JAERI-M
90-235

DEEP CODE TO CALCULATE DOSE EQUIVALENTS IN HUMAN PHANTOM FOR EXTERNAL PHOTON EXPOSURE BY MONTE CARLO METHOD

January 1991

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編集兼発行　日本原子力研究所
印　　刷　ニッセイエブロ株式会社

DEEP Code to Calculate Dose Equivalents in Human Phantom for External Photon Exposure by Monte Carlo Method

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(Received December 17, 1990)

The present report describes a computer code DEEP which calculates the organ dose equivalents and the effective dose equivalent for external photon exposure by the Monte Carlo method. MORSE-CG, Monte Carlo radiation transport code, is incorporated into the DEEP code to simulate photon transport phenomena in and around a human body. The code treats an anthropomorphic phantom represented by mathematical formulae and user has a choice for the phantom sex: male, female and unisex. The phantom can wear personal dosimeters on it and user can specify their location and dimension.

This document includes instruction and sample problem for the code as well as the general description of dose calculation, human phantom and computer code.

Keywords: DEEP Code, External Exposure, Photon, Organ Dose, Effective Dose Equivalent, Monte Carlo Method, MORSE-CG, Mathematical Phantom

JAERI-M 90-235

光子外部被曝に対する人体模型の線量当量を評価するための モンテカルロ計算コードDEEP

日本原子力研究所東海研究所保健物理部
山口　恭弘

（1990年12月17日受理）

本報告書は，光子外部被曝に対する臓器線量及び実効線量当量をモンテカルロ法を用いて計算する計算コードDEEPに関し述べるものである。DEEPコードには，人体内外における光子の輸送現象をシミュレーションするために，モンテカルロ放射線輸送コードMORSE－CGが組み込まれている。計算コードは，人体形状模型を対象とし，この模型の形状は全て数式によって表現されている。人体形状模型は，使用者がその性別（男性，女性及び中性）を指定できるようになっている。また，人体形状模型上には複数の個人線量計を着用させることができ，それらの位置及び大きさを指定することができる。

本報告書には，線量計算，人体形状模型，計算コードに関する記述の外に，計算コードの使用法及び例題も含まれている。

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1. INTRODUCTION

Efforts have been made to assess the dose equivalent in various organs or tissues(the organ dose equivalent, hereafter for simplicity) and the effective dose equivalent due to external radiation exposure since the International Commission on Radiological Protection(ICRP) introduced a new concept of radiation dose quantity in 1977[1]. The effective dose equivalent, defined as a weighted sum of organ dose equivalents, has been considered to be an excellent dosimetric quantity from a viewpoint of quantifying the radiation exposure risk with a simple quantity. It is, however, fairly hard to measure practically the organ dose equivalents and consequently the effective dose equivalent of the human body. Hence calculational approach is found to be a possible one to ensure the substantial evaluation of these quantities.

Recent progress of computer technology has made it possible to simulate the radiation transport in the human body in reasonable computation time with the Monte Carlo technique and to evaluate the organ dose equivalents and then the effective dose equivalent. Such computational technique was developed at first in evaluating the internal doses to an anthropomorphic mathematical phantom which is simplified in geometry and tissue medium[2]. These computer code and phantom have been modified to be applicable to the external dose calculation. A comprehensive calculation of the organ dose equivalents and the effective dose equivalent was made for photon and neutron exposures with such modified codes and phantoms, and the results can be seen in ICRP Publication 51[3]. All of the results are presented for five typical irradiation geometries: anteroposterior, posteroanterior, lateral and rotational irradiations by a plane parallel beam and also isotropic one.

The present report describes a computer code DEEP(Dose Equivalent for External Photon) to calculate the organ dose equivalents and the effective dose equivalent for external photon exposure by the Monte Carlo method. The code has been developed for the purposes of analyzing angular dependence of these quantities and relationship between those and response of personal dosimeters worn on the human body. The mathematical phantom treated by this code is based on the MIRD-5 phantom[4], and its exterior and some organ shapes have been revised slightly to meet the above purposes. MORSE-CG[5], Monte Carlo radiation transport code, is incorporated into this dose calculation code to simulate photon transport in and around the phantom. The following chapters describe in turn dose evaluation method, mathematical phantom, computer code and sample problem for the code.

2. ORGAN DOSE EQUIVALENT AND EFFECTIVE DOSE EQUIVALENT

The organ dose equivalents and the effective dose equivalent can be obtained by simulation of radiation transport from a photon source to target organs and tissues and by evaluation of energy deposition density in these organs and tissues. While the discrete ordinates transport codes such as ANISN[6] and DOT[7] have been used for radiation transport simulation in a simple geometry, the Monte Carlo method is the most sutable one for simulation in a three dimensional geometry like human phantom in interest here. This chapter briefs an evaluation method of the organ dose equivalents and the effective dose equivalent by the Monte Carlo techniques.

2.1 Photon Transport and Energy Deposition in Human Body

The photon is an indirectly ionizing radiation and hence when it enters the human body it transfers all or a part of its energy to the human tissue by secondary charged particles produced through interactions with matter of the human tissue. In the photon energy range in question of radiation protection, interactions can be classified into three competing alternative types: photoelectric effect, Compton scattering and pair production. While the photon transport can be terminated by the photoelectric effect, energy degradiated photons by the Compton scattering and anihiration radiation(photons of 0.5 MeV) due to the positron produced by the pair production continue to transport until they escape the system or transfer their whole energy to the human tissue. In the general Monte Carlo calculation, the radiation transport is simulated mathematically in the computer by determining interaction mode, scattering angle, flight path and other items of interaction by using a series of random number.

The MORSE-CG code employed in our computer code has the following major characteristics:

(1) Photon energy is collapsed into finite groups;

(2) Regarding scattering angle, scattered photons can take any azimuthal

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The MORSE-CG code employed in our computer code has the following major characteristics:

(1) Photon energy is collapsed into finite groups;

(2) Regarding scattering angle, scattered photons can take any azimuthal

angle and discrete polar angles specified by the generalized Gaussian quadrature scheme;

(3) A weighted tracking method is employed, which means that photons are weighted by a survival probability instead of being killed by absorbing interaction;

(4) Some special techniques such as sampling, splitting and Russian roulette, are employed to improve the statistics of photons in the regions; and

(5) Three dimensional material configuration is described by "Combinatorial Geometry" which can assemble a phantom by combining one or more of different simple geometric elemental bodies (to be described in detail in the following chapter).

The MORSE-CG code calculates the photon fluences averaged over each region but accumulates the amount of deposited energy. With the calculated photon fluence, the energy deposition density in the region can be evaluated as kerma K_{reg} (Gy) in the form

$$K_{reg} = \Sigma_i \, \phi(E_i) \cdot k(E_i) \tag{1}$$

where $\phi(E_i)$ = energy-differential fluence of photon(cm $^{-2}$), averaged over the region ,

$k(E_i)$ = kerma factor(Gy cm^2) of the tissue for photon,

E_i = photon energy(MeV) of ith energy group, respectively.

Assuming the local energy deposition of electron in the region, this kerma can be regarded as the absorbed dose D_{reg} , which provides a good approximation for the photons below several MeV. If the region corresponds to organ T, D_{reg} consequently equals the absorbed dose to the organ, D_T (Gy), and then

$$D_T = K_{reg} \quad . \tag{2}$$

2.2 Organ Dose Equivalent

The organ dose equivalent H_T (Sv) is defined as:

$$H_T = D_T \cdot Q \cdot N \tag{3}$$

where Q = quality factor, assigned the value of 1 for photon irradiation,
N = product of all other modifying factors, assigned generally the value of 1, respectively.

H_T has consequently the same value as D_T for photon irradiation.

In the case where the tissue is distributed in the phantom body as the red bone marrow is, or where the organ consists of plural parts as the lung does, the dose equivalent averaged over the parts needs to be obtained. Averaged dose equivalent $\overline{H}_T$ (Sv) is calculated by dividing the sum of energy absorbed in the parts by total mass of the organ or tissue and then

$$\overline{H}_T = \left(\frac{\Sigma_j D_{Tj} \cdot M_{Tj}}{\Sigma_j M_{Tj}} \right) \cdot Q \cdot N = \frac{\Sigma_j H_{Tj} \cdot M_{Tj}}{\Sigma_j M_{Tj}} \quad (4)$$

where D_{Tj} = absorbed dose (Gy) in j^{th} part of organ or tissue T,
H_{Tj} = dose equivalent (Sv) in j^{th} part of organ or tissue T,
M_{Tj} = mass (kg) of j^{th} part of organ or tissue T, respectively.

In the case of single organ or sole tissue, on the other hand, simply $\overline{H}_T = H_T$.

2.3 Effective Dose Equivalent

The effective dose equivalent is defined as a weighted sum of dose equivalents over all the relevant organs or tissues and given in the form

$$H_E = \Sigma_T w_T \cdot \overline{H}_T \quad (5)$$

where w_T is the weighting factor specified by ICRP[1], which represents the proportional share of the stochastic risk in organ or tissue T to the total risk. Table 1 gives the values of w_T for male, female and unisex body, which includes six organs and tissues and remainder. Since a male cannot be considered to have the breasts, the values of w_T for him were slightly modified as sharing $w_{breasts}$ to other w_T proportionally. A value of w_T = 0.06 for female and unisex body, or 0.07 for male is applied to each of the five organs or tissues of the remainder receiving the highest dose equivalents and the exposure to all other remaining tissues is neglected according to the recommendation of ICRP[1]. The list of remaining organs is shown in Table 2, which is based on the list of the target organs selected in ICRP Publication 30 Part I[8].

Regarding the dose equivalent to gonades in the calculation of H_E, the doses to testes and ovaries are used for male and female phantoms, respectively. For a unisex phantom, two different types of the effective dose equivalent are calculated by using a mean value of dose equivalents to testes and ovaries or a larger value of them, respectively.

3. MATHEMATICAL HUMAN PHANTOM FOR MONTE CARLO CALCULATION

The photon transport simulation in the human body by the Monte Carlo method needs a three-dimensional mathematical phantom. Snyder has developed an anthropomorphic mathematical phantom for the purpose of internal dosimetry. That is usually called MIRD-5 phantom[4], which is simplified in geometry and tissue medium based on the human data. Some phantoms have been made based on this phantom and used for different purposes[9],[10],[11].

The phantom used in our computer code is also based on the MIRD-5 phantom and its revised phantoms. Our phantom has been modified lightly in shape of exterior and organs and then added some functions.

3.1 Description of the Mathematical Human Phantom

Prepared were three types of phantom: male, female and unisex, and user has a choice of them in the input data set to the code. While the male and female phantoms have their proper organs, the unisex one has hypothetically both of them.

3.1.1 Exterior

The phantom consists of three main parts: head, trunk and legs as can be seen in Figure 1 and all the parts are covered with 2 mm thick skin. The center of the coordinate system is located at the center of the bottom of the phantom as shown in Figure 1 and all the lengths are expressed in centimeter in the following description.

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(1) Head

The head consists of two parts: the part upper than the chin and the neck part, which are specified as follows:

for the upper part

$$\left(\frac{x}{8.0}\right)^2 + \left(\frac{y}{10.0}\right)^2 + \left(\frac{z-86.85}{7.15}\right)^2 \leq 1.0 \quad \text{and} \quad z \geq 86.85 \ ;$$

$$\left(\frac{x}{8.0}\right)^2 + \left(\frac{y}{10.0}\right)^2 \leq 1.0 \quad \text{and} \quad 73.8 \leq z \leq 86.85 \ ;$$

and for the neck part

$$\left(\frac{x}{8.0}\right)^2 + \left(\frac{y}{10.0}\right)^2 \leq 1.0 \quad \text{and} \quad y \geq 0.0 \ ;$$

$$\left(\frac{x}{8.0}\right)^2 + \left(\frac{y}{7.0}\right)^2 \leq 1.0 \ , \quad y < 0.0 \quad \text{and} \quad 70.0 \leq z \leq 73.8 \ .$$

(2) Trunk

The trunk including arm bone within it is represented by an elliptical cylinder specified by

$$\left(\frac{x}{20.0}\right)^2 + \left(\frac{y}{10.0}\right)^2 \leq 1.0 \quad \text{and} \quad 0.0 \leq z \leq 70.0 \ .$$

The female and unisex phantoms have the female breasts represented by

$$\left(\frac{x \pm 10.0}{4.8}\right)^2 + \left(\frac{y+8.66}{b}\right)^2 + \left(\frac{z-52.0}{4.06}\right)^2 \leq 1.0 \quad \text{and}$$

$$\left(\frac{x}{20.0}\right)^2 + \left(\frac{y}{10.0}\right)^2 > 1.0 \ .$$

The positive sign in the first term of the former inequality is for the left breast and the negative sign for the right breast. User can change the breast volume by specifying the parameter "b" in the input data set to the code.

(3) Legs

The legs consist of the frustrums of two circular cones specified by

$$x^2+y^2 \leqq \pm x \left(20.0+\frac{z}{5.0}\right) \quad \text{and} \quad -80.0 \leqq z \leqq 0.0 \quad .$$

The positive sign in the inequality is for the left leg and the negative sign for the right leg.

(4) Male genitalia region

The male and unisex phantoms have the male genitalia region immediately in front of the upper end of the legs, given by

$$x^2+y^2 \geqq \pm x \left(20.0+\frac{z}{5.0}\right) \quad \text{and} \quad -4.8 \leqq z \leqq 0.0 \quad ;$$

$$-\left(10.0+\frac{z}{10.0}\right) \leqq x \leqq 10.0+\frac{z}{10.0} \quad \text{and}$$

$$-\left(10.0+\frac{z}{10.0}\right) \leqq y \leqq 0.0 \quad .$$

The phantoms are designed to be 174 cm tall. Their total weight depends on choice of the phantom and female breast size and, as an example, the unisex phantom with breasts of 360 g weighs 71 kg.

3.1.2 Revised Organs

The basic design of the phantom is taken from the MIRD-5 phantom but the shapes of some organs have been modified in the following ways.

(1) Eye region[11)]

The eyes added to the phantom consist of three sections: eye lenses, front eye region and rear eye region. The mathematical formulae of these sections are given as follows:

for the front region

$$\left(\frac{x}{8.0}\right)^2+\left(\frac{y}{10.0}\right)^2 \leqq 1.0 ,$$

$$\left(\frac{x}{7.8}\right)^2+\left(\frac{y}{9.8}\right)^2 \geqq 1.0 ,$$

$$-6.146 \leqq x \leqq 6.146 ,\quad y \leqq 0.0 \text{ and } 81.5 \leqq z \leqq 85.5 ;$$

for the rear region

$$\left(\frac{x}{6.6}\right)^2+\left(\frac{y}{8.6}\right)^2+\left(\frac{z-86.85}{5.75}\right)^2 \leqq 1.0 ,$$

$$\left(\frac{x}{6.4}\right)^2+\left(\frac{y}{8.4}\right)^2+\left(\frac{z-86.85}{5.55}\right)^2 \geqq 1.0 ,$$

$$y \leqq 0.0 \text{ and } 81.5 \leqq z \leqq 85.5 ;$$

and for the lenses

$$\left(\frac{x}{8.0}\right)^2+\left(\frac{y}{10.0}\right)^2 \leqq 1.0 ,$$

$$\left(\frac{x}{7.8}\right)^2+\left(\frac{y}{9.8}\right)^2 \geqq 1.0 ,$$

$$2.208 \leqq x \leqq 4.208 \text{ and } 82.5 \leqq z \leqq 84.5 .$$

(2) Facial skellton [10)]

The facial skellton is added, which is represented by the portion between two concentric elliptical cylinders. The mathematical formulae of the facial skellton are given by

$$\left(\frac{x}{7.0}\right)^2+\left(\frac{y}{9.0}\right)^2 \leqq 1.0 ,$$

$$\left(\frac{x}{6.1}\right)^2 + \left(\frac{y}{8.1}\right)^2 \geq 1.0 \ ,$$

$$y \leq 0.0 \quad \text{and} \quad 74.0 \leq z \leq 84.72 \ ;$$

$$\left(\frac{x}{7.5}\right)^2 + \left(\frac{y}{9.5}\right)^2 + \left(\frac{z-86.85}{6.65}\right)^2 > 1.0 \quad .$$

(3) Thyroid

The thyroid has so complicated shape that the combinatorial geometry system can not describe it with 12 CG-bodies. Thus the shape of the thyroid has been simplified to two ellipsoid conserving its volume. In addition, the thyroid retreats slightly back because of hollowing the neck part, which allows more realistic estimation of the thyroid dose equivalent. The expression of the thyroid is:

$$\left(\frac{x \pm 1.0}{0.9745}\right)^2 + \left(\frac{y + 5.0}{0.9745}\right)^2 + \left(\frac{z-72.5}{2.5}\right)^2 \leq 1.0 \quad .$$

The positive sign is for the left part of the thyroid and the negative part for the right part.

(4) Heart

Much detailed shape of the heart has been employed in our phantom. While the original model had a quite simple shape, i.e. half an ellipsoid capped by a hemisphere, the present one consists of two venticles and two atrias which are represented by ellipsoids cut in complex manner. A complete set of formulae describing the shape of venticles and atrias is given by Cristy's report[9] .

(5) Lungs

The lungs have been modified being correlated with the revision of the heart. While lungs were symmetric with respect to z-y plane in the original model, the left one has been cut with a larger box than that for the right one in the present model. Cristy's report[9] gives a set of formulae for the lungs.

(6) Adrenal

The adrenals have been slightly modified with respect to their location and coordinate system, but the dimension and volume of them have been conserved. The equations for the adrenals are given by Cristy's report[9] .

3.1.3 Composition of the Phantom

The phantom consists approximately of three media with different elemental composion and density: skeletal, lung and other soft tissues, as the MIRD-5 phantom does. Table 3 shows number densities of the element and densities for three tissues of the phantom. In this approximation, the skeleton includes red and yellow marrow tissues as well as bone tissue. Both marrows are distributed inhomogeneously as is seen in Table 4 which gives a set of weight percentage of the marrows in each part of the skeletal system of the phantom.

While photon transport is simulated by the Monte Carlo method for the three media specified in Table 3, the dose equivalents to organs and tissues are to be calculated for five media; skeleton, lung, soft tissue, and red and yellow marrows.

3.2 Assembly of the Phantom with CG-Bodies

The MORSE-CG code employs "Combinatorial Geometry system" to define the three dimensional configurations of the materials concerned with radiation transport simulation. The original version of the code has nine elemental geometrical bodies such as box, sphere and cone, which do not suffice for describing the shapes of organs and tissues of the phantom. Three geometrical bodies: torus(TOR), general ellipsoid(GEL) and elliptical cone(QUA), have been added to the CG package and then the phantom has been assembled with these 12 geometrical bodies connected by operators such as "OR", "+" and "-".

Table 5 gives list of 12 body types and parameters required for their description. Figures 2, 3 and 4 show the way of description for the newly added bodies. Figure 5 shows an example of geometry description for right and left lungs with two elemental bodies: general ellipsoids(GEL) and rectangular parallelepiped(RPP). In this example, the lungs are defined as the remainder of two general ellipsoids hollowed by two rectangular parallelepipeds.

All of the exterior, organs and tissues of the phantom are described in this manner with CG-bodies connected by operators. Listed in Table 6 are organs and tissues, and their volume. All the CG-data and cross sections of the phantom are included in Appendices A and B, respectively.

3.3 Personal Dosimeter

User has an option to set one or more personal dosimeters on the surface of the phantom in order to analyze the relationship between dosimeter indication and organ dose equivalents or effective dose equivalent. While shape of the dosimeters is fixed to be rectangular parallelepiped, user can specify not only their location but also their dimension. It is possible to set eight dosimeters at most at the same time: three on each of front and rear trunk, and one on each of front and rear head. These dosimeters can be specified independently. The dosimeter is made of the soft tissue specified by Table 3. Figure 6 shows a configuration of the phantom with personal dosimeters.

3.4 Source-to-Phantom Configuration

User has a choice of isotropic point or parallel beam source in photon source geometry. Figure 6 shows source-to-phantom configuration. For the choice of point isotropic source, user can specify the location of the source with r, distance between the center of coordinate system and the source, polar angle θ and azimuthal angle η. As r is designed to range from 0 to 10 m, user can set the point source not only outside but also inside the phantom body. On the other hand, for the choice of parallel photon beam source, user can specify the incident direction of the beam with polar angle θ and azimuthal angle η. In both cases, the center of coordinate system is fixed at the center of the bottom of the phantom's trunk.

4. COMPUTER CODE

The computer code is to simulate the photon transport phenomena in the human phantom under a specified condition and to evaluate the organ dose

All of the exterior, organs and tissues of the phantom are described in this manner with CG-bodies connected by operators. Listed in Table 6 are organs and tissues, and their volume. All the CG-data and cross sections of the phantom are included in Appendices A and B, respectively.

3.3 Personal Dosimeter

User has an option to set one or more personal dosimeters on the surface of the phantom in order to analyze the relationship between dosimeter indication and organ dose equivalents or effective dose equivalent. While shape of the dosimeters is fixed to be rectangular parallelepiped, user can specify not only their location but also their dimension. It is possible to set eight dosimeters at most at the same time: three on each of front and rear trunk, and one on each of front and rear head. These dosimeters can be specified independently. The dosimeter is made of the soft tissue specified by Table 3. Figure 6 shows a configuration of the phantom with personal dosimeters.

3.4 Source-to-Phantom Configuration

User has a choice of isotropic point or parallel beam source in photon source geometry. Figure 6 shows source-to-phantom configuration. For the choice of point isotropic source, user can specify the location of the source with r, distance between the center of coordinate system and the source, polar angle θ and azimuthal angle η. As r is designed to range from 0 to 10 m, user can set the point source not only outside but also inside the phantom body. On the other hand, for the choice of parallel photon beam source, user can specify the incident direction of the beam with polar angle θ and azimuthal angle η. In both cases, the center of coordinate system is fixed at the center of the bottom of the phantom's trunk.

4. COMPUTER CODE

The computer code is to simulate the photon transport phenomena in the human phantom under a specified condition and to evaluate the organ dose equivalents and cosenquently the effective dose equivalent. The photon transport simulation is considered to be the major part in a series of computaion and the MORSE-CG code, widely used in radiation shielding design and radiation dosimetry, is incorporated into the code for this purpose.

The computer code consists of three processing parts and three data files as shown in Figure 7. The processing parts are "Pre-processor", "MORSE" and "Post-processor", which are classified by their computatinal functions. Two data files regarding the phantom geometrical description and random walk control are called by Pre- and Post-processors, and the rest, photon cross section library, by MORSE. A job control language carries out consecutively a seies of computations. The following sections describe in detail the computer code, data files and instruction for the code.

4.1 Pre-processor

Pre-processor exercises a function of arranging circumstances for the Monte Carlo simulation of photon transport according to the dose evaluation condition specified by user. For this purpose, Pre-processor reads a set of user's input data, modifies two basic data files and consequently arranges a complete set of data for the Monte Carlo simulation by MORSE. One basic data file defines the geometries and media of organs and tissues of the phantom, i.e. CG-data given in Appendix A. The other includes data of incident photons, elemental composition of the phantom media and others required by random walk process.

Figure 8 gives a tree structure of subroutines of Pre-processor. The main routine calls consecutively eight subroutines one by one. The function of each subroutine can be summarized as follows:

① Subroutine INPUT reads in a set of input data for dose evaluation (see Section 4.5),

② Subroutine PARASET sets some parameters which depend on the sex of the phantom,

③ Subroutine DANSEI modifies the basic CG-data and forms a data set for the male phantom,

④ Subroutine JYOSEI modifies the basic CG-data and forms a data set for the female phantom,

⑤ Subroutine DOSSET defines location and dimension of personal dosimeters on the phantom,

⑥ Subroutine SETVOL calculates volume of trunk, trunk skin and breasts of the phantom, and that of personal dosimeters according to the specification by input data,

⑦ Subroutine MORSDT modifies the basic data set for random walk process according to the specification by in put data,

⑧ Subroutine OUTPUT outputs two modified basic data sets to two temporary data files to be used by MORSE and to a line-printer.

4.2 MORSE

MORSE simulates the photon transport from a photon source to organs or tissues of the phantom by the Monte Carlo method. Computation is to be executed based on the data sets prepared by Pre-processor and the photon cross section library which will be mentioned in Section 4.4. No sooner terminated all of the histories than MORSE outputs photon fluence in each region and other data required by Post-processor.

Some modification has been made for the data input style and subroutines of the original version of the code for the purpose of user's convenience. Subroutines JOMIN and GTVLIN have been modified so that CG-data of the phantom can be read from the data file of logical unit number 10. Such modification has been made for subroutine FFREAD which can read a set of photon cross section data from the file of logical unit number 20. Subroutine SCORIN, BDRY and SDATA were deleted, but, in return, subroutine TRACE has been newly developed to evaluate a total lengh of photon trajectories in each region, i.e. photon fluence integrated over the region volume. In this connection, subroutines BANKER, STBATCH and NBATCH have been also ammended slightly. Subroutines MSOUR and SOURCE have been revised in order that user has a choice of a parallel photon beam source or point isotropic one. Subroutine NRUN has been revised in its entirety so that the photon fluence integrated over each region, its standard deviation and other data necessary for dose evaluation can be outputed to a line-printer and a data file of logical unit number 1.

4.3 Post-processor

Post-processor exercises a function of evaluating the organ dose equivalents and the effective dose equivqlnet based on the results of photon transport simulation by MORSE. For this purpose, Post-processor converts the energy-differential fluence averaged over a region of organ or tissue to the organ dose equivalents with sets of energy-dependent kerma factors as given by Equations (1), (2) and (3). It estimates consequently the effective dose equivalent by summing up weighted organ dose equivalents as shown in Equation (5).

Figure 9 shows a trêe structure of subroutines of Post-processor. The main routine calls consecutively eight subroutines one by one. The function of each subroutine can be summarized as follows:

① Subroutine READ5 reads in a set of data on the phantom,

② Subroutine ORGAN relates the regions of the phantom in transport simulation to the organs or tissues of the human body,

③ Subroutine FLUXIN reads in sets of energy-defferential fluence in each region, their standard deviations and data on the photon source from the data file made by the precedent step. It calls subroutine EXDOSE which calculates the exposure in free air at the center of coordinate system,

④ Subroutine KERMIN reads in and writes down sets of kerma factor for human tisssues,

⑤ Subroutine REGDOS calculates the dose equivalent to organs and tissues except red and yellow bone marrows. It outputs these data to a line-printer and also a data file of logical unit number 40,

⑥ Subroutine MRDOSE calculates the dose equivalents to red and yellow bone marrows and skeletal tissues distributed over the human body. It outputs these data in the same manner as above,

⑦ Subroutine PAIRS calculates averaged dose equivalents for pair organs such as lungs and ovaries. It outputs these data in the same manner as above,

⑧ Subroutine EFDOSE evaluates the effective dose equivalent and outputs the result in the same manner as above. It calls subroutine NSORT which chooses five organs of highest dose among those in Table 2.

4.4 Kerma Factor Table and Photon Cross Section Library

A multi-group photon cross section library has been generated by GAMLEG-JR code[12] for 17 elements composing the phantom, listed in Table 3. The cross sections have been prepared for the interactions of photo-electric effect, coherent scattering, Compton scattering and pair-production. The photon energy from 5.0 keV to 10 MeV collapsed into 11 groups as shown in Table 7. The library contains multi-group constants determining group-to-group transfer probabilities, and probabilities and angles of scattering for each group-to-group transfer. The cross section is described in the form of card-image of ANISN-type and expanded in the order of five.

Post-processor uses a table of kerma factor for human tissues to convert the energy-differential fluence averaged over a region of organ or tissue to the organ dose equivalents. The table is prepared for five different media and included in the computer program as a "BLOCK DATA" : lung, skeletal and soft tissues, and red and yellow bone marrow tissues. Kerma factors for these tissues are listed in Table 8 as a function of grouped photon energy. While the phantom is recognized to be approximately made of lung, skeletal and soft tissues in photon transport simulation, the kerma factors of red and yellow bone marrow tissues are added in order to estimate the dose equivalents to these tissues more precisely.

4.5 Computer Output

The DEEP code is designed to output the processed results to not only a line-printer but also a data file assigned for logical unit number 40. This latter will be used as a data base for further data analyses . Appendix C gives examples of output for a sample problem which will be discussed in the next chapter.

The output to a line-printer includes the processed results by Pre-processor, MORSE and Post-processor. Since user does not usually need the results of the MORSE step, they can be cut by the job control language. Pre-processor outputs all the input data prepared by user and processed data for geometry of breasts and personal dosimeters. Post-processor outputs the photon fluence averaged over each region, kerma factors for human tissues, organ dose equivalents and effective dose equivalent.

The output to the data file consists of an index part and a set of numerical data. The index part gives date and time of computation, and specification for dose estimation such as phantom sex, incident photon energy, angles and history. The latter part describes the organ dose equivalent, its standard deviation, number of photon interaction in the organ or tissue and information of the incident photon and the phantom. The effective dose equivalent and dose equivalent to the remainder organ are also included in the data file.

4.6 Instruction for the DEEP code

User is needed to make a set of input data cards, assign input and output files, and finally prepare a set of job control cards.

4.6.1 Input Instruction

Input data to the DEEP code are to be written in the Name List format. Two sets of Name List cards are needed. One is &PREPDT which gives a specification of the human phantom and personal dosimeters on it. The other is &MORSE which specifies a random walk condition.

(1) Parameters for &PREPDT:

① IPICT : 0 = Make data set for MORSE(default)
1 = Make data set for PICTURE

② IWRITE : 0 = Output no data modified by Pre-processor(default)
1 = Output CG-data modified by Pre-processor to line-printer

③ SEX : 'H' = Unisex phantom(default)
'F' = Female phantom
'M' = Male phantom

④ BRSTHT : Breast height(in cm) for female or unisex phantom (default = 4.9)

⑤ IDOS(i): 0 = Without personal dosimeter on the phantom(default)
1 = With personal dosimeter on the phantom

⑥ ADS(i) : Width(in cm) of personal dosimeter

⑦ BDS(i) : Thickness(in cm) of personal dosimeter

⑧ ZDS(i) : Length(in cm) of personal dosimeter

⑨ YDS(i) : Distance(in cm) between dosimeter's center and surface of the phantom trunk or head

⑩ DTX(i) : X-coordinate(in cm) of the dosimeter's center

⑪ DTZ(i) : Z-coordinate(in cm) of the dosimeter's center

where "i" is personal dosimerter number that assigns rough location of dosimeters as follows:

i : 1 = On the front head
2 = On the rear head
3, 4, 5 = On the front trunk
6, 7, 8 = On the rear trunk

(2) Parameters for &MORSE:

① ISO : 0 = Point isotropic photon source (default)
1 = Parallel photon beam source

② RSO : Distance(in cm) between coordinate's center and point source (default = 200.0)

③ THSO : Polar angle θ of vector to the photon source (default = 0.0)

④ ETSO : Azimuthal angle η of vector to photon source (default = 0.0)

⑤ NBAT : Number of batch for Monte Carlo calculation (default = 200)

⑥ NPART : Number of photon particle per batch generated by the source (default = 300)

⑦ IGRP : Energy group number of incident photon (default = 1)

⑧ ICUT : Cut-off energy group number of photon (default =19)

4.6.2 Files of the Code and Input/Output file Assignment

Data sets required for executing the DEEP code are given in Table 9. All what user must assign are an input data file and an output one for storing computed results.

4.6.3 Job Control Language

Figures 10 and 11 show a typical job control language for executing the DEEP code and the PICTURE code drawing a cross sectional views of the phantom.

Job control languages consist of a definition part of the cataloged procedures and an execution part of it.

5. SAMPLE PROBLEM FOR THE DEEP CODE

5.1 Sample Calculation for External Photon Exposure

A sample problem for the DEEP code is a problem to calculate the organ dose equivalents and the effective dose equivalent to the unisex phantom with a personal dosimeter on the chest part of it. The photon source used is an isotropic source. The calculational condition is given in Table 10.

Figure 12 shows a set of input data specified in Table 10. The result for the sample computation is given in Appendix C. The execution time, memory size and number of I/O for the sample problem are 10.59 CPU minutes, 2012 k bytes and 244 times, respectively on the FACOM M-780 computer at JAERI.

5.2 Comparison to Other Calculation

Computation has been made to compare the effective dose equivalent by the DEEP code with that by another code[3). Benchmark calculation has been performed for anterior-posterior, posterior-anterior and lateral photon irradiation geometries as shown in Figure 13.

The results are shown in Figure 14. A good agreement has been obtained in the photon energy range of 17 keV $\sim$ 4.3 MeV.

6. CONCLUSION

A computer code DEEP has been developed to calculate the organ dose equivalents and the effective dose equivalent for external photon exposure by the Monte Carlo method. MORSE-CG, Monte Carlo radiation transport cose, is incorporated into the DEEP code, which simulates photon transport phenomena in and around the human body. The DEEP code treats an anthropomorphic phantom whose organs and tissues are described by mathematical formulae. The phantom has been designed so as user can specify its sex, personal dosimeters worn on it and female's breast volume in the input cards.

Instruction and a sample problem for the code are involved in this report. The code has been designed especially so as user can easily prepare a set of input data for dose estimation.

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Instruction and a sample problem for the code are involved in this report. The code has been designed especially so as user can easily prepare a set of input data for dose estimation.

A benchmark calculation for the effective dose equivalent gives a good agreement between the resulted data and the data in the ICRP Publication 51.

ACKNOWLEDGEMENT

The author wishes to thank Mr. Shigeru KUMAZAWA for his constructive advice and discussion.

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Table 1 Tissue weighting factors for male, female and unisex body

Organ or Tissue	Tissue Weighting Factor W_T		
	Female	Unisex	Male
Gonads	0.25 (Ovaries)	0.25 (Testes and/or Ovaries)	0.29 (Testes)
Breast	0.15	0.15	———
Red bone marrow	0.12	0.12	0.14
Lung	0.12	0.12	0.14
Thyroid	0.03	0.03	0.04
Bone surfaces	0.03	0.03	0.04
Remainder	0.30	0.30	0.35

Table 2 Organs for remainder

No.	Organ	No.	Organ
1	Adrenals	8	Liver
2	Bladder wall	9	Pancreas
3	Stomach wall	10	Spleen
4	Small intestine wall	11	Thymus
5	Upper large intestine wall	12	Uterus
6	Lower large intestine wall	13	Brain
7	Kidneys		

Table 3 Elemental number densities ($\times 10^{24}$ cm^{-3}) in tissues of the phantom

Ele.	Lung Tissue	Skeletal Tissue	Soft Tissue
	ρ = 0.2958 g/cm^3	ρ = 1.4682 g/cm^3	ρ = 0.9869 g/cm^3
H	1.804×10^{-2}	6.178×10^{-2}	6.172×10^{-2}
C	1.485×10^{-3}	1.678×10^{-2}	1.139×10^{-2}
N	3.561×10^{-4}	2.443×10^{-3}	9.927×10^{-4}
O	8.487×10^{-3}	2.684×10^{-2}	2.348×10^{-2}
Na	1.472×10^{-5}	1.231×10^{-4}	3.361×10^{-5}
Mg	5.423×10^{-7}	4.001×10^{-5}	3.668×10^{-6}
P	4.658×10^{-6}	1.981×10^{-3}	4.606×10^{-5}
S	1.278×10^{-5}	4.687×10^{-5}	4.077×10^{-5}
Cl	1.357×10^{-5}	3.491×10^{-5}	2.347×10^{-5}
K	9.112×10^{-6}	3.392×10^{-5}	3.192×10^{-5}
Ca	3.112×10^{-7}	2.186×10^{-3}	―――
Fe	1.180×10^{-6}	1.267×10^{-6}	6.704×10^{-7}
Zn	2.997×10^{-8}	6.490×10^{-7}	2.908×10^{-7}
Rb	7.708×10^{-9}	―――	3.963×10^{-8}
Sr	1.199×10^{-10}	3.229×10^{-7}	2.306×10^{-9}
Zr	―――	―――	5.212×10^{-8}
Pb	3.525×10^{-10}	4.694×10^{-8}	4.589×10^{-10}

Table 4 Weight percentage of red and yellow bone marrows in the skeletal system

Skeletal Region	Weight pecentage	
	Red Bone Marrow	Yellow Bone Marrow
Skull (cranium + facial skeleton)	8.32	6.35
Scapulae	2.85	2.17
Clavicles	0.79	0.75
Ribs	19.22	3.86
Upper spine	2.66	0.53
Middle spine	17.41	3.50
Lower spine	9.79	1.97
Pelvis	33.31	16.07
Upper leg bone	3.35	4.70
Middle leg bone	0	12.53
Lower leg bone	0	32.05
Upper arm bone	2.29	3.21
Middle arm bone	0	4.29
Lower arm bone	0	8.02

Table 5 Geometrical body types and parameters required for description

No.	Geometrical Body	Sym.	Parameters defining body (Number of card)
1	Box	BOX	V_x, V_y, V_z, H_{1X}, H_{1Y}, H_{1Z}, H_{2X}, H_{2Y}, H_{2Z}, H_{3X}, H_{3Y}, H_{3Z} (2)
2	Rectangular parallelepiped	RPP	X_{MIN}, X_{MAX}, Y_{MIN}, Y_{MAX}, Z_{MIN}, Z_{MAX} (1)
3	Sphere	SPH	V_X, V_Y, V_Z, R (1)
4	Right circular cylinder	RCC	V_X, V_Y, V_Z, H_X, H_Y, H_Z, R (1)
5	Right elliptical cylinder	REC	V_X, V_Y, V_Z, H_X, H_Y, H_Z, R_{1X}, R_{1Y}, R_{1Z}, R_{2X}, R_{2Y}, R_{2Z}, (2)
6	Rotative ellipsoid	ELL	V_{1X}, V_{1Y}, V_{1Z}, V_{2X}, V_{2Y}, V_{2Z}, L (2)
7	Truncated right cone	TRC	V_X, V_Y, V_Z, H_X, H_Y, H_Z, L_1, L_2 (2)
8	Right angle wedge	WED	V_x, V_y, V_z, H_{1X}, H_{1Y}, H_{1Z}, H_{2X}, H_{2Y}, H_{2Z}, H_{3X}, H_{3Y}, H_{3Z} (2)
9	Arbitrary polyhedron	ARB	V_{1X}, V_{1Y}, V_{1Z}, V_{2X}, V_{2Y}, V_{2Z}, V_{3X}, V_{3Y}, V_{3Z}, V_{4X}, V_{4Y}, V_{4Z}, V_{5X}, V_{5Y}, V_{5Z}, V_{6X}, V_{6Y}, V_{6Z}, V_{7X}, V_{7Y}, V_{7Z}, V_{8X}, V_{8Y}, V_{8Z}, Face Descriptions (5)
10	Torus	TOR	X_o, Y_o, Z_o, R, a, b, FXYZ, θ_1, θ_2 (2)
11	General ellipsoid	GEL	V_X, V_Y, V_Z, R_{1X}, R_{1Y}, R_{1Z}, R_{2X}, R_{2Y}, R_{2Z}, R_{3X}, R_{3Y}, R_{3Z} (2)
12	Trancated right elliptical cone	QUA	a, b, c, d, e, f, g, h, z_1, z_2 (2)

Table 6 Organs and tissues involved in the phantom and thier volume

No	Organ or Tissue	Volume－cm³	No	Organ or Tissue	Volume－cm³
1	Brain	1346.0	31	Lower spine	205.8
2	Left adrenal	7.855	32	Clavicles	54.7
3	Right adrenal	7.855	32	Scapulae	201.4
4	Gall bladder	10.14	34	Upper left arm bone	180.3
5	Gall contents	53.55	35	Middle left arm bone	135.5
6	Urinary bladder	45.73	36	Lower left arm bone	162.2
7	Urinary bladder contents	202.6	37	Upper right arm bone	180.3
8	Stomach	151.9	38	Middle right arm bone	135.5
9	Upper large intestine	211.9	39	Lower right arm bone	162.2
10	Lower large intestine	160.4	40	Upper left leg bone	388.3
11	Stomach & large intestine contents	611.0	41	Middle left leg bone	568.1
			42	Lower left leg bone	443.3
12	Small intestine + contents	1054.0	43	Upper right leg bone	388.3
13	Heart + contents	739.2	44	Middle right leg bone	568.1
14	Left kidney	144.0	45	Lower right leg bone	443.3
15	Right kidney	144.0	46	Pelvis	606.1
16	Liver	1833.0	47	Ribs	694.0
17	Left lung	1560.0	48	Head	2536.8
18	Right lung	1810.0	49	Trunk	30327.3
19	Pancreas	175.9	50	Legs	16786.5
20	Spleen	61.07	51	Head skin	264.8
21	Thymus	20.11	52	Trunk skin	1384.6
22	Thyroid	19.89	53	Leg skin	1358.0
23	Left eye lense	0.9183	54	Left breast	variable
24	Right eye lense	0.9183	55	Right breast	variable
25	Front eye region	10.90	56	Left testis	18.79
26	Rear eye region	21.10	57	Right testis	18.79
27	Cranium	617.6	58	Left ovary	8.378
28	Facial skeleton	305.1	59	Right ovary	8.378
29	Upper spine	165.6	60	Uterus	66.27
30	Middle spine	548.2			

Table 7 Energy group structure in photon transport calculation

Group No.	Energy Range (keV)	Mid-point Energy(keV)	Group No.	Energy Range (keV)	Mid-point Energy(keV)
1	10000 ~ 5600	7800	12	80 ~ 62	71
2	5600 ~ 3000	4300	13	62 ~ 50	56
3	3000 ~ 1800	2400	14	50 ~ 40	45
4	1800 ~ 1000	1400	15	40 ~ 33	36.5
5	1000 ~ 620	810	16	33 ~ 26	29.5
6	620 ~ 400	510	17	26 ~ 20	23
7	400 ~ 270	335	18	20 ~ 14	17
8	270 ~ 190	230	19	14 ~ 10	12
9	190 ~ 130	160	20	10 ~ 7.4	8.7
10	130 ~ 100	115	21	7.4 ~ 5.0	6.2
11	100 ~ 80	90			

Table 8 Kerma factors for soft, lung, skeletal, red bone marrow and yellow bone marrow tissues for each energy group

No	Energy (keV)	Kerma Factor ($\times 10^{-2}$ Gy · cm^2)				
		Soft Tissue	Lung Tissue	Skel. Tissue	Red Marrow	Yel. Marrow
1	7800	2.11×10^{-9}	2.12×10^{-9}	2.17×10^{-9}	2.09×10^{-9}	2.08×10^{-9}
2	4300	1.39×10^{-9}	1.40×10^{-9}	1.38×10^{-9}	1.34×10^{-9}	1.40×10^{-9}
3	2400	9.45×10^{-10}	9.39×10^{-10}	9.18×10^{-10}	9.41×10^{-10}	9.49×10^{-10}
4	1400	6.47×10^{-10}	6.45×10^{-10}	6.27×10^{-10}	6.47×10^{-10}	6.54×10^{-10}
5	810	4.14×10^{-10}	4.13×10^{-10}	4.02×10^{-10}	4.14×10^{-10}	4.18×10^{-10}
6	510	2.68×10^{-10}	2.67×10^{-10}	2.61×10^{-10}	2.68×10^{-10}	2.70×10^{-10}
7	335	1.73×10^{-10}	1.72×10^{-10}	1.69×10^{-10}	1.73×10^{-10}	1.74×10^{-10}
8	230	1.12×10^{-10}	1.12×10^{-10}	1.12×10^{-10}	1.12×10^{-10}	1.13×10^{-10}
9	160	7.16×10^{-11}	7.17×10^{-11}	7.63×10^{-11}	7.15×10^{-11}	7.17×10^{-11}
10	115	4.74×10^{-11}	4.77×10^{-11}	6.01×10^{-11}	4.69×10^{-11}	4.64×10^{-11}
11	90	3.61×10^{-11}	3.68×10^{-11}	5.85×10^{-11}	3.54×10^{-11}	3.42×10^{-11}
12	71	3.04×10^{-11}	3.15×10^{-11}	6.83×10^{-11}	2.92×10^{-11}	2.68×10^{-11}
13	56	3.00×10^{-11}	3.20×10^{-11}	9.36×10^{-11}	2.79×10^{-11}	2.37×10^{-11}
14	45	3.56×10^{-11}	3.89×10^{-11}	1.37×10^{-11}	3.20×10^{-11}	2.50×10^{-11}
15	36.5	4.79×10^{-11}	5.32×10^{-11}	2.04×10^{-11}	4.21×10^{-11}	3.11×10^{-11}
16	29.5	7.10×10^{-11}	7.95×10^{-11}	3.11×10^{-11}	6.14×10^{-11}	4.39×10^{-11}
17	23	1.19×10^{-10}	1.33×10^{-10}	5.12×10^{-10}	1.02×10^{-10}	7.17×10^{-11}
18	17	2.27×10^{-10}	2.55×10^{-10}	9.27×10^{-10}	1.94×10^{-10}	1.37×10^{-10}
19	12	4.80×10^{-10}	5.38×10^{-10}	1.81×10^{-9}	4.09×10^{-10}	2.93×10^{-10}
20	8.7	9.55×10^{-10}	1.07×10^{-9}	3.31×10^{-9}	8.13×10^{-10}	5.88×10^{-10}
21	6.2	1.92×10^{-9}	2.13×10^{-9}	5.88×10^{-9}	1.62×10^{-9}	1.21×10^{-9}

Table 9 Data sets and files required for execution of the DEEP code

STEP	Logical Unit	Data Set Name	Contents	DCB Information		
				LRECL	BLKSIZE	RECFM
Pre-processor	———	PHANTOM.V2.LOAD	Load module of DEEP code (Member: PREP89)	——	——	——
	FT01F001	&&OM	Complete set of control data for random walk and cross section library (scratch file)	80	3120	FB
	FT02F001	&&OG	Complete set of CG-data for phantom (scratch file)			
	FT05F001	PREP.DATA	Input data set prepared by user			
	FT20F001	MORSE.DATA	Basic control data for random walk and cross section library	——	——	——
	FT21F001	PICTURE.DATA	Basic CG-data for phantom	——	——	——
MORSE	———	PHANTOM.V2.LOAD	Load module of DEEP code (Member: MORSE89)	——	——	——
	FT01F001	&&FLUX	Photon fluence calculated by MORSE (scratch file)	80	3120	FB
	FT05F001	&&OM	Complete set of control data for random walk and cross section library (scratch file)			
	FT10F001	&&OG	Complete set of CG-data for phantom (scratch file)			
	FT20F001	PHOTOX.DATA	Photon cross section library	——	——	——
Post-processor	———	PHANTOM.V2.LOAD	Load module of DEEP code (Member: POST89)	——	——	——
	FT02F001	&&FLUX	Photon fluence calculated by MORSE (scratch file)	80	3120	FB
	FT05F001	PREP.DATA	Input data set prepared by user			
	FT40F001	RESULT.DATA	Data file for storing calculated organ dose equivalents, to be prepared by user			

Table 10 Calculational condition for sample problem

Item	Specification
Phantom	Sex : Unisex phantom (SEX='H') Breast height : 4.9 cm (BRSTHT=4.9)
Personal Dosimeter	Number of dosimeter : 1 (IDOS=1) Dimension : 5 x 5 x 1 cm(ADS=5.0, BDS=1.0, ZDS=5.0) Location : On chest (YDS=1.0, DTX=5.0, DTZ=60.0)
Photon Source	Type : Point isotropic (ISO=0) Distance : 2.0 m (RSO=2.0) Polar angle : 90° (THSO=90.0) Azimuthal angle : 270 ° (ETSO=270.0) Incident energy group : 11 (IGRP=11) Cutoff energy group : 21 (ICUT=21) Number of photon per batch : 300 (NPART=300) Number of batch : 1000 (NBAT=3000)

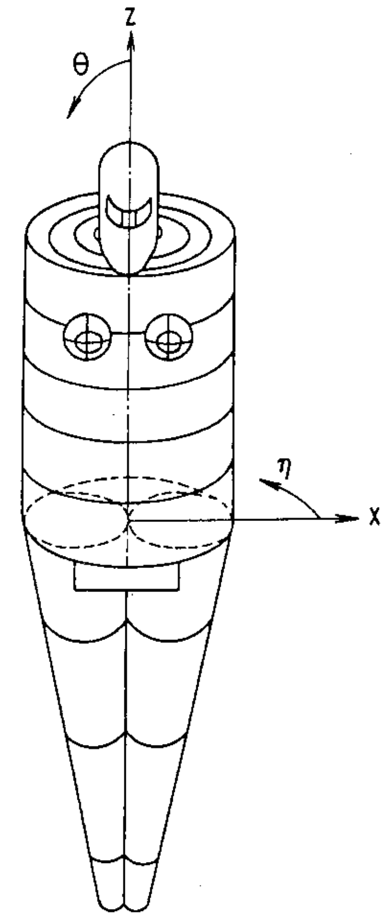


Fig. 1 Perspective of mathematical human phantom.

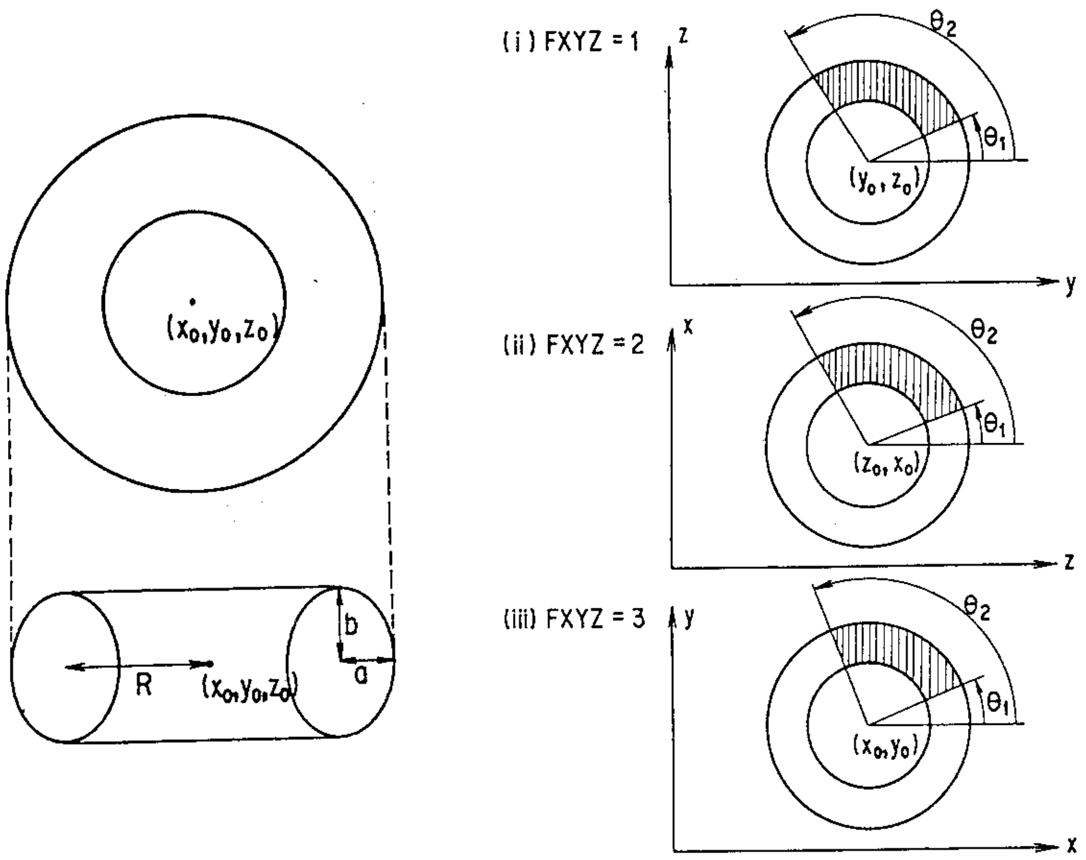


Fig. 2 Parameters defining torus body (TOR).

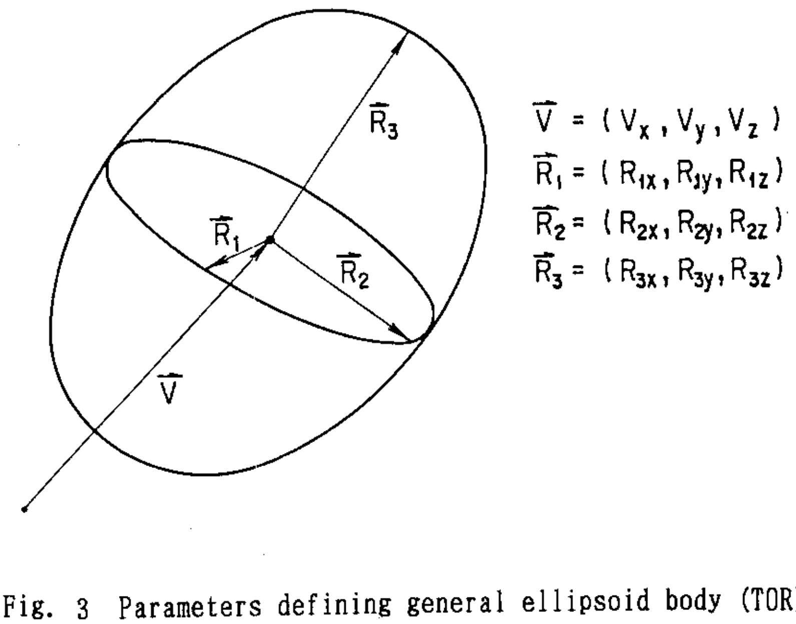
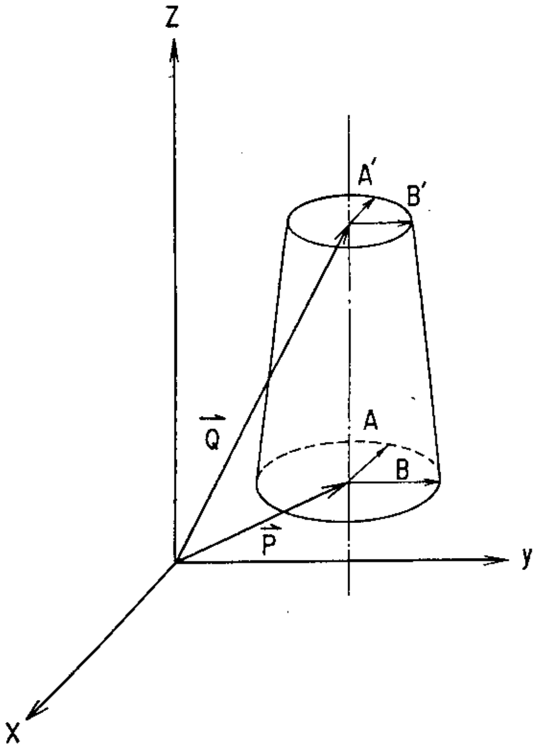


Fig. 3 Parameters defining general ellipsoid body (TOR).



$$(ax+bz+c)^2+(dy+ez+f)^2=(gz+h)^2$$

or

$$\left\{\frac{x+(bZ+C)/a}{(gZ+h)/a}\right\}^2+\left\{\frac{y+(eZ+f)/d}{(gZ+h)/d}\right\}^2=1$$

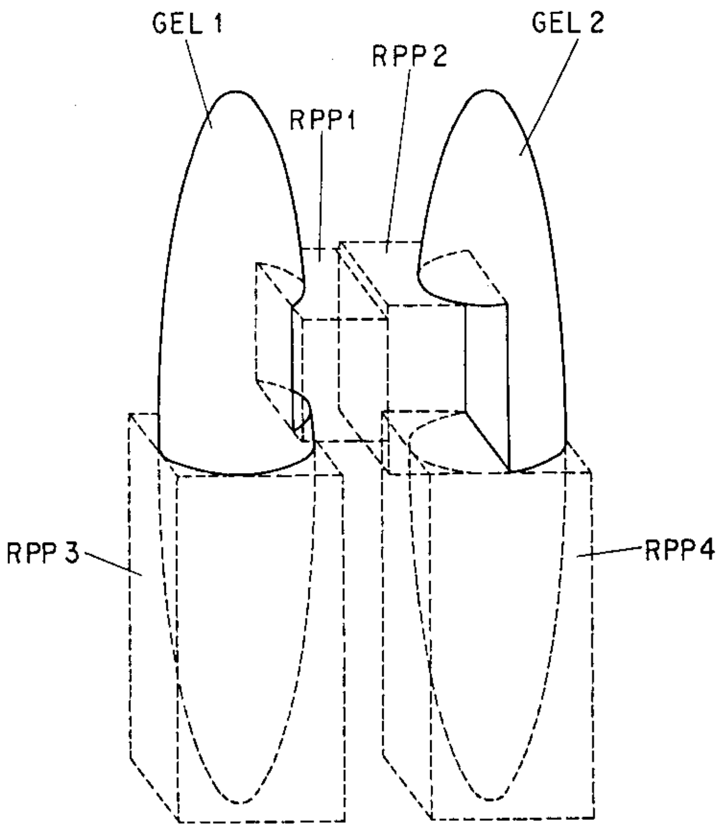
$$\vec{P}=\left(-\frac{bZ_1+C}{a},\ -\frac{eZ_1+f}{d},\ Z_1\right)$$

$$\vec{Q}=\left(-\frac{bZ_2+C}{a},\ -\frac{eZ_2+f}{d},\ Z_2\right)$$

$$(A,B)=\left(\frac{gZ_1+h}{a},\ \frac{gZ_1+h}{d}\right)$$

$$(A',B')=\left(\frac{gZ_2+h}{a},\ \frac{gZ_2+h}{d}\right)$$

Fig. 4 Parameters defining trancated right elliptical cone body (QUA).



Right Lung : GEL 1 - RPP1 - RPP3

Left Lung : GEL 2 - RPP2 - RPP4

Fig. 5 Geometrical definition of right and left lungs with CG-bodies.

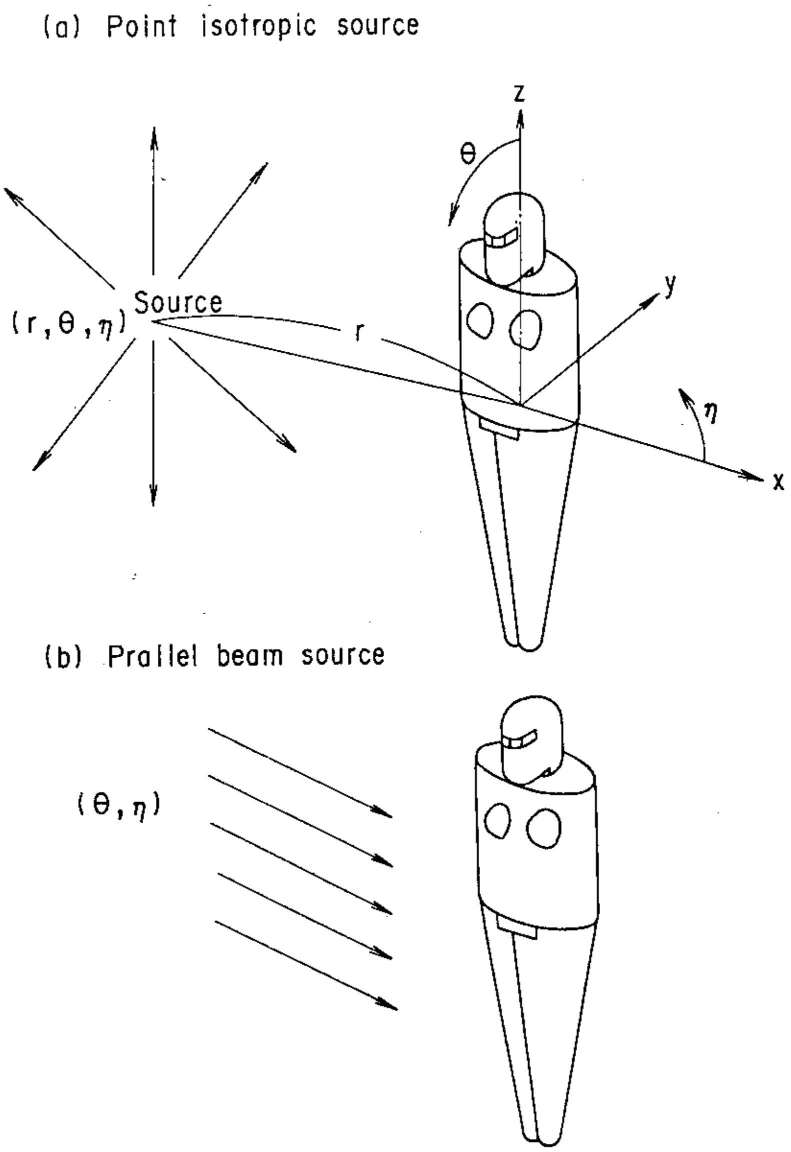


Fig. 6 Configuration of photon source and phantom.

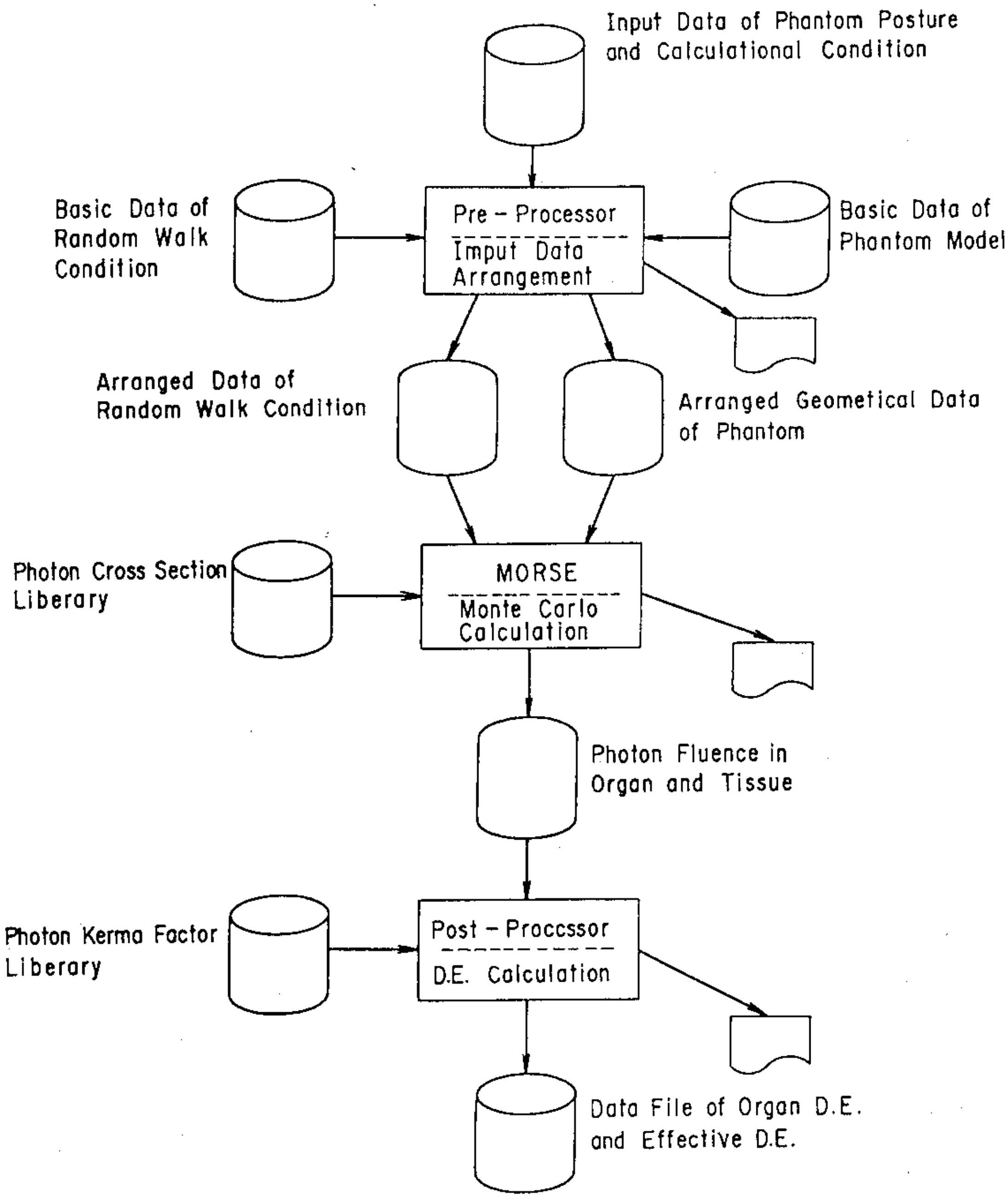


Fig. 7 Flow chart of the DEEP code.

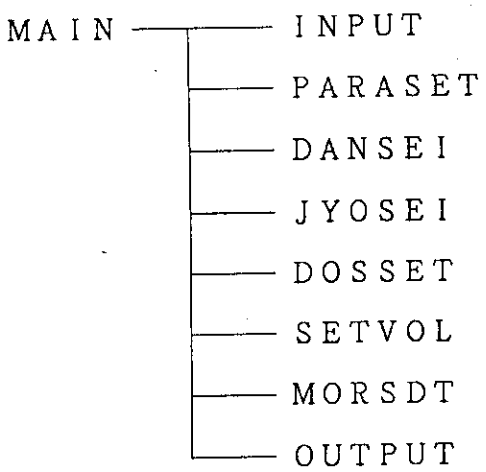


Fig. 8 Tree structure of the Pre-processor of the DEEP code.

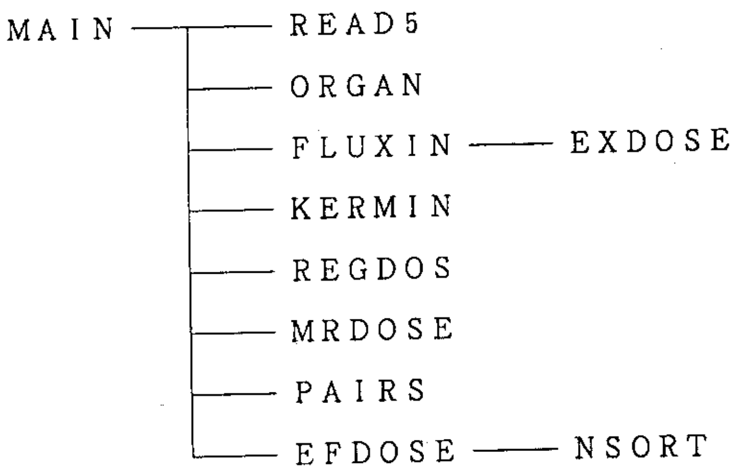


Fig. 9 Tree structure of the Post-processor of the DEEP code.

```
//JCLG JOB
// EXEC JCLG
//SYSIN DD DATA,DLM='++'
// JUSER
  T.7 W.0 C.2 I.1  SRP
  OPTP PASSWORD=     ,NOTIFY=J3527,MSGLEVEL=(2,0)
//PHANTOM PROC  SYSOUT='*',ELM='TEST',DISP='MOD'
//*****  PRE PROCESSOR
//PREP     EXEC PGM=PREP89
//STEPLIB   DD DSN=J3527.PHANTOM.V2.LOAD,DISP=SHR
//FT05F001  DD DSN=J3527.PREP.DATA(&ELM),
//             DISP=SHR,LABEL=(,,,IN)
//FT06F001  DD SYSOUT=&SYSOUT
//FT01F001  DD DSN=&&OM,DISP=(NEW,PASS,DELETE),
//             SPACE=(TRK,(10,10)),UNIT=WK10,
//             DCB=(RECFM=FB,LRECL=80,BLKSIZE=3120)
//FT02F001  DD DSN=&&OG,DISP=(NEW,PASS,DELETE),
//             SPACE=(TRK,(10,10)),UNIT=WK10,
//             DCB=(RECFM=FB,LRECL=80,BLKSIZE=3120)
//FT20F001  DD DSN=J3527.MORSE.DATA(BASIC),
//             DISP=SHR,LABEL=(,,,IN)
//FT21F001  DD DSN=J3527.PICTURE.DATA(SEISI),
//             DISP=SHR,LABEL=(,,,IN)
//*****  MORSE
//MORSE    EXEC PGM=MORSE89
//STEPLIB   DD DSN=J3527.PHANTOM.V2.LOAD,DISP=SHR
//FT01F001  DD DSN=&&FLUX,DISP=(NEW,PASS,DELETE),
//             SPACE=(TRK,(10,10)),UNIT=TSSWK,
//             DCB=(RECFM=FB,LRECL=80,BLKSIZE=3120)
//FT05F001  DD DSN=&&OM,DISP=(OLD,DELETE,DELETE)
//FT06F001  DD DUMMY
//FT10F001  DD DSN=&&OG,DISP=(OLD,DELETE,DELETE)
//FT16F001  DD SPACE=(TRK,(10,10)),UNIT=VIO,DISP=(NEW,DELETE,DELETE)
//FT20F001  DD DSN=J3527.PHOTOX.DATA,DISP=SHR
//*****  POST PROCESSOR
//POSTP    EXEC PGM=POST89
//STEPLIB   DD DSN=J3527.PHANTOM.V2.LOAD,DISP=SHR
//FT05F001  DD DSN=J3527.PREP.DATA(&ELM),
//             DISP=SHR,LABEL=(,,,IN)
//FT06F001  DD SYSOUT=*
//FT02F001  DD DSN=&&FLUX,DISP=(OLD,DELETE,DELETE)
//FT40F001  DD DSN=J3527.RESULT.DATA,DISP=&DISP
//*T40F001  DD DUMMY
//  PEND PHANTOM
//*******************************************************
//GO1     EXEC PHANTOM,ELM=TEST
++
//
```

Fig. 10 Job control cards for the DEEP code on the FACOM M-780 computer at JAERI.

```
//JCLG JOB
// EXEC JCLG
//SYSIN DD DATA,DLM='++'
// JUSER
  T.0 W.3 C.1 I.2  SRP
  OPTP PASSWORD=     ,NOTIFY=J3527,MSGLEVEL=(2,0)
//PHANTOM PROC  SYSOUT='*',ELM='TEST'
//*****  PRE PROCESSOR
//PREP     EXEC PGM=PREP89
//STEPLIB  DD DSN=J3527.PHANTOM.V2.LOAD,DISP=SHR
//FT05F001 DD DSN=J3527.PREP.DATA(&ELM),
//            DISP=SHR,LABEL=(,,,IN)
//FT06F001 DD SYSOUT=&SYSOUT
//FT01F001 DD DUMMY
//FT02F001 DD DSN=&&OG,DISP=(NEW,PASS,DELETE),
//            SPACE=(TRK,(10,10)),UNIT=WK10,
//            DCB=(RECFM=FB,LRECL=80,BLKSIZE=3120)
//FT20F001 DD DSN=J3527.MORSE.DATA(BASIC),
//            DISP=SHR,LABEL=(,,,IN)
//FT21F001 DD DSN=J3527.PICTURE.DATA(SEISI),
//            DISP=SHR,LABEL=(,,,IN)
//*****  PICTURE
//PICT     EXEC PGM=PICTURE
//STEPLIB  DD DSN=J3527.PHANTOM.V2.LOAD,DISP=SHR
//FT05F001 DD DSN=&&OG,DISP=(OLD,DELETE,DELETE)
//FT06F001 DD SYSOUT=*
//FT16F001 DD SPACE=(TRK,(10,10)),UNIT=WK10,DISP=(NEW,DELETE,DELETE)
//  PEND PHANTOM
//*********************************************************************
//GO1      EXEC PHANTOM,ELM=TTEST
++
//
```

Fig. 11 Job control cards for the PICTURE code on the FACOM M-780 computer at JAERI.

```
&PREPDT
IPICT=0,IWRITE=1,SEX='H',BRSTHT=4.9,
IDOS(1)=1,ADS(1)=5.0,BDS(1)=1.0,ZDS(1)=5.0,
YDS(1)=1.0,DTX(1)=5.0,DTZ(1)=60.0,
&END
&MORSE
ISO=0,RSO=200,THSO=90.0,ETSO=270.0,
NBAT=3000,NPART=300,IGRP=11,ICUT=21,
&END
```

Fig. 12 Input data cards for sample problem.

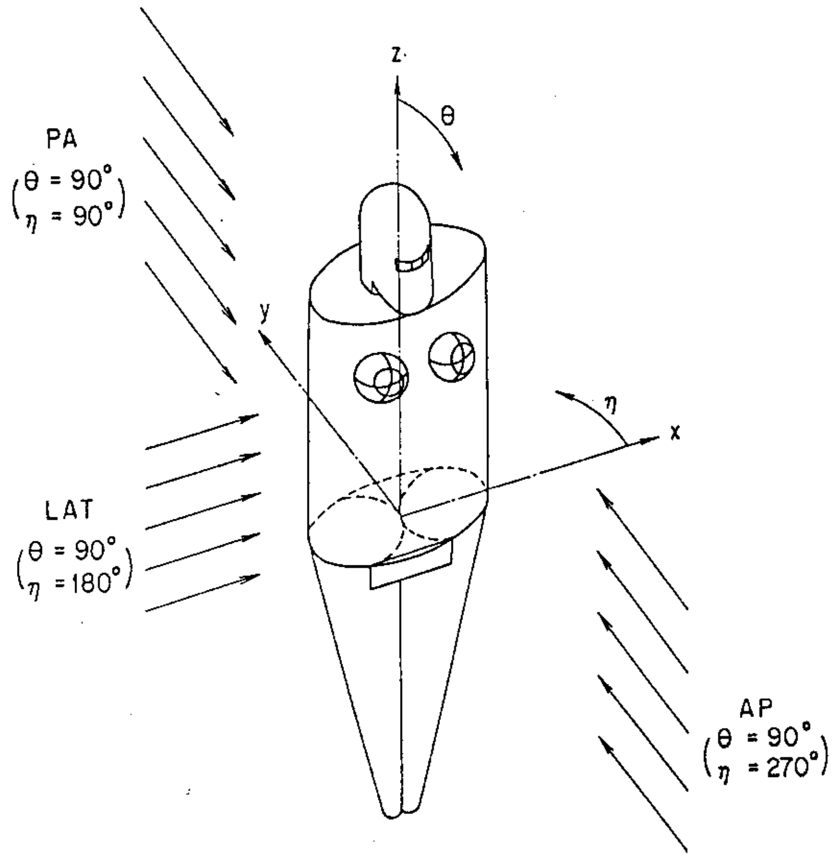


Fig. 13 Irradiation geometries for benchmark calculation.

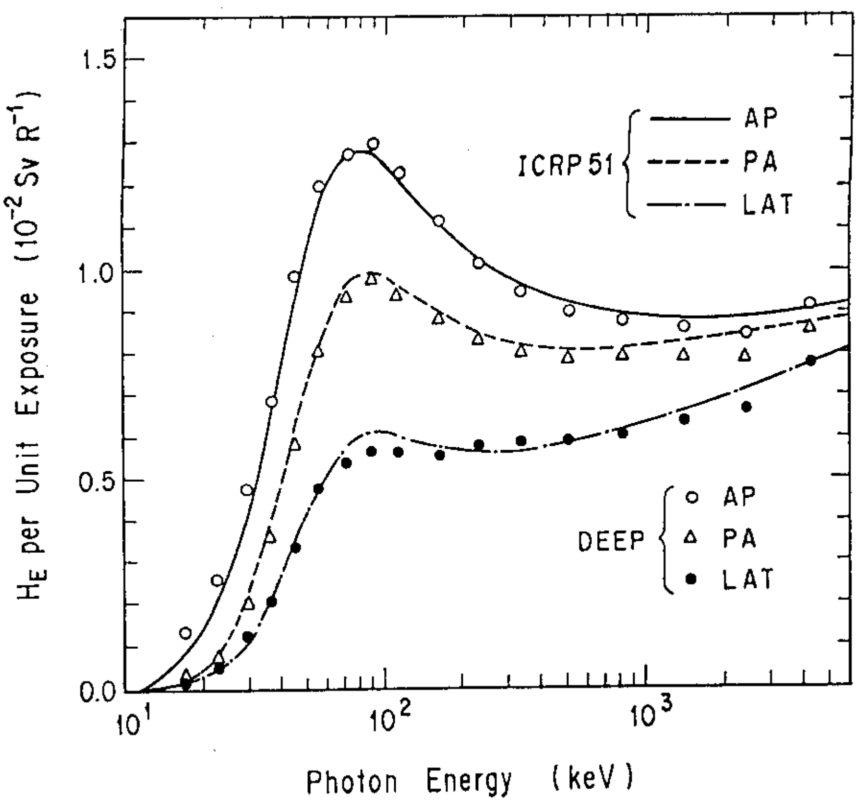


Fig. 14 Comparison of the effective dose equivalent between by the DEEP code and in the ICRP Publication 51.

Appendix A CG-Data of the Mathematical Human Phantom

PAGE-0001

```
                    *********************
                    *                   *
                    *  INPUT DATA LIST  *
                    *                   *
                    *********************

....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
   35
 *>& |=..-LH+=:.LH=IX+.II.+.+LR-IV>
   3     0    HUMAN PHANTOM BASED ON MIRD MODEL  (AUGAST 1989)
  QUA    1   1.0        0.1        10.0       1.0        0.0        0.0       R.LEG
             0.1       10.0       -80.0       0.0                             R.LEG
  QUA    2  -1.0        0.1        10.0       1.0        0.0        0.0       L.LEG
             0.1       10.0       -80.0       0.0                             L.LEG
  REC    3   0.0        0.0         0.0       0.0        0.0       70.0       TRUNK
            20.0        0.0         0.0       0.0       10.0        0.0       TRUNK
  RPP    4  -8.0        8.0       -10.0       0.0       70.0       73.8       NECK
  REC    5   0.0        0.0        70.0       0.0        0.0        3.80      NECK
             8.0        0.0         0.0       0.0        7.0        0.0       NECK
  REC    6   0.0        0.0        70.0       0.0        0.0       16.85      HEAD
             8.0        0.0         0.0       0.0       10.0        0.0       HEAD
  GEL    7   0.0        0.0        86.85      8.0        0.0        0.0       HEAD
             0.0       10.0         0.0       0.0        0.0        7.15      HEAD
  SPH    8      0.         0.          0.     1.0E +3                         AIR
  SPH    9      0.         0.          0.     2.0E +3                         VACUUM
  TOR   10   3.0        0.0         8.72      5.72       1.57       1.57      U.S.COL
             2.0       90.0       180.0                                       U.S.COL
  TOR   11   3.0        0.0         8.72      5.72       0.91       0.91      U.S.COL
             2.0       90.0       180.0                                       U.S.COL
  TOR   12   3.0        0.0         0.0       3.0        1.57       1.57      L.S.COL
             2.0      270.0       360.0                                       L.S.COL
  TOR   13   3.0        0.0         0.0       3.0        0.91       0.91      L.S.COL
             2.0      270.0       360.0                                       L.S.COL
  QUA   14 0.5319149-9.7471E-3 -4.55330  0.469483  7.6813E-2-0.669813         D.COLON
           0.0          1.0         8.72     24.0                             D.COLON
  QUA   15 0.6329114-1.1598E-2 -5.41785  0.746269  0.1220989-1.064703         D.COLON
           0.0          1.0         8.72     24.0                             D.COLON
  RCC   16  -8.5       -2.36       14.45      0.0        0.0        9.55      A.COLON
            1.7915                                                            A.COLON
  RCC   17  -8.5       -2.36       14.45      0.0        0.0        9.55      A.COLON
            2.5000                                                            A.COLON
  REC   18  -10.5      -2.36       25.5      21.0        0.0        0.0       T.COLON
              0.0       2.5         0.0       0.0        0.0        1.5       T.COLON
  REC   19  -10.5      -2.36       25.5      21.0        0.0        0.0       T.COLON
              0.0       1.973       0.0       0.0        0.0        0.973     T.COLON
  RPP   20  -11.3      11.3        -4.86      2.2       17.0       27.0       S.INTES
  GEL   21   8.0       -4.0        35.0       4.0        0.0        0.0       STOMACH
             0.0        3.0         0.0       0.0        0.0        8.0       STOMACH
  GEL   22   8.0       -4.0        35.0       3.387      0.0        0.0       STOMACH
             0.0        2.387       0.0       0.0        0.0        7.387     STOMACH
  GEL   23   0.0        0.0        86.85      6.6        0.0        0.0       BRAIN
             0.0        8.6         0.0       0.0        0.0        5.75      BRAIN
  GEL   24   0.0        0.0        86.85      7.5        0.0        0.0       SKUL
             0.0        9.5         0.0       0.0        0.0        6.65      SKUL
  GEL   25   0.0        0.0        37.0      15.0        0.0        0.0       PANCRE
             0.0        1.0         0.0       0.0        0.0        3.0       PANCRE
  RPP   26   0.0       15.0        -1.0       1.0       34.0       40.0       PANCRE
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8

*** CONTINUE ***
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PAGE-0002

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*                  *
*  INPUT DATA LIST *
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....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
   RPP   27    3.0      15.0     -1.0       1.0        34.0     37.0      PANCRE
   TOR   28    0.0      11.1     68.25     20.0        0.7883   0.7883    CLAVICL
               3.0     221.91   261.91                                    CLAVICL
   TOR   29    0.0      11.1     68.25     20.0        0.7883   0.7883    CLAVICL
               3.0     278.09   318.09                                    CLAVICL
   GEL   30    3.5       5.0     38.0       0.9234     1.1820   0.0       L.A.GRAN
              -0.3940    0.3078   0.0       0.0        0.0      5.0       L.A.GRAN
   BOX   31    2.9706    3.5102  38.0       1.8468     2.3640   0.0       L.A.GRAN
              -0.7880    0.6156   0.0       0.0        0.0      5.0       L.A.GRAN
   GEL   32   -3.5       5.0     38.0       0.9234    -1.1820   0.0       R.A.GRAN
               0.3940    0.3078   0.0       0.0        0.0      5.0       R.A.GRAN
   BOX   33   -4.8174    5.8742  38.0       1.8468    -2.3640   0.0       R.A.GRAN
               0.7880    0.6156   0.0       0.0        0.0      5.0       R.A.GRAN
   TRC   34   -4.5      -3.2     30.0       2.150      1.672    7.522     G.BLADDE
               2.12      0.3                                              G.BLADDE
   TRC   35   -4.5      -3.2     30.0       2.150      1.672    7.522     G.BLADDE
               2.00      0.18                                             G.BLADDE
   SPH   36   -4.5      -3.2     30.0       2.12                          G.BLADDE
   SPH   37   -4.5      -3.2     30.0       2.00                          G.BLADDE
   BOX   38   -6.98633  -5.7162  29.0148    4.07676    0.0     -1.16515   G.BLADDE
              -0.24337   4.1463  -0.8514    0.56964    0.44308  1.99344   G.BLADDE
   GEL   39    6.0       6.0     32.5       4.5        0.0      0.0       L.KIDNEY
               0.0       1.5      0.0       0.0        0.0      5.5       L.KIDNEY
   RPP   40    3.0      10.5      4.5       7.5       27.0     38.0       L.KIDNEY
   GEL   41   -6.0       6.0     32.5       4.5        0.0      0.0       R.KIDNEY
               0.0       1.5      0.0       0.0        0.0      5.5       R.KIDNEY
   RPP   42  -10.5      -3.0      4.5       7.5       27.0     38.0       R.KIDNEY
   GEL   43   11.0       3.0     37.0       3.5        0.0      0.0       SPLEEN
               0.0       2.0      0.0       0.0        0.0      6.0       SPLEEN
   GEL   44    0.0      -7.3     57.0       1.5        0.0      0.0       THYMUS
               0.0       0.8      0.0       0.0        0.0      4.0       THYMUS
   ELL   45   -3.553    -4.5      8.0       3.553     -4.5      8.0       U.BLADD
               9.916                                                      U.BLADD
   ELL   46   -3.445    -4.5      8.0       3.445     -4.5      8.0       U.BLADD
               9.412                                                      U.BLADD
   REC   47    0.0       0.0      0.0       0.0        0.0     69.8       RIB-RIB
              16.5       0.0      0.0       0.0        9.3      0.0       RIB-RIB
   REC   48    0.0       0.0     35.1       0.0        0.0      1.4       RIB1
              17.0       0.0      0.0       0.0        9.8      0.0       RIB1
   REC   49    0.0       0.0     37.9       0.0        0.0      1.4       RIB2
              17.0       0.0      0.0       0.0        9.8      0.0       RIB2
   REC   50    0.0       0.0     40.7       0.0        0.0      1.4       RIB3
              17.0       0.0      0.0       0.0        9.8      0.0       RIB3
   REC   51    0.0       0.0     43.5       0.0        0.0      1.4       RIB4
              17.0       0.0      0.0       0.0        9.8      0.0       RIB4
   REC   52    0.0       0.0     46.3       0.0        0.0      1.4       RIB5
              17.0       0.0      0.0       0.0        9.8      0.0       RIB5
   REC   53    0.0       0.0     49.1       0.0        0.0      1.4       RIB6
              17.0       0.0      0.0       0.0        9.8      0.0       RIB6
   REC   54    0.0       0.0     51.9       0.0        0.0      1.4       RIB7
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8

*** CONTINUE ***
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PAGE-0003

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**********************
*                    *
*  INPUT DATA LIST   *
*                    *
**********************

....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
101            17.0        0.0        0.0        0.0        9.8        0.0        RIB7        101
102      REC   55  0.0     0.0        54.7       0.0        0.0        1.4        RIB8        102
103            17.0        0.0        0.0        0.0        9.8        0.0        RIB8        103
104      REC   56  0.0     0.0        57.5       0.0        0.0        1.4        RIB9        104
105            17.0        0.0        0.0        0.0        9.8        0.0        RIB9        105
106      REC   57  0.0     0.0        60.3       0.0        0.0        1.4        RIB10       106
107            17.0        0.0        0.0        0.0        9.8        0.0        RIB10       107
108      REC   58  0.0     0.0        63.1       0.0        0.0        1.4        RIB11       108
109            17.0        0.0        0.0        0.0        9.8        0.0        RIB11       109
110      REC   59  0.0     0.0        65.9       0.0        0.0        1.4        RIB12       110
111            17.0        0.0        0.0        0.0        9.8        0.0        RIB12       111
112      REC   60  0.0     0.0        27.0       0.0        0.0        16.0       LIVER       112
113            16.5        0.0        0.0        0.0        8.0        0.0        LIVER       113
114      ARB   61-20.0     -8.0       27.0       -6.801     -8.0       27.0       LIVER       114
115           -19.245      8.0        27.0       -20.0      8.0        27.0       LIVER       115
116           -6.222       8.0        43.0       -20.0      8.0        43.0       LIVER       116
117           -20.0        -8.0       43.0       6.222      -8.0       43.0       LIVER       117
118            1234.0      4356.0     6587.0     7821.0     1467.0     2853.0     LIVER       118
119      RCC   62  0.0     -3.0       0.0        0.0        0.0        27.0       PELVIS      119
120            12.0                                                               PELVIS      120
121      RCC   63  0.0     -3.8       0.0        0.0        0.0        27.0       PELVIS      121
122            11.3                                                               PELVIS      122
123      RPP   64-12.0     12.0       -3.0       9.0        0.0        22.0       PELVIS      123
124      RPP   65-11.5     11.5       5.0        9.0        0.0        14.0       PELVIS      124
125      REC   66  0.0     5.5        70.0       0.0        0.0        10.54      U.SPINE     125
126            0.0         2.5        0.0        2.0        0.0        0.0        U.SPINE     126
127      REC   67  0.0     5.5        35.1       0.0        0.0        34.9       M.SPINE     127
128            0.0         2.5        0.0        2.0        0.0        0.0        M.SPINE     128
129      REC   68  0.0     5.5        22.0       0.0        0.0        13.1       L.SPINE     129
130            0.0         2.5        0.0        2.0        0.0        0.0        L.SPINE     130
131      REC   69  0.0     0.0        0.0        0.0        0.0        69.8       SCAPULA     131
132            19.0        0.0        0.0        0.0        9.8        0.0        SCAPULA     132
133      REC   70  0.0     0.0        0.0        0.0        0.0        69.8       SCAPULA     133
134            17.0        0.0        0.0        0.0        9.8        0.0        SCAPULA     134
135      WED   71 13.1707  10.5366    50.9       4.8293     -6.0366    0.0        SCAPULA     135
136           -13.1707     -10.5366   0.0        0.0        0.0        16.4       SCAPULA     136
137      WED   72-13.1707  10.5366    50.9       -4.8293    -6.0366    0.0        SCAPULA     137
138            13.1707     -10.5366   0.0        0.0        0.0        16.4       SCAPULA     138
139      REC   73  0.0     0.0        74.0       0.0        0.0        10.721     F.SKELET    139
140            0.0         9.0        0.0        7.0        0.0        0.0        F.SKELET    140
141      REC   74  0.0     0.0        74.0       0.0        0.0        10.721     F.SKELET    141
142            0.0         8.1        0.0        6.1        0.0        0.0        F.SKELET    142
143      RPP   75 -8.0     8.0        -10.0      0.0        74.0       84.721     F.SKELET    143
144      QUA   76  -1.0    -0.1002506  -10.0     1.0        0.0        0.0        R.LEG.B.    144
145            0.03132832  3.5        -79.8      0.0                              R.LEG.B.    145
146      QUA   77   1.0    -0.1002506  -10.0     1.0        0.0        0.0        L.LEG.B.    146
147            0.03132832  3.5        -79.8      0.0                              L.LEG.B.    147
148      QUA   78 0.7142857 0.0072464 -13.64285 0.3703703   0.0        0.0        L.ARM       148
149            0.0072464   0.5        0.0        69.0                             L.ARM       149
150      QUA   79-0.7142857 0.0072464 -13.64285 0.3703703   0.0        0.0        R.ARM       150
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            0.0072464    0.5          0.0       69.0                             R.ARM
      QUA   80  -1.0   -0.1002506   -10.0       1.0        0.0        0.0        R.LEG.B.
           0.03132832    3.5         -11.17     0.0                              R.LEG.B.
      QUA   81   1.0   -0.1002506   -10.0       1.0        0.0        0.0        L.LEG.B.
           0.03132832    3.5         -11.17     0.0                              L.LEG.B.
      QUA   82  -1.0   -0.1002506   -10.0       1.0        0.0        0.0        R.LEG.B.
           0.03132832    3.5         -34.31   -11.17                             R.LEG.B.
      QUA   83   1.0   -0.1002506   -10.0       1.0        0.0        0.0        L.LEG.B.
           0.03132832    3.5         -34.31   -11.17                             L.LEG.B.
      QUA   84 0.7142857 0.0072464 -13.64285 0.3703703    0.0        0.0         L.ARM
            0.0072464    0.5         51.75     69.0                              L.ARM
      QUA   85-0.7142857 0.0072464 -13.64285 0.3703703    0.0        0.0         R.ARM
            0.0072464    0.5         51.75     69.0                              R.ARM
      QUA   86 0.7142857 0.0072464 -13.64285 0.3703703    0.0        0.0         L.ARM
            0.0072464    0.5         34.5      51.75                             L.ARM
      QUA   87-0.7142857 0.0072464 -13.64285 0.3703703    0.0        0.0         R.ARM
            0.0072464    0.5         34.5      51.75                             R.ARM
      GEL   88   1.0      -1.8       50.0      5.80586  -4.06522 -4.87104        L.VENTIC
                -2.3200    1.6245    -4.1205   1.77816   2.53611  0.0            L.VENTIC
      BOX   89   1.54184  -5.9606    54.1205   5.80586  -4.06522 -4.87104        L.VENTIC
                -4.6400    3.2490    -8.2410   3.55632   5.07222  0.0            L.VENTIC
      GEL   90   1.0      -1.8       50.0      4.92823  -3.45071 -4.13472        L.VENTIC
                -1.71680   1.20213   -3.04917  1.03248   1.47258  0.0            L.VENTIC
      GEL   91   1.0      -1.8       50.0      5.80586  -4.06522 -4.87104        R.VENTIC
                -2.3200    1.6245    -4.1205   4.01520   5.72670  0.0            R.VENTIC
      BOX   92  -0.69520  -9.1512    54.1205   5.80586  -4.06522 -4.87104        R.VENTIC
                -4.6400    3.2490    -8.2410   4.01520   5.72670  0.0            R.VENTIC
      GEL   93   1.0      -1.8       50.0      5.40080  -3.78160 -4.53120        R.VENTIC
                -2.04160   1.42956   -3.62604  3.67104   5.23584  0.0            R.VENTIC
      GEL   94   1.0      -1.8       50.0      3.64554  -2.55258 -3.05856        L.ATRIUM
                -2.32000   1.62450   -4.12050  1.77816   2.53611  0.0            L.ATRIUM
      BOX   95 -0.32554   -0.87192   57.179    3.64554  -2.55258 -3.05856        L.ATRIUM
                -4.64000   3.24900   -8.24100  1.77816   2.53611  0.0            L.ATRIUM
      GEL   96   1.0      -1.8       50.0      3.44301  -2.41077 -2.88864        L.ATRIUM
                -2.18080   1.52703   -3.87327  1.60608   2.29068  0.0            L.ATRIUM
      GEL   97   1.0      -1.8       50.0      3.64554  -2.55258 -3.05856        L.ATRIUM
                -2.32000   1.62450   -4.12050  1.20456   1.71801  0.0            L.ATRIUM
      BOX   98 -4.34074   -6.59862   57.179    3.64554  -2.55258 -3.05856        L.ATRIUM
                -4.64000   3.24900   -8.24100  4.01520   5.72670  0.0            L.ATRIUM
      GEL   99   1.0      -1.8       50.0      3.44301  -2.41077 -2.88864        L.ATRIUM
                -2.18080   1.52703   -3.87327  1.03248   1.47258  0.0            L.ATRIUM
      GEL  100   1.0      -1.8       50.0      3.64554  -2.55258 -3.05856        R.ATRIUM
                -2.32000   1.62450   -4.12050  4.01520   5.72670  0.0            R.ATRIUM
      GEL  101   1.0      -1.8       50.0      3.44301  -2.41077 -2.88864        R.ATRIUM
                -2.18080   1.52703   -3.87327  3.84312   5.48127  0.0            R.ATRIUM
      GEL  102  -8.5       0.0       43.5      5.0       0.0      0.0            R.LUNG
                 0.0       7.5        0.0      0.0       0.0     24.0            R.LUNG
      RPP  103 -13.5      -3.5       -7.5      7.5      43.5     67.5            R.LUNG
      RPP  104  -5.4       0.0       -7.5      1.5      46.0     54.0            R.LUNG
      GEL  105   8.5       0.0       43.5      5.0       0.0      0.0            L.LUNG
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201			0.0	7.5	0.0	0.0	0.0	24.0	L.LUNG
202	RPP	106	3.5	13.5	-7.5	7.5	43.5	67.5	L.LUNG
203	RPP	107	0.0	8.0	-7.5	1.0	43.5	55.0	L.LUNG
204	QUA	108	1.0	0.1	10.0	1.0	0.0	0.0	R.LEG.SK
205			0.1	9.8	-79.8	0.0			R.LEG.SK
206	QUA	109	-1.0	0.1	10.0	1.0	0.0	0.0	L.LEG.SK
207			0.1	9.8	-79.8	0.0			L.LEG.SK
208	REC	110	0.0	0.0	0.0	0.0	0.0	70.0	TRUNK.SK
209			19.8	0.0	0.0	0.0	9.8	0.0	TRUNK.SK
210	REC	111	0.0	0.0	69.8	0.0	0.0	0.2	TRUNK.SK
211			19.8	0.0	0.0	0.0	9.8	0.0	TRUNK.SK
212	REC	112	0.0	0.0	69.8	0.0	0.0	0.2	TRUNK.SK
213			7.8	0.0	0.0	0.0	9.8	0.0	TRUNK.SK
214	RPP	113	-7.8	7.8	-9.8	0.0	70.0	74.0	N.SKIN
215	REC	114	0.0	0.0	70.0	0.0	0.0	4.0	N.SKIN
216			7.8	0.0	0.0	0.0	6.8	0.0	N.SKIN
217	REC	115	0.0	0.0	70.0	0.0	0.0	16.85	H.SKIN
218			7.8	0.0	0.0	0.0	9.8	0.0	H.SKIN
219	GEL	116	0.0	0.0	86.85	7.8	0.0	0.0	H.SKIN
220			0.0	9.8	0.0	0.0	0.0	6.95	H.SKIN
221	RPP	117	-8.0	8.0	-10.0	0.0	70.0	74.0	N.SKIN
222	GEL	118	-1.0	-5.0	72.5	0.9745	0.0	0.0	R.THYRO
223			0.0	0.9745	0.0	0.0	0.0	2.5	R.THYRO
224	GEL	119	1.0	-5.0	72.5	0.9745	0.0	0.0	L.THYRO
225			0.0	0.9745	0.0	0.0	0.0	2.5	L.THYRO
226	GEL	120	6.0	0.0	15.0	1.0	0.0	0.0	L.OVARY
227			0.0	0.5	0.0	0.0	0.0	2.0	L.OVARY
228	GEL	121	-6.0	0.0	15.0	1.0	0.0	0.0	R.OVARY
229			0.0	0.5	0.0	0.0	0.0	2.0	R.OVARY
230	RPP	122	-6.416	6.416	-10.0	0.0	81.5	85.5	F.EYE
231	RPP	123	-4.208	-2.208	-10.0	0.0	82.5	84.5	R.EYE
232	RPP	124	2.208	4.208	-10.0	0.0	82.5	84.5	L.EYE
233	GEL	125	0.0	0.0	86.85	6.4	0.0	0.0	REAR.EYE
234			0.0	8.4	0.0	0.0	0.0	5.55	REAR.EYE
235	GEL	126	0.0	-2.0	14.0	2.5	0.0	0.0	UTERUS
236			0.0	5.0	0.0	0.0	0.0	1.5	UTERUS
237	RPP	127	-2.5	2.5	-4.5	3.0	12.5	15.5	UTERUS
238	GEL	128	1.3	-8.0	-2.3	1.3	0.0	0.0	L.TESTT
239			0.0	1.5	0.0	0.0	0.0	2.3	L.TESTT
240	GEL	129	-1.3	-8.0	-2.3	1.3	0.0	0.0	R.TESTT
241			0.0	1.5	0.0	0.0	0.0	2.3	R.TESTT
242	ARB	130	-9.52	-9.52	-4.8	9.52	-9.52	-4.8	GENITAL
243			9.52	0.0	-4.8	-9.52	0.0	-4.8	GENITAL
244			10.0	0.0	0.0	-10.0	0.0	0.0	GENITAL
245			-10.0	-10.0	0.0	10.0	-10.0	0.0	GENITAL
246			1234.0	4356.0	6587.0	7821.0	1467.0	2853.0	GENITAL
247	ARB	131	-9.52	-9.32	-4.6	9.52	-9.32	-4.6	GENITAL
248			9.52	0.0	-4.6	-9.52	0.0	-4.6	GENITAL
249			10.0	0.0	0.0	-10.0	0.0	0.0	GENITAL
250			-10.0	-9.8	0.0	10.0	-9.80	0.0	GENITAL

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              1234.0     4356.0     6587.0     7821.0    1467.0     2853.0     GENITAL
BRGEL  132  10.0       -8.66      52.0        4.86       0.0        0.0       L.BREAS
BR          0.0          4.90     0.0         0.0        0.0        4.06      L.BREAS
BRGEL  133 -10.0       -8.66      52.0        4.86       0.0        0.0       R.BREAS
BR          0.0          4.90     0.0         0.0        0.0        4.06      R.BREAS
BRGEL  134  10.0       -8.66      52.0        4.66       0.0        0.0       L.BREAS
BR          0.0          4.70     0.0         0.0        0.0        3.86      L.BREAS
BRGEL  135 -10.0       -8.66      52.0        4.66       0.0        0.0       R.BREAS
BR          0.0          4.70     0.0         0.0        0.0        3.86      R.BREAS
DDBOX  136  1.0         1.0        2.0        1.0        0.0        0.0       DET.1
DD          0.0         1.0        0.0        0.0        0.0        1.0       DET.1
DDBOX  137  1.0         8.6        2.0        4.6        0.0        0.0       DET.2
DD          0.0         4.0        0.0        0.0        0.0        3.0       DET.2
DDBOX  138  1.0         8.6        2.0        4.6        0.0        0.0       DET.3
DD          0.0         4.0        0.0        0.0        0.0        3.0       DET.3
DDBOX  139  1.0         8.6        2.0        4.6        0.0        0.0       DET.4
DD          0.0         4.0        0.0        0.0        0.0        3.0       DET.4
DDBOX  140  1.0         8.6        2.0        4.6        0.0        0.0       DET.5
DD          0.0         4.0        0.0        0.0        0.0        3.0       DET.5
DDBOX  141  1.0         8.6        2.0        4.6        0.0        0.0       DET.6
DD          0.0         4.0        0.0        0.0        0.0        3.0       DET.6
DDBOX  142  1.0         8.6        2.0        4.6        0.0        0.0       DET.7
DD          0.0         4.06       0.0        0.0        0.0        3.0       DET.7
DDBOX  143  1.0         8.66       2.0        4.6        0.0        0.0       DET.8
DD          0.0         4.06       0.0        0.0        0.0        3.0       DET.8
  END
  1BRA     OR +125OR -125     +23    -122
  2AGR        +30    +31                                                   L.ADREN
  3AGR        +32    +33                                                   R.ADREN
  4GBL     OR +34    -35OR   +38     +36    -37                            G.BLADD
  5GBL     OR +35OR  +38     +37                                           CONTENT
  6UBL        +45    -46                                                   U.BLADD
  7UBL        +46                                                          CONTENT
  8STO        +21    -22                                                   STOMACH
  9COL     OR +17    -16OR   +18     -19                                   U.L.I
 10COL     OR +10    -11OR   +12     -13OR  +14    -15                     L.L.I
 11CON     OR +16OR  +19                                                   U.L.I.
           OR +11OR  +13OR   +15                                           L.L.I.
           OR +22                                                          STOMACH
 12SI         +63    +20     -10     -12    -14    -17    -18              S.INTES
 13HER     OR +91    +92     -93     -88                                   R.VEN
           OR +88    +89     -90                                           L.VEN
           OR +95    +94     -96OR   +98    +97    -99                     L.ATR
           OR +98    +100    -101    -97                                   R.ATR
           OR +92    +93     -88OR   +90    +89                            CONTENT
           OR +95    +96OR   +98     +99OR  +98    +101   -97              CONTENT
 14KID        +39    +40                                                   L.KID
 15KID        +41    +42                                                   R.KID
 16LIV        +61    +60
 17LUN       +106    +105    -107                                          L.LUNG
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18LUN        +103   +102   -104                                              R.LUNG
19SPL        +43
20PAN        +26    +25    -27
21TMS        +44
22THY    OR +1180R +119                                                      THYROID
23EYE         +6    -115   +124                                              L.LEN
24EYE         +6    -115   +123                                              R.LEN
25EYE         +6    -115   +122   -123   -124                                F.EYE.R
26REY        +23    -125   +122                                              R.EYE.R
27SKL   20   +24    -23
28FSC        +75    +73    -74    -24
29SPI        +66    -24                                                      UPPER
30SPI        +67                                                             MIDDLE
31SPI        +68                                                             LOWER
32CLA     OR +280R  +29
33SCA     OR +69    -70    +710R  +69    -70    +72
34ARM        +84                                                             L.UP
35ARM        +86                                                             L.MID
36ARM        +78    -84    -86                                               L.LOW
37ARM        +85                                                             R.UP
38ARM        +87                                                             R.MID
39ARM        +79    -85    -87                                               R.LOW
40LBO        +81                                                             L.UP
41LBO        +83                                                             L.MID
42LBO        +77    -81    -83                                               L.LOW
43LBO        +80                                                             R.UP
44LBO        +82                                                             R.MID
45LBO        +76    -80    -82                                               R.LOW
46PEL        +64    +62    -63    -65
47RIB     OR +48    -470R  +49    -470R  +50    -470R  +51    -47
          OR +52    -470R  +53    -470R  +54    -470R  +55    -47
          OR +56    -470R  +57    -470R  +58    -470R  +59    -47
48BED   200R +115   -113   -24    -66    -75    -118   -119
          OR +115   -113   -24    -66    +75    -73    -118   -119
          OR +115   -113   -24    -66    +75    +74    -118   -119
          OR +113   +114   -118   -119
          OR +116   -24    -6
49TRK   200R +47    -10    -12    -26    -78    -79    -14
             -17    -18    -21    -28    -29    -31    -33
             -34    -38    -40    -42    -103   -106   -43    -44    -45
             -61    -62    -67    -68    -88    -92    -95    -98
          OR +26    -250R  +27
          OR +31    -30
          OR +33    -32
          OR +38    -36
          OR +40    -39    -61
          OR +42    -41    -61
          OR +70    -47    -30    -31    -28    -29    -48    -49    -50
             -51    -52    -53    -54    -55    -56    -57    -58    -59
          OR +47    +61    -60
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....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
             OR  +47    +63    -20    -10    -12    -14    -17    -45         PELVIS
                -120   -121                                                   FEMALE
                -1270R +127   -126                                            FEMALE
             OR  +47    +62    -63    -64    -65                              PELVIS
             OR  +47    +62    -63    +65                                     PELVIS
             OR  +69    -70    -78    -79    -28    -29    -71    -72
             OR +110    -69    -78    -79    -28    -29   -1110R +112    -67
             OR  +47    +92    -91    -44    -61                              LHEART
             OR  +47    +88    -89    -95    -98    -44    -61   +104         LHEART
             OR  +47    +88    -89    -95    -98    -44    -61   -104   -102LHEART
             OR  +47    +95    -94    -44    -61                              LHEART
             OR  +98   -100   +104    -44    -61                              LHEART
             OR  +98   -100   -102   -104    -44    -61                       LHEART
             OR +104    -88    -92    -95    -98                              LHEART
             OR +103   -102   -104    -67    -68    -88    -92    -95    -98LHEART
                 +47                                                          LHEART
             OR +107    -88    -92    -95    -98                              LHEART
             OR +106   -105   -107    -67    -68    -88    -92    -95    -98LHEART
                 +47                                                          LHEART
             OR   +3   -110   +1320R   +3   -110   +133                       FEMALE
             OR +131     -1     -2   -128   -129                              MALE
    50LEG    OR +109    -77
             OR +108    -76
    51SKN    OR   +7   -116     -6                                            HEAD
             OR   +6   -115     -4   -1220R   +4     +5   -114                HEAD
             OR   +6   -114     -4   +117                                     HEAD
    52SKN    OR   +3   -110   -111                                            TRUNK
                -132   -133                                                   FEMALE
             OR +111   -112                                                   TRUNK
             OR +132   -134    -30R +133   -135     -3                        FEMALE
             OR +130   -131     -1     -2                                     MALE
    53SKN    OR   +1   -1080R   +2   -109                                     LEG
    54BRE       +134     -3                                                   FEMALE
    55BRE       +135     -3                                                   FEMALE
    56TES       +128                                                          MALE
    57TES       +129                                                          MALE
    58OVA       +120                                                          FEMALE
    59OVA       +121                                                          FEMALE
    60UTE       +126   +127                                                   FEMALE
    61AIR   20OR  +8     -1     -2     -3     -6     -7
                -130                                                          MALE
                -132   -133                                                   FEMALE
             OR   +4     -5
    62VAC         +9     -8                                                   VACUUM
     END
       1    2    3    4    5    6    7    8    9   10   11   12   13   14    REGION1
      15   16   17   18   19   20   21   22   23   24   25   26   27   28    REGION2
      29   30   31   32   33   34   35   36   37   38   39   40   41   42    REGION3
      43   44   45   46   47   48   49   50   51   52   53   54   55   56    REGION4
      57   58   59   60   61   62                                           REGION5
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8

*** CONTINUE ***
```

PAGE-0009

```
*********************
*                   *
*  INPUT DATA LIST  *
*                   *
*********************

....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
   1   29   30   12    5    6    7    8    9   10   11   12   13   29  MEDIUM1
  30   11   29   30   16   16   17   18   29   30   19   20   21   22  MEDIUM2
  23   24   25   26   27   29   12    5   30   32   33   29    9   10  MEDIUM3
  30   14   13   15   14    3    3    3    5    5    5   29   30   29  MEDIUM4
  30   29   30    2    4    0                                          MEDIUM5
   1346.0     7.855      7.855     10.14      53.55      45.73     202.6      VOLUME1
    151.9     211.9      160.4     611.0      1054.0     739.2     144.0      VOLUME2
    144.0     1833.0     1560.0    1810.0     175.9      61.07     20.11      VOLUME3
    19.89     0.9183     0.9183    10.90      21.10      617.6     305.1      VOLUME4
    165.6     548.2      205.8     54.7       201.4      180.3     135.5      VOLUME5
    162.2     180.3      135.5     162.2      388.3      568.1     443.3      VOLUME6
    388.3     568.1      443.3     606.1      694.0      2536.8    30401.305  VOLUME7
  16786.5     264.8    1439.213    1358.0      182.378    182.378     18.790  VOLUME8
    18.790      8.378      8.378     66.270      1.000      1.000             VOLUME9
 0 1  Z =87.0                                                                 PICTURE
      -20.0      -14.0       87.0       20.0       14.0       87.0            PICTURE
        0.0        1.0        0.0        1.0        0.0        0.0            PICTURE
        130                                                                   PICTURE
 0 1  Z =83.5
      -10.0      -10.5       83.5       10.0        2.0       83.5
        0.0        1.0        0.0        1.0        0.0        0.0
        130
 0 1  Z =75.0
      -20.0      -14.0       75.0       20.0       14.0       75.0
        0.0        1.0        0.0        1.0        0.0        0.0
        130
 0 1   Z =73.9
      -20.0      -14.0       73.9       20.0       14.0       73.9
        0.0        1.0        0.0        1.0        0.0        0.0
        130
 0 1   Z =72.0
      -20.0      -14.0       72.0       20.0       14.0       72.0
        0.0        1.0        0.0        1.0        0.0        0.0
        130
 0 1   Z =69.9
       20.0      -14.0       69.9      -20.0       14.0       69.9
        0.0        1.0        0.0       -1.0        0.0        0.0
        130
 0 1   Z =68.25
       20.0      -14.0      68.25      -20.0       14.0      68.25
        0.0        1.0        0.0       -1.0        0.0        0.0
        130
 0 1   Z =52.0
       20.0      -14.0       52.0      -20.0       14.0       52.0
        0.0        1.0        0.0       -1.0        0.0        0.0
        130
 0 1   Z =38.5
       20.0      -14.0       38.5      -20.0       14.0       38.5
        0.0        1.0        0.0       -1.0        0.0        0.0
        130
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8

*** CONTINUE ***
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PAGE-0010

```
*********************
*                   *
*  INPUT DATA LIST  *
*                   *
*********************

....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
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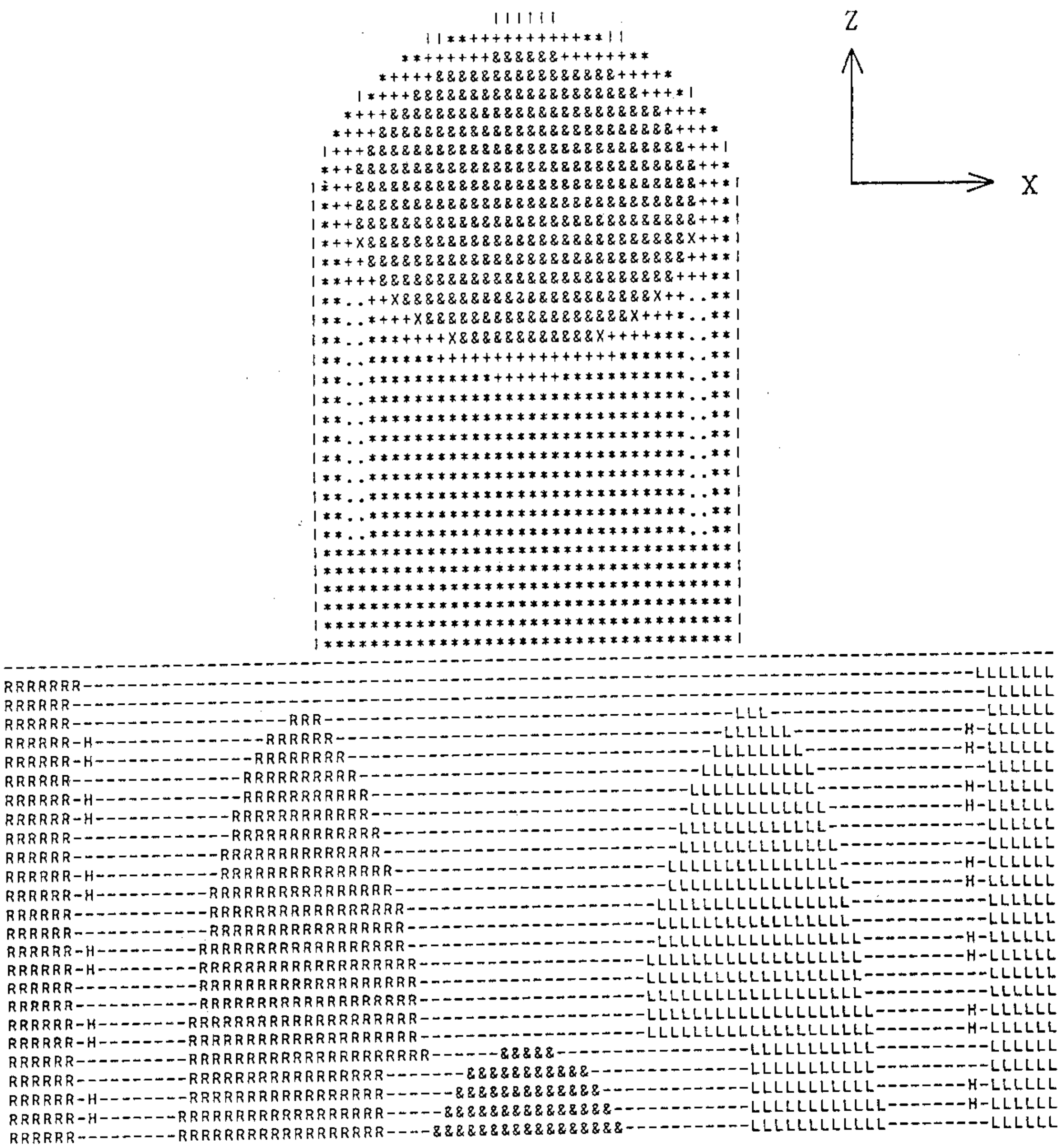
      20.0     -14.0      25.5     -20.0      10.5      25.5
       0.0       1.0       0.0      -1.0       0.0       0.0
       130
 0 1   Z =14.0
      20.0     -14.0      14.0     -20.0      14.0      14.0
       0.0       1.0       0.0      -1.0       0.0       0.0
       130
 0 1   Z =-2.3
      20.0     -14.0      -2.3     -20.0      14.0      -2.3
       0.0       1.0       0.0      -1.0       0.0       0.0
       130
 0 1   Y =  0.0
      20.0       0.0      95.0     -20.0       0.0     -80.0
       0.0       0.0      -1.0      -1.0       0.0       0.0          00350006
       130                                                          00360006
 0 1   X =  0.0
       0.0     -15.0      95.0       0.0      15.0      -6.0
       0.0       0.0      -1.0       0.0       1.0       0.0          00350006
       130                                                          00360006
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8

*** INPUT DATA END ***
```

Appendix B Cross Sectional Views of the Phantom



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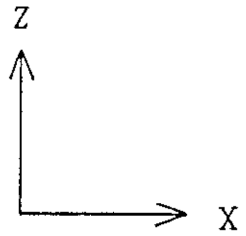


```
RRRRRR---------RRRRRRRRRRRRRRRRRR----&&&&&&&&&&&&&&&&&&&&&&-----------LLLLLLLLLLLL---------LLLLLL
RRRRRR-H-------RRRRRRRRRRRRRRRRRR----&&&&&&&&&&&&&&&&&&&&&&&----------LLLLLLLLLLLL-------H-LLLLLL
RRRRRR-H-------RRRRRRRRRRRRRRRRRR----&&&&&&&&&&&&&&&&&&&&&&&----------LLLLLLLLLLLL-------H-LLLLLL
RRRRRR---------RRRRRRRRRRRRRRRRRR----&&&&&&&&&&&&&&&&&&&&&&&----------LLLLLLLLLLLL---------LLLLLL
RRRRRR---------RRRRRRRRRRRRRRRRRR-----&&&&&&&&&&&&&&&&&&&&&-----------LLLLLLLLLLLL---------LLLLLL
RRRRRR-H-------RRRRRRRRRRRRRRRRRR------&&&&&&&&&&&&&&&&&&&&-----------LLLLLLLLLLLL-------H-LLLLLL
RRRRR--H-------RRRRRRRRRRRRRRRRRR--------&&&&&&&&&&&&&&&&&------------LLLLLLLLLLLL-------H--LLLLL
RRRRR----------RRRRRRRRRRRRRRRRRRRRRRRR------&&&&&&-------------------LLLLLLLLLLLL----------LLLLL
RRRRR----------RRRRRRRRRRRRRRRRRRRRRRRR-------------------------------LLLLLLLLLLLL----------LLLLL
RRRRR--H-------RRRRRRRRRRRRRRRRRRRRRRRR-------------------------------LLLLLLLLLLLL-------H--LLLLL
RRRRR--H-------RRRRRRRRRRRRRRRRRRRRRRRR-------------------------------LLLLLLLLLLLL-------H--LLLLL
RRRRR---HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH-------------------------------------------LLLLL
RRRRR---HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH--------------------------------------------LLLLL
RRRRR--HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH-------------------------------------------H--LLLLL
RRRRR--HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH--------------------------------------------H--LLLLL
RRRRR---HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH-------------------------------------------------LLLLL
RRRRR---HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH-------&&&&&&&&&&&&&&&&&&&&&&&&-------------------LLLLL
RRRRR--HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH---------&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&----------H--LLLLL
RRRRR--HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH-----------&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&-----H--LLLLL
RRRRR---HHHHHHHHHHHHHHHHHHHHHHHHHHHHHH-----------&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&------LLLLL
RRRRR--HHHHHHHHHHHHHHHHHHHHHHHHHHHHH-------------&&&&&&&---------------------------------H--LLLLL
RRRRR--HHHHHHHHHHHHHHHHHHHHHHHHHHH---------------&&&&&&&---------------------------------H--LLLLL
RRRRR---HHHHHHHHHHHHHHHHHHHHHHHHHH---------------&&&&&&&------------------------------------LLLLL
RRRRR---HHHHHHHHHHHHHHHHHHHHHHHH-----------------&&&&&&&------------------------------------LLLLL
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RRRR----------------XX--------------------------------------------LHHHHHHHLXX----------------LLLL
RRRR----------------XX--------------------------------------------LHHHHHHHLXX----------------LLLL
RRRR----------------XX---------------------------------------------LHHHHLL-XX----------------LLLL
RRRR----------------XX--------------------------------------------LLHHHHLL-XX----------------LLLL
RRRR----------------XX--------------------------------------------LHHHHHL--XX----------------LLLL
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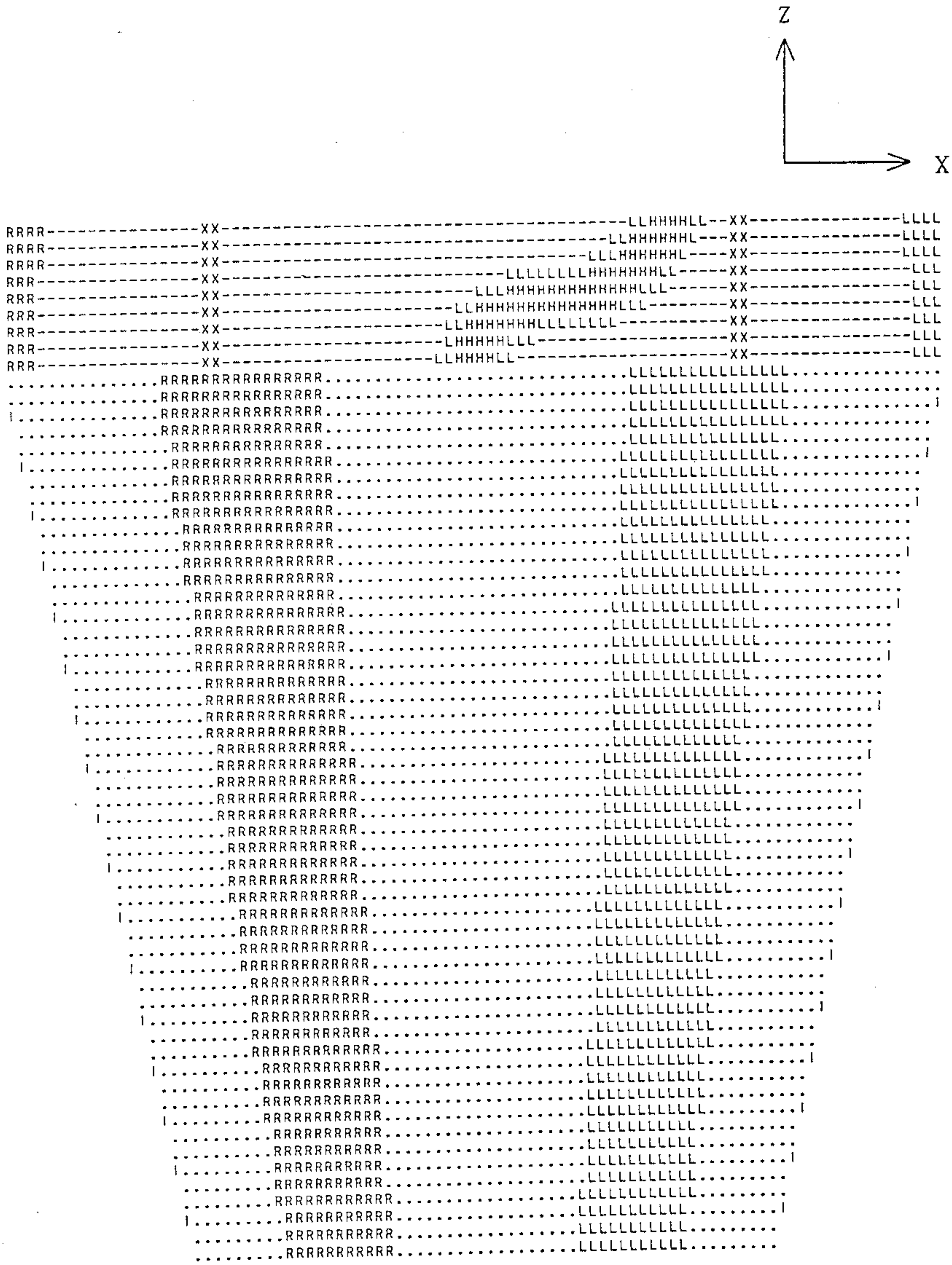
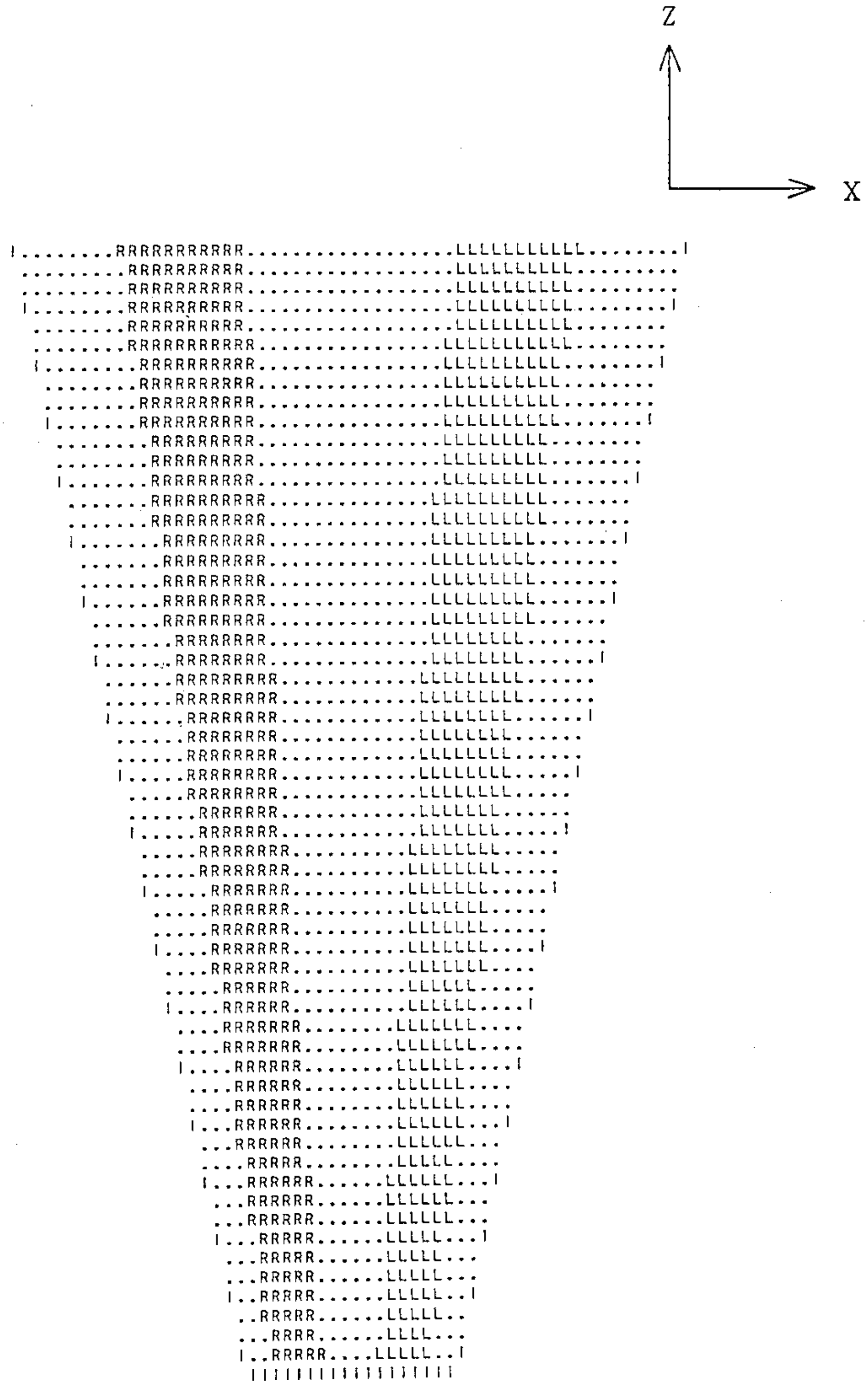
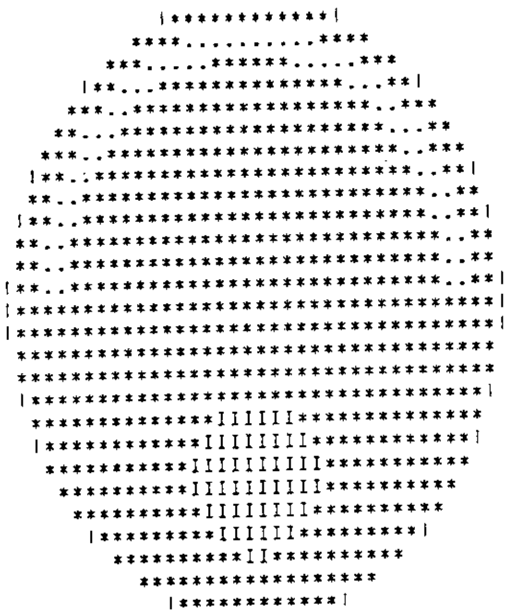
Y = 0.0 cm (Continued)



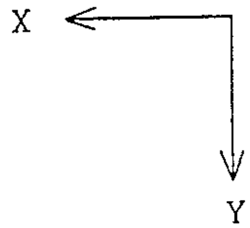
Y = 0.0 cm (Continued)

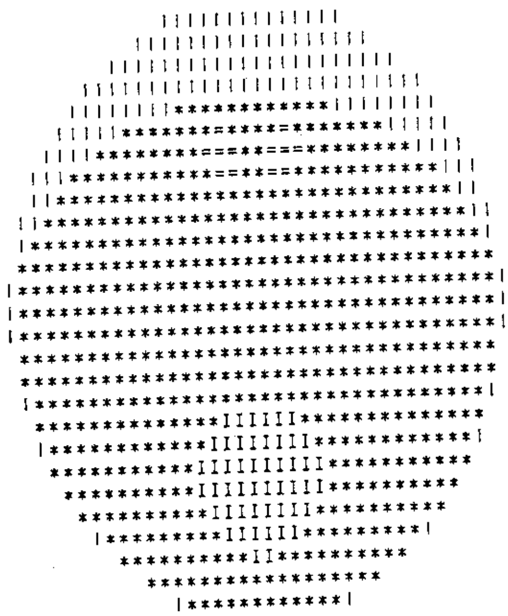


Y = 0.0 cm (Continued)

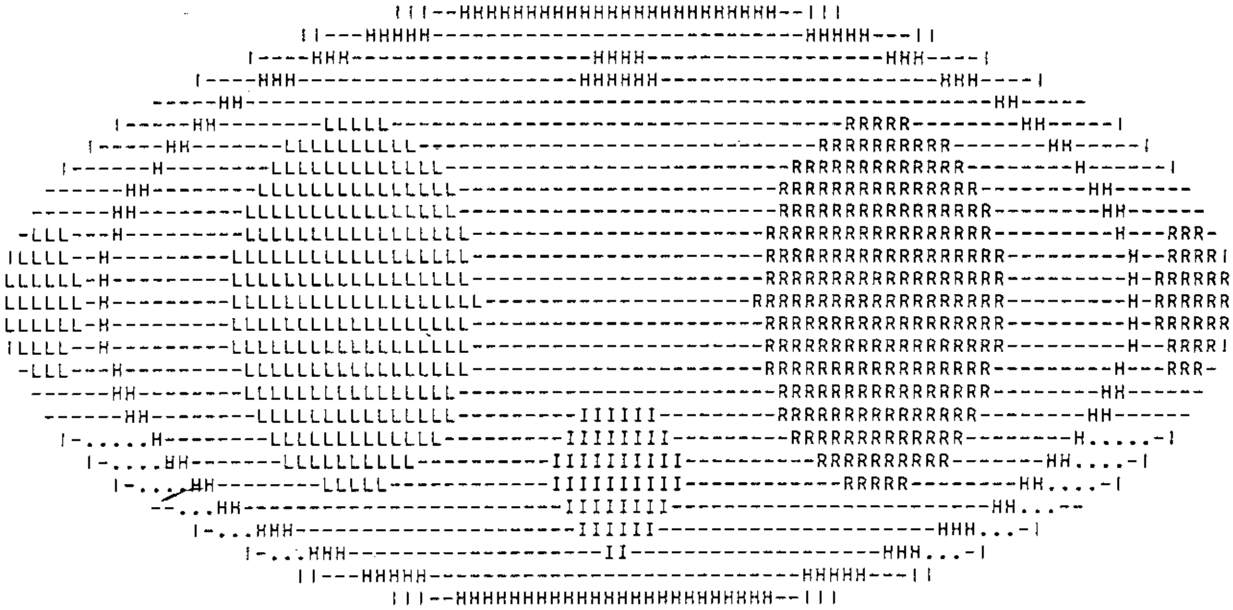


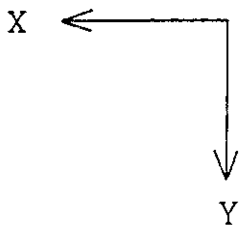
Z = 76.0 cm



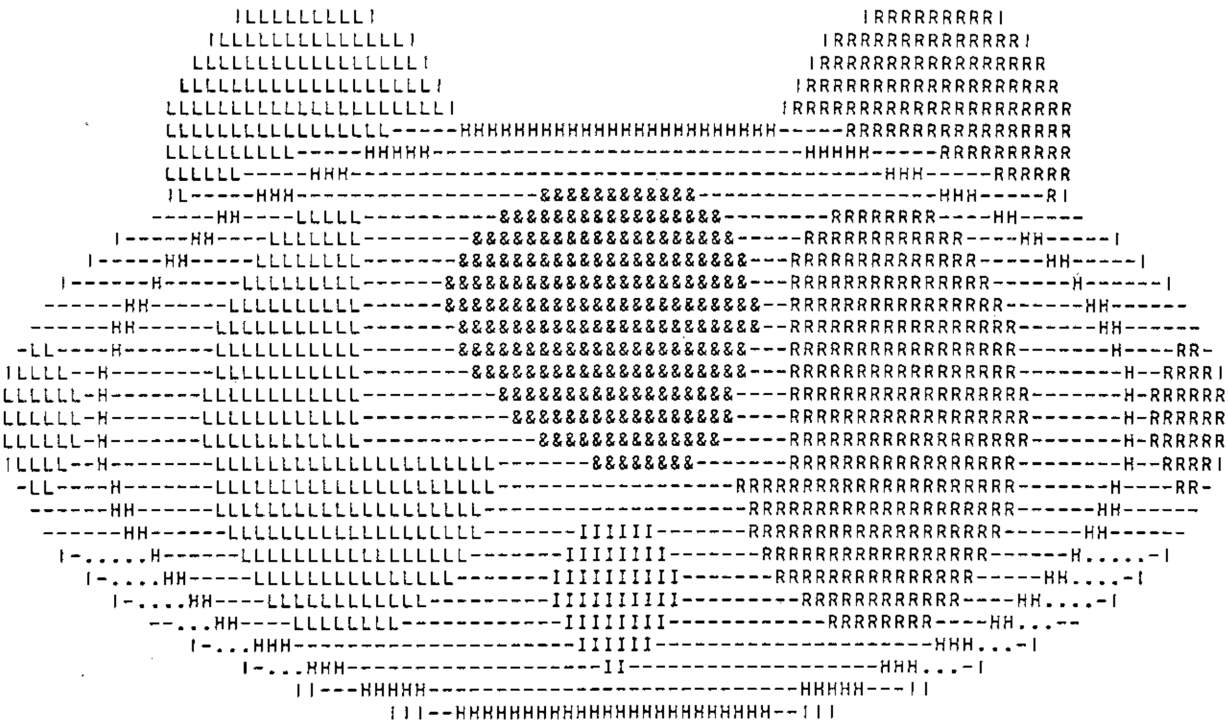


Z = 74.0 cm



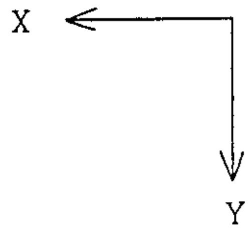


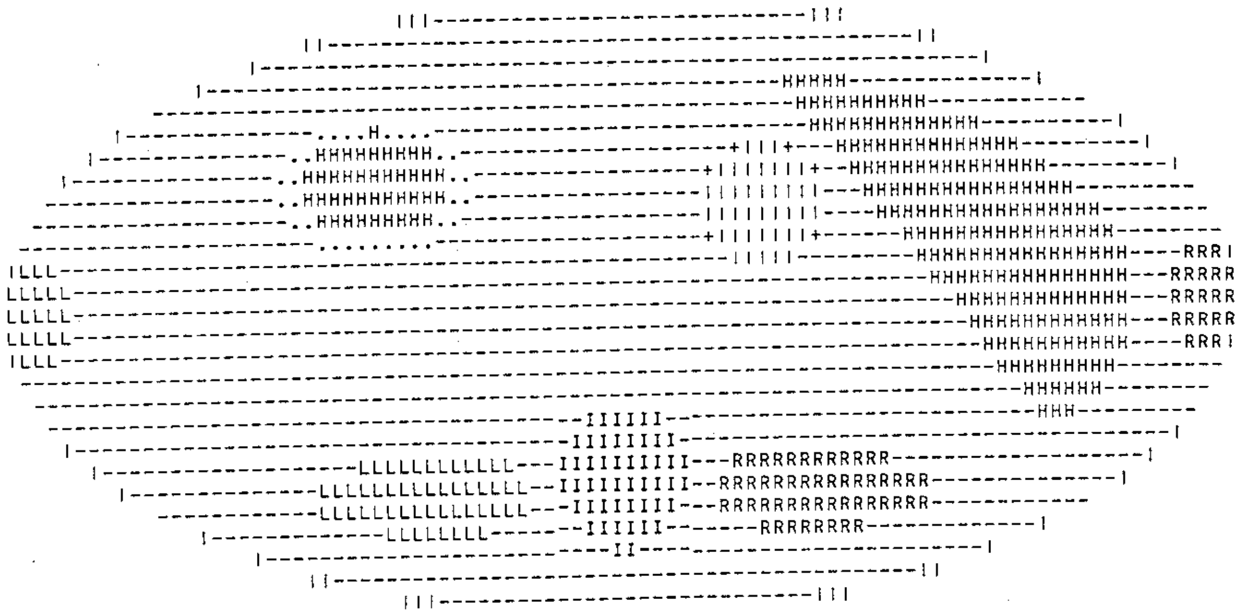
Z = 58.0 cm



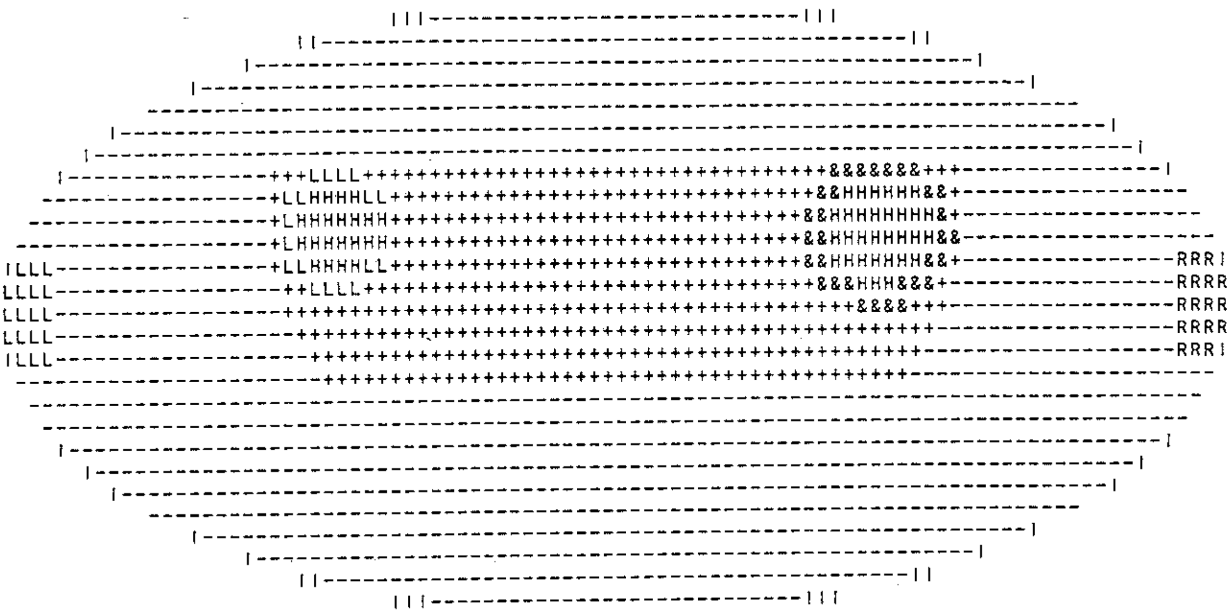
Z = 52.0 cm

Z = 38.0 cm

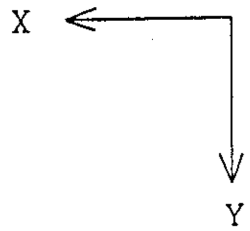


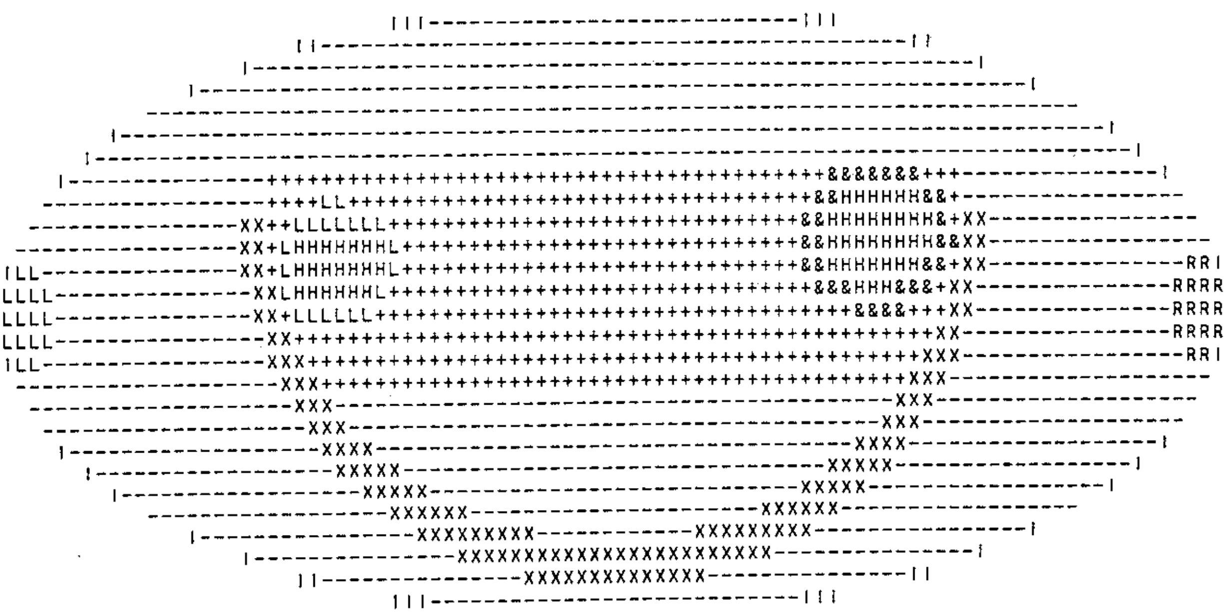


Z = 30.0 cm

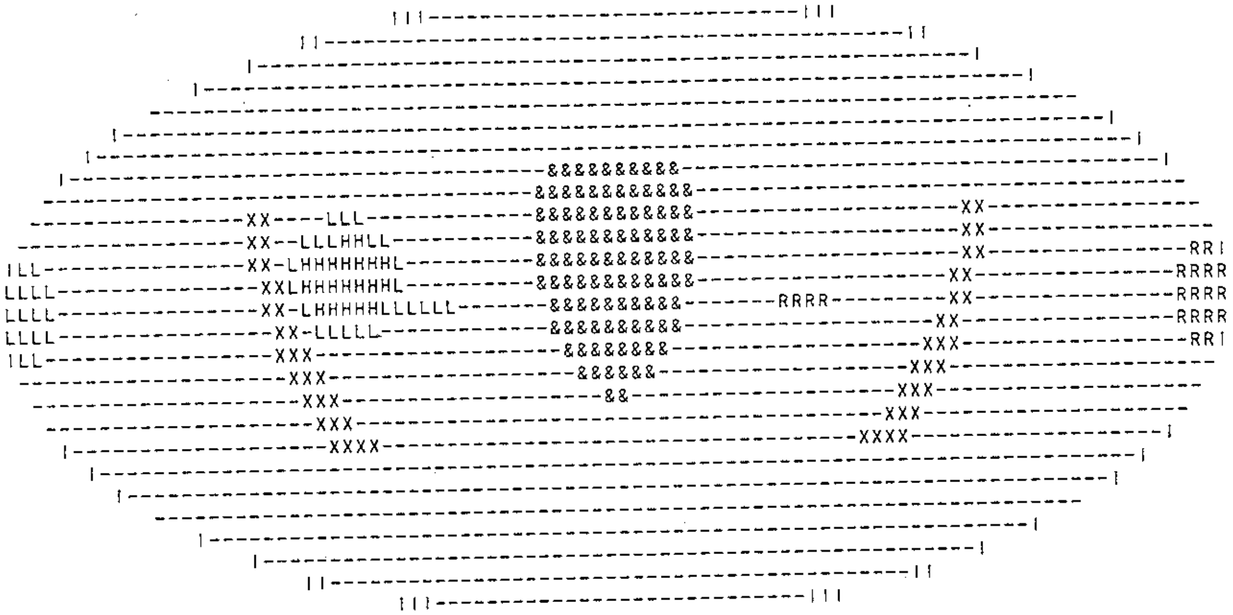


Z = 24.0 cm

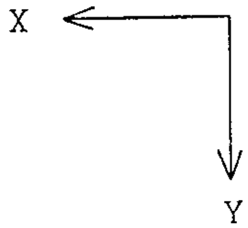


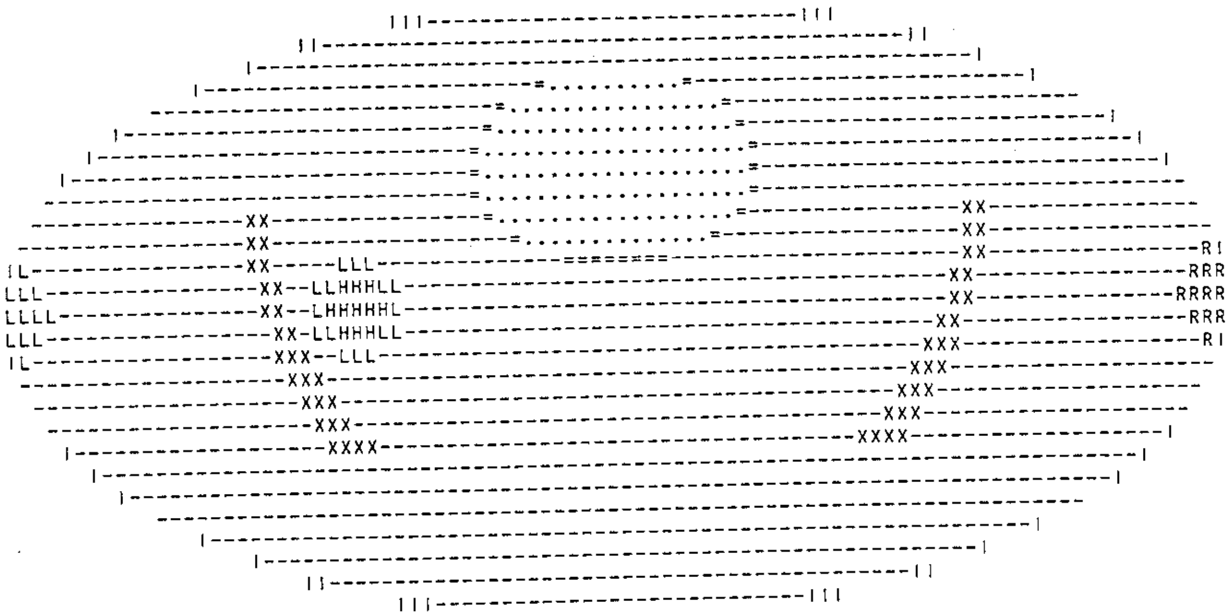


Z = 20.0 cm

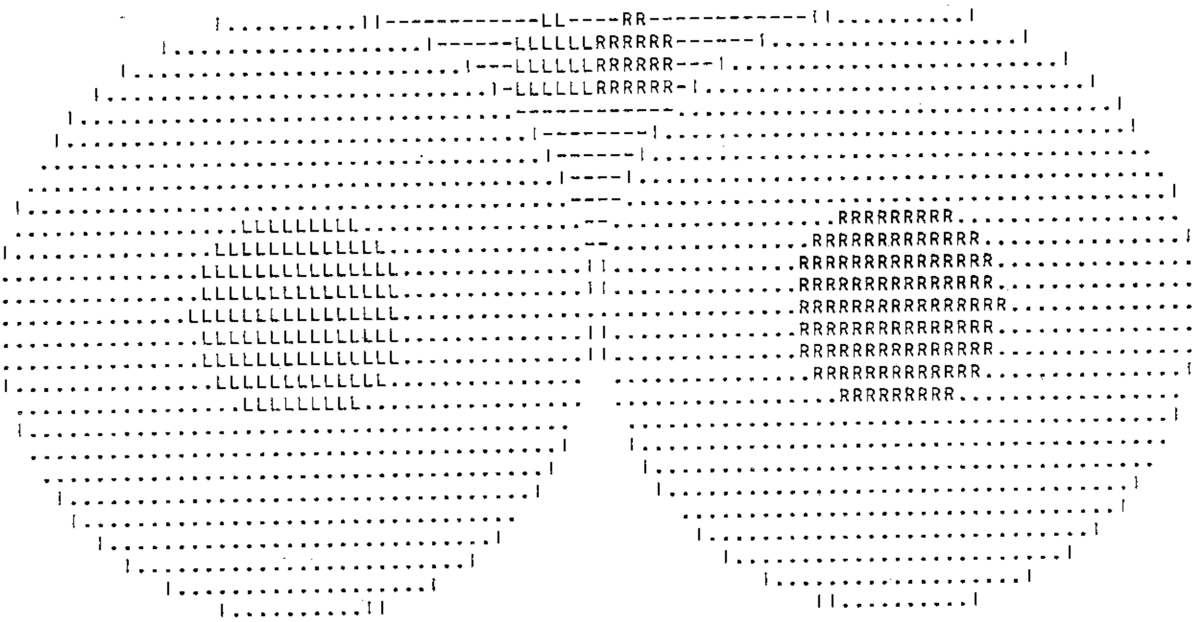


Z = 14.0 cm

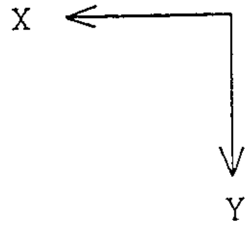


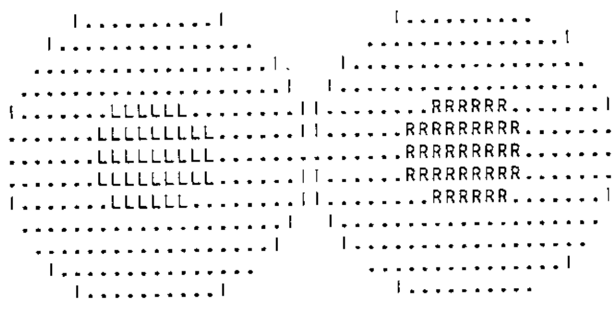


Z = 7.0 cm



Z = −2.3 cm





Z = −50.0 cm

Appendix C Output List for Sample Problem

```
*************************************************
**       PRE-PROCESSOR FOR PHANTOM89           **
*************************************************


     IOPT = 0  (PHANTOM OF FIXED DESIGN)
      SEX  = M
    IPICT = 0  (OUTPUT FOR PHANTOM89)
    INEUT = 0  (GAMMA RAY RADIATION)
    ISO   = 0  (POINT SOURCE)


&MORSE
ISO=0,RSO=200.000000,THSO=90.0000000,ETSO=270.000000,NBAT=3000,NPART=300,IGRP=11,ICUT=21,ICUTN=42,
&END



******* DETECTOR NUMBER : 1
        VX  =       3.59 VY  =     -9.93 VZ  =     57.50
        A1X =       0.71 A1Y =     -0.71 A1Z =      0.0
        A2X =       3.53 A2Y =      3.54 A2Z =      0.0
        A3X =       0.0  A3Y =      0.0  A3Z =      5.00


******* GEOMETRICAL PARAMETERS  FOR BREAST ********
        A  =    4.86  B =    4.90  C =    4.06
        AT =   20.00 BT =   10.00 SKN=    0.20
        XO =   10.00 ZO =   52.00
******* BREAST VOLUME & BREAST SKIN VOLUME *******
        BREAST VOLUME(EXCLUDING SKIN)........   1.8238E+02
        TRUNK SKIN VOLUME COVERED BY BREAST..   1.2419E+01
        BREAST SKIN VOLUME...................   2.6466E+01
```

```
****************************************************
          EVALUATION OF DOSE EQUIVALENT
****************************************************
 DATE: 90-11-20 TIME(H:M): 15: 3

 MOVABLE/FIXED (1/0).......................    0
 NEUTRON SOURCE YES/NO (1/0,-1)...........    0
 SEX......................................    M
 BREAST HEIGHT............................  4.9

******* DETECTOR NUMBER : 1
        ZDS =      5.00 ADS =      5.00 BDS =      1.00 YDS =      1.00 DTX =      5.00 DTZ =     60.00
```

```
*** INPUT DATA FROM MORSEX  ***
    NO. OF BATCH.......................    3000
    NO. OF PARTICLES FOR EACH BATCH....     300
    NO. OF SOURCE PARTICLES............  900000
    AVE. SOURCE PARTICLE ENERGY(KEV)...  9.000E+01
    THE NUMBER OF PRIMARY PART. GROUPS.       0
    (RADIATION FROM POINT SOURCE)
         SOURCE POSITION X(CM).........     0.0
                         Y(CM).........  -200.0
                         Z(CM).........     0.0
                         R(CM).........   200.0
                     THETA(DEG.).......    90.0
                       ETA(DEG.).......   -90.0
    EXPOSURE(ROENTGEN) ................  1.01E-09

----- AVERAGE FLUENCE(CM**(-2)) FOR EACH REGION -----
     REGION NUMBER =  1 TOTAL   FLUENCE =  1.590E+01 S.D.=  2.934E-01 MEDIUM NO. =  3 VOLUME =  1.346E+03
     REGION NUMBER =  2 TOTAL   FLUENCE =  1.713E+01 S.D.=  1.544E+00 MEDIUM NO. =  3 VOLUME =  7.855E+00
     REGION NUMBER =  3 TOTAL   FLUENCE =  1.565E+01 S.D.=  1.472E+00 MEDIUM NO. =  3 VOLUME =  7.855E+00
     REGION NUMBER =  4 TOTAL   FLUENCE =  4.218E+01 S.D.=  1.430E+00 MEDIUM NO. =  3 VOLUME =  1.014E+01
     REGION NUMBER =  5 TOTAL   FLUENCE =  4.243E+01 S.D.=  1.406E+00 MEDIUM NO. =  3 VOLUME =  5.355E+01
     REGION NUMBER =  6 TOTAL   FLUENCE =  4.843E+01 S.D.=  9.990E-01 MEDIUM NO. =  3 VOLUME =  4.573E+01
     REGION NUMBER =  7 TOTAL   FLUENCE =  4.942E+01 S.D.=  1.000E+00 MEDIUM NO. =  3 VOLUME =  2.026E+02
     REGION NUMBER =  8 TOTAL   FLUENCE =  4.431E+01 S.D.=  7.213E-01 MEDIUM NO. =  3 VOLUME =  1.519E+02
     REGION NUMBER =  9 TOTAL   FLUENCE =  4.043E+01 S.D.=  5.990E-01 MEDIUM NO. =  3 VOLUME =  2.119E+02
     REGION NUMBER = 10 TOTAL   FLUENCE =  3.486E+01 S.D.=  6.201E-01 MEDIUM NO. =  3 VOLUME =  1.604E+02
     REGION NUMBER = 11 TOTAL   FLUENCE =  4.135E+01 S.D.=  4.774E-01 MEDIUM NO. =  3 VOLUME =  6.110E+02
     REGION NUMBER = 12 TOTAL   FLUENCE =  3.675E+01 S.D.=  4.241E-01 MEDIUM NO. =  3 VOLUME =  1.054E+03
     REGION NUMBER = 13 TOTAL   FLUENCE =  4.168E+01 S.D.=  5.832E-01 MEDIUM NO. =  3 VOLUME =  7.392E+02
     REGION NUMBER = 14 TOTAL   FLUENCE =  1.517E+01 S.D.=  5.568E-01 MEDIUM NO. =  3 VOLUME =  1.440E+02
     REGION NUMBER = 15 TOTAL   FLUENCE =  1.471E+01 S.D.=  5.384E-01 MEDIUM NO. =  3 VOLUME =  1.440E+02
     REGION NUMBER = 16 TOTAL   FLUENCE =  3.760E+01 S.D.=  3.800E-01 MEDIUM NO. =  3 VOLUME =  1.833E+03
     REGION NUMBER = 17 TOTAL   FLUENCE =  2.869E+01 S.D.=  3.884E-01 MEDIUM NO. =  1 VOLUME =  1.560E+03
     REGION NUMBER = 18 TOTAL   FLUENCE =  3.084E+01 S.D.=  3.922E-01 MEDIUM NO. =  1 VOLUME =  1.810E+03
     REGION NUMBER = 19 TOTAL   FLUENCE =  2.327E+01 S.D.=  6.865E-01 MEDIUM NO. =  3 VOLUME =  1.759E+02
     REGION NUMBER = 20 TOTAL   FLUENCE =  2.894E+01 S.D.=  9.641E-01 MEDIUM NO. =  3 VOLUME =  6.107E+01
     REGION NUMBER = 21 TOTAL   FLUENCE =  4.873E+01 S.D.=  2.040E+00 MEDIUM NO. =  3 VOLUME =  2.011E+01
     REGION NUMBER = 22 TOTAL   FLUENCE =  4.345E+01 S.D.=  1.950E+00 MEDIUM NO. =  3 VOLUME =  1.989E+01
     REGION NUMBER = 23 TOTAL   FLUENCE =  3.890E+01 S.D.=  3.468E+00 MEDIUM NO. =  3 VOLUME =  9.183E-01
     REGION NUMBER = 24 TOTAL   FLUENCE =  3.544E+01 S.D.=  3.538E+00 MEDIUM NO. =  3 VOLUME =  9.183E-01
     REGION NUMBER = 25 TOTAL   FLUENCE =  3.524E+01 S.D.=  1.074E+00 MEDIUM NO. =  3 VOLUME =  1.090E+01
     REGION NUMBER = 26 TOTAL   FLUENCE =  2.457E+01 S.D.=  7.948E-01 MEDIUM NO. =  3 VOLUME =  2.110E+01
     REGION NUMBER = 27 TOTAL   FLUENCE =  1.586E+01 S.D.=  2.562E-01 MEDIUM NO. =  2 VOLUME =  6.176E+02
     REGION NUMBER = 28 TOTAL   FLUENCE =  2.249E+01 S.D.=  3.758E-01 MEDIUM NO. =  2 VOLUME =  3.051E+02
     REGION NUMBER = 29 TOTAL   FLUENCE =  8.400E+00 S.D.=  3.848E-01 MEDIUM NO. =  2 VOLUME =  1.656E+02
     REGION NUMBER = 30 TOTAL   FLUENCE =  1.193E+01 S.D.=  2.651E-01 MEDIUM NO. =  2 VOLUME =  5.482E+02
     REGION NUMBER = 31 TOTAL   FLUENCE =  8.717E+00 S.D.=  3.530E-01 MEDIUM NO. =  2 VOLUME =  2.058E+02
     REGION NUMBER = 32 TOTAL   FLUENCE =  3.653E+01 S.D.=  1.005E+00 MEDIUM NO. =  2 VOLUME =  5.470E+01
     REGION NUMBER = 33 TOTAL   FLUENCE =  1.005E+01 S.D.=  2.570E-01 MEDIUM NO. =  2 VOLUME =  2.014E+02
     REGION NUMBER = 34 TOTAL   FLUENCE =  2.304E+01 S.D.=  6.225E-01 MEDIUM NO. =  2 VOLUME =  1.803E+02
     REGION NUMBER = 35 TOTAL   FLUENCE =  2.759E+01 S.D.=  7.592E-01 MEDIUM NO. =  2 VOLUME =  1.355E+02
     REGION NUMBER = 36 TOTAL   FLUENCE =  2.838E+01 S.D.=  6.338E-01 MEDIUM NO. =  2 VOLUME =  1.622E+02
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REGION NUMBER =  37 TOTAL    FLUENCE =   2.385E+01 S.D.=   6.459E-01 MEDIUM NO. =   2 VOLUME =   1.803E+02
REGION NUMBER =  38 TOTAL    FLUENCE =   2.769E+01 S.D.=   7.554E-01 MEDIUM NO. =   2 VOLUME =   1.355E+02
REGION NUMBER =  39 TOTAL    FLUENCE =   2.870E+01 S.D.=   6.425E-01 MEDIUM NO. =   2 VOLUME =   1.622E+02
REGION NUMBER =  40 TOTAL    FLUENCE =   2.347E+01 S.D.=   4.762E-01 MEDIUM NO. =   2 VOLUME =   3.883E+02
REGION NUMBER =  41 TOTAL    FLUENCE =   2.533E+01 S.D.=   4.057E-01 MEDIUM NO. =   2 VOLUME =   5.681E+02
REGION NUMBER =  42 TOTAL    FLUENCE =   2.755E+01 S.D.=   4.308E-01 MEDIUM NO. =   2 VOLUME =   4.433E+02
REGION NUMBER =  43 TOTAL    FLUENCE =   2.270E+01 S.D.=   4.784E-01 MEDIUM NO. =   2 VOLUME =   3.883E+02
REGION NUMBER =  44 TOTAL    FLUENCE =   2.604E+01 S.D.=   4.163E-01 MEDIUM NO. =   2 VOLUME =   5.681E+02
REGION NUMBER =  45 TOTAL    FLUENCE =   2.638E+01 S.D.=   4.149E-01 MEDIUM NO. =   2 VOLUME =   4.433E+02
REGION NUMBER =  46 TOTAL    FLUENCE =   1.976E+01 S.D.=   2.516E-01 MEDIUM NO. =   2 VOLUME =   6.061E+02
REGION NUMBER =  47 TOTAL    FLUENCE =   2.791E+01 S.D.=   1.952E-01 MEDIUM NO. =   2 VOLUME =   6.940E+02
REGION NUMBER =  48 TOTAL    FLUENCE =   2.261E+01 S.D.=   2.508E-01 MEDIUM NO. =   3 VOLUME =   2.537E+03
REGION NUMBER =  49 TOTAL    FLUENCE =   3.052E+01 S.D.=   9.286E-02 MEDIUM NO. =   3 VOLUME =   3.040E+04
REGION NUMBER =  50 TOTAL    FLUENCE =   3.023E+01 S.D.=   1.177E-01 MEDIUM NO. =   3 VOLUME =   1.679E+04
REGION NUMBER =  51 TOTAL    FLUENCE =   2.014E+01 S.D.=   2.807E-01 MEDIUM NO. =   3 VOLUME =   2.648E+02
REGION NUMBER =  52 TOTAL    FLUENCE =   2.745E+01 S.D.=   1.107E-01 MEDIUM NO. =   3 VOLUME =   1.439E+03
REGION NUMBER =  53 TOTAL    FLUENCE =   2.635E+01 S.D.=   1.301E-01 MEDIUM NO. =   3 VOLUME =   1.358E+03
REGION NUMBER =  54 TOTAL    FLUENCE =   4.254E+01 S.D.=   9.360E-01 MEDIUM NO. =   3 VOLUME =   1.824E+02
REGION NUMBER =  55 TOTAL    FLUENCE =   3.999E+01 S.D.=   8.935E-01 MEDIUM NO. =   3 VOLUME =   1.824E+02
REGION NUMBER =  56 TOTAL    FLUENCE =   5.513E+01 S.D.=   2.472E+00 MEDIUM NO. =   3 VOLUME =   1.879E+01
REGION NUMBER =  57 TOTAL    FLUENCE =   5.700E+01 S.D.=   2.510E+00 MEDIUM NO. =   3 VOLUME =   1.879E+01
REGION NUMBER =  58 TOTAL    FLUENCE =   1.706E+01 S.D.=   1.417E+00 MEDIUM NO. =   3 VOLUME =   8.378E+00
REGION NUMBER =  59 TOTAL    FLUENCE =   1.662E+01 S.D.=   1.399E+00 MEDIUM NO. =   3 VOLUME =   8.378E+00
REGION NUMBER =  60 TOTAL    FLUENCE =   3.880E+01 S.D.=   1.343E+00 MEDIUM NO. =   3 VOLUME =   6.627E+01
REGION NUMBER =  61 TOTAL    FLUENCE =   1.030E+09 S.D.=   5.094E+05 MEDIUM NO. =   4 VOLUME =   1.000E+00
REGION NUMBER =  62 TOTAL    FLUENCE =   0.0       S.D.=   0.0       MEDIUM NO. =   0 VOLUME =   1.000E+00

----- AVERAGE FLUENCE (CM**(-2)) FOR DOSIMETERS -----

REGION NUMBER =  63 IG =  11 FLUENCE =   9.585E+00 S.D.=   7.105E-01 MEDIUM NO. =   3
                 63       12 FLUENCE =   2.020E+00 S.D.=   3.577E-01
                 63       13 FLUENCE =   4.717E-01 S.D.=   1.211E-01
                 63       14 FLUENCE =   5.609E-02 S.D.=   2.656E-02
                 63       15 FLUENCE =   6.293E-02 S.D.=   3.231E-02
                 63       16 FLUENCE =   2.841E-02 S.D.=   2.256E-02
                 63       17 FLUENCE =   0.0       S.D.=   0.0
                 63       18 FLUENCE =   0.0       S.D.=   0.0
                 63       19 FLUENCE =   0.0       S.D.=   0.0
                 63       20 FLUENCE =   0.0       S.D.=   0.0
                 63       21 FLUENCE =   0.0       S.D.=   0.0
REGION NUMBER =  63 TOTAL    FLUENCE =   1.222E+01 S.D.=   8.060E-01 MEDIUM NO. =   3 VOLUME =   2.500E+01
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** KERMA FACTORS FOR GAMMA RAY **
   UNIT: CGY*(CM**2)/PHOTON

MEDIUM NUMBER :    1  (LUNG)

  2.1200E-09  1.4000E-09  9.3900E-10  6.4500E-10  4.1300E-10  2.6700E-10
  1.7200E-10  1.1200E-10  7.1700E-11  4.7700E-11  3.6800E-11  3.1500E-11
  3.2000E-11  3.8900E-11  5.3200E-11  7.9500E-11  1.3300E-10  2.5500E-10
  5.3800E-10  1.0700E-09  2.1300E-09

MEDIUM NUMBER :    2  (SKELETAL TISSUE)

  2.1700E-09  1.3800E-09  9.1800E-10  6.2700E-10  4.0200E-10  2.6100E-10
  1.6900E-10  1.1200E-10  7.6300E-11  6.0100E-11  5.8500E-11  6.8300E-11
  9.3600E-11  1.3700E-10  2.0400E-10  3.1100E-10  5.1200E-10  9.2700E-10
  1.8100E-09  3.3100E-09  5.8800E-09

MEDIUM NUMBER :    3  (SOFT TISSUE)

  2.1100E-09  1.3900E-09  9.4500E-10  6.4700E-10  4.1400E-10  2.6800E-10
  1.7300E-10  1.1200E-10  7.1600E-11  4.7400E-11  3.6100E-11  3.0400E-11
  3.0000E-11  3.5600E-11  4.7900E-11  7.1000E-11  1.1900E-10  2.2700E-10
  4.8000E-10  9.5500E-10  1.9200E-09

MEDIUM NUMBER :    4  (RED MARROW)

  2.0900E-09  1.3400E-09  9.4100E-10  6.4700E-10  4.1400E-10  2.6800E-10
  1.7300E-10  1.1200E-10  7.1500E-11  4.6900E-11  3.5400E-11  2.9200E-11
  2.7900E-11  3.2000E-11  4.2100E-11  6.1400E-11  1.0200E-10  1.9400E-10
  4.0900E-10  8.1300E-10  1.6200E-09

MEDIUM NUMBER :    5  (YERROW MARROW)

  2.0800E-09  1.4000E-09  9.4900E-10  6.5400E-10  4.1800E-10  2.7000E-10
  1.7400E-10  1.1300E-10  7.1700E-11  4.6400E-11  3.4200E-11  2.6800E-11
  2.3700E-11  2.5000E-11  3.1100E-11  4.3900E-11  7.1700E-10  1.3700E-10
  2.9300E-10  5.8800E-10  1.2100E-09
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***** DOSE EQUIVALENT FOR EACH REGION *****

NUMBER OF ORGANS = 60 NUMBER OF DOSIMETERS = 1

REG.NO.	ORGAN NAME	D.E.(CSV/R)	D.E. STD	D.E. FSD	COLLISIONS	MASS(GRAM)	E(G.CGY/R)	STD OF E	EXPOSURE	FLUENCE
1	BRAIN	5.4083E-01	1.0011E-02	1.8511E-02	4.2291E+03	1.3284E+03	7.1843E+02	1.3299E+01	1.0059E-09	1.590E+01
2	LEFT ADRENAL	5.8745E-01	5.1768E-02	8.8124E-02	3.6624E+01	7.7521E+00	4.5540E+00	4.0131E-01	1.0059E-09	1.713E+01
3	RIGHT ADRENAL	5.3816E-01	5.0282E-02	9.3432E-02	2.5690E+01	7.7521E+00	4.1719E+00	3.8979E-01	1.0059E-09	1.565E+01
4	GALL BLADDER	1.4646E+00	4.8838E-02	3.3346E-02	9.4877E+01	1.0007E+01	1.4656E+01	4.8873E-01	1.0059E-09	4.218E+01
5	GALL CONTENTS	1.4747E+00	4.8395E-02	3.2816E-02	4.9467E+02	5.2848E+01	7.7937E+01	2.5576E+00	1.0059E-09	4.243E+01
6	UR.BLADDER	1.6720E+00	3.4173E-02	2.0438E-02	4.4529E+02	4.5131E+01	7.5461E+01	1.5423E+00	1.0059E-09	4.843E+01
7	UR.BL.CONTS	1.7102E+00	3.4260E-02	2.0033E-02	2.0719E+03	1.9995E+02	3.4195E+02	6.8502E+00	1.0059E-09	4.942E+01
8	G.I. STOMACH	1.5269E+00	2.4518E-02	1.6057E-02	1.3931E+03	1.4991E+02	2.2889E+02	3.6754E+00	1.0059E-09	4.431E+01
9	G.I. U.L.I.	1.4019E+00	2.0512E-02	1.4631E-02	1.8262E+03	2.0912E+02	2.9317E+02	4.2895E+00	1.0059E-09	4.043E+01
10	G.I. L.L.I.	1.1981E+00	2.0915E-02	1.7456E-02	1.1674E+03	1.5830E+02	1.8966E+02	3.3108E+00	1.0059E-09	3.486E+01
11	G.I. CONTENTS	1.4247E+00	1.6181E-02	1.1358E-02	5.1706E+03	6.0300E+02	8.5910E+02	9.7573E+00	1.0059E-09	4.135E+01
12	SM.INT,+CONTS	1.2746E+00	1.4431E-02	1.1322E-02	8.0833E+03	1.0402E+03	1.3259E+03	1.5011E+01	1.0059E-09	3.675E+01
13	HEART	1.4345E+00	1.9915E-02	1.3882E-02	6.2575E+03	7.2952E+02	1.0465E+03	1.4528E+01	1.0059E-09	4.168E+01
14	LEFT KIDNEY	5.3421E-01	1.9095E-02	3.5745E-02	4.8655E+02	1.4211E+02	7.5919E+01	2.7137E+00	1.0059E-09	1.517E+01
15	RIGHT KIDNEY	5.1360E-01	1.8404E-02	3.5833E-02	4.1610E+02	1.4211E+02	7.2990E+01	2.6155E+00	1.0059E-09	1.471E+01
16	LIVER	1.2906E+00	1.2915E-02	1.0007E-02	1.3876E+04	1.8090E+03	2.3346E+03	2.3363E+01	1.0059E-09	3.760E+01
17	LEFT LUNG	1.0331E+00	1.3910E-02	1.3464E-02	2.7883E+03	4.6145E+02	4.7673E+02	6.4189E+00	1.0059E-09	2.869E+01
18	RIGHT LUNG	1.1084E+00	1.4007E-02	1.2638E-02	3.4273E+03	5.3540E+02	5.9341E+02	7.4996E+00	1.0059E-09	3.084E+01
19	PANCREAS	8.0487E-01	2.3205E-02	2.8831E-02	8.2125E+02	1.7360E+02	1.3972E+02	4.0283E+00	1.0059E-09	2.327E+01
20	SPLEEN	1.0229E+00	3.3537E-02	3.2785E-02	3.6313E+02	6.0270E+01	6.1651E+01	2.0213E+00	1.0059E-09	2.894E+01
21	THYMUS	1.6568E+00	6.8534E-02	4.1366E-02	2.0087E+02	1.9847E+01	3.2882E+01	1.3602E+00	1.0059E-09	4.873E+01
22	THYROID	1.4940E+00	6.6628E-02	4.4597E-02	1.5900E+02	1.9629E+01	2.9326E+01	1.3079E+00	1.0059E-09	4.345E+01
23	L. EYE LENSE	1.3414E+00	1.1950E-01	8.9087E-02	6.1023E+00	9.0627E-01	1.2156E+00	1.0830E-01	1.0059E-09	3.890E+01
24	R. EYE LENSE	1.1975E+00	1.1667E-01	9.7427E-02	9.8578E+00	9.0627E-01	1.0852E+00	1.0573E-01	1.0059E-09	3.544E+01
25	F.EYE REGION	1.2111E+00	3.6438E-02	3.0087E-02	7.6324E+01	1.0757E+01	1.3028E+01	3.9197E-01	1.0059E-09	3.524E+01
26	R.EYE REGION	8.3108E-01	2.6478E-02	3.1860E-02	9.0330E+01	2.0824E+01	1.7306E+01	5.5136E-01	1.0059E-09	2.457E+01
27	CRANIUM	1.1345E+00	1.7358E-02	1.5301E-02	3.3597E+03	9.0676E+02	1.0287E+03	1.5740E+01	1.0059E-09	1.586E+01
28	FACIAL SKEL	1.5726E+00	2.5832E-02	1.6426E-02	2.2040E+03	4.4795E+02	7.0444E+02	1.1571E+01	1.0059E-09	2.249E+01
29	UPP.SPINE	6.8930E-01	3.0095E-02	4.3661E-02	5.2898E+02	2.4313E+02	1.6759E+02	7.3171E+00	1.0059E-09	8.400E+00
30	MID.SPINE	1.0375E+00	2.1555E-02	2.0776E-02	2.5552E+03	8.0487E+02	8.3502E+02	1.7349E+01	1.0059E-09	1.193E+01
31	LOW.SPINE	7.6481E-01	2.8803E-02	3.7660E-02	6.9659E+02	3.0216E+02	2.3109E+02	8.7029E+00	1.0059E-09	8.717E+00
32	CLAVICLES	2.5854E+00	7.0930E-02	2.7435E-02	6.6499E+02	8.0311E+01	2.0764E+02	5.6964E+00	1.0059E-09	3.653E+01
33	SCAPULAE	7.9734E-01	2.0360E-02	2.5535E-02	7.5822E+02	2.9570E+02	2.3577E+02	6.0203E+00	1.0059E-09	1.005E+01
34	UP,L.ARM	1.6012E+00	4.1815E-02	2.6115E-02	1.3792E+03	2.6472E+02	4.2387E+02	1.1069E+01	1.0059E-09	2.304E+01
35	MID.L.ARM	1.9114E+00	5.0414E-02	2.6375E-02	1.1744E+03	1.9894E+02	3.8027E+02	1.0029E+01	1.0059E-09	2.759E+01
36	LOW.L.ARM	1.9812E+00	4.2920E-02	2.1663E-02	1.5197E+03	2.3814E+02	4.7182E+02	1.0221E+01	1.0059E-09	2.838E+01
37	UP,R.ARM	1.6473E+00	4.2934E-02	2.6064E-02	1.3599E+03	2.6472E+02	4.3607E+02	1.1365E+01	1.0059E-09	2.385E+01
38	MID,R.ARM	1.9231E+00	5.0522E-02	2.6271E-02	1.1509E+03	1.9894E+02	3.8259E+02	1.0051E+01	1.0059E-09	2.769E+01
39	LOW,R.ARM	1.9968E+00	4.3553E-02	2.1812E-02	1.5025E+03	2.3814E+02	4.7551E+02	1.0372E+01	1.0059E-09	2.870E+01
40	UP,L.LEG	1.8575E+00	3.5405E-02	1.9061E-02	3.4153E+03	5.7010E+02	1.0590E+03	2.0185E+01	1.0059E-09	2.347E+01
41	MID,L.LEG	1.9309E+00	2.9587E-02	1.5323E-02	5.0686E+03	8.3408E+02	1.6105E+03	2.4678E+01	1.0059E-09	2.533E+01
42	LOW,L.LEG	1.9610E+00	3.0190E-02	1.5395E-02	4.1161E+03	6.5085E+02	1.2763E+03	1.9649E+01	1.0059E-09	2.755E+01
43	UP,R.LEG	1.7910E+00	3.5333E-02	1.9728E-02	3.2259E+03	5.7010E+02	1.0211E+03	2.0143E+01	1.0059E-09	2.270E+01
44	MID,R.LEG	1.9910E+00	3.0355E-02	1.5246E-02	5.2358E+03	8.3408E+02	1.6606E+03	2.5319E+01	1.0059E-09	2.604E+01
45	LOW,R.LEG	1.8729E+00	2.9054E-02	1.5513E-02	3.8300E+03	6.5085E+02	1.2190E+03	1.8910E+01	1.0059E-09	2.638E+01
46	PELVIS	1.6847E+00	2.0405E-02	1.2112E-02	4.6591E+03	8.8988E+02	1.4992E+03	1.8158E+01	1.0059E-09	1.976E+01
47	RIBS	2.0729E+00	1.4482E-02	6.9862E-03	6.5264E+03	1.0189E+03	2.1122E+03	1.4756E+01	1.0059E-09	2.791E+01

48	HEAD	7.7238E-01	8.5750E-03	1.1102E-02	1.1280E+04	2.5036E+03	1.9337E+03	2.1468E+01	1.0059E-09	2.261E+01
49	TRUNK	1.0476E+00	3.1584E-03	3.0150E-03	1.8180E+05	3.0003E+04	3.1430E+04	9.4761E+01	1.0059E-09	3.052E+01
50	LEGS	1.0294E+00	3.9965E-03	3.8823E-03	9.7883E+04	1.6567E+04	1.7054E+04	6.6208E+01	1.0059E-09	3.023E+01
51	HEAD SKIN	6.9471E-01	9.8190E-03	1.4134E-02	9.5047E+02	2.6133E+02	1.8155E+02	2.5660E+00	1.0059E-09	2.014E+01
52	TRUNK SKIN	9.4268E-01	3.7557E-03	3.9840E-03	7.6919E+03	1.4204E+03	1.3390E+03	5.3344E+00	1.0059E-09	2.745E+01
53	LEG SKIN	9.0578E-01	4.4771E-03	4.9428E-03	6.8356E+03	1.3402E+03	1.2139E+03	6.0002E+00	1.0059E-09	2.635E+01
54	LEFT BREAST	1.4464E+00	3.1806E-02	2.1990E-02	1.4554E+03	1.7999E+02	2.6033E+02	5.7247E+00	1.0059E-09	4.254E+01
55	RIGHT BREAST	1.3636E+00	3.0444E-02	2.2327E-02	1.4741E+03	1.7999E+02	2.4543E+02	5.4795E+00	1.0059E-09	3.999E+01
56	LEFT TESTIS	1.8675E+00	8.3783E-02	4.4864E-02	1.9303E+02	1.8544E+01	3.4630E+01	1.5537E+00	1.0059E-09	5.513E+01
57	RIGHT TESTIS	1.9150E+00	8.3883E-02	4.3803E-02	2.0933E+02	1.8544E+01	3.5511E+01	1.5555E+00	1.0059E-09	5.700E+01
58	LEFT OVARY	5.8821E-01	4.7663E-02	8.1031E-02	3.0477E+01	8.2682E+00	4.8634E+00	3.9409E-01	1.0059E-09	1.706E+01
59	RIGHT OVARY	5.7859E-01	4.7351E-02	8.1839E-02	3.7588E+01	8.2682E+00	4.7839E+00	3.9151E-01	1.0059E-09	1.662E+01
60	UTERUS	1.3399E+00	4.6013E-02	3.4341E-02	5.5047E+02	6.5402E+01	8.7630E+01	3.0093E+00	1.0059E-09	3.880E+01
63	DOSIMETER1	4.2610E-01	2.8032E-02	6.5788E-02	5.1983E+01	2.4672E+01	1.0513E+01	6.9162E-01	1.0059E-09	1.222E+01
64	TOTALBODY	1.1306E+00	2.0093E-03	1.7772E-03	4.1934E+05	7.1016E+04	8.0293E+04	1.4270E+02	1.0059E-09	2.945E+01

***** DOSE EQUIVALENT FOR RED & YERROW MARROWS *****

REG.NO.	ORGAN NAME	D.E.(CSV/R)	D.E. STD	D.E. FSD	COLLISIONS	MASS(GRAM)	E(G.CGY/R)	STD OF E	EXPOSURE	FLUENCE
27	CRANIUM	1.1345E+00	1.7358E-02	1.5301E-02	3.3597E+03	9.0676E+02	1.0287E+03	1.5740E+01	1.0059E-09	1.586E+01
	RM CRANIUM	5.1907E-01	8.5416E-03	1.6456E-02	1.8714E+02	5.0507E+01	2.6216E+01	4.3141E-01		
	YM CRANIUM	4.8723E-01	8.3090E-03	1.7053E-02	1.4312E+02	3.8628E+01	1.8821E+01	3.2096E-01		
28	FACIAL SKEL	1.5726E+00	2.5832E-02	1.6426E-02	2.2040E+03	4.4795E+02	7.0444E+02	1.1571E+01	1.0059E-09	2.249E+01
	RM FACIAL SK	7.3726E-01	1.2385E-02	1.6799E-02	6.0609E+01	1.2319E+01	9.0819E+00	1.5257E-01		
	YM FACIAL SK	6.9018E-01	1.1773E-02	1.7057E-02	4.6063E+01	9.3621E+00	6.4616E+00	1.1022E-01		
29	UPP.SPINE	6.8930E-01	3.0095E-02	4.3661E-02	5.2898E+02	2.4313E+02	1.6759E+02	7.3171E+00	1.0059E-09	8.400E+00
	RM UPP.SPINE	2.6689E-01	1.2376E-02	4.6372E-02	1.4071E+01	6.4674E+00	1.7261E+00	8.0042E-02		
	YM UPP.SPINE	2.4150E-01	1.1477E-02	4.7525E-02	2.8036E+00	1.2886E+00	3.1120E-01	1.4790E-02		
30	MID.SPINE	1.0375E+00	2.1555E-02	2.0776E-02	2.5552E+03	8.0487E+02	8.3502E+02	1.7349E+01	1.0059E-09	1.193E+01
	RM MID.SPINE	3.8003E-01	8.4539E-03	2.2245E-02	4.4486E+02	1.4013E+02	5.3253E+01	1.1846E+00		
	YM MID.SPINE	3.4473E-01	7.9685E-03	2.3115E-02	8.9431E+02	2.8170E+02	9.7113E+01	2.2448E+00		
31	LOW.SPINE	7.6481E-01	2.8803E-02	3.7660E-02	6.9659E+02	3.0216E+02	2.3109E+02	8.7029E+00	1.0059E-09	8.717E+00
	RM LOW.SPINE	2.7970E-01	1.1342E-02	4.0549E-02	6.8196E+01	2.9581E+01	8.2739E+00	3.3550E-01		
	YM LOW.SPINE	2.5527E-01	1.0756E-02	4.2136E-02	1.3723E+01	5.9525E+00	1.5195E+00	6.4023E-02		
32	CLAVICLES	2.5854E+00	7.0930E-02	2.7435E-02	6.6499E+02	8.0311E+01	2.0764E+02	5.6964E+00	1.0059E-09	3.653E+01
	RM CLAVICLES	1.1991E+00	3.3139E-02	2.7637E-02	5.2534E+00	6.3445E-01	7.6077E-01	2.1025E-02		
	YM CLAVICLES	1.1249E+00	3.1697E-02	2.8179E-02	4.9874E+00	6.0233E-01	6.7753E-01	1.9092E-02		
33	SCAPULAE	7.9734E-01	2.0360E-02	2.5535E-02	7.5822E+02	2.9570E+02	2.3577E+02	6.0203E+00	1.0059E-09	1.005E+01
	RM SCAPULAE	3.2586E-01	8.2749E-03	2.5394E-02	2.1609E+01	8.4273E+00	2.7461E+00	6.9735E-02		
	YM SCAPULAE	3.0293E-01	8.1715E-03	2.6975E-02	1.6453E+01	6.4166E+00	1.9437E+00	5.2433E-02		
34	UP,L.ARM	1.6012E+00	4.1815E-02	2.6115E-02	1.3792E+03	2.6472E+02	4.2387E+02	1.1069E+01	1.0059E-09	2.304E+01
	RM UP,L.ARM	7.5342E-01	2.0703E-02	2.7478E-02	3.1584E+01	6.0620E+00	4.5673E+00	1.2550E-01		
	YM UP,L.ARM	7.0576E-01	1.9788E-02	2.8038E-02	4.4272E+01	8.4974E+00	5.9971E+00	1.6815E-01		
35	MID.L.ARM	1.9114E+00	5.0414E-02	2.6375E-02	1.1744E+03	1.9894E+02	3.8027E+02	1.0029E+01	1.0059E-09	2.759E+01
	RM MID.L.ARM	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	YM MID.L.ARM	8.4808E-01	2.4127E-02	2.8449E-02	5.0381E+01	8.5346E+00	7.2380E+00	2.0591E-01		
36	LOW.L.ARM	1.9812E+00	4.2920E-02	2.1663E-02	1.5197E+03	2.3814E+02	4.7182E+02	1.0221E+01	1.0059E-09	2.838E+01
	RM LOW.L.ARM	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	YM LOW.L.ARM	8.7525E-01	1.9983E-02	2.2831E-02	1.2188E+02	1.9099E+01	1.6716E+01	3.8165E-01		
37	UP,R.ARM	1.6473E+00	4.2934E-02	2.6064E-02	1.3599E+03	2.6472E+02	4.3607E+02	1.1365E+01	1.0059E-09	2.385E+01
	RM UP,R.ARM	7.8724E-01	2.1699E-02	2.7563E-02	3.1142E+01	6.0620E+00	4.7723E+00	1.3154E-01		
	YM UP,R.ARM	7.4238E-01	2.1149E-02	2.8488E-02	4.3654E+01	8.4974E+00	6.3083E+00	1.7971E-01		
38	MID,R.ARM	1.9231E+00	5.0522E-02	2.6271E-02	1.1509E+03	1.9894E+02	3.8259E+02	1.0051E+01	1.0059E-09	2.769E+01
	RM MID.R.ARM	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	YM MID.R.ARM	8.5714E-01	2.4403E-02	2.8470E-02	4.9374E+01	8.5346E+00	7.3153E+00	2.0827E-01		
39	LOW,R.ARM	1.9968E+00	4.3553E-02	2.1812E-02	1.5025E+03	2.3814E+02	4.7551E+02	1.0372E+01	1.0059E-09	2.870E+01
	RM LOW.R.ARM	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	YM LOW.R.ARM	8.8563E-01	2.0380E-02	2.3011E-02	1.2050E+02	1.9099E+01	1.6915E+01	3.8923E-01		
40	UP,L.LEG	1.8575E+00	3.5405E-02	1.9061E-02	3.4153E+03	5.7010E+02	1.0590E+03	2.0185E+01	1.0059E-09	2.347E+01
	RM UP,L.LEG	7.5084E-01	1.5345E-02	2.0437E-02	1.2124E+02	2.0239E+01	1.5196E+01	3.1056E-01		
	YM UP,L.LEG	6.8707E-01	1.4388E-02	2.0940E-02	1.6052E+02	2.6795E+01	1.8410E+01	3.8551E-01		
41	MID,L.LEG	1.9309E+00	2.9587E-02	1.5323E-02	5.0686E+03	8.3408E+02	1.6105E+03	2.4678E+01	1.0059E-09	2.533E+01
	RM MID.L.LEG	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	YM MID.L.LEG	7.4456E-01	1.2367E-02	1.6609E-02	6.2598E+02	1.0301E+02	7.6697E+01	1.2739E+00		
42	LOW,L.LEG	1.9610E+00	3.0190E-02	1.5395E-02	4.1161E+03	6.5085E+02	1.2763E+03	1.9649E+01	1.0059E-09	2.755E+01
	RM LOW.L.LEG	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	YM LOW.L.LEG	8.3347E-01	1.3262E-02	1.5912E-02	1.3377E+03	2.1153E+02	1.7630E+02	2.8053E+00		

43	UP,R.LEG	1.7910E+00	3.5333E-02	1.9728E-02	3.2259E+03	5.7010E+02	1.0211E+03	2.0143E+01	1.0059E-09	2.270E+01
	RM UP,R.LEG	7.2455E-01	1.5439E-02	2.1308E-02	1.1452E+02	2.0239E+01	1.4664E+01	3.1246E-01		
	YM UP,R.LEG	6.6325E-01	1.4558E-02	2.1950E-02	1.5162E+02	2.6795E+01	1.7772E+01	3.9008E-01		
44	MID,R.LEG	1.9910E+00	3.0355E-02	1.5246E-02	5.2358E+03	8.3408E+02	1.6606E+03	2.5319E+01	1.0059E-09	2.604E+01
	RM MID.R.LEG	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	YM MID.R.LEG	7.6467E-01	1.2609E-02	1.6490E-02	6.4662E+02	1.0301E+02	7.8768E+01	1.2989E+00		
45	LOW,R.LEG	1.8729E+00	2.9054E-02	1.5513E-02	3.8300E+03	6.5085E+02	1.2190E+03	1.8910E+01	1.0059E-09	2.638E+01
	RM LOW.R.LEG	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	YM LOW.R.LEG	7.9761E-01	1.2783E-02	1.6027E-02	1.2448E+03	2.1153E+02	1.6872E+02	2.7040E+00		
46	PELVIS	1.6847E+00	2.0405E-02	1.2112E-02	4.6591E+03	8.8938E+02	1.4992E+03	1.8158E+01	1.0059E-09	1.976E+01
	RM PELVIS	6.3562E-01	8.0643E-03	1.2687E-02	1.5519E+03	2.9642E+02	1.8841E+02	2.3904E+00		
	YM PELVIS	5.8331E-01	7.7249E-03	1.3243E-02	7.4871E+02	1.4300E+02	8.3415E+01	1.1047E+00		
47	RIBS	2.0729E+00	1.4482E-02	6.9862E-03	6.5264E+03	1.0189E+03	2.1122E+03	1.4756E+01	1.0059E-09	2.791E+01
	RM RIBS	9.1156E-01	6.3531E-03	6.9695E-03	1.2544E+03	1.9584E+02	1.7852E+02	1.2442E+00		
	YM RIBS	8.5157E-01	6.2601E-03	7.3513E-03	2.5192E+02	3.9331E+01	3.3493E+01	2.4621E-01		
	RED MARROW	6.4090E-01	3.8307E-03	5.9771E-03	3.9065E+03	7.9292E+02	5.0819E+02	3.0375E+00		
	YERROW MARROW	6.5634E-01	3.9551E-03	6.0261E-03	6.7194E+03	1.2812E+03	8.4091E+02	5.0674E+00		
	SKELETON	1.6602E+00	6.6647E-03	4.0143E-03	5.4931E+04	1.0503E+04	1.7438E+04	7.0002E+01		

***** DOSE EQUIVALENT FOR A PAIR OF ORGANS *****

REG.NO.	ORGAN NAME	D.E.(CSV/R)	D.E. STD	D.E. FSD	COLLISIONS	MASS(GRAM)	E(G.CGY/R)	STD OF E	EXPOSURE	FLUENCE
2	ADRENALS	5.6281E-01	3.6084E-02	6.4114E-02	6.2313E+01	1.5504E+01	8.7259E+00	5.5945E-01	1.0059E-09	1.639E+01
14	KIDNEYS	5.2391E-01	1.3260E-02	2.5310E-02	9.0265E+02	2.8423E+02	1.4891E+02	3.7689E+00	1.0059E-09	1.494E+01
17	LUNGS	1.0735E+00	9.9027E-03	9.2244E-03	6.2155E+03	9.9685E+02	1.0701E+03	9.8714E+00	1.0059E-09	2.984E+01
54	BREASTS	1.4050E+00	2.2014E-02	1.5669E-02	2.9296E+03	3.5998E+02	5.0576E+02	7.9245E+00	1.0059E-09	4.126E+01
56	TESTES	1.8912E+00	5.9279E-02	3.1344E-02	4.0236E+02	3.7088E+01	7.0142E+01	2.1985E+00	1.0059E-09	5.607E+01
58	OVARIES	5.8340E-01	3.3593E-02	5.7581E-02	6.8065E+01	1.6536E+01	9.6473E+00	5.5551E-01	1.0059E-09	1.684E+01

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***** EFFECTIVE DOSE WITH AND WITHOUT BRAIN *****
      EFFECTIVE DOSE EQUIVALENT PER UNIT FLUENCE
      DOSE IN UNIT OF CSV/R

    ORGAN( 1) = TESTES          DOSE =   1.8912E+00   S.D. =   5.9279E-02 F.S.D =   3.1344E-02
    ORGAN( 1) = GONADS(AVE)     DOSE =   1.2373E+00   S.D. =   3.4068E-02 F.S.D =   2.7534E-02
    ORGAN( 2) = BREASTS         DOSE =   1.4050E+00   S.D. =   2.2014E-02 F.S.D =   1.5669E-02
    ORGAN( 3) = RED MARROW      DOSE =   6.4090E-01   S.D. =   3.8307E-03 F.S.D =   5.9771E-03
    ORGAN( 4) = LUNGS           DOSE =   1.0735E+00   S.D. =   9.9027E-03 F.S.D =   9.2244E-03
    ORGAN( 5) = THYROID         DOSE =   1.4940E+00   S.D. =   6.6628E-02 F.S.D =   4.4597E-02
    ORGAN( 6) = SKELETON        DOSE =   1.6602E+00   S.D. =   6.6647E-03 F.S.D =   4.0143E-03

    ORGAN( 1) = UR.BLADDER      DOSE =   1.6720E+00   S.D. =   3.4173E-02 F.S.D =   2.0438E-02
    ORGAN( 2) = THYMUS          DOSE =   1.6568E+00   S.D. =   6.8534E-02 F.S.D =   4.1366E-02
    ORGAN( 3) = G.I. STOMACH    DOSE =   1.5269E+00   S.D. =   2.4518E-02 F.S.D =   1.6057E-02
    ORGAN( 4) = G.I. U.L.I.     DOSE =   1.4019E+00   S.D. =   2.0512E-02 F.S.D =   1.4631E-02
    ORGAN( 5) = UTERUS          DOSE =   1.3399E+00   S.D. =   4.6013E-02 F.S.D =   3.4341E-02

    ORGAN( 6) = LIVER           DOSE =   1.2906E+00   S.D. =   1.2915E-02 F.S.D =   1.0007E-02
    ORGAN( 7) = SM.INT,+CONTS   DOSE =   1.2746E+00   S.D. =   1.4431E-02 F.S.D =   1.1322E-02
    ORGAN( 8) = G.I. L.L.I.     DOSE =   1.1981E+00   S.D. =   2.0915E-02 F.S.D =   1.7456E-02
    ORGAN( 9) = SPLEEN          DOSE =   1.0229E+00   S.D. =   3.3537E-02 F.S.D =   3.2785E-02
    ORGAN(10) = PANCREAS        DOSE =   8.0487E-01   S.D. =   2.3205E-02 F.S.D =   2.8831E-02
    ORGAN(11) = ADRENALS        DOSE =   5.6281E-01   S.D. =   3.6084E-02 F.S.D =   6.4114E-02
    ORGAN(12) = BRAIN           DOSE =   5.4083E-01   S.D. =   1.0011E-02 F.S.D =   1.8511E-02
    ORGAN(13) = KIDNEYS         DOSE =   5.2391E-01   S.D. =   1.3260E-02 F.S.D =   2.5310E-02

EFDOSE(BRAIN)   =   1.440E+00 S.D. =   1.639E-02 F.S.D. =   1.138E-02
EFDAVE(BRAIN)   =   1.276E+00 S.D. =   1.102E-02 F.S.D. =   8.637E-03
OTHER 5 ORGANS =   4.558E-01 S.D. =   5.693E-03 F.S.D. =   1.249E-02

EFDOSE          =   1.440E+00 S.D. =   1.639E-02 F.S.D. =   1.138E-02
EFDAVE          =   1.276E+00 S.D. =   1.102E-02 F.S.D. =   8.637E-03
OTHER 5 ORGANS =   4.558E-01 S.D. =   5.693E-03 F.S.D. =   1.249E-02
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