g}{\lambda_g+\lambda_R}\right]\right\}$
e	$\frac{D_p\, F_e}{\lambda_e + \lambda_R}$	f	$\frac{D_p\, F_f}{\lambda_f + \lambda_R}$
g	$\frac{D_p\, F_g}{\lambda_g + \lambda_R}$	h	$\frac{D_p\, F_h}{\lambda_h + \lambda_R}$
i	$\frac{D_p\, F_h\, \lambda_h\, F_i}{(\lambda_h+\lambda_R)(\lambda_i+\lambda_R)}$	j	$\frac{D_p\, F_h\, \lambda_h\, F_j\, (1-e^{-\eta\lambda_R})}{(\lambda_h + \lambda_R)\, \lambda_R}$

[a]Source: ICRP Publication 30 [IC79].

TABLE 2.4. Approximate expressions for the number of transformations of a radioactive daughter in the subcompartments of the lung. A_a to A_j refers to the number of transformations of the immediate parent in subcompartments a to j of the lung. λ_R' is the radiological decay constant of the daughter.[a]

Compartment	Number of transformations	Compartment	Number of transformations
a	$\frac{A_a \lambda_R'}{\lambda_a + \lambda_R'}$	b	$\frac{A_b \lambda_R'}{\lambda_b + \lambda_R'}$
c	$\frac{A_c \lambda_R'}{\lambda_c + \lambda_R'}$	d	$\frac{A_d \lambda_R'}{\lambda_d+\lambda_R'} + \frac{\lambda_R'}{\lambda_d+\lambda_R'}\left[\frac{A_f \lambda_f}{\lambda_f+\lambda_R'} + \frac{A_g \lambda_g}{\lambda_g+\lambda_R'}\right]$
e	$\frac{A_e \lambda_R'}{\lambda_e + \lambda_R'}$	f	$\frac{A_f \lambda_R'}{\lambda_f + \lambda_R'}$
g	$\frac{A_g \lambda_R'}{\lambda_g + \lambda_R'}$	h	$\frac{A_h \lambda_R'}{\lambda_h + \lambda_R'}$
i	$\frac{A_i \lambda_R'}{\lambda_i+\lambda_R'} + \frac{A_h \lambda_R' \lambda_h F_i}{(\lambda_h+\lambda_R')(\lambda_i+\lambda_R')}$	j	$\left[A_j + \frac{A_h \lambda_h F_j}{\lambda_h + \lambda_R'}\right]\left[1-e^{-\eta\lambda_R'}\right]$

[a] Source: ICRP Publication 30 [IC79].

With the source organ transformations known in each subcompartment, we can sum them all to determine a total value for the respiratory system. However, the ICRP model neglects the values for transformations in the nasopharyngeal region, since for most particle sizes, the dose received by this region is very small compared to the other regions. Hence, defining the lung as a single source organ, the value of transformations for a nuclide k is given by

$$U_L^k = \left[U_{T-B}^k + U_P^k + U_L^k\right] \times B_k \ . \qquad (2.32)$$

where $U_{T-B}^k = U_c^k + U_d^k$,

$U_P^k = U_e^k + U_f^k + U_g^k + U_h^k$,

$U_L^k = U_i^k + U_j^k$, and

B_k is the branching ratio of nuclide k ($B_1 = 1$).

The lung is also treated as a single target organ of mass 1000 g.

c) Transfer of a Radionuclide from the Lungs Directly to Body Fluids or to the GI Tract: From Fig. 2.2 we can see that the rate of transfer of a radionuclide k directly from the lungs to the body fluids [BF(t)] is given by

$$BF^k(t) = \lambda_a\, q_a^k(t) + \lambda_c q_c^k(t) + \lambda_e q_e^k(t) + \lambda_i q_i^k(t), \qquad (2.33)$$

whether the radionuclide is inhaled or produced in lungs. Similarly, the rate of transfer to the GI tract is given by

$$G^k(t) = \lambda_b q_b^k(t) + \lambda_d q_d^k(t) \quad . \tag{2.34}$$

Thus, the total activity f^k_{BFDIR} of an inhaled radionuclide k transferred directly to the body fluids can be determined as

$$f^k_{BFDIR} = B_k \times \int_0^{50y} BF^k(t)\, dt \quad , \tag{2.35}$$

or

$$f^k_{BFDIR} = B_k \times \left[\lambda_a \int_0^{50y} q_a^k(t)\, dt + \lambda_c \int_0^{50y} q_c^k(t)\, dt + \lambda_e \int_0^{50y} q_e^k(t)\, dt + \lambda_i \int_0^{50y} q_i^k(t)\, dt\right] \quad , \tag{2.36}$$

or

$$f^k_{BFDIR} = B_k \times \left[\lambda_a U_a^k + \lambda_c U_c^k + \lambda_e U_e^k + \lambda_i U_i^k\right] \quad . \tag{2.37}$$

Similarly, the total activity translocated to the gastrointestinal tract is

$$f^k_{GI} = B_k \times \left[\lambda_b U_b^k + \lambda_d U_d^k\right] \quad . \tag{2.38}$$

d) Particle Size Correction: If the AMAD is unknown, then a value of 1 μm is used for inhaled materials. Values of specific committed dose are reported for 1 μm in ICRP Publication 30. Correction for other

values of AMAD is made as follows:

$$\frac{\hat{H}_{50,T}\ (\text{AMAD})}{\hat{H}_{50,T}\ (1\mu m)} = f_{N-P}\ \frac{D_{N-P}\ (\text{AMAD})}{D_{N-P}\ (1\mu m)} + f_{T-B}\ \frac{D_{T-B}\ (\text{AMAD})}{D_{T-B}\ (1\mu m)} + f_{P}\ \frac{D_{P}\ (\text{AMAD})}{D_{P}\ (1\mu m)}$$

The fractions f_{N-P}, f_{T-B}, and f_P are respectively the proportions of $\hat{H}_{50,T}$ (1μm) resulting from deposition in the N-P, T-B, and P regions.

If the AMAD is not 1 μm, then the values of D_{N-P} (AMAD), D_{T-B} (AMAD), and D_P(AMAD) are determined from a logarithm fit of Fig. 2.3 as described below:

If the AMAD is between 0.1 and 0.2 μm, then

$$D_{T-B} = -0.163 - 0.151\ (\ln \text{AMAD}), \tag{2.39}$$

$$D_{N-P} = -\ 0.059 - 0.068\ (\ln \text{AMAD}), \text{ and} \tag{2.40}$$

$$D_P = 0.289 - 0.126\ (\ln \text{AMAD})\ . \tag{2.41}$$

If the AMAD is between 0.2 and 10 μm, then

$$D_{T-B} = 0.08\ . \tag{2.42}$$

$$D_{N-P} = 0.351 + 0.219\ (\ln \text{AMAD}), \text{ and} \tag{2.43}$$

$$D_P = 0.289 - 0.126\ (\ln \text{AMAD})\ . \tag{2.44}$$

If the AMAD is between 10 and 20 μm, then

$$D_{T-B} = 0.229 - 0.065 \text{ (ln AMAD)} \ . \tag{2.45}$$

$$D_{N-P} = 0.621 + 0.110 \text{ (ln AMAD), and} \tag{2.46}$$

$$D_{P} = 0.141 - 0.040 \text{ (ln AMAD)} \ . \tag{2.47}$$

2.2.5 Gastrointentinal Tract:

Knowledge of transformations of a nuclide in the various organs of the GI tract is very crucial to the calculation of other source-organ transformations, because translocation of the material to the body fluid compartment and then eventually to the source organ is directly dependent, in case of ingestion, and partially dependent, in case of inhalation, upon absorption of the material in the bloodstream through the small intestine.

The model proposed by the ICRP is illustrated in Fig. 2.5. It consists of 4 organs. Table 2.5 provides values of wall mass, contents mass, and mean residence times for the contents of each organ. The rate constant λ for transfer of contents from organ to organ is the reciprocal of the mean residence time.

In general, the only site of absorption from the GI tract to the body fluids is assumed to be the small intestine. The rate constant λ_{BF} for transfer from the small intestine to the body fluids after ingestion, can be estimated from the fraction of *stable* element

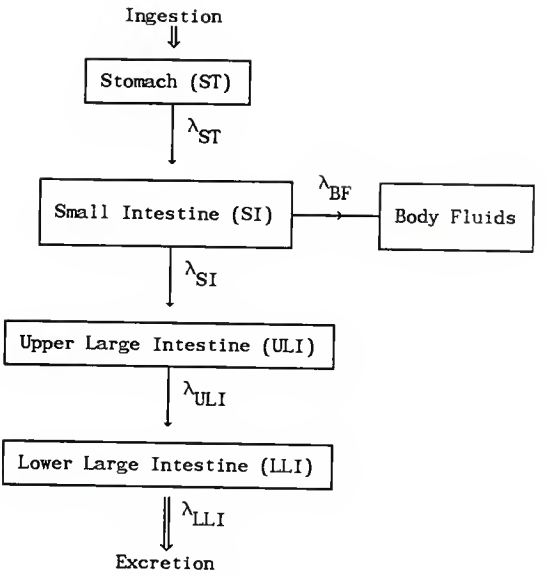


FIG. 2.5. Model of gastrointestinal tract as proposed by the ICRP-30.

reaching the body fluids f_1, i.e.,

$$\frac{\lambda_{BF}}{\lambda_{SI} + \lambda_{BF}} = f_1 \quad . \tag{2.48}$$

Therefore,

$$\lambda_{BF} = \frac{f_1 \lambda_{SI}}{1 - f_1} \quad . \tag{2.49}$$

Values of f_1 for a number of classes of compounds of each element are given in the metabolic data. Radioactive progeny are assumed to have the same f_1 as the ingested ancestral nuclide.

When a value of $f_1 = 1$ is given, it implies that the radionuclide passes directly from the stomach to body fluids and does not pass through other sections of the GI tract.

TABLE 2.5. Mathematical model used to describe the kinetics of radionuclides in the gastrointestinal tract as proposed by the ICRP-30.

Section of Tract	Mass of Walls (g)	Mass of Contents (g)	Mean Residence time (day)	λ (day^{-1})
Stomach (ST)	150	250	1/24	24
Small Intestine (SI)	640	400	4/24	6
Upper Large Intestine (ULI)	210	220	13/24	1.8
Lower Large Intestine (LLI)	160	135	24/24	1

a) Radionuclide Transport in the GI Tract: Consider the ingestion of unit activity of a radionuclide at time t = 0. For this parent

radionuclide, the time dependent activity in different sections of the GI tract is governed by the following equations:

$$\frac{dq_{ST}(t)}{dt} = -(\lambda_{ST} + \lambda_R)\, q_{ST}(t) \ , \qquad (2.50)$$

$$\frac{dq_{SI}(t)}{dt} = -(\lambda_R + \lambda_{SI} + \lambda_{BF}) q_{SI}(t) + \lambda_{ST}\, q_{ST}(t) \ , \qquad (2.51)$$

$$\frac{dq_{ULI}(t)}{dt} = -(\lambda_{ULI} + \lambda_R)\, q_{ULI}(t) + \lambda_{SI}\, q_{SI}(t) \ , \qquad (2.52)$$

$$\frac{dq_{LLI}(t)}{dt} = -(\lambda_R + \lambda_{LLI})\, q_{LLI}(t) + \lambda_{ULI}\, q_{ULI}(t) \ , \qquad (2.53)$$

where λ_R is the radiological decay constant of the radionuclide, and

$\lambda_{BF} q_{SI}(t)$ is the rate of transfer of activity to the body fluids from the small intestine.

A similar set of equations may be written for the radioactive progeny. Solution of these equations can then be used in calculating the number of transformations in each section of the GI tract. Approximate expressions for numbers of transformations of the parent and daughters in the various sections of the tract, following ingestion of unit activity, is given in Tables 2.6 and 2.7 respectively. The approximation is that the residence times are short in comparison to the 50 year dose-evaluation time. These values should, of course, be multiplied by the corresponding branching ratio of the radionuclide.

TABLE 2.6. Approximate expressions for the number of transformations of the parent in the various regions of the gastro-intestinal tract following ingestion of 1 Bq of activity. Based on ICRP Publication 30.

Region	Number of Transformations
Stomach	$\frac{1}{\lambda_{ST} + \lambda_R}$
Small Intestine	$\frac{\lambda_{ST}}{(\lambda_{ST}+\lambda_R)(\lambda_{SI}+\lambda_{BF}+\lambda_R)}$
Upper Large Intestine	$\frac{\lambda_{ST}\,\lambda_{SI}}{(\lambda_{ST}+\lambda_R)(\lambda_{SI}+\lambda_{BF}+\lambda_R)(\lambda_{ULI}+\lambda_R)}$
Lower Large Intestine	$\frac{\lambda_{ST}\,\lambda_{SI}\,\lambda_{ULI}}{(\lambda_{ST}+\lambda_R)(\lambda_{SI}+\lambda_{BF}+\lambda_R)(\lambda_{ULI}+\lambda_R)(\lambda_{LLI}+\lambda_R)}$

TABLE 2.7. Approximate expressions for the number of transformations of a radioactive daughter in the various sections of the GI tract. A_{ST}, A_{SI}, A_{ULI}, A_{LLI} are the number of transformations of the parent in the various regions of the tract. λ_R' is the radiological decay constant of the daughter. Based on ICRP Publication 30.

Region	Number of Transformations
Stomach	$\frac{A_{ST}\,\lambda_R'}{\lambda_{ST}+\lambda_R'}$
Small Intestine	$\frac{A_{ST}\,\lambda_R'\,\lambda_{ST}}{(\lambda_{ST}+\lambda_R')(\lambda_{SI}+\lambda_{BF}+\lambda_R')} + \frac{A_{SI}\,\lambda_R'}{(\lambda_{SI}+\lambda_{BF}+\lambda_R')}$
Upper Large Intestine	$\frac{A_{ST}\,\lambda_R'\,\lambda_{ST}\,\lambda_{SI}}{(\lambda_{ST}+\lambda_R')(\lambda_{SI}+\lambda_{BF}+\lambda_R')(\lambda_{ULI}+\lambda_R')}$ $+ \frac{A_{SI}\,\lambda_R'\,\lambda_{SI}}{(\lambda_{SI}+\lambda_{BF}+\lambda_R')(\lambda_{ULI}+\lambda_R')} + \frac{A_{ULI}\,\lambda_R'}{(\lambda_{ULI}+\lambda_R')}$
Lower Large Intestine	$\frac{A_{ST}\,\lambda_R'\,\lambda_{ST}\,\lambda_{SI}\,\lambda_{ULI}}{(\lambda_{ST}+\lambda_R')(\lambda_{SI}+\lambda_{BF}+\lambda_R')(\lambda_{ULI}+\lambda_R')(\lambda_{LLI}+\lambda_R')}$ $+ \frac{A_{SI}\,\lambda_R'\,\lambda_{SI}\,\lambda_{ULI}}{(\lambda_{SI}+\lambda_{BF}+\lambda_R')(\lambda_{ULI}+\lambda_R')(\lambda_{LLI}+\lambda_R')}$ $+ \frac{A_{ULI}\,\lambda_R'\,\lambda_{ULI}}{(\lambda_{ULI}+\lambda_R')(\lambda_{LLI}+\lambda_R')} + \frac{A_{LLI}\,\lambda_R'}{(\lambda_{LLI}+\lambda_R')}$

b) Inhaled Radionuclides: In case of inhaled radionuclides, the radioactive material is translocated from the various subcompartments of the lung to the GI tract. The total activity transferred is different for different nuclides and is given by f_{GI}^{k} for species k. In case of the parent, the number of transformations in the various sections of the GI tract can simply be found by multiplying the expressions in Table 2.6 by f_{GI}^{1} (k = 1 for parent). However, in case of the radioactive daughters, the expressions in Table 2.7 cannot be used, since each daughter may be deposited initially in the GI tract in different amounts, i.e., f_{GI}^{k} is different, and the immediate parent may decay into the daughter in the sections of the tract.

For this different set of differential equations for activity in the GI tract, compared to the ones in the case of ingestion, the number of transformations, derived in the pattern described in the transfer compartment, results in

$$U_{Gj} = B_j \times \sum_{i=1}^{j} \left\{ \left[\prod_{k=i+1}^{j} \lambda_k \right] q_{Gi}(0) \left[\sum_{m=i}^{j} \frac{(1 - e^{-(\lambda_G+\lambda_m)T})}{(\lambda_G+\lambda_m) \prod_{\substack{k=i \\ k\neq m}}^{j} (\lambda_k-\lambda_m)} \right] \right\}, \qquad (2.54)$$

$$j = 2, \ldots, N$$

where G is the index for the different sections of the tract, i.e., ST, SI, ULI, and LLI.

T is, of course, the 50 year period.

λ_G is the clearance constant corresponding to the section of the GI tract. For example, in case of the stomach, $\lambda_G = \lambda_{ST}$. However, in case of small intestine,

$$\lambda_G = \lambda_{SI} + \lambda_{BF} \ .$$

j is in the index of the radioactive progeny of the parent, and

$q_{Gi}(0)$ is the total activity deposited instantaneously at time t = 0.

The last term is given by the following expression

$$q_{Gi}(0) = \lambda_{G-1,i} \int_0^{50y} q_{G-1,i}(t)\, dt, \qquad (2.55)$$

where G-1 represents the compartment immediately preceding the one for which the transformations are calculated.

But,

$$U_{G-1,i} = \left[\int_0^{50y} q_{G-1,i}(t)dt\right] \times B_i \ , \qquad (2.56)$$

Therefore,

$$q_{Gi}(0) = \lambda_{G-1,i}\ U_{G-1,i}/B_i \ . \qquad (2.57)$$

$U_{G-1,i}$ is the number of transformations of species i in the preceding compartment. For example, in the case of calculation of the number of transformations in the small intestine, $U_{G-1,i} = U_{ST,i}$ and in the case of stomach, $U_{G-1,i} = f_{GI}^i$.

2.2.6 Activity translocated to the transfer compartment f_T^i:

This quantity was assumed to be known in the calculation of number of transformations in the transfer compartment. After the discussion

of the respiratory and the gastrointestinal system, we are now in a position to calculate this quantity.

a) Ingestion: In the case of ingestion of radionuclides, the total activity of species i translocated to the transfer compartment from the small intestine, per unit activity ingested, i is given by,

$$f_T^i = \int_0^{50y} \lambda_{BF}\, q_{SI}^i(t)\, dt, \tag{2.58}$$

or

$$f_T^i = \lambda_{BF}\, U_{SI}^i \,. \tag{2.59}$$

where U_{SI}^i is given in Tables 2.6 and 2.7 for the parent and the daughters respectively.

If the fraction of the stable element reaching the body fluids f_1 is 1, then the translocation is considered to be directly from the stomach. In this case,

$$f_T^i = \lambda_{ST}\, U_{ST}^i \,. \tag{2.60}$$

b) Inhalation: In case of inhalation, there are two pathways to the body fluid compartment. One is directly from the different compartments of the respiratory system and the other is indirectly through the material deposited in the GI tract from the respiratory system. Hence, the total initial activity f_T^i of species i deposited in the transfer compartment is given by

$$f_T^i = \left\{ f_{BFDIR}^i + f_{GI}^i \left[\lambda_{BF} \, U_{SI}^i \right] \right\} \times \frac{1}{B_i} \, , \qquad (2.61)$$

where B_i is the branching ratio of species i ,

f_{BFDIR}^i is the total activity of inhaled radionuclide i transferred directly to the body fluid compartment, which is given by equation (2.37), and

f_{GI}^i is the total activity translocated to the gastrointestinal tract, given by equation (2.38).

Again, in case of $f_1 = 1$, the above equation can be modified as

$$f_T^i = \left\{ f_{BFDIR}^i + f_{GI}^i \left[\lambda_{ST} \, U_{ST}^i \right] \right\} \times \frac{1}{B_i} \qquad (2.62)$$

2.2.7 Source organ as bone:

According to the ICRP model, the transformations in the cortical and trabecular bone are taken as a fraction of the transformations in the mineral bone calculated by the methods described earlier for any general source organ.

i) For the parent radionuclide assumed to be on bone surface, $U_{trabecular}^i = U_{cortical}^i = 0.5 \, U_{mineral\ bone}^i$ for any species i including the radioactive progeny.

ii) For the parent radionuclide assumed to be uniformly distributed throughout the volume of mineral bone, $U_{trabecular}^i = 0.2 \, U_{mineral\ bone}^i$, and $U_{cortical}^i = 0.8 \, U_{mineral\ bone}^i$ for any species i.

2.2.8 Three compartment model for iodine:

Iodine and all its radioactive isotopes require an exception to the treatment described for all other radionuclides. The metabolic model proposed for iodine by the ICRP is shown in Fig. 2.6. The model consists of three compartments. Since the value of f_1 = 1 for isotopes of iodine, the material is translocated from the stomach to the body fluids.

Of iodine entering the body fluid compartment, a fraction 0.3 is assumed to be translocated to the thyroid while the remainder is assumed to go directly to excretion. Iodine in the thyroid is assumed to be retained with a biological half-life of 120 days and to be lost

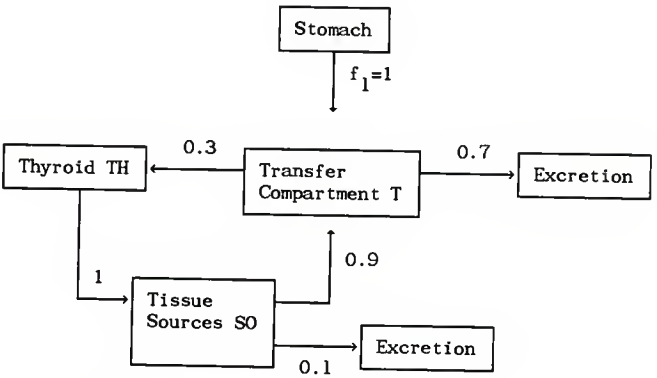


FIG. 2.6. Mathematical model proposed by the ICRP-30 for radioactive iodine.

from the gland in the form of organic iodine. Organic iodine is assumed to be uniformly distributed among all organs and tissues of the body other than the thyroid and to be retained there with a biological half-life of 12 days. One-tenth of this organic iodine is assumed to go directly to faecal excretion and the rest is assumed to be returned to the transfer compartment as inorganic iodine.

The time-dependent activity of the nuclide in the three compartments in accordance with Fig. 2.6 is given by the following differential equation for species i:

$$\frac{dq_{T,i}(t)}{dt} = -\lambda_T\, q_{T,i}(t) - \lambda_i\, q_{T,i}(t) + 0.9\,\lambda_{SO}\, q_{SO,i}(t), \quad (2.63)$$

@ t = 0, $\quad q_{T,i}(0) = f_T^i$.

$\lambda_{SO} = \ln 2/12$ days .

$$\frac{dq_{Th,i}(t)}{dt} = 0.3\,\lambda_T\, q_{T,i}(t) - \lambda_{Th}\, q_{Th,i}(t) - \lambda_i\, q_{Th,i}(t) \quad (2.64)$$

@ t = 0, $\quad q_{Th,i}(0) = 0$.

$\lambda_{Th} = \ell n\ 2/120$ days .

$$\frac{dq_{SO,i}(t)}{dt} = \lambda_{Th}\, q_{Th,i}(t) - \lambda_{SO} q_{SO,i}(t) - \lambda_i\, q_{SO,i}(t) . \quad (2.65)$$

@ t = 0, $\quad q_{SO,i}(0) = 0$.

Indices SO, T, and TH represent tissue sources, body fluid, and thyroid respectively. Taking the Laplace transform of the above equations, we obtain

$$\overline{q_{T,i}}(s) = \frac{0.9\,\lambda_{SO}\,\overline{q_{SO,i}}(s) + f_T^i}{[s + (\lambda_T + \lambda_i)]} \,. \tag{2.66}$$

$$\overline{q_{Th,i}}(s) = \frac{0.3\,\lambda_T\,\overline{q_{T,i}}(s)}{[s + (\lambda_i + \lambda_{TH})]} \,. \tag{2.67}$$

$$\overline{q_{SO,i}}(s) = \frac{\lambda_{Th}\,\overline{q_{SO,i}}(s)}{[s + (\lambda_i + \lambda_{SO})]} \,. \tag{2.68}$$

Since we are interested in the number of transformations in each of the compartments, which is the 50 year integral of the activities, we can use the final value theorem as follows:

$$\text{Let } F(t) = \int_0^t q(t')dt', \text{ then } U = \lim_{t\to\infty} F(t) = \lim_{s\to o} s\,\bar{F}(s) \,.$$

But

$$\bar{F}(s) = \frac{1}{s}\,\bar{q}(s) \,,$$

therefore,

$$U = \lim_{s\to 0} \bar{q}(s) \,.$$

Using Cramer's rule, we obtain

$$U_T^i = \frac{f_T^i\,(\lambda_i + \lambda_{SO})(\lambda_i + \lambda_{Th})}{(\lambda_i+\lambda_T)(\lambda_i+\lambda_{Th})(\lambda_i+\lambda_{SO}) - 0.3(0.9)\lambda_T\,\lambda_{SO}\,\lambda_{Th}} . \qquad (2.69)$$

$$U_{Th}^i = \frac{0.3\,\lambda_T\,f_T^i\,(\lambda_i + \lambda_{SO})}{(\lambda_i+\lambda_T)(\lambda_i+\lambda_{Th})(\lambda_i+\lambda_{SO}) - 0.3(0.9)\lambda_T\,\lambda_{SO}\,\lambda_{Th}} + \frac{M_{Th} \times U_T^i}{70000}, \qquad (2.70)$$

$$U_{SO}^i = \frac{0.3\,\lambda_T\,\lambda_{Th}\,f_T^i}{(\lambda_i+\lambda_T)(\lambda_i+\lambda_{Th})(\lambda_i+\lambda_{SO}) - 0.3(0.9)\lambda_T\,\lambda_{SO}\,\lambda_{Th}}$$

$$+ \frac{U_T^i\,(70000-M_{Th})}{70000} . \qquad (2.71)$$

where M_{Th} is the mass of thyroid.

3.0 DOCUMENTATION FOR "DOSE FORTRAN"

3.1 OBJECTIVE

"DOSE FORTRAN" is a software package, written in FORTRAN-77, that implements the methods expounded in Part 1 of Publication 30 of the International Commission on Radiological Protection (ICRP) to calculate committed dose equivalents from an internal radionuclide to organs and tissues of an adult "reference man" (as described in ICRP Publication 23). The program can consider any of the three major modes of intake of a radionuclide, namely, ingestion, inhalation, or submersion in a cloud of inert radioactive gas or elemental tritium. Specifically, the program can calculate the following:

i) Specific committed dose equivalent HFIFTY (Sv/Bq) in 19 target organs,

ii) Weighted committed dose equivalent WDOSE (Sv/Bq) in selected target organs,

iii) Annual limit of intake ALI (Bq) of the radionuclide,

iv) Derived air concentration DAC (Bq/m^3) of the radionuclide in case of inhalation or submersion, and

v) Specific effective energies in a table for 17 source and 19 target organs.

A list of the source and target organs along with the masses in reference man is given in Table 3.1.

TABLE 3.1 Masses of organs and tissues of "Reference Man" in this program.

No.	Source Organs	Mass (g)	No.	Target Organs	Mass (g)
1.	Bladder content	200.00	1.	Lungs	999.00
2.	Stomach content	250.00	2.	Thyroid	19.60
3.	SI content	400.00	3.	Testes	37.10
4.	ULI content	220.00	4.	Ovaries	8.27
5.	LLI content	135.00	5.	Red marrow	1500.00
6.	Kidneys	310.00	6.	Stomach wall	150.00
7.	Liver	1800.00	7.	SI + contents	1040.00
8.	Lungs	1000.00	8.	ULI wall	209.00
9.	Muscle	48200.00	9.	LLI wall	160.00
10.	Ovaries	11.00	10.	Liver	1810.00
11.	Pancreas	100.00	11.	Kidneys	284.00
12.	Trabecular Bone	1000.00	12.	Bladder wall	45.10
13.	Skin	2600.00	13.	Muscle	48200.00
14.	Spleen	180.00	14.	Bone surface cells	10500.00
15.	Testes	35.00	15.	Skin	2830.00
16.	Thyroid	20.00	16.	Spleen	174.00
17.	Total body	70000.00	17.	Uterus	65.40
18.	Cortical Bone	4000.00	18.	Pancreas	60.30
			19.	Total body	69900.00

3.2 REQUIREMENTS FOR EXECUTION

Some text files of auxiliary subroutines need to be linked to the central program "DOSE FORTRAN" for its execution. The subroutines (explained later) are as follows:

i) DECAY1 FORTRAN,

ii) ATOMNO FORTRAN,

iii) ICLASS FORTRAN in case of inhalation,

iv) F1VALU FORTRAN,

v) FACTOR FORTRAN,

vi) ICRP FORTRAN,

vii) INGEST, INHALE, OR SUBMER FORTRAN,

viii) PCLASS FORTRAN in case of inhalation,

ix) RESPIR FORTRAN in case of inhalation,

x) DECAY FORTRAN,

xi) FRAC FORTRAN,

xii) THALF FORTRAN,

xiii) REFMAN FORTRAN,

xiv) TFRAC FORTRAN,

xv) TRNSFM FORTRAN,

xvi) SPEFF FORTRAN,

xvii) YERROR FORTRAN,

xviii) INTRPT FORTRAN,

xix) ENERGY FORTRAN,

xx) I1 FORTRAN,

xxi) SOURCE FORTRAN,

xxii) UXP FORTRAN,

xxiii) RESULT FORTRAN, and

xxiv) FLOW FORTRAN

The directly accessed data files for decay schemes of radionuclides, number of transformations for radioactive alkaline earths, dose equivalent rates in body tissues from submersion, absorbed fractions of photon energies in organs, retention fractions of nuclides

in source organs, and the fractional transfer of the nuclides to the body fluid compartment are:

i) ISOTIPS FILE (sequentially accessed),
ii) ISOTOPE FILE,
iii) ALPHA FILE,
iv) BETA FILE,
v) ELECTRN FILE,
vi) DAUTER FILE,
vii) POSITRN FILE,
viii) ABSFRAC FILE,
ix) RETENT FILE,
x) BFFRAC FILE,
xi) INDEXI FILE,
xii) INDEXO FILE,
xiii) EXCEPT FILE,
xiv) LIST FILE, and
xv) NOBLE FILE

3.3 EXECUTION OF THE PROGRAM

This program was written on the IBM Mainframe computer at Kansas State University. Conversational Monitor System (CMS) is the operating system used there to run under global control program (CP) which handles the resources of the mainframe computer. A feature of the CMS is the EXEC processor. A CMS EXEC processor is a CMS file that

contains executable statements. Hence, in this case, the "DOSE EXEC" file contains statements to retrieve, expand, and load the compiled text files of all supporting subroutines and the main program, thus functioning as a catalogued procedure for execution of the program. With the file on "A" (temporary) disk, one can invoke its execution by entering the word "DOSE".

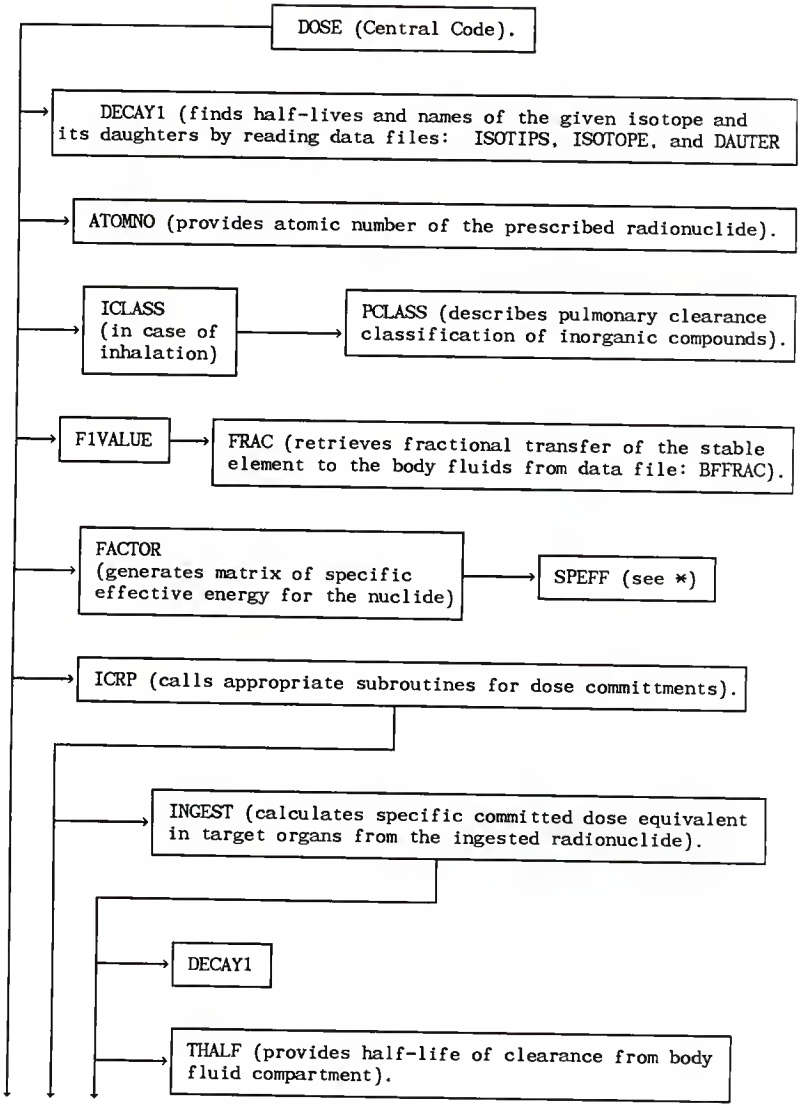
The main program in this package is "DOSE FORTRAN" which calls other subroutines to perform certain calculations. What follows are descriptions of the function and role of each subroutine as it is addressed by the calling program in execution. All three modes of exposure are considered. A summary of the program flow is illustrated in Fig. 3.1. We begin with the central code.

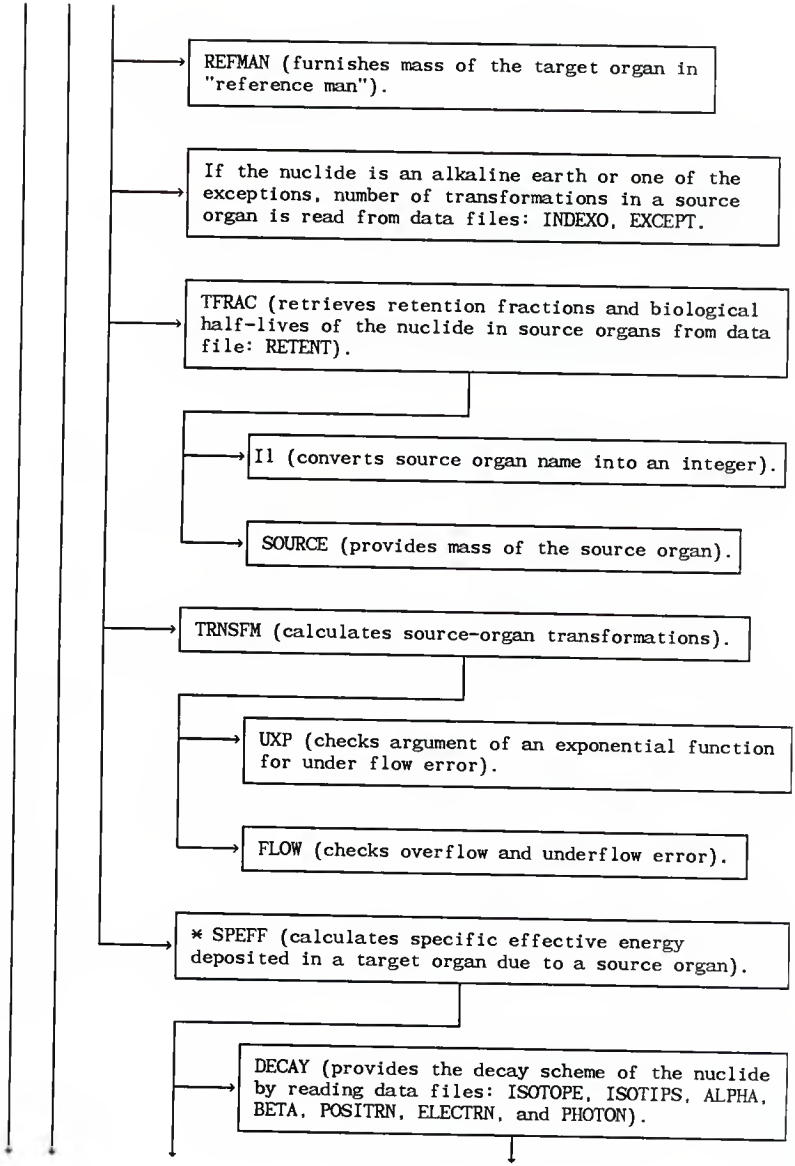
3.4 DOSE FORTRAN

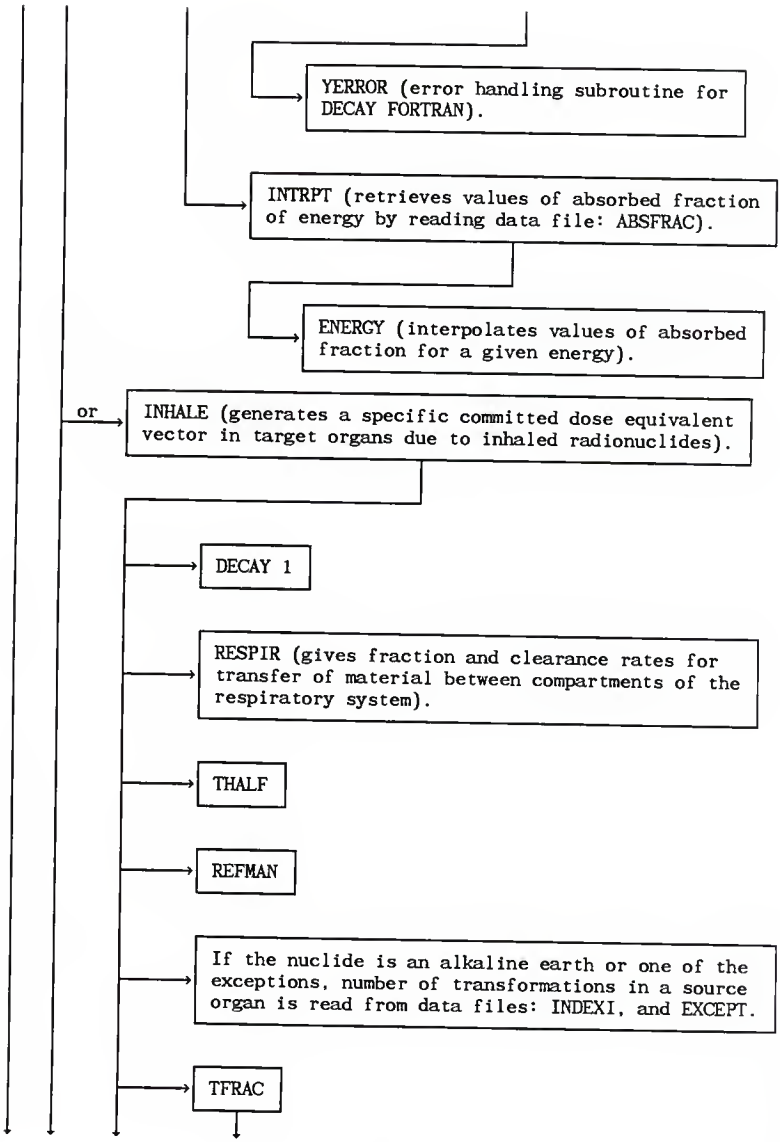
This is an interactive, user-friendly code which prompts the user to enter some basic information for its execution. To avoid confusion, an explanation of the screen-by-screen sequence in actual execution of the program is given below:

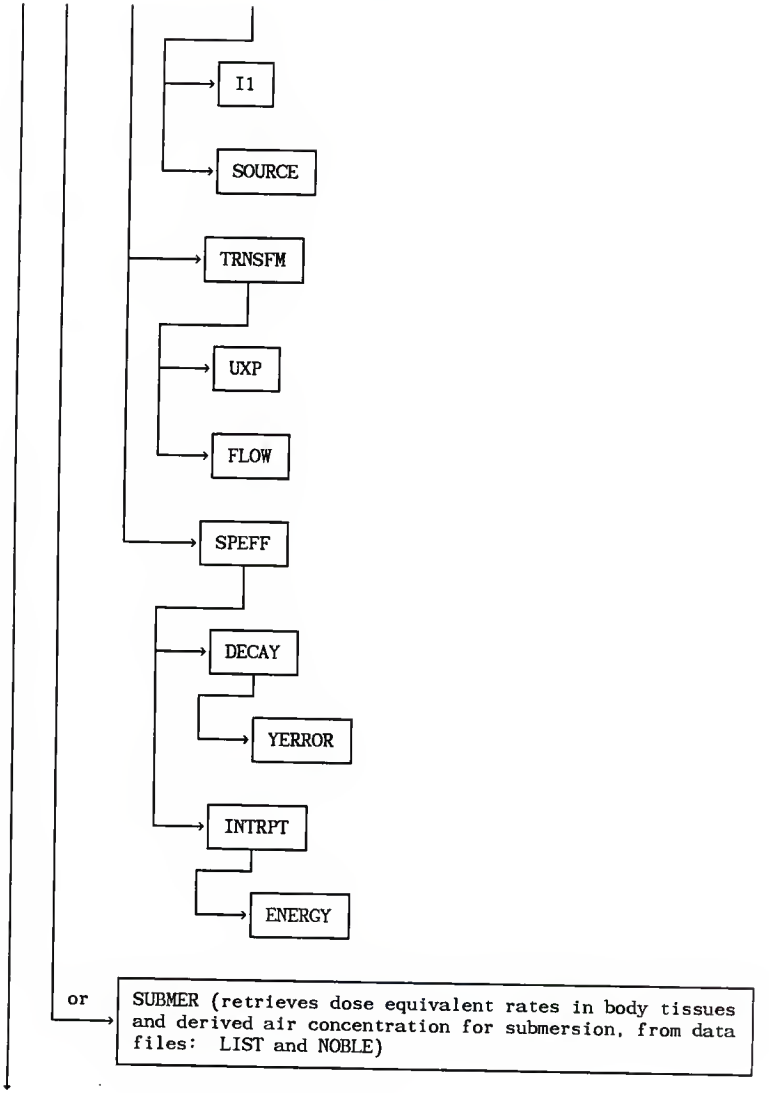
i) First and Second Screen: The first screen orients the user with the name of the program as well as the author, with the time and place of documentation of the code. The second screen explains the scope of the program.

ii) Third Screen: There are three ways to provide the preliminary data required for a calculation. They are: 1) data input from the keyboard, 2) data input from a file, or 3) preparation of a


DOSE (Central Code).
DECAY1 (finds half-lives and names of the given isotope and its daughters by reading data files: ISOTIPS, ISOTOPE, and DAUTER
ATOMNO (provides atomic number of the prescribed radionuclide).
ICLASS (in case of inhalation)
PCLASS (describes pulmonary clearance classification of inorganic compounds).
F1VALUE
FRAC (retrieves fractional transfer of the stable element to the body fluids from data file: BFFRAC).
FACTOR (generates matrix of specific effective energy for the nuclide)
SPEFF (see *)
ICRP (calls appropriate subroutines for dose committments).
INGEST (calculates specific committed dose equivalent in target organs from the ingested radionuclide).
DECAY1
THALF (provides half-life of clearance from body fluid compartment).


REFMAN (furnishes mass of the target organ in "reference man").
If the nuclide is an alkaline earth or one of the exceptions, number of transformations in a source organ is read from data files: INDEXO, EXCEPT.
TFRAC (retrieves retention fractions and biological half-lives of the nuclide in source organs from data file: RETENT).
I1 (converts source organ name into an integer).
SOURCE (provides mass of the source organ).
TRNSFM (calculates source-organ transformations).
UXP (checks argument of an exponential function for under flow error).
FLOW (checks overflow and underflow error).
* SPEFF (calculates specific effective energy deposited in a target organ due to a source organ).
DECAY (provides the decay scheme of the nuclide by reading data files: ISOTOPE, ISOTIPS, ALPHA, BETA, POSITRN, ELECTRN, and PHOTON).


YERROR (error handling subroutine for DECAY FORTRAN).
INTRPT (retrieves values of absorbed fraction of energy by reading data file: ABSFRAC).
ENERGY (interpolates values of absorbed fraction for a given energy).
or
INHALE (generates a specific committed dose equivalent vector in target organs due to inhaled radionuclides).
DECAY 1
RESPIR (gives fraction and clearance rates for transfer of material between compartments of the respiratory system).
THALF
REFMAN
If the nuclide is an alkaline earth or one of the exceptions, number of transformations in a source organ is read from data files: INDEXI, and EXCEPT.
TFRAC


I1
SOURCE
TRNSFM
UXP
FLOW
SPEFF
DECAY
YERROR
INTRPT
ENERGY
or
SUBMER (retrieves dose equivalent rates in body tissues and derived air concentration for submersion, from data files: LIST and NOBLE)

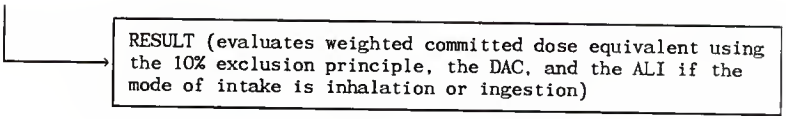


FIG. 3.1. Points of call of subroutines in execution of the program.

data input file. The user is queried in this screen to opt for one of three choices. The choice is stored as an integer variable, NDATA which may have a value of 0, 1, or 2. Under choices 1 or 2, an error in program execution results in program termination.

If the user selects the option of data input from an already prepared file (NDATA = 1) residing on the temporary disk (A disk), the fourth screen inquires the name of the input file. The name is saved as a character variable FFILE(3). Since the CMS environment allows only 7 characters for the name of a file, a longer name is therefore truncated to 7 characters. The file is then opened and, according to the data read, the appropriate course of action is taken.

Also, if the user wishes to prepare a data input file, (NDATA=2) the fourth screen asks for a name that can be associated to such a file [FFILE(3)] and subsequent screens, then prompt the user for data from the keyboard which is then entered in the file. These screens for input data collection are also displayed in the event the user chooses the first option (NDATA=0) to enter data directly from the keyboard. These screens are explained below.

iii) Fourth screen: The user is prompted to enter a radionuclide identification according to displayed example of cesium-137 as CS-137. This is stored as the character variable WORD. If there is a mistake in the format of entry, the screen is displayed again until the entry is corrected. The screen also informs the user, that to begin termination of the program at this point, the return key may be pressed. When the return key is pressed, the user is questioned again

to confirm if termination is really what is desired. Of course, an assent results in the termination and a dissent shows the fourth screen again.

At this point, with the nuclide identified, a subroutine DECAY1 is called to find the daughters of the given radionuclide.

3.4.1 DECAY1 FORTRAN:

The objective of this subroutine is to access the half-lives and names of the daughters of the radionuclide under consideration. The data files used for this purpose are "ISOTIPS", "ISOTOPE", and DAUTER". The arguments of the subroutine are:

WORD - Identification of the entered nuclide.

RHALF - This is a vector of maximum length 50. It stores half lives of the given radioisotope and its daughters in sequential order of decay.

ULIFE - This is a character vector of length 50. It saves units of half-lives of nuclides in RHALF as a character, e.g., S, M, H, D, or Y for seconds, minutes, hours, days, and years respectively.

BRA - This is a vector of branching ratios of the given isotope (BRA(1)=1), and its daughters. Its maximum length is 50.

RADIO - This is a vector of length 50. Its elements are characters, each of length 8. It stores identities (i.e., symbol-atomic weight, e.g., CS-137) of given nuclide and its daughter.

NO - This is an integer which stands for the number of daughters plus one (for the given isotope).

The given identification WORD of the nuclide is used to find a match in the sequentially accessed data file "ISOTIPS". Once a match occurs, a pointer or record number is read, which is then used to directly access the decay scheme from data file "ISOTOPE". The variables read are:

ERT - Name of the isotope.

JO - Atomic weight of the isotope.

J - Atomic number of the isotope.

B - Half life of the isotope.

U - Half life units (S, M, H, D, or Y).

K - Number of radioactive daughters.

L - Pointer or record no. for first daughter.

M - Number of alpha particles.

N - Pointer or record no. of first alpha particle.

I1 - Number of beta particles.

I2 - Pointer to first beta-particle record.

I3 - Number of positrons.

I4 - Pointer to first positron record.

I5 - Number of electrons.

I6 - Pointer to first electron record.

I7 - Number of photons.

I8 - Pointer to first photon record.

The pointer to the first daughter is used to directly access the branching ratio of the daughter from the data file "DAUTER". The variables read are:

I9 - Pointer to daughter isotope. This record number could now be used to access the decay scheme of the daughter from "ISOTOPE", and so on.

YIELD - Branching ratio of the daughter.

The decay mode considered in this program is

$$A \rightarrow B \rightarrow C \rightarrow \ldots$$

Hence, if a nuclide decays into more than one daughter, that is, if

$$A \rightarrow B1, \quad A \rightarrow B2, \quad A \rightarrow B3 \quad \text{etc.}$$

then the pointer and yield of only the daughter with the highest branching ratio is saved.

An inability to read any of the data files results in display of an appropriate error message and return to the fourth screen of the main program.

The half lives of the parent and the radioactive progeny are first converted into days if they are in any other units. If a daughter is a radioactive noble gas, then the daughter and its subsequent progeny are neglected and assumed to escape from the body. If the ancestral nuclide entered in the fourth screen is a noble gas, then an integer variable OPT is assigned a value of 3, and the following queries are skipped to the output screen, which asks for the output file name.

iv) Fifth Screen: The user is prompted to enter the sex of the exposed subject as either M or F. Character variable SEX stores the entry. An incorrect entry will again lead to same screen display until it is corrected.

v) Sixth Screen: The user is questioned whether or not, a full table of specific effective energies (S-matrix) of the nuclide for 17 source and 19 target organs is desired. To answer yes or no, the user is asked to enter the integer 1 or 2 respectively. Of course, an error is again handled with repeated displays of the same screen until proper entry is made.

If the user opts to see the table, the following screens are shown:

vi) Seventh Screen: It asks for the file name to which the matrix can be written. This name is stored as a character variable FFILE(1).

vii) Eight Screen: There are three units, i.e., MeV/g, rad/micro Ci.h, and mSv/GBq.h in which the S-matrix can be seen. The user is asked to choose one of them as an integer variable NU with a value of 1, 2, or 3.

If from the earlier call of subroutine "DECAY1" it is found that the radionuclide has daughters, then the ninth screen is as follows:

vii) Ninth Screen: The daughters of the nuclide are shown, and the user is prompted to enter integer 1 or 2 expressing yes or no to whether the S-tables of the daughters are desired. This expression is saved as an integer variable MON.

ix) Tenth Screen: At this point, the user is asked to choose one of the following options:

1) Continue data entry for calculation of dose committments,

2) Conclude data entry and STOP, or

3) Proceed with calculations of S-matrix only.

Another choice is added if the user chooses the third option of preparation of a data input file in the third screen. It is:

4) Continue data entry for calculation of S-matrix only.

The choice is saved as an integer variable INRE with a value of 1, 2, 3, or 4 respectively. Of course, selection of option (1) here, would result in end of the program. If the user chooses to enter data from the keyboard in the third screen, and option number (3) here, then the query screens end, and the program proceeds with calculation of the S-matrix. However, if the choice was preparation of data input file in the third screen, then a selection of option (3) or (4) here, would first lead to writing of the data obtained from screen queries onto the file named by the user. After that, option (4) would display the fourth screen again, continuing the data entry process, while option (3) would read the written data and advance with calculation of the S-matrix, informing the user with a display of which calculation is being performed.

Now, regardless of the choice of either data entry from keyboard or preparation of an input file in the third screen, if option (1) is selected here, then the screen query continues as follows:

x) Eleventh Screen: The user is prompted to choose a mode of intake of the radionuclide by entering either 1 or 2 for ingestion or inhalation respectively. Integer variable OPT stores the selection.

xi) Twelfth Screen: The user is inquired if the transformations of the nuclide in source organs are fancied. The response can be

expressed as 1 or 2 for yes or no which is stored as integer variable MAIS. If the answer is yes, then the following two screens would ask for the name of a file, saved as character variable FFILE(4), to which the transformations can be written, and whether the transformations of the daughters (if any) are also desired. This response is stored as an integer variable ISAY which has a value of 1 or 2 for yes or no respectively.

3.4.2 ATOMNO FORTRAN:

At this point, this subroutine is called to assign an atomic number to the given radionuclide by comparing its symbol to the 103 in the program. A match results in an assignment of atomic number, or else, the user is asked through an error message to check the symbol and try again. The arguments of this subroutine are:

SYM - First two characters of the variable WORD entered by the user which describes the symbol of the radionuclide. If, for instance in the case of phosphorus, the symbol is represented by only one character "P", then the second character is "-".

KZ - This is the assigned atomic number by the subroutine and is naturally, an integer variable.

If the mode of intake was chosen to be inhalation in the eleventh screen, then the following subroutine is called.

3.4.3 ICLASS FORTRAN:

This subroutine provides the inhalation class of the given radionuclide. It first displays a laconic definition of the three classes, D, W, and Y, and then, questions the user if a detailed explanation aiding in selection of the pulmonary clearance classification is wished. If the user acquiesces, then another subroutine "PCLASS FORTRAN" is called, and after that the user is prompted to enter the inhalation class of the given radionuclide, which is the argument CLASS of the subroutine.

3.4.4 PCLASS FORTRAN:

This is an information file. It displays pulmonary clearance categories of different inorganic compounds which may aid the user in determining the inhalation class of the radionuclide. Its argument IWISH is merely the selection integer 1 indicating acceptance to view the file.

The next step is the determination of fractional transfer of the element from the GI system to the body fluids. For this purpose, subroutine F1VALU is called.

3.4.5 F1VALU FORTRAN:

An auxiliary function subprogram FRAC FORTRAN is required. The arguments of this subroutine are:

KZ - Integer variable describing the atomic number of the given radionuclide, and

F1 - The fractional transfer of the stable element from the GI system to the body fluids.

3.4.6. FRAC FORTRAN:

This function subprogram retrieves the fractional transfer F1 of the stable element to the body fluid compartment from data file "BFFRAC". Since the fraction may differ according to the inhalation class of the nuclide, the user is asked to enter the appropriate value from choices displayed on screen. Of course, a mistake in reading of data file is handled through an error message, suggested corrective action, and return to the fourth screen. The arguments of this subroutine are the atomic number of the nuclide KZ and the integer ITRACK, which is given a positive value in case of an error.

Again, if the mode of intake was chosen to be inhalation, the following screen is flashed.

xii) AMAD Screen: The user is inquired if the aerodynamic diameter (AMAD) for inhalation, is 1 micrometer. An affirmation or negation assigns a value of 1 or 2 respectively to integer variable LOT. In the event of a negative response, the user is prompted to enter the value of AMAD in micrometers between 0.1 and 20, which is stored as variable AMAD.

With these basic input values, the execution of "DOSE FORTRAN" can be initiated with call to appropriate subroutines. But before that, the name for output table for dose committment results is needed.

xiii) Output Screen: A filename for output table is requested and a character variable FFILE(2) is assigned the name.

If the parent nuclide is a radioactive noble gas then at this point, the subroutine "ICRP" is called, and the following steps are ignored.

If the user is preparing a data input file, then at this stage a selection must be made from the following three choices:

1) Conclude data entry and STOP,

2) Continue data entry, or

3) Proceed with calculations.

Integer variable MORE is assigned a value of 0, 1, or 2 respectively according to choices described above. Except for option (1), choice of any other option would lead to writing of the data onto the named file. After that, option (2) would return to the fourth screen while option (3) would read the written data and progress with execution of "DOSE FORTRAN". To facilitate comprehension of the central code's working, most of the subroutines are explained in sequence of calling.

The step première in execution is S-matrix generation and printing of its results if, a positive response was given in sixth screen to view the S-table. A loop is initiated to do the same for the daughters if there are any, and if the user wishes to see their S-tables too.

3.4.7. FACTOR FORTRAN:

As mentioned earlier, this subroutine is called if a full specific effective energy (SEE) table (S-matrix) is requested in the sixth screen prompt of the main program. While this subroutine is generating the matrix, the main program flashes the message that it is calculating the S-matrix of the radionuclide transferred as an argument, and that the results are stored in the file named by the user. The arguments of this subroutine are:

WORD - This is a character variable of length 8 which describes the parent radionuclide or its daughters found by the call of DECAY1 in the main program.

NU - This is also a character variable. It has a length of 16 bytes, and it particularizes the choice of the user to see the SEE table in any of three sets of units, namely MeV/g, rad/micro Ci.h, or mSv/GBq.h.

SFACT - This is the matrix of SEE values. Its size is 19 target organs in one dimension and 18 source organs in the other.

NDATA - This is an integer variable which represents the option chosen in the main program of entering the data directly from keyboard or preparing a data input file.

NUCLID - This character variable of length 8 identifies the parent radionuclide as entered by the user in the main program.

PLIFE - This variable represents the half-life of the parent radionuclide converted in units of days.

The SFACT matrix is generated with uses of subroutines such as "DECAY FORTRAN" for the decay scheme of the radionuclide, and the subroutine "SPEFF FORTRAN", which in turn, calls other subroutines for effective energy absorbed in a tissue or organ. A detailed account of these subroutines follows later. The variable NDATA aids in properly redirecting the subroutine to the fourth screen in the main program if it has a value equal to zero or stopping the program if it has a value equal to one, in case of an error.

After generation of SEE values, stored in matrix SFACT, the main program writes these values as a table in the file FFILE(1) named by the user. If the mode of entry of data was keyboard, then these results are also written on screen for user's convenience.

At this juncture, if the user has prepared a data input file or had one on the A disk before the commencement of the program, i.e., if NDATA has a value of either 1 or 2 and, if a selection was made to proceed with calculations (only the S-matrix, INRE=3) in the screen prompt number 10, then the program will end here. However, if variable INRE has a value of 4 representing the wish to generate S-matrices of other nuclides as well, then the program would return to reading the data in the input file and will proceed according to the input. On the other hand, if the user were using the keyboard as mode of data entry, i.e., NDATA = 0, and if INRE = 3, the program would not end but could revert to the fourth screen allowing the user to end it personally or continue for any other nuclide.

Excluding the redirections in the above cases, the program will advance to calculate the dose committments by calling the subroutine "ICRP FORTRAN".

3.4.8 ICRP FORTRAN:

This subroutine calls other appropriate subroutines for dose committments according to the mode of intake. The arguments of this subroutine are:

INTAKE - Integer variable with a value of either 1, 2, or 3 representing the mode of intake as ingestion, inhalation, or submersion respectively.

WORD - Name of the given isotope, e.g., IN-113M a character variable.

SEX - Sex of the subject as either M or F, a character variable.

F1 - Fractional transfer of stable element from the GI system to the body fluids, a real variable.

CLASS - In case of inhalation, pulmonary uptake classification of the nuclide, a character variable.

AMAD - This is a real variable describing the activity median aerodynamic diameter of the nuclide in case of inhalation.

ROB - Mass of whole body (70000 g) minus the masses of those organs and tissues mentioned in the metabolic model of ICRP-30 for a particular radionuclide.

KZ - Atomic number of the nuclide.

HFIFTY - Specific committed dose equivalent to target organ or tissue. This is a vector of length 24.

US(I,J) - Matrix of transformations of nuclide I in source organ J.

NDATA - An integer variable describing the options chosen in the main program of mode of data entry.

DER - In case of submersion, this real variable represents derived air concentration for an inert radioactive gas.

RISK - This real variable describes derived air concentration for an inert radioactive gas if it is determined by consideration of non-stochastic effects in case of submersion.

ORGAN - This integer variable gives the organ or tissue number when the derived air concentration is determined by non-stochastic effects in case of submersion.

This subroutine merely calls subroutines "INGEST", "INHALE", or "SUBMER" according to the mode of intake transferred in the argument INTAKE as 1, 2, or 3 respectively. However, in case of inhalation, if the AMAD is not equal to 1 micrometer, then it also calculates the specific committed dose corresponding to the given AMAD from the 1 micrometer specific committed dose by law of proportions. The variable NDATA helps in properly re-routing the subroutine in case of an error. The three important subroutines mentioned above are described below.

3.4.9 INHALE FORTRAN:

This subroutine is called if the user chooses inhalation as the mode of intake. Its purpose is to generate a vector of specific

committed dose equivalents (Sv/Bq) in target organs or tissues due to inhaled radionuclides. The arguments of this subroutine are:

WORD - This is a character variable of length 8 which identifies the given radionuclide.

KZ - The atomic number of the nuclide.

SEX - This is a character variable of length 1. and is either M or F for male or female respectively.

HFIFTY(24) - This is a vector of length 24. The 19 elements of this vector represent the specific committed dose equivalents in 19 target organs or tissues.

FNP(20) - This is a vector of length 20. The 19 elements represent the fractions of the committed dose equivalent in the reference target tissue resulting from deposition in the naso-pharyngeal (N-P) compartment of the lung model.

FTB(20) - The 19 elements of this 20 element vector represent the fractions of committed dose equivalent in the target tissue resulting from deposition in the tracheo-bronchial compartment (T-B) of the model.

FP(20) - The fractions of committed dose equivalent in the target tissue resulting from deposition in the pulmonary (P) region of the lung model are the first 19 elements of this 20 element vector.

ROB - This is a variable which represents the mass of whole body (70000 g) minus the masses of those organs and tissues mentioned in the metabolic model of ICRP-30 for a

particular radionuclide. These organs are named in the data file "RETENT".

CLASS - This is a character variable of length 1 representing the pulmonary uptake classification of the radionuclide.

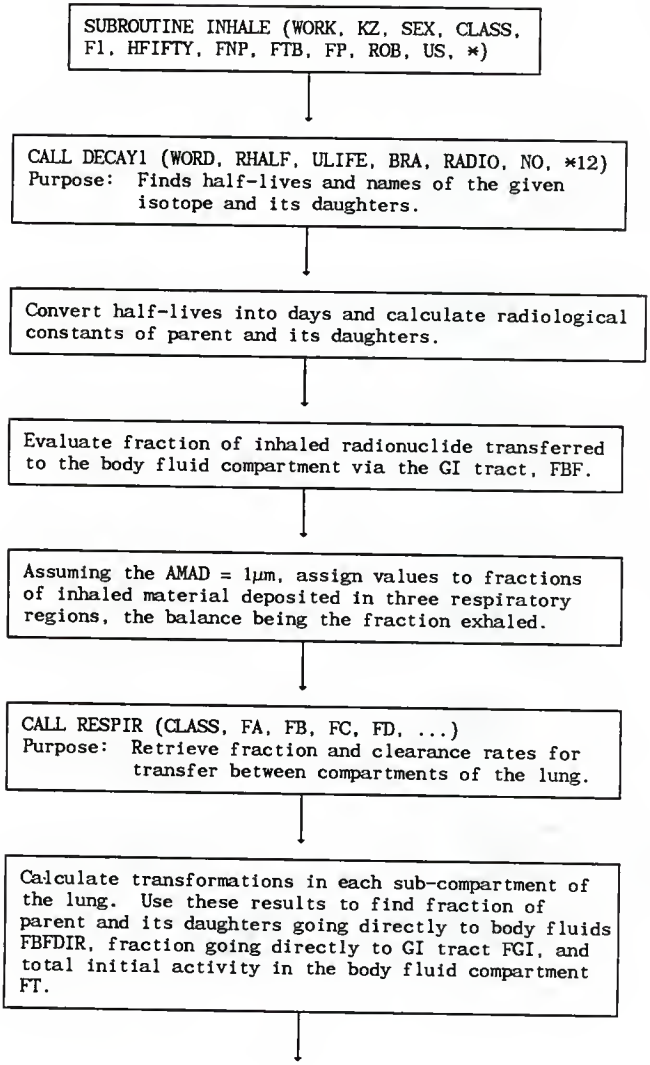
F1 - Fractional transfer of the stable element from the GI system to the body fluids.

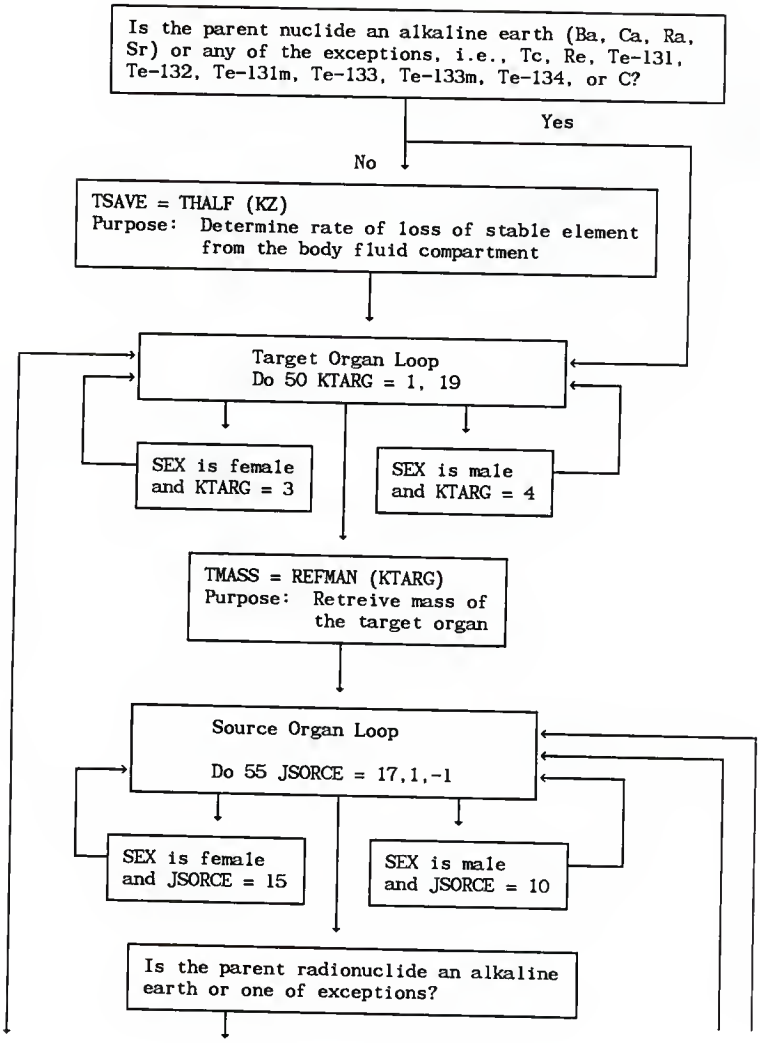
US(I,J) - Matrix of transformations of nuclide I in source organ J.

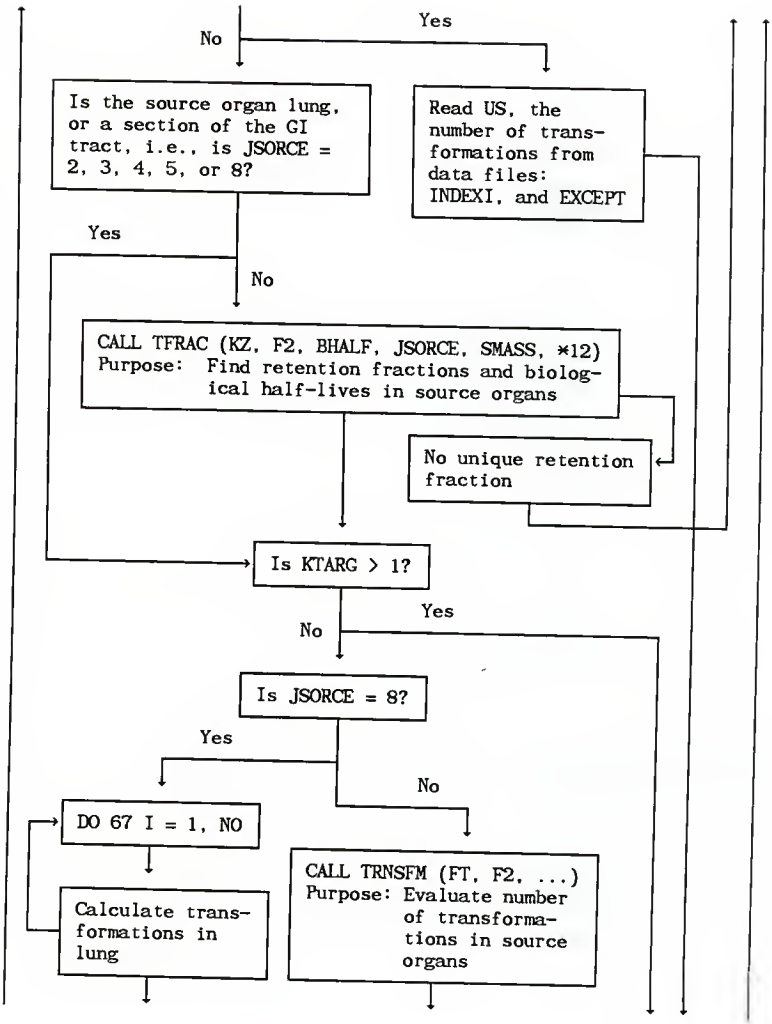
A flowchart of this subroutine is shown in Fig. 3.2. This subroutine is initiated by calling the subroutine "DECAY1" to find the daughters of the radionuclide. Details of this subroutine were given earlier. After accession of the decay scheme from the above subroutine, half lives of parent and daughters, if not in units of days, are converted into days and then radiological constants are calculated. If the daughter is a radioactive inert gas, then that nuclide and its subsequent progeny are neglected and are assumed to escape out of the body.

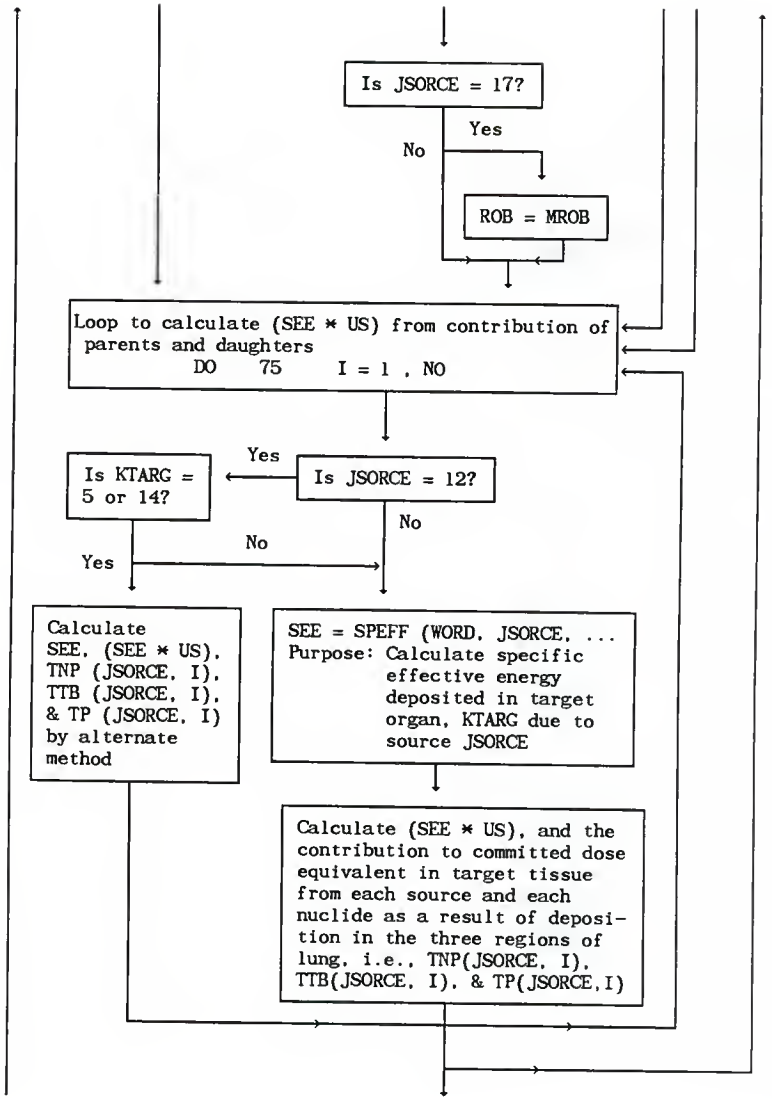
With the use of the fraction of stable element F1 the fraction of the radioactive parent and its daughters to the body fluid compartment via the GI tract is calculated. This is saved in a vector of maximum length 50, named FBF.

The lung model of ICRP-30, described in a previous chapter, considers fractions of inhaled material to be deposited in three respiratory regions, the naso-pharyngeal passage (N-P), the trachea and bronchial tree (T-B), and the pulmonary region (P), the balance being the fraction exhaled. Initially, it is assumed that the activity


SUBROUTINE INHALE (WORK, KZ, SEX, CLASS, F1, HFIFTY, FNP, FTB, FP, ROB, US, *)
CALL DECAY1 (WORD, RHALF, ULIFE, BRA, RADIO, NO, *12)
Purpose: Finds half-lives and names of the given isotope and its daughters.
Convert half-lives into days and calculate radiological constants of parent and its daughters.
Evaluate fraction of inhaled radionuclide transferred to the body fluid compartment via the GI tract, FBF.
Assuming the AMAD = 1μm, assign values to fractions of inhaled material deposited in three respiratory regions, the balance being the fraction exhaled.
CALL RESPIR (CLASS, FA, FB, FC, FD, ...)
Purpose: Retrieve fraction and clearance rates for transfer between compartments of the lung.
Calculate transformations in each sub-compartment of the lung. Use these results to find fraction of parent and its daughters going directly to body fluids FBFDIR, fraction going directly to GI tract FGI, and total initial activity in the body fluid compartment FT.


Is the parent nuclide an alkaline earth (Ba, Ca, Ra, Sr) or any of the exceptions, i.e., Tc, Re, Te-131, Te-132, Te-131m, Te-133, Te-133m, Te-134, or C?
Yes
No
TSAVE = THALF (KZ)
Purpose: Determine rate of loss of stable element from the body fluid compartment
Target Organ Loop
Do 50 KTARG = 1, 19
SEX is female and KTARG = 3
SEX is male and KTARG = 4
TMASS = REFMAN (KTARG)
Purpose: Retreive mass of the target organ
Source Organ Loop
Do 55 JSORCE = 17,1,-1
SEX is female and JSORCE = 15
SEX is male and JSORCE = 10
Is the parent radionuclide an alkaline earth or one of exceptions?


No
Yes
Is the source organ lung, or a section of the GI tract, i.e., is JSORCE = 2, 3, 4, 5, or 8?
Read US, the number of transformations from data files: INDEXI, and EXCEPT
Yes
No
CALL TFRAC (KZ, F2, BHALF, JSORCE, SMASS, *12)
Purpose: Find retention fractions and biological half-lives in source organs
No unique retention fraction
Is KTARG > 1?
No
Yes
Is JSORCE = 8?
Yes
No
DO 67 I = 1, NO
Calculate transformations in lung
CALL TRNSFM (FT, F2, ...)
Purpose: Evaluate number of transformations in source organs


Is JSORCE = 17?
Yes
No
ROB = MROB
Loop to calculate (SEE * US) from contribution of parents and daughters
DO 75 I = 1 , NO
Is KTARG = 5 or 14?
Yes
Is JSORCE = 12?
No
Yes
No
Calculate SEE, (SEE * US), TNP (JSORCE, I), TTB (JSORCE, I), & TP (JSORCE, I) by alternate method
SEE = SPEFF (WORD, JSORCE, ...
Purpose: Calculate specific effective energy deposited in target organ, KTARG due to source JSORCE
Calculate (SEE * US), and the contribution to committed dose equivalent in target tissue from each source and each nuclide as a result of deposition in the three regions of lung, i.e., TNP(JSORCE, I), TTB(JSORCE, I), & TP(JSORCE,I)

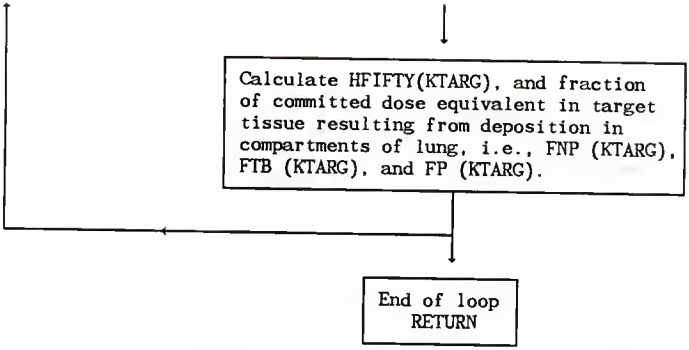


FIG. 3.2 Flowchart of "INHALE FORTRAN"

median aerodynamic diameter (AMAD) of the nuclide inhaled is 1 micrometer, and the corresponding deposition fractions in each compartment of the lung are utilized for calculation of specific committed dose equivalent. The reason for this assumption is that, even in alternate cases, when the AMAD is not 1 μm, values of HFIFTY for 1 μm AMAD are used to estimate HFIFTY in those cases, using the law of proportions.

The clearance rates and fractions in each sub-compartment of the three major divisions of the lung is first initialized as zero and then, a subroutine "RESPIR" is called for their values.

3.4.10 RESPIR FORTRAN:

This subroutine merely provides the fraction and clearance rates for transfer of nuclide between compartments of the lung according to the inhalation class of the nuclide. The arguments are:

CLASS - Character variable of length 1 describing inhalation class of the nuclide.

FA - Fraction of material deposited in the body fluid compartment from the nasal passage region (N-P).

FB - Fraction deposited in the GI tract from the nasal passage.

FC - Fraction deposited in the body fluid compartment from the trachea and bronchial tree region (T-B).

FD - Fraction deposited in the GI tract from the trachea and bronchial tree region (T-B).

FE - Fraction deposited in the body fluids from the pulmonary region (P).

FF - Fraction transferred to the T-B region from the P region with a half-life.

FG - Fraction transferred to the T-B region from the P region with a different half life.

FH - Fraction transferred to the lymphatic system (L) from the P region.

FI - Fraction deposited in the body fluids from the L region with a half life.

CLA - Clearance rate of material from the N-P to the body fluids which is found from dividing ln 2 by the removal half time (in days) in each compartment.

CLB - Clearance rate of material from the N-P to the GI tract.

CLC - Clearance rate of material from the T-B to the body fluids.

CLD - Clearance rate of material from the T-B to the GI tract.

CLE - Clearance rate of material from the P to the body fluids.

CLF - Clearance rate of material from the P to the T-B region.

CLG - Clearance rate of material from the P to the T-B region.

CLH - Clearance rate of material from the P to the L region.

CLI - Clearance rate of material from the L to the body fluids.

CLJ - Clearance rate of material from the L to the body fluids.

With the use of these fractions and clearance rates, transformations in various sub-compartments of the lung for the parent and its daughters are assessed, and these transformations allow calculation of the fraction of the inhaled radionuclide and its daughters transferred directly to the body fluid compartment, and the fraction transferred to the GI tract. The former is saved as a vector FBFDIR, and the latter as a vector FGI. Both vectors are of maximum length 50. These results aid in determining the total initial activities of the given radionuclide and its daughters in the body fluid or transfer compartment. The activities are saved as a vector FT (length = 50).

Since different elements have different clearance times from the body fluid compartment, function subprogram "THALF" is called to determine the suitable half-life of clearance. However, if the parent nuclide is an alkaline earth (Ba, Ca, Ra, Sr) or one of the exception nuclides, i.e., Tc, Re, Te-131, Te-132, Te-131m, Te-133, Te-133m, Te-134, or C, this step is skipped to the target organ loop.

3.4.11 THALF FORTRAN:

This function subprogram uses the argument KZ, the atomic number of the nuclide, to provide the half-life of clearance from the transfer compartment. The daughters are assumed to have the same half-life of clearance as the parent.

With this half-life of clearance, the rate of loss of the stable element from the transfer compartment TCONST, is calculated. After that, the source-organ transformations in each source organ for the parent and its daughters are initialized to zero, and then, an outer loop to calculate HFIFTY in each target organ, is commenced. The target organs ovaries and testes are skipped if the sex of the subject is male or female respectively. To determine the mass of each target organ, a function subprogram named "REFMAN" is called.

3.4.12 REFMAN FORTRAN:

This function subprogram uses the target number as the argument and returns the mass as shown in Table 3.1.

Some variables which will be described later as they are used, are initialized to zero at this point. For each target organ in the outer loop, a nested loop to add contribution from all source organs is initiated. As in the target organ loop, if the subject is male, ovaries are omitted as source organ and similarly testes are ignored if the subject is female.

At this juncture, if the ancestral nuclide inhaled is an alkaline earth or one of the exceptions described above, the number of transformations in each source organ are not calculated but retrieved from data files. The first letter of the nuclide symbol is used to search for a match in file "INDEXI". Once a match occurs, the values of F1 (described above) and the class of the nuclide are compared.

Beside each value of F1 and class, is a record number, which is read on proper match. This record number is a pointer for file "EXCEPT". Using this record number, the numbers of transformations for different source organs are read from this file.

In the case of nuclides technetium (Tc) and rhenium (Re), an anomaly exists. The ICRP 30 describes transformations in stomach wall as well as stomach content as source organs. However, in this report both are summed and treated as only one source organ, the stomach content. Similarly, the ICRP-30 also gives specific effective energy values (described later) for both source organs. Since this program cannot generate specific affective energy values for stomach wall as source organ, the summed value of transformations is multiplied by the SEE values for stomach content as source organ. Although this treatment does not affect the results of dose committment in other target organs appreciably, it does lead to underestimation as compared to ICRP-30 in the case of target organ stomach wall and hence, must be used with caution.

For all other nuclides, to find the fractions of nuclide retained in source organs as a result of transfer from the body fluid compartment, a subroutine "TFRAC" is called. The contribution to committed dose in organs of the GI tract and lung through this route is minimal. Since the nuclide enters the body-fluid compartment after passage through these organs, the major contribution is direct. Moreover, this minimal part is taken care of in the source organ total body.

3.4.13 TFRAC FORTRAN:

The purpose of this subroutine is to retrieve the retention fractions F2 and the biological half-lives BHALF of the nuclide in the source organs from data file "RETENT". The auxiliary subroutines needed are "I1" and "SOURCE". The arguments used are:

KZ - The atomic number of the nuclide.

F2 - This describes the fraction retained in source organ except organs of the GI tract and lung. It is a vector of length 3 since source organs are modelled to have 3 compartments.

BHALF - This vector of length 3 gives the biological half-lives of the fractions in the source organs.

JSORCE - This is the source organ number as shown in Table 3.1.

SMASS - This variable invokes the function subprogram "SOURCE" to obtain the mass of the source organ, except when the source organ is total body. In that case, if other organs are linked with retention fractions, then this variable is assigned a value of $70000 - (\sum_i M_i)$ where M_i are the masses of organs associated with different retention fractions.

A flow diagram of this subroutine is illustrated in Fig. 3.3. A loop is started to access retention fraction and biological half-lives associated with source organs for a given nuclide. Variable C2 describes the source organ name. Other variables D, E, and F describe the retention fractions in different compartments of source organ, and G, H, B read the corresponding biological half lives. After retrieving

the source organ name associated with retention fractions, and biological half-lives from the data file, function subprogram "I1" is called with the source organ name C2 in alpha numeric characters as argument. "I1" converts C2 to an integer from the source list presented in Table 3.1.

The source integer is now compared with JSORCE, the argument. If they are equal, then the corresponding retention fractions and biological half-lives associated with C2 are equated with F2 and BHALF respectively. The function subprogram SOURCE is called with source organ integer as argument. This function subprogram provides the mass of the source organ which is equated with variable SMASS. With these values, the subroutine "TFRAC" is returned.

If, however, the source integer linked with C2 does not match the JSORCE, then there are two possiblities. The obvious one is that the loop is continued until a match is found, and then the values returned, or no match found, and values = 0 are returned. The other route is that if JSORCE is 17, i.e., the source organ is total body and if the source integer corresponding to C2 is not 18, linked with "all other" then the masses of source organs are summed, and the loop continued, until the integer is 18, and at that time, retention fractions and biological half-lives related to it are taken to be the ones sought. The SMASS variable is, however, assigned a value of 70000 minus the previous sum of source organs, rather than 70000, the mass of total body. This mode of accession works because the records in the data

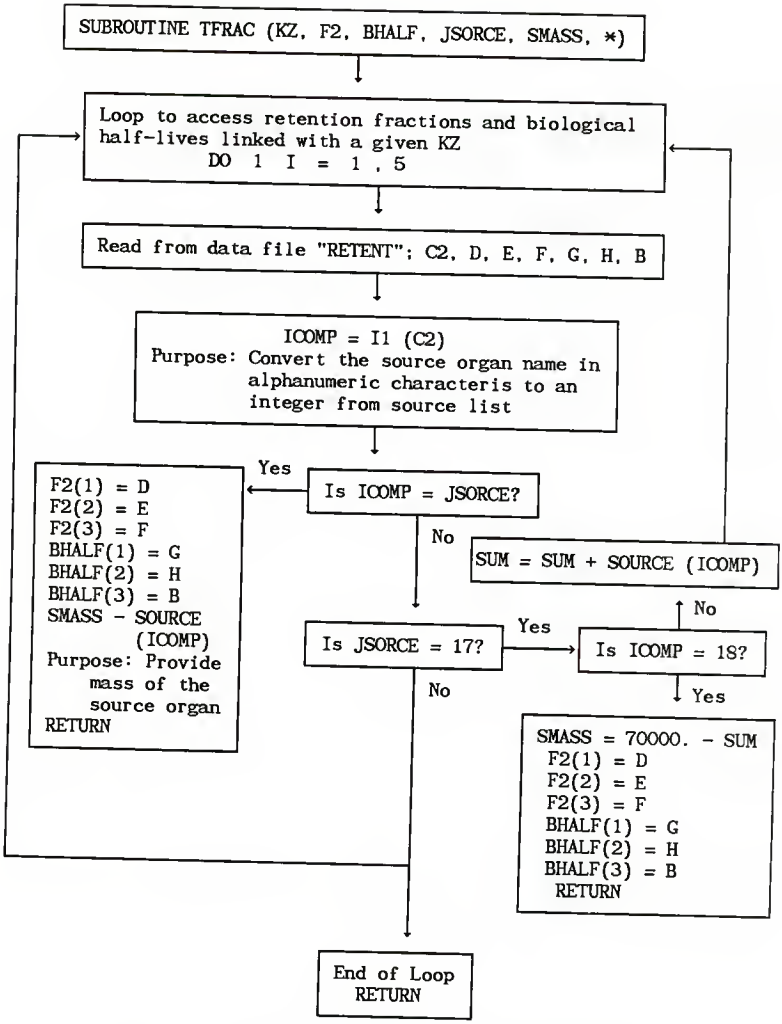


FIG. 3.3. Flowchart of Subroutine "TFRAC FORTRAN".

file are entered in such a way that for a given KZ, entry of "all other" is always at the end, after specific organs.

Of course, an error in reading or accessing a data file is disclosed by a display of appropriate message and suggested corrective action.

If a source organ does not have a unique retention fraction, that is, after the subroutine call, the retention fractions and biological half-lives for that organ are zero, then the source organ is skipped because often it will be included in the source organ total body. Since the transformations are evaluated in the source organ, their values remain the same for different target organs. Thus, if the target organ number is greater than 1 in the outer loop, repeated evaluation of source organ transformations is bypassed. Also if the source organ is lung, the subroutine for transformations is not called. Instead, the transformations calculated in each subcompartment earlier are summed, except for the N-P region. This treatment, as explained in the previous chapter, is based on the assumption that the dose received by the nasophryngeal region for most particles sizes, is small in comparison with the doses received by other regions and hence, can be neglected. For all other sources, though, the subroutine "TRNSFM" is called.

3.4.14 TRNSFM FORTRAN:

This subroutine provides the source-organ transformations of the parent and its daughters in each source organ. The arguments are:

FT - A vector of length NO (variable dimensioning) which describes the total initial activity of the given radionuclide and its daughters in the transfer compartment.

F2 - A vector of length 3, which describes retention fractions in three compartments of the source organ.

BHALF - Also a vector of length 3 which relates to the biological half-lives of the fraction retained in source organs.

RCONST - This is a vector of length NO which describes the radiological constants of the parent and the daughters.

NO - Integer variable describing number of daughters plus one for the parent.

BRA - Branching ratio of the parent [BRA(1)=1] and its daughter saved as a vector of length NO.

US - This is a matrix of size 20 x NO. The first dimension refers to the source integer number, and the second to the nuclide of interest. This array describes the transformations in a particular source organ for a particular nuclide.

TCONST - Rate of loss of stable element from the transfer compartment.

JSORCE - Source integer number.

F1 - Fractional transfer of the stable element to the body fluid compartment.

IPROG - Integer variable identifying the calling subroutine as "INHALE" if value = 1, and "INGEST" if value = 0.

FGI - A vector of length NO, describing the fraction of the inhaled radionuclide and its daughter transferred to the GI tract.

SMASS - Variable describing mass of the source organ except if the source organ is total body and other organs of mass Mi have unique retention fractions. In that event, the variable equals $70000 - \sum_i M_i$.

UROB - A vector of length NO describing the total number of transformations of each nuclide in rest of the body of mass, $70000 - \sum_i M_i$ where M_i is the mass of organ i for each unique retention fraction.

MROB - This is a real variable which is assigned the value equal to $70000 - \sum_i M_i$ when the source organ is total body.

KZ - Atomic number of the given radionuclide.

This subroutine begins with the calculation of biological constants BCONST from the biological half-lives in different compartments of the source organ. Depending on the mode of intake, i.e., the value of IPROG, the calculations for organs of the GI tract are directed to appropriate line numbers for the evaluation of source-organ transformations by alternate methods.

An outer loop is initiated for the calculation of US for each nuclide. If TCONST is equal to zero, that is, there is instantaneous

transfer to the tissue compartment, then calculation of UTJ, the vector of length NO describing transformations of the nuclide under consideration in the transfer compartment, is omitted. Otherwise, a nested loop calculates UTJ for each nuclide. Another nested loop evaluates the transformations in the three compartments of the source organ, and adds them. Of course, the initial activity of the nuclide in the source organ after transfer from the body fluid compartment is first calculated within the loop. Transformation in each compartment of the source organ is stored as a variable UJ. Use of UTJ and UJ allows calculation of US(JSORCE, J) where J is the nuclide under consideration.

If the source organ is total body, then the source-organ transformations calculated are equated with UROB(J). This quantity is associated with transformation in "rest of the body" and the source-organ transformations used in conjunction with total body as the source organ is over estimated by multiplying by 70000/SMASS, where SMASS as expplined previously is $70000 - \sum_i M_i$, M_i being the mass of the organ with unique retention fraction. This overestimation in case of total body is compensated for each organ with unique retention fraction by subtracting the quantity, $M_i \times \text{UROB(J)}/(70000 - \sum_i M_i)$ for organ i. The outer loop for each nuclide is closed at this point and the value of US(JSORCE,J) is returned.

As remarked earlier, for organs of the GI tract, depending on mode of intake, there are separate blocks for calculation of US(JSORCE,J), which follows the loop described above. In the case of iodine, a

separate three compartment model is described in the previous chapter. Transformations in the source organs are calculated using this model. A flow chart can be seen in Fig. 3.4.

After the determination of US, another nested loop is initiated to calculate the product of US and specific effective energy absorbed in the tissue for each nuclide. For this purpose, use of another function subprogram called "SPEFF" is required.

3.4.15 SPEFF FORTRAN:

This function subprogram calculates the specific effective energy deposited in each target organ due to each source organ. The arguments transferred are:

WORD - Identification of the nuclide.

JSORCE - Source integer number.

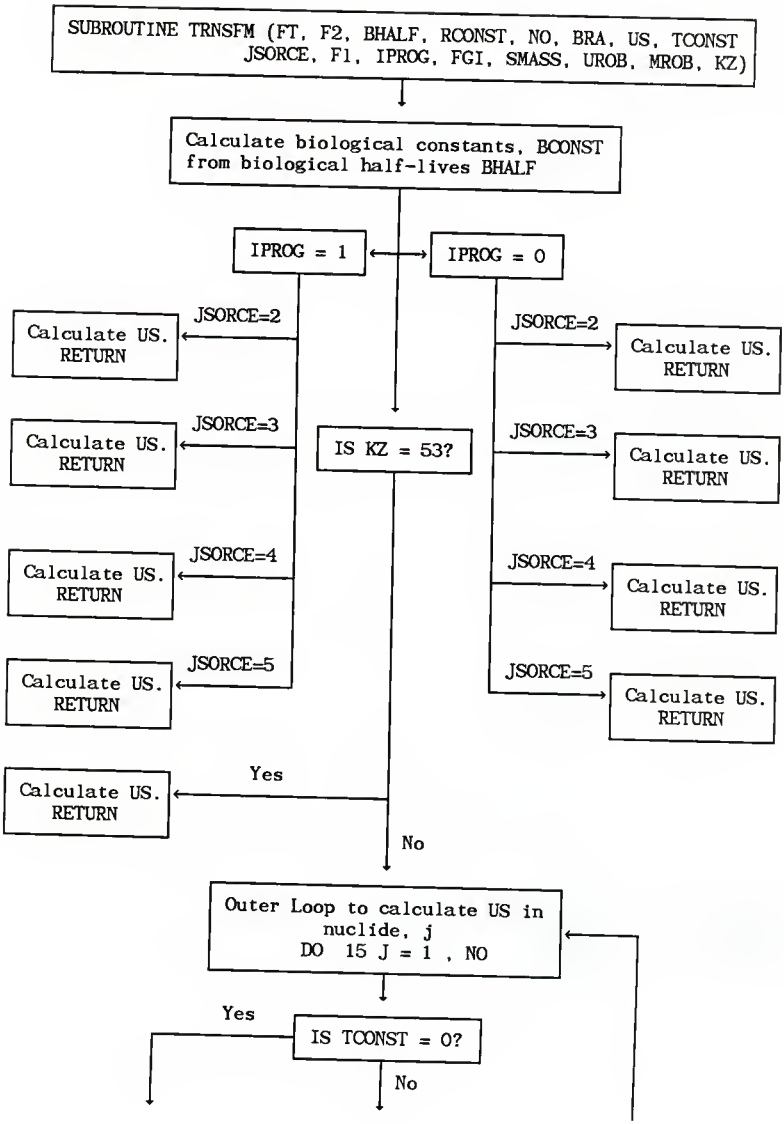
KTARG - Target mass in grams.

LOOP - Integer variable which has a value of either 0, 1, or 2.

MOTS - Identification of the parent nuclide.

PLIFE - Half life of the parent in days.

At the outset, the source number is compared with the target number according to Table 3.1. If the organs are the same, the integer variable ICOM is assigned a value of 0, otherwise a value of 1. For the decay scheme, a subroutine "DECAY" is called which will be explained later. The character variable SAVE stores the identification of the radionuclide when this function subprogram is first called, and


SUBROUTINE TRNSFM (FT, F2, BHALF, RCONST, NO, BRA, US, TCONST
JSORCE, F1, IPROG, FGI, SMASS, UROB, MROB, KZ)
Calculate biological constants, BCONST from biological half-lives BHALF
IPROG = 1
IPROG = 0
JSORCE=2
Calculate US. RETURN
JSORCE=3
Calculate US. RETURN
JSORCE=4
Calculate US. RETURN
JSORCE=5
Calculate US. RETURN
IS KZ = 53?
JSORCE=2
Calculate US. RETURN
JSORCE=3
Calculate US. RETURN
JSORCE=4
Calculate US. RETURN
JSORCE=5
Calculate US. RETURN
Yes
Calculate US. RETURN
No
Outer Loop to calculate US in nuclide, j
DO 15 J = 1 , NO
Yes
IS TCONST = 0?
No

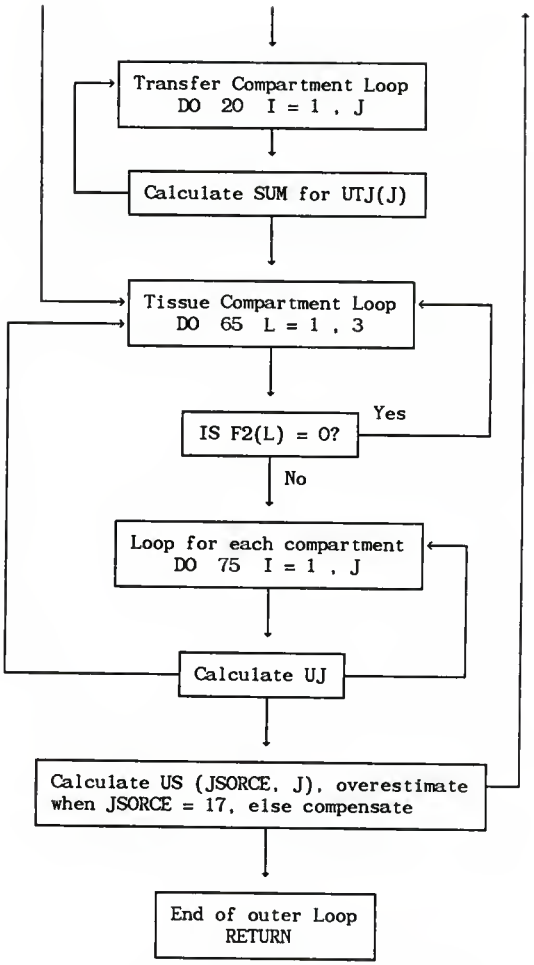


FIG. 3.4. Flowchart of "TRNSFM FORTRAN"

hence when it is equal to WORD, the function does not have to call "DECAY" again. At this point, if positrons are found in the decay scheme, corresponding annihilation photons are added to the list of decaying photons.

There are alternate methods for calculation of SPEFF for target organs of the GI tract, bladder, and bone. For all organs, there are five blocks for treating particles alpha, beta, positron, electron and photon. For target organs other than the GI tract, bladder, and bone, in the case of charged particles, the specific absorbed fraction in the target organ $\hat{AF}$ is zero if the source and target organs are not equal, except in the following cases:

i) When the source organ is total body, the specific absorbed fraction equals 1/69900.

ii) When the target organ is total body and the source organ is bladder content, the specific absorbed fraction is equal to $45.1/(2 \times 200 \times 69900)$.

iii) When the target organ is total body and the source organ is stomach content, the specific absorbed fraction equals $150/(2 \times 250 \times 69900)$.

iv) When the target organ is total body and the source is SI content, $\hat{AF} = 640/(2 \times 400 \times 69900)$.

v) When the target organ is total body, and the source organ is ULI content, $\hat{AF} = 210/(2 \times 220 \times 69900)$.

vi) When the target organ is total body, and the source organ is LLI content, $\hat{AF} = 160/(2 \times 135 \times 69900)$.

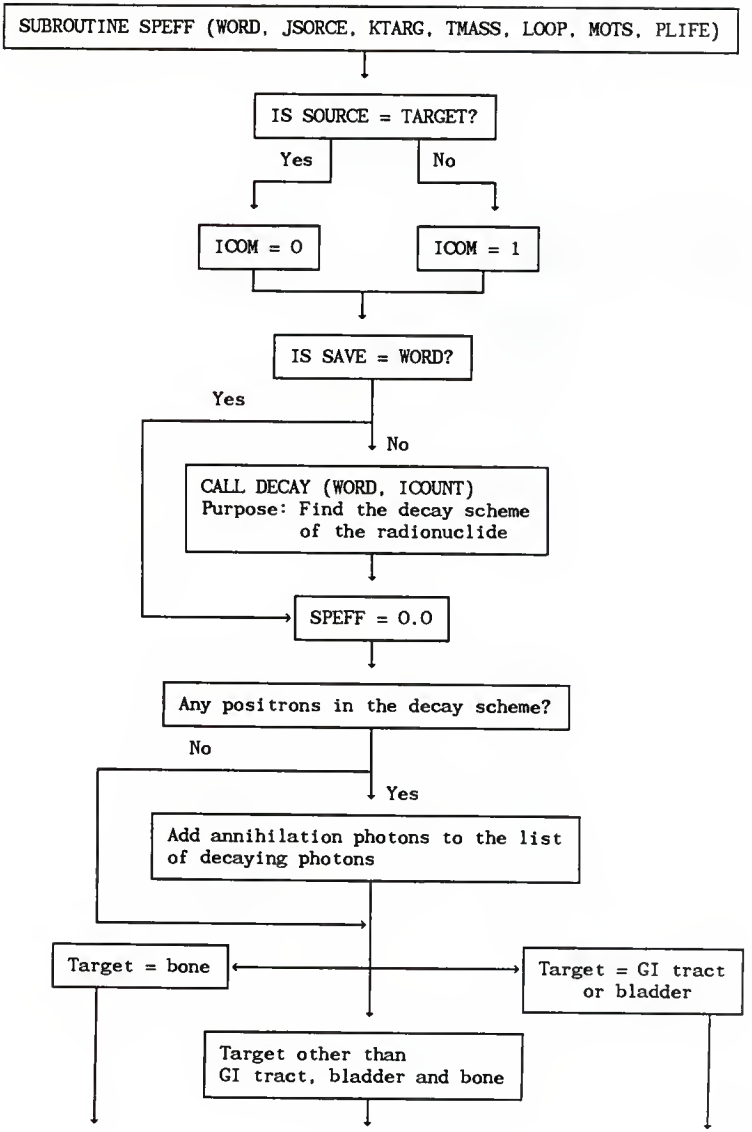
vii) When the target organ is total body, and the source organ is any organ except ones described above, $\hat{AF}$ = 1/69900.

In the case of photons, the same cases hold true if the energy is less than 0.01 MeV. For higher energies a function subprogram "INTRPT" is called which will be explained later.

For target organs of the GI tract, bone and bladder, in the case of charged particles, the specific absorbed fraction is zero, if the sources and targets are not the same except when the source is total body. In that case, $\hat{AF}$ = 1/69900. For photons, the same conditions hold true if the energy is less than 0.01 MeV, or else "INTRPT" is called. A flow diagram is sketched in Fig. 3.5.

3.4.16 DECAY FORTRAN:

This subroutine provides the decay scheme of the radionuclide. The data files are based on the radioactive decay data tables by D. C. Kocher, DOE/TIC-11026 (1981). It uses character variable WORD and integer variable ICOUNT as arguments. ICOUNT is normally 0, until an error occurs, in that case, its value is 1. Similar to "DECAY1", the symbol in WORD is used to find a match in the sequentially accessed data file "ISOTIPS". Once a match is found, a record number ITR is read which is then used to access directly the decay scheme from data file "ISOTOPE". Any error in this subroutine, is recorded as a particular element of an integer vector, for which subroutine "YERROR" is called, which will be explained later. Variables used to access "ISOTOPE" are:


SUBROUTINE SPEFF (WORD, JSORCE, KTARG, TMASS, LOOP, MOTS, PLIFE)
IS SOURCE = TARGET?
Yes
No
ICOM = 0
ICOM = 1
IS SAVE = WORD?
Yes
No
CALL DECAY (WORD, ICOUNT)
Purpose: Find the decay scheme
of the radionuclide
SPEFF = 0.0
Any positrons in the decay scheme?
No
Yes
Add annihilation photons to the list
of decaying photons
Target = bone
Target = GI tract
or bladder
Target other than
GI tract, bladder and bone

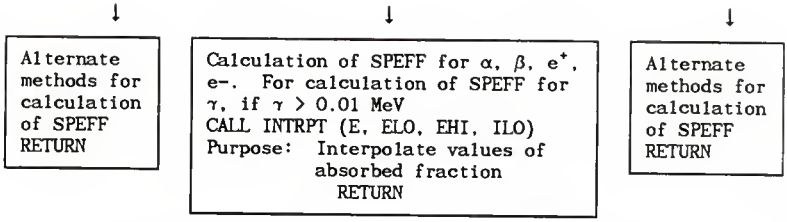


FIG. 3.5. Flowchart of Function Subprogram "SPEFF FORTRAN"

ERT - Name of the isotope.

JO - Atomic weight.

J - Atomic number.

B - Half-life.

C - Half-life units (S, M, H, D, Y).

K - Number of daughters.

L - Pointer to first daughter record.

M - Number of alpha particles.

N - Pointer to first alpha particle record.

I1 - Number of beta particles.

I2 - Pointer to first beta particle record.

I3 - Number of positrons.

I4 - Pointer to first positron record.

I5 - Number of electrons.

I6 - Pointer to first electron record.

I7 - Number of photons.

I8 - Pointer to first photon record.

The pointer to first alpha particle is used to access the data file "ALPHA". The variables read are:

AL1 - Energy in MeV.

AL2 - Intensity.

The pointer to beta is used to access the data file "BETA" with the variable being:

BE1 - Endpoint energy in MeV.

BE2 - Average energy in MeV.

BE3 - Intensity.

The pointer to positron is the key to access the data file "POSITRN" for reading the following variables:

POS1 - Endpoint energy in MeV.

POS2 - Average energy in MeV.

POS3 - Intensity.

The pointer to electron is the record number to access "ELECTRN". Variables read are:

ELE1 - Energy in MeV.

ELE2 - Intensity.

Similarly, pointer to photon is used for file "PHOTON" with variables:

PHO1 - Energy in MeV.

PHO2 - Intensity.

Each of these variables starting from AL1 are stored as a vector for the decay of parent and daughters, and all of these vectors are common to function subprogram "SPEFF". Besides these vectors other variables that are common are M, I1, I3, I5, I7, HLIFE. HLIFE, a variable, describes the half lives in units of days.

3.4.17 YERROR FORTRAN:

This is the error handling subroutine for the subroutine "DECAY FORTRAN". It gives error messages when called from "DECAY" in case of an error in reading data files, discloses the source of error as "DECAY", and suggests appropriate action. The argument of this

subroutine is DECERR(7). This is an integer vector of length 7. Each kind of error relates to a particular element of this vector. The element is assigned an integer value greater than zero in case of an error.

3.4.18 INTRPT FORTRAN:

This function subprogram is called by "SPEFF" for calculation of SPEFF in the case of photon decay for energy greater than 0.01 MeV. The purpose of this subprogram is to interpolate the values of absorbed fraction. The data file required is "ABSFRAC" and the subroutine "ENERGY". The arguments of this subprogram are:

E - Energy of gamma.

JSORCE - Source integer.

KTARG - Target integer.

It utilizes subroutine "ENERGY" to obtain the upper and lower bounds of energy which aids in interpolation. The data file "ABSFRAC" is used to read absorbed fraction for the upper and lower bounds of energy.

After determining the specific effective energy SEE the product of SEE and US is required for calculation of HFIFTY from contributions of all radionuclides. If the source organ is mineral bone and the target is either red marrow or bone surface cells then the contribution from both trabecular bone and cortical bone as part of mineral bone is calculated by first calling "SPEFF" with a value of variable LOOP as 0

which implies photon decay from radionuclies, then with a value of LOOP = 1 which takes care of charged particle dose in trabecular bone, and finally with LOOP = 2 which accounts for charged particle dose in cortical bone.

For other source organs, value of LOOP = 0. To determine the contribution to committed dose equivalent in target tissue from each source and each nuclide as a result of deposition in the N-P, T-B and P regions of the lung model, three matrices named TNP, TTB, and TP are evaluated which have a maximum size of 20 x NO where 20 represents each source integer, and NO, the number of nuclides.

The products (SEE × US) are added from contribution of each source in variable GRNSUM. The source loop is now closed at this point. FNP, FTB, FP, and HFIFTY described earlier is calculated at this point for each target organ and the target loop is then closed. The calculated values are returned to the subroutine "ICRP".

If the value of AMAD is not equal to 1, the subroutine "ICRP" calculates the committed dose by law of proportions, and then returns the calculated value to the control code "DOSE".

As mentioned earlier, the subroutine "ICRP" will call the subroutine "INGEST" to calculate the specific committed dose equivalent in target organs from the ingested radionuclide, if the value of variable, INTAKE is 1. The mode of operation of this subroutine is very similar to "INHALE" and hence the subroutines called by "INGEST" which are common to "INHALE" are not described to avoid redundancy.

3.4.19 INGEST FORTRAN:

The arguments passed by the subroutine "ICRP" for calculation of the specific committed dose equivalent due to the ingested radionuclide are:

WORD - The character variable of length 8 which identifies the radionuclide.

KZ - The atomic number of the nuclide.

SEX - Character variable of length 1 identifying the sex of the exposed subject.

F1 - Fractional transfer of the stable element from the GI system to the body fluids.

HFIFTY(24) - The first 19 elements of this vector represent the specific committed dose equivalents in 19 target organs or tissues.

ROB - This variable stands for the mass of whole body minus the masses of those organs and tissues with unique retention fractions mentioned in the metabolic model.

US(I,J) - This is a matrix of transformations of nuclide I in source J.

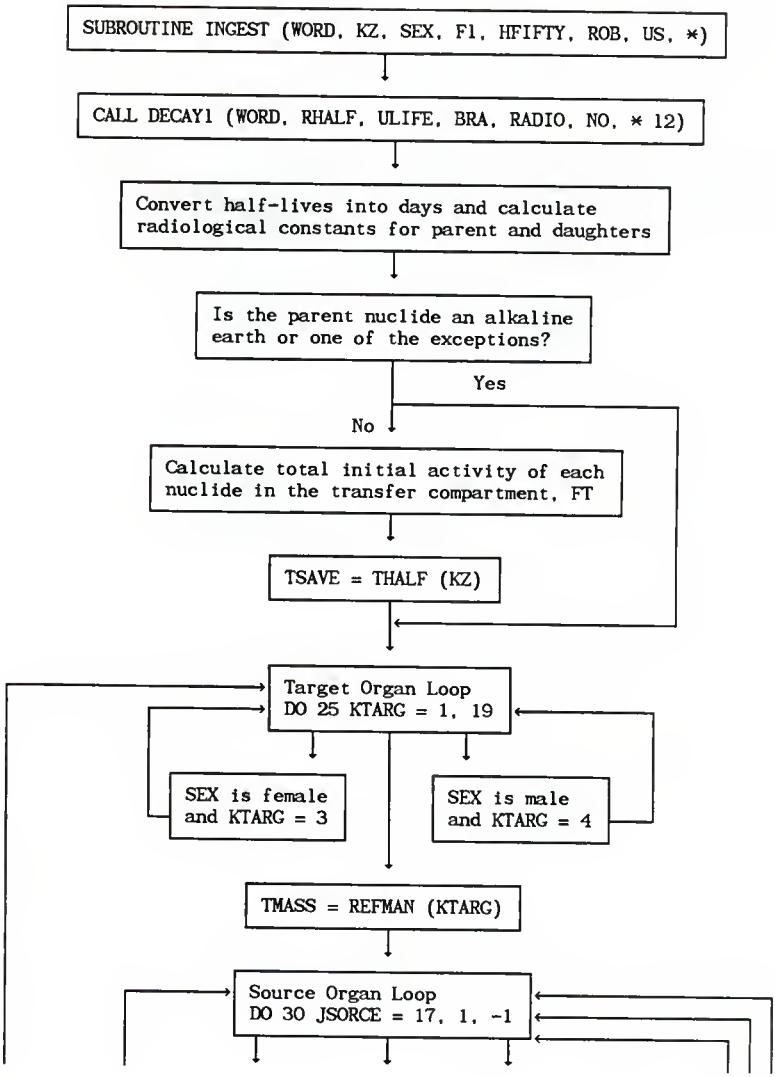
This subroutine like its counterpart "INHALE" is initiated by calling "DECAY1" for half-lives and names of the parent isotope and its daughters. The half-lives are converted into days and radiological constants calculated. Again, if the progeny is a radioactive inert gas, it is assumed to escape out of the body.

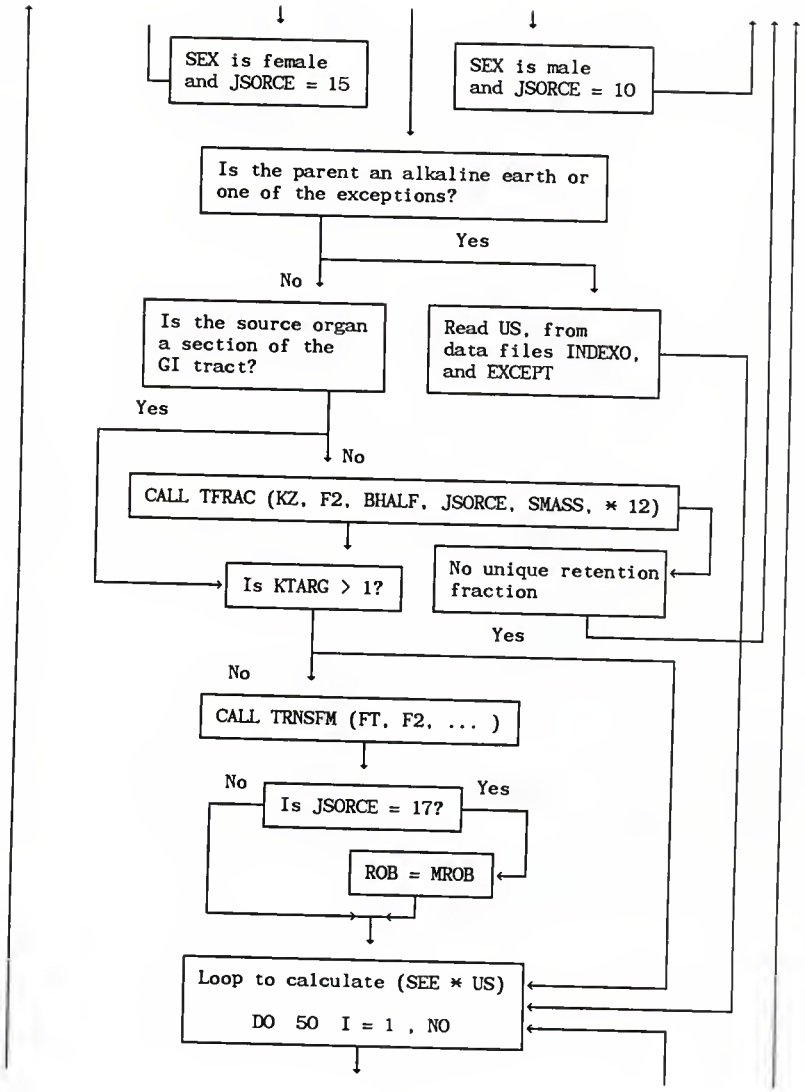
The initial activity FT of the parent and its daughters in the transfer compartment is evaluated using the fractional transfer of the stable element from the GI tract to the body fluids.

Except for the alkaline earths and the nuclides Tc, Re, Te-131, Te-131m, Te-132, Te-133, Te-133m, Te-134, and C, for which the number of transformations in source organs are retrieved from a data file "EXCEPT", the half life of clearance for other nuclides is obtained from function subprogram "THALF".

A target organ loop to calculate HFIFTY is started at this point. Mass of each target organ is given by function subprogram "REFMAN". For each target organ, contribution from all source organs is evaluated through a nested source loop.

To calculate the number of transformations in source organs, the retention fractions of the nuclides in these source organs must first be determined. Subroutine "TFRAC" retrieves these retention fractions and their biological half lives in the source organs. After this step, subroutine "TRNSFM" is called for the source organ transformations of each nuclide, and then subroutine "SPEFF" for specific effective energy in each target organ due to each source organ. The product of both the quantities is added from contribution of all sources in each target organ. The source loop is closed and then the specific committed dose equivalent in each target organ is calculated. After covering all 19 target organs, the loop is closed and the values returned to "ICRP" which in turn routes it to "DOSE". A flow diagram for "INGEST" is shown in Fig. 3.6.


SUBROUTINE INGEST (WORD, KZ, SEX, F1, HFIFTY, ROB, US, *)
CALL DECAY1 (WORD, RHALF, ULIFE, BRA, RADIO, NO, * 12)
Convert half-lives into days and calculate radiological constants for parent and daughters
Is the parent nuclide an alkaline earth or one of the exceptions?
Yes
No
Calculate total initial activity of each nuclide in the transfer compartment, FT
TSAVE = THALF (KZ)
Target Organ Loop
DO 25 KTARG = 1, 19
SEX is female and KTARG = 3
SEX is male and KTARG = 4
TMASS = REFMAN (KTARG)
Source Organ Loop
DO 30 JSORCE = 17, 1, -1


SEX is female and JSORCE = 15
SEX is male and JSORCE = 10
Is the parent an alkaline earth or one of the exceptions?
Yes
No
Is the source organ a section of the GI tract?
Read US, from data files INDEXO, and EXCEPT
Yes
No
CALL TFRAC (KZ, F2, BHALF, JSORCE, SMASS, * 12)
Is KTARG > 1?
No unique retention fraction
Yes
No
CALL TRNSFM (FT, F2, ...)
No
Is JSORCE = 17?
Yes
ROB = MROB
Loop to calculate (SEE * US)
DO 50 I = 1 , NO

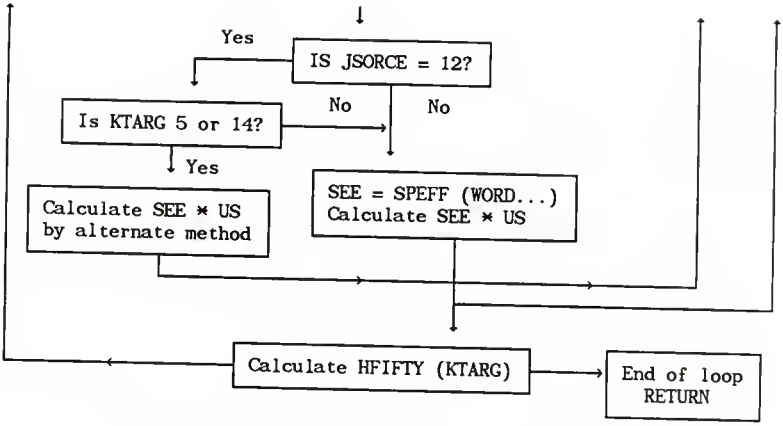


FIG. 3.6. Flow Diagram for "INGEST FORTRAN"

After receiving all the values that were originally requested, the main program now writes these results onto the named files. To begin with, if the source-organ transformations were asked (i.e., MAIS = 1) in the twelfth screen prompt, then the values of US are written to the file FFILE(4). Again, if the mode of data entry was keyboard, then these values are also written on screen for user's convenience.

Before the results of dose committment can be written onto the named file, a subroutine "RESULT" is called to evaluate weighted committed dose and other quantities as explained below.

3.4.20. RESULT FORTRAN:

The purpose of this subroutine is to evaluate the weighted committed dose equivalent using the 10% exclusion principle. In other words, weighted dose equivalents that are reported are greater than or equal to 10% of the maximum weighted dose. The subroutine also calculates the annual limit on intake. In addition, if the mode of intake is inhalation, it determines the derived air concentration of the nuclide. The arguments of this subroutine are:

HFIFTY(24) - This vector of maximum length 24, represents the specific committed dose equivalent (Sv/Bq) in 19 target organs or tissues.

WDOSE(24) - Also a vector of length 24, it describes the weighted committed dose equivalent (Sv/Bq) in 19 target organs or tissues which are greater than or equal to 10% of the maximum.

ALI - This is a real variable which gives the annual limit on intake (Bq) of the radionuclide. It is equal to variable POST. However, when the annual limit on intake is determined by the nonstochastic limit, this variable stands for the greatest value of the annual intake (Bq) that satisfies the Commission's recommendation for limiting non-stochastic effects.

POST - This real variable describes the greatest value of annual intake (Bq) that proscribes to the criterion for limiting stochastic effects as recommended by the ICRP-30.

IRGANT - When the annual limit on intake is determined by the non-stochastic limit on dose equivalent in a particular organ or tissue, that organ or tissue number (according to Table 3.1) is given by this integer variable.

DAC - This variable gives the concentration of the radionuclide which if inhaled at the (occupational) rate of 9600 liters per day, 5 days per week, 50 weeks per year, would lead to the annual limit of intake for inhalation (Bq/m^3).

KZ - Atomic number of the nuclide.

REMDR - Maximum committed dose equivalent in a target organ or tissue which is not included in the metabolic model, GI tract model, and the table of weighting factors shown in Table 1.1.

WTF - This is a weighting factor determined by the number of target organs and tissues, up to a maximum of 5, which

are not eliminated under the 10% rule or included in metabolic model, GI tract, and Table 1.1, which also qualify for a weighting factor of 0.06.

WREMDR - Weighted committed dose equivalent that is obtained by multiplying REMDR and WTF.

SUM - Sum of all the weighted committed dose equivalents (Sv/Bq).

This subroutine first finds a maximum of target organs or tissues collectively called "remainder" that are not included in organs in Table 1.1, receiving the highest dose equivalents; the exposure of all other remaining tissues is neglected. After that, the weighted committed dose equivalent in each target organ is calculated by multiplying the specific committed dose equivalent with respective weights.

The weighted doses are then compared with the maximum, and if any of the target organ or tissue has a weighted dose less than 10% of the maximum, it is neglected.

The committed dose equivalent assigned to the "Remainder" as a variable REMDR is the maximum committed dose equivalent in any target or tissue which is not included in the GI model, Table 1.1, and the metabolic model. The metabolic model is checked by using the data file "RETENT". A weighting factor WTF is determined by the number of organs, which are not eliminated under the 10% rule or included in the above categories, which also qualify for a weighting factor of 0.06. In the event of no such organ or tissues, no committed dose equivalent,

or weighted committed dose equivalent WREMDR which is merely the product of REMDR and WTF, is given for remainder tissues.

The annual limit on intake for occupational exposure is calcualted as the greatest value which satisfies both the stochastic and non-stochastic limit set forth by the Commission in ICRP-30. If the non-stochastic limit overrides the stochastic, then the value that meets both the criteria are reported with the particular organ or tissue concerned.

With the value of ALI, the derived air concentration is then calculated in the case of inhalation, and all these values returned to the main program.

3.4.21 SUBMER FORTRAN:

This is the third possible route from the subroutine "ICRP" when the value of integer variable INTAKE equals 3. This subroutine opens data files "LIST" and "NOBLE" for dose equivalent rate in target organs from submersion in a semi-infinite cloud of radioactive noble gas or elemental tritium.

The arguments are:

WORD - Identification of the radionuclide.

HRATE(24) - A vector of length 24, it represents the dose equivalent rate in target organs or tissues from submersion in unit concentration of the isotope.

DER - A real variable representating derived air concentration (DAC).

RISK - A real variable that describes derived air concentration when determined by the non-stochastic limit.

ORGAN - An integer variable which gives the organ number when DAC is determined by consideration of non-stochastic effects.

A search is done in data file "LIST" by comparing the variable WORD with the nuclides in the file. In the event of a proper match, a record number beside the identification of nuclide is retrieved. This record number is the pointer to dose equivalent rates and DAC for that nuclide in data file "EXCEPT". After retrieval of these quantities, the values are returned to the subroutine "ICRP" which directs them to the main program "DOSE".

The results from the above subroutine are then written onto the file FFILE(2) named by the user. After that according to the data input in earlier screens, the program is either stopped automatically, returned to the fourth screen for more data entry or manual stop, or reads more data from the input file.

3.5 RESULTS AND DISCUSSION

Sample calculations of specific effective energy in a target organ from each transformation in a source organ is shown in Table 3.2, 3.3, and 3.4 for radionuclides ^{131}I, ^{113m}In, and ^{121}Te respectively. These radionuclides were chosen due to their different modes of radioactive decay. ^{131}I decays by emission of a beta particle into ^{131}Xe. ^{121}Te decays by positron emission into ^{121}Sb, and ^{113m}In goes through

isomeric transition from metastable to stable state by emission of gamma radiation.

Results of calculations of specific committed dose equivalents, along with the annual limits of intake, are presented in Tables 3.5 - 3.13 for selected radionuclides. Both modes of intake, ingestion and inhalation are considered in these tables. These results are compared against the published values of the ICRP-30 in Tables 3.14 - 3.17 for a few radionuclides. The ICRP-30 selects data for inclusion in the tables by applying the 10% rule for exclusion of target organs. Only those values are reported which are greater than or equal to 10% of the maximum. Hence, comparison is possible only for selected target organs in tables 3.14 - 3.17.

One can see from the Tables 3.14 - 3.17 that except for three radionuclides, namely, ^{89}Sr, ^{99m}Tc, and ^{131m}Te, all values of specific committed dose equivalents are almost identical (differences in decay schemes used by the two programs account for these minor discrepancies) to the results of ICRP-30. The differences in the exceptions are explained below:

a) ^{89}Sr: To understand the difference in the specific committed dose equivalent of the target organ red marrow, first the S-table for ^{89}Sr was checked against the one in ICRP-30. The results were identical. After that, the table of number of transformations in source organs was compared. It seemed that the difference was due to the number of transformations in the source organ mineral bone. In the case of ingestion for f1 = 0.3, the ICRP-30 reports a value of 1.7E05 for the

number of transformations per unit intake of activity in cortical bone and a value of 1.4E05 for trabecular bone as source organ. The half life of ^{89}Sr is 50.5 days. Now, according to the criteria described in Part I of Publication 30, isotopes of alkaline earth elements with radioactive half-lives greater than 15 days should be considered to be uniformly distributed throughout the volume of mineral bone, and for radionuclides assumed to be uniformly distributed throughout the volume of mineral bone, $U_{trabecular} = 0.2\ U_{mineral}$ and $U_{cortical} = 0.8\ U_{mineral}$. We can see that there is a discrepancy between stated and applied ICRP criteria since the values that are given for $U_{cortical}$, the number of transformations per unit intake of activity in the cortical bone, and $U_{trabecular}$ are not in the required ratio. The same is the case with inhalation as the mode of intake.

b) ^{99m}Tc: The difference in the results of specific committed dose equivalents for stomach wall as the target organ, both in the case of ingestion and inhalation, is expected. As described earlier, there is an anomaly in the case of isotopes of elements technetium and rhenium. The ICRP-30 reports both the stomach content and the stomach wall as source organs, and describes transformations for each of them. This is in contrast to all other radionuclides in which only the stomach content is treated as the source organ. In this program, the transformations per unit intake of activity given in the ICRP-30 for both the stomach content and the stomach wall were summed and treated as only one source organ, the stomach content.

c) ^{131}Te: The difference in this cae is due to the mode of radioactive decay. This program, as mentioned earlier, considers only one major branch, i.e.,

$$A \rightarrow B \rightarrow C \rightarrow \ldots$$

whereas, the ICRP program can consider a decay mode like

$$A \rightarrow B1,\ A \rightarrow B2, \text{ etc.}$$

For the vast majority of nuclides, this lack of feature does not affect the result appreciably since one major mode of deacy is usually predominant. But in this special case, ^{131m}Te decays 77.8% of the time into ^{131}I and 22.8% of the time into ^{131}Te. But this program can consider only the major path, i.e.,

$$^{131m}Te \rightarrow {}^{131}I$$

and thus will underpredict the results.

d) Features: As explained earlier, the whole program is divided into separate subroutines for calcuation of important quantities. The central code "DOSE" merely calls the subroutine "ICRP" with the given input data and prints the output data received from the "ICRP" in a prescribed format. The "ICRP" subroutine, in turn, calls different subroutines for calculation of different quantities according to the given input. This feature of independent subroutines allows more freedom to manipulate or modify the program, e.g., if the specific committed dose equivalent is described in any other subject other than the "reference man", the masses of source and target organs can be changed in the appropriate subroutines.

This convenience of alteration is also provided in the case of biological and radiological decay data. In the case of biological decay, each element is linked with five lines of records in the data files "BFFRAC" and "RETENT" with the unused ones as blanks, so that new data can be entered or the present data can be changed easily. Also with the use of pointers described earlier, an appendage or change in the data files on radiological decay can be done easily.

TABLE 3.2. I-131 S-FACTORS FOR THE ADULT - MeV/g

SOURCE ORGAN

TARGET ORGAN	Bladder	Stomach	SI	ULI	LLI	Kidneys	Liver	Lungs	Muscle
Bladder	5.73E-04	4.84E-07	4.02E-06	2.67E-06	7.97E-06	4.75E-07	3.50E-07	8.68E-08	2.36E-06
Stomach	4.20E-07	4.49E-04	4.66E-06	4.85E-06	2.37E-06	4.46E-06	2.54E-06	2.46E-06	1.86E-06
SI	3.61E-06	3.47E-06	2.79E-04	2.19E-05	1.21E-05	3.70E-06	2.15E-06	3.29E-07	2.06E-06
ULI	3.10E-06	4.48E-06	3.07E-05	4.89E-04	5.60E-06	3.82E-06	3.33E-06	4.33E-07	2.16E-06
LLI	9.37E-06	1.70E-06	9.19E-06	4.00E-06	7.73E-04	1.15E-06	3.81E-07	1.23E-07	2.25E-06
Kidneys	4.52E-07	4.49E-06	4.13E-06	3.63E-06	1.18E-06	7.65E-04	5.01E-06	1.30E-06	1.89E-06
Liver	3.40E-07	2.66E-06	2.42E-06	3.35E-06	4.28E-07	5.21E-06	1.39E-04	3.21E-06	1.46E-06
Lungs	5.41E-08	2.37E-06	4.02E-07	4.20E-07	1.31E-07	1.21E-06	3.22E-06	2.10E-04	1.77E-06
Muscle	2.36E-06	1.86E-06	2.06E-06	1.96E-06	2.25E-06	1.89E-06	1.47E-06	1.76E-06	5.92E-06
Ovaries	8.94E-06	6.88E-07	1.27E-05	1.60E-05	2.34E-05	1.60E-06	4.54E-07	1.88E-07	2.64E-06
Pancreas	3.71E-07	2.35E-05	2.73E-06	2.73E-06	9.66E-07	8.63E-06	5.82E-06	3.52E-06	2.38E-06
Bone Surf	8.72E-07	2.24E-06	1.16E-06	1.06E-06	1.52E-06	1.40E-06	1.07E-06	1.42E-06	1.44E-06
Red Marr.	1.91E-06	1.53E-06	3.75E-06	3.23E-06	4.58E-06	3.59E-06	1.56E-06	1.80E-06	1.95E-06
Skin	8.21E-07	7.22E-07	6.68E-07	6.86E-07	7.51E-07	8.38E-07	7.64E-07	8.54E-07	1.14E-06
Spleen	2.65E-07	1.29E-05	2.07E-06	1.73E-06	1.17E-06	1.13E-05	1.30E-06	2.92E-06	1.95E-06
Testes	6.41E-06	6.36E-08	4.86E-07	5.83E-07	2.69E-06	1.83E-07	1.44E-07	2.70E-08	1.61E-06
Thyroid	9.95E-09	1.87E-07	4.49E-08	4.85E-08	1.97E-08	1.12E-07	2.68E-07	1.41E-06	1.80E-06
Uterus	2.01E-05	1.15E-06	1.19E-05	6.07E-06	8.19E-06	1.24E-06	5.55E-07	1.30E-07	2.80E-06
Tot. Body	2.79E-06	3.17E-06	4.80E-06	3.84E-06	4.14E-06	4.96E-06	4.98E-06	4.65E-06	4.60E-06

SOURCE ORGAN

TARGET ORGAN	Ovaries	Pancreas	Trab Bone	Cort Bone	Skin	Spleen	Testes	Thyroid	Tot. Body
Bladder	8.96E-06	2.35E-07	7.61E-07	7.61E-07	7.95E-07	2.12E-07	6.60E-06	1.01E-08	5.11E-06
Stomach	1.08E-06	2.34E-05	7.71E-07	7.71E-07	8.14E-07	1.28E-05	1.16E-07	1.24E-07	5.15E-06
SI	1.57E-05	2.39E-06	1.05E-06	1.05E-06	7.00E-07	1.86E-06	6.47E-07	1.64E-08	5.35E-06
ULI	1.48E-05	2.89E-06	9.58E-07	9.58E-07	7.15E-07	1.77E-06	4.57E-07	1.65E-08	5.23E-06
LLI	1.89E-05	7.32E-07	1.33E-06	1.33E-06	7.50E-07	8.88E-07	3.71E-06	1.64E-08	5.19E-06
Kidneys	1.41E-06	8.31E-06	1.23E-06	1.23E-06	9.43E-07	1.15E-05	1.19E-07	6.43E-08	5.04E-06
Liver	8.02E-07	5.58E-06	9.22E-07	9.22E-07	8.43E-07	1.40E-06	6.61E-08	1.92E-07	4.98E-06
Lungs	1.30E-07	3.23E-06	1.31E-06	1.31E-06	8.83E-07	2.93E-06	1.88E-08	1.36E-06	4.71E-06
Muscle	2.64E-06	2.39E-06	1.44E-06	1.44E-06	1.14E-06	1.95E-06	1.61E-06	1.80E-06	4.60E-06
Ovaries	2.40E-02	5.09E-07	1.23E-06	1.23E-06	5.20E-07	1.12E-06	0.00E-01	1.94E-08	5.03E-06
Pancreas	7.28E-07	3.43E-03	1.30E-06	1.30E-06	7.68E-07	2.54E-05	7.47E-08	1.12E-07	5.24E-06
Bone Surf	1.37E-06	1.34E-06	3.87E-04	3.86E-04	1.14E-06	1.11E-06	9.35E-07	1.05E-06	4.80E-06
Red Marr.	4.65E-06	2.55E-06	6.78E-05	4.29E-06	1.07E-06	1.66E-06	7.53E-07	1.16E-06	5.05E-06
Skin	6.62E-07	6.38E-07	1.08E-06	1.08E-06	6.98E-05	7.74E-07	2.04E-06	1.12E-06	3.86E-06
Spleen	8.43E-07	2.54E-05	1.02E-06	1.02E-06	8.40E-07	1.26E-03	1.11E-07	1.71E-07	5.09E-06
Testes	0.00E-01	9.43E-08	7.95E-07	7.95E-07	1.25E-06	1.13E-07	5.60E-03	3.46E-09	4.79E-06
Thyroid	1.94E-08	2.20E-07	1.34E-06	1.34E-06	1.07E-06	1.80E-07	3.45E-09	1.03E-02	4.53E-06
Uterus	2.55E-05	8.42E-07	8.11E-07	8.11E-07	6.72E-07	5.91E-07	0.00E-01	1.83E-08	5.28E-06
Tot. Body	5.39E-06	5.34E-06	4.63E-06	4.63E-06	3.88E-06	4.97E-06	4.59E-06	4.44E-06	4.62E-06

TABLE 3.3. IN-113M S-FACTORS FOR THE ADULT - MeV/g

SOURCE ORGAN

TARGET ORGAN	Bladder	Stomach	SI	ULI	LLI	Kidneys	Liver	Lungs	Muscle
Bladder	3.98E-04	3.30E-07	2.79E-06	1.78E-06	5.40E-06	3.17E-07	2.48E-07	5.82E-08	1.61E-06
Stomach	2.72E-07	3.12E-04	3.15E-06	3.32E-06	1.61E-06	3.01E-06	1.71E-06	1.67E-06	1.28E-06
SI	2.42E-06	2.35E-06	1.94E-04	1.53E-05	8.44E-06	2.49E-06	1.45E-06	2.21E-07	1.40E-06
ULI	2.11E-06	3.05E-06	2.23E-05	3.39E-04	3.92E-06	2.57E-06	2.27E-06	2.93E-07	1.48E-06
LLI	6.39E-06	1.14E-06	6.47E-06	2.74E-06	5.35E-04	7.74E-07	2.60E-07	8.08E-08	1.54E-06
Kidneys	3.08E-07	3.02E-06	2.79E-06	2.43E-06	7.82E-07	5.33E-04	3.40E-06	8.81E-07	1.30E-06
Liver	2.29E-07	1.80E-06	1.63E-06	2.26E-06	2.87E-07	3.55E-06	9.70E-05	2.20E-06	1.00E-06
Lungs	3.54E-08	1.62E-06	2.72E-07	2.81E-07	8.56E-08	8.12E-07	2.18E-06	1.46E-04	1.23E-06
Muscle	1.62E-06	1.27E-06	1.41E-06	1.34E-06	1.53E-06	1.30E-06	1.00E-06	1.23E-06	4.10E-06
Ovaries	6.10E-06	4.19E-07	8.63E-06	1.13E-05	1.63E-05	1.05E-06	2.72E-07	1.26E-07	1.83E-06
Pancreas	2.46E-07	1.62E-05	1.84E-06	1.80E-06	6.50E-07	5.83E-06	3.99E-06	2.41E-06	1.65E-06
Bone Surf	5.81E-07	1.44E-06	7.82E-07	7.14E-07	1.05E-06	9.51E-07	7.25E-07	9.74E-07	9.78E-07
Red Marr.	1.27E-06	1.03E-06	2.54E-06	2.20E-06	3.20E-06	2.44E-06	1.05E-06	1.23E-06	1.36E-06
Skin	5.54E-07	4.90E-07	4.49E-07	4.64E-07	5.08E-07	5.72E-07	5.18E-07	5.80E-07	7.97E-07
Spleen	1.75E-07	8.74E-06	1.40E-06	1.15E-06	7.81E-07	7.78E-06	8.68E-07	1.98E-06	1.34E-06
Testes	4.35E-06	3.52E-08	3.19E-07	3.95E-07	1.84E-06	1.23E-07	9.14E-08	1.79E-08	1.10E-06
Thyroid	6.53E-09	1.25E-07	3.00E-08	3.24E-08	1.31E-08	7.53E-08	1.78E-07	9.49E-07	1.27E-06
Uterus	1.38E-05	7.72E-07	8.12E-06	4.07E-06	5.49E-06	8.27E-07	3.76E-07	8.58E-08	1.91E-06
Tot. Body	1.94E-06	2.20E-06	3.32E-06	2.67E-06	2.87E-06	3.44E-06	3.45E-06	3.23E-06	3.19E-06

SOURCE ORGAN

TARGET ORGAN	Ovaries	Pancreas	Trab Bone	Cort Bone	Skin	Spleen	Testes	Thyroid	Tot. Body
Bladder	6.03E-06	1.62E-07	5.26E-07	5.26E-07	5.33E-07	1.31E-07	4.46E-06	6.61E-09	3.54E-06
Stomach	7.31E-07	1.63E-05	5.22E-07	5.22E-07	5.52E-07	8.78E-06	8.18E-08	8.54E-08	3.57E-06
SI	1.09E-05	1.60E-06	7.07E-07	7.07E-07	4.71E-07	1.25E-06	4.38E-07	9.34E-09	3.70E-06
ULI	1.05E-05	1.94E-06	6.41E-07	6.41E-07	4.81E-07	1.19E-06	3.01E-07	9.60E-09	3.63E-06
LLI	1.34E-05	4.89E-07	8.92E-07	8.92E-07	5.04E-07	6.01E-07	2.53E-06	1.09E-08	3.60E-06
Kidneys	9.55E-07	5.63E-06	8.16E-07	8.16E-07	6.43E-07	7.94E-06	7.91E-08	4.03E-08	3.48E-06
Liver	5.37E-07	3.78E-06	6.22E-07	6.22E-07	5.73E-07	9.38E-07	4.23E-08	1.29E-07	3.45E-06
Lungs	8.66E-08	2.18E-06	8.83E-07	8.83E-07	5.98E-07	2.00E-06	1.21E-08	9.11E-07	3.28E-06
Muscle	1.83E-06	1.65E-06	9.76E-07	9.76E-07	7.95E-07	1.34E-06	1.10E-06	1.27E-06	3.19E-06
Ovaries	1.66E-02	3.13E-07	8.48E-07	8.48E-07	3.30E-07	7.90E-07	0.00E-01	1.28E-08	3.50E-06
Pancreas	4.73E-07	2.38E-03	8.70E-07	8.70E-07	5.22E-07	1.78E-05	4.61E-08	7.47E-08	3.63E-06
Bone Surf	9.27E-07	8.99E-07	3.40E-05	2.32E-05	7.96E-07	7.50E-07	6.24E-07	7.07E-07	3.35E-06
Red Marr.	3.15E-06	1.71E-06	4.69E-05	3.27E-06	7.45E-07	1.12E-06	5.01E-07	7.77E-07	3.52E-06
Skin	4.45E-07	4.28E-07	7.41E-07	7.41E-07	4.82E-05	5.25E-07	1.45E-06	7.71E-07	2.67E-06
Spleen	5.73E-07	1.78E-05	6.94E-07	6.94E-07	5.63E-07	8.81E-04	8.07E-08	1.12E-07	3.52E-06
Testes	0.00E-01	6.02E-08	5.29E-07	5.29E-07	8.69E-07	7.59E-08	3.89E-03	2.22E-09	3.33E-06
Thyroid	1.29E-08	1.56E-07	9.38E-07	9.38E-07	7.42E-07	1.21E-07	2.22E-09	7.17E-03	3.15E-06
Uterus	1.75E-05	5.66E-07	5.29E-07	5.29E-07	4.48E-07	3.91E-07	0.00E-01	1.21E-08	3.61E-06
Tot. Body	3.73E-06	3.69E-06	3.21E-06	3.21E-06	2.68E-06	3.44E-06	3.18E-06	3.08E-06	3.21E-06

TABLE 3.4. TE-121 S-FACTORS FOR THE ADULT - MeV/g

SOURCE ORGAN

TARGET ORGAN	Bladder	Stomach	SI	ULI	LLI	Kidneys	Liver	Lungs	Muscle
Bladder	1.83E-04	8.85E-07	6.30E-06	3.73E-06	1.10E-05	7.53E-07	6.30E-07	1.46E-07	3.55E-06
Stomach	6.65E-07	1.30E-04	6.70E-06	7.23E-06	3.46E-06	6.51E-06	3.68E-06	3.66E-06	2.81E-06
SI	5.06E-06	5.09E-06	7.77E-05	3.37E-05	1.84E-05	5.32E-06	3.06E-06	5.41E-07	3.07E-06
ULI	4.46E-06	6.44E-06	4.96E-05	1.13E-04	8.56E-06	5.56E-06	4.98E-06	7.40E-07	3.25E-06
LLI	1.39E-05	2.46E-06	1.41E-05	6.10E-06	1.45E-04	1.68E-06	6.07E-07	1.53E-07	3.36E-06
Kidneys	7.30E-07	6.36E-06	6.14E-06	5.28E-06	1.61E-06	1.95E-04	7.35E-06	2.01E-06	2.90E-06
Liver	5.47E-07	3.92E-06	3.51E-06	4.80E-06	6.68E-07	7.83E-06	6.01E-05	4.76E-06	2.23E-06
Lungs	1.00E-07	3.64E-06	6.48E-07	6.67E-07	2.08E-07	1.85E-06	4.64E-06	4.20E-05	2.75E-06
Muscle	3.55E-06	2.81E-06	3.08E-06	2.94E-06	3.36E-06	2.90E-06	2.24E-06	2.75E-06	3.32E-06
Ovaries	1.19E-05	1.19E-06	1.81E-05	2.44E-05	3.37E-05	2.31E-06	4.93E-07	2.97E-07	4.03E-06
Pancreas	5.04E-07	3.54E-05	3.98E-06	3.49E-06	1.44E-06	1.29E-05	9.28E-06	5.32E-06	3.65E-06
Bone Surf	1.13E-06	1.20E-06	1.57E-06	1.44E-06	2.20E-06	1.99E-06	1.49E-06	2.07E-06	2.17E-06
Red Marr.	2.42E-06	2.04E-06	5.08E-06	4.40E-06	6.76E-06	5.06E-06	2.13E-06	2.59E-06	2.89E-06
Skin	1.28E-06	1.16E-06	1.04E-06	1.08E-06	1.15E-06	1.31E-06	1.18E-06	1.33E-06	1.87E-06
Spleen	4.40E-07	1.88E-05	3.02E-06	2.39E-06	1.83E-06	1.69E-05	1.95E-06	4.27E-06	2.98E-06
Testes	9.84E-06	7.87E-08	7.29E-07	1.00E-06	3.88E-06	2.92E-07	2.51E-07	4.95E-08	2.46E-06
Thyroid	1.98E-08	2.96E-07	7.99E-08	8.55E-08	3.70E-08	1.86E-07	3.55E-07	2.35E-06	2.87E-06
Uterus	3.00E-05	1.72E-06	1.74E-05	8.72E-06	1.09E-05	1.60E-06	8.31E-07	1.88E-07	4.08E-06
Tot. Body	3.84E-06	3.68E-06	4.10E-06	3.96E-06	3.96E-06	3.60E-06	3.63E-06	3.14E-06	3.08E-06

SOURCE ORGAN

TARGET ORGAN	Ovaries	Pancreas	Treb Bone	Cort Bone	Skin	Spleen	Testes	Thyroid	Tot. Body
Bladder	1.31E-05	3.61E-07	1.21E-06	1.21E-06	1.27E-06	3.07E-07	9.99E-06	2.00E-08	3.89E-06
Stomach	1.59E-06	3.51E-05	1.12E-06	1.12E-06	1.28E-06	1.94E-05	2.17E-07	2.48E-07	3.74E-06
SI	2.40E-05	3.39E-06	1.57E-06	1.57E-06	1.08E-06	2.66E-06	1.02E-06	2.16E-08	4.15E-06
ULI	2.31E-05	4.15E-06	1.37E-06	1.37E-06	1.15E-06	2.70E-06	6.34E-07	2.81E-08	4.10E-06
LLI	2.97E-05	1.03E-06	1.89E-06	1.89E-06	1.18E-06	1.33E-06	5.39E-06	3.10E-08	4.14E-06
Kidneys	2.16E-06	1.21E-05	1.83E-06	1.83E-06	1.49E-06	1.72E-05	2.06E-07	1.11E-07	3.71E-06
Liver	1.18E-06	8.02E-06	1.38E-06	1.38E-06	1.33E-06	2.05E-06	1.11E-07	3.13E-07	3.70E-06
Lungs	2.26E-07	4.65E-06	1.93E-06	1.93E-06	1.35E-06	4.37E-06	3.11E-08	2.07E-06	3.31E-06
Muscle	4.03E-06	3.65E-06	2.17E-06	2.17E-06	1.86E-06	2.97E-06	2.46E-06	2.86E-06	3.09E-06
Ovaries	2.81E-03	8.67E-07	2.11E-06	2.11E-06	6.54E-07	1.92E-06	0.00E-01	3.69E-08	3.52E-06
Pancreas	1.15E-06	6.28E-04	1.77E-06	1.77E-06	1.11E-06	4.01E-05	8.74E-08	1.28E-07	3.67E-06
Bone Surf	1.87E-06	1.82E-06	1.99E-05	1.97E-05	1.79E-06	1.56E-06	1.28E-06	1.48E-06	3.36E-06
Red Marr.	6.32E-06	3.42E-06	1.02E-05	7.49E-06	1.66E-06	2.25E-06	1.01E-06	1.63E-06	3.69E-06
Skin	1.02E-06	9.87E-07	1.70E-06	1.70E-06	7.44E-06	1.24E-06	3.32E-06	1.76E-06	1.96E-06
Spleen	1.31E-06	3.96E-05	1.65E-06	1.65E-06	1.32E-06	3.43E-04	2.36E-07	2.64E-07	3.77E-06
Testes	0.00E-01	1.34E-07	1.13E-06	1.13E-06	1.79E-06	1.87E-07	1.05E-03	7.39E-09	3.86E-06
Thyroid	3.69E-08	3.22E-07	2.02E-06	2.02E-06	1.66E-06	2.88E-07	7.38E-09	1.55E-03	3.11E-06
Uterus	3.62E-05	1.20E-06	1.20E-06	1.20E-06	1.14E-06	9.29E-07	0.00E-01	3.50E-08	3.84E-06
Tot. Body	4.20E-06	4.12E-06	3.12E-06	3.12E-06	2.01E-06	3.61E-06	3.05E-06	2.85E-06	3.11E-06

TABLE 3.5 Specific committed dose equivalents (Sv/Bq) for selected ingested radionuclides and their daughters. Annual limits of intake are the lesser of the values for stochastic and non-stochastic risks.

Nuclide	Na-24	P-32	K-40	Cr-51	Cr-51	Mn-54	Mn-56	Fe-55	Fe-59	Co-58	Co-60
f1	1.0	0.8	1.0	0.1	0.01	0.1	0.1	0.1	0.1	0.05	0.05
ALI (Bq)	1.3E+08	2.4E+07	1.1E+07	1.4E+09	1.3E+09	6.8E+07	2.0E+08	3.2E+08	2.8E+07	6.4E+07	1.8E+07
Lungs	2.6E-10	6.6E-10	4.3E-09	4.3E-12	9.5E-13	2.3E-10	8.8E-12	1.0E-10	6.4E-10	8.5E-11	8.8E-10
Thyroid	2.6E-10	6.6E-10	4.3E-09	3.6E-12	4.2E-13	1.3E-10	2.4E-12	1.0E-10	6.1E-10	6.3E-11	7.9E-10
Testes	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01
Ovaries	3.4E-10	6.6E-10	4.5E-09	4.0E-11	3.9E-11	9.5E-10	8.5E-11	1.0E-10	1.7E-09	1.0E-09	3.2E-09
Red Marrow	3.7E-10	7.8E-09	4.3E-09	1.3E-11	8.7E-12	5.1E-10	2.4E-11	1.0E-10	8.5E-10	2.6E-10	1.3E-09
Stomach wall	1.2E-09	1.5E-09	4.8E-09	1.9E-11	1.6E-11	4.1E-10	9.0E-10	1.1E-10	1.1E-09	3.9E-10	1.6E-09
SI + contents	3.2E-10	1.1E-09	4.4E-09	4.8E-11	4.6E-11	9.9E-10	1.1E-09	1.1E-10	2.1E-09	1.1E-09	3.6E-09
ULI wall	3.1E-10	3.0E-09	4.4E-09	1.2E-10	1.3E-10	1.4E-09	1.4E-09	1.9E-10	4.0E-09	2.0E-09	5.8E-09
LLI wall	3.4E-10	7.2E-09	4.4E-09	2.8E-10	3.1E-10	2.2E-09	5.3E-10	3.6E-10	8.4E-09	4.0E-09	1.1E-08
Liver	2.9E-10	6.6E-10	4.4E-09	7.0E-12	3.6E-12	1.0E-09	2.6E-11	3.3E-10	1.5E-09	2.5E-10	2.3E-09
Kidneys	3.0E-10	6.6E-10	4.4E-09	8.5E-12	5.0E-12	3.8E-10	3.2E-11	1.0E-10	9.1E-10	2.1E-10	1.4E-09
Bladder wall	3.0E-10	6.6E-10	4.4E-09	1.5E-11	1.2E-11	3.7E-10	2.6E-11	1.0E-10	1.1E-09	3.7E-10	1.8E-09
Muscle	2.7E-10	6.6E-10	4.3E-09	7.5E-12	4.5E-12	2.6E-10	1.8E-11	1.0E-10	7.4E-10	1.8E-10	1.1E-09
Bone Surface	4.7E-10	7.8E-09	4.3E-09	7.9E-12	3.3E-12	5.6E-10	1.1E-11	1.0E-10	6.6E-10	1.3E-10	9.4E-10
Skin	2.1E-10	6.6E-10	4.2E-09	3.9E-12	1.6E-12	1.6E-10	7.8E-12	1.0E-10	5.0E-10	8.5E-11	6.9E-10
Spleen	3.1E-10	6.6E-10	4.3E-09	7.4E-12	3.6E-12	2.7E-10	3.5E-11	5.5E-10	1.8E-09	1.7E-10	1.2E-09
Uterus	3.3E-10	6.6E-10	4.4E-09	1.9E-11	1.6E-11	5.0E-10	5.9E-11	1.0E-10	1.3E-09	4.8E-10	2.1E-09
Pancreas	4.4E-10	6.6E-10	4.4E-09	8.9E-12	5.0E-12	3.8E-10	5.6E-11	1.0E-10	9.1E-10	2.0E-10	1.3E-09
Total Body	3.0E-10	1.3E-09	4.3E-09	9.2E-12	6.2E-12	3.4E-10	3.6E-11	1.1E-10	8.0E-10	2.1E-10	1.2E-09
Remainder	4.4E-10		4.4E-09			5.0E-10				4.8E-10	2.1E-09

Nuclide	Ni-63	Ni-65	Cu-64	Zn-65	Zn-69	Br-83	Br-84	Rb-88	Rb-89	Sr-89	Sr-90
f1	0.05	0.05	0.5	0.5	0.5	1.0	1.0	1.0	1.0	0.3	0.3
ALI (Bq)	3.4E+08	3.0E+08	4.3E+08	1.3E+07	2.2E+09	1.7E+09	7.2E+08	6.8E+08	1.4E+09	2.4E+07	1.3E+06
Lungs	8.5E-11	2.8E-12	1.3E-11	3.1E-09	4.0E-13	7.1E-12	7.1E-12	2.9E-12	3.8E-12	2.3E-10	0.0E-01
Thyroid	8.5E-11	6.8E-13	1.1E-11	3.2E-09	4.0E-13	7.1E-12	5.3E-12	2.4E-12	2.3E-12	2.3E-10	0.0E-01
Testes	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01
Ovaries	8.5E-11	2.4E-11	4.8E-11	3.5E-09	4.0E-13	7.1E-12	6.8E-12	2.8E-12	3.4E-12	2.3E-10	0.0E-01
Red Marrow	8.5E-11	7.3E-12	1.9E-11	4.9E-09	4.9E-13	7.1E-12	6.3E-12	2.8E-12	4.4E-12	1.6E-09	1.3E-07
Stomach wall	1.0E-10	6.2E-10	1.7E-10	3.4E-09	2.1E-10	2.9E-10	6.9E-10	7.3E-10	3.7E-10	2.3E-10	0.0E-01
SI + contents	1.3E-10	7.3E-10	2.1E-10	4.3E-09	1.1E-10	7.1E-12	8.7E-12	3.3E-12	4.7E-12	2.3E-10	0.0E-01
ULI wall	3.7E-10	9.4E-10	6.2E-10	4.3E-09	5.9E-11	7.1E-12	9.2E-12	3.5E-12	5.3E-12	7.2E-09	4.2E-09
LLI wall	9.2E-10	3.6E-10	7.5E-10	5.0E-09	9.5E-12	7.1E-12	7.2E-12	2.9E-12	3.6E-12	2.1E-08	1.8E-08
Liver	8.5E-11	7.3E-12	3.7E-11	3.7E-09	4.0E-13	+.1E-12	7.8E-12	3.1E-12	4.1E-12	2.3E-10	0.0E-01
Kidneys	8.5E-11	1.0E-11	2.0E-11	3.9E-09	4.0E-13	7.1E-12	9.2E-12	3.4E-12	5.3E-12	2.3E-10	0.0E-01
Bladder wall	8.5E-11	8.5E-12	2.2E-11	4.1E-09	4.0E-13	7.1E-12	5.9E-12	2.6E-12	2.7E-12	2.3E-10	0.0E-01
Muscle	8.5E-11	5.6E-12	1.6E-11	3.3E-09	4.0E-13	7.1E-12	6.7E-12	2.8E-12	3.4E-12	2.3E-10	0.0E-01
Bone Surface	8.5E-11	2.9E-12	1.4E-11	4.5E-09	4.9E-13	7.1E-12	5.6E-12	2.8E-12	4.6E-12	4.3E-09	4.0E-07
Skin	8.5E-11	2.5E-12	1.1E-11	2.3E-09	4.0E-13	7.1E-12	5.3E-12	2.5E-12	2.5E-12	2.3E-10	0.0E-01
Spleen	8.5E-11	1.2E-11	1.9E-11	3.6E-09	4.0E-13	7.2E-12	1.6E-11	5.3E-12	1.1E-11	2.3E-10	0.0E-01
Uterus	8.5E-11	1.9E-11	2.8E-11	4.7E-09	4.0E-13	7.1E-12	7.0E-12	2.8E-12	3.3E-12	2.3E-10	0.0E-01
Pancreas	8.5E-11	1.8E-11	5.4E-11	3.6E-09	4.0E-13	7.3E-12	2.5E-11	7.6E-12	1.8E-11	2.3E-10	0.0E-01
Total Body	8.8E-11	1.8E-11	2.2E-11	3.4E-09	2.0E-12	7.7E-12	8.4E-12	4.5E-12	4.6E-12	7.1E-10	4.0E-08
Remainder				4.7E-09							4.0E-08

TABLE 3.6 Specific committed dose equivalents (Sv/Bq) for selected ingested radionuclides and their daughters. Annual limits of intake are the lesser of the values for stochastic and non-stochastic risks.

Nuclide	Y-90	Y-91m	Y-91	Y-92	Y-93	Zr-95	Zr-97	Nb-95	Mo-99	Tc-99m	Tc-101
f1	0.0001	0.0001	0.0001	0.0001	0.0001	0.002	0.002	0.01	0.8	0.8	0.8
ALI (Bq)	1.6E+07	4.8E+09	1.7E+07	9.9E+07	4.1E+07	5.4E+07	2.3E+07	8.2E+07	6.0E+07	3.5E+09	3.3E+09
Lungs	1.2E-14	1.3E-12	1.6E-13	1.4E-12	8.7E-13	2.3E-11	1.8E-11	2.8E-11	2.0E-10	2.9E-12	3.3E-13
Thyroid	1.2E-14	1.2E-13	8.9E-14	1.8E-13	1.3E-13	8.2E-12	2.7E-12	1.2E-11	1.7E-10	8.4E-11	2.6E-14
Testes	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01
Ovaries	1.2E-14	6.9E-12	3.5E-12	2.0E-11	2.2E-11	8.2E-10	6.3E-10	8.1E-10	2.3E-10	9.5E-12	5.1E-13
Red Marrow	3.6E-13	2.2E-12	4.4E-12	4.9E-12	4.9E-12	2.1E-10	1.3E-10	2.0E-10	4.8E-10	6.0E-12	3.4E-13
Stomach wall	1.1E-09	4.9E-11	6.9E-10	1.4E-09	1.3E-09	3.6E-10	1.2E-09	2.8E-10	6.7E-10	3.9E-11	1.5E-10
SI + contents	2.6E-09	3.1E-11	1.7E-09	2.0E-09	2.5E-09	1.1E-09	3.4E-09	9.2E-10	4.7E-10	2.2E-11	2.3E-11
ULI wall	1.4E-08	3.1E-11	1.0E-08	3.3E-09	7.9E-09	3.1E-09	1.2E-08	1.9E-09	1.5E-09	3.6E-11	1.6E-12
LLI wall	3.1E-08	2.4E-11	3.0E-08	1.7E-09	8.7E-09	7.8E-09	1.8E-08	4.0E-09	3.2E-09	2.4E-11	5.3E-13
Liver	3.5E-13	2.5E-12	4.1E-12	4.6E-12	3.6E-12	7.9E-11	8.1E-11	8.4E-11	2.7E-09	5.7E-12	4.4E-13
Kidneys	1.2E-14	3.9E-12	5.8E-13	6.5E-12	4.8E-12	1.1E-10	1.1E-10	1.4E-10	2.7E-09	4.9E-12	7.6E-13
Bladder wall	1.2E-14	2.3E-12	1.2E-12	5.6E-12	6.5E-12	2.4E-10	1.8E-10	2.4E-10	1.9E-10	4.3E-12	1.9E-13
Muscle	1.2E-14	1.8E-12	5.2E-13	3.5E-12	3.1E-12	1.1E-10	8.2E-11	1.1E-10	1.9E-10	3.3E-12	3.2E-13
Bone Surface	3.6E-13	8.7E-13	4.0E-12	1.8E-12	1.8E-12	4.8E-10	4.6E-11	2.9E-10	7.6E-10	4.1E-12	4.2E-13
Skin	1.2E-14	7.1E-13	2.5E-13	1.4E-12	1.2E-12	4.2E-11	3.1E-11	4.4E-11	1.6E-10	1.8E-12	1.2E-13
Spleen	1.2E-14	6.4E-12	4.7E-13	6.5E-12	3.9E-12	8.9E-11	8.1E-11	1.1E-10	2.0E-10	6.2E-12	1.8E-12
Uterus	1.2E-14	5.8E-12	1.6E-12	1.3E-11	1.1E-11	3.3E-10	2.9E-10	3.4E-10	2.1E-10	6.9E-12	5.5E-13
Pancreas	1.2E-14	1.1E-11	5.3E-13	1.0E-11	5.7E-12	1.1E-10	1.1E-10	1.1E-10	2.4E-10	9.3E-12	3.3E-12
Total Body	1.4E-10	2.5E-12	1.2E-10	3.9E-11	7.3E-11	1.5E-10	2.0E-10	1.4E-10	3.0E-10	4.0E-12	9.1E-13
Remainder		1.1E-11								9.3E-12	

Nuclide	Ru-103	Ru-105	Ru-106	Ag-110m	Te-125m	Te-127	Te-129m	Te-129	Te-131m	Te-131	Te-132
f1	0.05	0.05	0.05	0.05	0.2	0.2	0.2	0.2	0.2	0.2	0.2
ALI (Bq)	6.9E+07	1.9E+08	7.1E+06	1.7E+07	3.5E+07	2.7E+08	1.9E+07	9.7E+08	1.2E+07	1.2E+08	8.4E+06
Lungs	7.4E-11	6.1E-12	1.4E-09	8.3E-10	4.8E-11	2.9E-12	1.6E-10	4.9E-13	4.4E-11	3.3E-12	3.1E-10
Thyroid	6.2E-11	1.7E-12	1.4E-09	1.8E-10	4.3E-11	2.9E-12	1.6E-10	3.4E-13	4.3E-08	4.3E-09	6.0E-08
Testes	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01
Ovaries	5.9E-10	9.5E-11	1.6E-09	3.0E-09	1.3E-10	4.0E-12	2.4E-10	1.6E-12	6.7E-10	1.5E-11	4.5E-10
Red Marrow	1.7E-10	2.3E-11	1.5E-09	9.4E-10	1.4E-09	6.4E-12	3.4E-09	7.5E-13	1.7E-10	6.1E-12	3.5E-10
Stomach wall	3.1E-10	5.0E-10	3.1E-09	1.5E-09	2.1E-10	2.4E-10	6.3E-10	4.0E-10	1.6E-10	6.3E-10	3.3E-10
SI + contents	8.6E-10	7.9E-10	5.5E-09	3.5E-09	4.2E-10	3.9E-10	1.5E-09	2.7E-10	1.2E-09	5.6E-10	4.1E-10
ULI wall	2.5E-09	1.6E-09	2.5E-08	5.9E-09	1.9E-09	1.2E-09	8.6E-09	1.9E-10	2.9E-09	5.4E-10	3.7E-10
LLI wall	6.3E-09	1.2E-09	7.1E-08	1.1E-08	5.4E-09	1.2E-09	2.5E-08	3.6E-11	4.8E-09	9.3E-12	3.6E-09
Liver	1.1E-10	1.9E-11	1.4E-09	8.5E-09	4.6E-11	3.0E-12	1.6E-10	6.7E-13	1.0E-10	5.2E-12	3.3E-10
Kidneys	1.3E-10	2.7E-11	1.5E-09	1.5E-09	4.6E-11	3.1E-12	1.7E-10	8.7E-13	1.3E-10	7.2E-12	3.3E-10
Bladder wall	2.3E-10	2.7E-11	1.5E-09	1.0E-09	5.2E-11	3.2E-12	1.7E-10	6.6E-13	2.2E-10	4.8E-12	3.9E-10
Muscle	1.2E-10	1.6E-11	1.4E-09	7.5E-10	5.0E-11	3.0E-12	1.7E-10	6.0E-13	1.1E-10	4.8E-12	3.2E-10
Bone Surface	9.8E-11	9.0E-12	1.4E-09	4.9E-10	1.4E-08	6.4E-12	7.7E-09	5.6E-13	7.4E-11	3.5E-12	3.1E-10
Skin	6.9E-11	6.4E-12	1.4E-09	3.7E-10	4.2E-11	2.9E-12	1.6E-10	4.1E-13	5.3E-11	2.6E-12	2.4E-10
Spleen	1.2E-10	2.5E-11	1.5E-09	7.1E-10	4.7E-11	3.1E-12	1.6E-10	1.2E-12	9.0E-11	9.1E-12	3.3E-10
Uterus	2.7E-10	5.5E-11	1.5E-09	1.4E-09	5.7E-11	3.4E-12	1.8E-10	1.2E-12	3.2E-10	1.1E-11	4.0E-10
Pancreas	1.3E-10	3.8E-11	1.5E-09	1.6E-09	4.8E-11	3.2E-12	1.6E-10	1.9E-12	1.0E-10	1.4E-11	3.2E-10
Total Body	1.5E-10	3.2E-11	1.7E-09	1.0E-09	1.9E-10	1.4E-11	5.4E-10	4.6E-12	1.6E-10	1.4E-11	3.4E-10
Remainder				1.6E-09							

TABLE 3.7 Specific committed dose equivalents (Sv/Bq) for selected ingested radionuclides and their daughters. Annual limits of intake are the lesser of the values for stochastic and non-stochastic risks.

Nuclide	Np-239
f1	0.01
ALI (Bq)	6.2E+07
Lungs	2.4E-12
Thyroid	2.8E-13
Testes	0.0E-01
Ovaries	1.6E-10
Red Marrow	5.6E-11
Stomach wall	3.3E-10
SI + contents	8.2E-10
ULI wall	3.7E-09
LLI wall	8.1E-09
Liver	5.4E-11
Kidneys	2.1E-11
Bladder wall	4.7E-11
Muscle	1.7E-11
Bone Surface	1.5E-10
Skin	5.1E-12
Spleen	1.5E-11
Uterus	6.8E-11
Pancreas	2.2E-11
Total Body	5.9E-11
Remainder	

TABLE 3.8 Specific committed dose equivalents (Sv/Bq) for selected inhaled radionuclides and their daughters. Annual limits of intake are the lesser of the values for stochastic and non-stochastic risks.

Nuclide	Na-24	P-32	P-32	K-40	Cr-51	Cr-51	Cr-51	Mn-54	Mn-54	Mn-56	Mn-56
f1	1.0	0.8	0.8	1.0	0.01	0.01	0.01	0.1	0.1	0.1	0.1
Class	D	W	D	D	D	W	Y	D	W	D	W
ALI (Bq)	1.9E+08	1.4E+07	3.5E+07	1.7E+07	1.7E+09	8.7E+08	7.0E+08	3.6E+07	3.2E+07	5.7E+08	7.8E+08
DAC (Bq/m^3)	7.9E+04	5.9E+03	1.4E+04	7.1E+03	7.0E+05	3.6E+05	2.9E+05	1.5E+04	1.3E+04	2.4E+05	3.2E+05
Lungs	1.2E-09	2.6E-08	2.5E-09	4.1E-09	3.7E-11	3.7E-10	5.2E-10	1.2E-09	6.6E-09	4.4E-10	5.4E-10
Thyroid	1.5E-10	3.4E-10	4.8E-10	2.7E-09	1.7E-11	9.4E-12	9.3E-12	6.5E-10	7.4E-10	1.2E-11	6.2E-12
Testes	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01
Ovaries	1.8E-10	3.4E-10	4.8E-10	2.8E-09	2.7E-11	2.2E-11	2.0E-11	8.9E-10	7.1E-10	2.2E-11	9.4E-12
Red Marrow	2.1E-10	4.0E-09	5.8E-09	2.7E-09	3.1E-11	1.8E-11	1.7E-11	1.8E-09	1.1E-09	2.3E-11	1.0E-11
Stomach wall	3.1E-10	6.7E-10	6.1E-10	2.8E-09	2.4E-11	2.2E-11	2.4E-11	9.4E-10	1.2E-09	1.4E-10	7.6E-11
SI + contents	1.7E-10	5.0E-10	5.5E-10	2.8E-09	3.0E-11	2.7E-11	2.5E-11	1.1E-09	8.4E-10	1.6E-10	8.2E-11
ULI wall	1.6E-10	1.3E-09	8.5E-10	2.6E-09	4.1E-11	6.1E-11	6.3E-11	1.3E-09	1.1E-09	2.0E-10	1.1E-10
LLI wall	1.7E-10	3.1E-09	1.5E-09	2.6E-09	6.6E-11	1.4E-10	1.5E-10	1.2E-09	1.3E-09	8.4E-11	4.3E-11
Liver	1.9E-10	3.4E-10	4.8E-10	2.6E-09	2.1E-11	2.1E-11	2.4E-11	4.6E-09	2.5E-09	4.0E-11	1.7E-11
Kidneys	1.6E-10	3.4E-10	4.8E-10	2.7E-09	2.1E-11	1.2E-11	1.1E-11	1.4E-09	8.9E-10	1.7E-11	8.0E-12
Bladder wall	1.6E-10	3.4E-10	4.6E-10	2.8E-09	2.2E-11	9.2E-12	6.4E-12	7.2E-10	3.8E-10	1.3E-11	4.7E-12
Muscle	1.6E-10	3.4E-10	4.8E-10	2.7E-09	1.9E-11	1.3E-11	1.4E-11	9.1E-10	8.6E-10	1.5E-11	7.8E-12
Bone Surface	2.6E-10	4.0E-09	5.8E-09	2.7E-09	2.6E-11	1.3E-11	1.2E-11	2.5E-09	1.2E-09	2.0E-11	8.2E-12
Skin	1.2E-10	3.4E-10	4.8E-10	2.6E-09	1.3E-11	7.0E-12	6.6E-12	6.2E-10	4.9E-10	1.1E-11	4.8E-12
Spleen	1.8E-10	3.4E-10	4.8E-10	2.7E-09	2.2E-11	1.9E-11	2.2E-11	9.2E-10	1.2E-09	2.0E-11	1.2E-11
Uterus	1.7E-10	3.4E-10	4.8E-10	2.6E-09	2.4E-11	1.2E-11	8.6E-12	9.2E-10	4.9E-10	1.9E-11	7.6E-12
Pancreas	2.3E-10	3.4E-10	4.6E-10	2.7E-09	2.4E-11	2.3E-11	2.6E-11	1.4E-09	1.4E-09	2.4E-11	1.4E-11
Total Body	1.9E-10	1.0E-09	9.7E-10	2.7E-09	2.0E-11	1.9E-11	2.2E-11	1.1E-09	9.9E-10	2.4E-11	1.7E-11
Remainder				2.8E-09	2.4E-11			1.4E-09	1.4E-09		

Nuclide	Fe-55	Fe-55	Fe-59	Fe-59	Co-58	Co-58	Co-60	Co-60	Ni-63	Ni-63	Ni-65
f1	0.1	0.1	0.1	0.1	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Class	D	W	D	W	W	Y	W	Y	W	D	W
ALI (Bq)	7.5E+07	1.4E+08	1.3E+07	1.9E+07	4.1E+07	2.6E+07	6.7E+06	1.2E+06	9.8E+07	5.9E+07	1.1E+09
DAC (Bq/m^3)	3.1E+04	6.3E+04	5.2E+03	7.9E+03	1.7E+04	1.1E+04	2.8E+03	5.0E+02	4.1E+04	2.5E+04	4.6E+05
Lungs	5.1E-10	1.1E-09	3.5E-09	1.4E-08	7.9E-09	1.6E-08	3.6E-08	3.4E-07	3.1E-09	8.8E-10	3.8E-10
Thyroid	4.9E-10	1.7E-10	3.0E-09	1.2E-09	5.5E-10	8.7E-10	3.7E-09	1.6E-08	2.5E-10	8.2E-10	2.3E-12
Testes	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01
Ovaries	4.9E-10	1.7E-10	3.3E-09	1.4E-09	6.5E-10	6.2E-10	4.0E-09	4.8E-09	2.5E-10	8.2E-10	3.3E-12
Red Marrow	4.9E-10	1.7E-10	3.2E-09	1.3E-09	6.3E-10	9.2E-10	4.2E-09	1.7E-08	2.5E-10	8.2E-10	3.0E-12
Stomach wall	4.9E-10	1.7E-10	3.4E-09	1.7E-09	9.0E-10	1.4E-09	5.4E-09	2.7E-08	2.6E-10	8.3E-10	4.8E-11
SI + contents	4.9E-10	1.7E-10	3.9E-09	1.7E-09	7.8E-10	7.5E-10	4.7E-09	7.1E-09	2.7E-10	8.3E-10	5.5E-11
ULI wall	5.0E-10	2.1E-10	4.1E-09	2.6E-09	1.2E-09	1.2E-09	5.9E-09	9.7E-09	3.9E-10	8.7E-10	7.1E-11
LLI wall	5.3E-10	3.0E-10	4.6E-09	4.5E-09	2.0E-09	2.0E-09	8.1E-09	7.9E-09	6.7E-10	9.5E-10	2.8E-11
Liver	1.6E-09	5.5E-10	7.1E-09	2.7E-09	1.1E-09	1.6E-09	9.2E-09	3.4E-08	2.5E-10	8.2E-10	4.1E-12
Kidneys	4.9E-10	1.7E-10	3.8E-09	1.4E-09	5.7E-10	7.6E-10	4.5E-09	1.6E-08	2.5E-10	8.2E-10	3.1E-12
Bladder wall	4.9E-10	1.7E-10	3.7E-09	1.2E-09	3.4E-10	2.4E-10	3.4E-09	3.0E-09	2.5E-10	8.2E-10	2.0E-12
Muscle	4.9E-10	1.7E-10	3.0E-09	1.3E-09	6.1E-10	9.4E-10	4.2E-09	1.8E-08	2.5E-10	8.2E-10	2.9E-12
Bone Surface	4.9E-10	1.7E-10	2.9E-09	1.1E-09	4.8E-10	6.9E-10	3.5E-09	1.4E-08	2.5E-10	8.2E-10	2.4E-12
Skin	4.9E-10	1.7E-10	2.2E-09	8.5E-10	3.3E-10	4.8E-10	2.6E-09	1.0E-08	2.5E-10	8.2E-10	2.0E-12
Spleen	2.7E-09	9.3E-10	8.5E-09	3.0E-09	8.9E-10	1.5E-09	5.2E-09	2.7E-08	2.5E-10	8.2E-10	4.0E-12
Uterus	4.9E-10	1.7E-10	4.0E-09	1.4E-09	4.2E-10	3.1E-10	3.9E-09	4.6E-09	2.5E-10	8.2E-10	3.0E-12
Pancreas	4.9E-10	1.7E-10	3.6E-09	1.8E-09	1.0E-09	1.7E-09	6.0E-09	3.2E-08	2.5E-10	8.2E-10	4.9E-12
Total Body	5.2E-10	1.9E-10	3.1E-09	1.5E-09	7.1E-10	1.1E-09	4.6E-09	2.2E-08	2.9E-10	8.3E-10	9.2E-12
Remainder	5.2E-10		4.0E-09								

TABLE 3.9 Specific committed dose equivalents (Sv/Bq) for selected inhaled radionuclides and their daughters. Annual limits of intake are the lesser of the values for stochastic and non-stochastic risks.

Nuclide	Ni-65	Cu-64	Cu-64	Cu-64	Zn-65	Zn-69	Br-83	Br-83	Br-84	Br-84	Rb-88
f1	0.05	0.5	0.5	0.5	0.5	0.5	1.0	1.0	1.0	1.0	1.0
Class	D	D	W	Y	Y	Y	D	W	D	W	D
ALI (Bq)	8.7E+08	1.1E+09	8.7E+08	8.0E+08	1.2E+07	5.3E+09	2.5E+09	2.3E+09	2.1E+09	2.4E+09	2.3E+09
DAC (Bq/m^3)	3.6E+05	4.4E+05	3.6E+05	3.3E+05	4.9E+03	2.2E+06	1.0E+06	9.8E+09	8.8E+05	1.0E+06	9.7E+05
Lungs	3.1E-10	2.0E-10	3.4E-10	3.5E-10	2.1E-08	7.8E-11	1.5E-10	1.8E-10	1.6E-10	1.7E-10	1.5E-10
Thyroid	5.5E-12	1.1E-11	6.0E-12	4.9E-12	3.0E-09	2.6E-14	3.2E-12	1.1E-12	3.1E-12	1.4E-12	1.4E-12
Testes	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01
Ovaries	8.5E-12	1.6E-11	1.2E-11	1.2E-11	2.0E-09	2.6E-14	3.2E-12	1.1E-12	2.9E-12	8.6E-13	1.3E-12
Red Marrow	6.7E-12	1.3E-11	7.9E-12	7.0E-12	3.9E-09	3.2E-14	3.2E-12	1.1E-12	3.3E-12	1.5E-12	1.5E-12
Stomach wall	9.2E-11	3.7E-11	4.1E-11	4.7E-11	3.8E-09	8.4E-12	4.3E-11	2.1E-11	7.5E-11	1.5E-11	6.2E-11
SI + contents	1.1E-10	4.2E-11	4.7E-11	5.4E-11	2.6E-09	4.2E-12	3.2E-12	1.1E-12	3.1E-12	1.0E-12	1.4E-12
ULI wall	1.4E-10	1.0E-10	1.3E-10	1.6E-10	2.7E-09	2.3E-12	3.2E-12	1.1E-12	3.2E-12	1.1E-12	1.4E-12
LLI wall	5.5E-11	1.2E-10	1.6E-10	1.9E-10	2.7E-09	3.8E-13	3.2E-12	1.1E-12	2.9E-12	8.0E-13	1.3E-12
Liver	7.7E-12	3.3E-11	1.7E-11	1.4E-11	4.3E-09	2.6E-14	3.2E-12	1.1E-12	4.2E-12	2.3E-12	1.6E-12
Kidneys	7.1E-12	1.4E-11	7.7E-12	6.8E-12	3.1E-09	2.6E-14	3.2E-12	1.1E-12	3.5E-12	1.4E-12	1.5E-12
Bladder wall	6.2E-12	1.3E-11	6.6E-12	5.7E-12	2.3E-09	2.6E-14	3.2E-12	1.1E-12	2.7E-12	7.8E-13	1.3E-12
Muscle	6.5E-12	1.2E-11	7.2E-12	6.4E-12	3.1E-09	2.6E-14	3.2E-12	1.1E-12	3.3E-12	1.6E-12	1.4E-12
Bone Surface	5.8E-12	1.2E-11	6.2E-12	5.2E-12	3.4E-09	3.2E-14	3.2E-12	1.1E-12	3.0E-12	1.3E-12	1.5E-12
Skin	5.3E-12	9.8E-12	5.0E-12	4.1E-12	1.9E-09	2.6E-14	3.2E-12	1.1E-12	2.6E-12	1.1E-12	1.3E-12
Spleen	7.9E-12	1.4E-11	9.2E-12	8.4E-12	4.0E-09	2.6E-14	3.2E-12	1.1E-12	4.9E-12	2.3E-12	1.7E-12
Uterus	7.8E-12	1.4E-11	7.9E-12	7.4E-12	2.7E-09	2.6E-14	3.2E-12	1.1E-12	3.0E-12	9.0E-13	1.3E-12
Pancreas	9.2E-12	4.6E-11	2.3E-11	1.9E-11	4.2E-09	2.6E-14	3.2E-12	1.1E-12	6.1E-12	2.6E-12	2.0E-12
Total Body	1.2E-11	1.6E-11	1.3E-11	1.3E-11	3.3E-09	1.2E-12	5.3E-12	3.7E-12	5.7E-12	4.0E-12	3.7E-12
Remainder					4.3E-09						

Nuclide	Rb-89	Sr-89	Sr-89	Sr-90	Sr-90	Y-90	Y-90	Y-91m	Y-91m	Y-91	Y-91
f1	1.0	0.3	0.01	0.3	0.01	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Class	D	D	Y	D	Y	W	Y	W	Y	W	Y
ALI (Bq)	4.9E+09	3.7E+07	5.2E+06	7.3E+05	1.4E+05	2.5E+07	2.3E+07	9.0E+09	6.0E+09	7.0E+06	4.2E+06
DAC (Bq/m^3)	2.1E+06	1.5E+04	2.2E+03	3.0E+02	5.8E+01	1.0E+04	9.5E+03	3.8E+06	2.5E+06	2.9E+03	1.8E+03
Lungs	6.9E-11	2.2E-09	8.1E-08	1.1E-09	3.0E-06	8.9E-09	9.3E-09	4.2E-11	7.0E-11	5.3E-08	9.9E-08
Thyroid	1.6E-12	3.9E-10	7.5E-12	0.0E-01	0.0E-01	9.4E-12	5.1E-13	6.0E-13	5.0E-13	7.3E-11	6.4E-12
Testes	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01
Ovaries	1.3E-12	3.9E-10	7.5E-12	0.0E-01	0.0E-01	9.4E-12	5.1E-13	4.1E-13	3.2E-13	7.3E-11	6.1E-12
Red Marrow	2.3E-12	2.8E-09	5.3E-11	2.3E-07	2.2E-08	2.7E-10	1.5E-11	2.7E-12	7.1E-13	3.5E-09	2.0E-10
Stomach wall	3.0E-11	3.9E-10	7.5E-12	0.0E-01	0.0E-01	3.8E-10	4.3E-10	2.4E-12	2.7E-12	3.9E-10	3.4E-10
SI + contents	1.5E-12	3.9E-10	7.5E-12	0.0E-01	0.0E-01	8.9E-10	1.0E-09	1.6E-12	1.7E-12	8.7E-10	8.4E-10
LLI wall	1.5E-12	1.5E-09	5.0E-09	6.6E-10	5.7E-09	4.7E-09	5.4E-09	3.8E-12	4.0E-12	4.9E-09	5.0E-09
LLI wall	1.3E-12	3.7E-09	1.4E-08	2.8E-09	2.0E-08	1.1E-08	1.3E-08	8.5E-12	8.8E-12	1.4E-08	1.5E-08
Liver	2.2E-12	3.9E-10	7.5E-12	0.0E-01	0.0E-01	2.7E-10	1.5E-11	3.2E-12	1.2E-12	3.5E-09	2.0E-10
Kidneys	1.7E-12	3.9E-10	7.4E-12	0.0E-01	0.0E-01	9.4E-12	5.1E-13	6.6E-13	5.7E-13	7.3E-11	6.3E-12
Bladder wall	1.2E-12	3.9E-10	7.4E-12	0.0E-01	0.0E-01	9.4E-12	5.1E-13	2.6E-13	1.2E-13	7.2E-11	4.8E-12
Muscle	1.7E-12	3.9E-10	7.5E-12	0.0E-01	0.0E-01	9.4E-12	5.1E-13	6.9E-13	6.1E-13	7.3E-11	6.8E-12
Bone Surface	2.4E-12	7.6E-09	1.4E-10	6.9E-07	6.6E-08	2.7E-10	1.5E-11	2.6E-12	5.5E-13	3.6E-09	2.0E-10
Skin	1.3E-12	3.9E-10	7.4E-12	0.0E-01	0.0E-01	9.4E-12	5.1E-13	3.8E-13	3.0E-13	7.2E-11	5.5E-12
Spleen	2.6E-12	3.9E-10	7.5E-12	0.0E-01	0.0E-01	9.4E-12	5.1E-13	1.1E-12	1.1E-12	7.4E-11	8.1E-12
Uterus	1.3E-12	3.9E-10	7.4E-12	0.0E-01	0.0E-01	9.4E-12	5.1E-13	3.6E-13	2.5E-13	7.2E-11	5.2E-12
Pancreas	3.2E-12	3.9E-10	7.5E-12	0.0E-01	0.0E-01	9.4E-12	5.1E-13	1.5E-12	1.5E-12	7.4E-11	8.6E-12
Total Body	2.8E-12	1.2E-09	1.2E-09	6.9E-08	4.9E-08	2.1E-10	1.9E-10	1.5E-12	1.6E-12	1.3E-09	1.5E-09
Remainder		1.2E-09		6.9E-08							

TABLE 3.10 Specific committed dose equivalents (Sv/Bq) for selected inhaled radionuclides and their daughters. Annual limits of intake are the lesser of the values for stochastic and non-stochastic risks.

Nuclide	Y-92	Y-92	Y-93	Y-93	Zr-95	Zr-95	Zr-95	Zr-97	Zr-97	Zr-97	Nb-95
f1	0.0001	0.0001	0.0001	0.0001	0.002	0.002	0.002	0.002	0.002	0.001	0.01
Class	W	Y	W	Y	W	Y	D	W	Y	D	W
ALI (Bq)	3.2E+08	2.9E+08	1.1E+08	8.9E+07	1.4E+07	1.0E+07	4.9E+06	5.2E+07	4.7E+07	7.4E+07	4.8E+07
DAC (Bq/m^3)	1.3E+05	1.2E+05	4.4E+04	3.7E+04	6.0E+03	4.3E+03	2.0E+03	2.2E+04	2.0E+04	3.1E+04	2.0E+04
Lungs	1.2E-09	1.2E-09	2.4E-09	2.5E-09	1.8E-08	4.0E-08	2.2E-09	3.9E-09	4.0E-09	2.1E-09	5.5E-09
Thyroid	3.7E-12	1.1E-12	5.1E-12	9.2E-13	7.8E-10	1.2E-09	1.4E-09	3.7E-11	2.3E-11	9.6E-11	3.1E-10
Testes	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01
Ovaries	4.9E-12	2.6E-12	8.7E-12	5.3E-12	8.4E-10	5.7E-10	1.9E-09	1.7E-10	1.8E-10	1.8E-10	4.8E-10
Red Marrow	1.3E-11	2.1E-12	4.1E-11	4.0E-12	3.2E-09	1.3E-09	1.3E-08	1.4E-10	6.3E-11	4.8E-10	6.7E-10
Stomach wall	1.4E-10	1.7E-10	2.4E-10	2.9E-10	1.1E-09	1.8E-09	1.1E-09	4.1E-10	4.7E-10	3.0E-10	5.3E-10
SI + contents	1.9E-10	2.4E-10	4.7E-10	5.7E-10	9.8E-10	8.4E-10	1.7E-09	8.8E-10	1.0E-09	6.2E-10	5.6E-10
ULI wall	3.2E-10	4.0E-10	1.5E-09	1.8E-09	1.9E-09	1.9E-09	1.8E-09	3.0E-09	3.5E-09	2.0E-09	9.9E-10
LLI wall	1.7E-10	2.0E-10	1.6E-09	2.0E-09	4.1E-09	3.9E-09	3.0E-09	4.2E-09	5.1E-09	2.8E-09	1.9E-09
Liver	1.3E-11	2.8E-12	4.1E-11	4.3E-12	1.2E-09	2.1E-09	1.3E-09	7.4E-11	6.4E-11	1.2E-10	5.3E-10
Kidneys	4.2E-12	1.7E-12	5.9E-12	1.9E-12	8.1E-10	9.6E-10	1.9E-09	6.1E-11	5.1E-11	1.2E-10	5.2E-10
Bladder wall	3.5E-12	8.9E-13	5.7E-12	1.8E-12	3.8E-10	2.1E-10	1.1E-09	6.1E-11	5.3E-11	1.2E-10	2.0E-10
Muscle	4.1E-12	1.5E-12	5.8E-12	1.7E-12	9.3E-10	1.2E-09	1.9E-09	5.8E-11	4.7E-11	1.1E-10	3.8E-10
Bone Surface	1.2E-11	1.5E-12	4.0E-11	3.1E-12	2.2E-08	2.3E-09	1.0E-07	1.2E-10	3.5E-11	5.1E-10	2.4E-09
Skin	3.4E-12	8.1E-13	5.0E-12	9.4E-13	5.8E-10	6.3E-10	1.5E-09	3.3E-11	2.1E-11	8.6E-11	2.1E-10
Spleen	4.9E-12	2.4E-12	6.4E-12	2.4E-12	1.1E-09	1.9E-09	1.6E-09	7.2E-11	6.1E-11	1.2E-10	6.9E-10
Uterus	4.3E-12	1.8E-12	6.7E-12	2.9E-12	5.1E-10	2.8E-10	1.5E-09	8.9E-11	8.6E-11	1.4E-10	2.7E-10
Pancreas	5.4E-12	3.0E-12	6.9E-12	2.9E-12	1.3E-09	2.2E-09	1.7E-09	8.6E-11	7.7E-11	1.3E-10	5.9E-10
Total Body	2.5E-11	2.3E-11	5.7E-11	5.4E-11	1.4E-09	1.8E-09	3.1E-09	1.5E-10	1.4E-10	1.9E-10	4.8E-10
Remainder											

Nuclide	Nb-95	Mo-99	Mo-99	Tc-99m	Tc-99m	Tc-101	Tc-101	Ru-103	Ru-103	Ru-103	Ru-105
f1	0.01	0.05	0.8	0.8	0.8	0.8	0.8	0.05	0.05	0.05	0.05
Class	Y	Y	D	W	D	W	D	W	D	Y	W
ALI (Bq)	4.1E+07	5.0E+07	9.4E+07	9.6E+09	6.4E+09	1.4E+10	1.2E+10	3.8E+07	6.3E+07	2.5E+07	5.7E+08
DAC (Bq/m^3)	1.7E+04	2.1E+04	3.9E+04	4.0E+06	2.7E+06	5.8E+06	5.1E+06	1.6E+04	2.6E+04	1.0E+04	2.4E+05
Lungs	8.3E-09	4.3E-09	1.2E-09	3.0E-11	2.2E-11	3.0E-11	2.8E-11	9.5E-09	1.0E-09	1.5E-08	5.2E-10
Thyroid	3.6E-10	1.5E-11	1.2E-10	2.1E-11	5.0E-11	7.4E-14	7.1E-14	2.8E-10	6.0E-10	2.6E-10	6.2E-12
Testes	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01
Ovaries	4.3E-10	9.7E-11	1.3E-10	1.7E-12	2.8E-12	1.4E-14	4.6E-14	4.0E-10	7.4E-10	3.2E-10	1.5E-11
Red Marrow	4.4E-10	5.1E-11	3.4E-10	2.4E-12	3.4E-12	1.0E-13	1.2E-13	3.5E-10	6.7E-10	3.3E-10	9.1E-12
Stomach wall	6.3E-10	2.3E-10	2.2E-10	9.5E-12	1.6E-11	1.7E-12	1.2E-11	4.9E-10	7.2E-10	5.1E-10	6.8E-11
SI + contents	5.2E-10	5.2E-10	1.8E-10	3.5E-12	4.9E-12	2.0E-13	1.6E-12	5.5E-10	8.5E-10	4.7E-10	1.0E-10
ULI wall	9.9E-10	2.4E-09	3.4E-10	5.5E-12	6.9E-12	3.7E-14	1.4E-13	1.3E-09	1.1E-09	1.3E-09	2.2E-10
LLI wall	1.9E-09	5.5E-09	5.8E-10	3.7E-12	5.0E-12	1.2E-14	4.6E-14	3.0E-09	1.7E-09	3.0E-09	2.1E-10
Liver	6.7E-10	1.1E-10	1.9E-09	2.8E-12	4.0E-12	1.8E-13	2.0E-13	4.6E-10	6.8E-10	5.1E-10	1.2E-11
Kidneys	3.5E-10	1.0E-10	1.9E-09	1.6E-12	2.6E-12	7.7E-14	1.2E-13	3.1E-10	6.9E-10	2.7E-10	8.8E-12
Bladder wall	1.4E-10	3.3E-11	1.3E-10	9.0E-13	1.9E-12	6.2E-15	1.8E-14	2.4E-10	7.1E-10	1.3E-10	6.4E-12
Muscle	4.1E-10	2.8E-11	1.3E-10	1.5E-12	2.2E-12	9.9E-14	1.1E-13	3.2E-10	6.1E-10	3.2E-10	8.1E-12
Bone Surface	5.1E-10	4.1E-11	5.3E-10	1.8E-12	2.8E-12	8.3E-14	1.1E-13	2.8E-10	6.2E-10	2.4E-10	6.5E-12
Skin	2.1E-10	1.4E-11	1.1E-10	7.4E-13	1.2E-12	4.7E-14	5.2E-14	2.0E-10	4.6E-10	1.7E-10	4.9E-12
Spleen	6.3E-10	3.6E-11	1.4E-10	2.8E-12	3.8E-12	1.8E-13	2.9E-13	4.3E-10	7.0E-10	4.7E-10	1.2E-11
Uterus	1.9E-10	4.5E-11	1.3E-10	1.3E-12	2.5E-12	1.2E-14	4.6E-14	2.6E-10	7.0E-10	1.6E-10	9.9E-12
Pancreas	7.1E-10	4.3E-11	1.7E-10	3.6E-12	5.1E-12	2.2E-13	4.3E-13	5.1E-10	6.9E-10	6.0E-10	1.4E-11
Total Body	5.1E-10	1.2E-10	2.2E-10	2.1E-12	2.7E-12	5.3E-13	5.5E-13	4.6E-10	6.2E-10	5.3E-10	1.7E-11
Remainder					5.1E-12				7.1E-10		

TABLE 3.11 Specific committed dose equivalents (Sv/Bq) for selected inhaled radionuclides and their daughters. Annual limits of intake are the lesser of the values for stochastic and non-stochastic risks.

Nuclide	Ru-105	Ru-105	Ru-106	Ru-106	Ru-106	Ag-110m	Ag-110m	Ag-110m	Te-125m	Te-125m	Te-127m
f1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.2	0.2	0.2
Class	Y	0	W	Y	0	W	Y	0	0	W	0
ALI (Bq)	4.8E+08	5.6E+08	2.0E+06	4.0E+05	3.3E+06	7.5E+06	3.5E+06	5.2E+06	1.4E+07	2.4E+07	9.6E+06
DAC (Bq/m^3)	2.0E+05	2.4E+05	8.3E+02	1.7E+02	1.4E+03	3.1E+03	1.5E+03	2.2E+03	5.7E+03	9.9E+03	4.0E+03
Lungs	5.5E-10	3.6E-10	2.1E-07	1.0E-06	1.8E-08	3.1E-08	1.2E-07	8.0E-09	5.2E-10	1.2E-08	8.9E-10
Thyroid	4.0E-12	1.4E-11	4.0E-09	1.7E-09	1.4E-08	2.0E-09	6.3E-09	1.7E-09	1.1E-10	4.2E-11	2.4E-10
Testes	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01
Ovaries	1.5E-11	2.6E-11	4.0E-09	1.3E-09	1.4E-08	2.3E-09	2.4E-09	3.2E-09	1.3E-10	8.2E-11	2.5E-10
Red Marrow	7.4E-12	1.8E-11	4.1E-09	1.8E-09	1.4E-08	2.9E-09	6.7E-09	4.0E-09	3.4E-09	1.3E-09	1.4E-08
Stomach wall	8.0E-11	8.8E-11	5.0E-09	2.9E-09	1.4E-08	4.5E-09	1.0E-08	6.5E-09	1.4E-10	1.4E-10	2.6E-10
SI + contents	1.2E-10	1.3E-10	6.0E-09	3.4E-09	1.5E-08	3.4E-09	3.4E-09	6.0E-09	1.7E-10	2.1E-10	2.9E-10
ULI wall	2.6E-10	2.4E-10	1.6E-08	1.4E-08	1.8E-08	5.1E-09	5.2E-09	8.4E-09	4.0E-10	9.1E-10	7.2E-10
LLI wall	2.5E-10	1.9E-10	3.9E-08	3.7E-08	2.5E-08	5.8E-09	5.8E-09	3.9E-09	9.4E-10	2.5E-09	1.9E-09
Liver	9.9E-12	2.0E-11	4.2E-09	2.3E-09	1.4E-08	2.5E-08	1.8E-08	8.0E-08	1.1E-10	8.0E-11	2.4E-10
Kidneys	7.0E-12	1.8E-11	4.1E-09	1.7E-09	1.4E-08	4.5E-09	6.2E-09	1.1E-08	1.1E-10	4.5E-11	2.4E-10
Bladder wall	4.4E-12	1.7E-11	4.0E-09	1.2E-09	1.4E-08	1.1E-09	1.0E-09	2.2E-09	1.1E-10	4.4E-11	2.4E-10
Muscle	6.4E-12	1.6E-11	4.0E-09	1.8E-09	1.4E-08	2.9E-09	7.1E-09	4.1E-09	1.2E-10	7.4E-11	2.4E-10
Bone Surface	4.4E-12	1.5E-11	4.0E-09	1.6E-09	1.4E-08	2.1E-09	5.2E-09	3.0E-09	3.7E-08	1.3E-08	5.2E-08
Skin	3.0E-12	1.2E-11	3.9E-09	1.4E-09	1.3E-08	1.6E-09	3.7E-09	2.4E-09	1.1E-10	4.4E-11	2.4E-10
Spleen	1.0E-11	2.0E-11	4.2E-09	2.2E-09	1.4E-08	3.8E-09	1.1E-08	4.2E-09	1.2E-10	7.6E-11	2.4E-10
Uterus	8.6E-12	2.1E-11	4.0E-09	1.2E-09	1.4E-08	1.5E-09	1.5E-09	2.9E-09	1.1E-10	4.7E-11	2.4E-10
Pancreas	1.3E-11	2.3E-11	4.2E-09	2.5E-09	1.4E-08	6.7E-09	1.3E-08	1.3E-08	1.1E-10	6.6E-11	2.4E-10
Total Body	1.7E-11	2.4E-11	7.1E-09	1.7E-08	1.4E-08	3.7E-09	8.4E-09	5.9E-09	4.3E-10	3.6E-10	1.4E-09
Remainder					1.4E-08	6.7E-09		1.3E-08			

Nuclide	Te-127m	Te-127	Te-127	Te-129m	Te-129m	Te-129	Te-129	Te-131m	Te-131	Te-132	I-125
f1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	1.0
Class	W	0	W	0	W	0	W	0	0	0	0
ALI (Bq)	9.5E+06	8.4E+08	6.4E+08	2.4E+07	9.1E+06	2.4E+09	2.7E+09	1.5E+07	1.8E+08	8.4E+06	2.4E+06
DAC (Bq/m^3)	4.0E+03	3.5E+05	2.7E+05	9.8E+03	3.8E+03	9.8E+05	1.1E+06	6.3E+03	7.7E+04	3.5E+03	1.0E+03
Lungs	3.3E-08	2.8E-10	4.3E-10	2.2E-09	4.0E-08	1.3E-10	1.5E-10	5.9E-10	2.5E-10	6.2E-10	1.1E-10
Thyroid	9.6E-11	6.5E-12	1.8E-12	3.9E-10	1.5E-10	1.6E-12	5.1E-13	3.3E-08	2.7E-09	6.0E-08	2.1E-07
Testes	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01
Ovaries	1.1E-10	6.6E-12	2.0E-12	4.1E-10	1.8E-10	1.8E-12	5.0E-13	1.6E-10	5.7E-12	3.4E-10	1.3E-11
Red Marrow	5.3E-09	1.4E-11	4.0E-12	8.6E-09	3.0E-09	2.0E-12	6.1E-13	9.4E-11	5.5E-12	3.5E-10	3.6E-11
Stomach wall	2.2E-10	4.2E-11	4.5E-11	4.7E-10	4.5E-10	5.2E-11	1.6E-11	9.9E-11	8.7E-11	3.4E-10	1.9E-11
SI + contents	3.5E-10	6.4E-11	7.1E-11	6.0E-10	7.8E-10	3.6E-11	1.1E-11	2.5E-10	7.6E-11	3.8E-10	1.4E-11
ULI wall	1.8E-09	1.8E-10	2.1E-10	1.7E-09	3.9E-09	2.5E-11	7.5E-12	5.1E-10	7.5E-11	3.6E-10	1.4E-11
LLI wall	5.6E-09	1.9E-10	2.2E-10	4.2E-09	1.1E-08	6.1E-12	1.8E-12	7.9E-10	5.1E-12	8.7E-10	1.3E-11
Liver	1.1E-10	6.5E-12	1.9E-12	3.9E-10	1.8E-10	1.8E-12	6.0E-13	9.5E-11	5.6E-12	3.5E-10	1.5E-11
Kidneys	9.7E-11	6.5E-12	1.9E-12	4.0E-10	1.6E-10	1.7E-12	5.2E-13	8.6E-11	5.2E-12	3.5E-10	1.2E-11
Bladder wall	9.3E-11	6.5E-12	1.9E-12	3.9E-10	1.5E-10	1.6E-12	4.7E-13	9.4E-11	4.5E-12	3.7E-10	1.3E-11
Muscle	1.1E-10	6.5E-12	1.9E-12	4.0E-10	1.7E-10	1.7E-12	5.4E-13	8.3E-11	5.2E-12	3.3E-10	8.9E-11
Bone Surface	2.0E-08	1.4E-11	4.1E-12	1.9E-08	6.8E-09	2.0E-12	6.2E-13	7.4E-11	4.9E-12	3.3E-10	3.6E-11
Skin	9.5E-11	6.4E-12	1.8E-12	3.9E-10	1.5E-10	1.6E-12	4.8E-13	5.4E-11	4.2E-12	2.5E-10	4.1E-11
Spleen	1.1E-10	6.5E-12	1.9E-12	4.0E-10	1.8E-10	1.8E-12	6.1E-13	9.1E-11	6.0E-12	3.5E-10	1.5E-11
Utsrus	9.5E-11	6.5E-12	1.9E-12	4.0E-10	1.5E-10	1.7E-12	4.9E-13	1.2E-10	5.4E-12	3.9E-10	1.3E-11
Pancreas	1.1E-10	6.6E-12	2.0E-12	4.0E-10	1.8E-10	1.9E-12	6.5E-13	9.5E-11	6.9E-12	3.5E-10	1.5E-11
Total Body	1.1E-09	1.3E-11	1.0E-11	1.1E-09	1.0E-09	4.1E-12	2.9E-12	1.0E-10	1.0E-11	3.5E-10	1.3E-10
Remainder											

TABLE 3.12 Specific committed dose equivalents (Sv/Bq) for selected inhaled radionuclides and their daughters. Annual limits of intake are the lesser of the values for stochastic and non-stochastic risks.

Nuclide	I-130	I-131	I-133	I-134	I-135	Ca-134	Cs-136	Ca-137	Ca-138	Ba-139	Ba-140
f1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.1	0.1
Class	D	D	D	D	D	D	D	D	D	D	D
ALI (Bq)	2.6E+07	1.6E+06	1.1E+07	1.7E+09	6.4E+07	4.1E+06	2.6E+07	6.1E+06	2.1E+09	1.1E+09	5.2E+07
DAC (Bq/m^3)	1.2E+04	7.5E+02	4.6E+03	7.3E+05	2.7E+04	1.7E+03	1.1E+04	2.6E+03	8.7E+05	4.8E+05	2.2E+04
Lungs	5.9E-10	6.5E-10	8.2E-10	1.4E-10	4.4E-10	1.2E-08	2.3E-09	8.5E-09	1.6E-10	2.5E-10	1.6E-09
Thyroid	1.8E-08	2.8E-07	4.5E-08	2.6E-10	7.8E-09	1.1E-08	1.7E-09	7.6E-09	3.6E-12	2.4E-12	2.4E-10
Testes	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01
Ovaries	2.7E-11	2.2E-11	1.9E-11	4.2E-12	1.7E-11	1.1E-08	1.7E-09	7.8E-09	3.3E-12	2.5E-12	4.2E-10
Red Marrow	4.5E-11	5.7E-11	2.7E-11	6.0E-12	2.2E-11	1.2E-08	1.9E-09	8.0E-09	4.0E-12	2.5E-12	1.4E-09
Stomach wall	1.2E-10	7.1E-11	1.0E-10	7.0E-11	1.0E-10	1.2E-08	2.0E-09	8.3E-09	7.8E-11	9.3E-11	2.6E-10
SI + contents	3.4E-11	2.3E-11	2.2E-11	5.5E-12	1.9E-11	1.4E-08	2.1E-09	8.6E-09	3.7E-12	7.3E-11	5.1E-10
ULI wall	3.5E-11	2.3E-11	2.2E-11	5.7E-12	1.9E-11	1.3E-08	2.0E-09	8.7E-09	3.9E-12	5.9E-11	1.4E-09
LLI wall	3.1E-11	2.2E-11	2.1E-11	4.6E-12	1.6E-11	1.4E-08	2.1E-09	8.8E-09	3.4E-12	1.5E-11	4.3E-09
Liver	5.4E-11	3.5E-11	2.9E-11	8.4E-12	2.6E-11	1.3E-08	2.0E-09	8.3E-09	5.2E-12	2.5E-12	2.7E-10
Kidneys	4.0E-11	2.6E-11	2.4E-11	6.6E-12	2.2E-11	1.3E-08	2.0E-09	8.3E-09	4.3E-12	2.4E-12	2.8E-10
Bladder wall	3.0E-11	2.1E-11	2.0E-11	4.5E-12	1.7E-11	1.3E-08	2.1E-09	8.6E-09	3.1E-12	2.4E-12	3.0E-10
Muscle	4.8E-11	7.2E-11	2.9E-11	6.1E-12	2.3E-11	1.1E-08	1.7E-09	7.5E-09	4.0E-12	2.4E-12	2.8E-10
Bone Surface	4.0E-11	5.2E-11	2.5E-11	5.3E-12	2.0E-11	1.1E-08	1.7E-09	7.6E-09	3.6E-12	2.4E-12	2.6E-09
Skin	3.1E-11	4.8E-11	2.2E-11	4.1E-12	1.7E-11	7.6E-09	1.2E-09	6.3E-09	3.1E-12	2.4E-12	2.2E-10
Spleen	5.6E-11	3.5E-11	2.9E-11	1.0E-11	2.6E-11	1.3E-08	2.0E-09	8.3E-09	6.2E-12	2.5E-12	2.6E-10
Uterus	3.1E-11	2.2E-11	2.0E-11	5.0E-12	1.9E-11	1.4E-08	2.4E-09	8.7E-09	3.4E-12	2.5E-12	3.0E-10
Pancreas	6.4E-11	3.6E-11	3.2E-11	1.3E-11	3.4E-11	1.2E-08	1.9E-09	8.1E-09	8.0E-12	2.6E-12	3.0E-10
Total Body	5.9E-11	1.5E-10	5.2E-11	8.2E-12	3.1E-11	1.1E-08	1.7E-09	7.5E-09	6.4E-12	7.0E-12	4.1E-10
Remainder						1.4E-08	2.4E-09	8.7E-09			

Nuclide	Ba-141	La-140	La-140	La-142	La-142	Ca-141	Ca-141	Ca-143	Ca-143	Ca-144	Ca-144
f1	0.1	0.001	0.001	0.001	0.001	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Class	D	D	W	D	W	W	Y	W	Y	W	Y
ALI (Bq)	2.6E+09	5.5E+07	4.3E+07	8.0E+08	1.2E+09	2.6E+07	2.2E+07	6.6E+07	5.9E+07	9.5E+05	5.3E+05
DAC (Bq/m^3)	1.1E+06	2.3E+04	1.6E+04	3.4E+05	4.6E+05	1.1E+04	9.3E+03	2.7E+04	2.4E+04	4.0E+02	2.2E+02
Lungs	1.1E-10	1.7E-09	4.2E-09	3.1E-10	3.6E-10	1.1E-08	1.7E-08	3.6E-09	3.9E-09	1.6E-07	7.6E-07
Thyroid	1.3E-12	1.2E-10	6.9E-11	9.0E-12	5.0E-12	4.6E-11	2.6E-11	1.2E-11	6.0E-12	1.9E-09	2.9E-10
Testes	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01
Ovaries	1.4E-12	3.6E-10	4.5E-10	1.7E-11	6.2E-12	8.5E-11	5.6E-11	6.9E-11	7.4E-11	1.9E-09	2.3E-10
Red Marrow	1.5E-12	4.4E-10	2.1E-10	1.4E-11	7.0E-12	4.1E-10	9.0E-11	7.6E-11	2.9E-11	2.5E-08	2.7E-09
Stomach wall	3.9E-11	3.9E-10	4.7E-10	1.2E-10	5.1E-11	1.9E-10	1.6E-10	1.9E-10	2.1E-10	2.7E-09	1.1E-09
SI + contents	2.3E-11	6.5E-10	9.7E-10	1.1E-10	4.3E-11	3.1E-10	2.9E-10	4.3E-10	4.9E-10	3.8E-09	2.1E-09
ULI wall	3.1E-11	1.6E-09	2.9E-09	1.1E-10	4.1E-11	1.4E-09	1.5E-09	1.8E-09	2.1E-09	1.3E-08	1.2E-08
LLI wall	1.7E-11	2.6E-09	5.4E-09	3.4E-11	1.2E-11	3.6E-09	4.1E-09	3.7E-09	4.3E-09	3.4E-08	3.4E-08
Liver	1.7E-12	3.5E-09	7.6E-10	3.9E-11	1.6E-11	3.4E-09	2.6E-10	5.1E-10	4.8E-11	2.5E-07	2.5E-08
Kidneys	1.5E-12	3.4E-10	1.7E-10	1.4E-11	6.3E-12	9.6E-11	3.2E-11	2.4E-11	1.5E-11	2.1E-09	3.1E-10
Bladder wall	1.2E-12	1.9E-10	1.7E-10	9.7E-12	3.2E-12	4.7E-11	1.8E-11	2.3E-11	2.0E-11	1.9E-09	2.0E-10
Muscle	1.4E-12	2.0E-10	1.5E-10	1.2E-11	6.4E-12	7.1E-11	4.5E-11	2.2E-11	1.6E-11	1.9E-09	3.4E-10
Bone Surface	1.3E-12	4.0E-10	1.4E-10	1.1E-11	5.5E-12	3.8E-09	2.5E-10	7.8E-11	1.6E-11	4.5E-08	4.7E-09
Skin	1.2E-12	1.4E-10	7.6E-11	7.8E-12	3.9E-12	4.4E-11	1.8E-11	1.2E-11	6.4E-12	1.9E-09	2.5E-10
Spleen	2.0E-12	2.1E-10	1.7E-10	1.7E-11	1.0E-11	2.9E-09	2.2E-10	4.4E-10	4.3E-11	2.2E-07	2.2E-08
Uterus	1.3E-12	2.3E-10	2.3E-10	1.5E-11	5.3E-12	5.6E-11	2.6E-11	3.2E-11	3.0E-11	1.9E-09	2.1E-10
Pancreas	2.4E-12	3.9E-10	2.4E-10	2.3E-11	1.2E-11	1.4E-10	8.2E-11	3.5E-11	2.5E-11	2.2E-09	4.7E-10
Total Body	3.4E-12	3.4E-10	2.5E-10	1.6E-11	1.2E-11	3.7E-10	3.1E-10	1.1E-10	9.4E-11	1.4E-08	1.3E-08
Remainder											

TABLE 3.13 Specific committed dose equivalents (Sv/Bq) for selected inhaled radionuclides and their daughters. Annual limits of intake are the lesser of the values for stochastic and non-stochastic risks.

Nuclide	Pr-143	Pr-145	Pr-144	Pr-144	Nd-147	Nd-147	W-187	Np-239
f1	0.0003	0.0005	0.0005	0.0003	0.0003	0.0005	0.5	0.01
Class	W	Y	W	Y	W	Y	D	W
ALI (Bq)	5.0E+07	2.5E+07	4.7E+09	4.4E+09	5.5E+07	2.9E+07	5.5E+08	9.2E+07
DAC (Bq/m^3)	1.2E+04	1.0E+04	2.0E+06	1.8E+06	1.5E+04	1.2E+04	1.5E+05	5.8E+04
Lungs	1.1E-08	1.5E-08	8.9E-11	9.4E-11	8.4E-09	1.1E-08	6.0E-10	2.2E-09
Thyroid	1.6E-18	1.7E-18	8.0E-15	8.5E-15	1.9E-11	1.8E-11	4.5E-12	5.8E-12
Testes	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01
Ovaries	4.3E-18	4.4E-18	2.2E-15	2.4E-15	8.0E-11	8.5E-11	3.0E-11	7.5E-11
Red Marrow	2.7E-10	1.5E-11	1.6E-15	1.8E-14	5.0E-10	9.2E-11	2.7E-11	1.4E-10
Stomach wall	1.5E-10	1.7E-10	4.2E-12	5.4E-12	1.8E-10	2.0E-10	7.0E-11	1.2E-10
SI + contents	3.7E-10	4.1E-10	9.8E-15	1.3E-12	4.0E-10	4.5E-10	1.2E-10	2.8E-10
ULI wall	2.2E-09	2.4E-09	1.8E-15	2.4E-15	1.9E-09	2.2E-09	4.0E-10	1.2E-09
LLI wall	6.1E-09	6.8E-09	1.0E-14	1.3E-14	5.2E-09	5.8E-09	6.6E-10	2.7E-09
Liver	2.2E-09	1.2E-10	5.4E-15	3.5E-14	1.6E-09	1.8E-10	5.2E-11	5.8E-10
Kidneys	4.9E-10	2.7E-11	2.6E-13	2.2E-14	4.0E-11	2.6E-11	8.5E-11	1.6E-11
Bladder wall	1.4E-18	1.5E-18	1.1E-15	1.1E-15	2.4E-11	2.4E-11	8.7E-12	1.7E-11
Muscle	2.5E-18	2.2E-18	9.9E-15	1.0E-14	5.8E-11	3.5E-11	8.8E-12	1.5E-11
Bone Surface	2.7E-10	1.5E-11	1.5E-13	1.6E-14	2.5E-09	5.2E-10	9.7E-11	1.5E-09
Skin	1.5E-18	1.1E-18	5.4E-15	5.7E-15	1.7E-11	1.4E-11	4.0E-12	5.6E-12
Spleen	5.3E-18	5.2E-18	1.7E-14	1.8E+14	4.7E-11	4.8E-11	7.5E-11	1.8E-11
Uterus	1.9E-18	1.9E-18	2.1E-15	2.5E-15	5.5E-11	3.5E-11	1.5E-11	2.4E-11
Pancreas	5.0E-18	3.8E-18	1.9E-14	2.1E-14	7.0E-11	5.8E-11	1.7E-11	2.5E-11
Total Body	2.6E-10	2.2E-10	1.5E-12	1.4E-12	2.6E-10	2.2E-10	2.5E-11	7.9E-11
Remainder								

TABLE 3.14 Comparison of specific committed dose equivalents (Sv/Bq) to the results in ICRP Publication 30 for selected ingested radionuclides and their daughters. Values reported are greater than or equal to 10 % of the maximum.

Nuclide	P-32		Mn-54		Co-60		Ni-63		Zn-65	
f1	0.8		0.1		0.05		0.05		0.5	
Program	ICRP	OOSE	ICRP	OOSE	ICRP	OOSE	ICRP	OOSE	ICRP	OOSE
Lungs			2.3E-10	2.3E-10	8.7E-10	8.8E-10	8.5E-11	8.5E-11	3.1E-09	3.1E-09
Thyroid									3.2E-09	3.2E-09
Testes										
Ovaries	6.5E-10	6.6E-10	9.5E-10	9.5E-10	3.2E-09	3.2E-09	8.5E-11	8.5E-11	3.5E-09	3.5E-09
Red Marrow	8.1E-09	7.8E-09	4.9E-10	5.1E-10	1.3E-09	1.3E-09	8.5E-11	8.5E-11	4.5E-09	4.9E-09
Stomach wall							1.0E-10	1.0E-10		
SI + contents			9.8E-10	9.9E-10	3.6E-09	3.6E-09	1.3E-10	1.3E-10	4.3E-09	4.3E-09
ULI wall	3.0E-09	3.0E-09	1.4E-09	1.4E-09	5.7E-09	5.8E-09	3.6E-10	3.7E-10	4.2E-09	4.3E-09
LLI wall	7.2E-09	7.2E-09	2.2E-09	2.2E-09	1.1E-08	1.1E-08	9.2E-10	9.2E-10	5.0E-09	5.0E-09
Liver			1.0E-09	1.0E-09	2.3E-09	2.3E-09				
Kidneys										
Bladder wall										
Muscle	6.5E-10	6.6E-10	2.8E-10	2.8E-10	1.1E-09	1.1E-09	8.5E-11	8.5E-11	3.3E-09	3.3E-09
Bone Surface	7.9E-09	7.8E-09							4.5E-09	4.5E-09
Skin										
Spleen										
Uterus										
Pancreas										
Total Body										
Remainder			5.0E-10	5.0E-10	2.1E-09	2.1E-09			4.8E-09	4.7E-09

Nuclide	Sr-89		Y-91m		Mo-99		Tc-99m		Ru-105	
f1	0.3		0.0001		0.8		0.8		0.05	
Program	ICRP	OOSE	ICRP	DOSE	ICRP	OOSE	ICRP	DOSE	ICRP	DOSE
Lungs					1.9E-10	2.0E-10				
Thyroid							8.5E-11	8.4E-11		
Testes										
Ovaries			6.9E-12	6.9E-12	2.2E-10	2.3E-10	9.7E-12	9.5E-12	9.7E-11	9.5E-11
Red Marrow	3.2E-09	1.6E-09			5.3E-10	4.8E-10	6.3E-12	6.0E-12		
Stomach wall			4.9E-11	4.9E-11	6.7E-10	6.7E-10	7.2E-11	3.9E-11	5.0E-10	5.0E-10
SI + contents			3.1E-11	3.1E-11			2.2E-11	2.2E-11	7.9E-10	7.9E-10
ULI wall	7.3E-09	7.2E-09	3.1E-11	3.1E-11	1.4E-09	1.5E-09	3.7E-11	3.6E-11	1.6E-09	1.6E-09
LLI wall	2.1E-08	2.1E-08	2.4E-11	2.4E-11	3.1E-09	3.2E-09	2.5E-11	2.4E-11	1.3E-09	1.2E-09
Liver					2.7E-09	2.7E-09				
Kidneys					2.5E-09	2.7E-09				
Bladder wall										
Muscle					1.8E-10	1.9E-10	3.6E-12	3.3E-12		
Bone Surface	4.8E-09	4.3E-09			7.7E-10	7.6E-10				
Skin										
Spleen										
Uterus										
Pancreas										
Total Body										
Remainder			1.1E-11	1.1E-11			1.1E-11	9.3E-12		

TABLE 3.15 Comparison of specific committed dose equivalents (Sv/Bq) to the results in ICRP Publication 30 for selected ingested radionuclides and their daughters. Values reported are greater than or equal to 10 % of the maximum.

Nuclide	Te-127		Te-131m		I-131		I-135		Cs-137	
f1	0.2		0.2		1.0		1.0		1.0	
Program	ICRP	DOSE	ICRP	DOSE	ICRP	DOSE	ICRP	DOSE	ICRP	DOSE
Lungs									1.3E-08	1.2E-08
Thyroid			4.3E-08	4.3E-08	4.8E-07	4.5E-07	1.8E-08	1.7E-08	1.3E-08	1.2E-08
Testes										
Ovaries			7.3E-10	1.5E-11					1.4E-08	1.2E-08
Red Marrow									1.3E-08	1.3E-08
Stomach wall	2.4E-10	2.4E-10								
SI + contents	3.9E-10	3.9E-10							1.4E-08	1.4E-08
ULI wall	1.2E-09	1.2E-09	4.6E-09	5.4E-10					1.4E-08	1.4E-08
LLI wall	1.3E-09	1.2E-09	8.2E-09	9.3E-12					1.4E-08	1.4E-08
Liver										
Kidneys										
Bladder wall										
Muscle									1.2E-08	1.2E-08
Bone Surface									1.3E-08	1.2E-08
Skin										
Spleen										
Uterus										
Pancrees										
Total Body										
Remainder									1.5E-08	1.4E-08

Nuclide	Be-141		Ce-143		Pr-144		W-187		Np-239	
f1	0.1		0.0003		0.0003		0.01		0.01	
Program	ICRP	DOSE	ICRP	DOSE	ICRP	DOSE	ICRP	DOSE	ICRP	DOSE
Lungs										
Thyroid										
Testes										
Ovaries							2.6E-10	2.6E-10		
Red Marrow										
Stomach wall	3.9E-10	3.9E-10			4.1E-10	4.1E-10				
SI + contents	1.9E-10	1.8E-10	1.4E-09	1.4E-09	9.6E-11	9.6E-11	1.0E-09	1.0E-09	8.7E-10	8.2E-10
ULI wall	2.2E-10	2.2E-10	5.7E-09	5.9E-09			3.6E-09	3.6E-09	3.8E-09	3.7E-09
LLI wall	1.2E-10	1.1E-10	1.2E-08	1.2E-08			6.0E-09	5.9E-09	8.6E-09	8.1E-09
Liver										
Kidneys										
Bladder wall										
Muscle										
Bone Surface										
Skin										
Spleen										
Uterus										
Pancreas										
Total Body										
Remainder										

TABLE 3.16 Comparison of specific committed dose equivalents (Sv/Bq) to the results in ICRP Publication 30 for selected inhaled radionuclides and their daughters. Values reported are greater than or equal to 10 % of the maximum.

Nuclide	P-32		Cr-51		Mn-54		Fe-59		Co-60	
f1	0.8		0.01		0.1		0.1		0.05	
Class	D		D		W		D		W	
Program	ICRP	DDSE	ICRP	DDSE	ICRP	DDSE	ICRP	DDSE	ICRP	DDSE
Lungs	2.5E-09	2.5E-09	3.8E-11	3.7E-11	6.7E-09	6.6E-09	3.5E-09	3.5E-09	3.6E-08	3.6E-08
Thyroid							2.9E-09	3.0E-09		
Testes										
Ovaries	4.8E-10	4.8E-10	2.7E-11	2.7E-11	7.1E-10	7.1E-10	3.3E-09	3.3E-09	4.0E-09	4.0E-09
Red Marrow	6.0E-09	5.8E-09	2.7E-11	3.1E-11	1.1E-09	1.1E-09	3.2E-09	3.2E-09	4.2E-09	4.2E-09
Stomach wall										
SI + contents			3.0E-11	3.0E-11						
ULI wall			3.8E-11	4.1E-11			4.1E-09	4.1E-09		
LLI wall	1.5E-09	1.5E-09	5.9E-11	6.8E-11			4.8E-09	4.8E-09	8.2E-09	8.1E-09
Liver					2.5E-09	2.5E-09	7.1E-09	7.1E-09	9.2E-09	9.2E-09
Kidneys										
Bladder wall										
Muscle	4.8E-10	4.8E-10	1.9E-11	1.9E-11	8.6E-10	8.6E-10	3.0E-09	3.0E-09	4.2E-09	4.2E-09
Bone Surface	5.8E-09	5.8E-09	2.7E-11	2.6E-11			2.9E-09	2.9E-09		
Skin										
Spleen							8.3E-09	8.5E-09		
Uterus										
Pancreas										
Total Body										
Remainder			2.5E-11	2.4E-11	1.8E-09	1.4E-09	4.7E-09	4.0E-09		

Nuclide	Sr-90		Y-93		Nb-95		Tc-99m		Ag-110m	
f1	0.3		0.0001		0.01		0.8		0.05	
Class	D		Y		W		D		W	
Program	ICRP	DDSE	ICRP	DDSE	ICRP	DDSE	ICRP	DOSE	ICRP	DDSE
Lungs			2.5E-09	2.5E-09	5.5E-09	5.5E-09	2.3E-11	2.2E-11	3.2E-08	3.1E-08
Thyroid							5.0E-11	5.0E-11		
Testes										
Ovaries					4.8E-10	4.8E-10	2.8E-12	2.8E-12	2.3E-09	2.3E-09
Red Marrow	3.3E-07	2.3E-07			6.7E-10	6.7E-10	3.4E-12	3.4E-12		
Stomach wall							2.9E-11	1.6E-11		
SI + contents			5.7E-10	5.7E-10			4.8E-12	4.9E-12		
ULI wall			1.8E-09	1.8E-09			7.0E-12	6.9E-12		
LLI wall			2.0E-09	2.0E-09	1.9E-09	1.9E-09	5.0E-12	5.0E-12		
Liver									2.6E-08	2.5E-08
Kidneys										
Bladder wall										
Muscle							2.1E-12	2.2E-12	2.9E-09	2.9E-09
Bone Surface	7.3E-07	6.9E-07			2.4E-09	2.4E-09				
Skin										
Spleen										
Uterus										
Pancreas										
Total Body										
Remainder							5.0E-12	5.1E-12	6.9E-09	6.7E-09

TABLE 3.17 Comparison of specific committed dose equivalents (Sv/Bq) to the results in ICRP Publication 30 for selected inhaled radionuclides and their daughters. Values reported are greater than or equal to 10 % of the maximum.

Nuclide	Te-129m		I-130		Ce-134		Ba-140		La-140	
f1	0.2		1.0		1.0		0.1		0.001	
Class	D		D		D		D		W	
Program	**ICRP**	**DOSE**	**ICRP**	**DOSE**	**ICRP**	**DOSE**	**ICRP**	**DOSE**	**ICRP**	**DOSE**
Lungs	2.2E-09	2.2E-09	6.0E-10	5.9E-10	1.2E-08	1.2E-08	1.7E-09	1.6E-09	4.2E-09	4.2E-09
Thyroid			2.0E-08	1.8E-08	1.1E-08	1.1E-08				
Testes										
Ovaries					1.3E-08	1.1E-08	4.3E-10	4.2E-10	4.4E-10	4.5E-10
Red Marrow	8.8E-09	8.6E-09			1.2E-08	1.2E-08	1.3E-09	1.4E-09		
Stomach wall										
SI + contents					1.4E-08	1.4E-08	5.3E-10	5.1E-10	9.7E-10	9.7E-10
ULI wall							1.5E-09	1.4E-09	2.9E-09	2.9E-09
LLI wall	4.2E-09	4.2E-09			1.4E-08	1.4E-08	4.4E-09	4.3E-09	5.5E-09	5.4E-09
Liver										
Kidneys										
Bladder wall										
Muscle										
Bone Surface	2.0E-08	1.9E-08			1.1E-08	1.1E-08	2.9E-10	2.8E-10		
Skin					1.1E-08	1.1E-08	2.4E-09	2.6E-09		
Spleen										
Uterus										
Pancreas										
Total Body										
Remainder					1.5E-08	1.4E-08				

Nuclide	Zr-97		Ce-143		Pr-143		Nd-147		N-239	
f1	0.002		0.0003		0.0003		0.0003		0.01	
Class	Y		Y		D		Y		W	
Program	**ICRP**	**DOSE**	**ICRP**	**DOSE**	**ICRP**	**DOSE**	**ICRP**	**DOSE**	**ICRP**	**DOSE**
Lungs	4.1E-09	4.0E-09	3.9E-09	3.9E-09	1.1E-08	1.1E-08	1.1E-08	1.1E-08	2.4E-09	2.2E-09
Thyroid										
Testes										
Ovaries										
Red Marrow										
Stomach wall										
SI + contents	1.0E-09	1.0E-09								
ULI wall	3.5E-09	3.5E-09	2.1E-09	2.1E-09					1.3E-09	1.2E-09
LLI wall	5.1E-09	5.1E-09	4.3E-09	4.3E-09	6.1E-09	6.1E-09	5.9E-09	5.8E-09	2.9E-09	2.7E-09
Liver										
Kidneys										
Bladder wall										
Muscle										
Bone Surface										
Skin									1.4E-09	1.3E-09
Spleen										
Uterus										
Pancreas										
Total Body										
Remainder										

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Appendix A

Listing of Computer Programs

ATOMNO.FOR

10-15-1987

```
************************************************************************
*                                                                      *
*       SUBROUTINE NAME: ATOMND FORTRAN                                *
*       PURPOSE:         Search for atomic number of the nuclide       *
*       INPUT:           Symbol of the radionuclide                    *
*                                                                      *
************************************************************************
      SUBROUTINE ATOMND (SYM,KZ)
      CHARACTER*2 SYM
      CHARACTER*2 ZNAME(103)
      DATA ZNAME/'N-','HE','LI','BE','B-','C-','N-','O-','F-','NE','NA',
     &'MG','AL','SI','P-','S-','CL','AR','K-','CA','SC','TI','V-','CR','
     &MN','FE','CO','NI','CU','ZN','GA','GE','AS','SE','BR','KR','RB','S
     &R','Y-','ZR','NB','MO','TC','RU','RH','PD','AG','CD','IN','SN','SB
     &','TE','I-','XE','CS','BA','LA','CE','PR','ND','PM','SM','EU','GD'
     &,'TB','DY','HO','ER','TM','YB','LU','NF','TA','W-','RE','OS','IR',
     &'PT','AU','HG','TL','PB','BI','PO','AT','RN','FR','RA','AC','TH','
     &PA','U-','NP','PU','AM','CM','BK','CF','ES','FM','MD','NO','LR'/
************************************************************************
*       Comparison                                                     *
************************************************************************
      DO 5 I=1,103
      IF (ZNAME(I) .EQ. SYM)THEN
         KZ=I
         RETURN
      END IF
    5 CONTINUE
      RETURN
      END
```

DECAY.FOR

10-15-1987

```
************************************************************************
*                                                                      *
*       SUBROUTINE NAME : DECAY FORTRAN                                *
*       PURPOSE: Provide the decay scheme of e radionuclide            *
*       DATA FILES REQUIRED:    a) ISOTIPS FILE                        *
*                               b) ISOTOPE FILE                        *
*                               c) ALPHA   FILE                        *
*                               d) BETA    FILE                        *
*                               e) POSITRN FILE                        *
*                               f) ELECTRN FILE                        *
*                               g) PHOTON  FILE                        *
*                                                                      *
************************************************************************
      SUBROUTINE DECAY (WORD,ICOUNT)
      COMMON EALPHA(1:20),YALPHA(1:20),EBETA(1:50),YBETA(1:50),EPOST(1:
     &15),YPOST(1:15),EELEC(1:115),YELEC(1:115),EGAMMA(1:190),YGAMMA(1:
     &190),N,I1,I3,I5,I7,HLIFE
      CHARACTER*1 C
      CHARACTER*8 ERT,WORD
      CHARACTER*10 B
      INTEGER DECERR(7)
      OPEN (UNIT=1,FILE='ISOTIPS',ACCESS='DIRECT',RECL=8,FORM='FORMATTED
     &',STATUS='OLD')
      OPEN (UNIT=2,FILE='ISOTOPE',ACCESS='DIRECT',RECL=59,FORM='FORMATTE
     &D',STATUS='OLD')
      OPEN (UNIT=3,FILE='ALPHA',ACCESS='DIRECT',RECL=20,FORM='FORMATTED'
     &,STATUS='OLD')
      OPEN (UNIT=4,FILE='BETA',ACCESS='DIRECT',RECL=39,FORM='FORMATTED',
     &STATUS='OLD')
      OPEN (UNIT=8,FILE='POSITRN',ACCESS='DIRECT',RECL=31,FORM='FORMATTE
     &D',STATUS='OLD')
      OPEN (UNIT=10,FILE='ELECTRN',ACCESS='DIRECT',RECL=26,FORM='FORMATT
     &ED',STATUS='OLD')
      OPEN (UNIT=11,FILE='PHOTON',ACCESS='DIRECT',RECL=26,FORM='FORMATTE
     &D',STATUS='OLD')
************************************************************************
*                                                                      *
*                           ISOTIPS                                    *
*       Comparing the given nuclide name with the alphabetically       *
*       ordered names (ERT) in the file                                *
*                                                                      *
************************************************************************
      ITR=0
      IF (WORD(1:1) .GE. 'R')THEN
      N1=321
      ELSE IF (WORD(1:1) .GE. 'N')THEN
      N1=225
      ELSE IF (WORD(1:1) .GE. 'C')THEN
      N1=65
      ELSE
      N1=1
      END IF
      DO 10 I=N1,496
      READ(1,15,REC=I)ERT
```

```
   15 FORMAT(A8)
      IF (ERT .EQ. WORD)THEN
*************************************************************************
*                                                                       *
*         ITR------> Record number of the radionuclide                  *
*                                                                       *
*************************************************************************
      ITR=I
      GO TO 20
      END IF
   10 CONTINUE
      IF (ITR .EQ. 0)THEN
        DECERR(1)=1
        GOTO 80
      END IF
*************************************************************************
*                                                                       *
*                          ISOTOPE                                      *
*                    DESCRIPTION OF VARIABLES                           *
*                    ------------------------                           *
*         ERT-----> Name of the isotope                                 *
*         JO------> Atomic weight                                       *
*         J-------> Atomic number                                       *
*         B-------> Half-life                                           *
*         C-------> Half-life units(S,M,H,D,Y).                         *
*         K-------> Number of daughters                                 *
*         L-------> Pointer to first daughter                           *
*         M-------> Number of alphas                                    *
*         N-------> Pointer to first alpha                              *
*         I1------> Number of betas                                     *
*         I2------> Pointer to first beta                               *
*         I3------> Number of positrons                                 *
*         I4------> Pointer to first positron                           *
*         I5------> Number of electrons                                 *
*         I6------> Pointer to first electron                           *
*         I7------> Number of photons                                   *
*         I8------> Pointer to first photon                             *
*                                                                       *
*************************************************************************
   20 READ (2,25,REC=ITR,IOSTAT=DECERR(2),ERR=80)ERT,JO,J,HLIFE,C,K,L,M,
     &N,I1,I2,I3,I4,I5,I6,I7,I8
   25 FORMAT(A8,I3,I3,G10.0,A1,I1,I3,I2,I3,I2,I4,I2,I3,I3,I4,I3,I4)
*************************************************************************
*                                                                       *
*                          ALPHA                                        *
*         AL1------> Energy in MeV                                      *
*         AL2------> Intensity                                          *
*                                                                       *
*************************************************************************
      K1=0
      IF (M .EQ. 0)GOTO 39
      DO 30 JOB=N,N+M-1
      READ(3,35,REC=JOB,IOSTAT=DECERR(3),ERR=80)AL1,AL2
   35 FORMAT(F7.4,1PE13.6)
```

```
      K1=K1+1
      EALPHA(K1)=AL1
      YALPHA(K1)=AL2
   30 CONTINUE
*************************************************************************
*                                                                       *
*                              BETA                                     *
*          BE1-------> Endpoint energy in MeV                           *
*          BE2-------> Averege energy in MeV                            *
*          BE3-------> Intensity                                        *
*                                                                       *
*************************************************************************
   39 K1=0
      IF (I1 .EQ. 0) GOTO 49
      DO 40 J1=I2,I2+I1-1
      READ(4,45,REC=J1,IOSTAT=DECERR(4),ERR=80)BE1,BE2,BE3
   45 FORMAT(1PE13.6,1PE13.6,1PE13.6)
      K1=K1+1
      EBETA(K1)=BE2
      YBETA(K1)=BE3
   40 CONTINUE
*************************************************************************
*                                                                       *
*                             POSITRON                                  *
*          POS1-------> Endpoint energy in MeV                          *
*          POS2-------> Average energy in MeV                           *
*          POS3-------> Intensity                                       *
*                                                                       *
*************************************************************************
   49 K1=0
      IF (I3 .EQ. 0)GO TO 59
      DO 50 J3=I4,I4+I3-1
      READ(8,55,REC=J3,IOSTAT=DECERR(5),ERR=80)POS1,POS2,POS3
   55 FORMAT(F8.5,F10.7,1PE13.6)
      K1=K1+1
      EPOST(K1)=POS2
      YPOST(K1)=POS3
   50 CONTINUE
*************************************************************************
*                                                                       *
*                             ELECTRON                                  *
*          ELE1-------> Energy in MeV                                   *
*          ELE2-------> Intensity                                       *
*                                                                       *
*************************************************************************
   59 K1=0
      IF (I5 .EQ. 0)GOTO 69
      DO 60 J4=I6,I6+I5-1
      READ(10,65,REC=J4,IOSTAT=DECERR(6),ERR=80)ELE1,ELE2
   65 FORMAT(1PE13.6,1PE13.6)
      K1=K1+1
      EELEC(K1)=ELE1
      YELEC(K1)=ELE2
   60 CONTINUE
```

DECAY.FOR

10-15-1987

```
*****************************************************************
*                                                               *
*                          PHOTON                               *
*         PHO1------> Energy in MeV                             *
*         PHO2------> Intensity                                 *
*                                                               *
*****************************************************************
   69 K1=0
      IF (I7 .EQ. 0)GOTO 79
      DO 70 J5=I8,I8+I7-1
      READ(11,75,REC=J5,IOSTAT=DECERR(7),ERR=80)PHO1,PHO2
   75 FORMAT(1PE13.6,1PE13.6)
      K1=K1+1
      EGAMMA(K1)=PHO1
      YGAMMA(K1)=PHO2
   70 CONTINUE
*****************************************************************
*                                                               *
*         Convert half lives into days                          *
*                                                               *
*****************************************************************
   79 IF(C .EQ. 'S')THEN
         HLIFE=HLIFE/86400.
      ELSE IF (C .EQ. 'M')THEN
         HLIFE=HLIFE/(60.*24.)
      ELSE IF (C .EQ. 'H')THEN
         HLIFE=HLIFE/24.
      ELSE IF (C .EQ. 'Y')THEN
         HLIFE=HLIFE*365.25
      END IF
      RETURN
   80 CALL CLEAR
      CALL YERROR(DECERR)
      ICOUNT=1
      RETURN
      END
```

DECAY1.FOR

10-15-1987

```
************************************************************************
*                                                                      *
*       SUBROUTINE NAME: DECAY1 FORTRAN                                *
*       PURPOSE: Find half-lives and names of the given isotope        *
*                and its daughters                                     *
*       DECAY MODE: A---->B---->C---->D                                *
*       DATA FILES REQUIRED:   a) ISOTIPS FILE                         *
*                              b) ISOTOPE FILE                         *
*                              c) DAUTER  FILE                         *
*                                                                      *
*       DESCRIPTION OF VARIABLES:                                      *
*                                                                      *
*       WORD-----> Name of the given isotope                           *
*       RHALF----> Vector of half-lives of the given isotope           *
*                  and its daughters                                   *
*       ULIFE----> Vector of half-life units of the given              *
*                  isotope and its daughters                           *
*       BRA------> Vector of branching ratios of the given             *
*                  isotope (BRA(1)=1) and its daughters                *
*       RADID----> Vector of names of the given isotope and            *
*                  its daughters                                       *
*       NO-------> Number of daughters plus one (for the given         *
*                  isotope                                             *
*                                                                      *
************************************************************************
      SUBROUTINE DECAY1 (WORD,RHALF,ULIFE,BRA,RADID,NO,*)
      DIMENSION RHALF(1:50),BRA(1:50)
      CHARACTER*1 ULIFE(50),U
      CHARACTER*8 ERT,RADID(50),WORD
      OPEN(UNIT=1,FILE='ISOTIPS',ACCESS='DIRECT',RECL=8,FORM='FORMATTED'
     -&)
      OPEN(UNIT=2,FILE='ISOTOPE',ACCESS='DIRECT',RECL=59,FORM='FORMATTED
     &')
      OPEN(UNIT=12,FILE='DAUTER',ACCESS='DIRECT',RECL=16,FORM='FORMATTED
     &')
      RADID(1)=WORD
************************************************************************
*                                                                      *
*         Data File:  ISOTIPS                                          *
*                                                                      *
************************************************************************
      ITR=0
      IF (WORD(1:1) .GE. 'R')THEN
         M1=321
      ELSE IF(WORD(1:1) .GE. 'N')THEN
         M1=225
      ELSE IF(WORD(1:1) .GE. 'C')THEN
         M1=65
      ELSE
         M1=1
      END IF
      DO 10 I=M1,496
      READ(1,15,REC=I)ERT
   15 FORMAT(A8)
```

```
      IF (ERT .EQ. WORD)THEN
         ITR=I
         GOTO 20
      END IF
   10 CONTINUE
      IF (ITR .EQ. 0)GOTO 50
*****************************************************************
*                                                               *
*        Deta File: ISOTOPE                                     *
*                                                               *
*****************************************************************
   20 READ(2,25,REC=ITR,ERR=60)ERT,JD,J,B,U,K,L,M,N,I1,I2,I3,I4,I5,I6,I7
     &,I8
*****************************************************************
*                                                               *
*                    DESCRIPTION OF VARIABLES                   *
*                    ------------------------                   *
*        ERT----->Name of the isotope                           *
*        JO------>Atomic weight                                 *
*        J------->Atomic number                                 *
*        B------->Half life                                     *
*        U------->Half life units (S,M,H,D,Y)                   *
*        K------->Number of daughters                           *
*        L------->Pointer to first daughter                     *
*        M------->Number of alphas                              *
*        N------->Pointer to first alpha                        *
*        I1------>Number of betas                               *
*        I2------>Pointer to first beta                         *
*        I3------>Number of positrons                           *
*        I4------>Pointer to first positron                     *
*        I5------>Number of electrons                           *
*        I6------>Pointer to first electron                     *
*        I7------>Number of photons                             *
*        I8------>Pointer to first photon                       *
*                                                               *
*****************************************************************
   25 FORMAT(A8,I3,I3,G10.0,A1,I1,I3,I2,I3,I2,I4,I2,I3,I3,I4,I3,I4)
      RHALF(I)=B
      ULIFE(I)=U
      BRA(I)=1.
*****************************************************************
*                                                               *
*        Date File: Dauter                                      *
*             I9---->Pointer to daughter isotope                *
*             YIELD->Branching ratio of daughter                *
*                                                               *
*****************************************************************
      I=1
   30 IF (K .EQ. 0)GOTO 45
      YSAVE=0.
      ISAVE=0
*****************************************************************
*                                                               *
*        If K > 1 and the decay mode is A----->B1, and A---->B2,*
```

```
*        then save the pointer and yield of only the higher          *
*        branching ratio                                             *
*                                                                    *
**********************************************************************
      DO 35 J2=L,L+K-1
      READ(12,40,REC=J2,ERR=70)I9,YIELD
   40 FORMAT(I3,1PE13.6)
      IF (YIELD .GT. YSAVE)THEN
         YSAVE=YIELD
         ISAVE=I9
      END IF
   35 CONTINUE
      I=I+1
      BRA(I)=YSAVE
      READ(2,25,REC=ISAVE,ERR=80)ERT,JO,J,B,U,K,L,M,N,I1,I2,I3,I4,I5,I6,
     &I7,I8
      RADID(I)=ERT
      ULIFE(I)=U
      RHALF(I)=B
      GOTO 30
   45 NO=I
      RETURN
**********************************************************************
*                                                                    *
*         ERROR HANDLER                                              *
*                                                                    *
**********************************************************************
   50 CALL CLEAR
      WRITE (*,55)
   55 FORMAT(//,' ERROR: No match found in file "ISOTOPS" for the given
     &radionuclide!!',/,' SOURCE: DECAY1 FORTRAN',/,' CORRECTIVE ACTION:
     & Try another nuclide!!',////)
      PAUSE '  TO RESUME PRESS <RETURN>!!'
      RETURN 1
   60 CALL CLEAR
      WRITE (*,65)
   65 FORMAT(//,' ERROR: Unable to read the decay scheme from file "ISOT
     &OPE" for the given radio  nuclide!!',/,' SOURCE: DECAY1 FORTRAN',/
     &,' CORRECTIVE ACTION: Try another nuclide!!',////)
      PAUSE '  TO RESUME PRESS <RETURN>!!'
      RETURN 1
   70 CALL CLEAR
      WRITE (*,75)
   75 FORMAT(//,' ERROR: Unable to read the branching retio and pointer
     &of daughter nuclide in    file "DAUTER"!!',/,' SOURCE: DECAY1 FORT
     &RAN',/,' CORRECTIVE ACTION: Try another nuclide!!',////)
      PAUSE '  TO RESUME PRESS <RETURN>!!'
      RETURN 1
   80 CALL CLEAR
      WRITE (*,85)
   85 FORMAT(//,' ERROR: Unable to read the decay scheme of the daughter
     & from file "ISOTOPE"!',/,' SOURCE: DECAY1 FORTRAN',/,' CORRECTIVE
     &ACTION: Try another nuclide!!',////)
      PAUSE '  TO RESUME PRESS <RETURN>!!'
```

```
RETURN 1
END
```

```
FMR SPEFF TEXT
FMR DECAY TEXT
FMR INTRPT TEXT
FMR ENERGY TEXT
FMR FRAC TEXT
FMR DECAY1 TEXT
FMR THALF TEXT
FMR TFRAC TEXT
FMR SOURCE TEXT
FMR SUBMER TEXT
FMR I1 TEXT
FMR TRNSFM TEXT
FMR REFMAN TEXT
FMR INHALE TEXT
FMR RESPIR TEXT
FMR PCLASS TEXT
FMR RESULT TEXT
FMR FACTOR TEXT
FMR INGEST TEXT
FMR YERROR TEXT
FMR DOSE TEXT
FMR ATOMNO TEXT
FMR ICRP TEXT
FMR ICLASS TEXT
FMR F1VALU TEXT
FMR UXP TEXT
EXPAND SUBMER TEXT
EXPAND ATOMNO TEXT
EXPAND SPEFF TEXT
EXPAND DECAY TEXT
EXPAND INTRPT TEXT
EXPAND ENERGY TEXT
EXPAND FRAC TEXT
EXPAND DECAY1 TEXT
EXPAND THALF TEXT
EXPAND TFRAC TEXT
EXPAND SOURCE TEXT
EXPAND I1 TEXT
EXPAND TRNSFM TEXT
EXPAND INHALE TEXT
EXPAND REFMAN TEXT
EXPAND PCLASS TEXT
EXPAND RESPIR TEXT
EXPAND RESULT TEXT
EXPAND FACTOR TEXT
EXPAND INGEST TEXT
EXPAND YERROR TEXT
EXPAND DOSE TEXT
EXPAND ICRP TEXT
EXPAND F1VALU TEXT
EXPAND UXP TEXT
EXPAND ICLASS TEXT
FMR ISOTIPS FILE
FMR ISOTOPE FILE
```

DOSE.EXE

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```
FMR ALPHA FILE
FMR BETA FILE
FMR POSITRN FILE
FMR ELECTRN FILE
FMR PHOTON FILE
FMR ABSFRAC FILE
FMR BFFRAC FILE
FMR RETENT FILE
FMR DAUTER FILE
FMR INDEXI FILE
FMR INDEXD FILE
FMR EXCEPT FILE
FMR LIST FILE
FMR NOBLE FILE
FMR CLEAR TEXT
EXPAND CLEAR TEXT
EXPAND ISOTIPS FILE
EXPAND ISOTOPE FILE
EXPAND ALPHA FILE
EXPAND BETA FILE
EXPAND ELECTRN FILE
EXPAND POSITRN FILE
EXPAND PHOTON FILE
EXPAND BFFRAC FILE
EXPAND RETENT FILE
EXPAND DAUTER FILE
EXPAND ABSFRAC FILE
EXPAND INDEXD FILE
EXPAND INDEXI FILE
EXPAND EXCEPT FILE
EXPAND NOBLE FILE
EXPAND LIST FILE
FILEDEF ISOTIPS DISX ISOTIPS FILE A1 (PERM XTENT 496
FILEDEF ISOTOPE DISX ISOTOPE FILE A1 (PERM XTENT 496
FILEDEF ALPHA DISX ALPHA FILE A1 (PERM XTENT 360
FILEDEF BETA DISX BETA FILE A1 (PERM XTENT 1700
FILEDEF POSITRN DISK POSITRN FILE A1 (PERM XTENT 138
FILEDEF ELECTRN DISX ELECTRN FILE A1 (PERM XTENT 3882
FILEDEF PHOTON DISX PHOTON FILE A1 (PERM XTENT 7480
FILEDEF ABSFRAC DISX ABSFRAC FILE A1 (PERM XTENT 4560
FILEDEF BFFRAC DISX BFFRAC FILE A1 (PERM XTENT 501
FILEDEF DAUTER DISX DAUTER FILE A1 (PERM XTENT 291
FILEDEF RETENT DISX RETENT FILE A1 (PERM XTENT 460
FILEDEF INDEXI DISX INDEXI FILE A1 (PERM XTENT 46
FILEDEF INDEXD DISX INDEXD FILE A1 (PERM XTENT 46
FILEDEF EXCEPT DISX EXCEPT FILE A1 (PERM XTENT 695
FILEDEF LIST DISK LIST FILE A1 (PERM XTENT 26
FILEDEF NOBLE DISK NOBLE FILE A1 (PERM XTENT 26
LOAD DOSE
START
ERASE ISOTIPS FILE
ERASE ISOTOPE FILE
ERASE ALPHA FILE
ERASE BETA FILE
```

DOSE.EXE

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```
ERASE POSITRN FILE
ERASE ELECTRN FILE
ERASE PHOTON FILE
ERASE DAUTER FILE
ERASE RETENT FILE
ERASE ABSFRAC FILE
ERASE BFFRAC FILE
ERASE SPEFF TEXT
ERASE DECAY TEXT
ERASE INTRPT TEXT
ERASE ENERGY TEXT
ERASE FRAC TEXT
ERASE DECAY1 TEXT
ERASE TNALF TEXT
ERASE TFRAC TEXT
ERASE SOURCE TEXT
ERASE I1 TEXT
ERASE TRNSFM TEXT
ERASE REFMAN TEXT
ERASE INHALE TEXT
ERASE RESPIR TEXT
ERASE PCLASS TEXT
ERASE RESULT TEXT
ERASE FACTOR TEXT
ERASE CLEAR TEXT
ERASE INGEST TEXT
ERASE YERROR TEXT
ERASE DOSE TEXT
ERASE ATOMND TEXT
ERASE ICLASS TEXT
ERASE F1VALU TEXT
ERASE ICRP TEXT
ERASE UXP TEXT
ERASE EXCEPT FILE
ERASE INDEXI FILE
ERASE INDEXD FILE
ERASE LIST FILE
ERASE NOBLE FILE
ERASE SUBMER TEXT
```

DOSE.FOR

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```
************************************************************************
*                                                                      *
*     DESCRIPTION OF VARIABLES:                                        *
*                                                                      *
*         WORD------> Name of the given isotope                        *
*         KZ -------> Atomic Number of the nuclide                     *
*         HFIFTY ---> Specific committed dose equivalent to target     *
*                     organ or tissues                                 *
*                                                                      *
************************************************************************
      DIMENSION HFIFTY(1:24),WDOSE(1:24),SFACT(19,18),KS(18),KT(19),US(1
     &:20,1:50),RHALF(1:50),BRA(1:50),DOSE(1:20)
      INTEGER DOSERR(1:5),OPT,OUI,ORGAN
      CHARACTER*1 SEX,ULIFE(50),CLASS
      CHARACTER*8 WORD,RADID(50),NUCLID,ISOTOP
      CHARACTER*15 UNITS(3)
      CNARACTER*9 SNAME(18)
      CHARACTER*15 TNAME(24)
      CHARACTER*32 UCASE
      CHARACTER*7 FFILE(4)
    5 FORMAT(A)
   10 FORMAT(A8,A2,8I2,I3,A2,2E10.3,3(A7))
      DATA AMAD,CLASS,F1,KZ,OPT,MAIS,ISAY,MORE,MON,NU,INRE/1.,'D',0.,0,1
     &,2*2,0,2,1,2/
      DATA SEX,OUI/'F',2/
      DATA FFILE /4*'DUMMY  '/
      DATA KS/1,2,3,4,5,6,7,8,9,10,11,12,18,13,14,15,16,17/
      DATA KT/12,6,7,8,9,11,10,1,13,4,18,14,5,15,16,3,2,17,19/
      DATA TNAME/'Lungs','Thyroid','Testes','Ovaries','Red Marrow','Stom
     &ach wall','SI + contents','ULI wall','LLI wall','Liver','Kidneys',
     &'Bladder wall','Muscle','Bone Surface','Skin','Spleen','Uterus','P
     &ancreas','Total Body','Gonads','Adrenals','Lens','Thymus','Brain'/
      DATA SNAME/'Bladder','Stomach','SI','ULI','LLI','Kidneys','Liver',
     &'Lungs','Muscle','Ovaries','Pancreas','Trab Bone','Skin','Spleen',
     &'Testes','Thyroid','Tot. Body','Cort Bone'/
      DATA UNITS/'MeV/g','rad/micro Ci.h','mSv/GBq.h'/
************************************************************************
*                                                                      *
*        Display initial screens                                       *
*                                                                      *
************************************************************************
      CALL CLEAR
      WRITE(*,11)
   11 FORMAT(5(/))
      PRINT*,'*****************************************************
     &*****************'
      WRITE (*,15)
   15 FORMAT(2(/),29X,' D D $ E  VERSION 1.0, 1987',/)
      WRITE (*,20)
   20 FORMAT(19X,'Written by: Amiruddin Nude')
      WRITE (*,22)
   22 FORMAT(19X,'Address:    c/o  Dr. R. E. Faw')
      WRITE (*,25)
   25 FORMAT(19X,'            Department of Nuclear Engineering')
```

```
      WRITE (*,30)
   30 FORMAT(19X,'              Kansas Stete University')
      WRITE (*,35)
   35 FORMAT(19X,'              Manhattan, Kensas 66502',//)
      PRINT*,'*****************************************************************
     &*****************'
      PAUSE  '  TO RESUME PRESS <RETURN>!'
      CALL CLEAR
      PRINT*,'*****************************************************************
     &*****************'
      WRITE (*,40)
   40 FORMAT(//,5X,' PROGRAM NAME: DOSE FORTRAN')
      WRITE (*,45)
   45 FORMAT(5X,' BASIS:          ICRP Methodology')
      WRITE (*,50)
   50 FORMAT(5X,' PURPOSE:        TO CALCULATE')
      WRITE (*,55)
   55 FORMAT(/,8X,'e) Specific committed dose equivalent, HFIFTY (Sv/Bq)
     & in terget organs')
      WRITE (*,60)
   60 FORMAT(/,8X,'b) Weighted committed dose equivelent, WDOSE (Sv/Bq)
     &in terget orgens')
      WRITE (*,65)
   65 FORMAT(/,8X,'c) Annual Limits on Inteka, ALI (Bq) of the nuclide')
      WRITE (*,70)
   70 FORMAT(/,8X,'d) Darived Air Concentration, DAC (Bq/cu.m) of tha nu
     &clide')
      WRITE (*,75)
   75 FORMAT(/,8X,'a) Specific Effective Energy Table for 17 sources & 1
     &9 targets')
      WRITE (*,80)
   80 FORMAT(/,8X,'f) Source-orgen transformations per unit ectivity of
     &intake',/)
      PRINT*,'*****************************************************************
     &*****************'
   85 PAUSE '  TO RESUME PRESS <RETURN>!'
*     CALL CLEAR
*************************************************************************
*                                                                       *
*        Additionsl preliminaries                                       *
*                                                                       *
*************************************************************************
*     PRINT *
*     PRINT *
*     PRINT *,' 0 - IBM-PC/XT/AT or compatible microcomputer'
*     PRINT *,' 1 - IBM-Meinframe computer, CMS or equivalent system'
*     PRINT *
*     PRINT *,' Salect integer 0 or 1'
*     PRINT *
*     READ *, MICRO
*************************************************************************
  110 CALL CLEAR
      PRINT *
      PRINT *,' 0 - Date input from the keyboard'
```

```
      PRINT *,' 1 - Data input from a file'
      PRINT *,' 2 - Preperation of a date input file'
      PRINT *
      PRINT *,' Select integer 0, 1 or 2'
      PRINT *
      READ  (*,115,ERR=110,END=111)NDATA
  115 FORMAT(I1)
      IF(NDATA .NE. 0 .AND. (NDATA .NE. 1) .AND. (NDATA .NE. 2))THEN
  111   REWIND 5
        GOTO 110
      END IF
      IF(NDATA .NE. 0)THEN
  120   CALL CLEAR
        PRINT *,' Enter name of date input file (less than or equal to 7
     & characters) :'
        PRINT *
        READ (*,121,ERR=120,END=122)FFILE(3)
  121   FORMAT(A7)
        IF (FFILE(3) .EQ. '       ')THEN
  122     REWIND 5
          GOTO 120
        END IF
        OPEN (75,FILE=FFILE(3),STATUS='UNKNOWN')
        REWIND (75)
      END IF
*****************************************************************************
*                                                                           *
*         Input date collection                                             *
*                                                                           *
*****************************************************************************
      IF (NDATA .EQ. 1)GOTO 255
*****************************************************************************
*                                                                           *
*         Identificetion of nuclida                                         *
*                                                                           *
*****************************************************************************
  125 CALL CLEAR
      PRINT *
      PRINT *,'NOTE: TO INITIATE TERMINATION PRESS <RETURN>!!'
      PRINT *
      WRITE (*,130)
  130 FORMAT(10(/),' Enter radionuclida identification, e.g., CS-137',/)
      READ  (*,5,ERR=125,END=9000)WORD
      NUCLID=WORD
*     WORD=UCASE(WORD,1,2)
*****************************************************************************
*                                                                           *
*         Call subroutine DECAY1 for daughters                              *
*                                                                           *
*****************************************************************************
      CALL DECAY1 (WORD,RHALF,ULIFE,BRA,RADIO,NO,*125)
      DO 142 I=1,NO
      ISOTOP=RADIO(I)
*****************************************************************************
```

```
*         Convart helf-lives into days                                  *
**********************************************************************
      IF (ULIFE(I) .EQ. 'S')THEN
         RHALF(I)=RHALF(I)/86400.
      ELSE IF (ULIFE(I) .EQ. 'M')THEN
         RHALF(I)=RHALF(I)/(60.*24.)
      ELSE IF (ULIFE(I) .EQ. 'H')THEN
         RNALF(I)=RNALF(I)/24.
      ELSE IF (ULIFE(I) .EQ. 'Y')THEN
         RNALF(I)=RHALF(I)*365.25
      END IF
      IF (I .NE. 1)THEN
        IF (ISOTOP(1:2) .EQ. 'AR' .OR. (ISOTOP(1:2) .EQ. 'KR') .OR. (ISO
     &TOP(1:2) .EQ. 'XE') .OR. (ISOTOP(1:2) .EQ. 'NE'))THEN
           NO=I-1
           GOTO 143
        END IF
      END IF
  142 CONTINUE
**********************************************************************
*                                                                    *
*         In case of noble radioactive gases or elemental tritium    *
*         the following queries are skipped                          *
*                                                                    *
**********************************************************************
  143 IF (WORD(1:2) .EQ. 'H-' .OR. (WORD(1:2) .EQ. 'KR') .OR. (WORD(1:2)
     & .EQ. 'XE') .OR. (WORD(1:2) .EQ. 'AR'))THEN
         OPT=3
         GOTO 250
      END IF
**********************************************************************
*                                                                    *
*         Identification sex of subject                              *
*                                                                    *
**********************************************************************
  135 CALL CLEAR
      WRITE (*,140)
  140 FORMAT(10(/),' Enter the sex of the exposed individual, e.g., M or
     & F',//)
      READ  (*,5,ERR=135,END=141)SEX
      IF (SEX .NE.'M' .AND. (SEX .NE. 'F'))THEN
  141    REWIND 5
         GOTO 135
      END IF
*     SEX=UCASE(SEX,1,1)
**********************************************************************
*                                                                    *
*         Query desire for S-matrix table                            *
*                                                                    *
**********************************************************************
  145 CALL CLEAR
      WRITE (*,150)
  150 FORMAT(///,' Would you like to see the specific effective energy t
     &able of the nuclide for    17 sources and 19 target organs?',///,'
```

```
     &   1 Yee',/,'    2 No',////,' Select option by integer---->')
         READ (*,115,ERR=145,END=151)OUI
         IF (OUI .NE. 1 .AND. (OUI .NE. 2))THEN
  151      REWIND 5
           GOTO 145
         END IF
         IF (OUI .EQ. 1) THEN
  155    CALL CLEAR
         PRINT *,' Enter file epecification for table (leaa then or equal
     & to 7 characte):'
         READ (*,121,ERR=155,END=156)FFILE(1)
         IF (FFILE(1) .EQ. '       ')THEN
  156      REWIND 5
           GOTO 155
         END IF
  160    CALL CLEAR
         WRITE (*,165)UNITS(1),UNITS(2),UNITS(3)
  165    FORMAT(1D(/),' Enter integer for unite eelection',//,' 1 ',A,//,
     &' 2 ',A,//,' 3 ',A,/)
         READ  (*,115,ERR=160,END=161)NU
         IF (NU .NE. 1 .AND. (NU .NE. 2) .AND. (NU .NE. 3))THEN
  161      REWIND 5
           GOTO 160
         END IF
         IF (ND .GT. 1)THEN
  170      CALL CLEAR
           PRINT *,' THE DAUGNTERS OF THE GIVEN NUCLIDE ARE:'
           DO 175 I=2,ND
  175      PRINT *,  RADID(I)
           PRINT *
           PRINT *
           PRINT *,' Would you like to eee their S-tables too?'
           PRINT *
           PRINT *,'    1 Yaa'
           PRINT *,'    2 No'
           PRINT *
           PRINT *,' Select option by integer--->'
           READ (*,115,ERR=170,END=171)MON
           IF (MON .NE. 1 .AND. (MON .NE. 2))THEN
  171        REWIND 5
             GOTO 170
           END IF
         END IF
*************************************************************************
*                                                                       *
*        Query celculetion of dose committments                         *
*                                                                       *
*************************************************************************
  176    CALL CLEAR
         PRINT *,' Choose one of the following:'
         PRINT *
         PRINT *,'     1 Continue data entry for calculation of dose comm
     &ittments'
         PRINT *,'     2 Conclude date entry and STOP'
```

```
      PRINT *,'     3 Proceed with calculations of S-matrix only'
      IF (NDATA .EQ. 2)THEN
        PRINT *,'     4 Continue data entry for calculation of S-matr
     &ix only'
      END IF
      PRINT *
      READ  (*,115,ERR=176,END=178)INRE
      IF (INRE .NE. 1 .AND. (INRE .NE. 2) .AND. (INRE .NE. 3) .AND. (I
     &NRE .NE. 4))THEN
  178   REWIND 5
        GOTO 176
      END IF
      IF (INRE .EQ. 2)GOTO 9009
      IF (INRE .EQ. 3  .AND. (NDATA .EQ. 0))GOTO 260
      IF (INRE .NE. 1 .AND. (NDATA .EQ. 2))THEN
        WRITE(75,10)WORD,SEX,OUI,NU,MON,INRE,OPT,MAIS,ISAY,MORE,KZ,CL
     &ASS,AMAD,F1,FFILE(1),FFILE(2),FFILE(4)
        IF (INRE .EQ. 3)THEN
          NDATA=1
          REWIND(75)
        ELSE IF (INRE .EQ. 4)THEN
          GOTO 125
        END IF
      END IF
  177 IF (NDATA .EQ. 1)THEN
        READ(75,10,ERR=9009,END=9009)WORD,SEX,OUI,NU,MON,INRE,OPT,MAI
     &S,ISAY,MORE,KZ,CLASS,AMAD,F1,FFILE(1),FFILE(2),FFILE(4)
        NUCLID=WORD
        CALL DECAY1 (WORD,RNALF,ULIFE,BRA,RADIO,NO,*9009)
        DO 179 I=1,NO
        ISOTOP=RADIO(I)
*************************************************************************
*       Convert half-lives into days                                    *
*************************************************************************
     IF (ULIFE(I) .EQ. 'S')THEN
       RHALF(I)=RHALF(I)/86400.
     ELSE IF (ULIFE(I) .EQ. 'M')THEN
       RHALF(I)=RHALF(I)/(60.*24.)
     ELSE IF (ULIFE(I) .EQ. 'H')THEN
       RHALF(I)=RHALF(I)/24.
     ELSE IF (ULIFE(I) .EQ. 'Y')THEN
       RHALF(I)=RHALF(I)*365.25
     END IF
        IF (I .NE. 1)THEN
      IF (ISOTOP(1:2) .EQ. 'AR' .OR. (ISOTOP(1:2) .EQ. 'KR') .OR. (ISO
     &TOP(1:2) .EQ. 'XE') .OR. (ISOTOP(1:2) .EQ. 'NE'))THEN
          NO=I-1
          GOTO 260
        END IF
      END IF
  179   CONTINUE
        GOTO 260
      END IF
    END IF
```

```
C**********************************************************************
C*                                                                    *
C*        Identification of mode of intake                            *
C*                                                                    *
C**********************************************************************
  180 CALL CLEAR
      WRITE(*,185)
  185 FORMAT(10(/),' MODE OF INTAKE OF THE RADIONUCLIDE:',/)
      WRITE (*,190)
  190 FORMAT(/,8X,'1. .....Ingestion')
      WRITE (*,195)
  195 FORMAT(8X,'2. .....Inhalation')
      WRITE (*,205)
  205 FORMAT(///,' Select Option by Integer ----->',/)
      READ  (*,115,ERR=180,END=181)OPT
      IF (OPT .LT. 1 .OR. (OPT .GT. 2))THEN
  181    REWIND 5
         GOTO 180
      END IF
        IF (WORD(1:2) .EQ. 'AR' .OR. (WORD(1:2) .EQ. 'KR') .OR. (WORD(1:
     &2) .EQ. 'XE') .OR. (WORD(1:2) .EQ. 'N-'))THEN
           DOSERR(2)=1
           GOTO 1000
        END IF
  210   CALL CLEAR
        WRITE (*,215)
  215   FORMAT(5(/),' Would you like to see the number of transformation
     &s of the nuclide in source    organs?',//,'     1 Yes',/,'     2 N
     &o',////,' Select option by integer --->',//)
        READ  (*,115,ERR=210,END=211)MAIS
        IF (MAIS .NE. 1 .AND. (MAIS .NE. 2))THEN
  211      REWIND 5
           GOTO 210
        END IF
        IF (MAIS .EQ. 1)THEN
  216      CALL CLEAR
           PRINT *,' Enter file specification for transformations:'
           PRINT *,' (less than or equal to 7 characters !)'
           READ  (*,121,ERR=216,END=217)FFILE(4)
           IF (FFILE(4) .EQ. '       ')THEN
  217         REWIND 5
              GOTO 216
           END IF
           IF (NO .GT. 1)THEN
  220         CALL CLEAR
              WRITE (*,225)
  225         FORMAT(5(/),' Would you like to see the number of transfor
     &mations of the daughters too?',//,'     1 Yes',/,'     2 No',////,
     &' SELECT OPTION BY INTEGER--->',/)
              READ  (*,115,ERR=220,END=221)ISAY
              IF (ISAY .NE. 1 .AND. (ISAY .NE. 2))THEN
  221            REWIND 5
                 GOTO 220
              END IF
```

```
          END IF
        END IF
*****************************************************************
*                                                               *
*         Atomic Number of the given radionuclide               *
*                                                               *
*****************************************************************
      KZ=0
      CALL ATOMNO (WORD(1:2),KZ)
      IF (KZ .EQ. 0)THEN
        DOSERR(3)=1
        GOTO 1000
      END IF
*****************************************************************
*                                                               *
*         Obtain data for inhalation class and transfer to body fluid *
*                                                               *
*****************************************************************
      IF (OPT .EQ. 2)THEN
        CALL ICLASS(CLASS)
      END IF
      CALL F1VALU(KZ,F1,*125)
*****************************************************************
*                                                               *
*         Identification of aerodynamic diameter for inhalation *
*                                                               *
*****************************************************************
      IF (OPT .EQ. 2)THEN
  230   CALL CLEAR
        WRITE (*,235)
  235   FORMAT(//,' Is the activity median aerodynamic diameter equal to
     & 1 micrometer?',//,' 1 Yes',/,' 2 No',////,' Select option by inte
     &ger--->',/)
        READ  (*,115,ERR=230,END=231)LOT
        IF (LOT .NE. 1 .AND. (LOT .NE. 2))THEN
  231     REWIND 5
          GOTO 230
        END IF
        IF (LOT .EQ. 2)THEN
  240     CALL CLEAR
          WRITE (*,245)
  245     FORMAT(/,' Enter the value of AMAD (micrometers) between 0.1
     &and 20 micrometers !')
          READ(*,*,ERR=240,END=241)AMAD
          IF (AMAD .LT. 0.1 .OR. (AMAD .GT. 20.))THEN
  241       REWIND 5
            GOTO 240
          END IF
        END IF
      END IF
*****************************************************************
*                                                               *
*         Query filename for output table                       *
*                                                               *
```

```
*************************************************************************
  250 CALL CLEAR
      PRINT *,' Enter file specification for dose committment results:'
      PRINT *,' (less than or equal to 7 characters !)'
      READ (*,121,ERR=250,END=252)FFILE(2)
      IF (FFILE(2) .EQ. '       ')THEN
  252   REWIND 5
        GOTO 250
      END IF
      IF (NDATA .NE. 2)THEN
        IF (WORD(1:2) .EQ. 'AR' .OR. (WORD(1:2) .EQ. 'KR') .OR. (WORD(1:
     &2) .EQ. 'XE') .OR. (WORD(1:2) .EQ. 'H-'))THEN
          GOTO 268
        END IF
*************************************************************************
*                                                                       *
*         Query continuation of data input                              *
*                                                                       *
*************************************************************************
      ELSE
  251   CALL CLEAR
        PRINT *
        PRINT *, ' 0 - Conclude data entry and STOP'
        PRINT *, ' 1 - Continue data entry'
        PRINT *, ' 2 - Proceed with calculations'
        PRINT *
        PRINT *, ' Select integer 0, 1, or 2'
        PRINT *
        READ (*,115,ERR=251,END=253)MORE
        IF (MORE .NE. 0 .AND. (MORE .NE. 1) .AND. (MORE .NE. 2))THEN
  253     REWIND 5
          GOTO 251
        END IF
        WRITE(75,10)WORD,SEX,OUI,NU,MON,IHRE,OPT,MAIS,ISAY,MORE,KZ,CLASS
     &,AMAD,F1,FFILE(1),FFILE(2),FFILE(4)
        IF (MORE .EQ. 1)THEN
          GOTO 125
        ELSE IF (MORE .EQ. 2)THEN
          NDATA=1
          REWIND(75)
        ELSE
          CALL CLEAR
          GOTO 9009
        END IF
      END IF
  255 IF (NDATA .EQ. 1)THEN
        READ(75,10,ERR=9009,END=9009)WORD,SEX,OUI,NU,MON,IHRE,OPT,MAIS,I
     &SAT,MORE,KZ,CLASS,AMAD,F1,FFILE(1),FFILE(2),FFILE(4)
       NUCLID=WORD
      IF (OPT .EQ. 3)THEN
        IF (WORD(1:2) .NE. 'AR' .AND. (WORD(1:2) .NE. 'KR') .AND. (WORD(
     &1:2) .NE. 'XE') .AND. (WORD(1:2) .NE. 'H-'))THEN
          DOSERR(2)=1
          GOTO 1000
```

```
        ELSE
           GOTO 268
        END IF
      ELSE IF (OPT .NE. 3)THEN
        IF (WORD(1:2) .EQ. 'AR' .OR. (WORD(1:2) .EQ. 'KR') .OR. (WORO(1:
     &2) .EQ. 'XE') .OR. (WORO(1:2) .EQ. 'H-'))THEN
           DOSERR(2)=1
           GOTO 1000
        END IF
       CALL OECAY1 (WORO,RHALF,ULIFE,BRA,RADIO,NO,*9009)
       DO 256 I=1,NO
       ISOTOP=RADIO(I)
*************************************************************************
*         Convert half-lives into days                                  *
*************************************************************************
      IF (ULIFE(I) .EQ. 'S')THEN
         RHALF(I)=RHALF(I)/86400.
      ELSE IF (ULIFE(I) .EQ. 'M')THEN
         RHALF(I)=RHALF(I)/(60.*24.)
      ELSE IF (ULIFE(I) .EQ. 'H')THEN
         RHALF(I)=RHALF(I)/24.
      ELSE IF (ULIFE(I) .EQ. 'Y')THEN
         RHALF(I)=RHALF(I)*365.25
      END IF
       IF (I .NE. 1)THEN
        IF (ISOTOP(1:2) .EQ. 'AR' .OR. (ISOTOP(1:2) .EQ. 'KR') .OR. (ISO
     &TOP(1:2) .EQ. 'XE') .OR. (ISOTOP(1:2) .EQ. 'HE'))THEN
           NO=I-1
           GOTO 260
        END IF
       ENO IF
  256  CONTINUE
      END IF
      END IF
*************************************************************************
*                                                                       *
*         Calculation and printing results of S-matrix                  *
*                                                                       *
*************************************************************************
  260 CALL CLEAR
      IF (OUI .EQ. 1)THEN
        IF (MON .EQ. 2)THEN
           MES=1
        ELSE
           MES=NO
        ENO IF
        OPEN(55,FILE=FFILE(1),STATUS='UNKNOWN')
        OO 265 I=1,MES
        PRINT *, ' Calculating S-matrix for ',RADIO(I)
        WRITE (*,270)FFILE(1)
  270   FORMAT(//,' Results are in file ',A)
        CALL FACTOR (RADIO(I),NU,SFACT,NOATA,WORD,RHALF(1),*125,*9009)
        CALL CLEAR
        WRITE (55,275)
```

```
      IF (NDATA .EQ. 0)THEN
      WRITE (*,275)
      END IF
  275 FORMAT(/,'      ********************************************
     &**********',/,6X,'*',64K,'*',/,6X,'*  S-FACTORS FOR THE AD
     &ULT BY METHODS OF ICRP-30, V. 1.0, 1987   *',/,6K,'*',64K,'*',/,6X
     &,'*  Based on :  "Radioactive Decay Data Tables"',18X,'*',/,6X,'*
     &',16X,'D.C. Kocher, DOE/TIC-11026 (1981)',15K,'*',/,6X,'*  Written
     & by :  Amiruddin Nuda',34K,'*',/,6X,'*  Address :     c/o Dr. R.E.
     & Faw',32X,'*',/,6X,'*',16X,'Department of Nuclear Engineering',15K
     &,'*',/,6X,'*',16X,'Kansas State University',25K,'*',/,6X,'*',16X,'
     &Manhattan, Kansas 66506',25K,'*',/,6X,'*',64K,'*',/,'      *******
     &**********************************************************')
        WRITE (55,280)RADIO(I),UNITS(NU)
        IF (NDATA .EQ. 0)THEN
        WRITE (*,280) RADIO(I),UNITS(NU)
        END IF
  280   FORMAT(//,21K,A,' S-FACTORS (',A,')')
        WRITE (55,285)
        IF (NDATA .EQ. 0)THEN
        WRITE (*,285)
        END IF
  285   FORMAT(/,9X,'TARGET',28X,'SOURCE ORGANS')
        WRITE (55,290)(SNAME(KS(J)),J=1,4)
        IF (NDATA .EQ. 0)THEN
        WRITE (*,290)(SNAME(KS(J)),J=1,4)
        END IF
  290   FORMAT(9X,'ORGAN',11K,4(3K,A),//)
        DO 295 K=1,19
        WRITE (55,300) TNAME(KT(K)),(SFACT(KT(K),KS(J)),J=1,4)
        IF (NDATA .EQ. 0)THEN
        WRITE (*,300)TNAME(KT(K)),(SFACT(KT(K),KS(J)),J=1,4)
        END IF
  295   CONTINUE
  300   FORMAT(9X,A,4(3K,1PE9.2))
        WRITE (55,305)
        IF (NDATA .EQ. 0)THEN
        WRITE (*,305)
        END IF
  305   FORMAT(1N1)
        WRITE (55,280)RADIO(I),UNITS(NU)
        WRITE (55,285)
        WRITE (55,290)(SNAME(KS(J)),J=5,8)
        IF (NDATA .EQ. 0)THEN
        WRITE (*,280) RADIO(I),UNITS(NU)
        WRITE (*,285)
        WRITE (*,290)(SNAME(KS(J)),J=5,8)
        END IF
        DO 310 K=1,19
        WRITE (55,300) TNAME(KT(K)),(SFACT(KT(K),KS(J)),J=5,8)
        IF (NDATA .EQ. 0)THEN
        WRITE (*,300) TNAME(KT(K)),(SFACT(KT(K),KS(J)),J=5,8)
        END IF
  310   CONTINUE
```

```
      WRITE (55,305)
      WRITE (55,280)RADID(I),UNITS(NU)
      WRITE (55,285)
      WRITE (55,290)(SNAME(KS(J)),J=9,12)
      IF (NDATA .EQ. 0)THEN
      WRITE (*,305)
      WRITE (*,280) RADID(I),UNITS(NU)
      WRITE (*,285)
      WRITE (*,290)(SNAME(KS(J)),J=9,12)
      END IF
      DO 315 K=1,19
      WRITE (55,300) TNAME(KT(K)),(SFACT(KT(K),KS(J)),J=9,12)
      IF (NDATA .EQ. 0)THEN
      WRITE (*,300)TNAME(KT(K)),(SFACT(KT(K),KS(J)),J=9,12)
      END IF
315   CONTINUE
      WRITE (55,305)
      WRITE (55,280)RADID(I),UNITS(NU)
      WRITE (55,285)
      WRITE (55,290)(SNAME(KS(J)),J=13,16)
      IF (NDATA .EQ. 0)THEN
      WRITE (*,305)
      WRITE (*,280) RADID(I),UNITS(NU)
      WRITE (*,285)
      WRITE (*,290)(SNAME(KS(J)),J=13,16)
      END IF
      DO 320 K=1,19
      WRITE (55,300) TNAME(KT(K)),(SFACT(KT(K),KS(J)),J=13,16)
      IF (NDATA .EQ. 0)THEN
      WRITE (*,300) TNAME(KT(K)),(SFACT(KT(K),KS(J)),J=13,16)
      ENDIF
320   CONTINUE
      WRITE (55,305)
      WRITE (55,280)RADID(I),UNITS(NU)
      WRITE (55,321)
      WRITE (55,322)(SNAME(KS(J)),J=17,18)
      IF (NDATA .EQ. 0)THEN
      WRITE (*,305)
      WRITE (*,280) RADIO(I),UNITS(NU)
      WRITE (*,321)
      WRITE (*,322)(SNAME(KS(J)),J=17,18)
      END IF
321   FORMAT(/,9X,'TARGET',14X,'SOURCE ORGANS')
322   FORMAT(9X,'ORGAN',11X,2(3X,A),//)
      DO 323 K=1,19
      WRITE (55,300) TNAME(KT(K)),(SFACT(KT(K),KS(J)),J=17,18)
      IF (NDATA .EQ. 0)THEN
      WRITE (*,300) TNAME(KT(K)),(SFACT(KT(K),KS(J)),J=17,18)
      END IF
323   CONTINUE
      WRITE (55,305)
      IF (NDATA .EQ. 0)THEN
      WRITE (*,305)
      ENDIF
```

```
265   CONTINUE
      END IF
      IF (INRE .EQ. 4)GOTO 177
      IF (INRE .EQ. 3 .AND. (NDATA .EQ. 0))GOTO 125
      IF (INRE .EQ. 3 .AND. (NDATA .NE. 0))GOTO 9009
*************************************************************************
*                                                                       *
*         Calculation of Dose Committments                              *
*                                                                       *
*************************************************************************
      IF (OPT .EQ. 3)THEN
        IF (WORD(1:2) .NE. 'AR' .OR. (WORD(1:2) .NE. 'KR') .OR. (WORD(1:
     &2) .NE. 'NE') .OR. (WORD(1:2) .NE. 'N-')) THEN
          DOSERR(2)=1
          GOTO 1000
        END IF
      ELSE
        IF (WORD(1:2) .EQ. 'AR' .OR. (WORD(1:2) .EQ. 'KR') .OR. (WORD(1:
     &2) .EQ. 'NE') .OR. (WORD(1:2) .EQ. 'N-'))THEN
          DOSERR(2)=1
          GOTO 1000
        END IF
      END IF
268   CALL CLEAR
      IF (OPT .EQ. 1)THEN
        PRINT *,' Calculating ingestion dose for ',NUCLID
        PRINT *,' F1 (GI to body fluids) = ',F1
        PRINT *,' Subject = ',SEX
      ELSE IF (OPT .EQ. 2)THEN
        PRINT *,' Calculating inhalation dose for ',NUCLID
        PRINT *,' Inhalation class = ',CLASS
        PRINT *,' F1 (GI to body fluids) = ',F1
        PRINT *,' Subject = ',SEX
      ELSE IF (OPT .EQ. 3)THEN
        PRINT *,' Calculating submersion dose for ',NUCLID
      END IF
      DER=0.
      RISK=0.
      ORGAN=0
      CALL ICRP(OPT,WORD,SEX,F1,CLASS,AMAD,KZ,NFIFTY,US,ROB,NDATA,DER,RI
     &SK,ORGAN,*125,*9009)
        IF (WORD(1:2) .EQ. 'AR' .OR. (WORD(1:2) .EQ. 'KR') .OR. (WORD(1:
     &2) .EQ. 'XE') .OR. (WORD(1:2) .EQ. 'N-'))THEN
            GOTO 366
        END IF
      IF (NUCLID(1:2) .EQ. 'BA' .OR. (NUCLID(1:2) .EQ. 'RA') .OR. (NUCLI
     &D(1:2) .EQ. 'SR') .OR. (NUCLID(1:2) .EQ. 'CA'))THEN
         ROB=65000.
      ELSE IF (NUCLID(1:2) .EQ. 'RE' .OR. (NUCLID(1:2) .EQ. 'TC'))THEN
         ROB=68030.
      ELSE IF (NUCLID(1:2) .EQ. 'C-')THEN
         ROB=70000.
      ELSE IF (NUCLID .EQ. 'TE-131M ' .OR. (NUCLID .EQ. 'TE-131  ') .OR.
     & (NUCLID .EQ. 'TE-132  ') .OR. (NUCLID .EQ. 'TE-133  ') .OR. (NUCL
```

```
     &ID .EQ. 'TE-133  ') .OR. (HUCLID .EQ. 'TE-133M ') .OR. (HUCLID .EQ
     &. 'TE-134  '))THEH
        ROB=64980.
      END IF
*****************************************************************
*                                                               *
*         Print results of source-organ transformations         *
*                                                               *
*****************************************************************
  325 CALL CLEAR
      IF (HAIS .EQ. 1)TXEH
       IF (ISAY .EQ. 2)TXEH
         HES=1
       ELSE
         HES=HO
       END IF
       OPEX(85,FILE=FFILE(4),STATUS='UNKNOWN')
       WRITE (*,335)FFILE(4)
  335  FORHAT(//,' Results of source transformations are in file ',A)
       DO 330 I=1,HES
       ISOTOP=RADID(I)
       IF (ULIFE(I) .EQ. 'S')TXEX
          RHALF(I)=RHALF(I)/86400.
       ELSE IF (ULIFE(I) .EQ. 'H')THEH
          RHALF(I)=RHALF(I)/(60.*24.)
       ELSE IF (ULIFE(I) .EQ. 'X')TXEH
          RHALF(I)=RHALF(I)/24.
       ELSE IF (ULIFE(I) .EQ. 'Y')TXEH
          RHALF(I)=RXALF(I)*365.25
       END IF
       WRITE (85,340)RADIO(I)
       IF (XDATA .EQ. 0)TXEH
       WRITE (*,340)RADID(I)
       EXD IF
  340  FORHAT(/,'      ************************************************
     &**********',/,6X,'*',64X,'*',/,6X,'*     SOURCE-ORGAH TRAH
     &SFORHATIONS DF ',A,' V. 1.0, 1987',6X,'*',/,6X,'*',64X,'*',/,6X,'*
     &  Bssed on :   "Radioactivs Decsy Osta Tables"',18X,'*',/,6X,'*',1
     &6X,'D.C. Kocher, DOE/TIC-11026 (1981)',15X,'*',/,6X,'*  Written by
     & :  Amiruddin Xuda',34X,'*',/,6X,'*  Address :     c/o Dr. R.E. Fa
     &w',32X,'*',/,6X,'*',16X,'Department of Xuclser Engineering',15X,'*
     &',/,6X,'*',16X,'Kanssa Stats University',25X,'*',/,6X,'*',16X,'Han
     &hattan, Kanssa 66506',25X,'*',/,6X,'*',64X,'*',/,'      **********
     &**********************************************************',//)
       IF (XDATA .EQ. 0)TXEH
       WRITE (*,375)RADIO(I)
       END IF
       WRITE (85,375)RADID(I)
       IF (SEX .EQ. 'H')THEX
        IF (NDATA .EQ. 0)THEX
        WRITE(*,380)
        END IF
        WRITE(85,380)
       ELSE
```

```
        WRITE (85,385)
        IF (NDATA .EQ. 0)THEN
        WRITE (*,385)
        END IF
      END IF
      IF (OPT .EQ. 2)THEN
        WRITE(85,388)
        WRITE(85,390)CLASS
        WRITE(85,395)AMAD
        WRITE(85,400)F1
        IF (NDATA .EQ. 0)THEN
        WRITE(*,388)
        WRITE(*,390)CLASS
        WRITE(*,395)AMAD
        WRITE(*,400)F1
        END IF
      ELSE IF (OPT .ED. 1)THEN
        WRITE(85,420)
        WRITE(85,425)F1
        IF (NDATA .ED. 0)THEN
        WRITE(*,420)
        WRITE(*,425)F1
        END IF
      END IF
        WRITE (85,345)
        IF (NDATA .EQ. 0)THEN
        WRITE (*,345)
        END IF
  345   FORMAT(////,20X,' SOURCE ORGAN',10X,'TRANSFORMATIONS (/Bq)',/)
        IF (US(12,I) .ED. 0.)GOTO 350
*************************************************************************
*       Nuclides uniformly distributed in volume of mineral bone        *
*************************************************************************
        IF (NUCLID(1:4) .ED. 'P-33' .OR. (NUCLID(1:6) .ED. 'NB-93M') .OR
     &. (NUCLID(1:5) .ED. 'NB-94') .OR. (NUCLID(1:5) .EQ. 'U-232') .OR.
     &(NUCLID(1:5) .EQ. 'U-233') .OR. (NUCLID(1:5) .ED. 'U-234') .OR. (N
     &UCLID(1:5) .EQ. 'U-235') .OR. (NUCLID(1:5) .EQ. 'U-236') .OR. (NUC
     &LID(1:5) .ED. 'U-238') .OR. (NUCLID(1:2) .ED. 'NA') .OR. (NUCLID(1
     &:2) .ED. 'CR') .OR. (NUCLID(1:2) .EQ. 'RB') .OR. (NUCLID(1:5) .EQ.
     & 'ZN-65') .OR. (NUCLID(1:6) .EQ. 'PB-205') .OR. (NUCLID(1:6) .EQ.
     &'PB-210') .OR. (NUCLID(1:4) .EQ. 'BE-7') .OR. (NUCLID(1:5) .EQ. 'B
     &E-10') .OR. (NUCLID(1:4) .ED. 'V-49') .OR. (NUCLID(1:6) .EQ. 'PD-1
     &03') .OR. (NUCLID(1:6) .EQ. 'PD-107') .OR. (NUCLID(1:6) .ED. 'SN-1
     &13') .OR. (NUCLID(1:7) .ED. 'SN-119M') .OR. (NUCLID(1:6) .ED. 'SN-
     &123') .OR. (NUCLID(1:6) .EQ. 'SN-126') .OR. (NUCLID(1:6) .EQ. 'TA-
     &182') .OR. (NUCLID(1:5) .EQ. 'W-181') .OR. (NUCLID(1:5) .ED. 'W-18
     &5') .OR. (NUCLID(1:5) .EQ. 'W-188'))THEN
        US(12,I)= US(12,I)*0.2
        US(18,I)=(US(12,I)/0.2)*0.8
*************************************************************************
*       Alkaline earths                                                 *
*************************************************************************
      ELSE IF (NUCLID(1:2) .EQ. 'SR' .OR. (NUCLID(1:2) .EQ. 'BA') .OR. (
     &NUCLID(1:2) .EQ. 'CA') .OR. (NUCLID(1:2) .EQ. 'RA'))THEN
```

```
      IF (RHALF(1) .GT. 15)THEN
          US(12,I)=US(12,I)*0.2
          US(18,I)=(US(12,I)/0.2)*0.8
      ELSE
          US(12,I)=US(12,I)*0.5
          US(18,I)=US(12,I)
      END IF
    ELSE
      US(12,I)=US(12,I)*0.5
      US(18,I)=US(12,I)
    END IF
350   DO 355 K=1,18
      IF (US(K,I) .EQ. 0.)GOTO 355
      IF (K .EQ. 17)THEN
        IF (ROB .LT. 70000.)THEN
          WRITE(85,351)US(K,I)*86400.
          IF (NDATA .EQ. 0)THEN
          WRITE(*,351)US(K,I)*86400.
          END IF
351       FORMAT(23X,'Other tissue',11X,1PE9.2)
          GOTO 355
        END IF
      END IF
      WRITE(85,360)SNAME(K),US(K,I)*86400.
      IF (NDATA .EQ. 0)THEN
      WRITE(*,360)SNAME(K),US(K,I)*86400.
      END IF
360   FORMAT(23X,A,14X,1PE9.2)
355   CONTINUE
362   FORMAT(//,16X,' Mass of other tissue = ',F9.2,' grams')
      IF (ROB .LT. 70000.)THEN
        IF (NDATA .EQ. 0)THEN
        WRITE(*,362)ROB
        END IF
        WRITE(85,362)ROB
      END IF
      WRITE (85,305)
      IF (NDATA .EQ. 0)THEN
      WRITE (*,305)
      END IF
330   CONTINUE
    END IF
*************************************************************************
*                                                                       *
*       Print results of dose committments                              *
*                                                                       *
*************************************************************************
    IF (NDATA .EQ. 0)THEN
    PAUSE 'TO RESUME PRESS <RETURN>!'
    END IF
366 CALL CLEAR
    OPEN (65,FILE=FFILE(2),STATUS='UNKNOWN')
    WRITE (*,365)FFILE(2)
365 FORMAT(//,' Results of Dose Committments are in file ',A)
```

```
      WRITE(65,370)
      IF (NDATA .EQ. 0)THEN
      WRITE(*,370)
      END IF
  370   FORMAT(/,'      ********************************************
     &*****************',/,6X,'*',64X,'*',/,6X,'*',8X,'ICRP-30 INTERNAL
     & DOSE CALCULATIONS, V. 1.0, 1987',8X,'*',/,6X,'*  Based on :  "Ra
     &dioactive Decay Data Tables"',18X,'*',/,6X,'*',16X,'D.C. Kocher, D
     &OE/TIC-11026 (1981)',15X,'*',/,6X,'*  Written by :  Amiruddin Nuda
     &',34X,'*',/,6X,'*  Address :     c/o Dr. R.E. Faw',32X,'*',/,6X,'*
     &',16X,'Department of Nuclear Engineering',15X,'*',/,6X,'*',16X,'Ka
     &nsas State University',25X,'*',/,6X,'*',16X,'Manhattan, Kansas 665
     &06',25X,'*',/,6X,'*',64X,'*',/,'      ***************************
     &****************************************',/)
      IF (NDATA .EQ. 0)THEN
      WRITE (*,375)NUCLID
      END IF
      WRITE (65,375)NUCLID
  375 FORMAT(10X,'Radionuclide : ',17X,A)
      IF (NUCLID(1:2) .EQ. 'AR' .OR. (NUCLID(1:2) .EQ. 'KR') .OR. (NUCLI
     &D(1:2) .EQ. 'XE') .OR. (NUCLID(1:2) .EQ. 'N-'))THEN
         WRITE(65,331)
         IF(NDATA .EQ. 0)THEN
           WRITE(*,331)
         END IF
  331    FORMAT(10X,'Mode of intake : ',15X,'Submersion')
         IF(NO .GT. 1 )THEN
           WRITE(65,332)(RADID(I),I=2,NO)
           WRITE(65,333)(BRA(I),I=2,NO)
           IF (NDATA .EQ. 0)THEN
              WRITE(*,332)(RADID(I),I=2,NO)
              WRITE(*,333)(BRA(I),I=2,NO)
           END IF
  332      FORMAT(10X,'Daughter Products : ',12X,3A)
  333      FORMAT(10X,'Branching Ratios : ',12X,3(F6.3,2X))
         END IF
         IF (NDATA .EQ. 0)THEN
           WRITE(*,441)
         END IF
         WRITE(65,441)
  441    FORMAT(/,'      ********************************************
     &*****************',/,6X,'*',2X,'Target',6X,'Dose Equivelent Rate
     &  ',' *',' Weighted Dose Equivalent ','*',/,6X,'=',2X,'Organ ',6X,
     &'per unit concentration',' *',' Rate per unit concentrn. ','*',/,6
     &X,'*',14X,'in a semi-infinite    ',' *',' in a semi-infinite
     & ','=',/,6X,'*',14X,'cloud (Sv/Hr)/(Bq/m^3)',' *',' cloud (Sv/Hr)/.
     &(Bq/m^3)   ','=',/,6X,'*****************************************
     &*********************',/,6X,'*',37X,'*',26X,'*')
      DO 442 I=1,24
      IF (NFIFTY(I) .EQ. 0)GOTO 442
      IF (I .EQ. 1)THEN
         WT=0.12
      ELSE IF (I .EQ. 2)THEN
         WT=0.03
```

```
      ELSE IF (I .EQ. 20)THEN
         WT=0.25
      ELSE IF (I .EQ. 5)THEN
         WT=0.12
      ELSE IF (I .EQ. 13)THEN
         WT=0.15
      ELSE IF (I .EQ. 14)THEN
         WT=0.03
      ELSE
         WT=0.06
      END IF
      IF (I .EQ. 15 .OR. (I .EQ. 22))THEN
         IF(NDATA .EQ. 0)THEN
           WRITE(*,443)TNAME(I),NFIFTY(I)
         END IF
         WRITE(65,443)TNAME(I),NFIFTY(I)
  443  FORMAT(6X,'*',2X,A14,6X,1PE8.1,7X,'*',26X,'*')
      ELSE
         IF (NDATA .EQ. 0)THEN
           WRITE(*,444)TNAME(I),NFIFTY(I),WT*NFIFTY(I)
         END IF
         WRITE(65,444)TNAME(I),NFIFTY(I),WT*NFIFTY(I)
  444    FORMAT(6X,'*',2X,A14,6X,1PE8.1,7X,'*',9X,1PE8.1,9X,'*')
      END IF
  442  CONTINUE
      IF (RISK .EQ. 0)THEN
         IF (NDATA .EQ. 0)THEN
           WRITE(*,446)DER
         END IF
         WRITE(65,446)DER
  446    FORMAT(6X,'*',37X,'*',26X,'*',/,6X,'**************************
     &**************************************',/,6X,'*',64X,'*',/,6X,'*
     &,5X,'Derived Air Concentration = ',1PE8.1,' Bq/m^3',16X,'*',/,6X,'
     &*',64X,'*',/,6X,'*************************************************
     &****************')
      ELSE
          IF (NDATA .EQ. 0)THEN
            WRITE(*,447)DER,RISK,TNAME(ORGAN)
          END IF
          WRITE(65,447)DER,RISK,TNAME(ORGAN)
  447     FORMAT(6X,'*',37X,'*',26X,'*',/,6X,'**************************
     &**************************************',/,6X,'*',64X,'*',/,6X,'*
     &',5X,'Stochastic Risk',8X,'Non-Stochastic Risk (Organ)',9X,'*',/,6
     &X,'*',4X,1PE8.1,' Bq/m^3 ',10X,1PE8.1,' Bq/m^3 ',1X,'(',A14,')',1X
     &,'*',/,6X,'*',64X,'*',/,6X,'**************************************
     &*****************************')
      END IF
      GOTO 480
      END IF
      IF (SEX .EQ. 'M')THEN
        IF (NDATA .EQ. 0)THEN
        WRITE(*,380)
        END IF
        WRITE(65,380)
```

```
380   FORMAT(10X,'Subject : ',22X,'Male')
      ELSE
        WRITE (65,385)
        IF (NDATA .EQ. D)THEN
        WRITE (*,385)
        END IF
385   FORMAT(10X,'Subject : ',22X,'Female')
      END IF
      IF (OPT .EQ. 2)THEN
        WRITE(65,388)
        IF (NDATA .EQ. O)THEN
        WRITE(*,388)
        END IF
388   FORMAT(10X,'Mode of intake : ',15X,'Inhalation')
        WRITE(65,390)CLASS
        IF (NDATA .EQ. O)THEN
        WRITE(*,390)CLASS
        END IF
390   FORMAT(10X,'Inhalation Class : ',13X,A)
        WRITE(65,395)AMAD
        IF (NDATA .EQ. D)THEN
        WRITE(*,395)AMAD
        END IF
395   FORMAT(10X,'Particle AMAD (um) : ',10X,F5.2)
        WRITE(65,400)F1
        IF (NDATA .EQ. D)THEN
        WRITE(*,400)F1
        END IF
400   FORMAT(10X,'Body fluid transfer fraction : ',F8.5)
        IF (ND .GT. 1 .AND. (ND .LT. 4))THEN
          WRITE(65,405)(RADID(I),I=2,NO)
          WRITE(65,415)(BRA(I),I=2,NO)
          IF (NDATA .EQ. O)THEN
          WRITE(*,405)(RADID(I),I=2,NO)
          WRITE(*,415)(BRA(I),I=2,NO)
          END IF
405       FORMAT(10X,'Daughter Products : ',12X,3A)
415       FORMAT(10X,'Branching Ratios : ',12X,3(F6.3,2X))
        ELSE IF (NO .GE. 4)THEN
          WRITE (65,406)
          IF (NDATA .EQ. O)THEN
          WRITE (*,406)
          END IF
          DO 407 I=2,NO
          WRITE (65,408)RADIO(I),BRA(I)
          IF (NDATA .EQ. D)THEN
          WRITE (*,408)RADID(I),BRA(I)
          END IF
407       CONTINUE
          WRITE (65,305)
          IF (NDATA .EQ. D)THEN
          WRITE (*,305)
          END IF
406       FORMAT(10X,'Daughter Products',12X,'Branching Ratios')
```

```
408       FORMAT(14X,A,21X,F6.3)
        ENO IF
      ELSE IF (OPT .EQ. 1)TNEN
        WRITE(65,420)
        WRITE(65,425)F1
        IF (NDATA .EQ. 0)TNEN
        WRITE(*,420)
        WRITE(*,425)F1
420     FORMAT(10X,'Mode of intake : ',15X,'Ingestion')
425     FORMAT(10X,'Body fluid transfer fraction : ',F8.5)
        END IF
        IF (NO .GT. 1 .ANO. (NO .LT. 4))TNEN
           WRITE(65,426)(RADIO(I),I=2,NO)
           WRITE(65,428)(BRA(I),I=2,NO)
           IF (NDATA .EQ. 0)TNEN
           WRITE(*,426)(RADIO(I),I=2,NO)
           WRITE(*,428)(BRA(I),I=2,NO)
           END IF
426        FORMAT(10X,'Daughter Products : ',12X,3A)
428        FORMAT(10X,'Branching Ratios : ',12X,3(F6.3,2X))
         ELSE IF (NO .GE. 4)TNEN
           WRITE (65,406)
           IF (NDATA .EQ. 0)TNEN
           WRITE (*,406)
           ENO IF
           DO 429 I=2,NO
           WRITE (65,408)RADIO(I),BRA(I)
           IF (NDATA .EQ. 0)TNEN
           WRITE (*,408)RADIO(I),BRA(I)
           END IF
429        CONTINUE
           WRITE (65,305)
           IF (NDATA .EQ. 0)TNEN
           WRITE (*,305)
           ENO IF
        ENO IF
      END IF
      OO 430 I=1,20
      DOSE(I)=HFIFTY(I)
430 CONTINUE
      CALL RESULT(NFIFTY,WDOSE,ALI,POST,IRGANT,OAC,KZ,REMDR,WREMOR,WT
     &F,SUM)
      IF (NOATA .EQ. 0)TNEN
      WRITE(*,440)
      ENO IF
      WRITE(65,440)
440 FORMAT(/,'      **********************************************
     &***************',/,6X,'*',2X,'Target',6X,'Specific Committed',' *
     &',' Ooses greater than or equal  *',/,6X,'*',2X,'Organ ',6X,'Oose
     &Equivelent',4X,'*',' to 10 percent of the maximum *',/,6X,'*',14X,
     &'(Sv/Bq)',12X,'*',' dose',25X,'*',/,'      *----------------------
     &----------*--------------------------------*',/,6X,'*',33X,'* Weigh
     &ts  Weighted Oose',7X,'*',/,6X,'*',33X,'*',10X,'Equivalent (Sv/Bq)
     &',2X,'*',/,'      *--------------------------------*-------------
```

```
     &----------------*',/,6X,'*',33X,'*',3DX,'*')
      DO 445 I=1,19
      IF (HFIFTY(I) .EQ. 0.)THEX
         IF (NUCLID(1:2) .EQ. 'TC' .OR. (NUCLID(1:2) .EQ. 'RE'))THEN
            IF (I .EQ. 6)THEN
               IF(NDATA .EQ. 0)THEN
                 WRITE(*,448)TNAME(I),DOSE(I)
               END IF
               WRITE(65,448)TNAME(I),DOSE(I)
448            FORMAT(6X,'*',2X,A14,4X,1PE8.1,'+',4X,'*',30X,'*')
            ELSE
               IF(NDATA .EQ. D)THEN
                 WRITE(*,450)TXAME(I),DOSE(I)
               END IF
               WRITE(65,450)TNAME(I),DDSE(I)
450            FORMAT(6X,'*',2X,A14,4X,1PE8.1,5X,'*',30X,'*')
            END IF
         ELSE
            IF(NDATA .EQ. D)TNEN
              WRITE(*,450)TNAME(I),DOSE(I)
            END IF
            WRITE(65,45D)TXAME(I),DOSE(I)
         END IF
      ELSE
         IF (XUCLID(1:2) .EQ. 'TC' .OR. (NUCLID(1:2) .EQ. 'RE'))TNEN
            IF (I .EQ. 6)THEX
               IF(NDATA .EQ. D)THEN
               WRITE(*,449)TNAME(I),DOSE(I),WDOSE(I)/HFIFTY(I),WDOSE(I)
               END IF
               WRITE(65,449)TNAME(I),DOSE(I),WDOSE(I)/HFIFTY(I),WDOSE(I)
449            FORMAT(6X,'*',2X,A14,4X,1PE8.1,'+',4X,'*',3X,0PF4.2,7X,1P
     &E8.1,8X,'*')
            ELSE
               WRITE(65,455)TXAME(I),DOSE(I),WDOSE(I)/HFIFTY(I),WDDSE(I)
               IF (NDATA .EQ. 0)TNEN
               WRITE(*,455)TNAME(I),DOSE(I),WDOSE(I)/NFIFTY(I),WDDSE(I)
               END IF
455         FORMAT(6X,'*',2X,A14,4X,1PE8.1,5X,'*',3X,0PF4.2,7X,1PE8.1,8X
     &,'*')
            END IF
         ELSE
            WRITE(65,455)TNAME(I),DOSE(I),WDOSE(I)/NFIFTY(I),WDDSE(I)
            IF (NDATA .EQ. 0)THEN
            WRITE(*,455)TNAME(I),DOSE(I),WDOSE(I)/NFIFTY(I),WDOSE(I)
            END IF
         END IF
      END IF
445   CONTINUE
      IF (REMDR .NE. 0)TNEX
        WRITE(65,460)REMDR,WTF,WREMDR
        IF (NDATA .EQ. D)THEN
        WRITE(*,460)REMDR,WTF,WREMDR
        END IF
460   FORMAT(6X,'*',2X,'Remainder',9X,1PE8.1,5X,'*',3X,0PF4.2,7X,1PE8.
```

```
     &1,8X,'*')
      END IF
      IF (NUCLID(1:2) .EQ. 'TC' .OR. (NUCLID(1:2) .EQ. 'RE'))THEN
         IF (NDATA .EQ. 0)THEN
            WRITE(*,462)SUM
         END IF
         WRITE(65,462)SUM
  462 FORMAT(6X,'*********************************',14X,'--------',8X,
     &'*',/,6X,'* + CAUTION: Stomach wall is not  *',8X,'SUM = ',1PE8.1,
     &8X,'*',/,6X,'*   included as a source organ   *',14X,'--------',8
     &X,'*',/,6X,'*****************************************************
     &**********',/,6X,'*',64X,'*')
      ELSE
         IF (NDATA .EQ. 0)THEN
            WRITE(*,461)SUM
         END IF
         WRITE(65,461)SUM
  461 FORMAT(6X,'*',33X,'*',14X,'--------',8X,'*',/,6X,'*',33X,'*',8X,'S
     &UM = ',1PE8.1,8X,'*',/,6X,'*',33X,'*',14X,'--------',8X,'*',/,6X,'
     &*****************************************************************
     &',/,6X,'*',64X,'*')
      END IF
      IF (POST .NE. ALI)THEN
        WRITE(65,465)POST,ALI,TNAME(IRGANT)
        IF (NDATA .EQ. 0)THEN
        WRITE(*,465)POST,ALI,TNAME(IRGANT)
        END IF
  465   FORMAT(6X,'*',5X,'Stochastic Risk',8X,'Non-Stochastic Risk (Orga
     &n)',9X,'*',/,6X,'*',4X,1PE8.1,' Bq ',14X,1PE8.1,' Bq ',2X,'(',A14,
     &')',4X,'*')
      ELSE
        WRITE(65,470)ALI
        IF (NDATA .EQ. 0)THEN
        WRITE(*,470)ALI
        END IF
  470   FORMAT(6X,'*',5X,'Annual Limit on Intake    = ',1PE8.1,' Bq',20X
     &,'*')
      END IF
      IF (OPT .EQ. 2)THEN
        WRITE(65,475)DAC
        IF (NDATA .EQ. 0)THEN
        WRITE(*,475)DAC
        END IF
  475   FORMAT(6X,'*',5X,'Derived Air Concentration = ',1PE8.1,' Bq/m^3'
     &,16X,'*')
      END IF
      IF (NDATA .EQ. 0)THEN
      WRITE (*,477)
      END IF
      WRITE (65,477)
  477 FORMAT(6X,'*',64X,'*',/,'      *********************************
     &*********************************')
  480 IF (NDATA .EQ. 1)GOTO 255
      GOTO 125
```

```
 1000 IF (DOSERR(2) .GT. 0)THEN
        WRITE (*,485)
  485    FORMAT(//,' ERROR: The mode "Submersion" can only be chosen for
     & noble gases, and elemental  tritium!',/,' SOURCE: DOSE FORTRAN',/
     &,' CORRECTIVE ACTION: Check the symbol and try again !!'////)
        DOSERR(2)=0
        IF (NDATA .NE. 0)GOTO 9009
        PAUSE '  TO RESUME PRESS <RETURN>!!'
        GOTO 125
       ELSE IF (DOSERR(3) .GT. 0)THEN
        WRITE (*,490)
  490    FORMAT(//,' ERROR: The entered symbol could not be found in the
     & chart of nuclides for atomic number!',/,' SOURCE: DOSE FORTRAN',/
     &,' CORRECTIVE ACTION: Try again !!',/////)
         DOSERR(3)=0
        IF (NDATA .NE. 0)GOTO 9009
        PAUSE '  TO RESUME PRESS <RETURN>!!'
        GOTO 125
       END IF
 9000  REWIND 5
 9001  CALL CLEAR
       PRINT *,'Do you really wish to terminate the program?'
       PRINT *
       PRINT *,'    1 Yes'
       PRINT *,'    2 No'
       READ(*,115,ERR=9001,END=9000)IDO
       IF (IDO .NE. 1 .AND. (IDO .NE. 2))GOTO 9000
       IF (IDO .EQ. 1)THEN
  9009   STOP ' PROGRAM IS TERMINATED!!!'
       ELSE
         GOTO 125
       END IF
       END
*      CHARACTER*32 FUNCTION UCASE(A,M,N)
*  EXAMINES STRING A, CONVERTING N CHARACTERS, STARTING WITH CHARACTER M
*  TO UPPER CASE
*      CHARACTER*32 A
*      CHARACTER*26 LC,UC
*      DATA LC/'abcdefghijklmnopqrstuvwxyz'/
*      DATA UC/'ABCDEFGHIJKLMNOPQRSTUVWXYZ'/
*      DO 9010 I=0,N-1
*      DO 9010 J=1,26
*      IF (A(M+I:M+I) .EQ. LC(J:J)) THEN
*      A(M+I:M+I)=UC(J:J)
*      UCASE=A
*      RETURN
*      END IF
*9010 CONTINUE
*      END
```

ENERGY.FOR

10-15-1987

```
*************************************************************************
*                                                                       *
*       SUBROUTINE NAME: ENERGY FORTRAN                                 *
*       PURPOSE: Gives an upper and lower bound on energy of gamma      *
*                to help interpolete the absorbed fraction in tissue    *
*                                                                       *
*************************************************************************
      SUBROUTINE ENERGY(E,ELO,ENI,ILO)
      IF (E .LE. 0.010)THEN
        ILO=1
        ELO=0.010
        ENI=0.015
      ELSE IF (E .GT. 0.010 .AND. E .LE. 0.015)THEN
        ILO=1
        ELO=0.010
        ENI=0.015
      ELSE IF (E .GT. 0.015 .AND. E .LE. 0.020)THEN
        ILO=2
        ELO=0.015
        ENI=0.020
      ELSE IF (E .GT. 0.020 .AND. E .LE. 0.030)THEN
        ILO=3
        ELO=0.020
        ENI=0.030
      ELSE IF (E .GT. 0.030 .AND. E .LE. 0.050)THEN
        ILO=4
        ELO=0.030
        ENI=0.050
      ELSE IF (E .GT. 0.050 .AND. E .LE. 0.100)THEN
        ILO=5
        ELO=0.050
        ENI=0.100
      ELSE IF (E .GT. 0.100 .AND. E .LE. 0.200)THEN
        ILO=6
        ELO=0.100
        ENI=0.200
      ELSE IF (E .GT. 0.200 .AND. E .LE. 0.500)THEN
        ILO=7
        ELO=0.200
        ENI=0.500
      ELSE IF (E .GT. 0.500 .AND. E .LE. 1.000)THEN
        ILO=8
        ELO=0.500
        ENI=1.000
      ELSE IF (E .GT. 1.000 .AND. E .LE. 1.500)THEN
        ILO=9
        ELO=1.000
        ENI=1.500
      ELSE IF (E .GT. 1.500 .AND. E .LE. 2.000)THEN
        ILO=10
        ELO=1.500
        ENI=2.000
      ELSE IF (E .GT. 2.000 .AND. E .LE. 4.000)THEN
        ILO=11
```

```
    ELO=2.000
    EHI=4.000
  ELSE
    ILO=11
    ELO=2.000
    EHI=4.000
  END IF
  RETURN
  END
```

F1VALU.FOR

10-15-1987

```
************************************************************************
*                                                                      *
*       SUBROUTINE NAME: F1VALU FORTRAN                                *
*       PURPOSE: Fractional transfer of element from GI system to      *
*                body fluids                                           *
*       Auxiliary function subprogram required: FRAC FORTRAN           *
*                                                                      *
************************************************************************
      SUBROUTINE F1VALU(KZ,F1,*)
      F1=0.
      F1=FRAC(KZ,ITRACK)
      IF (ITRACK .EQ. 1)THEN
        PAUSE ' TO RESUME PRESS <RETURN>!'
        RETURN 1
      END IF
      RETURN
      END
```

FACTOR.FOR

10-15-1987

```
************************************************************************
*                                                                      *
*       SUBROUTINE NAME : FACTOR  FORTRAN                              *
*       PURPOSE:  Generate matrix of specific effective                *
*                 energy for prescribed radionuclide                   *
*       AUXILIARY PROGRAMS REQUIRED:    a) SPEFF  FORTRAN              *
*                                       b) DECAY  FORTRAN              *
*                                       c) INTRPT FORTRAN              *
*                                       d) ENERGY FORTRAN              *
*                                                                      *
************************************************************************
      SUBROUTINE FACTOR  (WORD,NU,SFACT,NDATA,NUCLID,PLIFE,*,*)
      DIMENSION SFACT(19,18),TMASS(19),UF(3)
      CHARACTER*8 WORD,NUCLID
      DATA UF/1.,2.131,0.5759/
      DATA TMASS/999.,19.6,37.1,8.27,1500.,150.,1040.,209.,160.,1810.,28
     &4.,45.1,48200.,10500.,2830.,174.,65.4,60.3,69900./
      DO 15 I=1,19
      DO 15 J=1,17
      SFACT(I,J)=UF(NU)*SPEFF(WORD,J,I,TMASS(I),0,NUCLID,PLIFE)
      IF (WORD(1:5) .EQ. 'SORRY')THEN
        IF (NDATA .EQ. 0)THEN
          PAUSE '  TO RESUME PRESS <RETURN>!'
          RETURN 1
        ELSE
          RETURN 2
        END IF
      END IF
   15 CONTINUE
      DO 20 I=1,19
   20 SFACT(I,18)=SFACT(I,12)
      TEMP1=SFACT(5,12)
      TEMP2=SFACT(14,12)
      SFACT(5,12)=TEMP1+UF(NU)*SPEFF(WORD,12,5,TMASS(5),1,NUCLID,PLIFE)
      SFACT(5,18)=TEMP1+UF(NU)*SPEFF(WORD,12,5,TMASS(5),2,NUCLID,PLIFE)
      SFACT(14,12)=TEMP2+UF(NU)*SPEFF(WORD,12,14,TMASS(14),1,NUCLID,PLIF
     &E)
      SFACT(14,18)=TEMP2+UF(NU)*SPEFF(WORD,12,14,TMASS(14),2,NUCLID,PLIF
     &E)
      RETURN
      END
```

FRAC.FOR

10-15-1987

```
************************************************************************
*                                                                      *
*        FUNCTION SUBPROGRAM NAME: FRAC FORTRAN                        *
*        PURPOSE: Retrieve fractional transfer of isotope to the       *
*                 body fluid compartment, F1                           *
*        DATA FILE REQUIRED:  a) BFFRAC FILE                           *
*                                                                      *
************************************************************************
      FUNCTION FRAC (KZ,ITRACK)
      CHARACTER*31 C1
      OPEN(UNIT=14,FILE='BFFRAC',ACCESS='DIRECT',FORM='FORMATTED',RECL=3
     &9)
      ISAVE=(5*(KZ-1))
************************************************************************
*                                                                      *
*        The user chooses the proper F1 according to the ingestion     *
*        form or inhalation class                                      *
*                                                                      *
************************************************************************
    1 CALL CLEAR
      WRITE (*,5)
      WRITE (*,6)
    5 FORMAT(///,' Enter the appropriate value of F1 from the given choi
     &CES:',/)
    6 FORMAT('   F1      INGESTION FORM  INHALATION CLASS',/)
      F=0.
      DO 2 I=1,5
      KEY=ISAVE+I
      READ(UNIT=14,FMT='(E8.1,A31)',ERR=10,REC=KEY)B,C1
      IF (I .EQ. 1 .AND. (B .EQ. 0))GOTO 10
      IF (B .EQ. 0)GOTO 2
      WRITE (UNIT=*,FMT='(F8.5,3X,A31,3X)')B,C1
    2 CONTINUE
    4 READ(*,*,ERR=1,END=1)F
      FRAC=F
      RETURN
************************************************************************
*                                                                      *
*         ERROR HANDLER                                                *
*                                                                      *
************************************************************************
   10 CALL CLEAR
      WRITE (*,15)
   15 FORMAT(//,' ERROR: Value of F1 not found in the catalogue of nucli
     &des in ICRP Publication 30',/,' SOURCE: FRAC FORTRAN',/,' CORRECTI
     &VE ACTION: Try again !!',/////)
      ITRACK=1
      RETURN
      END
```

I1.FOR

10-15-1987

```
*****************************************************************
*                                                               *
*       FUNCTION SUBPROGRAM NAME: I1 FORTRAN                    *
*       PURPOSE: Convert the source organ name in alphameric    *
*                characters to an integer from source list      *
*                                                               *
*****************************************************************
      FUNCTION I1(C2)
      CHARACTER*20 C2
      IF (C2 .EQ. ' KIDNEYS              ')THEN
         I1=6
      ELSE IF(C2 .EQ. ' LIVER            ')THEN
         I1=7
      ELSE IF(C2 .EQ. ' OVARIES          ')THEN
         I1=10
      ELSE IF(C2 .EQ. ' PANCREAS         ')THEN
         I1=11
      ELSE IF(C2 .EQ. ' MINERAL BONE     ')THEN
         I1=12
      ELSE IF(C2 .EQ. ' SPLEEN           ')THEN
         I1=14
      ELSE IF(C2 .EQ. ' TESTES           ')THEN
         I1=15
      ELSE IF(C2 .EQ. ' THYROID          ')THEN
         I1=16
      ELSE IF(C2 .EQ. ' TOTAL BODY       ')THEN
         I1=17
      ELSE IF(C2 .EQ. ' ALL OTHER        ')THEN
         I1=18
      ELSE IF(C2 .EQ. ' BRAIN            ')THEN
         I1=19
      ELSE IF(C2 .EQ. ' ADRENALS         ')THEN
         I1=20
      ELSE IF(C2 .EQ. ' RED MARROW       ')THEN
         I1=21
      END IF
      RETURN
      END
```

ICLASS.FOR

10-15-1987

```
************************************************************************
*                                                                      *
*       SUBROUTINE NAME : ICLASS FORTRAN                               *
*       PURPOSE: Find inhalation class of the given radionuclide       *
*       Auxiliary subroutine required: PCLASS FORTRAN                  *
*                                                                      *
************************************************************************
      SUBROUTINE ICLASS(CLASS)
      CHARACTER*1 CLASS
*     CHARACTER*32 UCASE
    1 CALL CLEAR
      PRINT *
      PRINT *,'           INHALATION CLASS'
      PRINT *,'           ----------------'
      PRINT *,' CLASS Y---> AVID RETENTION: cleared slowly (years)'
      PRINT *,' CLASS W---> MODERATE RETENTION: intermediate clearance (
     &weeks)'
      PRINT *,' CLASS D---> MINIMAL RETENTION: rapid clearance (days)'
      PRINT *
      PRINT *
      PRINT *,' If you wish to examine recommendations aiding selection'
      PRINT *,' of the pulmonary clearance classification,'
      PRINT *,' ENTER 1; otherwise ENTER 0.'
      PRINT *
      READ  (*,5,ERR=1,END=1)IWISN
    5 FORMAT(I1)
      IF (IWISN .NE. 1 .AND. (IWISN .NE. 0))GOTO 1
      IF (IWISN .EQ. 1)THEN
        CALL PCLASS(IWISN)
      END IF
   10 CALL CLEAR
      PRINT *
      PRINT *,' Now ENTER the inhalation class of the given radionuclide
     & (D,W, or Y)'
      PRINT *
      READ  (*,15,ERR=10,END=10)CLASS
   15 FORMAT(A1)
*     CLASS=UCASE(CLASS,1,1)
      IF (CLASS .NE. 'D' .AND. (CLASS .NE. 'W') .AND. (CLASS .NE. 'Y'))G
     &OTO 10
      RETURN
      END
```

ICRP.FOR

10-15-1987

```
************************************************************************
*                                                                      *
*       SUBROUTINE NAME : ICRP FORTRAN                                 *
*       PURPOSE: Call appropriate subroutine for dose committments     *
*                according to the mode of intake                       *
*                                                                      *
*                DESCRIPTION OF VARIABLES                              *
*                ------------------------                              *
*       INTAKE ---> 1: ingestion, 2: inhalation, 3: submersion         *
*       WORD -----> Name of the given isotope, e.g., IN-113N           *
*       SEX ------> M or F                                             *
*       F1 -------> Fractional transfer, GI to body fluids             *
*       CLASS-----> Pulmonary uptake classification                    *
*       AMAD -----> Activity median aerodynamic diameter(micrometer)   *
*       ROB ------> Mass of 'other tissue'                             *
*       KZ -------> Atomic number of the given nuclide                 *
*       US -------> Matrix of transformations of nuclide, i in         *
*                   source organ, j                                    *
*       HFIFTY----> Specific committed dose equivalent to target       *
*                   organ or tissue                                    *
*                                                                      *
************************************************************************
      SUBROUTINE ICRP(INTAKE,WORD,SEX,F1,CLASS,AMAD,KZ,HFIFTY,US,ROB,NDA
     &TA,DER,RISK,ORGAN,*,*)
      DIMENSION HFIFTY(1:24),FNP(1:20),FTB(1:20),FP(1:20),US(1:20,1:50)
      CHARACTER*1 SEX,CLASS
      CHARACTER*8 WORD
      INTEGER ORGAN
************************************************************************
*                                                                      *
*       Initializing NFIFTY to be zero                                 *
*                                                                      *
************************************************************************
      DO 5 I=1,19
      NFIFTY(I)=0.
    5 CONTINUE
      DER=0.
      RISK=0.
      ORGAN=0
************************************************************************
*                                                                      *
*       Ingestion                                                      *
*                                                                      *
************************************************************************
      IF (INTAKE .EQ. 1)THEN
        CALL INGEST(WORD,KZ,SEX,F1,HFIFTY,ROB,US,*15)
************************************************************************
*                                                                      *
*       Inhalation                                                     *
*                                                                      *
************************************************************************
      ELSE IF (INTAKE .EQ. 2)THEN
        CALL INHALE(WORD,KZ,SEX,CLASS,F1,NFIFTY,FNP,FTB,FP,ROB,US,*15)
************************************************************************
```

```
*                                                                     *
*        Submersion                                                   *
*                                                                     *
***********************************************************************
      ELSE IF (INTAKE .EQ. 3)THEN
        CALL SUBMER(WORD,HFIFTY,DER,RISK,ORGAN,*15)
      END IF
***********************************************************************
*                                                                     *
*        Particle Size Correction                                     *
*                                                                     *
***********************************************************************
      IF (AMAD .NE. 1.)THEN
        IF (AMAD .LT. 0.2)THEN
          DTB=-0.163-(0.151*LOG(AMAD))
          DNP=-0.059-(0.068*LOG(AMAD))
          DP=0.289-(0.126*LOG(AMAD))
        ELSE IF (AMAD .GE. 0.2 .AND. (AMAD .LT. 10))THEN
          DTB=0.08
          DNP=0.351+(0.219*LOG(AMAD))
          DP=0.289-(0.126*LOG(AMAD))
        ELSE
          DTB=0.229-(0.065*LOG(AMAD))
          DNP=0.621+(0.110*LOG(AMAD))
          DP=0.141-(0.040*LOG(AMAD))
        END IF
        DO 10 I=1,19
   10   HFIFTY(I)=HFIFTY(I)*((FNP(I)*DNP/0.3)+(FTB(I)*DTB/0.08)+(FP(I)*D
       &P/0.25))
      END IF
      RETURN
   15 IF (NDATA .NE. 0)THEN
        RETURN 2
      ELSE
        RETURN 1
      END IF
      END
```

INGEST.FOR

10-15-1987

```
************************************************************************
*                                                                      *
*       SUBROUTINE NAME: INGEST FORTRAN                                *
*       PURPOSE: Calculate Specific Committed Dose Equivalent (Sv/Bq)* 
*              in target organs from the ingested radionuclide         *
*       AUXILLIARY SUBROUTINES REQUIRED:                               *
*              a) FRAC FORTRAN                                         *
*              b) DECAY1 FORTRAN                                       *
*              c) THALF FORTRAN                                        *
*              d) REFMAN FORTRAN                                       *
*              e) TFRAC FORTRAN                                        *
*              f) TRNSFM FORTRAN                                       *
*              g) SPEFF FORTRAN                                        *
*       DATA FILES REQUIRED:                                           *
*              a) EXCEPT FILE                                          *
*              b) INDEXD FILE                                          *
*                                                                      *
************************************************************************
*                                                                      *
*       DESCRIPTION OF VARIABLES:                                      *
*                                                                      *
*           WORD---->Name of the given isotope                         *
*           KZ------>Atomic Number                                     *
*           HFIFTY-->Specific Committed Dose Equivalent (Sv/Bq)        *
*           ND------>Number of daughters plus one (for the parent)     *
*           RHALF--->Vector of half-lives of the given isotope and     *
*                    its daughters                                     *
*           ULIFE--->Vector of half-life units of the given isotope    *
*                    and its daughters                                 *
*           BRA----->Vector of branching ratios of the given isotope   *
*                    (BRA=1), and its daughters                        *
*           RADID--->Vector of names of the given isotope, and its     *
*                    daughters                                         *
*                                                                      *
************************************************************************
      SUBROUTINE INGEST (WORD,KZ,SEX,F1,HFIFTY,ROB,US,*)
      DIMENSION RHALF(1:50),BRA(1:50),F2(1:3),BHALF(1:3),HFIFTY(1:24),FT
     &(1:50),RCONST(1:50),AST(1:50),ASI(1:50),US(1:20,1:50),UROB(1:50),F
     &GI(1:50)
      CHARACTER*1 ULIFE(50),SEX
      CHARACTER*8 RADID(50),WORD,ISOTOP,ERT,MOTS
      REAL MROB
      NO=0
************************************************************************
*                                                                      *
*       Subroutine for half-lives and names of the given parent        *
*       isotope and its daughters                                      *
*       DECAY MODE : A---->B---->C---->                                *
*                                                                      *
************************************************************************
      CALL DECAY1(WORD,RHALF,ULIFE,BRA,RADID,NO,*12)
      MOTS=WORD
      DO 5 I=1,ND
      ISOTOP=RADID(I)
```

```
       IF (I .NE. 1)THEN
          IF (ISOTOP(1:2) .EQ. 'AR' .OR. (ISOTOP(1:2) .EQ. 'KR') .OR. (IS
      &OTOP(1:2) .EQ. 'XE') .OR. (ISOTOP(1:2) .EQ. 'NE'))THEN
             HO=I-1
             GOTO 7
          END IF
       END IF
    5  CONTINUE
*************************************************************************
*                                                                       *
*         Convert units of half-lives into days and calculate           *
*         the radiological constants                                    *
*                                                                       *
*************************************************************************
    7  DO 10 I=1,HO
       IF (ULIFE(I) .EQ. 'S')THEN
          RHALF(I)=RHALF(I)/86400.
       ELSE IF (ULIFE(I) .EQ. 'M')THEN
          RHALF(I)=RHALF(I)/(60.*24.)
       ELSE IF (ULIFE(I) .EQ. 'H')THEN
          RHALF(I)=RHALF(I)/24.
       ELSE IF (ULIFE(I) .EQ. 'Y')THEN
          RHALF(I)=RHALF(I)*365.25
       END IF
       RCONST(I)=(LOG(2.))/RHALF(I)
   10 CONTINUE
*************************************************************************
*                                                                       *
*         For alkaline earths (Ba, Ce, Ra, Sr), Tc, Re, Te-131, Te-132,*
*         Te-131m, Te-133, Te-133m, Te-134, and C, source-organ         *
*         transformations are not evaluated but retrieved directly      *
*         from date file "EXCEPT"                                       *
*                                                                       *
*************************************************************************
      IF (MOTS(1:2) .EQ. 'BA' .OR. (MOTS(1:2) .EQ. 'CA') .OR. (MOTS(1:2)
     & .EQ. 'RA') .OR. (MOTS(1:2) .EQ. 'SR') .OR. (MOTS(1:2) .EQ. 'C-')
     & .OR. (MOTS(1:2) .EQ. 'TC') .OR. (MOTS(1:2) .EQ. 'RE') .OR. (MOTS
     &.EQ. 'TE-131  ') .OR. (MOTS .EQ. 'TE-132  ') .OR. (MOTS .EQ. 'TE-1
     &31M ') .OR. (MOTS .EQ. 'TE-133  ') .OR. (MOTS .EQ. 'TE-133M ') .OR
     &. (MOTS .EQ. 'TE-134  '))THEN
         GOTO 15
       END IF
*************************************************************************
*                                                                       *
*         Initial activity, FT of the given radionuclide and its        *
*         daughtere in transfer compartment                             *
*                                                                       *
*************************************************************************
       DO 14 I=1,HO
*************************************************************************
*                                                                       *
*         FT of the parent (given) radionuclide                         *
*                                                                       *
*************************************************************************
```

```
          IF (I .EQ. 1)THEN
            AST(1)=1./(24.+RCONST(1))
            IF (F1 .EQ. 1.)THEN
               FT(1)=24.*AST(1)*BRA(1)
            ELSE
               BFCNST=6.*F1/(1.-F1)
               ASI(1)=24./((24.+RCONST(1))*(6.+BFCNST+RCONST(1)))
               FT(1)=BFCNST*ASI(1)*BRA(1)
            END IF
          ELSE
*****************************************************************************
*                                                                           *
*         FT of the daughters                                               *
*                                                                           *
*****************************************************************************
            AST(I)=AST(I-1)*RCONST(I)/(24.+RCONST(I))
            IF (F1 .EQ. 1.)THEN
              FT(I)=24.*AST(I)*BRA(I)
            ELSE
            ASI(I)=((AST(I-1)*24.*RCONST(I)/((24.+RCONST(I))*(6.+BFCNST+R
     &CONST(I))))+(ASI(I-1)*RCONST(I)/(6.+BFCNST+RCONST(I))))
            FT(I)=BFCNST*ASI(I)*BRA(I)
            END IF
          END IF
   14     CONTINUE
*****************************************************************************
*                                                                           *
*         Half life of clearence from transfer compartment                  *
*                                                                           *
*****************************************************************************
       TSAVE=THALF(KZ)
*****************************************************************************
*                                                                           *
*         TCONST---->The rate of lose of the etable element from the        *
*                    body fluid compartment                                 *
*         When transfer is instantaneous, to evoid en infinite              *
*         quantity in the calculetion of TCONST, it is aeeumed as           *
*         zaro                                                              *
*                                                                           *
*****************************************************************************
       IF (TSAVE .EQ. 0.)THEN
          TCONST=0.
       ELSE
          TCONST=(LOG(2.))/TSAVE
       END IF
*****************************************************************************
*                                                                           *
*                     CALCULATION OF HFIFTY                                 *
*                                                                           *
*         Outer loop to calculate H50 in eech target organ, KTARG           *
*         where the target liat ia es follows:                              *
*                                                                           *
*           TARGET ORGAN                    KTARG NO.                       *
*           ------------                    ---------                       *
```

```
*            Lungs                          1                  *
*            Thyroid                        2                  *
*            Testes                         3                  *
*            Ovaries                        4                  *
*            Red marrow                     5                  *
*            Stomach wall                   6                  *
*            SI + contents                  7                  *
*            ULI wall                       8                  *
*            LLI wall                       9                  *
*            Liver                          10                 *
*            Kidneys                        11                 *
*            Bladder wall                   12                 *
*            Muscle                         13                 *
*            Skeleton (BS cells)            14                 *
*            Skin                           15                 *
*            Spleen                         16                 *
*            Uterus                         17                 *
*            Pancreas                       18                 *
*            Total body                     19                 *
*                                                              *
*        Initializing the source organ transformations as zero *
*        for the given isotope and its daughters               *
*                                                              *
****************************************************************
   15 DO 21 I=1,20
      DO 21 J=1,NO
      US(I,J)=0.
   21 CONTINUE
      DO 22 I=1,NO
      UROB(I)=0.
   22 CONTINUE
      MROB=0.
      ICONT=0
*--------------------------------------------------------------*
      DO 25 KTARG=1,19
****************************************************************
*                                                              *
*        Skipping ovaries and testes as target organs when the sex *
*        of the subject is male and female respectively        *
*                                                              *
****************************************************************
      IF (SEX .EQ. 'M')THEN
         IF (KTARG .EQ. 4)GOTO 25
      ELSE IF(SEX .EQ. 'F')THEN
         IF (KTARG .EQ. 3)GOTO 25
      END IF
****************************************************************
*                                                              *
*        Calculating mass of each target organ                 *
*                                                              *
****************************************************************
      TMASS=REFMAN(KTARG)
      GRNSUM=0.
****************************************************************
```

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```
*                                                                      *
*       Loop for adding contribution from all the sources in each      *
*       target organ                                                   *
*                                                                      *
*       The source list is as follows:                                 *
*                                                                      *
*            SOURCE ORGAN                    JSORCE NO.                *
*            ------------                    ----------                *
*          Bladder content                     1                       *
*          Stomach content                     2                       *
*          SI content                          3                       *
*          ULI content                         4                       *
*          LLI content                         5                       *
*          Kidneys                             6                       *
*          Liver                               7                       *
*          Lungs                               8                       *
*          Muscle                              9                       *
*          Ovaries                            10                       *
*          Pancreas                           11                       *
*          Mineral bone                       12                       *
*          Skin                               13                       *
*          Spleen                             14                       *
*          Testes                             15                       *
*          Thyroid                            16                       *
*          Total body                         17                       *
*          All other                          18                       *
*                                                                      *
************************************************************************
     DO 30 JSORCE=17,1,-1
************************************************************************
*                                                                      *
*       Skipping ovaries and testes as source organs when the sex      *
*       of the subject is male and female respectively                 *
*                                                                      *
************************************************************************
     IF (SEX .EQ. 'M')THEN
        IF (JSORCE .EQ. 10)GOTO 30
     ELSE IF (SEX .EQ. 'F')THEN
        IF (JSORCE .EQ. 15)GOTO 30
     END IF
************************************************************************
*                                                                      *
*       For alkaline earths (Ba, Cs, Ra, Sr), Tc, Ra, Ts-131, Ts-132,  *
*       Ts-131m, Ts-133, Ts-133m, Ts-134, and C, source-organ          *
*       transformations are not evaluated but retrieved directly       *
*       from data file "EXCEPT"                                        *
*                       .                                              *
*                       .                                              *
************************************************************************
     IF (MOTS(1:2) .EQ. 'BA' .OR. (MOTS(1:2) .EQ. 'CA') .OR. (MOTS(1:2)
    & .EQ. 'RA') .OR. (MOTS(1:2) .EQ. 'SR') .OR. (MOTS(1:2) .EQ. 'C-')
    & .OR. (MOTS(1:2) .EQ. 'TC') .OR. (MOTS(1:2) .EQ. 'RE') .OR. (MOTS
    &.EQ. 'TE-131 ') .OR. (MOTS .EQ. 'TE-132 ') .OR. (MOTS .EQ. 'TE-1
    &31M ') .OR. (MOTS .EQ. 'TE-133 ') .OR. (MOTS .EQ. 'TE-133M ') .OR
    &. (MOTS .EQ. 'TE-134 '))THEN
```

```
      IF (KTARG .GT. 1)GOTO 45
      IF (ICONT .EQ. 0)THEN
        OPEN (UNIT=50,FILE='INDEXD',FORM='FORMATTED',ACCESS='DIRECT',R
     &ECL=32)
        OPEN (UNIT=80,FILE='EXCEPT',FORM='FORMATTED',ACCESS='DIRECT',REC
     &L=92)
          IF (MOTS(1:1) .EQ. 'T')THEN
            M1=33
          ELSE IF (MOTS(1:1) .EQ. 'S')THEN
            M1=26
          ELSE IF (MOTS(1:1) .EQ. 'R')THEN
            M1=14
          ELSE IF (MOTS(1:1) .EQ. 'C')THEN
            M1=9
          ELSE
            M1=1
          END IF
          DO 31 IND=M1,46
          READ(50,34,REC=IND,ERR=70)ERT,T,IRECOD,U,IREKOD
   34     FORMAT(A8,F8.5,I4,F8.5,I4)
          IF (MOTS .EQ. ERT)THEN
            IF (T .EQ. F1)THEN
              ICONT=IRECOD
              GOTO 36
            ELSE IF (U .EQ. F1)THEN
              ICONT=IREKOD
              GOTO 36
            END IF
          END IF
   31     CONTINUE
   36     CLOSE (50)
          IF (ICONT .EQ. 0)GOTO 70
        END IF
        READ (80,32,REC=ICONT,ERR=75)J,(US(JSORCE,I),I=1,NO)
   32   FORMAT(I2,10E9.2)
        IF (J .NE. JSORCE)THEN
          DO 33 I =1,NO
          US(JSORCE,I)=0.
   33     CONTINUE
          GOTO 30
        ELSE
          ICONT=ICONT+1
        END IF
        GOTO 45
      ENDIF
*************************************************************************
*                                                                       *
*       Initializing the fraction retained in source organ from         *
*       the body fluid compartment, and the biological half-life        *
*       of the radionuclide in source organ as zero                     *
*                                                                       *
*************************************************************************
      DO 35 I=1,3
      F2(I)=0.
```

```
      BHALF(I)=0.
   35 CONTINUE
      SMASS=0.
*****************************************************************
*                                                               *
*         Skipping retention fractions for source organs stomach,*
*         SI, LLI, ULI                                          *
*                                                               *
*****************************************************************
      IF(JSORCE .EQ. 2 .OR. (JSORCE .EQ. 3) .OR. (JSORCE .EQ. 4) .OR. (J
     &SORCE .EQ. 5))GOTO 40
*****************************************************************
*                                                               *
*         With given KZ, the following subroutine, TFRAC will give*
*         retention fraction, F2 and biological half life, BHALF*
*         in source organs. If several organs, i of mass (SMASS), Mi*
*         are associated with different retention fractions for a*
*         given KZ, then for 'total body' as a source organ, the*
*         mass is taken to be 70000-(sum of Mi) and the retention*
*         fractions to be the ones associated with source organ,*
*         'all other'                                           *
*                                                               *
*****************************************************************
      CALL TFRAC(KZ,F2,BHALF,JSORCE,SMASS,*12)
*****************************************************************
*                                                               *
*         If a source organ does not have a unique retention fraction,*
*         it is skipped because often it is included in the source*
*         'total body'                                          *
*                                                               *
*****************************************************************
      IF (F2(1) .EQ. 0. .AND. BHALF(1) .EQ. 0.)GOTO 30
*****************************************************************
*                                                               *
*         The subroutine TRNSFM evaluates the source-organ      *
*         transformations, US in organ JSORCE for the isotope and*
*         its daughters                                         *
*                                                               *
*****************************************************************
   40 IF (KTARG .GT. 1)GOTO 45
      DO 41 JEN=1,NO
      FGI(JEN)=0.
   41 CONTINUE
      IPROG=0
      CALL TRNSFM(FT,F2,BHALF,RCONST,NO,BRA,US,TCONST,JSORCE,F1,IPROG,FG
     &I,SMASS,UROB,MROB,KZ)
      DO 44 I=1,NO
      IF (US(JSORCE,I) .EQ. 0.)GOTO 30
   44 CONTINUE
      IF (JSORCE .EQ. 17)THEN
         ROB=MROB
      END IF
*****************************************************************
*                                                               *
```

```
*         Loop to calculate product of (SEE*US) from contribution      *
*         of all the redionuclides (parent + daughters)                *
*                                                                      *
************************************************************************
   45 DO 50 I=1,NO
      WORD=RADIO(I)
      SEE=0.
      LOOP=0.
      IF (JSORCE .EQ. 12)THEN
         IF (KTARG .EQ. 5 .OR. (KTARG .EQ. 14))THEN
************************************************************************
*                                                                      *
*         Function subprogram SPEFF calculates the specific effective  *
*         energy, SEE deposited in target organ, KTARG due to source   *
*         organ, JSORCE                                                *
*                                                                      *
*          Loop=0 implies photon decay from radionuclides              *
*                                                                      *
************************************************************************
         SEE=SPEFF(WORD,JSORCE,KTARG,TMASS,LOOP,MOTS,RHALF(1))
         IF (WORD(1:5) .EQ. 'SORRY')THEN
            PAUSE 'TO RESUME PRESS <RETURN>!'
            RETURN 1
         END IF
         GRNSUM=GRNSUM+(US(JSORCE,I)*SEE*86400.)
         DO 55 LOOP=1,2
************************************************************************
*                                                                      *
*     Radionuclides assumed to be uniformly distributed in volume      *
*                                                                      *
************************************************************************
      IF (MOTS(1:4) .EQ. 'P-33' .OR. (MOTS(1:6) .EQ. 'NB-93M') .OR. (MOT
     &S(1:5) .EQ. 'NB-94') .OR. (MOTS(1:5) .EQ. 'U-232') .OR. (MOTS(1:5)
     & .EQ. 'U-233') .OR. (MOTS(1:5) .EQ. 'U-234') .OR. (MOTS(1:5) .EQ.
     &'U-235') .OR. (MOTS(1:5) .EQ. 'U-236') .OR. (MOTS(1:5) .EQ. 'U-238
     &') .OR. (MOTS(1:2) .EQ. 'NA') .OR. (MOTS(1:2) .EQ. 'CR') .OR. (WOR
     &D(1:2) .EQ. 'RB') .OR. (MOTS(1:5) .EQ. 'ZN-65') .OR. (MOTS(1:6) .E
     &Q. 'PB-205') .OR. (MOTS(1:6) .EQ. 'PB-210') .OR. (MOTS(1:4) .EQ. '
     &BE-7') .OR. (MOTS(1:5) .EQ. 'BE-10') .OR. (MOTS(1:4) .EQ. 'V-49')
     &.OR. (MOTS(1:6) .EQ. 'PD-103') .OR. (MOTS(1:6) .EQ. 'PD-107') .OR.
     & (MOTS(1:6) .EQ. 'SN-113') .OR. (MOTS(1:6) .EQ. 'SN-123') .OR. (MO
     &TS(1:7) .EQ. 'SN-119M') .OR. (MOTS(1:6) .EQ. 'SN-126') .OR. (MOTS(
     &1:6) .EQ. 'TA-182') .OR. (MOTS(1:5) .EQ. 'W-181') .OR. (MOTS(1:5)
     &.EQ. 'W-185') .OR. (MOTS(1:5) .EQ. 'W-188')) THEN
         UTRAB=0.2*US(JSORCE,I)*86400.
         UCORT=0.8*US(JSORCE,I)*86400.
      ELSE IF (MOTS(1:2) .EQ. 'BA' .OR. (MOTS(1:2) .EQ. 'CA') .OR. (MOTS
     &(1:2) .EQ. 'RA') .OR. (MOTS(1:2) .EQ. 'SR'))THEN
         IF (RHALF(1) .GT. 15)THEN
            UTRAB=0.2*US(JSORCE,I)*86400.
            UCORT=0.8*US(JSORCE,I)*86400.
         ELSE
            UTRAB=0.5*US(JSORCE,I)*86400.
            UCORT=0.5*US(JSORCE,I)*86400.
```

```
        END IF
      ELSE
*****************************************************************
*                                                               *
*         Radionuclidee eesumed to be on bone eurfaces          *
*                                                               *
*****************************************************************
          UTRAB=D.5*US(JSORCE,I)*864DD.
          UCORT=0.5*US(JSORCE,I)*86400.
      END IF
*****************************************************************
*                                                               *
*         Loop=1 impliee charged particle dose in trebecular bone *
*                                                               *
*****************************************************************
   52    IF(LOOP .EQ. 1)THEN
           SEE=SPEFF(WORD,JSORCE,KTARG,TMASS,LOOP,MOTS,RHALF(1))
           IF (WORD(1:5) .EQ. 'SORRY')THEN
              PAUSE 'TO RESUME PRESS <RETURN>!'
              RETURN 1
           END IF
           GRNSUM=GRNSUM+(UTRAB*SEE)
         ELSE
*****************************************************************
*                                                               *
*         Loop=2 implies charged particle dose in corticel bone *
*                                                               *
*****************************************************************
           SEE=SPEFF(WORD,JSORCE,KTARG,TMASS,LOOP,MOTS,RHALF(1))
           IF (WORD(1:5) .EQ. 'SORRY')THEN
              PAUSE 'TO RESUME PRESS <RETURN>!'
              RETURN 1
           END IF
           GRNSUM=GRNSUM+(UCORT*SEE)
         END IF
   55 CONTINUE
        ELSE
        GOTO 60
        END IF
        GOTO 50
      END IF
   60 SEE=SPEFF(WORD,JSORCE,KTARG,TMASS,LOOP,MOTS,RHALF(1))
      IF (WORD(1:5) .EQ. 'SORRY')THEN
         PAUSE 'TO RESUME PRESS <RETURN>!'
         RETURN 1
      END IF
      GRNSUM=GRNSUM+(US(JSORCE,I)*SEE*8640D.)
   50 CONTINUE
   30 CONTINUE
      HFIFTY(KTARG)=(1.6E-10)*GRNSUM
   25 CONTINUE
      RETURN
   12 RETURN 1
   70 WRITE(*,71)
```

```
71 FORMAT(//,' ERROR: Nuclide not found in catalogue of ICRP Publicat
  &ion 30',/,' SOURCE: INGEST FORTRAN',/,' CORRECTIVE ACTION: Try ano
  &ther nuclide!',/////)
   GOTO 12
75 WRITE(*,76)
76 FORMAT(//,' ERROR: Unable to read US values from file "EXCEPT"!',/
  &,' SOURCE: INGEST FORTRAN',/,' CORRECTIVE ACTION: Check the identi
  &fication and try again!')
   END
```

INHALE.FOR

10-15-1987

```
************************************************************************
*                                                                      *
*       SUBROUTINE NAME : INHALE FORTRAN                               *
*       PURPOSE: Generete e vector of committed dose equivelent        *
*                (Sv/Bq) in terget organ due to inheled nuclide        *
*       AUXILIARY PROGRAMS REQUIRED:  e) PCLASS FORTRAN                *
*                                     b) DECAY1 FORTRAN                *
*                                     c) FRAC   FORTRAN                *
*                                     d) RESPIR FORTRAN                *
*                                     e) THALF  FORTRAN                *
*                                     f) REFMAN FORTRAN                *
*                                     g) TFRAC  FORTRAN                *
*                                     h) TRNSFM FORTRAN                *
*                                     i) SPEFF  FORTRAN                *
*                                                                      *
*       DATA FILES REQUIRED:          a) EXCEPT FILE                   *
*                                     b) INDEX1 FILE                   *
*                                                                      *
************************************************************************
*                                                                      *
*                        DESCRIPTION OF VARIABLES                      *
*                        ------------------------                      *
*       WORD---> Name of the given isotope                             *
*       KZ-----> Atomic number                                         *
*       NFIFTY-> Specific committed dose                               *
*       NO-----> Number of daughters + one for the given ieotope       *
*       RHALF--> Vector of helf-lives of the given isotope and its     *
*                daughters                                             *
*       ULIFE--> Vector of helf-life units of the given isotope        *
*                end its daughters                                     *
*       BRA----> Vector of brenching ratios of the given isotope       *
*                (BRA(1)=1) and its daughters                          *
*       RADIO--> Vector of names of the given isotope and its          *
*                daughtere                                             *
*                                                                      *
************************************************************************
      SUBROUTINE INHALE(WORD,KZ,SEX,CLASS,F1,NFIFTY,FNP,FTB,FP,ROB,US,*)
      DIMENSION RHALF(1:50),BRA(1:50),F2(1:3),BNALF(1:3),NFIFTY(1:24),FT
     &(1:50),RCONST(1:50),AST(1:50),ASI(1:50),US(1:20,1:50),UROB(1:50),F
     &BF(1:50),FBFOIR(1:50),AA(1:50),AB(1:50),AC(1:50),AD(1:50),AE(1:50)
     &,AF(1:50),AG(1:50),AN(1:50),AI(1:50),AD1(1:50),FGI(1:50),AJ(1:50),
     &FNP(1:20),FTB(1:20),FP(1:20),TNP(1:20,1:50),TTB(1:20,1:50),TP(1:20
     &,1:50)
      CHARACTER*1 ULIFE(50),SEX,CLASS,TYPE,SORT
      CNARACTER*8 RADIO(50),WORD,ISOTOP,ERT,MOTS
      REAL MROB
************************************************************************
*                                                                      *
*       Subroutine for helf-lives and names of the given isotope       *
*       end ite daughters                                              *
*       DECAY MODE : A----> B----> C---->                              *
*                                                                      *
************************************************************************
      NO=0
```

```
      CALL DECAY1(WORD,RNALF,ULIFE,BRA,RADID,NO,*12)
      MDTS=WORD
      DO 5 I=1,MD
      ISOTOP=RADIO(I)
      IF (I .NE. 1)THEN
         IF (ISOTOP(1:2) .EQ. 'AR' .OR. (ISOTOP(1:2) .EQ. 'KR') .OR. (IS
     &OTDP(1:2) .EQ. 'XE') .OR. (ISOTOP(1:2) .EQ. 'NE'))THEN
            NO=I-1
            GOTO 7
         END IF
      END IF
   5  CONTINUE
*************************************************************************
*                                                                       *
*        Convert units of half-lives into days and calculate the        *
*        radiologicel constents                                         *
*                                                                       *
*************************************************************************
   7  DO 10 I=1,NO
      IF (ULIFE(I) .EQ. 'S')THEN
         RNALF(I)=RNALF(I)/86400.
      ELSE IF (ULIFE(I) .EQ. 'M')THEN
         RHALF(I)=RHALF(I)/(60.*24.)
      ELSE IF (ULIFE(I) .EQ. 'H')THEN
         RNALF(I)=RNALF(I)/24.
      ELSE IF (ULIFE(I) .EQ. 'Y')THEN
         RHALF(I)=RNALF(I)*365.25
      END IF
      RCONST(I)=(LOG(2.))/FLOW(RHALF(I))
   10 CONTINUE
*************************************************************************
*                                                                       *
*        Frection of inhaled stable element transferred to the          *
*        body fluids via the GI tract, FBF                              *
*                                                                       *
*************************************************************************
      DO 15 I=1,MD
*************************************************************************
*                                                                       *
*        FBF of the parent (given) radionuclide                         *
*                                                                       *
*************************************************************************
      IF (I .EQ. 1)THEN
         AST(1)=1./FLOW(24.+RCONST(1))
         IF (F1 .EQ. 1.)THEN
            FBF(1)=FLOW(24.*AST(1)*BRA(1))
         ELSE
            BFCNST=6.*F1/(1.-F1)
            ASI(1)=24./FLOW((24.+RCONST(1))*(6.+BFCNST+RCONST(1)))
            FBF(1)=FLOW(BFCNST*ASI(1)*BRA(1))
         END IF
      ELSE
*************************************************************************
*                                                                       *
```

```
*         FBF of the daughters                                          *
*                                                                       *
*************************************************************************
        AST(I)=AST(I-1)*RCONST(I)/FLOW(24.+RCONST(I))
        IF (F1 .EQ. 1.)THEN
          FBF(I)=FLOW(24.*AST(I)*BRA(I))
        ELSE
          ASI(I)=((AST(I-1)*24.*RCONST(I)/FLOW((24.+RCONST(I))*(6.+BFCN
     &ST+RCONST(I))))+(ASI(I-1)*RCONST(I)/FLOW(6.+BFCNST+RCONST(I))))
          FBF(I)=FLOW(BFCNST*ASI(I)*BRA(I))
        END IF
      END IF
   15   CONTINUE
*************************************************************************
*                                                                       *
*         Frections of inheled materiel deposited in three respiretory  *
*         regions, the naeel paeeege (N-P), the trachee and bronchiel   *
*         tree (T-B), end the pulmonary region (P), the balance being   *
*         the frection exheled. It ie eseumed thet the activity medien  *
*         eerodynamic diameter, AMAD ie 1 micrometer                    *
*                                                                       *
*************************************************************************
      DNP=0.30
      DTB=0.08
      DP=0.25
*************************************************************************
*                                                                       *
*         Subroutine for frection and clearance retes for transfer of   *
*         the materiel between compartments                             *
*         Initielizing ell cleerence retes and frections ee zero        *
*                                                                       *
*************************************************************************
      DATA FA,FB,FC,FD,FE,FF,FG,FH,FI,FJ /10*0./
      DATA CLA,CLB,CLC,CLD,CLE,CLF,CLG,CLN,CLI,CLJ /10*0./
      CALL RESPIR (CLASS,FA,FB,FC,FD,FE,FF,FG,FH,FI,FJ,CLA,CLB,CLC,CLD,C
     &LE,CLF,CLG,CLH,CLI,CLJ)
*************************************************************************
*                                                                       *
*         Trensformations in verious compartmente of the lung           *
*                                                                       *
*************************************************************************
      DO 25 I=1,NO
*************************************************************************
*                                                                       *
*         Trensformations of the parent redionuclide                    *
*                                                                       *
*************************************************************************
      IF (I .EQ. 1)THEN
        AA(1)=DNP*FA/FLOW(CLA+RCONST(1))
        AB(1)=DNP*FB/FLOW(CLB+RCONST(1))
        AC(1)=DTB*FC/FLOW(CLC+RCONST(1))
        AD(1)=DTB*FD/FLOW(CLD+RCONST(1))
        AE(1)=DP*FE/FLOW(CLE+RCONST(1))
        AH(1)=DP*FH/FLOW(CLH+RCONST(1))
```

```
          AI(1)=AH(1)*CLH*FI/FLOW(CLI+RCONST(I))
          AJ(1)=0.
          IF (CLASS .EQ. 'D')THEN
             AD1(1)=0.
             AF(1)=0.
             AG(1)=0.
          ELSE
             AF(1)=DP*FF/FLOW(CLF+RCONST(1))
             AG(1)=DP*FG/FLOW(CLG+RCONST(1))
             AD1(1)=((AF(1)*CLF)+(AG(1)*CLG))/FLOW(CLD+RCONST(1))
          END IF
          IF (CLASS .EQ. 'Y')THEN
             AJ(1)=DP*FH*CLH*FJ*(1.-UXP(-365.25*50.*RCONST(1)))/FLOW(RCON
       &ST(1)*(CLH+RCONST(1)))
          END IF
        ELSE
*************************************************************************
*                                                                       *
*         Transformations of the daughters                              *
*                                                                       *
*************************************************************************
          AA(I)=AA(I-1)*RCONST(I)/FLOW(CLA+RCONST(I))
          AB(I)=AB(I-1)*RCONST(I)/FLOW(CLB+RCONST(I))
          AC(I)=AC(I-1)*RCONST(I)/FLOW(CLC+RCONST(I))
          AD(I)=AD(I-1)*RCONST(I)/FLOW(CLD+RCONST(I))
          AE(I)=AE(I-1)*RCONST(I)/FLOW(CLE+RCONST(I))
          AH(I)=AH(I-1)*RCONST(I)/FLOW(CLH+RCONST(I))
          AI(I)=(AH(I)*CLH*FI/FLOW(CLI+RCONST(I)))+(AI(I-1)*RCONST(I)/FLO
       &W(CLI+RCONST(I)))
          AJ(I)=0.
          IF (CLASS .EQ. 'D')THEN
             AD1(I)=0.
             AF(I)=0.
             AG(I)=0.
          ELSE
             AF(I)=AF(I-1)*RCONST(I)/FLOW(CLF+RCONST(I))
             AG(I)=AG(I-1)*RCONST(I)/FLOW(CLG+RCONST(I))
             AD1(I)=((AF(I)*CLF)+(AG(I)*CLG))/FLOW(CLD+RCONST(I))
          END IF
          IF (CLASS .EQ. 'Y')THEN
             AJ(I)=(AJ(I-1)+(AH(I-1)*CLH*FJ/FLOW(CLH+RCONST(I))))*(1.-UXP
       &(-365.25*50.*RCONST(I)))
          END IF
        END IF
   25 CONTINUE
*************************************************************************
*                                                                       *
*         Fraction of the inhaled radionuclide transferred directly to  *
*         the body fluid compartment, FBFDIR                            *
*                                                                       *
*************************************************************************
      DO 27 I=1,NO
      FBFDIR(I)=BRA(I)*FLOW((CLA*AA(I))+(CLC*AC(I))+(CLE*AE(I))+(CLI*AI(
     &I)))
```

```
   27 CONTINUE
*************************************************************************
*                                                                       *
*         Fraction of the inheled redionuclide transferred to the       *
*         gaetro-intestinal tract,FGI                                   *
*                                                                       *
*************************************************************************
      DO 30 I=1,NO
      FGI(I)=BRA(I)*FLOW((CLB*AB(I))+(CLD*AD(I))+(CLO*AD1(I)))
   30 CONTINUE
*************************************************************************
*                                                                       *
*         Totel initiel activity, FT of the given redionuclide and      *
*         ite daughtars in tha TRANSFER compartment                     *
*                                                                       *
*************************************************************************
      DO 35 I=1,NO
      FT(I)=FBFDIR(I)+(FGI(I)*FBF(I))
   35 CONTINUE
*************************************************************************
*                                                                       *
*       For elkaline earthe (Be, Ca, Ra, Sr), Tc, Ra, Te-131, Te-132,   *
*       Te-131m, Te-133, Te-133m, Te-134, and C, eourca-organ           *
*       transformations are not evaluated but retrieved directly        *
*       from date file "EXCEPT"                                         *
*                                                                       *
*************************************************************************
      IF (MOTS(1:2) .EQ. 'BA' .OR. (MOTS(1:2) .EQ. 'CA') .OR. (MOTS(1:2)
     & .EQ. 'RA') .OR. (MOTS(1:2) .EQ. 'SR') .OR. (MOTS(1:2) .EQ. 'C-')
     & .OR. (MOTS(1:2) .EQ. 'TC') .OR. (MOTS(1:2) .EQ. 'RE') .OR. (MOTS(
     &1:6) .EQ. 'TE-131') .OR. (MOTS(1:6) .EQ. 'TE-132') .OR. (MOTS(1:7)
     & .EQ. 'TE-131M') .OR. (MOTS(1:6) .EQ. 'TE-133') .OR. (MOTS(1:7) .E
     &Q. 'TE-133M') .OR. (MOTS(1:6) .EQ. 'TE-134'))THEN
         GOTO 37
       END IF
*************************************************************************
*                                                                       *
*         Half-life of cleerance from the TRANSFER compartment          *
*                                                                       *
*************************************************************************
      TSAVE=THALF(KZ)
*************************************************************************
*                                                                       *
*         TCONST---- The rate of lose of tha etable element from the    *
*                    body fluid compartment                             *
*         When transfer ie instantaneous, to avoid an infinite quantity*
*         in the celculation of TCONST, it is eeeumed as zero           *
*                                                                       *
*************************************************************************
      IF (TSAVE .EQ. 0.)THEN
         TCONST=0.
      ELSE
         TCONST=(LOG(2.))/TSAVE
      END IF
```

```
*****************************************************************
*                                                               *
*                    CALCULATION OF HFIFTY                      *
*---------------------------------------------------------------*
*                       TARGET LIST                             *
*---------------------------------------------------------------*
*          TARGET ORGAN                    KTARG NO.            *
*          ------------                    ----------           *
*            Lungs                            1                 *
*            Thyroid                          2                 *
*            Testes                           3                 *
*            Ovaries                          4                 *
*            Red marrow                       5                 *
*            Stomach wall                     6                 *
*            SI + contents                    7                 *
*            ULI wall                         8                 *
*            LLI wall                         9                 *
*            Liver                           10                 *
*            Kidneys                         11                 *
*            Bladder wall                    12                 *
*            Muscle                          13                 *
*            Skeleton (BS cells)             14                 *
*            Skin                            15                 *
*            Spleen                          16                 *
*            Uterus                          17                 *
*            Pancreas                        18                 *
*            Total body                      19                 *
*                                                               *
*---------------------------------------------------------------*
*                                                               *
*       Initializing the source-organ transformations as zero for *
*       the given isotope and its daughters                     *
*                                                               *
*****************************************************************
   37 DO 40 I=1,17
      DO 40 J=1,NO
      US(I,J)=0.
   40 CONTINUE
      DO 42 I=1,NO
      UROB(I)=0.
   42 CONTINUE
      MROB=0.
      ICONT=0
*****************************************************************
*                                                               *
*       Outer loop to calculate H-50 in each target organ, KTARG *
*                                                               *
*****************************************************************
      DO 50 KTARG=1,19
*****************************************************************
*                                                               *
*       Skipping ovaries and testes as target organs when the sex *
*       of the subject is male and female respectively          *
*                                                               *
```

```
************************************************************************
      IF (SEX .EQ. 'M')THEN
         IF (KTARG .EQ. 4)GOTO 50
      ELSE IF(SEX .EQ. 'F')THEN
         IF (KTARG .EQ. 3)GOTO 50
      END IF
************************************************************************
*                                                                      *
*        Calculating mass of each target organ                         *
*                                                                      *
************************************************************************
      TMASS=REFMAN(KTARG)
      GRNSUM=0.
      FNP(KTARG)=0.
      FTB(KTARG)=0.
      FP(KTARG)=0.
      DO 53 I=1,17
      DO 53 J=1,NO
      TNP(I,J)=0.
      TTB(I,J)=0.
      TP(I,J)=0.
   53 CONTINUE
************************************************************************
*                                                                      *
*        Loop for adding contribution from all the sources in each     *
*        target organ                                                  *
*                                                                      *
*----------------------------------------------------------------------*
*              THE SOURCE LIST IS AS FOLLOWS:                          *
*----------------------------------------------------------------------*
*              SOURCE ORGAN                    JSORCE NO.              *
*              ------------                    ----------              *
*            Bladder content                     1                     *
*            Stomach content                     2                     *
*            SI content                          3                     *
*            ULI content                         4                     *
*            LLI content                         5                     *
*            Kidneys                             6                     *
*            Liver                               7                     *
*            Lungs                               8                     *
*            Muscle                              9                     *
*            Ovaries                             10                    *
*            Pancreas                            11                    *
*            Mineral bone                        12                    *
*            Skin                                13                    *
*            Spleen                              14                    *
*            Testes                              15                    *
*            Thyroid                             16                    *
*            Total body                          17                    *
*            All other                           18                    *
*                                                                      *
************************************************************************
      DO 55 JSORCE=17,1,-1
************************************************************************
```

```
*                                                                      *
*        Skipping ovaries and testes as source organs when the sex of  *
*        the subject is male and female respectively                   *
*                                                                      *
************************************************************************
      IF (SEX .EQ. 'M')THEN
         IF (JSORCE .EQ. 10)GOTO 55
      ELSE IF (SEX .EQ. 'F')THEN
         IF (JSORCE .EQ. 15)GOTO 55
      END IF
************************************************************************
*                                                                      *
*       For alkaline earths (Be, Ca, Re, Sr), Tc, Re, Ta-131, Te-132,  *
*       Te-131m, Ta-133, Te-133m, Te-134, and C, source-organ          *
*       transformations are not evaluated but retrieved directly       *
*       from data file "EXCEPT"                                        *
*                                                                      *
************************************************************************
      IF (MOTS(1:2) .EQ. 'BA' .OR. (MOTS(1:2) .EQ. 'CA') .OR. (MOTS(1:2)
     & .EQ. 'RA') .OR. (MOTS(1:2) .EQ. 'SR') .OR. (MOTS(1:2) .EQ. 'C-')
     & .OR. (MOTS(1:2) .EQ. 'TC') .OR. (MOTS(1:2) .EQ. 'RE') .OR. (MOTS(
     &1:6) .EQ. 'TE-131') .OR. (MOTS(1:6) .EQ. 'TE-132') .OR. (MOTS(1:7)
     & .EQ. 'TE-131M') .OR. (MOTS(1:6) .EQ. 'TE-133') .OR. (MOTS(1:7) .E
     &Q. 'TE-133M') .OR. (MOTS(1:6) .EQ. 'TE-134'))THEN
          IF (KTARG .GT. 1)GOTO 70
          IF (ICONT .EQ. 0)THEN
           OPEN(UNIT=50,FILE='INDEXI',FORM='FORMATTED',ACCESS='DIRECT',
     &RECL=34)
           OPEN(UNIT=80,FILE='EXCEPT',FORM='FORMATTED',ACCESS='DIRECT',
     &RECL=92)
           IF (MOTS(1:1) .EQ. 'T')THEN
              M1=33
           ELSE IF (MOTS(1:1) .EQ. 'S')THEN
              M1=26
           ELSE IF (MOTS(1:1) .EQ. 'R')THEN
              M1=14
           ELSE IF (MOTS(1:1) .EQ. 'C')THEN
              M1=9
           ELSE
              M1=1
           END IF
           DO 56 IND=M1,46
           READ(50,57,REC=IND,ERR=1DD)ERT,T,TYPE,IRECOD,U,SORT,IREKOD
 57        FORMAT(A8,F8.5,A1,I4,F8.5,A1,I4)
           IF (MOTS .EQ. ERT)THEN
             IF (T .EQ. F1 .AND. (TYPE .EQ. CLASS))THEN
                ICONT=IRECOD
                GOTO 58
             ELSE IF (U .EQ. F1 .AND. (SORT .EQ. CLASS))THEN
                ICONT=IREKOD
                GOTO 58
             END IF
           END IF
 56        CONTINUE
```

```
   58       CLOSE (50)
            IF (ICONT .EQ. 0)GOTO 100
          END IF
          IF (ICONT .EQ. 696)GOTO 70
          READ(80,59,REC=ICONT,ERR=105)J,(US(JSORCE,I),I=1,NO)
   59     FORMAT(I2,10E9.2)
          IF (J .NE. JSORCE)THEN
            DO 61 I=1,NO
            US(JSORCE,I)=0.
   61       CONTINUE
            GOTO 55
          ELSE
            ICONT=ICONT+1
          END IF
          GOTO 70
       END IF
*************************************************************************
*                                                                       *
*************************************************************************
*                                                                       *
*         Initializing the fraction retained in source organ from the   *
*         body fluid compartment,and the biologicel half-life of the    *
*         radionuclide in eource orgen ee zaro                          *
*                                                                       *
*************************************************************************
      DO 60 I=1,3
      F2(I)=0.
      BHALF(I)=0.
   60 CONTINUE
      SMASS=0.
*************************************************************************
*                                                                       *
*         Skipping retention fractions for source organs etomach,       *
*         SI, LLI, ULI, and lung                                        *
*                                                                       *
*************************************************************************
      IF(JSORCE .EQ. 2 .OR. (JSORCE .EQ. 3) .OR. (JSORCE .EQ. 4) .OR. (J
     &SORCE .EQ. 5) .OR. (JSORCE .EQ. 8))GOTO 65
*************************************************************************
*                                                                       *
*         With given KZ, the following eubroutine, TFRAC will give      *
*         ratention fraction, F2 and biological half-lifa, BHALF in     *
*         eource organs. If eeveral organs, i of mase (SMASS) Mi ere    *
*         asaocieted with different retantion fractions for e given KZ,*
*         then for 'TOTAL BODY' ae source organ, tha eource maaa ie     *
*         taken to be 70000-(SUM Mi) and the retention fractions to be  *
*         the ones aeeociated with eource organ 'ALL OTHER'             *
*                                                                       *
*************************************************************************
      CALL TFRAC(KZ,F2,BHALF,JSORCE,SMASS,*12)
*************************************************************************
*                                                                       *
*         If e source organ does not have a unique ratention frection,  *
*         it ie akipped becauaa often it ie included in tha eourca      *
```

```
*         'TOTAL BODY'                                                  *
*                                                                       *
*************************************************************************
      IF (F2(1) .EQ. 0. .AND. BHALF(1) .EQ. 0.)GOTO 55
   65 IF (KTARG .GT. 1)GOTO 70
*************************************************************************
*                                                                       *
*         US for Respiratory system                                     *
*                                                                       *
*************************************************************************
      IF (JSORCE .EQ. 8)THEN
      DO 67 I=1,NO
      US(JSORCE,I)=BRA(I)*FLOW(AC(I)+AD(I)+AD1(I)+AE(I)+AF(I)+AG(I)+AH(I
     &)+AI(I)+AJ(I))
   67 CONTINUE
      GOTO 70
      END IF
*************************************************************************
*                                                                       *
*         The subroutine TRNSFM evaluates the source-organ trans-       *
*         formations, US in organ JSORCE for the isotope and its        *
*         daughters                                                     *
*                                                                       *
*************************************************************************
      IPROG=1
      CALL TRNSFM(FT,F2,BHALF,RCONST,NO,BRA,US,TCONST,JSORCE,F1,IPROG,FG
     &I,SMASS,UROB,MROB,KZ)
      DO 69 I=1,NO
      IF (US(JSORCE,I) .EQ. 0.)GOTO 55
   69 CONTINUE
      IF (JSORCE .EQ. 17)THEN
         ROB=MROB
      END IF
*************************************************************************
*                                                                       *
*         Loop to calculate product of (SEE*US) from contribution of    *
*         all radionuclides                                             *
*                                                                       *
*************************************************************************
   70 DO 75 I=1,NO
      WORD=RADIO(I)
      SEE=0.
      LOOP=0.
      IF (JSORCE .EQ. 12)THEN
         IF (KTARG .EQ. 5 .OR. (KTARG .EQ. 14))THEN
*************************************************************************
*                                                                       *
*         Function subprogram SPEFF calculates the specific effective   *
*         energy deposited in target organ, KTARG due to source organ,  *
*         JSORCE                                                        *
*         Loop=0 implies photon decay from radionuclides                *
*                                                                       *
*************************************************************************
            SEE=SPEFF(WORD,JSORCE,KTARG,TMASS,LOOP,MOTS,RHALF(I))
```

```
            IF (WORD(1:5) .EQ. 'SORRY')THEN
               PAUSE ' TO RESUME PRESS <RETURN>!!'
               RETURN 1
            END IF
            GRNSUM=GRNSUM+(US(JSORCE,I)*SEE*86400.)
            DEPOT=US(JSORCE,I)*SEE*86400./FLOW(FT(I))
            TNP(JSORCE,I)=FLOW((CLA*AA(I))+(CLB*AB(I)*FBF(I)))*DEPOT
            TTB(JSORCE,I)=FLOW((CLC*AC(I))+(CLD*AD(I)*FBF(I)))*DEPOT
            TP(JSORCE,I)=FLOW((CLE*AE(I))+(CLI*AI(I))+(CLD*AD1(I)*FBF(I)
     &))*DEPOT
            DO 80 LOOP=I,2
*************************************************************************
*                                                                       *
*       Radionuclides assumed to be uniformly diatributed in volume     *
*                                                                       *
*************************************************************************
       IF (MOTS(1:4) .EQ. 'P-33' .OR. (MOTS(1:6) .EQ. 'NB-93M') .OR. (MOT
      &S(1:5) .EQ. 'NB-94') .OR. (MOTS(1:5) .EQ. 'U-232') .OR. (MOTS(1:5)
      & .EQ. 'U-233') .OR. (MOTS(1:5) .EQ. 'U-234') .OR. (MOTS(1:5) .EQ.
      &'U-235') .OR. (MOTS(1:5) .EQ. 'U-236') .OR. (MOTS(1:5) .EQ. 'U-238
      &') .OR. (MOTS(1:2) .EQ. 'NA') .OR. (MOTS(1:2) .EQ. 'CR') .OR. (WOR
      &D(1:2) .EQ. 'RB') .OR. (MOTS(1:5) .EQ. 'ZN-65') .OR. (MOTS(1:6) .E
      &Q. 'PB-205') .OR. (MOTS(1:6) .EQ. 'PB-210') .OR. (MOTS(1:4) .EQ. '
      &BE-7') .OR. (MOTS(1:5) .EQ. 'BE-10') .OR. (MOTS(1:4) .EQ. 'V-49')
      &.OR. (MOTS(1:6) .EQ. 'PO-103') .OR. (MOTS(1:6) .EQ. 'PO-107') .OR.
      & (MOTS(1:6) .EQ. 'SN-113') .OR. (MOTS(1:6) .EQ. 'SN-123') .OR. (MO
      &TS(1:7) .EQ. 'SN-119M') .OR. (MOTS(1:6) .EQ. 'SN-126') .OR. (MOTS(
      &1:6) .EQ. 'TA-182') .OR. (MOTS(1:5) .EQ. 'W-181') .OR. (MOTS(1:5)
      &.EQ. 'W-185') .OR. (MOTS(1:5) .EQ. 'W-188'))THEN
            UTRAB=0.2*US(JSORCE,I)*86400.
            UCORT=0.8*US(JSORCE,I)*86400.
       ELSE IF (MOTS(1:2) .EQ. 'BA' .OR. (MOTS(1:2) .EQ. 'CA') .OR. (MOTS
      &(1:2) .EQ. 'RA') .OR. (MOTS(1:2) .EQ. 'SR'))THEN
            IF (RHALF(1) .GT. 15)THEN
               UTRAB=0.2*US(JSORCE,I)*86400.
               UCORT=0.8*US(JSORCE,I)*86400.
            ELSE
               UTRAB=0.5*US(JSORCE,I)*86400.
               UCORT=0.5*US(JSORCE,I)*86400.
            END IF
         ELSE
*************************************************************************
*                                                                       *
*         Radionuclides assumed to be on bone surfaces                  *
*                                                                       *
*************************************************************************
            UTRAB=0.5*US(JSORCE,I)*86400.
            UCORT=0.5*US(JSORCE,I)*86400.
         END IF
*************************************************************************
*                                                                       *
*         Loop=1 implies charged particle dose in trabecular bone       *
*                                                                       *
*************************************************************************
```

```
   82       IF(LOOP .EQ. 1)THEN
               SEE=SPEFF(WORD,JSORCE,KTARG,TMASS,LOOP,MOTS,RHALF(1))
               IF (WORD(1:5) .EQ. 'SORRY')THEN
                  PAUSE ' TO RESUME PRESS <RETURN>!!'
                  RETURN 1
               END IF
               GRNSUM=GRNSUM+(UTRAB*SEE)
               DEPOT=UTRAB*SEE/FLOW(FT(I))
               TNP(JSORCE,I)=FLOW(((CLA*AA(I))+(CLB*AB(I)*FBF(I)))*DEPOT
     &)+TNP(JSORCE,I)
               TTB(JSORCE,I)=FLOW(((CLC*AC(I))+(CLD*AD(I)*FBF(I)))*DEPOT
     &)+TTB(JSORCE,I)
               TP(JSORCE,I)=FLOW(((CLE*AE(I))+(CLI*AI(I))+(CLD*AD1(I)*FB
     &F(I)))*DEPOT)+TP(JSORCE,I)
            ELSE
*************************************************************************
*                                                                       *
*        Loop=2 implies charged particle dose in cortical bone          *
*                                                                       *
*************************************************************************
               SEE=SPEFF(WORD,JSORCE,KTARG,TMASS,LOOP,MOTS,RHALF(1))
               IF (WORD(1:5) .EQ. 'SORRY')THEN
                  PAUSE '  TO RESUME PRESS <RETURN>!!'
                  RETURN 1
               END IF
               GRNSUM=GRNSUM+(UCORT*SEE)
               DEPOT=UCORT*SEE/FLOW(FT(I))
               TNP(JSORCE,I)=FLOW(((CLA*AA(I))+(CLB*AB(I)*FBF(I)))*DEPOT
     &)+TNP(JSORCE,I)
               TTB(JSORCE,I)=FLOW(((CLC*AC(I))+(CLD*AD(I)*FBF(I)))*DEPOT
     &)+TTB(JSORCE,I)
               TP(JSORCE,I)=FLOW(((CLE*AE(I))+(CLI*AI(I))+(CLD*AD1(I)*FB
     &F(I)))*DEPOT)+TP(JSORCE,I)
            END IF
   80       CONTINUE
         ELSE
            GOTO 85
         END IF
         GOTO 75
      END IF
   85 SEE=SPEFF(WORD,JSORCE,KTARG,TMASS,LOOP,MOTS,RHALF(1))
      IF (WORD(1:5) .EQ. 'SORRY')THEN
         PAUSE '  TO RESUME PRESS <RETURN>!!'
         RETURN 1
      END IF
      GRNSUM=GRNSUM+(US(JSORCE,I)*SEE*86400.)
*************************************************************************
*                                                                       *
*        Fraction of committed dose equivalent in the target tissue     *
*        resulting from deposition in the N-P, T-B, and P regions       *
*                                                                       *
*************************************************************************
      DEPOT=US(JSORCE,I)*SEE*86400.
      IF (JSORCE .EQ. 8)THEN
```

```
          TNP(JSORCE,I)=0.
          TTB(JSORCE,I)=FLOW(AC(I)+AD(I))*BRA(I)*SEE*86400.
          TP(JSORCE,I)=FLOW(AD1(I)+AE(I)+AF(I)+AG(I)+AH(I))*BRA(I)*SEE*86
     &400.
       ELSE IF(JSORCE .EQ. 2 .OR. (JSORCE .EQ. 3) .OR. (JSORCE .EQ. 4)
     & .OR. (JSORCE .EQ. 5))THEN
             TNP(JSORCE,I)=FLOW(CLB*AB(I)*DEPOT/FGI(I))
             TTB(JSORCE,I)=FLOW(CLD*AD(I)*DEPOT/FGI(I))
             TP(JSORCE,I)=FLOW(CLO*AD1(I)*DEPOT/FGI(I))
       ELSE
             TNP(JSORCE,I)=FLOW(((CLA*AA(I))+(CLB*AB(I)*FBF(I)))*DEPOT/FT
     &(I))
             TTB(JSORCE,I)=FLOW(((CLC*AC(I))+(CLD*AD(I)*FBF(I)))*DEPOT/FT
     &(I))
             TP(JSORCE,I)=FLOW(((CLE*AE(I))+(CLI*AI(I))+(CLD*AD1(I)*FBF(I
     &)))*DEPOT/FT(I))
       END IF
    75 CONTINUE
       DO 95 I=1,NO
       FNP(KTARG)=FNP(KTARG)+TNP(JSORCE,I)
       FTB(KTARG)=FTB(KTARG)+TTB(JSORCE,I)
       FP(KTARG)=FP(KTARG)+TP(JSORCE,I)
    95 CONTINUE
    55 CONTINUE
       GROUP=FNP(KTARG)+FTB(KTARG)+FP(KTARG)
       FNP(KTARG)=FNP(KTARG)/FLOW(GROUP)
       FTB(KTARG)=FTB(KTARG)/FLOW(GROUP)
       FP(KTARG)=FP(KTARG)/FLOW(GROUP)
*************************************************************************
*                                                                       *
*         Specific committed dose , H-50 in each target organ          *
*                                                                       *
*************************************************************************
       HFIFTY(KTARG)=(1.6E-10)*GRNSUM
    50 CONTINUE
       RETURN
    12 RETURN 1
   100 WRITE(*,101)
   101 FORMAT(//,' ERROR: Nuclide not found in catalogue of ICRP Publicat
     &ion 30',/,' SOURCE: INHALE FORTRAN',/,' CORRECTIVE ACTION: Try ano
     &ther nuclide!',////)
       GOTO 12
   105 WRITE(*,106)
   106 FORMAT(//,' ERROR: Unable to read US values from file "EXCEPT"!',/
     &,' SOURCE: INHALE FORTRAN',/,' CORRECTIVE ACTION: Check the identi
     &fication and try again!')
       END
```

INTRPT.FOR

10-15-1987

```
************************************************************************
*                                                                      *
*       FUNCTION SUBPROGRAM NAME : INTRPT FORTRAN                      *
*       PURPOSE: Interpolates the values of absorbed fraction          *
*       AUXILIARY PROGRAM REQUIRED:  e) ENERGY  FORTRAN                *
*       DATA FILE REQUIRED:          a) ABSFRAC FILE                   *
*                                                                      *
************************************************************************
      FUNCTION INTRPT (E,JSORCE,KTARG,ICHECK)
      REAL INTRPT
      OPEN (UNIT=13,FILE='ABSFRAC',ACCESS='DIRECT',FORM='FORMATTED',RECL
     &=9)
      ILO=0
      ELO=0.
      ENI=0.
      CALL ENERGY(E,ELO,ENI,ILO)
      INI=ILO+1
      KEY=ILO+((JSORCE-1)*12)+((KTARG-1)*12*20)
      READ (UNIT=13,FMT='(E9.3)',REC=KEY,ERR=5)AFLO
      KEY=INI+((JSORCE-1)*12)+((KTARG-1)*12*20)
      READ (UNIT=13,FMT='(E9.3)',REC=KEY,ERR=5)AFHI
      DIFF=((AFNI-AFLO)*(E-ELO))/(ENI-ELO)
      INTRPT=AFLO+DIFF
      RETURN
    5 CALL CLEAR
      WRITE (*,10)
   10 FORMAT(//,' ERROR: Unable to read the value of absorbed fraction f
     &or the given photon       energy, source, and terget from file "AB
     &SFRAC"',/,' SOURCE: INTRPT FORTRAN',/,' CORRECTIVE ACTION: Check t
     &he nuclide decay scheme and try again!!',////)
      ICHECK=1
      RETURN
      END
```

PCLASS.FOR

10-15-1987

```
*************************************************************************
*                                                                       *
*       SUBROUTINE NAME : PCLASS FORTRAN                                *
*       PURPOSE:  To explein the pulmonary clearance classification     *
*                 of inorganic compounds                                *
*                                                                       *
*************************************************************************
      SUBROUTINE PCLASS (IWISH)
    1 CALL CLEAR
      PRINT *,'PULMONARY CLEARANCE CLASSIFICATION OF INORGANIC COMPDS.'
      PRINT *,'-----------------------------------------------------'
      PRINT *
      PRINT *,'CLASS Y---> AVIO RETENTION: CLEAREO SLOWLY (YEARS)     '
      PRINT *,'*******************************************************'
      PRINT *,'  Carbides--> actinides,lanthanides,Zr,Y,Mn             '
      PRINT *,'  Sulfides--> none                                      '
      PRINT *,'  Sulfetes--> none                                      '
      PRINT *,'  Carbonates--> none                                    '
      PRINT *,'  Phosphates--> none                                    '
      PRINT *,'  Oxides and hydroxides--> lanthanides, actinidee Groups'
      PRINT *,'                           8 (V and VI), 1b,2b(IV and V)'
      PRINT *,'                           3b except Sc(3+),and 6b      '
      PRINT *,'  Helides--> lanthanide fluorides                       '
      PRINT *,'  Nitrates--> none                                      '
      PRINT *
      PAUSE '    TO RESUME PRESS <RETURN>!!'
      CALL CLEAR
      PRINT *,'Cleee W--> Moderate retention: intermedieta reta (weeks)'
      PRINT *,'*******************************************************'
      PRINT *,'  Carbides--> Cations of ell Claee W hydroxides except  '
      PRINT *,'              those liated as Claee Y cerbides          '
      PRINT *,'  Sulfides--> Groups 2a(V + VI), 4a(IV-VI), 5e(IV-VI),1b'
      PRINT *,'              2b, and 6b(V+VI)                          '
      PRINT *,'  Sulfates--> Groups 2e(IV-VII), and 5a(IV-VI)          '
      PRINT *,'  Cerbonates--> lenthanides, Bi(3+), Group 2e(IV-VII)   '
      PRINT *,'  Phosphetaa--> Zn(2+), Sn(3+), Mg(2+), Fe(3+), Bi(3+)  '
      PRINT *,'                and lanthanides                         '
      PRINT *,'  Oxides and hydroxides--> Groups 2e(II-VII),3e(III-VI),'
      PRINT *,'                           4a(III-VI), 5a(IV-VI), 6a(IV-'
      PRINT *,'                           VI), 8, 2b(VI),4b, 5b, end 7b'
      PRINT *,'                           Sc(3+)                      '
      PRINT *,'  Halides--> lanthenides (except fluorides),Groups 2a,3e'
      PRINT *,'             (III-VI). 4e(IV-VI),5a(IV-VI),8,1b,2b,3b(IV'
      PRINT *,'             -V),4b,5b,6b,and 7b                        '
      PRINT *,'  Nitrates--> all cations whosa hydroxides ere Claes Y   '
      PRINT *,'              and W                                     '
      PRINT *
      PAUSE '    TO RESUME PRESS <RETURN>!!'
      CALL CLEAR
      PRINT *,'Claee O--> Minimal ratantion: rapid cleerance (daye)    '
      PRINT *,'*******************************************************'
      PRINT *,'  Cerbides--> eee hydroxides                            '
      PRINT *,'  Sulfides--> ell except Claee W                        '
      PRINT *,'  Sulfatas--> ell except Claee W                        '
```

```
      PRINT *,'  Carbonates--> all except Class W                    '
      PRINT *,'  Phosphates--> all except Class W                    '
      PRINT *,'  Oxides and Hydroxides--> Groups 1a, 3a(II), 4a(II), 5a'
      PRINT *,'                              (II,III), 6a(III)       '
      PRINT *,'  Halides--> Groups 1a and 7a                         '
      PRINT *,'  Nitretes--> all except Cleee W                      '
      PRINT *,'  Noble Gases--> Group 0                             '
      PRINT *,'                                                     '
      PRINT *,'Note: Where reference ie made from one chemical form to '
      PRINT *,'      another, it implies that an in vivo convereion  '
      PRINT *,'      occurs, a.g. hydrolysie reaction                '
    5 PRINT *
      PRINT *,' Enter integer 1 to repeat or 0 to continue.'
      READ (*,*,ERR=5,END=5)NCON
      IF (NCON .NE. 1 .AND. (NCON .NE. 0))GOTO 5
      IF (NCON .EQ. 1)GOTO 1
      CALL CLEAR
      END
```

REFMAN.FOR

10-15-1987

```
************************************************************************
*                                                                      *
*       FUNCTION SUBPROGRAM NAME: REFMAN FORTRAN                       *
*       PURPOSE: Provide mass of a target organ in a "reference man"   *
*                                                                      *
************************************************************************
      FUNCTION REFMAN(KTARG)
      IF (KTARG .EQ. 1)THEN
      REFMAN=999.
      ELSE IF (KTARG .EQ. 2)THEN
      REFMAN=19.6
      ELSE IF (KTARG .EQ. 3)THEN
      REFMAN=37.1
      ELSE IF (KTARG .EQ. 4)THEN
      REFMAN=8.27
      ELSE IF (KTARG .EQ. 5)THEN
      REFMAN=1500.
      ELSE IF (KTARG .EQ. 6)THEN
      REFMAN=150.
      ELSE IF (KTARG .EQ. 7)THEN
      REFMAN=1040.
      ELSE IF (KTARG .EQ. 8)THEN
      REFMAN=209.
      ELSE IF (KTARG .EQ. 9)THEN
      REFMAN=160.
      ELSE IF (KTARG .EQ. 10)THEN
      REFMAN=1810.
      ELSE IF (KTARG .EQ. 11)THEN
      REFMAN=284.
      ELSE IF (KTARG .EQ. 12)THEN
      REFMAN=45.1
      ELSE IF (KTARG .EQ. 13)THEN
      REFMAN=48200.
      ELSE IF (KTARG .EQ. 14)THEN
      REFMAN=10500.
      ELSE IF (KTARG .EQ. 15)THEN
      REFMAN=2830.
      ELSE IF (KTARG .EQ. 16)THEN
      REFMAN=174.
      ELSE IF (KTARG .EQ. 17)THEN
      REFMAN=65.4
      ELSE IF (KTARG .EQ. 18)THEN
      REFMAN=60.3
      ELSE IF (KTARG .EQ. 19)THEN
      REFMAN=69900.
      END IF
      RETURN
      END
```

RESPIR.FOR

10-15-1987

```
************************************************************************
*                                                                      *
*       SUBROUTINE NAME : RESPIR FORTRAN                               *
*       PURPOSE: Provide fraction of materiel deposited, and ite       *
*                clearance rate from each compartment of the lung      *
*                                                                      *
************************************************************************
      SUBROUTINE RESPIR (CLASS,FA,FB,FC,FD,FE,FF,FG,FH,FI,FJ,CLA,CLB,CLC
     &,CLD,CLE,CLF,CLG,CLH,CLI,CLJ)
      CHARACTER*1 CLASS
************************************************************************
*                                                                      *
*                        DESCRIPTION OF VARIABLES                      *
*                        ------------------------                      *
*     FA--> Fraction of material deposited in tha body fluid compartm- *
*           ent from the nasal paesage region (N-P)                    *
*     FB--> Fraction depoeited in the GI tract from the naeel paesage  *
*     FC--> Fraction deposited in the body fluid compartment from tha  *
*           trechee and bronchiel tree region (T-B)                    *
*     FD--> Fraction deposited in the GI tract from the trachaa and    *
*           bronchial tree region (T-B)                                *
*     FE--> Frection deposited in the body fluids from tha pulmonary   *
*           region (P)                                                 *
*     FF--> Fraction transferred to T-B region from P region with e    *
*           half-life                                                  *
*     FG--> Frection transferred to T-B region from P region with a    *
*           different half-lifa                                        *
*     FH--> Fraction transferred to tha lymphatic eystem (L) from      *
*           P region                                                   *
*     FI--> Fraction deposited in tha body fluids from L region with   *
*           a half-life                                                *
*     FJ--> Fraction deposited in tha body fluids from L region with   *
*           e different half-life                                      *
*                                                                      *
*                        CLEARANCE RATES (/DAYS)                       *
*                        -----------------------                       *
*    CLA--> Clearance rete of materiel from N-P to body fluids         *
*    CLB--> Cleerence rate of materiel from N-P to GI tract            *
*    CLC--> Clearance rete of materiel from T-B to body fluids         *
*    CLD--> Cleerance rate of materiel from T-B to GI tract            *
*    CLE--> Clearance rete of material from P   to body fluids         *
*    CLF--> Clearance rete of materiel from P   to T-B region          *
*    CLG--> Clearance reta of material from P   to T-B region          *
*    CLH--> Cleerance rete of materiel from P   to L   region          *
*    CLI--> Clearance rete of materiel from L   to body fluids         *
*    CLJ--> Clearance rate of material from L   to body fluids         *
*                                                                      *
************************************************************************
      IF (CLASS .EQ. 'D')THEN
         FA=0.5
         FB=0.5
         FC=0.95
         FD=0.05
         FE=0.8
```

```
      FH=0.2
      FI=1.0
      CLA=LOG(2.)/0.01
      CLB=LOG(2.)/0.01
      CLC=LOG(2.)/0.01
      CLD=LOG(2.)/0.2
      CLE=LOG(2.)/0.5
      CLH=LOG(2.)/0.5
      CLI=LOG(2.)/0.5
   ELSE IF (CLASS .EQ. 'W')THEN
      FA=0.1
      FB=0.9
      FC=0.5
      FD=0.5
      FE=0.15
      FF=0.4
      FG=0.4
      FH=0.05
      FI=1.0
      CLA=LOG(2.)/0.01
      CLB=LOG(2.)/0.40
      CLC=LOG(2.)/0.01
      CLD=LOG(2.)/0.2
      CLE=LOG(2.)/50.
      CLF=LOG(2.)/1.0
      CLG=LOG(2.)/50.
      CLH=LOG(2.)/50.
      CLI=LOG(2.)/50.
   ELSE IF (CLASS .EQ. 'Y')THEN
      FA=0.01
      FB=0.99
      FC=0.01
      FD=0.99
      FE=0.05
      FF=0.4
      FG=0.4
      FH=0.15
      FI=0.9
      FJ=0.1
      CLA=LOG(2.)/0.01
      CLB=LOG(2.)/0.40
      CLC=LOG(2.)/0.01
      CLD=LOG(2.)/0.2
      CLE=LOG(2.)/500.
      CLF=LOG(2.)/1.0
      CLG=LOG(2.)/500.
      CLH=LOG(2.)/500.
      CLI=LOG(2.)/1000.
      CLJ=0.
   END IF
   END
```

RESULT.FOR

10-15-1987

```
************************************************************************
*                                                                      *
*       SUBROUTINE NAME : RESULT FORTRAN                               *
*       PURPOSE: Evaluate Weighted Committed Dose Equivelent using     *
*                the 10% exclusion principle, the DAC, and the ALI     *
*       DATA FILE REQUIRED :  e) RETENT FILE                           *
*                                                                      *
************************************************************************
      SUBROUTINE RESULT (HFIFTY,WDOSE,ALI,POST,IRGANT,DAC,KZ,REMDR,WREMD
     &R,WTF,SUM)
      DIMENSION HFIFTY(1:24),WDOSE(1:24),TEMP(1:12),REM(1:5),NTARG(1:5)
      CHARACTER*2D C2
      REAL MAXDOS
      OPEN (UNIT=15,FILE='RETENT',ACCESS='DIRECT',FORM='FORMATTED',RECL=
     &66,STATUS='OLD')
************************************************************************
*                                                                      *
*     Finding the five organs or tissues of the remainder receiving    *
*     the highest dose equivalents; the exposure of all other          *
*     remaining tissues is neglected                                   *
*                                                                      *
************************************************************************
      DO 1 I=1,20
      WDOSE(I)=0.
    1 CONTINUE
      DO 5 I=1,12
      IF(I .GE. 8)THEN
        TEMP(I)=HFIFTY(I+7)
      ELSE
        TEMP(I)=HFIFTY(I+5)
      END IF
    5 CONTINUE
      DO 1D I=1,5
      REM(I)=AMAX1(TEMP(1),TEMP(2),TEMP(3),TEMP(4),TEMP(5),TEMP(6),TEMP(
     &7),TEMP(8),TEMP(9),TEMP(10),TEMP(11),TEMP(12))
      DO 15 J=1,12
      IF (REM(I) .EQ. TEMP(J))THEN
         TEMP(J)=0.
         GOTO 10
      END IF
   15 CONTINUE
   10 CONTINUE
************************************************************************
*                                                                      *
*     Weighted committed dose equivalent, WDOSE                        *
*                                                                      *
************************************************************************
      DO 20 I=1,19
      IF (I .EQ. 1)THEN
         WT=0.12
         WDOSE(I)=WT*HFIFTY(I)
      ELSE IF(I .EQ. 2)THEN
         WT=0.03
         WDOSE(I)=WT*HFIFTY(I)
```

```
      ELSE IF(I .EQ. 3 .OR. (I .EQ. 4))THEN
         WT=0.25
         WDOSE(I)=WT*HFIFTY(I)
      ELSE IF(I .EQ. 5)THEN
         WT=0.12
         WDOSE(I)=WT*HFIFTY(I)
      ELSE IF(I .EQ. 13)THEN
         WT=0.15
         WDOSE(I)=WT*HFIFTY(I)
      ELSE IF (I .EQ. 14)THEN
         WT=0.03
         WDOSE(I)=WT*HFIFTY(I)
      ELSE
         WT=0.06
         DO 25 J=1,5
         IF (HFIFTY(I) .EQ. REM(J))THEN
            WDOSE(I)=WT*REM(J)
            GOTO 20
         END IF
   25    CONTINUE
      END IF
   20 CONTINUE
*************************************************************************
*                                                                       *
*     The maximum weighted committed dose equivalent, MAXDOS            *
*                                                                       *
*************************************************************************
      MAXDOS=AMAX1(WDOSE(1),WDOSE(2),WDOSE(3),WDOSE(4),WDOSE(5),WDOSE(6)
     &,WDOSE(7),WDOSE(8),WDOSE(9),WDOSE(10),WDOSE(11),WDOSE(12),WDOSE(13
     &),WDOSE(14),WDOSE(15),WDOSE(16),WDOSE(17),WDOSE(18),WDOSE(19))
*************************************************************************
*                                                                       *
*     Weighted committed dose equivalent,WDOSE which is greater         *
*     than or equal to 10% of the maximum weighted value of H-50        *
*     per unit intake in any tissue,MAXDOS                              *
*                                                                       *
*************************************************************************
      PERC=0.1*MAXDOS
      DO 30 I=1,19
      IF (WDOSE(I) .LT. PERC)THEN
         WDOSE(I)=0.
      END IF
   30 CONTINUE
*************************************************************************
*                                                                       *
*     Check for the organ named in the metabolic model                  *
*                                                                       *
*************************************************************************
      ISAVE=(5*(KZ-1))
      SUM=0.
      DO 35 I=1,5
      NTARG(I)=0
   35 CONTINUE
      DO 40 I=1,5
```

```
      KEY=ISAVE+I
      READ(UNIT=15,FMT='(A20)',REC=KEY)C2
      ISORCE=I1(C2)
      IF(ISORCE .EQ. 6)THEN
        NTARG(1)=11
      ELSE IF(ISORCE .EQ. 7)THEN
        NTARG(2)=10
      ELSE IF (ISORCE .EQ. 11)THEN
        NTARG(3)=18
      ELSE IF (ISORCE .EQ. 14)THEN
        NTARG(4)=16
      ELSE IF (ISORCE .EQ. 17)THEN
        NTARG(5)=19
      ELSE
        GOTO 40
      END IF
   40 CONTINUE
*************************************************************************
*                                                                       *
*     Assigning a committed dose equivalent to the "REMAINDER" with     *
*     weighting factor                                                  *
*                                                                       *
*************************************************************************
      DO 45 I=1,19
      IF (WDOSE(I) .EQ. 0.)THEN
        NFIFTY(I)=0.
      END IF
   45 CONTINUE
      DO 50 I=1,5
      REM(I)=0.
   50 CONTINUE
      ICOUNT=0
      DO 55 I=10,19
      IF (I .EQ. 13 .OR. (I .EQ. 14))GOTO 55
      DO 60 J=1,5
      IF (I .EQ. NTARG(J))GOTO 55
   60 CONTINUE
      IF (NFIFTY(I) .GT. 0.)THEN
        ICOUNT=ICOUNT+1
        REM(ICOUNT)=NFIFTY(I)
        NFIFTY(I)=0.
        WDOSE(I)=0.
      END IF
   55 CONTINUE
      REMDR=AMAX1(REM(1),REM(2),REM(3),REM(4),REM(5))
      WTF=0.06*ICOUNT
      WREMDR=WTF*REMDR
*************************************************************************
*                                                                       *
*     Annual limit on intake, ALI                                       *
*                                                                       *
*************************************************************************
      SUM=WREMDR
      DO 65 I=1,19
```

```
      IF (WDOSE(I) .EQ. 0.)GOTO 65
      SUM=SUM+WDOSE(I)
   65 CONTINUE
      POST=0.05/SUM
      ALI=POST
      SAVE=0.
      IRGANT=0
      DO 70 I=1,19
      IF (HFIFTY(I) .EQ. 0.)GOTO 70
      POST1=0.5/POST
      IF (HFIFTY(I) .GT. POST1)THEN
         IF (HFIFTY(I) .GT. SAVE)THEN
            SAVE=HFIFTY(I)
            IRGANT=I
         ELSE
            GOTO 70
         END IF
      END IF
   70 CONTINUE
      IF (SAVE .NE. 0.)THEN
      ALI=0.5/SAVE
      END IF
*************************************************************************
*                                                                       *
*     Derived air concentration, DAC                                    *
*                                                                       *
*************************************************************************
      DAC=ALI/2.4E+03
      RETURN
      END
```

SOURCE.FOR

10-15-1987

```
************************************************************************
*                                                                      *
*        FUNCTION SUBPROGRAM NAME: SOURCE FORTRAN                      *
*        PURPOSE: Provide mass of the source organ when source organ   *
*                 integer is given as input                            *
*                                                                      *
************************************************************************
      FUNCTION SOURCE(ICOMP)
      IF (ICOMP .EQ. 6)THEN
         SOURCE=310.
      ELSE IF (ICOMP .EQ. 7)THEN
         SOURCE=1800.
      ELSE IF (ICOMP .EQ. 10)THEN
         SOURCE=11.
      ELSE IF (ICOMP .EQ. 11)THEN
         SOURCE=100.
      ELSE IF (ICOMP .EQ. 12)THEN
         SOURCE=5000.
      ELSE IF (ICOMP .EQ. 14)THEN
         SOURCE=180.
      ELSE IF(ICOMP .EQ. 15)THEN
         SOURCE=35.
      ELSE IF (ICOMP .EQ. 16)THEN
         SOURCE=20.
      ELSE IF (ICOMP .EQ. 17)THEN
         SOURCE=70000.
      ELSE IF (ICOMP .EQ. 19)THEN
         SOURCE=1450.
      ELSE IF (ICOMP .EQ. 20)THEN
         SOURCE=14.
      ELSE IF (ICOMP .EQ. 21)THEN
         SOURCE=1500.
      END IF
      RETURN
      END
```

SPEFF.FOR

10-15-1987

```
************************************************************************
*                                                                      *
*       FUNCTION SUBPROGRAM NAME : SPEFF FORTRAN                       *
*       PURPOSE: Calculetes the specific effective energy deposited    *
*                in terget organ, KTARG due to source organ, JSORCE    *
*       AUXILIARY PROGRAM REQUIRED:  a) DECAY  FORTRAN                 *
*                                    b) INTRPT FORTRAN                 *
*                                    c) ENERGY FORTRAN                 *
*                                                                      *
************************************************************************
      FUNCTION SPEFF(WORD,JSORCE,KTARG,TMASS,LOOP,MOTS,PLIFE)
      REAL INTRPT
      DIMENSION EALPHA(1:20),YALPHA(1:20),EBETA(1:50),YBETA(1:50),EPOST(
     &1:15),YPOST(1:15),EELEC(1:115),YELEC(1:115),EGAMMA(1:190),YGAMMA(1
     &:190)
      COMMON EALPHA,YALPHA,EBETA,YBETA,EPOST,YPOST,EELEC,YELEC,EGAMMA,YG
     &AMMA,H,I1,I3,I5,I7,HLIFE
      CHARACTER*8 SAVE,WORD,MOTS
************************************************************************
*                                                                      *
*       Comparing source organ, JSORCE end terget, KTARG. When         *
*       source organ is not equal to the terget organ, ICOM=1          *
*       elee ICOM=0                                                    *
*                                                                      *
************************************************************************
      IF(JSORCE .EQ. 1 .AND. KTARG .EQ. 12)THEN
         ICOM=0
      ELSE IF(JSORCE .EQ. 2 .AND. KTARG .EQ. 6)THEN
         ICOM=0
      ELSE IF(JSORCE .EQ. 3 .AND. KTARG .EQ. 7)THEN
         ICOM=0
      ELSE IF(JSORCE .EQ. 4 .AND. KTARG .EQ. 8)THEN
         ICOM=0
      ELSE IF(JSORCE .EQ. 5 .AND. KTARG .EQ. 9)THEN
         ICOM=0
      ELSE IF(JSORCE .EQ. 6 .AND. KTARG .EQ. 11)THEN
         ICOM=0
      ELSE IF(JSORCE .EQ. 7 .AND. KTARG .EQ. 10)THEN
         ICOM=0
      ELSE IF(JSORCE .EQ. 8 .AND. KTARG .EQ. 1)THEN
         ICOM=0
      ELSE IF(JSORCE .EQ. 9 .AND. KTARG .EQ. 13)THEN
         ICOM=0
      ELSE IF(JSORCE .EQ. 10 .AND. KTARG .EQ. 4)THEN
         ICOM=0
      ELSE IF(JSORCE .EQ. 11 .AND. KTARG .EQ. 18)THEN
         ICOM=0
      ELSE IF(JSORCE .EQ. 12 .AND. KTARG .EQ. 5)THEN
         ICOM=0
      ELSE IF(JSORCE .EQ. 12 .AND. KTARG .EQ. 14)THEN
         ICOM=0
      ELSE IF(JSORCE .EQ. 13 .AND. KTARG .EQ. 15)THEN
         ICOM=0
      ELSE IF(JSORCE .EQ. 14 .AND. KTARG .EQ. 16)THEN
```

```
         ICOM=0
       ELSE IF(JSORCE .EQ. 15 .AND. KTARG .EQ. 3)THEN
         ICOM=0
       ELSE IF(JSORCE .EQ. 16 .AND. KTARG .EQ. 2)THEN
         ICOM=0
       ELSE IF(JSORCE .EQ. 17 .AND. KTARG .EQ. 19)THEN
         ICOM=0
       ELSE
         ICOM=1
       END IF
*****************************************************************************
*                                                                           *
*         Begin with 'Total body' as source.                                *
*         The character variable 'SAVE' stores the name of the              *
*         previous radionuclide and hence when it is equal to               *
*         'WORD', the function 'SPEFF' does not have to call                *
*         'DECAY' again                                                     *
*                                                                           *
*****************************************************************************
      IF (SAVE .EQ. WORD)GOTO 5
      ICOUNT=0
      CALL DECAY (WORD,ICOUNT)
      IF (ICOUNT .EQ. 1)THEN
         WORD(1:5)='SORRY'
         RETURN
      END IF
    5 SPEFF=0.
      ICHECK=0
*****************************************************************************
*         Annihilation photons                                              *
*****************************************************************************
      IF (I3 .NE. 0)THEN
         DO 6 I=I7+1,I7+I3
         EGAMMA(I)=0.511
         YGAMMA(I)=2.*YPOST(I-I7)
    6    CONTINUE
      END IF
*****************************************************************************
      IF(KTARG .EQ. 6 .OR. (KTARG .EQ. 7) .OR. (KTARG .EQ. 8) .OR. (KTAR
     &G .EQ. 9) .OR. (KTARG .EQ. 12))THEN
      GOTO 55
      ELSE IF(KTARG .EQ. 5 .OR. KTARG .EQ. 14)THEN
      GOTO 105
      END IF
*****************************************************************************
*                                                                           *
*         Organs other than bladder, GI tract and bone                      *
*                                                                           *
*                         ALPHA                                             *
*                                                                           *
*****************************************************************************
      IF (M .EQ. 0)GOTO 15
      OF=20
      DO 10 I=1,M
```

```
      IF (ICOM .EQ. 1)THEN
         IF (JSORCE .EQ. 17)THEN
            AF=1./69900.
            SPEFF=SPEFF+(YALPNA(I)*EALPNA(I)*AF*QF)
         ELSE IF (KTARG .EQ. 19)THEN
            IF (JSORCE .EQ. 1)THEN
               AF=45.1/(2*200.*69900.)
            ELSE IF (JSORCE .EQ. 2)THEN
               AF=150./(2*250.*69900.)
            ELSE IF (JSORCE .EQ. 3)THEN
               AF=640./(2*400.*69900.)
            ELSE IF (JSORCE .EQ. 4)THEN
               AF=210./(2*220.*69900.)
            ELSE IF (JSORCE .EQ. 5)THEN
               AF=160./(2*135.*69900.)
            ELSE
               AF=1./69900.
            END IF
            SPEFF=SPEFF+(YALPNA(I)*EALPNA(I)*AF*QF)
         ELSE
            AF=0.
         END IF
      ELSE
         AF=1.0
         SPEFF=SPEFF+((YALPHA(I)*EALPHA(I)*AF*QF)/TMASS)
      END IF
   10 CONTINUE
*************************************************************************
*                                                                       *
*                              BETA                                     *
*                                                                       *
*************************************************************************
   15 IF (I1 .EQ. 0)GOTO 25
      QF=1
      DO 20 I=1,I1
      IF (ICOM .EQ. 1)THEN
         IF (JSORCE .EQ. 17)THEN
            AF=1./69900.
            SPEFF=SPEFF+(YBETA(I)*EBETA(I)*QF*AF)
         ELSE IF (KTARG .EQ. 19)THEN
            IF (JSORCE .EQ. 1)THEN
               AF=45.1/(2*200.*69900.)
            ELSE IF (JSORCE .EQ. 2)THEN
               AF=150./(2*250.*69900.)
            ELSE IF (JSORCE .EQ. 3)THEN
               AF=640./(2*400.*69900.)
            ELSE IF (JSORCE .EQ. 4)THEN
               AF=210./(2*220.*69900.)
            ELSE IF (JSORCE .EQ. 5)THEN
               AF=160./(2*135.*69900.)
            ELSE
               AF=1./69900.
            END IF
            SPEFF=SPEFF+(YBETA(I)*EBETA(I)*QF*AF)
```

```
        ELSE
          AF=0.
        END IF
      ELSE
        AF=1.0
        SPEFF=SPEFF+((YBETA(I)*EBETA(I)*QF*AF)/TMASS)
      END IF
   20 CONTINUE
*****************************************************************
*                                                               *
*                          POSITRON                             *
*                                                               *
*****************************************************************
   25 IF (I3 .EQ. 0)GOTO 35
      QF=1
      DO 30 I=1,I3
      IF (ICOM .EQ. 1)THEN
        IF (JSORCE .EQ. 17)THEN
          AF=1./69900.
          SPEFF=SPEFF+(YPOST(I)*EPOST(I)*QF*AF)
        ELSE IF (KTARG .EQ. 19)THEN
          IF (JSORCE .EQ. 1)THEN
            AF=45.1/(2*200.*69900.)
          ELSE IF (JSORCE .EQ. 2)THEN
            AF=150./(2*250.*69900.)
          ELSE IF (JSORCE .EQ. 3)THEN
            AF=640./(2*400.*69900.)
          ELSE IF (JSORCE .EQ. 4)THEN
            AF=210./(2*220.*69900.)
          ELSE IF (JSORCE .EQ. 5)THEN
            AF=160./(2*135.*69900.)
          ELSE
            AF=1./69900.
          END IF
          SPEFF=SPEFF+(YPOST(I)*EPOST(I)*QF*AF)
        ELSE
          AF=0.
        END IF
      ELSE
        AF=1.0
        SPEFF=SPEFF+((YPOST(I)*EPOST(I)*QF*AF)/TMASS)
      END IF
   30 CONTINUE
*****************************************************************
*                                                               *
*                          ELECTRON                             *
*                                                               *
*****************************************************************
   35 IF (I5 .EQ. 0)GOTO 45
      QF=1
      DO 40 I=1,I5
      IF (ICOM .EQ. 1)THEN
        IF (JSORCE .EQ. 17)THEN
          AF=1./69900.
```

```
            SPEFF=SPEFF+(YELEC(I)*EELEC(I)*QF*AF)
         ELSE IF (KTARG .EQ. 19)THEN
            IF (JSORCE .EQ. 1)THEN
               AF=45.1/(2*200.*69900.)
            ELSE IF (JSORCE .EQ. 2)THEN
               AF=150./(2*250.*69900.)
            ELSE IF (JSORCE .EQ. 3)THEN
               AF=640./(2*400.*69900.)
            ELSE IF (JSORCE .EQ. 4)THEN
               AF=210./(2*220.*69900.)
            ELSE IF (JSORCE .EQ. 5)THEN
               AF=160./(2*135.*69900.)
            ELSE
               AF=1./69900.
            END IF
            SPEFF=SPEFF+(YELEC(I)*EELEC(I)*QF*AF)
         ELSE
            AF=0.
         END IF
      ELSE
         AF=1.0
         SPEFF=SPEFF+((YELEC(I)*EELEC(I)*QF*AF)/TMASS)
      END IF
   40 CONTINUE
*********************************************************************
*                                                                   *
*                              PHOTON                               *
*                                                                   *
*********************************************************************
   45 IF (I7 .EQ. 0 )GOTO 195
      QF=1
      DO 50 I=1,17
      AF=0.
      IF (EGAMMA(I) .LT. 0.01)THEN
         IF (ICOM .EQ. 1)THEN
            IF (JSORCE .EQ. 17)THEN
               AF=1.0/69900.
               SPEFF=SPEFF+(YGAMMA(I)*EGAMMA(I)*QF*AF)
            ELSE IF (KTARG .EQ. 19)THEN
               IF (JSORCE .EQ. 1)THEN
                  AF=45.1/(2*200.*69900.)
               ELSE IF (JSORCE .EQ. 2)THEN
                  AF=150./(2*250.*69900.)
               ELSE IF (JSORCE .EQ. 3)THEN
                  AF=640./(2*400.*69900.)
               ELSE IF (JSORCE .EQ. 4)THEN
                  AF=210./(2*220.*69900.)
               ELSE IF (JSORCE .EQ. 5)THEN
                  AF=160./(2*135.*69900.)
               ELSE
                  AF=1./69900.
               END IF
               SPEFF=SPEFF+(YGAMMA(I)*EGAMMA(I)*QF*AF)
            ELSE
```

```
            AF=0.
          END IF
        ELSE
          AF=1.
          SPEFF=SPEFF+((YGAMMA(I)*EGAMMA(I)*QF*AF)/TMASS)
        END IF
      ELSE
*****************************************************************
*                                                               *
*       The function IHTRPT interpolates the values of absorbed *
*       fraction, AF for the given energy, EGAMMA(I)            *
*                                                               *
*****************************************************************
      ICHECK=0
      AF=INTRPT(EGAMMA(I),JSORCE,KTARG,ICHECK)
      IF (ICHECK .EQ. 1)THEN
          WORD(1:5)='SORRY'
          RETURN
      END IF
      SPEFF=SPEFF+((YGAMMA(I)*EGAMMA(I)*QF*AF)/TMASS)
      END IF
   50 CONTINUE
      GOTO 195
*****************************************************************
*                                                               *
*       Target organs of the GI tract and bladder               *
*                                                               *
*                          ALPHA                                *
*                                                               *
*****************************************************************
   55 IF (M .EQ. 0)GOTO 65
      QF=20
      IF (ICOM .EQ. 1)THEN
        IF (JSORCE .EQ. 17)THEN
          AF=1./69900.
        ELSE
          AF=0.
        END IF
      ELSE
        IF (KTARG .EQ. 6)THEN
          AF=(0.5*0.01)/250.
        ELSE IF (KTARG .EQ. 7)THEN
          AF=(0.5*0.01)/400.
        ELSE IF (KTARG .EQ. 8)THEN
          AF=(0.5*0.01)/220.
        ELSE IF (KTARG .EQ. 9)THEN
          AF=(0.5*0.01)/135.
        ELSE IF (KTARG .EQ. 12)THEN
          AF=(0.5*0.01)/200.
        END IF
      END IF
      IF (AF .EQ. 0.)GOTO 65
      DO 60 I=1,M
      SPEFF=SPEFF+(YALPHA(I)*EALPHA(I)*QF*AF)
```

```
   60 CONTINUE
*
   65 QF=1
      IF (ICOM .EQ. 1)THEN
         IF (JSORCE .EQ. 17)THEN
            AF=1./69900.
         ELSE
            AF=0.
         END IF
      ELSE
         IF (KTARG .EQ. 6)THEN
            AF=(0.5*1.0)/250.
         ELSE IF (KTARG .EQ. 7)THEN
            AF=(0.5*1.0)/400.
         ELSE IF (KTARG .EQ. 8)THEN
            AF=(0.5*1.0)/220.
         ELSE IF (KTARG .EQ. 9)THEN
            AF=(0.5*1.0)/135.
         ELSE IF (KTARG .EQ. 12)THEN
            AF=(0.5*1.0)/200.
         END IF
      END IF
      IF (AF .EQ. 0.)GOTO 95
*****************************************************************
*                                                               *
*                            BETA                               *
*                                                               *
*****************************************************************
      IF (I1 .EQ. 0)GOTO 75
      DO 70 I=1,I1
      SPEFF=SPEFF+(YBETA(I)*EBETA(I)*QF*AF)
   70 CONTINUE
*****************************************************************
*                                                               *
*                           POSITRON                            *
*                                                               *
*****************************************************************
   75 IF (I3 .EQ. 0)GOTO 85
      DO 80 I=1,I3
      SPEFF=SPEFF+(YPOST(I)*EPOST(I)*QF*AF)
   80 CONTINUE
*****************************************************************
*                                                               *
*                           ELECTRON                            *
*                                                               *
*****************************************************************
   85 IF (I5 .EQ. 0)GOTO 95
      DO 90 I=1,I5
      SPEFF=SPEFF+(YELEC(I)*EELEC(I)*QF*AF)
   90 CONTINUE
*****************************************************************
*                                                               *
*                           PHOTON                              *
*                                                               *
```

```
*************************************************************************
   95 IF (I7 .EQ. 0)GOTO 195
      QF=1
      DO 100 I=1,I7
      AF=0.
      IF (EGAMMA(I) .LT. 0.01)THEN
         IF (ICOM .EQ. 1)THEN
            IF (JSORCE .EQ. 17)THEN
               AF=1./69900.
               SPEFF=SPEFF+(YGAMMA(I)*EGAMMA(I)*AF*QF)
            ELSE
               AF=0.
            END IF
         ELSE
            IF (KTARG .EQ. 6)THEN
               AF=1.0/(2.*250.)
            ELSE IF (KTARG .EQ. 7)THEN
               AF=1.0/(2.*400.)
            ELSE IF (KTARG .EQ. 8)THEN
               AF=1.0/(2.*220.)
            ELSE IF (KTARG .EQ. 9)THEN
               AF=1.0/(2.*135.)
            ELSE IF (KTARG .EQ. 12)THEN
               AF=1.0/(2.*200.)
            END IF
            SPEFF=SPEFF+(YGAMMA(I)*EGAMMA(I)*AF*QF)
         END IF
      ELSE
         ICNECK=0
         AF=INTRPT(EGAMMA(I),JSORCE,KTARG,ICNECK)
         IF (ICNECK .EQ. 1)THEN
            WORD(1:5)='SORRY'
            RETURN
         END IF
         SPEFF=SPEFF+((YGAMMA(I)*EGAMMA(I)*AF*QF)/TMASS)
      END IF
  100 CONTINUE
      GOTO 195
  105 IF (LOOP .EQ. 0. .AND. (JSORCE .EQ. 12))GOTO 185
*************************************************************************
*                                                                       *
*        Target organs in bone                                          *
*                                                                       *
*************************************************************************
      IF (M .EQ. 0)GOTO 125
      QF=20
      DO 120 I=1,M
      IF (ICOM .EQ. 1)THEN
         IF (JSORCE .EQ. 17)THEN
            AF=1./69900.
            SPEFF=SPEFF+(YALPHA(I)*EALPHA(I)*QF*AF)
         ELSE
            AF=0.
         END IF
```

```
      ELSE
*****************************************************************************
*                                                                           *
*       Bone surface calls                                                  *
*                                                                           *
*****************************************************************************
        IF (KTARG .EQ. 14)THEN
*****************************************************************************
*                                                                           *
*       Trabecular bone                                                     *
*                                                                           *
*****************************************************************************
          IF (LOOP .EQ. 1)THEN
*****************************************************************************
*       Alpha emitter uniform in volume                                     *
*****************************************************************************
            IF (MOTS(1:4) .EQ. 'P-33' .OR. (MOTS(1:6) .EQ. 'NB-93M') .O
     &R. (MOTS(1:5) .EQ. 'NB-94') .OR. (MOTS(1:5) .EQ. 'U-232') .OR. (MO
     &TS(1:5) .EQ. 'U-233') .OR. (MOTS(1:5) .EQ. 'U-234') .OR. (MOTS(1:5
     &) .EQ. 'U-235') .OR. (MOTS(1:5) .EQ. 'U-236') .OR. (MOTS(1:5) .EQ.
     & 'U-238') .OR. (MOTS(1:2) .EQ. 'NA') .OR. (MOTS(1:2) .EQ. 'CR') .O
     &R. (MOTS(1:2) .EQ. 'RB') .OR. (MOTS(1:5) .EQ. 'ZN-65') .OR. (MOTS(
     &1:6) .EQ. 'PB-205') .OR. (MOTS(1:6) .EQ. 'PB-210') .OR. (MOTS(1:4)
     & .EQ. 'BE-7') .OR. (MOTS(1:5) .EQ. 'BE-10') .OR. (MOTS(1:4) .EQ. '
     &V-49') .OR. (MOTS(1:6) .EQ. 'PD-103') .OR. (MOTS(1:6) .EQ. 'PD-107
     &') .OR. (MOTS(1:6) .EQ. 'SN-113') .OR. (MOTS(1:7) .EQ. 'SN-119M')
     &.OR. (MOTS(1:6) .EQ. 'SN-123') .OR. (MOTS(1:6) .EQ. 'SN-126') .OR.
     & (MOTS(1:6) .EQ. 'TA-182') .OR. (MOTS(1:5) .EQ. 'W-181') .OR. (MOT
     &S(1:5) .EQ. 'W-185') .OR. (MOTS(1:5) .EQ. 'W-188'))THEN
              AF=0.025
*****************************************************************************
*       Alkaline earths                                                     *
*****************************************************************************
            ELSE IF (MOTS(1:2) .EQ. 'SR' .OR. (MOTS(1:2) .EQ. 'CA') .OR
     &. (MOTS(1:2) .EQ. 'RA') .OR. (MOTS(1:2) .EQ. 'BA'))THEN
              IF (PLIFE .GT. 15)THEN
                AF=0.025
              ELSE
                AF=0.25
              END IF
            ELSE
*****************************************************************************
*       Alpha emittar on bone surfaces                                      *
*****************************************************************************
              AF=0.25
            END IF
*****************************************************************************
*                                                                           *
*       Cortical bone                                                       *
*                                                                           *
*****************************************************************************
          ELSE IF (LOOP .GT. 1)THEN
*****************************************************************************
*       Alpha emittar uniform in volume                                     *
```

```
************************************************************************
            IF (MOTS(1:4) .EQ. 'P-33' .OR. (MOTS(1:6) .EQ. 'NB-93M') .O
     &R. (MOTS(1:5) .EQ. 'NB-94') .OR. (MOTS(1:5) .EQ. 'U-232') .OR. (MO
     &TS(1:5) .EQ. 'U-233') .OR. (MOTS(1:5) .EQ. 'U-234') .OR. (MOTS(1:5
     &) .EQ. 'U-235') .OR. (MOTS(1:5) .EQ. 'U-236') .OR. (MOTS(1:5) .EQ.
     & 'U-238') .OR. (MOTS(1:2) .EQ. 'NA') .OR. (MOTS(1:2) .EQ. 'CR') .O
     &R. (MOTS(1:2) .EQ. 'RB') .OR. (MOTS(1:5) .EQ. 'ZN-65') .OR. (MOTS(
     &1:6) .EQ. 'PB-205') .OR. (MOTS(1:6) .EQ. 'PB-210') .OR. (MOTS(1:4)
     & .EQ. 'BE-7') .OR. (MOTS(1:5) .EQ. 'BE-10') .OR. (MOTS(1:4) .EQ. '
     &V-49') .OR. (MOTS(1:6) .EQ. 'PD-103') .OR. (MOTS(1:6) .EQ. 'PD-107
     &') .OR. (MOTS(1:6) .EQ. 'SN-113') .OR. (MOTS(1:7) .EQ. 'SN-119M')
     &.OR. (MOTS(1:6) .EQ. 'SN-123') .OR. (MOTS(1:6) .EQ. 'SN-126') .OR.
     & (MOTS(1:6) .EQ. 'TA-182') .OR. (MOTS(1:5) .EQ. 'W-181') .OR. (MOT
     &S(1:5) .EQ. 'W-185') .OR. (MOTS(1:5) .EQ. 'W-188'))THEN
              AF=0.01
************************************************************************
*       Alkaline earths                                                *
************************************************************************
            ELSE IF (MOTS(1:2) .EQ. 'SR' .OR. (MOTS(1:2) .EQ. 'CA') .OR
     &. (MOTS(1:2) .EQ. 'RA') .OR. (MOTS(1:2) .EQ. 'BA'))THEN
              IF (PLIFE .GT. 15)THEN
                AF=0.01
              ELSE
                AF=0.25
              END IF
            ELSE
************************************************************************
*       Alpha emitter on bone surfaces                                 *
************************************************************************
              AF=0.25
            END IF
          END IF
          SPEFF=SPEFF+((YALPHA(I)*EALPHA(I)*QF*AF)/120.)
************************************************************************
*                                                                      *
*       Red marrow                                                     *
*                                                                      *
************************************************************************
        ELSE IF (KTARG .EQ. 5)THEN
************************************************************************
*                                                                      *
*       Trabecular bone                                                *
*                                                                      *
************************************************************************
          IF (LOOP .EQ. 1)THEN
************************************************************************
*       Alpha emitter uniform in volume                                *
************************************************************************
            IF (MOTS(1:4) .EQ. 'P-33' .OR. (MOTS(1:6) .EQ. 'NB-93M') .O
     &R. (MOTS(1:5) .EQ. 'NB-94') .OR. (MOTS(1:5) .EQ. 'U-232') .OR. (MO
     &TS(1:5) .EQ. 'U-233') .OR. (MOTS(1:5) .EQ. 'U-234') .OR. (MOTS(1:5
     &) .EQ. 'U-235') .OR. (MOTS(1:5) .EQ. 'U-236') .OR. (MOTS(1:5) .EQ.
     & 'U-238') .OR. (MOTS(1:2) .EQ. 'NA') .OR. (MOTS(1:2) .EQ. 'CR') .O
     &R. (MOTS(1:2) .EQ. 'RB') .OR. (MOTS(1:5) .EQ. 'ZN-65') .OR. (MOTS(
```

```
     &1:6) .EQ. 'PB-205') .OR. (MOTS(1:6) .EQ. 'PB-210') .OR. (MOTS(1:4)
     & .EQ. 'BE-7') .OR. (MOTS(1:5) .EQ. 'BE-10') .OR. (MOTS(1:4) .EQ. '
     &V-49') .OR. (MOTS(1:6) .EQ. 'PD-103') .OR. (MOTS(1:6) .EQ. 'PD-107
     &') .OR. (MOTS(1:6) .EQ. 'SN-113') .OR. (MOTS(1:7) .EQ. 'SN-119M')
     &.OR. (MOTS(1:6) .EQ. 'SN-123') .OR. (MOTS(1:6) .EQ. 'SN-126') .OR.
     & (MOTS(1:6) .EQ. 'TA-182') .OR. (MOTS(1:5) .EQ. 'W-181') .OR. (MOT
     &S(1:5) .EQ. 'W-185') .OR. (MOTS(1:5) .EQ. 'W-188'))TNEN
               AF=0.05
*************************************************************************
*       Alkaline earths                                                 *
*************************************************************************
          ELSE IF (MOTS(1:2) .EQ. 'SR' .OR. (MOTS(1:2) .EQ. 'CA') .OR
     &. (MOTS(1:2) .EQ. 'RA') .OR. (MOTS(1:2) .EQ. 'BA'))TNEN
            IF (PLIFE .GT. 15)TNEN
              AF=0.05
            ELSE
              AF=0.5
            END IF
          ELSE
*************************************************************************
*       Alpha emitter on bone surfaces                                  *
*************************************************************************
            AF=0.5
          END IF
          SPEFF=SPEFF+((YALPNA(I)*EALPNA(I)*QF*AF)/1500.)
*************************************************************************
*                                                                       *
*       Cortical bone                                                   *
*                                                                       *
*************************************************************************
        ELSE IF (LOOP .GT. 1)THEN
          AF=0.0
        END IF
      END IF
    END IF
  120 CONTINUE
*                                                                       *
  125 QF=1
*************************************************************************
*                                                                       *
*        Beta                                                           *
*                                                                       *
*************************************************************************
    IF (I1 .EQ. 0)GOTO 165
    DO 160 I=1,I1
    IF (ICOM .EQ. 1)THEN
      IF (JSORCE .EQ. 17)THEN
        AF=1./69900.
        SPEFF=SPEFF+(YBETA(I)*EBETA(I)*QF*AF)
      ELSE
        AF=0.
      END IF
    ELSE
*************************************************************************
```

```
*                                                                      *
*       Bone surface cells                                             *
*                                                                      *
************************************************************************
        IF (KTARG .EQ. 14)THEN
************************************************************************
*                                                                      *
*       Trabecular bone                                                *
*                                                                      *
************************************************************************
          IF (LOOP .EQ. 1)THEN
************************************************************************
*       Beta  emitter uniform in volume                                *
************************************************************************
            IF (MOTS(1:4) .EQ. 'P-33' .OR. (MOTS(1:6) .EQ. 'NB-93M') .O
     &R. (MOTS(1:5) .EQ. 'NB-94') .OR. (MOTS(1:5) .EQ. 'U-232') .OR. (MO
     &TS(1:5) .EQ. 'U-233') .OR. (MOTS(1:5) .EQ. 'U-234') .OR. (MOTS(1:5
     &) .EQ. 'U-235') .OR. (MOTS(1:5) .EQ. 'U-236') .OR. (MOTS(1:5) .EQ.
     & 'U-238') .OR. (MOTS(1:2) .EQ. 'NA') .OR. (MOTS(1:2) .EQ. 'CR') .O
     &R. (MOTS(1:2) .EQ. 'RB') .OR. (MOTS(1:5) .EQ. 'ZN-65') .OR. (MOTS(
     &1:6) .EQ. 'PB-205') .OR. (MOTS(1:6) .EQ. 'PB-210') .OR. (MOTS(1:4)
     & .EQ. 'BE-7') .OR. (MOTS(1:5) .EQ. 'BE-10') .OR. (MOTS(1:4) .EQ. '
     &V-49') .OR. (MOTS(1:6) .EQ. 'PD-103') .OR. (MOTS(1:6) .EQ. 'PD-107
     &') .OR. (MOTS(1:6) .EQ. 'SN-113') .OR. (MOTS(1:7) .EQ. 'SH-119M')
     &.OR. (MOTS(1:6) .EQ. 'SN-123') .OR. (MOTS(1:6) .EQ. 'SN-126') .OR.
     & (MOTS(1:6) .EQ. 'TA-182') .OR. (MOTS(1:5) .EQ. 'W-181') .OR. (MOT
     &S(1:5) .EQ. 'W-185') .OR. (MOTS(1:5) .EQ. 'W-188'))THEN
              AF=0.025
************************************************************************
*       Alkaline earths                                                *
************************************************************************
            ELSE IF (MOTS(1:2) .EQ. 'SR' .OR. (MOTS(1:2) .EQ. 'CA') .OR
     &. (MOTS(1:2) .EQ. 'RA') .OR. (MOTS(1:2) .EQ. 'BA'))THEN
              IF (PLIFE .GT. 15)THEN
                AF=0.025
              ELSE
                IF (EBETA(I) .LT. 0.2)THEN
                  AF=0.25
                ELSE
                  AF=0.025
                ENQ IF
              END IF
            ELSE
************************************************************************
*       Beta  emitter on bone surfaces                                 *
************************************************************************
              IF (EBETA(I) .LT. 0.2)THEN
                AF=0.25
              ELSE IF (EBETA(I) .GE. 0.2)THEN
                AF=0.025
              END IF
            END IF
************************************************************************
*                                                                      *
```

```
*       Cortical bone                                                  *
*                                                                      *
************************************************************************
          ELSE IF (LOOP .GT. 1)THEN
************************************************************************
*       Beta  emitter uniform in volume                                *
************************************************************************
            IF (MOTS(1:4) .EQ. 'P-33' .OR. (MOTS(1:6) .EQ. 'NB-93M') .O
     &R. (MOTS(1:5) .EQ. 'NB-94') .OR. (MOTS(1:5) .EQ. 'U-232') .OR. (MO
     &TS(1:5) .EQ. 'U-233') .OR. (MOTS(1:5) .EQ. 'U-234') .OR. (MOTS(1:5
     &) .EQ. 'U-235') .OR. (MOTS(1:5) .EQ. 'U-236') .OR. (MOTS(1:5) .EQ.
     & 'U-238') .OR. (MOTS(1:2) .EQ. 'NA') .OR. (MOTS(1:2) .EQ. 'CR') .O
     &R. (MOTS(1:2) .EQ. 'RB') .OR. (MOTS(1:5) .EQ. 'ZN-65') .OR. (MOTS(
     &1:6) .EQ. 'PB-205') .OR. (MOTS(1:6) .EQ. 'PB-210') .OR. (MOTS(1:4)
     & .EQ. 'BE-7') .OR. (MOTS(1:5) .EQ. 'BE-10') .OR. (MOTS(1:4) .EQ. '
     &V-49') .OR. (MOTS(1:6) .EQ. 'PD-103') .OR. (MOTS(1:6) .EQ. 'PD-107
     &') .OR. (MOTS(1:6) .EQ. 'SN-113') .OR. (MOTS(1:7) .EQ. 'SN-119M')
     &.OR. (MOTS(1:6) .EQ. 'SN-123') .OR. (MOTS(1:6) .EQ. 'SN-126') .OR.
     & (MOTS(1:6) .EQ. 'TA-182') .OR. (MOTS(1:5) .EQ. 'W-181') .OR. (MOT
     &S(1:5) .EQ. 'W-185') .OR. (MOTS(1:5) .EQ. 'W-188'))THEN
              AF=0.015
************************************************************************
*       Alkaline earths                                                *
************************************************************************
          ELSE IF (MOTS(1:2) .EQ. 'SR' .OR. (MOTS(1:2) .EQ. 'CA') .OR
     &. (MOTS(1:2) .EQ. 'RA') .OR. (MOTS(1:2) .EQ. 'BA'))THEN
            IF (PLIFE .GT. 15)THEN
              AF=0.015
            ELSE
              IF (EBETA(I) .LT. 0.2)THEN
                AF=0.25
              ELSE
                AF=0.015
              END IF
            END IF
          ELSE
************************************************************************
*       Beta  emitter on bone surfaces                                 *
************************************************************************
            IF (EBETA(I) .LT. 0.2)THEN
              AF=0.25
            ELSE IF (EBETA(I) .GE. 0.2)THEN
              AF=0.015
            END IF
          END IF
        END IF
        SPEFF=SPEFF+((YBETA(I)*EBETA(I)*QF*AF)/120.)
************************************************************************
*                                                                      *
*       Red marrow                                                     *
*                                                                      *
************************************************************************
      ELSE
************************************************************************
```

SPEFF.FOR

10-15-1987

```
*                                                                       *
*       Trabecular bone                                                 *
*                                                                       *
*************************************************************************
          IF (LOOP .EQ. 1)THEN
*************************************************************************
*       Beta  emitter uniform in volume                                 *
*************************************************************************
            IF (MOTS(1:4) .EQ. 'P-33' .OR. (MOTS(1:6) .EQ. 'NB-93M') .O
     &R. (MOTS(1:5) .EQ. 'NB-94') .OR. (MOTS(1:5) .EQ. 'U-232') .OR. (MO
     &TS(1:5) .EQ. 'U-233') .OR. (MOTS(1:5) .EQ. 'U-234') .OR. (MOTS(1:5
     &) .EQ. 'U-235') .OR. (MOTS(1:5) .EQ. 'U-236') .OR. (MOTS(1:5) .EQ.
     & 'U-238') .OR. (MOTS(1:2) .EQ. 'NA') .OR. (MOTS(1:2) .EQ. 'CR') .O
     &R. (MOTS(1:2) .EQ. 'RB') .OR. (MOTS(1:5) .EQ. 'ZN-65') .OR. (MOTS(
     &1:6) .EQ. 'PB-205') .OR. (MOTS(1:6) .EQ. 'PB-210') .OR. (MOTS(1:4)
     & .EQ. 'BE-7') .OR. (MOTS(1:5) .EQ. 'BE-10') .OR. (MOTS(1:4) .EQ. '
     &V-49') .OR. (MOTS(1:6) .EQ. 'PD-103') .OR. (MOTS(1:6) .EQ. 'PD-107
     &') .OR. (MOTS(1:6) .EQ. 'SN-113') .OR. (MOTS(1:7) .EQ. 'SN-119M')
     &.OR. (MOTS(1:6) .EQ. 'SN-123') .OR. (MOTS(1:6) .EQ. 'SN-126') .OR.
     & (MOTS(1:6) .EQ. 'TA-182') .OR. (MOTS(1:5) .EQ. 'W-181') .OR. (MOT
     &S(1:5) .EQ. 'W-185') .OR. (MOTS(1:5) .EQ. 'W-188'))THEN
              AF=0.35
*************************************************************************
*       Alkaline eertha                                                 *
*************************************************************************
            ELSE IF (MOTS(1:2) .EQ. 'SR' .OR. (MOTS(1:2) .EQ. 'CA') .OR
     &. (MOTS(1:2) .EQ. 'RA') .OR. (MOTS(1:2) .EQ. 'BA'))THEN
              IF (PLIFE .GT. 15)THEN
                AF=0.35
              ELSE
                AF=0.5
              END IF
            ELSE
*************************************************************************
*       Beta  emitter on bone surfaces                                  *
*************************************************************************
              AF=0.5
            END IF
            SPEFF=SPEFF+((YBETA(I)*EBETA(I)*QF*AF)/1500.)
*************************************************************************
*                                                                       *
*       Cortical bone                                                   *
*                                                                       *
*************************************************************************
          ELSE IF (LOOP .GT. 1)THEN
            AF=0.0
          END IF
        END IF
      END IF
  160 CONTINUE
*************************************************************************
*                                                                       *
*       Positron                                                        *
*                                                                       *
```

```
*****************************************************************************
  165 IF (I3 .EQ. 0)GOTO 175
      DO 170 I=1,I3
      IF (ICOM .EQ. 1)THEN
         IF (JSORCE .EQ. 17)THEN
            AF=1./69900.
            SPEFF=SPEFF+(YPOST(I)*EPOST(I)*QF*AF)
         ELSE
            AF=0.
         END IF
      ELSE
*****************************************************************************
*                                                                           *
*       Bone surface cells                                                  *
*                                                                           *
*****************************************************************************
         IF (KTARG .EQ. 14)THEN
*****************************************************************************
*                                                                           *
*       Trabeculer bone                                                     *
*                                                                           *
*****************************************************************************
           IF (LOOP .EQ. 1)THEN
*****************************************************************************
*       Positron emitter uniform in volume                                  *
*****************************************************************************
             IF (MOTS(1:4) .EQ. 'P-33' .OR. (MOTS(1:6) .EQ. 'NB-93M') .O
     &R. (MOTS(1:5) .EQ. 'NB-94') .OR. (MOTS(1:5) .EQ. 'U-232') .OR. (MO
     &TS(1:5) .EQ. 'U-233') .OR. (MOTS(1:5) .EQ. 'U-234') .OR. (MOTS(1:5
     &) .EQ. 'U-235') .OR. (MOTS(1:5) .EQ. 'U-236') .OR. (MOTS(1:5) .EQ.
     & 'U-238') .OR. (MOTS(1:2) .EQ. 'NA') .OR. (MOTS(1:2) .EQ. 'CR') .O
     &R. (MOTS(1:2) .EQ. 'RB') .OR. (MOTS(1:5) .EQ. 'ZN-65') .OR. (MOTS(
     &1:6) .EQ. 'PB-205') .OR. (MOTS(1:6) .EQ. 'PB-210') .OR. (MOTS(I:4)
     & .EQ. 'BE-7') .OR. (MOTS(1:5) .EQ. 'BE-10') .OR. (MOTS(1:4) .EQ. '
     &V-49') .OR. (MOTS(1:6) .EQ. 'PD-103') .OR. (MOTS(1:6) .EQ. 'PD-107
     &') .OR. (MOTS(1:6) .EQ. 'SN-113') .OR. (MOTS(1:7) .EQ. 'SN-119M')
     &.OR. (MOTS(1:6) .EQ. 'SN-123') .OR. (MOTS(1:6) .EQ. 'SN-126') .OR.
     & (MOTS(1:6) .EQ. 'TA-182') .OR. (MOTS(1:5) .EQ. 'W-181') .OR. (MOT
     &S(1:5) .EQ. 'W-185') .OR. (MOTS(1:5) .EQ. 'W-188'))THEN
               AF=0.025
*****************************************************************************
*       Alkaline earths                                                     *
*****************************************************************************
             ELSE IF (MOTS(1:2) .EQ. 'SR' .OR. (MOTS(1:2) .EQ. 'CA') .OR
     &. (MOTS(1:2) .EQ. 'RA') .OR. (MOTS(1:2) .EQ. 'BA'))THEN
               IF (PLIFE .GT. 15)THEN
                 AF=0.025
               ELSE
                 IF (EPOST(I) .LT. 0.2)THEN
                    AF=0.25
                 ELSE
                    AF=0.025
                 END IF
               END IF
```

```
            ELSE
*****************************************************************
*       Positron emitter on bone surfaces                       *
*****************************************************************
              IF (EPOST(I) .LT. 0.2)THEN
                AF=0.25
              ELSE
                AF=0.025
              END IF
            END IF
*****************************************************************
*                                                               *
*       Cortical bone                                           *
*                                                               *
*****************************************************************
          ELSE IF (LOOP .GT. 1)THEN
*****************************************************************
*       Positron emitter uniform in volume                      *
*****************************************************************
            IF (MOTS(1:4) .EQ. 'P-33' .OR. (MOTS(1:6) .EQ. 'NB-93M') .O
     &R. (MOTS(1:5) .EQ. 'NB-94') .OR. (MOTS(1:5) .EQ. 'U-232') .OR. (MO
     &TS(1:5) .EQ. 'U-233') .OR. (MOTS(1:5) .EQ. 'U-234') .OR. (MOTS(1:5
     &) .EQ. 'U-235') .OR. (MOTS(1:5) .EQ. 'U-236') .OR. (MOTS(1:5) .EQ.
     & 'U-238') .OR. (MOTS(1:2) .EQ. 'NA') .OR. (MOTS(1:2) .EQ. 'CR') .O
     &R. (MOTS(1:2) .EQ. 'RB') .OR. (MOTS(1:5) .EQ. 'ZN-65') .OR. (MOTS(
     &1:6) .EQ. 'PB-205') .OR. (MOTS(1:6) .EQ. 'PB-210') .OR. (MOTS(1:4)
     & .EQ. 'BE-7') .OR. (MOTS(1:5) .EQ. 'BE-10') .OR. (MOTS(1:4) .EQ. '
     &V-49') .OR. (MOTS(1:6) .EQ. 'PD-103') .OR. (MOTS(1:6) .EQ. 'PD-107
     &') .OR. (MOTS(1:6) .EQ. 'SN-113') .OR. (MOTS(1:7) .EQ. 'SN-119M')
     &.OR. (MOTS(1:6) .EQ. 'SN-123') .OR. (MOTS(1:6) .EQ. 'SN-126') .OR.
     & (MOTS(1:6) .EQ. 'TA-182') .OR. (MOTS(1:5) .EQ. 'W-181') .OR. (MOT
     &S(1:5) .EQ. 'W-185') .OR. (MOTS(1:5) .EQ. 'W-188'))THEN
              AF=0.015
*****************************************************************
*       Alkaline earths                                         *
*****************************************************************
            ELSE IF (MOTS(1:2) .EQ. 'SR' .OR. (MOTS(1:2) .EQ. 'CA') .OR
     &. (MOTS(1:2) .EQ. 'RA') .OR. (MOTS(1:2) .EQ. 'BA'))THEN
              IF (PLIFE .GT. 15)THEN
                AF=0.015
              ELSE
                IF (EPOST(I) .LT. 0.2)THEN
                  AF=0.25
                ELSE
                  AF=0.015
                END IF
              END IF
            ELSE
*****************************************************************
*       Positron emitter on bone surfaces                       *
*****************************************************************
              IF (EPOST(I) .LT. 0.2)THEN
                AF=0.25
              ELSE
```

```
                AF=0.015
              END IF
            END IF
          END IF
          SPEFF=SPEFF+((YPOST(I)*EPOST(I)*QF*AF)/120.)
*****************************************************************************
*                                                                           *
*       Red marrow                                                          *
*                                                                           *
*****************************************************************************
        ELSE
*****************************************************************************
*                                                                           *
*      Trabecular bone                                                      *
*                                                                           *
*****************************************************************************
          IF (LOOP .EQ. 1)THEN
*****************************************************************************
*       Positron emitter uniform in volume                                  *
*****************************************************************************
            IF (MOTS(1:4) .EQ. 'P-33' .OR. (MOTS(1:6) .EQ. 'NB-93M') .O
     &R. (MOTS(1:5) .EQ. 'NB-94') .OR. (MOTS(1:5) .EQ. 'U-232') .OR. (MO
     &TS(1:5) .EQ. 'U-233') .OR. (MOTS(1:5) .EQ. 'U-234') .OR. (MOTS(1:5
     &) .EQ. 'U-235') .OR. (MOTS(1:5) .EQ. 'U-236') .OR. (MOTS(1:5) .EQ.
     & 'U-238') .OR. (MOTS(1:2) .EQ. 'NA') .OR. (MOTS(1:2) .EQ. 'CR') .O
     &R. (MOTS(1:2) .EQ. 'RB') .OR. (MOTS(1:5) .EQ. 'ZN-65') .OR. (MOTS(
     &1:6) .EQ. 'PB-205') .OR. (MOTS(1:6) .EQ. 'PB-210') .OR. (MOTS(1:4)
     & .EQ. 'BE-7') .OR. (MOTS(1:5) .EQ. 'BE-10') .OR. (MOTS(1:4) .EQ. '
     &V-49') .OR. (MOTS(1:6) .EQ. 'PD-103') .OR. (MOTS(1:6) .EQ. 'PD-107
     &') .OR. (MOTS(1:6) .EQ. 'SN-113') .OR. (MOTS(1:7) .EQ. 'SN-119M')
     &.OR. (MOTS(1:6) .EQ. 'SN-123') .OR. (MOTS(1:6) .EQ. 'SN-126') .OR.
     & (MOTS(1:6) .EQ. 'TA-182') .OR. (MOTS(1:5) .EQ. 'W-181') .OR. (MOT
     &S(1:5) .EQ. 'W-185') .OR. (MOTS(1:5) .EQ. 'W-188'))THEN
              AF=0.35
*****************************************************************************
*       Alkaline earths                                                     *
*****************************************************************************
            ELSE IF (MOTS(1:2) .EQ. 'SR' .OR. (MOTS(1:2) .EQ. 'CA') .OR
     &. (MOTS(1:2) .EQ. 'RA') .OR. (MOTS(1:2) .EQ. 'BA'))THEN
              IF (PLIFE .GT. 15)THEN
                AF=0.35
              ELSE
                AF=0.5
              END IF
            ELSE
*****************************************************************************
*       Positron emitter on bone surfaces                                   *
*****************************************************************************
              AF=0.5
            END IF
            SPEFF=SPEFF+((YPOST(I)*EPOST(I)*QF*AF)/1500.)
*****************************************************************************
*                                                                           *
*       Cortical bone                                                       *
```

```
*                                                                      *
************************************************************************
          ELSE IF (LOOP .GT. 1)THEN
            AF=0.0
          END IF
        END IF
      END IF
  170 CONTINUE
************************************************************************
*                                                                      *
*        Electron                                                      *
*                                                                      *
************************************************************************
  175 IF (I5 .EQ. 0)GOTO 182
      DO 180 I=1,I5
      IF (ICOM .EQ. 1)THEN
         IF (JSORCE .EQ. 17)THEN
            AF=1./69900.
            SPEFF=SPEFF+(YELEC(I)*EELEC(I)*QF*AF)
         ELSE
            AF=0.
         END IF
      ELSE
************************************************************************
*                                                                      *
*       Bone surface cells                                             *
*                                                                      *
************************************************************************
        IF (KTARG .EQ. 14)THEN
************************************************************************
*                                                                      *
*       Trabecular bone                                                *
*                                                                      *
************************************************************************
          IF (LOOP .EQ. 1)THEN
************************************************************************
*       Electron emitter uniform in volume                             *
************************************************************************
            IF (MOTS(1:4) .EQ. 'P-33' .OR. (MOTS(1:6) .EQ. 'NB-93M') .O
     &R. (MOTS(1:5) .EQ. 'NB-94') .OR. (MOTS(1:5) .EQ. 'U-232') .OR. (MO
     &TS(1:5) .EQ. 'U-233') .OR. (MOTS(1:5) .EQ. 'U-234') .OR. (MOTS(1:5
     &) .EQ. 'U-235') .OR. (MOTS(1:5) .EQ. 'U-236') .OR. (MOTS(1:5) .EQ.
     & 'U-238') .OR. (MOTS(1:2) .EQ. 'NA') .OR. (MOTS(1:2) .EQ. 'CR') .O
     &R. (MOTS(1:2) .EQ. 'RB') .OR. (MOTS(1:5) .EQ. 'ZN-65') .OR. (MOTS(
     &1:6) .EQ. 'PB-205') .OR. (MOTS(1:6) .EQ. 'PB-210') .OR. (MOTS(1:4)
     & .EQ. 'BE-7') .OR. (MOTS(1:5) .EQ. 'BE-10') .OR. (MOTS(1:4) .EQ. '
     &V-49') .OR. (MOTS(1:6) .EQ. 'PD-103') .OR. (MOTS(1:6) .EQ. 'PD-107
     &') .OR. (MOTS(1:6) .EQ. 'SN-113') .OR. (MOTS(1:7) .EQ. 'SN-119M')
     &.OR. (MOTS(1:6) .EQ. 'SN-123') .OR. (MOTS(1:6) .EQ. 'SN-126') .OR.
     & (MOTS(1:6) .EQ. 'TA-182') .OR. (MOTS(1:5) .EQ. 'W-181') .OR. (MOT
     &S(1:5) .EQ. 'W-185') .OR. (MOTS(1:5) .EQ. 'W-188'))THEN
              AF=0.025
************************************************************************
*       Alkaline earths                                                *
```

```
*****************************************************************************
          ELSE IF (MOTS(1:2) .EQ. 'SR' .OR. (MOTS(1:2) .EQ. 'CA') .OR
     &. (MOTS(1:2) .EQ. 'RA') .OR. (MOTS(1:2) .EQ. 'BA'))TNEN
              IF (PLIFE .GT. 15)TNEN
                AF=0.025
              ELSE
                IF (EELEC(I) .LT. 0.2)TNEN
                  AF=0.25
                ELSE
                  AF=0.025
                END IF
              END IF
            ELSE
*****************************************************************************
*       Electron emitter on bone surfaces                                   *
*****************************************************************************
              IF (EELEC(I) .LT. 0.2)TNEN
                AF=0.25
              ELSE
                AF=0.025
              END IF
            END IF
*****************************************************************************
*                                                                           *
*       Cortical bone                                                       *
*                                                                           *
*****************************************************************************
          ELSE IF (LOOP .GT. 1)TNEN
*****************************************************************************
*       Electron emitter uniform in volume                                  *
*****************************************************************************
            IF (MOTS(1:4) .EQ. 'P-33' .OR. (MOTS(1:6) .EQ. 'NB-93M') .O
     &R. (MOTS(1:5) .EQ. 'NB-94') .OR. (MOTS(1:5) .EQ. 'U-232') .OR. (MO
     &TS(1:5) .EQ. 'U-233') .OR. (MOTS(1:5) .EQ. 'U-234') .OR. (MOTS(1:5
     &) .EQ. 'U-235') .OR. (MOTS(1:5) .EQ. 'U-236') .OR. (MOTS(1:5) .EQ.
     & 'U-238') .OR. (MOTS(1:2) .EQ. 'NA') .OR. (MOTS(1:2) .EQ. 'CR') .O
     &R. (MOTS(1:2) .EQ. 'RB') .OR. (MOTS(1:5) .EQ. 'ZN-65') .OR. (MOTS(
     &1:6) .EQ. 'PB-205') .OR. (MOTS(1:6) .EQ. 'PB-210') .OR. (MOTS(1:4)
     & .EQ. 'BE-7') .OR. (MOTS(1:5) .EQ. 'BE-10') .OR. (MOTS(1:4) .EQ. '
     &V-49') .OR. (MOTS(1:6) .EQ. 'PD-103') .OR. (MOTS(1:6) .EQ. 'PD-107
     &') .OR. (MOTS(1:6) .EQ. 'SN-113') .OR. (MOTS(1:7) .EQ. 'SN-119M')
     &.OR. (MOTS(1:6) .EQ. 'SN-123') .OR. (MOTS(1:6) .EQ. 'SN-126') .OR.
     & (MOTS(1:6) .EQ. 'TA-182') .OR. (MOTS(1:5) .EQ. 'W-181') .OR. (MOT
     &S(1:5) .EQ. 'W-185') .OR. (MOTS(1:5) .EQ. 'W-188'))TNEN
              AF=0.015
*****************************************************************************
*       Alkaline earths                                                     *
*****************************************************************************
          ELSE IF (MOTS(1:2) .EQ. 'SR' .OR. (MOTS(1:2) .EQ. 'CA') .OR
     &. (MOTS(1:2) .EQ. 'RA') .OR. (MOTS(1:2) .EQ. 'BA'))TNEN
              IF (PLIFE .GT. 15)TNEN
                AF=0.015
              ELSE
                IF (EELEC(I) .LT. 0.2)TNEN
```

```
                AF=0.25
              ELSE
                AF=0.015
              END IF
            END IF
          ELSE
*****************************************************************
*       Electron emitter on bone surfaces                       *
*****************************************************************
            IF (EELEC(I) .LT. 0.2)THEN
              AF=0.25
            ELSE
              AF=0.015
            END IF
          END IF
        END IF
        SPEFF=SPEFF+((YELEC(I)*EELEC(I)*QF*AF)/120.)
*****************************************************************
*                                                               *
*       Red marrow                                              *
*                                                               *
*****************************************************************
       ELSE
*****************************************************************
*                                                               *
*       Trabecular bone                                         *
*                                                               *
*****************************************************************
         IF (LOOP .EQ. 1)THEN
*****************************************************************
*       Electron emitter uniform in volume                      *
*****************************************************************
           IF (MOTS(1:4) .EQ. 'P-33' .OR. (MOTS(1:6) .EQ. 'NB-93M') .O
     &R. (MOTS(1:5) .EQ. 'NB-94') .OR. (MOTS(1:5) .EQ. 'U-232') .OR. (MO
     &TS(1:5) .EQ. 'U-233') .OR. (MOTS(1:5) .EQ. 'U-234') .OR. (MOTS(1:5
     &) .EQ. 'U-235') .OR. (MOTS(1:5) .EQ. 'U-236') .OR. (MOTS(1:5) .EQ.
     & 'U-238') .OR. (MOTS(1:2) .EQ. 'NA') .OR. (MOTS(1:2) .EQ. 'CR') .O
     &R. (MOTS(1:2) .EQ. 'RB') .OR. (MOTS(1:5) .EQ. 'ZN-65') .OR. (MOTS(
     &1:6) .EQ. 'PB-205') .OR. (MOTS(1:6) .EQ. 'PB-210') .OR. (MOTS(1:4)
     & .EQ. 'BE-7') .OR. (MOTS(1:5) .EQ. 'BE-10') .OR. (MOTS(1:4) .EQ. '
     &V-49') .OR. (MOTS(1:6) .EQ. 'PD-103') .OR. (MOTS(1:6) .EQ. 'PD-107
     &') .OR. (MOTS(1:6) .EQ. 'SN-113') .OR. (MOTS(1:7) .EQ. 'SN-119M')
     &.OR. (MOTS(1:6) .EQ. 'SN-123') .OR. (MOTS(1:6) .EQ. 'SN-126') .OR.
     & (MOTS(1:6) .EQ. 'TA-182') .OR. (MOTS(1:5) .EQ. 'W-181') .OR. (MOT
     &S(1:5) .EQ. 'W-185') .OR. (MOTS(1:5) .EQ. 'W-188'))THEN
             AF=0.35
*****************************************************************
*       Alkaline earths                                         *
*****************************************************************
           ELSE IF (MOTS(1:2) .EQ. 'SR' .OR. (MOTS(1:2) .EQ. 'CA') .OR
     &. (MOTS(1:2) .EQ. 'RA') .OR. (MOTS(1:2) .EQ. 'BA'))THEN
             IF (PLIFE .GT. 15)THEN
               AF=0.35
             ELSE
```

```
                AF=0.5
              END IF
            ELSE
*****************************************************************
*       Electron emitter on bone surfaces                       *
*****************************************************************
              AF=0.5
            END IF
            SPEFF=SPEFF+((YELEC(I)*EELEC(I)*QF*AF)/1500.)
*****************************************************************
*                                                               *
*       Cortical bone                                           *
*                                                               *
*****************************************************************
          ELSE IF (LOOP .GT. 1)THEN
            AF=0.0
          END IF
        END IF
      END IF
  180 CONTINUE
  182 IF (LOOP .EQ. 0)GOTO 185
      GOTO 195
*****************************************************************
*                                                               *
*                         Photon                                *
*                                                               *
*****************************************************************
  185 IF (I7 .EQ. 0)GOTO 195
      QF=1
      DO 190 I=1,I7
      AF=0.
      IF (EGAMMA(I) .LT. 0.01)THEN
         IF (ICON .EQ. 1)THEN
            IF (JSORCE .EQ. 17)THEN
               AF=1.0/69900.
               SPEFF=SPEFF+(YGAMMA(I)*EGAMMA(I)*QF*AF)
            ELSE
               AF=0.
            END IF
         ELSE
            AF=1.0/TMASS
            SPEFF=SPEFF+(YGAMMA(I)*EGAMMA(I)*QF*AF)
         END IF
      ELSE
      ICHECK=0
      AF=INTRPT(EGAMMA(I),JSORCE,KTARG,ICHECK)
      IF (ICHECK .EQ. 1)THEN
         WORD(1:5)='SORRY'
         RETURN
      END IF
      SPEFF=SPEFF+((YGAMMA(I)*EGAMMA(I)*QF*AF)/TMASS)
      END IF
  190 CONTINUE
  195 SAVE=WORD
```

```
      RETURN
      END
```

SUBMER.FOR

10-15-1987

```
*************************************************************************
*                                                                       *
*       SUBROUTINE NAME : SUBMER FORTRAN                                *
*       PURPOSE: Call date files "LIST" and "NOBLE" for dose            *
*                equivalent rate in target organs from submersion       *
*                in a semi-infinite cloud of noble gases or             *
*                elemental tritium                                      *
*                                                                       *
*                DESCRIPTION OF VARIABLES                               *
*                ------------------------                               *
*       WORD ---> Name of the given isotope                             *
*       NRATE --> Dose equivalent rate in target organs or tissues      *
*                 from submersion in unit concentration of the          *
*                 isotope                                               *
*       DER ----> Derived Air Concentration                             *
*       RISK ---> DAC determined by the non-stochastic limit            *
*       ORGAN --> Tissue or organ of non-stochastic limit               *
*                                                                       *
*************************************************************************
      SUBROUTINE SUBMER (WORD,NRATE,DER,RISK,ORGAN,*)
      DIMENSION NRATE(1:24),JSORCE(1:13),VALUE(1:13)
      CHARACTER*8 ERT,WORD
      OPEN(UNIT=10,FILE='LIST',FORM='FORMATTED',ACCESS='DIRECT',RECL=10)
      OPEN(UNIT=11,FILE='NOBLE',FORM='FORMATTED',ACCESS='DIRECT',RECL=16
     &1)
      DO 2 I=1,24
      NRATE(I)=0.
    2 CONTINUE
      IF (WORD(1:3) .EQ. 'H-3')THEN
          NRATE(1)=9.9E-15
          DER=2.0E10
          RISK=0.0E+00
          ORGAN=0
          RETURN
      END IF
      ITREK=0
      DO 5 LIS=1,26
      READ(10,6,REC=LIS,ERR=20)ERT,ICONT
    6 FORMAT(A8,I2)
      IF (WORD .EQ. ERT)THEN
         ITREK=ICONT
         GOTO 7
      END IF
    5 CONTINUE
      IF (ITREK .EQ. 0)GOTO 20
    7 READ(11,9,REC=ITREK,ERR=25)DER,RISK,ORGAN,(JSORCE(I),VALUE(I),I=1,
     &13)
    9 FORMAT(1PE8.1,1PE8.1,I3,I2,1PE8.1,I3,1PE8.1,I3,1PE8.1,I3,1PE8.1,I3
     &,1PE8.1,I3,1PE8.1,I3,1PE8.1,I3,1PE8.1,I3,1PE8.1,I3,1PE8.1,I3,1PE8.
     &1,I3,1PE8.1,I3,1PE8.1)
      DO 10 I=1,13
      IF (JSORCE(I) .EQ. 0)GOTO 10
      NRATE(JSORCE(I))=VALUE(I)
   10 CONTINUE
```

```
      RETURN
   20 WRITE(*,21)
   21 FORMAT(//,' Error: Nuclide not found in the ICRP Publication 30',/
     &,' SOURCE: SUBMER FORTRAN',/,' CORRECTIVE ACTION: Try another nucl
     &ide!',////)
      RETURN 1
   25 WRITE(*,26)
   26 FORMAT(//,' ERROR: Unable to read dose equivelent rates from date
     &file "NOBLE"!',/,' SOURCE: SUBMER FORTRAN',/,' CORRECTIVE ACTION:
     &Check the file and try again!',///)
      RETURN 1
      END
```

TFRAC.FOR

11-02-1987

```
************************************************************************
*                                                                      *
*       SUBROUTINE NAME: TFRAC FORTRAN                                 *
*       PURPOSE: Ratriava tha ratention fractions, F2 and the          *
*                biological half-livea, BHALF of tha nuclide           *
*                in sourca organs                                      *
*       DATA FILE REQUIREO:  a) RETENT FILE                            *
*       AUXILIARY SUBROUTINES REQUIRED:                                *
*                a) I1 FORTRAN                                         *
*                b) SOURCE FORTRAN                                     *
*                                                                      *
************************************************************************
      SUBROUTINE TFRAC(KZ,F2,BHALF,JSORCE,SMASS,*)
      DIMENSION F2(1:3),BHALF(1:3)
      CHARACTER*20 C2
      OPEN (UNIT=15,FILE='RETENT',ACCESS='OIRECT',FORM='FORMATTEO',RECL=
     &66,STATUS='OLD')
       IF (KZ .GT. 92)THEN
          KZ=89
       END IF
       ISAVE=(5*(KZ-1))
       SUM=0.
       DO 1 I=1,5
       KEY=ISAVE+I
       READ(UNIT=15,FMT='(A20,F7.4,F7.4,F7.4,F9.2,F8.1,F8.1)',ERR=10,REC=
     &KEY)C2,D,E,F,G,H,B
************************************************************************
*                                                                      *
*       Function subprogram I1 converts C2, the aource organ in        *
*       alphameric charactara to an integar from aource list to        *
*       compara with JSORCE                                            *
*                                                                      *
************************************************************************
      IF (I .EQ. 1)THEN
        IF (D .EQ. 0. .AND. (G .EQ. 0.))GOTO 10
      END IF
      IF (D .EQ. 0. .AND. (G .EQ. 0.))GOTO 5
      ICOMP=I1(C2)
      IF (ICOMP .EQ. JSORCE)THEN
      F2(1)=D
      F2(2)=E
      F2(3)=F
      BHALF(1)=G
      BHALF(2)=H
      BHALF(3)=B
************************************************************************
*                                                                      *
*       Function subprogram SOURCE gives the maaa of tha sourca        *
*       organ, when ICOMP is given aa input                            *
*                                                                      *
************************************************************************
      SMASS=SOURCE(ICOMP)
      GOTO 5
      END IF
```

TFRAC.FOR

11-02-1987

```
*************************************************************************
*                                                                       *
*       When source organ is 'Total body' and several organs of         *
*       mass Mi are associated with different retention fractions,      *
*       then the masses of all these organs are first summed, i.e.      *
*       (sum of Mi) and then 'Total body' is aseigned a mass of         *
*       70000-(sum of Mi) and retention fractions which are             *
*       ssociated with 'all other'. The records are entered in          *
*       in such a way that for a given KZ, entry of 'all other' is      *
*       always at the and after all organs, i                           *
*                                                                       *
*************************************************************************
     IF (JSORCE .EQ. 17)THEN
        IF (ICOMP .NE. 18)THEN
          SUM=SUM+SOURCE(ICOMP)
        ELSE
          SMASS=70000.-SUM
          F2(1)=D
          F2(2)=E
          F2(3)=F
          BHALF(1)=G
          BHALF(2)=H
          BMALF(3)=B
        END IF
     END IF
   1 CONTINUE
   5 RETURN
  10 CALL CLEAR
     WRITE (*,15)
  15 FORMAT(//,' ERROR: Unable to read retention fractions, and biologi
    &cal half-lives in source  organ, from file "RETENT"',/,' SOURCE: T
    &FRAC FORTRAN',/,' CORRECTIVE ACTION: Try another nuclide!!',/////)
     PAUSE '  TO RESUME PRESS <RETURN>!!'
     RETURN 1
     END
```

THALF.FOR

11-02-1987

```
************************************************************************
*                                                                      *
*       FUNCTION SUBPROGRAM NAME: THALF FORTRAN                        *
*       PURPOSE: Provide half-life of clearance from body fluid        *
*                compartment given an atomic number of a nuclide       *
*                                                                      *
************************************************************************
      FUNCTION THALF(KZ)
      IF (KZ .EQ. 9 .OR. (KZ .EQ. 19) .OR. (KZ .EQ. 79) .OR. (KZ .EQ. 81
     &))THEN
      THALF=0.
      ELSE IF(KZ .EQ. 15 .OR. (KZ .EQ. 24) .OR. (KZ .EQ. 27) .OR. (KZ .E
     &Q. 90))THEN
      THALF=0.5
      ELSE IF (KZ .EQ. 43 .OR. KZ .EQ. 75)THEN
      THALF=0.02
      ELSE IF (KZ .EQ. 44 .OR. KZ .EQ. 45)THEN
      THALF=0.3
      ELSE IF (KZ .EQ. 52)THEN
      THALF=0.8
      ELSE IF (KZ .EQ. 83)THEN
      THALF=0.01
      ELSE
      THALF=0.25
      END IF
      RETURN
      END
```

TRNSFM.FOR

11-02-1987

```
C*********************************************************************
C*                                                                   *
C*        SUBROUTINE NAME : TRNSFM FORTRAN                           *
C*        PURPOSE: Calculates source-organ transformations, US       *
C*                                                                   *
C*                  DESCRIPTION OF VARIABLES                         *
C*                  ------------------------                         *
C*     UTJ(I)-----> Source-organ transformations of the isotope      *
C*                  under consideration,j in the body fluid          *
C*                  (transfer) compartment.                          *
C*     UROB(I)----> The total number of transformations of           *
C*                  radionuclide,i in 'rest of the body' of          *
C*                  mass, 70000-(sum of Mj) where Mj is the          *
C*                  mass of organ j for each unique retention        *
C*                  fraction.                                        *
C* US(JSORCE,I)---> Source-organ transformations of nuclide,i        *
C*       UJ------> Transformations in each compartment of the        *
C*                  source organ.                                    *
C*                                                                   *
C*********************************************************************
      SUBROUTINE TRNSFM (FT,F2,BHALF,RCONST,NO,BRA,US,TCONST,JSORCE,F1,I
     &PROG,FGI,SMASS,UROB,MROB,KZ)
      DIMENSION F2(1:3),BHALF(1:3),BCONST(1:3),RCONST(1:NO),BRA(1:NO),AS
     &T(1:50),ASI(1:50),AULI(1:50),ALLI(1:50),US(1:20,1:NO),FT(1:NO),UTJ
     &(1:50),FGI(1:NO),TEMP(1:3,1:50),UROB(1:NO)
      REAL MROB
C*********************************************************************
C*                                                                   *
C*       Calculating the biological constants,BCONST from the        *
C*       biological half-lives in different compartments of the      *
C*       source organ                                                *
C*                                                                   *
C*********************************************************************
      DO 10 I=1,3
      IF (BHALF(I) .EQ. 0. .OR. BHALF(I) .EQ. 99999.9)THEN
         BCONST(I)=0.
      ELSE
         BCONST(I)=(LOG(2.))/BHALF(I)
      END IF
   10 CONTINUE
C*********************************************************************
C*                                                                   *
C*     There are separate methods of calculating source-organ        *
C*     transformations for stomach, SI, LLI, ULI depending on the    *
C*     mode of intake                                                *
C*                                                                   *
C*********************************************************************
      IF (IPROG .EQ. 1)THEN
         IF (JSORCE .EQ. 2)GOTO 140
         IF (JSORCE .EQ. 3)GOTO 150
         IF (JSORCE .EQ. 4)GOTO 160
         IF (JSORCE .EQ. 5)GOTO 170
      ELSE IF (IPROG .EQ. 0)THEN
         IF (JSORCE .EQ. 2)GOTO 100
```

```
        IF (JSORCE .EQ. 3)GOTO 110
        IF (JSORCE .EQ. 4)GOTO 120
        IF (JSORCE .EQ. 5)GOTO 130
      END IF
*****************************************************************************
*     Special treatment for iodine                                          *
*****************************************************************************
      IF (KZ .EQ. 53)GOTO 300
*****************************************************************************
*                                                                           *
*     Outer most loop for calculation of US of nuclide species,J            *
*                                                                           *
*****************************************************************************
      DO 15 J=1,NO
*****************************************************************************
*                                                                           *
*     In caea of instanteneous transfer to tiesue compartment,              *
*     calculation of UTJ(I) in transfar compartment is akipped              *
*                                                                           *
*****************************************************************************
      IF (TCONST .EQ. 0.)THEN
         DO 16 I=1,NO
         UTJ(I)=0.
   16    CONTINUE
         GOTO 70
      END IF
*****************************************************************************
*                                                                           *
*                        TRANSFER COMPARTMENT                               *
*                                                                           *
*     Loop for outer sum term,SUM in the calculation of UTJ(J)              *
*                                                                           *
*****************************************************************************
      SUM=0.
      DO 20 I=1,J
*****************************************************************************
*                                                                           *
*     Loop for outer product tarm,PROD of RCONST in the equation            *
*     for celculetion of UTJ(J)                                             *
*                                                                           *
*****************************************************************************
      PROD=1.
*****************************************************************************
*                           Perent caea                                     *
*****************************************************************************
      IF (I+1 .GT. J)GOTO 30
*****************************************************************************
*                          Daughtars' caea                                  *
*****************************************************************************
      DO 25 K=I+1,J
      PROD=FLOW(RCONST(K)*PROD)
   25 CONTINUE
   30 SUM1=0.
*****************************************************************************
```

```
*                                                                      *
*     Loop for inner sum term,SUM1 in the equation for                 *
*     calculation of UTJ(J)                                            *
*                                                                      *
************************************************************************
      DO 35 M=I,J
      PROD1=1.
************************************************************************
*                                                                      *
*     Loop for inner product term,PROD1 in the denominator in          *
*     equation for calculation of UTJ                                  *
*                                                                      *
************************************************************************
      DO 40 K=I,J
      IF (K .EQ. M)GOTO 40
      PROD1=FLOW(PROD1*(RCONST(K)-RCONST(M)))
   40 CONTINUE
      SUM1=SUM1+((1-UXP(-(TCONST+RCONST(M))*365.25*50.))/FLOW((TCONST+RC
     &ONST(M))*PROD1))     .
   35 CONTINUE
      SUM=SUM+(PROD*FT(I)*SUM1/BRA(I))
   20 CONTINUE
      UTJ(J)=SUM*BRA(J)
   70 UJ=0.
************************************************************************
*                                                                      *
*     Loop for calculation of total source-organ transformations       *
*     from contribution of diffarent compartments of each source       *
*                                                                      *
************************************************************************
      DO 65 L=1,3
      IF (F2(L) .EQ. 0.)GOTO 65
      SUM2=0.
************************************************************************
*                                                                      *
*                          TISSUE COMPARTMENT                          *
*                                                                      *
*     Loop for outer sum term,SUM2 in calculation of source-organ      *
*     transformations,UJ in each compartment of the source organ       *
*                                                                      *
************************************************************************
      DO 75 I=1,J
************************************************************************
*                                                                      *
*     Loop for outer product term,PROD2 in the equation for            *
*     calculation of UJ                                                *
*                                                                      *
************************************************************************
      PROD2=1.
************************************************************************
*                            Parent case                               *
************************************************************************
      IF (I+1 .GT. J)GOTO 85
************************************************************************
```

```
*                        Daughters' case                                *
*************************************************************************
      DO 80 K=I+1,J
      PROD2=FLOW(RCONST(K)*PROD2)
   80 CONTINUE
   85 SUM3=0.
*************************************************************************
*     Loop for inner sum term,SUM3 in the equation                      *
*************************************************************************
      DO 90 M=I,J
      PROD3=1.
*************************************************************************
*     Loop for inner product term,PROD3 in the equation                 *
*************************************************************************
      DO 95 K=I,J
      IF (K .EQ. M)GOTO 95
      PROD3=FLOW(PROD3*(RCONST(K)-RCONST(M)))
   95 CONTINUE
      SUM3=SUM3+((1-UXP(-(BCONST(L)+RCONST(M))*365.25*50))/FLOW((BCONST(
     &L)+RCONST(M))*PROD3))
   90 CONTINUE
*************************************************************************
*     Initial activity,ACTJ of species,j in source organ.               *
*************************************************************************
      IF (TCONST .EQ. 0.)THEN
*************************************************************************
*     Instantaneous transfer from body fluid compartment                *
*************************************************************************
      ACTJ=F2(L)*FT(I)/BRA(I)
      ELSE
      ACTJ=FLOW(F2(L)*TCONST*UTJ(I)/BRA(I))
      END IF
      SUM2=SUM2+FLOW(PROD2*ACTJ*SUM3)
   75 CONTINUE
      UJ=UJ+(BRA(J)*SUM2)
   65 CONTINUE
      US(JSORCE,J)=(SMASS*UTJ(J)/70000.)+UJ
      IF (JSORCE .EQ. 17)THEN
*************************************************************************
*                                                                       *
*     Redistribute transformations uniformly through out all            *
*     organs and tissues of the body                                    *
*                                                                       *
*************************************************************************
        UROB(J)=US(JSORCE,J)
        MROB=SMASS
*************************************************************************
*     Source-organ transformations with source as 'total body'          *
*************************************************************************
        US(JSORCE,J)=US(JSORCE,J)*70000./SMASS
      ELSE
        IF (UROB(J) .EQ. 0.)GOTO 15
*************************************************************************
*     Reduce US(JSORCE,J) to compensate for redistribution of UROB(J)   *
```

```
*************************************************************************
        US(JSORCE,J)=US(JSORCE,J)-(SMASS*UROB(J)/MROB)
      END IF
   15 CONTINUE
      GOTO 180
*************************************************************************
*                  STOMACH  in case of INGESTION                        *
*************************************************************************
  100 DO 105 J=1,NO
*************************************************************************
*                           Parent case                                 *
*************************************************************************
      IF (J .EQ. 1)THEN
      US(JSORCE,1)=BRA(1)/FLOW(24.+RCONST(1))
      ELSE
*************************************************************************
*                         Daughters' case                               *
*************************************************************************
      US(JSORCE,J)=((US(JSORCE,J-1)/BRA(J-1))*RCONST(J)/FLOW(24.+RCONST(
     &J)))*BRA(J)
      END IF
  105 CONTINUE
      GOTO 180
*************************************************************************
*                                                                       *
*              SMALL INTESTINE in case of INGESTION                     *
*                                                                       *
*     If F1=1, it is assumed that the radionuclide passes directly      *
*     from the stomach to body fluids and does not pass through         *
*     other sections of the GI tract                                    *
*                                                                       *
*************************************************************************
  110 IF (F1 .EQ. 1.)GOTO 180
      BFCNST=F1*6./(1.-F1)
      DO 115 J=1,NO
*************************************************************************
*                           Parent case                                 *
*************************************************************************
      IF (J .EQ. 1)THEN
      US(JSORCE,1)=BRA(1)*24./FLOW((24.+RCONST(1))*(6.+BFCNST+RCONST(1))
     &)
      AST(1)=1./FLOW(24.+RCONST(1))
      ELSE
*************************************************************************
*                         Daughters' case                               *
*************************************************************************
      AST(J)=AST(J-1)*RCONST(J)/FLOW(24.+RCONST(J))
      R1=AST(J-1)*RCONST(J)*24./FLOW((24.+RCONST(J))*(6.+BFCNST+RCONST(J
     &)))
      R2=(US(JSORCE,J-1)/BRA(J-1))*RCONST(J)/FLOW(6.+BFCNST+RCONST(J))
      US(JSORCE,J)=BRA(J)*FLOW(R1+R2)
      END IF
  115 CONTINUE
      GOTO 180
```

```
*************************************************************************
*           UPPER LARGE INTESTINE in case of INGESTION                  *
*************************************************************************
  120 IF (F1 .EQ. 1.)GOTO 180
      BFCNST=F1*6./(1.-F1)
      DO 125 J=1,ND
*************************************************************************
*                          Parent case                                  *
*************************************************************************
      IF (J .EQ. 1)THEN
      US(JSORCE,1)=BRA(J)*24.*6./FLOW((24.+RCONST(1))*(6.+BFCNST+RCONST(
     &1))*(1.8+RCONST(1)))
       AST(1)=1./FLOW(24.+RCONST(1))
       ASI(1)=24./FLOW((24.+RCONST(1))*(6.+BFCNST+RCONST(1)))
       ELSE
*************************************************************************
*                         Daughtara' case                               *
*************************************************************************
       AST(J)=AST(J-1)*RCONST(J)/FLOW(24.+RCONST(J))
       R1=AST(J-1)*RCONST(J)*24./FLOW((24.+RCONST(J))*(6.+BFCNST+RCONST(J
      &)))
       R2=ASI(J-1)*RCONST(J)/FLOW(6.+BFCNST+RCONST(J))
       ASI(J)=FLOW(R1+R2)
       R3=AST(J-1)*24.*6.*RCONST(J)/FLOW((24.+RCONST(J))*(6.+BFCNST+RCONS
      &T(J))*(1.8+RCONST(J)))
       R4=ASI(J-1)*RCONST(J)*6./FLOW((6.+BFCNST+RCONST(J))*(1.8+RCONST(J)
      &))
       R5=(US(JSORCE,J-1)/BRA(J-1))*RCONST(J)/FLOW(1.8+RCONST(J))
       US(JSORCE,J)=FLOW(R3+R4+R5)*BRA(J)
       END IF
  125 CONTINUE
      GOTO 180
*************************************************************************
*           LOWER LARGE INTESTINE in case of INGESTION                  *
*************************************************************************
  130 IF (F1 .EQ. 1.)GOTO 180
      BFCNST=F1*6./(1.-F1)
      DO 135 J=1,ND
      R1=FLOW(24.+RCONST(J))
      R2=FLOW(6.+BFCNST+RCONST(J))
      R3=FLOW(1.8+RCONST(J))
      R4=FLOW(1.+RCONST(J))
*************************************************************************
*                          Parent case                                  *
*************************************************************************
      IF (J .EQ. 1)THEN
      US(JSORCE,1)=BRA(1)*24.*6.*1.8/FLOW(R1*R2*R3*R4)
      AST(1)=1./R1
      ASI(1)=24./FLOW(R1*R2)
      AULI(1)=24.*6./FLOW(R1*R2*R3)
      ELSE
*************************************************************************
*                         Daughtera' case                               *
*************************************************************************
```

```
      AST(J)=AST(J-1)*RCONST(J)/R1
      ASI(J)=FLOW((AST(J-1)*RCONST(J)*24./(R1*R2))+(ASI(J-1)*RCONST(J)/R
     &2))
      AULI(J)=FLOW((AST(J-1)*RCONST(J)*24.*6./(R1*R2*R3))+(ASI(J-1)*RCON
     &ST(J)*6./(R2*R3))+(AULI(J-1)*RCONST(J)/(R3)))
      US(JSORCE,J)=BRA(J)*FLOW((AST(J-1)*RCONST(J)*24.*6.*1.8/(R1*R2*R3*
     &R4))+(ASI(J-1)*RCONST(J)*6.*1.8/(R2*R3*R4))+(AULI(J-1)*RCONST(J)*1
     &.8/(R3*R4))+((US(JSORCE,J-1)/BRA(J-1))*RCONST(J)/R4))
      END IF
  135 CONTINUE
      GOTO 180
*************************************************************************
*              STOMACH in cases of INHALATION                           *
*************************************************************************
  140 DO 142 J=1,NO
*************************************************************************
*                          Parent case                                  *
*************************************************************************
      IF (J .EQ. 1)THEN
      US(JSORCE,1)=BRA(1)*FGI(1)/FLOW(24.*RCONST(1))
*************************************************************************
*                       Daughters' case                                 *
*************************************************************************
      ELSE
*************************************************************************
*     Loop for outer sum term,SUM4                                      *
*************************************************************************
      SUM4=0.
      DO 143 I=1,J
*************************************************************************
*     Loop for outer product term,PROD4                                 *
*************************************************************************
      PROD4=1.
      IF (I+1 .GT. J)GOTO 144
      DO 145 K=I+1,J
      PROD4=FLOW(RCONST(K)*PROD4)
  145 CONTINUE
  144 SUM5=0.
*************************************************************************
*     Loop for inner sum term,SUM5                                      *
*************************************************************************
      DO 146 M=I,J
      PROD5=1.
*************************************************************************
*     Loop for inner product term,PROD5                                 *
*************************************************************************
      DO 147 K=I,J
      IF (K .EQ. M)GOTO 147
      PROD5=FLOW(PROD5*(RCONST(K)-RCONST(M)))
  147 CONTINUE
      SUM5=SUM5+((1-UXP(-(24.*RCONST(M))*365.25*50.))/FLOW((24.*RCONST(M
     &))*PROD5))
  146 CONTINUE
      SUM4=SUM4+FLOW(PROD4*FGI(I)*SUM5/BRA(I))
```

```
  143 CONTINUE
      US(JSORCE,J)=SUM4*BRA(J)
      END IF
  142 CONTINUE
      GOTO 180
*****************************************************************
*              SMALL INTESTINE in case of INHALATION            *
*****************************************************************
  150 IF (F1 .EQ. 1.)GOTO 180
      BFCNST=F1*6./(1.-F1)
      DO 152 J=1,NO
*****************************************************************
*                          Parent case                          *
*****************************************************************
      IF (J .EQ. 1)THEN
      US(JSORCE,1)=BRA(1)*FGI(1)*24./FLOW((24.+RCONST(1))*(6.+BFCNST+RCO
     &NST(1)))
      INN=1
      DO 2 NUC=1,NO
      IF (NUC .EQ. 1)THEN
         TEMP(INN,NUC)=BRA(1)*FGI(1)/FLOW(24.+RCONST(1))
      ELSE
*
      SUM4=0.
      DO 3 I=1,NUC
*****************************************************************
*     Loop for outer product term,PROD4                         *
*****************************************************************
      PROD4=1.
      IF (I+1 .GT. NUC)GOTO 4
      DO 5 K=I+1,NUC
      PROD4=FLOW(RCONST(K)*PROD4)
    5 CONTINUE
    4 SUM5=0.
*****************************************************************
*     Loop for inner sum term,SUM5                              *
*****************************************************************
      DO 6 N=I,NUC
      PROD5=1.
*****************************************************************
*     Loop for inner product term,PROD5                         *
*****************************************************************
      DO 7 K=I,NUC
      IF (K .EQ. N)GOTO 7
      PROD5=FLOW(PROD5*(RCONST(K)-RCONST(N)))
    7 CONTINUE
      SUM5=SUM5+((1.-UXP(-(24.0+RCONST(N))*365.25*50.))/FLOW((24.+RCONST
     &(N))*PROD5))
*
    6 CONTINUE
         SUM4=SUM4+FLOW(PROD4*FGI(I)*SUM5/BRA(I))
    3 CONTINUE
      TEMP(INN,NUC)=SUM4*BRA(NUC)
      END IF
```

```
    2 CONTINUE
*****************************************************************************
*                          Daughters' case                                  *
*****************************************************************************
      ELSE
*****************************************************************************
*     Loop for outer sum term,SUM4                                          *
*****************************************************************************
      SUM4=0.
      DO 153 I=1,J
*****************************************************************************
*     Loop for outer product term,PROD4                                     *
*****************************************************************************
      PROD4=1.
      IF (I+1 .GT. J)GOTO 154
      DO 155 K=I+1,J
      PROD4=FLOW(RCONST(K)*PROD4)
  155 CONTINUE
  154 SUM5=0.
*****************************************************************************
*     Loop for inner sum term,SUM5                                          *
*****************************************************************************
      DO 156 M=I,J
      PROD5=1.
*****************************************************************************
*     Loop for inner product term,PROD5                                     *
*****************************************************************************
      DO 157 K=I,J
      IF (K .EQ. M)GOTO 157
      PROD5=FLOW(PROD5*(RCONST(K)-RCONST(M)))
  157 CONTINUE
      SUM5=SUM5+((1.-UXP(-(6.+BFCNST+RCONST(M))*365.25*50.))/FLOW((6.+BF
     &CNST+RCONST(M))*PROD5))
  156 CONTINUE
      SUM4=SUM4+FLOW(PROD4*24.*TEMP(1,I)*SUM5/BRA(I))
  153 CONTINUE
      US(JSORCE,J)=SUM4*BRA(J)
      END IF
  152 CONTINUE
      GOTO 180
*****************************************************************************
*           UPPER LARGE INTESTINE in case of INHALATION                     *
*****************************************************************************
  160 IF (F1 .EQ. 1.)GOTO 180
      BFCNST=F1*6./(1.-F1)
      DO 162 J=1,NO
*****************************************************************************
*                          Perent case                                      *
*****************************************************************************
      IF (J .EQ. 1)THEN
      US(JSORCE,1)=BRA(J)*FGI(J)*24.*6./FLOW((24.+RCONST(1))*(6.+BFCNST+
     &RCONST(1))*(1.8+RCONST(1)))
      DO 102 INH=1,2
      DO 102 NUC=1,NO
```

```
      IF (INN .EQ. 1 .AND. (NUC .EQ. 1))THEN
         TEMP(INN,NUC)=BRA(1)*FGI(1)/FLOW(24.+RCONST(1))
      ELSE IF (INN .EQ. 2 .AND. (NUC .EQ. 1))THEN
         TEMP(INN,NUC)=BRA(1)*FGI(1)*24./FLOW((24.+RCONST(1))*(6.+BFCNST
     &+RCONST(1)))
      ELSE
*
      SUM4=0.
      DO 103 I=1,NUC
*************************************************************************
*     Loop for outer product term,PROD4                                 *
*************************************************************************
      PROD4=1.
      IF (I+1 .GT. NUC)GOTO 104
      DO 108 K=I+1,NUC
      PROD4=FLOW(RCONST(K)*PROD4)
  108 CONTINUE
  104 SUM5=0.
*************************************************************************
*     Loop for inner sum term,SUM5                                      *
*************************************************************************
      DO 106 M=I,NUC
      PROD5=1.
*************************************************************************
*     Loop for inner product term,PROD5                                 *
*************************************************************************
      DO 107 K=I,NUC
      IF (K .EQ. M)GOTO 107
      PROD5=FLOW(PROD5*(RCONST(K)-RCONST(M)))
  107 CONTINUE
      IF (INN .EQ. 1)THEN
         SUM5=SUM5+((1.-UXP(-(24.0+RCONST(M))*365.25*50.))/FLOW((24.+RCO
     &NST(M))*PROD5))
      ELSE IF (INN .EQ. 2)THEN
         SUM5=SUM5+((1.-UXP(-(6.+BFCNST+RCONST(M))*365.25*50.))/FLOW((6.
     &0+BFCNST+RCONST(M))*PROD5))
      END IF
*
  106 CONTINUE
      IF (INN .EQ. 1)THEN
         SUM4=SUM4+FLOW(PROD4*FGI(I)*SUM5/BRA(I))
      ELSE IF (INN .EQ. 2)THEN
         SUM4=SUM4+FLOW(PROD4*TEMP(1,I)*24.*SUM5/BRA(I))
      END IF
  103 CONTINUE
      TEMP(INN,NUC)=SUM4*BRA(NUC)
      END IF
  102 CONTINUE
*************************************************************************
*                        Daughters' case                                *
*************************************************************************
      ELSE
*************************************************************************
*     Loop for outer sum term,SUM4                                      *
```

```
*****************************************************************
      SUM4=0.
      DO 163 I=1,J
*****************************************************************
*     Loop for outer product term,PROD4                         *
*****************************************************************
      PROD4=1.
      IF (I+1 .GT. J)GOTO 164
      DO 165 K=I+1,J
      PROD4=FLOW(RCONST(K)*PROD4)
  165 CONTINUE
  164 SUM5=0.
*****************************************************************
*     Loop for inner sum term,SUM5                              *
*****************************************************************
      DO 166 M=I,J
      PROD5=1.
*****************************************************************
*     Loop for inner product term,PROD5                         *
*****************************************************************
      DO 167 K=I,J
      IF (K .EQ. M)GOTO 167
      PROD5=FLOW(PROD5*(RCONST(K)-RCONST(M)))
  167 CONTINUE
      SUM5=SUM5+((1.-UXP(-(1.8+RCONST(M))*365.25*50.))/FLOW((1.8+RCONST(
     &M))*PROD5))
  166 CONTINUE
      SUM4=SUM4+FLOW(PROD4*6.*TEMP(2,I)*SUM5/BRA(I))
  163 CONTINUE
      US(JSORCE,J)=SUM4*BRA(J)
      END IF
  162 CONTINUE
      GOTO 180
*****************************************************************
*           LOWER LARGE INTESTINE in case of INHALATION         *
*****************************************************************
  170 IF (F1 .EQ. 1.)GOTO 180
      BFCNST=F1*6./(1.-F1)
      DO 172 J=1,NO
      R1=FLOW(24.+RCONST(J))
      R2=FLOW(6.+BFCNST+RCONST(J))
      R3=FLOW(1.8+RCONST(J))
      R4=FLOW(1.+RCONST(J))
*****************************************************************
*                          Parent case                          *
*****************************************************************
      IF (J .EQ. 1)THEN
      US(JSORCE,1)=BRA(1)*FGI(J)*24.*6.*1.8/FLOW(R1*R2*R3*R4)
      DO 202 INN=1,3
      DO 202 NUC=1,NO
      IF (INN .EQ. 1 .AND. (NUC .EQ. 1))THEN
         TEMP(INN,NUC)=BRA(1)*FGI(1)/FLOW(24.+RCONST(1))
      ELSE IF (INN .EQ. 2 .AND. (NUC .EQ. 1))THEN
         TEMP(INN,NUC)=BRA(1)*FGI(1)*24./FLOW((24.+RCONST(1))*(6.+BFCNST
```

```
     &+RCONST(1)))
      ELSE IF (INN .EQ. 3 .AND. (NUC .EQ. 1))THEN
         TEMP(INN,NUC)=BRA(1)*FGI(1)*24.*6./FLOW((24.+RCONST(1))*(6.+BFC
     &NST+RCONST(1))*(1.8+RCONST(1)))
      ELSE
*
      SUM4=0.
      DO 203 I=1,NUC
*************************************************************************
*     Loop for outer product term,PROD4                                 *
*************************************************************************
      PROD4=1.
      IF (I+1 .GT. NUC)GOTO 204
      DO 205 K=I+1,NUC
      PROD4=FLOW(RCONST(K)*PROD4)
  205 CONTINUE
  204 SUM5=0.
*************************************************************************
*     Loop for inner sum term,SUM5                                      *
*************************************************************************
      DO 206 N=I,NUC
      PROD5=1.
*************************************************************************
*     Loop for inner product term,PROD5                                 *
*************************************************************************
      DO 207 K=I,NUC
      IF (K .EQ. N)GOTO 207
      PROD5=FLOW(PROD5*(RCONST(K)-RCONST(N)))
  207 CONTINUE
      IF (INN .EQ. 1)THEN
         SUM5=SUM5+((1.-UXP(-(24.0+RCONST(N))*365.25*50.))/FLOW((24.+ROD
     &NST(N))*PROD5))
      ELSE IF (INN .EQ. 2)THEN
         SUM5=SUM5+((1.-UXP(-(6.+BFCNST+RCONST(N))*365.25*50.))/FLOW((6.
     &0+BFCNST+RCONST(N))*PROD5))
      ELSE IF (INN .EQ. 3)THEN
         SUM5=SUM5+((1.-UXP(-(1.8+RCONST(N))*365.25*50.))/FLOW((1.8+RCON
     &ST(N))*PROD5))
      END IF
*
  206 CONTINUE
      IF (INN .EQ. 1)THEN
         SUM4=SUM4+FLOW(PROD4*FGI(I)*SUM5/BRA(I))
      ELSE IF (INN .EQ. 2)THEN
         SUM4=SUM4+FLOW(PROD4*TEMP(1,I)*24.*SUM5/BRA(I))
      ELSE IF (INN .EQ. 3)THEN
         SUM4=SUM4+FLOW(PROD4*TEMP(2,I)*6.*SUM5/BRA(I))
      END IF
  203 CONTINUE
      TEMP(INN,NUC)=SUM4*BRA(NUC)
      END IF
  202 CONTINUE
*
*************************************************************************
```

```
*                    Deughters' cese                                    *
*************************************************************************
      ELSE
*************************************************************************
*     Loop for outer sum term,SUM4                                       *
*************************************************************************
      SUM4=0.
      00 173 I=1,J
*************************************************************************
*     Loop for outer product term,PROD4                                  *
*************************************************************************
      PROD4=1.
      IF (I+1 .GT. J)GOTO 174
      00 175 K=I+1,J
      PROD4=FLOW(RCONST(K)*PROD4)
  175 CONTINUE
  174 SUM5=0.
*************************************************************************
*     Loop for inner sum term,SUM5                                       *
*************************************************************************
      00 176 M=I,J
      PROD5=1.
*************************************************************************
*     Loop for inner product term,PROD5                                  *
*************************************************************************
      DO 177 K=I,J
      IF (K .EQ. M)GOTO 177
      PROD5=FLOW(PROD5*(RCONST(K)-RCONST(M)))
  177 CONTINUE
      SUM5=SUM5+((1.-UXP(-(1.0+RCONST(M))*365.25*50.))/FLOW((1.0+RCONST(
     &M))*PROD5))
  176 CONTINUE
      SUM4=SUM4+FLOW(PROD4*1.8*TEMP(3,I)*SUM5/BRA(I))
  173 CONTINUE
      US(JSORCE,J)=SUM4*BRA(J)
      END IF
  172 CONTINUE
      GOTO 180
*************************************************************************
*     Three compartment model for iodine                                 *
*************************************************************************
  300 DO 310 I=1,NO
      F2I=0.3
      F4=0.9
      BODY=LOG(2.)/120
      BSORCE=LOG(2.)/12
      PART1=(RCONST(I)+TCONST)*(RCONST(I)+BODY)*(RCONST(I)+BSORCE)
      PART2=F2I*F4*TCONST*BODY*BSORCE
      DENOM=PART1-PART2
      UBF=FT(I)*(RCONST(I)+BODY)*(RCONST(I)+BSORCE)/DENOM
      IF (JSORCE .EQ. 17)THEN
        UROB(I)=(F2I*TCONST*BODY*FT(I)/DENOM)+(SMASS*UBF/70000.)
        MROB=SMASS
        US(JSORCE,I)=UROB(I)*70000./SMASS
```

```
      ELSE IF (JSORCE .EQ. 16)THEN
        US(JSORCE,I)=(F21*TCONST*FT(I)*(RCONST(I)+BSORCE)/DENOM)+(SMASS*
     &UBF/70000.)-(SMASS*UROB(I)/MROB)
      ELSE
        US(JSORCE,I)=0.
      END IF
  310 CONTINUE
  180 DO 500 I=1,NO
      IF (US(JSORCE,I) .LT. 0.)THEN
          US(JSORCE,I)=0.
      END IF
  500 CONTINUE
      RETURN
      END
      FUNCTION FLOW(ARGUM)
      IF (ABS(ARGUM) .LT. 1.E-30)THEN
         FLOW=1.E-30
      ELSE IF (ABS(ARGUM) .GT. 1.E30)THEN
         FLOW=1.E30
      ELSE
         FLOW=ARGUM
      END IF
      RETURN
      END
```

UXP.FOR

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```
FUNCTION UXP(ARG) .
IF (ARG .GT. -80)THEN
   UXP = EXP(ARG)
ELSE
   UXP = 0.
END IF
RETURN
END
```

YERROR.FOR

11-02-1987

```
************************************************************************
*                                                                      *
*         SUBROUTINE NAME : YERROR FORTRAN                             *
*         PURPOSE: Error handling subroutine for DECAY FORTRAN         *
*                                                                      *
************************************************************************
      SUBROUTINE YERROR(DECERR)
      INTEGER DECERR(7)
      IF (DECERR(1) .GT. 0)THEN
          WRITE (*,5)
    5     FORMAT(//,' ERROR: No match found in file "ISOTOPS" for the gi
     &ven radionuclide!',/,' SOURCE: DECAY FORTRAN',/,' CORRECTIVE ACTID
     &N: Try enother nuclide !!',////)
          DECERR(1)=0
          RETURN
      ELSE IF (DECERR(2) .GT. 0)TNEN
          WRITE (*,10)
   10     FORMAT(//,' ERROR: Unable to read the decay echeme of the nuc
     &lide in file "ISOTOPE"!',/,' SOURCE: DECAY FORTRAN',/,' CORRECTIVE
     &ACTION: Try another nuclide!!',////)
          DECERR(2)=0
          RETURN
      ELSE IF (DECERR(3) .GT. 0)TNEN
          WRITE (*,15)
   15     FORMAT(//,' ERROR: Unable to read the elphe energy and intens
     &ity from file "ALPHA" for the nuclide!',/,' SOURCE: DECAY FORTRAN
     &',/,' CORRECTIVE ACTION: Try another nuclide!!',////)
          DECERR(3)=0
          RETURN
      ELSE IF (DECERR(4) .GT. 0)TNEN
          WRITE (*,20)
   20     FORMAT(//,'ERROR: Unable to read the beta energy and intensit
     &Y FROM FILE "BETA" FOR TNE    NUCLIDE!',/,' SOURCE: DECAY FORTRAN
     &',/,' CORRECTIVE ACTION: TRY ANDTHER NUCLIDE!!',////)
          DECERR(4)=0
          RETURN
      ELSE IF (DECERR(5) .GT. 0)TNEN
          WRITE (*,25)
   25     FORMAT(//,'ERROR: Unable to read the positron energy and inten
     &SITY FROM FILE "POSITRN" FOR  TNE NUCLIDE!',/,' SOURCE: DECAY FORT
     &RAN',/,' CORRECTIVE ACTION: TRY ANDTHER NUCLIDE!!',////)
          DECERR(5)=0
          RETURN
      ELSE IF (DECERR(6) .GT. 0)TNEN
          WRITE(*,30)
   30     FORMAT(//,'ERROR: Unable to read the electron energy and inten
     &eity from file "ELECTRN" for  the nuclide!',/,' SOURCE: DECAY FORT
     &RAN',/,' CORRECTIVE ACTION: Try enother nuclide!!',////)
          DECERR(6)=0
          RETURN
      ELSE IF (DECERR(7) .GT. 0)THEN
          WRITE (*,35)
   35     FORMAT(//,'ERROR: Unable to read the photon energy and intenei
     &ty from file "PHOTON" for the nuclide!',/,' SOURCE: DECAY FORTRAN'
```

```
&,/,' CORRECTIVE ACTION: Try another nuclide !!',////)
     DECERR(7)=0
     RETURN
 END IF
 END
```

A COMPUTER PROGRAM FOR INTERNAL DOSIMETRY ANALYSIS USING THE METHODS OF ICRP-30

by

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B.S., Kansas State University, 1985

AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

A software package written in the FORTRAN-77 language uses the methods described in Part 1 of Publication 30 of the International Commission on Radiological Protection (ICRP) to calculate committed dose equivalents from an internal radionuclide to organs and tissues of an adult "reference man". An alternate version for use on an IBM-PC or a compatible micro-computer is also available.

The program considers any of the three major modes of intake of a radionuclide, namely, ingestion, inhalation, or submersion in a cloud of inert radioactive gas or elemental tritium. Except for the source of radiological decay data, the general principles, definitions, mathematical models, and calculational procedures follow closely those described in ICRP-30. The program calculates specific committed dose equivalents (Sv/Bq) in 19 target organs, annual limit of intake (Bq), and derived air concentration (in the case of inhalation or submersion) of a radionuclide. Also, weighted committed dose equivalents (Sv/Bq) for selected target organs receiving greater than or equal to 10 percent of the maximum dose is shown. In addition, a table of specific effective energies in 17 sources and 19 target organs in three units (MeV/g, rad/μCi.h, and mSv/GBq.h), and a table for number of transformations in source organs per unit intake of activity of the radionuclide (/Bq) can be generated upon request. The features of independent subroutines and alterable data files on radiological decay and biological characteristics make modifications and update of the program simple and straightforward.