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ORNL-TM-4687

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AIRDOS—A Computer Code for Estimating Population and Individual Doses Resulting from Atmospheric Releases of Radionuclides from Nuclear Facilities

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MASTER

Environmental Sciences Division Publication No. 654

OAK RIDGE NATIONAL LABORATORY
OPERATED BY UNION CARBIDE CORPORATION FOR THE U.S. ATOMIC ENERGY COMMISSION

ORNL-TM-4687

Contract No. W-7405-eng-26

ENVIRONMENTAL SCIENCES DIVISION

AIRDOS--A COMPUTER CODE FOR ESTIMATING POPULATION AND INDIVIDUAL DOSES RESULTING FROM ATMOSPHERIC RELEASES OF RADIONUCLIDES FROM NUCLEAR FACILITIES

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JANUARY 1975

Environmental Sciences Division
Publication No. 554

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U.S. ATOMIC ENERGY COMMISSION

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ABSTRACT

AIRDOS, a Fortran IV computer code, was written to estimate population and individual doses resulting from the cortinuous simultaneous atmospheric release of as many as 36 radionuclides from a nuclear facility. This report presents details of the code and complete instructions for its use. Five pathways to man are considered: (1) inhalation of air containing radionuclide gases or particulates, (2) immersion in contaminated air, (3) exposure to surfaces contaminated by radioactive fallout, (4) ingestion of food produced on contaminated ground surfaces, and (5) immersion in contaminated water, as by swimming. Dose and dose commitments are estimated for each pathway and the following eleven reference organs: whole body, GI tract, bone, thyroid, lungs, muscle, kidneys, liver, spleen, testes, and ovaries.

The environmental model in AIRDOS consists of a 20 x 20 square grid with the nuclear facility located at the center. The size of each grid is specified in the input data. Human population, numbers of beef and dairy cattle, and identification as to whether an area is predominately used for production of vegetable crops or is a water area are specified for each of the 400 grids. Population doses are summarized in output tables in every possible manner--by nuclides, pathways, and organs. The highest individual dose received in the area and its location are printed in the output.

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Data found in the literature or provided by various investigators were used to validate the atmospheric dispersion model and the terrestrial model used in AIRDOS. Measured values were generally within the range from + 100% to - 50% of predicted values. Complete validation, however, will require comparisons for more nuclides and a wider range of conditions. Efforts are continuing to locate additional environmental data for validation.

INTRODUCTION

AIRDOS is a Fortran IV computer code used to estimate annual population doses (man-rems) and the annual maximum individual doses resulting from exposures to radionuclides released to the atmosphere from nuclear facilities. It is useful primarily for continuous releases of radionuclides rather than accidental or pulse releases. This code, including several previous versions and modifications, has been used at ORNL in the United States Plowshare Gas Program,[1,2] in the ORNL Cumulative Exposure Index (CUEX) Project,[3] and for several applications related to the preparation of environmental impact statements. Recent applications have included parametric analyses to evaluate uncertainties in dose estimates which result from uncertainties in our knowledge of parameters, such as deposition velocities of particulates, plume rise of released radionuclides, and the vertical and horizontal dispersion coefficients which describe the dispersion of a wind-blown plume of radionuclides.

AIRDOS estimates doses resulting from continuous simultaneous releases of as many as 36 radionuclides from as many as 6 plant stacks or roof vents. Pathways to man include (1) inhalation of radionuclides in air, (2) immersion in air containing radionuclides, (3) exposure to ground surfaces contaminated by deposited radionuclides, (4) ingestion of food produced in the area, and (5) immersion in contaminated water. Doses are estimated for these organs: whole-body, GI tract, bone thyroid, lungs, muscle, kidneys, liver, spleen, testes, and ovaries.

The area surrounding the nuclear facility is arranged as a 20 x 20 square grid with the facility at the center. The grid size is specified as input data. Human population, numbers of beef cattle and dairy cattle, and specification as to whether each of the 400 grids is used for producing vegetable crops or is a water area are required as input data.

The first part of AIRDOS is an atmospheric dispersion model (AIRMOD) which estimates concentrations of radionuclides in air at ground level and their rates of deposition on ground surfaces as a function of distance and direction from the point of release. Annual average meteorological data for the area are supplied as input for AIRMOD.

AIRMOD is interfaced with environmental models within AIRDOS to estimate doses to man through the five pathways. The most complex environmental model is a terrestrial model (TERMOD) developed by Booth, Kaye, and Rohwer.[4] This model estimates radionuclide intakes via ingestion of radionuclides deposited on crops, soil, and pastures. The intakes result from eating beef and vegetable crops and drinking milk.

The terrestrial model (TERMOD) is not applicable for tritium, which, in the form of tritiated water, follows ordinary water almost exactly through the terrestrial environment. The model used in AIRDOS for ingestion of tritium is one in which it is assumed that man's body water contains the same concentration of tritium as is contained in rain falling in the area. This assumption is conservative because it does not consider any dilution of tritium in man's body water as a result of drinking water or other beverages from sources outside the area.

The present version of AIRDOS does not estimate external doses from gamma radiation from overhead plumes. This additional external exposure may be important in the immediate vicinity of a nuclear facility, especially under stable atmospheric conditions. It should be estimated separately where conditions warrant and added to the external doses estimated by AIRDOS. A separate finite cloud calculation usually would not be necessary for distances greater than 10 stack heights from the point of release under average meteorological conditions. Ingestion of fish or other foods produced in water areas is also not included in the present version of AIRDOS.

Population doses are summarized in the output tables of AIRDOS in all possible ways--by nuclides, pathways, and organs. If more than 36 radionuclides must be considered in a source term, two or more computer runs can be made and the data in the summary tables from each computer run simply added together. The highest individual doses in the area for each organ are tabulated for each radionuclide and the highest organ doses from all radionuclides in the source term are listed. The location of the highest individual dose is specified.

THE ATMOSPHERIC DISPERSION MODEL

The basic equation used to estimate atmospheric dispersion in AIRDOS is Pasquill's Equation[5] as modified by Gifford:[6]

$$\chi = \frac{Q}{2\pi\sigma_y\sigma_z\mu} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \tag{1}$$

$$\left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right]\right\}$$

where

χ = concentration in air at the center line of a plume x meters downwind from the point of release (curies/m^3),

Q = uniform emission rate from the stack (curies/sec),

μ = mean wind speed (m/sec),

σ_y = horizontal dispersion coefficient (m),

σ_z = vertical dispersion coefficient (m),

H = effective stack height (physical stack height, h, plus the plume rise, Δh) (m),

y = crosswind distance (m), and

z = vertical distance (m).

The downwind distance, x, comes into Eq. (1) through σ_y and σ_z, which are functions of x as well as the atmospheric stability category applicable during emission from the stack. Pasquill[5] described six atmospheric stability categories ranging from A (very unstable) to F (very stable). A seventh category, G (extremely stable), has been included in AIRDOS. Values for σ_y and σ_z as functions of x for each of the six original Pasquill categories are the most recent values recommended by the Air Resources Atmospheric Turbulence and Diffusion Laboratory.[7] The values used for σ_y and σ_z for category G were extrapolated by subtracting half of the difference between corresponding values for the E and F categories from the values for the F category.

Three options are available in AIRDOS to estimate plume rise, Δh, for Eq. (1). These are

1. Briggs'[8] equations can be used to estimate plume rise resulting from buoyancy for cases in which hot plumes are emitted from a stack. The rate of heat release from the stack and the average air temperature are required input data for this option. In addition, the vertical temperature gradient of the air for atmospheric stability categories E, F, and G are required.
2. The equation of Rupp et al.[9] can be used to estimate plume rise caused by momentum of emitted stack gases. This equation is

$$\Delta h = 1.5\ vd/\mu \tag{2}$$

in which

Δh = plume rise (m),

v = effluent gas velocity (m/sec),

d = stack diameter (m), and

μ = wind velocity (m/sec).

3. Plume rise is designated by the user for each of the seven Pasquill atmospheric stability categories.

Option (2) would usually be used for nuclear plants for which gaseous effluents are near ambient temperatures. Option (3) may be used if the user desires to compute plume rise by another formula.

For part of each year a stable layer of air will exist above a less stable layer. This effect, referred to as a lid, restricts vertical dispersion, and it results in a higher ground-level air concentration than would exist in the absence of a lid. It is assumed in the AIRDOS code that a plume is not affected by the lid until the downwind distance, x, becomes equal to $2x_L$, where x_L is the value of x for which $\sigma_z = 0.47$ L. (L is the height of the lid.)[10] For greater values of x, vertical dispersion is restricted and the air concentration of the radionuclide is assumed to be uniform from ground level to the lid.

Radionuclides released as particulates may be substantially affected by gravity during plume travel. A value for the gravitational fall velocity, V_g, for each radionuclide is required input data. This value is zero for gases and usually zero for most particulates. For dense or large particulates, however, a positive value is used for V_g, and this results in computing the plume to have a downward tilt. This is accomplished in AIRDOS by decreasing the effective stack height, H, in Eq. (1) by the expression $V_g x/\mu$. A built-in protection prevents the plume from going below ground level.

Particulates will deposit on ground or water surfaces at a rate that is the product of their concentration in air at ground level and the deposition velocity (m/sec) as expressed by the equation,

$$w(x,y) = V_d \, X(x,y,o) \qquad (3)$$

where

$w(x,y)$ = deposition rate (Ci/m^2 sec),

V_d = deposition velocity (m/sec), and

$\chi(x,y,o)$ = air concentration of radionuclide at ground level (Ci/m^3).

Deposition velocities are dependent on surface characteristics. Measured values show wide scatter, averaging about 0.01 m/sec, a value often used for particulates for which reliable measured values are not available. It seems likely that particles which are falling as a result of gravity will deposit on surfaces at a rate at least as great as their rate of fall. It is recommended, accordingly, that any value used for the deposition velocity of a radionuclide be at least as great as its gravitational fall velocity.

Scavenging of radionuclides in a plume is the process through which rain or snow washes out particles or dissolves gases and deposits them on ground or water surfaces. The fraction of particles or soluble gases removed by scavenging from a vertical column of air per unit time during rain or snow is ϕ, the scavenging coefficient. If ϕ has the units of sec^{-1}, the rate of deposition on the ground or water surface is

$$R = \phi C h \ Ci/m^2 sec \tag{4}$$

where

C = the average concentration in the vertical column (Ci/m^3), and

h = the height of the vertical column (m).

The scavenging coefficient used in AIRDOS for each radionuclide is the sum of the washout, rainout, and snowout coefficients for particles or the coefficient for dissolving of gases in rain drops. The average concentration in the vertical column used in Eq. (4) is computed through the use of Eq. (1). The value of h is the distance from the ground to the bottom of the inversion layer (lid). A discussion of methods used to estimate scavenging coefficients during the periods of rainfall (or snowfall) at the plant site can be found in Meteorology and Atomic Energy--1968.[11] These scavenging coefficients must be averaged over a period of one year to be used in AIRDOS. The units of scavenging coefficients (sec^{-1}) as used in AIRDOS, therefore, described a continuous removal of a fraction of the plume per second over an entire year.

The rate of deposition is the sum of the rate from dry deposition and the rate from scavenging processes; it is used as input for the terrestrial model to estimate internal 50-year dose commitments through ingestion of food produced in the area. Concentrations on ground surfaces calculated for a 50-year period of deposition are computed from radioactive decay constants and environmental decay constants to estimate gamma doses from surfaces. Measured values of environmental decay constants for most radionuclides are not available; the use of a value of zero for these cases results in conservative dose estimates.

Depletion of the plume resulting from deposition processes is taken into account by substituting Q, the release rate in Eq. (1), by Q', a reduced release rate which is Q-D where D is the correction for the amount of radionuclide deposited by the plume from the point of release to the point of consideration. An expression for the depletion fraction, Q'/Q, as a function of X, the downwind distance, can be derived from the general expression,

$$\frac{\partial Q'}{\partial x} = -\int_{-\infty}^{\infty} w(x,y)\ dy \quad , \tag{5}$$

for depletion of a plume per unit distance from the point of release.

The deposition rate, $w(x,y)$, is equal to $v_d X(x,y,o)$ (see Eq. (3)), where $X(x,y,o)$ is equal to the expression of Eq. (1) with Q' substituted for Q, with the expression $v_g x/\mu$ subtracted from H, the effective stack height, to account for gravitational fall, and with functions of x, x^A/C and x^D/F, substituted for σ_y and σ_z, respectively. After substitutions are made, the resulting expression is

$$\frac{\partial Q'}{\partial x} = -2\int_0^{\infty} \frac{v_d Q'}{\pi(x^A/C)(x^D/F)u} \exp -\left(\frac{y^2}{2(x^A/C)^2} + \frac{(H-v_g x/u)^2}{2(x^D/F)^2}\right) dy \tag{6}$$

Integration of Eq. (5) leads to the depletion fraction:

$$\frac{Q'}{Q} = \exp \left[-\left(\frac{2}{\pi}\right)^{1/2} \frac{v_d}{u} \int_0^x \frac{dx}{(x^D/F)\exp(-(H-v_g x/u)^2/2(x^D/F)^2)}\right] \tag{7}$$

Computer subroutines based on Simpson's Rule were written by D. E. Dunning[12] to estimate Q'/Q in Eq. (7) for dry deposition as a function of X. The exponential factor $e^{-\phi t}$ is used to correct for plume depletion by scavenging processes.

AIRDOS makes use of Eq. (1) to compute annual average concentrations in air and rates of deposition on ground and water surfaces for each of 16 compass directions emanating from the stacks of the facility. The annual frequencies for the 16 wind directions, true average and reciprocal-averaged wind speeds for each wind direction, and annual frequencies of the seven atmospheric stability categories for each wind direction are required as input data. The resulting concentrations from Eq. (1) are averaged over each of the 16 sectors and then converted to a square grid specification.

Radioactive decay during plume travel is taken into account in AIRDOS, but doses from daughter buildup within the plume are not estimated. The user should examine the decay schemes of any short-lived radionuclides in the source term to ensure the absence of significant quantities of daughter products in the airborne plume which may contribute to dose.

DOSE ESTIMATES

Dose conversion factors for external doses from immersion in contaminated air, immersion in contaminated water as by swimming in a home pool subjected to surface deposition from plumes, and exposure to contaminated ground surfaces are supplied as input data. Only gamma radiation is considered for external doses. External dose conversion factors for each radionuclide can be obtained by use of the EXREM III computer code.[13] The contribution to the dose conversion factors for immersion in water and surface exposures from daughter products at equilibrium should be included in the dose conversion factors supplied as input data for each radionuclide. In AIRDOS, the external dose to each organ is estimated as equivalent to the whole-body dose, and it is added to the 50-year internal dose commitment for each organ resulting from inhalation and ingestion.

Dose conversion factors for internal doses from inhalation and ingestion are supplied as input data for each radionuclide for whole body and for each reference organ for that radionuclide. The internal dose conversion factors can be obtained through use of the INREM computer code.[14] For those organs not in the reference organ list, internal doses are estimated through the use of the dose conversion factors for whole body.

Each person living in the area is assumed to eat beef, milk, and vegetable crops produced within the entire 400 square grid surrounding the nuclear facility. If the 400 grid area does not produce enough of each of these three foods to supply the population within the area, the deficit for each of the three foods is assumed to be supplied by imported uncontaminated food.

Dose reduction factors are applied in AIRDOS to the ingestion doses estimated in TERMOD for the short-lived ($T_{1/2}$ = 8 days) radionuclide ^{131}I to account for cattle pasturing practices in the area and elapsed times between production of vegetable crops, milk, and beef and their human consumption. Ingestion doses for ^{131}I as estimated by TERMOD are reduced by 30 to 50% by application of these factors calculated on the basis of realistic local agricultural and food processing and distribution practices.

VALIDATION OF ENVIRONMENTAL MODELS

The environmental transport models, AIRMOD and TERMOD, in AIRDOS were validated partially by the use of data found in the literature or provided by various investigators. Results of these validation studies, given in this section, show that most of the measured values generally fall within the range + 100% to - 50% of the predicted values. These results lend some credence to AIRDOS, but complete validation will require comparisons for a larger number of nuclides under a wider variety of meteorological and terrestrial conditions. Efforts are continuing to locate additional environmental data which are closely related to known releases for which meteorological conditions are well defined.

Validation of the Atmospheric Transport Model

Radionuclide concentrations in air at ground level estimated by the AIRDOS code were compared with values measured in the vicinity of three nuclear reactors as described below.

1. Haddam Neck Pressurized Water Reactor

Concentrations of ^{85}Kr and ^{133}Xe in air were measured by the U. S. Environmental Protection Agency[15] near the Haddam Neck Reactor on April 16, 1971. The measurements were made at a distance of 600 meters from the plant stack in the direction toward which the wind was blowing. Slightly unstable atmospheric conditions prevailed during the day. Table 1 lists χ/Q values (concentration in air at ground level/release rate) for the four test periods. Estimated values from AIRDOS range from approximately 56% less than measured values to approximately 70% greater than measured values.

2. Noble Gas Releases from a Boiling Water Reactor

Doses resulting from immersion in air containing noble gases released from a boiling water reactor were estimated by AIRDOS, and

Table 1. Comparison of Measured and Estimated χ/Q Values for Releases of Noble Gas Radionuclides from the Haddam Neck Reactor[a]

	Test Period			
	I	II	III	IV
Average Wind Speed (m/sec)	3.2	5.0	5.7	5.4
Measured χ/Q for ^{85}Kr (sec/m^3)	---	1.9×10^{-5}	---	5.7×10^{-6}
Measured χ/Q for ^{133}Xe (sec/m^3)	8.8×10^{-6}	2.2×10^{-5}	6.8×10^{-6}	6.2×10^{-6}
Estimated χ/Q[b] (sec/m^3)	1.5×10^{-5}	9.6×10^{-6}	9.4×10^{-6}	8.9×10^{-6}

[a] Slightly unstable atmospheric conditions prevailed during releases on April 16, 1971. Measurements were made at a distance of 600 meters from the plant stack in the direction toward which the wind was blowing.

[b] The χ/Q values estimated by AIRDOS are the same for both ^{85}Kr and ^{133}Xe.

the results were compared with doses measured by the New York Health and Safety Laboratory (HASL)[16] resulting from direct exposure to the plumes. The measured release rates are listed in Table 2. Comparisons of results are listed in Table 3. These comparisons are for distances relatively far from the stack where external doses are computed in AIRDOS for infinite cloud immersion at ground level. These should be comparable to doses calculated by HASL for direct exposure to airborne plumes. Doses resulting from direct exposure to overhead plumes near the stack are much greater than immersion doses, which AIRDOS estimates, because air concentrations at ground level near the stack are very low. Good comparisons between results from the two calculational techniques are expected, therefore, only at downwind distances great enough that the plume has reached ground level.

3. Tritium Releases from the Argonne National Laboratory CP-5 Reactor

Tritium released from the ANL CP-5 Reactor (1 Ci/day) was measured by Sedlet, Golchert, and Duffy[17] during 1973 at a permanent monitoring station 50 meters east of the reactor. The average measured concentration during the year was $2.65 \times 10^{-3} \pm 2.0 \times 10^{-3}$ pCi/cm^3. The average tritium concentration estimated by AIRDOS using annual average meterological data[18] was 4.69×10^{-3} pCi/cm^3.

The stack height of the CP-5 reactor is 15 meters. A small plume rise of 5 meters was assumed for the AIRDOS computer run to account for momentum and buoyancy of the stack emissions. The agreement between estimated and measured tritium concentrations is good in view of the difficulties in estimating concentrations close to a reactor where building wakes and

Table 2. Measured Release Rates of Noble Gases from a Boiling Water Reactor[16]

Nuclide	Release Rate (pCi/sec)
^{133}Xe	1.37×10^{10}
^{133m}Xe	5.47×10^{8}
^{135}Xe	1.77×10^{10}
^{135m}Xe	5.17×10^{9}
^{138}Xe	3.22×10^{9}
^{85m}Kr	4.20×10^{9}
^{87}Kr	9.30×10^{9}
^{88}Kr	6.99×10^{9}

Table 3. Measured and Estimated Doses Resulting from Exposure to Noble Gas Plumes Released from a Boiling Water Reactor

Distance from Stack (meters)	Direction from Stack	Atmospheric Stability	Measured[a] Dose (mrems)	AIRDOS Estimate (mrems)	Difference (%)
6275	N	Predom. Stable	0.38	0.28	- 26
6758	NNE	Predom. Stable	0.15	0.25	+ 67
2896	SSE	Mixed	0.30	0.17	- 43

[a]Carl V. Gogolak, HASL-277 (1973), and personally communicated meteorological data for use in AIRDOS. The results are for a 740-hour monitoring period. The gamma-ray doses were measured with high-pressure ionization chambers and thermoluminescence dosimeters.

small uncertainties in plume rise can have a significant effect on ground-level air concentrations.

Validation of the Terrestrial Model

The terrestrial model (TERMOD) was validated partially by Booth, Kaye, and Rohwer[2] for three important radionuclides, ^{137}Cs, ^{90}Sr, and ^{131}I, by comparing model predictions from computer runs of their TERMOD computer code with literature values from actual monitoring data. Table 4 is a summary of their results, which constitute only a very small portion of those required for a complete validation. A continuing effort is in progress to find additional data suitable for validating the terrestrial model.

INSTRUCTIONS FOR USING AIRDOS

The code is listed in the Appendix. Data decks required for use of the code are presented in Table 5 through 10. Decks of Tables 5, 6, 7, and 8 should be consecutively stacked. Following the deck of Table 8, there must be a nuclide data deck (Table 9) for each radionuclide listed in the deck of Table 5 under NAMNUC. Associated organ decks (Table 10) for each radionuclide should immediately follow its nuclide deck. The number of associated organ decks following each nuclide deck must correspond to the number in Table 9 under NUMORG.

Tables listing individual doses to each organ through each of the five pathways for each of the 400 grid squares are printed for only the first three radionuclides in the input data deck. This restriction was imposed because these detailed tables are so long that the bulk of the computer output would be unmanageably large if all tables were printed

Table 4. Comparison of Literature Values of Actual Monitoring Data to Terrestrial Model Predictions[a]

Environmental Ratio	Ratio of Monitoring Data to Model Predictions		
	^{137}Cs	^{90}Sr	^{131}I
Input/conc. in grass	1.72		
Input/conc. in milk	1.65	0.73[b] 0.43[b]	
Conc. in milk/conc. in grass	1.00		0.78-1.96[c]
Conc. in milk/conc. in beef	0.62		
Conc. in milk/conc. in grain	0.55		
Conc. in beef/conc. in grain	0.91		

[a]The values in this table were taken from Reference 4, this report.

[b]These two ratios are from different sources.

[c]A range of published data.

Table 5. Data Deck for Atmospheric Dispersion and Ground Depostion

Card Numbers	Parameter Name	Parameter Identification	Units	Type	Format
1	LOPT[a]	Option 1	None	Integer (0 or 1)	6I10
	LORT[b]	Option 2	None	Integer (0 or 1)	
	LOST[c]	Option 3	None	Integer (0 or 1)	
	LOFT[d]	Option 4	None	Integer (0 or 1)	
	LONT[e]	Option 5	None	Integer (0 or 1)	
	LOOT[f]	Option 6	None	Integer (0 or 1)	
2	PRA	Designated plume rise for Pasquill category A	Meters	Fixed Point	7F10.1
	PRB	Designated plume rise for Pasquill category B	Meters	Fixed Point	

[a]Option for stopping the program after printing a table of concentrations in air at ground level and the rates of deposition on ground surfaces for each radionuclide for each of the 400 grid squares.

[b]Option for stopping the program after printing a table as above except that the listed values are for each of 16 compass directions from the nuclear facility for each of 20 specified distances (IDIST values) from the facility.

[c]Option to list plume center-line values instead of sector-averaged values for either option 1 or 2.

[d]Option for estimating plume rise by Briggs' equation for buoyant plumes.

[e]Option for estimating plume rise by the equation of Rupp et al. for momentum-type emissions.

[f]Option to designate a specific plume rise for each of the seven Pasquill atmospheric stability categories (A-G).

Table 5. Data Deck for Atmospheric Dispersion and Ground Deposition (contd)

Card Numbers	Parameter Name	Parameter Identification	Units	Type	Format
	PRC	Designated plume rise for Pasquill Category C	Meters	Fixed Point	
	PRD	Designated plume rise for Pasquill category D	Meters	Fixed Point	
	PRE	Designated plume rise for Pasquill category E	Meters	Fixed Point	
	PRF	Designated plume rise for Pasquill category F	Meters	Fixed Point	
	PRG	Designated plume rise for Pasquill category G	Meters	Fixed Point	
3	PLBN	North Plant Boundary	Meters	Fixed Point	4F10.1
	PLBW	West Plant Boundary	Meters	Fixed Point	
	PLBS	South Plant Boundary	Meters	Fixed Point	
	PLBE	East Plant Boundary	Meters	Fixed Point	
4	NADEC1[g]	Internal test for tritium in nuclide list	None	Alphameric	2A8
	NADEC2[h]	Internal test for ^{131}I in nuclide list			

[g] NADEC1 = H-3

[h] NADEC2 = I-131

Table 5. Data Deck for Atmospheric Dispersion and Ground Deposition (contd)

Card Numbers	Parameter Name	Parameter Identification	Units	Type	Format
5-7	IDIST	20 distances from the facility for use with option 2	Meters	Integer	8I10
8-12	NAMNUC	Nuclide name (up to 36)	None	Alphameric	8A8
13-39	REL	Up to 36 release rates of the above nuclides for 1 to 6 stacks	pCi/sec	Floating Point	8E10.3
40	NUMST	Number of stacks (up to 6)	None	Integer	I10
41	PERD	16 frequencies of wind direction (counterclockwise, starting with wind toward north)	None	Fixed Point	16F5.3
42-48	UDCAT[1]	Reciprocal-averaged wind speeds. One card for each Pasquill atmospheric stability category from A through G	Meters/sec	Fixed Point	16F5.2

[1]The reciprocal wind speeds for each of 16 wind directions (numbered counterclockwise starting at 1 for the wind blowing toward due north) are averaged. The reciprocal of this average value for each wind direction is the reciprocal-averaged wind speed for that direction. Reciprocal-averaged wind speeds are less than true average values.

Table 5. Data Deck for Atmospheric Dispersion and Ground Deposition (contd)

Card Numbers	Parameter Name	Parameter Identification	Units	Type	Format
49-55	UDAV	True average wind speeds (as above for UDCAT)	Meters/sec	Fixed Point	16F5.2
56	TA	Average air temperature in area	^{o}K	Fixed Point	F10.1
57	TGE[j]	Vertical temperature gradient of air for Pasquill category E	^{o}K/meter	Fixed Point	F10.4
58	TGF[k]	Same as above, but for category F	^{o}K/meter	Fixed Point	F10.4
59	TGG[l]	Same as above, but for category G	^{o}K/meter	Fixed Point	F10.4
60	PH	Physical height of each stack (up to 6)	Meters	Fixed Point	6F10.1
61	DIA	Inside diameter of each stack (up to 6)	Meters	Fixed Point	6F10.1

[j] A conservative value (i.e., one producing a small plume rise) of 0.0728 has been used in AIRDOS computer runs. A less conservative value may be used if desired.

[k] A conservative value of 0.1090 has been used in AIRDOS RUNS. See footnote j.

[l] A conservative value of 0.1455 has been used in AIRDOS runs. See footnote h.

Table 5. Data Deck for Atmospheric Dispersion and Ground Deposition (contd)

Card Numbers	Parameter Name	Parameter Identification	Units	Type	Format
62	VEL	Velocity of stack gases for each stack (up to 6)	Meters/sec	Fixed Point	6F10.1
63	QH	Heat release rate for each stack (up to 6)	Cal/sec	Floating Point	6E10.2
64-79	FRAW	Fraction of time that each of the 7 Pasquill atmospheric stability categories (A-G) exists for each of the 16 wind directions (one card for each wind direction). The sum of values for each card is 1.	None	Fixed Point	7F10.4
80	LIDA1	Average lid for area	Meters	Integer	I10
81	SQSD	Side of each grid of the 400 square grid area	Meters	Fixed Point	F10.1
82	SQSD2	Side of each grid of a smaller 100 square grid area	Meters	Fixed Point	F10.1

Table 5. Data Deck for Atmospheric Dispersion and Ground Deposition (contd)

Card Numbers	Parameter Name	Parameter Identification	Units	Type	Format
83-92	N5PTMO[m]	Integers from 1 to 16 to convert the 400 square grid centers to directions from the plant at the center of the area	None	Integer	40I2
93	ALPH	Blank card			
94	NNUCS	Number of nuclides	None	Integer	I5
95-99	VG	Gravitation fall velocity for each nuclide (up to 36)	Meters/sec	Fixed Point	8F10.3

[m]The following values listed as data card images must be used for NSPTMO:

Card No.	
1	7 7 7 7 6 6 6 6 5 5 5 5 4 4 4 4 3 3 3 3 7 7 7 7 6 6 6 6 5 5 5 5 4 4 4 4 3 3 3 3
2	7 7 7 7 7 6 6 6 6 5 5 4 4 4 4 3 3 3 3 3 7 7 7 7 7 7 6 6 6 5 5 4 4 4 3 3 3 3 3 3
3	8 8 7 7 7 7 6 6 6 5 5 4 4 4 3 3 3 3 2 2 8 8 8 7 7 7 7 6 6 5 5 4 4 3 3 3 3 2 2 2
4	8 8 8 8 8 7 7 7 6 5 5 4 3 3 3 2 2 2 2 2 8 8 8 8 8 8 7 7 6 5 5 4 3 3 2 2 2 2 2 2
5	9 9 8 8 8 8 8 8 7 6 4 3 2 2 2 2 2 2 1 1 9 9 9 9 9 9 9 9 8 7 3 2 1 1 1 1 1 1 1 1
6	9 9 9 9 9 9 9 910111516 1 1 1 1 1 1 1 1 9 91010101010101011121415161616161616 1 1
7	10101010101010111112131314151516161616161610101010101011111112131314151515161616161616
8	10101011111111121213131414151515151616161010111111111212121313141414151515151616
9	11111111111111121212131314141415151515151511111111111121212121313141414141515151515
10	11111111121212121313131314141414151515151111111111121212121313131314141414151515 15

Table 5. Data Deck for Atmospheric Dispersion and Ground Deposition (contd)

Card Numbers	Parameter Name	Parameter Identification	Units	Type	Format
100-104	VD	Deposition velocity for each nuclide (up to 36)	Meters/sec	Fixed Point	8F10.5
105-109	SC	Scavenging coefficient for each nuclide (up to 36)	Sec^{-1}	Floating Point	8E10.3
110-114	ANLAM	Radioactive decay constant for each nuclide (up to 36)	Day^{-1}	Floating Point	8E10.3
115	RR	Rainfall rate	Inches/year	Fixed Point	F10.2

Table 6. Data Deck for Statistical Description of Area

Card Numbers	Parameter Name	Parameter Identification	Units	Type	Format
1-25	NOBCT	Number of beef cattle in each of 400 grids	None	Integer	16I5
26-50	NOMCT	Number of dairy cattle in each of 400 grids	None	Integer	16I5
51-55	INTFC	Flag to denote whether each grid is primarily used for producing vegetable crops (1 for yes, 0 for no)	None	Integer	80I1
56-105	INTPA	Human population in each of 400 grids	None	Fixed point	8F10.1
106-115	INTWA	Flag to denote whether each grid is a water area (1 for yes, 0 for no)	None	Integer	40I2

Table 7. Data Deck for Parameters Used to Estimate Inhalation Doses and Doses Resulting from Submersion in Water

Card Numbers	Parameter Name	Parameter Identification	Units	Type	Format
1	BRTHRT[a]	Breathing rate of man	cm^3/hr	Fixed point	3F10.3
	DILFAC[b]	Dilution factor for swimming	cm		
	USEFAC[c]	Fraction of time spent swimming	None		

[a]A value of 0.833E6 is the accepted value.

[b]A value of 152.4 cm (5 ft) is used for the water depth of a home swimming pool for dilution of radionuclides depositing on the pool surface. The deeper water of a lake or municipal pool would result in greater dilution and smaller submersion doses.

[c]A value of 0.01 has been used in AIRDOS computer runs.

Table 8. Data Deck for the Radionuclide-Independent Parameters Used for the Terrestrial Model

Card Numbers	Parameter Name	Parameter Identification	Units	Type	Format	Recommended Values[a]
1	A	Soil surface required to furnish food crops for one man	$Meters^2$	Fixed point	10F8.4	0.1E4
	ASUBG	Pasture area per cow	$Meters^2$			0.1E5
	DSUBF	Dry weight areal density of man's above-surface food	$Kg/meter^2$			0.1E0
	DSUBG	Dry weight areal grass density	$Kg/meter^2$			0.15E0
	SMALLD	Depth of plow layer	Cm			0.2E2
	D1	Dietary correction factor for above-surface food	None			0.25E0
	D2	Dietary correction factor for uptake from soil	None			0.1E1
	D3	Dietary correction factor for beef	None			0.1E1
	D4	Dietary correction factor for milk	None			0.1E1

Table 8. Data Deck for the Radionuclide-Independent Parameters Used for the Terrestrial Model (contd)

Card Numbers	Parameter Name	Parameter Identification	Units	Type	Format	Recommended Values[a]
2	KSUBB	Rate of increase of steer muscle mass	kg/day	Fixed point	10F8.4	0.4E0
	MSUBB	Muscle mass of steer at slaughter	kg			0.2E3
	RHO	Soil density	g/cm^3			0.14E1
	S1	Fallout correction factor for above-surface food	None			0.1E0
	S2	Fallout correction factor for soil surface below food	None			0.9E0
	S3	Fallout correction factor for pasture	None			0.1E1
	TAUBEF	Fraction of beef herd slaughtered per day	None			0.381E-2
	TAUMLK	Transfer rate of milk from udder	day^{-1}			0.2E1
	TAUBM	Beef consumption of man	kg/day			0.3E0

Table 8. Data Deck for the Radionuclide-Independent Parameters Used for the Terrestrial Model (contd)

Card Numbers	Parameter Name	Parameter Identification	Units	Type	Format	Recommended Values[a]
	TAUCM	Milk consumption of man	liters/day			0.1E1
3	TAUES	Transfer rate--above-surface food to soil surface	day^{-1}	Fixed point	10F8.4	0.495E-1
	TAUGR	Transfer rate--pasture grass to pasture soil	day^{-1}			0.495E-1
	TAUPD	Transfer rate--soil pool to soil sink	day^{-1}			0.1096E-3
	TAURD	Transfer rate--pasture soil to soil sink	day^{-1}			0.1096E-3
	TAURG	Transfer rate--pasture soil to pasture grass	day^{-1}			0.274E-4
	TAUSP	Transfer rate--soil surface to soil pool	day^{-1}			0.6931E-3
	U	Milk capacity of udder	liters			0.55E1
	V	Vegetable food consumption of man	kg/day			0.25E0

Table 8. Data Deck for the Radionuclide-Independent Parameters Used for the Terrestrial Model (contd)

Card Numbers	Parameter Name	Parameter Identification	Units	Type	Format	Recommended Values[a]
	VSUBC	Grass consumption of cow	kg/day			0.1E2
	VSUBM	Milk production of cow	liters/day			0.11E2
4	PFIV	Dose reduction factor for ^{131}I (vegetable food)	none	fixed point	F10.2	
5	PFIC	Dose reduction factor for ^{131}I (milk)	none	fixed point	F10.2	
6	PFIB	Dose reduction factor for ^{131}I (beef)	none	fixed point	F10.2	

[a]Most of the recommended values are from reference 4 of this report, but some values have been changed to reflect more recent data found in the literature.

Table 9. Data Deck for Each Radionuclide

Card Numbers	Parameter Name	Parameter Identification	Units	Type	Format
1	NUMORG	Number of organs	None	Integer	I10,4E10.3
	LAMRR	Radioactive decay constant	day^{-1}	Floating point	
	CFSBA	Dose conversion factor for submersion in air	$\frac{rems\text{-}cm^3}{\mu Ci\text{-}hr}$	Floating point	
	CFSBW	Dose conversion factor for submersion in water	$\frac{rems\text{-}cm^3}{\mu Ci\text{-}hr}$	Floating point	
	CFSUR	Dose conversion factor for surface exposure	$\frac{rems\text{-}cm^2}{\mu Ci\text{-}hr}$	Floating point	
2	CSUBB[a]	Concentration of element in meat	ppm	Floating point	8E10.3
	CSUBP[a]	Concentration of element in forage	ppm		
	CSUBS[a]	Concentration of element in soil	ppm		
	FSUBM[a]	Fraction of isotope ingested by a cow and secreted	days/liter		
	LAME[a]	Turnover rate of stable isotope in man	day^{-1}		

Table 9. Data Deck for Each Radionuclide (contd)

Card Numbers	Parameter Name	Parameter Identification	Units	Type	Format
	CSUBBB[a]	Concentration of the element in man	ppm		
	MSUBEQ[a]	Equilibrium mass of stable element in soil from surface to depth of plow layer	grams		
	TAUEXC[a]	Excretion rate of stable isotope from muscle of steer	day^{-1}		
3	LAMSUR[a]	Environmental decay constant--surface	day^{-1}	Floating point	2E10.3
	LAMH2O[a]	Environmental decay constant--water	day^{-1}		

[a]Recommended values for these parameters for specific radionuclides have been compiled from literature sources by John P. Witherspoon, ORNL Environmental Sciences Division.

Table 10. Data Deck for Each Organ for Each Radionuclide

Card Numbers	Parameter Name	Parameter Identification	Units	Type	Format
1	NAMORG[a]	Name of organ	None	Alphameric	A8,E12.3,E10.3
	CFINHA[b]	Dose conversion factor for inhalation	rems/μCi	Floating point	
	CFINGA[b]	Dose conversion factor for ingestion	rems/μCi	Floating point	

[a]The names of the organs must be left justified, i.e., started in column 1, and must be punched exactly as follows: TOT.BODY, for whole body, GI TRACT, BONE, THYROID, LUNGS, MUSCLE, KIDNEYS, LIVER, SPLEEN, TESTES, OVARIES. Whole body (TOT.BODY) must be included for each radionuclide, and it must always be the first organ deck. Any other organ decks can be randomly sequenced.

[b]Internal dose conversion factors for each reference organ for each radionuclide can be obtained by use of the INREM computer code (reference 14, this report).

for a large source term. Any radionuclides for which such a detailed output listing is desired should be placed among the first three in the nuclide data listing.

The options available in AIRDOS are specified on the first data card (Table 5, card 1), and they are defined in footnotes 1-6 in Table 5. The options are imposed by the use of the integer 1 in the appropriate card column; the option is not imposed if the column is left blank. Option 2 can be selected only if option 1 is selected. Option 3 (for center line values) should be used only with options 1 or 2. Only one option should be chosen from among options 4, 5, and 6 for plume rise estimates. If option 6 is selected, plume rise values for each of the Pasquill atmospheric stability categories are specified by the user on the second data card (Table 5, card 2).

Plant boundary distances specified in Table 5, card 3 are used only for estimating the highest individual doses in the area. Doses which may be received inside the plant area are not computed for this purpose.

The parameter SOSD2 (Table 5, card 82) is the length of the side of each grid of a small 10 by 10 grid area surrounding the plant to obtain high resolution for estimating the highest individual doses in the area, which are likely to be received near the plant. Whereas the side of each grid of the large 20 by 20 square grid area (SOSD) may be 8000 meters in length, for example, a realistic grid size for SOSD2 might be 600 meters or less.

ACKNOWLEDGMENTS

Many members of the ORNL Environmental Sciences Division contributed in various ways to the development of AIRDOS. Stephen V. Kaye, Charles J. Barton, Paul S. Rohwer, and John P. Witherspoon were particularly helpful in defining the objectives of the code with respect to applications in the United States Plowshare Program, the ORNL Cumulative Exposure Index (CUEX) Project, and environmental impact statements.

A part of a computer program written for the terrestrial model of R. S. Booth, S. V. Kaye, and P. S. Rohwer was incorporated into AIRDOS. Subroutines used in AIRDOS for computing plume depletion resulting from dry deposition of radionuclide particulates were written by D. E. Dunning, a University of Tennessee student participant during the summer of 1973. His contributions are gratefully acknowledged.

Parts of a general CUEX computer code written by J. Charles Garvin, an undergraduate student at Ohio Wesleyan University participating in the Great Lakes Colleges Association (GLCA) science semester (September-December 1972) at ORNL were incorporated into AIRDOS. Mr. Garvin's logical approach to computer programming of dose and dose commitment calculations proved invaluable during development of AIRDOS.

Practical application of AIRDOS would not have been possible without the availability of realistic parameters for the radionuclides released from nuclear facilities. John P. Witherspoon compiled most of these parameters through comprehensive literature searches and data analysis.

Larry R. McKay constructed data lists of internal and external dose conversion factors for radionuclides used in AIRDOS applications, and analyzed their parent-daughter relationships to ensure the validity of dose estimates.

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APPENDIX

Listing of the AIRDOS computer code

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```
C
C                          AIRDOS CODE
C
      COMMON ACON(36,20,20),GCON(36,20,20),TA1(36),TGD(36),[illegible]
     1IDIST(20)
      INTEGER TAURCT,TACRCT
      DIMENSION ANLAM(36)
      DIMENSION DOSIN(11,36),FSTR(36,10,10),[illegible]TRG(36,10,10),[illegible]
     1[illegible]DMA(36),UDAV(7,16),UDCAT(7,16),AMULT(12),TADOS(37),[illegible]
     2DOSPA(5,11,36),PCT(5),SUMT(5),DOSP(5,11,36),SMD(5),SMJ(11),[illegible]
     3,DOSIN(11,36),DOSIJ(11),NSPTMD(20,20),H(6),PH(6),DH(6),[illegible]
     4ADH(6),BDH(6),PERD(16),RFL(6,36),FRAW(7,16),VG(36),VD(36),SC[illegible]
     5VEL(6),DIA(6),[illegible]RCT(20,20),NCRCT(20,20),INTEC(20,20),INTRA(20,20),
     6[illegible]TWS(20,20),CFINHA(11),CFINGA(11),NOMM2(36),NRMM2(36),[illegible]
     7[illegible](36),IGRID(36)
      REAL*8 NAMORG(11),NAMES(11),NAMNUC(36),MODE(5),NANUC(3),
     1NADEC1,NADEC2,NADEC3
      REAL INTRA,MSUBED,LAMRP,LAME,KSUBR,MSUBS,LAMSUR,LAMIRR
      DATA NAMES/'TOT. BODY','GI TRACT','BONE     ','THYROID ','LUNGS   ',
     1'MUSCLE  ','KIDNEYS ','LIVER   ','SPLEEN  ','TESTES  ','OVARIES '/
      DATA MODE/'INHAL. ','SUBM AIR','SURFACE ','INGEST. ','SWIMMING'/
      READ(50,7797)LOPT,LUPT,LOST,LOFT,LONT,LOUT
 7797 FORMAT(6I10)
      READ(50,740)PRA,PRB,PRC,PRD,PRE,PRF,PRG
  740 FORMAT(7F10.1)
      READ(50,554)PLBN,PLBW,PLBS,PLBE
  554 FORMAT(4F10.1)
      READ(50,4071)NADEC1,NADEC2
 4071 FORMAT(2A8)
      READ(50,7798)(IDIST(J),J=1,20)
 7798 FORMAT(8I10)
      READ(50,107)(NAMNUC(I),I=1,36)
  107 FORMAT(8A8)
      READ(50,106)((RFL(J,I),I=1,36),J=1,6)
  106 FORMAT(8E10.3)
      READ(50,105)NUMST
  105 FORMAT(I10)
      READ(50,103)(PERD(I),I=1,16)
  103 FORMAT(16F5.3)
      READ(50,101)((UDCAT(ICAT,MD),MD=1,16),ICAT=1,7)
  101 FORMAT(16F5.2)
      READ(50,101)((UDAV(ICAT,MD),MD=1,16),ICAT=1,7)
      READ(50,115)TA
  115 FORMAT(F10.1)
      READ(50,89)TGF
      READ(50,89)TGF
      READ(50,89)TGG
   89 FORMAT(F10.4)
      READ(50,116)(PH(I),I=1,6)
      READ(50,116)(DIA(I),I=1,6)
      READ(50,116)(VEL(I),I=1,6)
  116 FORMAT(6F10.4)
      READ(50,113)(DH(I),I=1,6)
  113 FORMAT(6F10.2)
      READ(50,104)((FRAW(I,MD),I=1,7),MD=1,16)
  104 FORMAT(7F10.4)
```

```
      READ(50,1150)LIDA1
 1150 FORMAT(I10)
      READ(50,551)SQSD
      READ(50,551)SQSD2
 551  FORMAT(F10.1)
      READ(50,550)((NSPTMD(I,J),J=1,20),I=1,20)
 550  FORMAT(40I2)
      READ(50,1151)ALPH
 1151 FORMAT(A4)
      READ(50,117)NNUCS
 117  FORMAT(I5)
      READ(50,118)(VG(I),I=1,36)
 118  FORMAT(8F10.3)
      READ(50,119)(VD(I),I=1,36)
 119  FORMAT(8F10.5)
      READ(50,120)(SC(I),I=1,36)
 120  FORMAT(8E10.3)
      READ(50,3457)(ANLAM(I),I=1,36)
 3457 FORMAT(8E10.3)
      READ(50,157)RR
 157  FORMAT(F10.2)
      DO 2030 I=1,37
 2030 TDOS(I)=0
      DO 9301 J=1,11
      DO 9302 I=1,36
      DOSON(J,I)=0
 9302 DOSIN(J,I)=0
 9301 CONTINUE
      DO 2031 I=1,36
      NOMA(I)=0
 2031 IRANK(I)=I
      DO 8030 MD=1,5
      DO 8031 J=1,11
      DO 8032 I=1,NNUCS
 8032 DOSP(MD,J,I)=0
 8031 CONTINUE
 8030 CONTINUE
      DO 8033 MD=1,5
 8033 SMD(MD)=0
      DO 8034 J=1,11
 8034 SMJ(J)=0
      DO 8035 I=1,NNUCS
 8035 SMI(I)=0
      DISTG=SQRT(2.*((10.*SQSD)**2))
      LA1=LIDA1
      IF(LIDA1.EQ.10000)LA1=ALPH
      WRITE(51,1152)
 1152 FORMAT('1',T56,'OUTPUT OF AIRDOS')
      WRITE(51,301)
 301  FORMAT('0')
      WRITE(51,8050)
 8050 FORMAT(' ',T20,'OPTIONS SELECTED--')
      IF(LOPT.EQ.0.AND.LORT.EQ.0)GO TO 8054
      WRITE(51,8051)
 8051 FORMAT('0',T30,'PROGRAM TERMINATED AFTER PRINTING RADIONUCLIDE CON
     1CENTRATIONS')
      IF(LORT.EQ.0)GO TO 8055
      WRITE(51,8052)
```

```
8052 FORMAT(' ',T30,'RADIONUCLIDE CONCENTRATIONS ARE LISTED FOR DIRECTI
    1ON AND DISTANCE FROM FACILITY')
8055 IF(LOST.EQ.0)GO TO 8054
     WRITE(51,8053)
8053 FORMAT(' ',T30,'RADIONUCLIDE CONCENTRATIONS LISTED ARE PLUME CENTE
    1RLINE VALUES')
     GO TO 8057
8054 WRITE(51,8056)
8056 FORMAT('0',T30,'RADIONUCLIDE CONCENTRATIONS LISTED ARE SECTOR-AVE
    1RAGED VALUES')
8057 IF(LOFT.EQ.0)GO TO 8061
     WRITE(51,8058)
8058 FORMAT(' ',T30,'PLUME RISE IS COMPUTED FOR BUOYANT PLUMES BY BRIGG
    1S EQUATIONS')
     GO TO 8063
8061 IF(LCNT.EQ.0)GO TO 8062
     WRITE(51,8059)
8059 FORMAT(' ',T30,'PLUME RISE IS COMPUTED FOR MOMENTUM-TYPE EMISSION
    1S')
     GO TO 8063
8062 WRITE(51,8060)
8060 FORMAT(' ',T30,'SPECIFIC PLUME RISE USED FOR EACH AIR STABILITY CL
    1ASS (METERS)-')
     WRITE(51,742)PRA,PRB,PRC,PRD,PRE,PRF,PRG
742  FORMAT(' ',T30,'A',F10.1,'   B',F10.1,'   C',F10.1,'   D',F10.1,
    1'   E',F10.1,'   F',F10.1,'   G',F10.1)
8063 CONTINUE
     WRITE(51,555)PLBN,PLBW,PLBS,PLBE
555  FORMAT('0',T20,'PLANT BOUNDARIES (METERS)--NORTH',F10.1,'   WEST',
    1F10.1,'   SOUTH',F10.1,'   EAST',F10.1)
     WRITE(51,301)
     WRITE(51,302)
302  FORMAT(' ',T40,'METEOROLOGICAL AND PLANT INFORMATION SUPPLIED TO P
    1ROGRAM----')
     WRITE(51,301)
     WRITE(51,301)
     WRITE(51,303)NUMST
303  FORMAT(' ',T40,'NUMBER OF STACKS IN THE PLANT',T115,I10)
     WRITE(51,306)TA
306  FORMAT('0',T40,'AVERAGE AIR TEMPERATURE (DEG K)',T115,F10.1)
     WRITE(51,340)
340  FORMAT('0',T40,'AVERAGE VERTICAL TEMPERATURE GRADIENT OF THE AIR')
     WRITE(51,341)TGE
341  FORMAT(' ',T40,'IN STABILITY CLASS E (DEG K/METERS)',T115,F10.4)
     WRITE(51,342)
342  FORMAT('0',T40,'AVERAGE VERTICAL TEMPERATURE GRADIENT OF THE AIR')
     WRITE(51,343)TGF
343  FORMAT(' ',T40,'IN STABILITY CLASS F (DEG K/METERS)',T115,F10.4)
     WRITE(51,344)
344  FORMAT('0',T40,'AVERAGE VERTICAL TEMPERATURE GRADIENT OF THE AIR')
     WRITE(51,345)TGG
345  FORMAT(' ',T40,'IN STABILITY CLASS G (DEG K/METERS)',T115,F10.4)
     WRITE(51,301)
     WRITE(51,301)
     WRITE(51,318)
318  FORMAT('1',T40,'STACK INFORMATION--')
     WRITE(51,301)
     WRITE(51,319)
```

```
319  FORMAT('0',T39,'STACK NUMBER')
     WRITE(51,301)
     WRITE(51,320)
320  FORMAT(' ',T70,'1',T80,'2',T90,'3',T100,'4',T110,'5',T120,'6')
     WRITE(51,301)
     WRITE(51,321)(PH(I),I=1,NUMST)
321  FORMAT(' ',T20,'HEIGHT (METERS)',T62,6F10.4)
     WRITE(51,460)(DIA(I),I=1,NUMST)
460  FORMAT('0',T20,'DIAMETER (METERS)',T62,6F10.4)
     WRITE(51,461)(VEL(I),I=1,NUMST)
461  FORMAT('0',T20,'EFFLUENT VELOCITY (METERS/SEC)',T52,6F10.4)
     WRITE(51,327)(QH(I),I=1,NUMST)
327  FORMAT('0',T20,'RATE OF HEAT EMISSION (CAL/SECOND)',T62,5E10.2)
     WRITE(51,1153)
1153 FORMAT('1',T26,'FREQUENCY OF ATMOSPHERIC STABILITY CLASSES FOR EAC
    1H DIRECTION')
     WRITE(51,301)
     WRITE(51,2050)
2050 FORMAT('0',T7,'SECTOR',T40,'FRACTION OF TIME IN EACH STABILITY CLA
    1SS')
     WRITE(51,2051)
2051 FORMAT('0',T25,'A',T37,'B',T49,'C',T61,'D',T73,'E',T85,'F',T97,'G'
    1)
     WRITE(51,301)
     DO 2054 MO=1,16
     WRITE(51,2053)MO,(FRAW(I,MO),I=1,7)
2053 FORMAT(' ',T7,I4,T23,F6.4,T35,F6.4,T47,F6.4,T59,F6.4,T71,F6.4,
    1T83,F6.4,T95,F6.4)
2054 CONTINUE
     WRITE(51,350)LAI
350  FORMAT('1',T20,'HEIGHT OF LID-',I6,1X,'METERS')
     WRITE(51,158)RP
158  FORMAT('0',T20,'RAINFALL RATE (INCHES/YEAR)-',F10.2)
     WRITE(51,1400)
1400 FORMAT('1',T50,'RELEASE RATES FOR RADIONUCLIDES')
     WRITE(51,1401)
1401 FORMAT('0',T45,'STACK',T61,'NUCLIDE',T80,'RELEASE RATE')
     WRITE(51,1402)
1402 FORMAT(' ',T82,'(PCI/SEC)')
     WRITE(51,301)
     DO 1404 J=1,NUMST
     DO 1405 I=1,NNUCS
     WRITE(51,1406)J,NAMNUC(I),REL(J,I)
1406 FORMAT(' ',T45,I2,T63,A8,T80,F10.3)
1405 CONTINUE
1404 CONTINUE
     WRITE(51,351)
351  FORMAT('1',T55,'DEPOSITION PARAMETERS')
     WRITE(51,352)
352  FORMAT('0',T20,'NUCLIDE',T40,'GRAVITATIONAL',T60,'DEPOSITION VELOC
    1ITY',T85,'SCAVENGING')
     WRITE(51,353)
353  FORMAT(' ',T40,'FALL VELOCITY',T85,'COEFFICIENT')
     WRITE(51,354)
354  FORMAT(' ',T41,'(METERS/SEC)',T63,'(METERS/SEC)',T87,'(1/SEC)')
     WRITE(51,301)
     DO 357 I=1,NNUCS
     WRITE(51,356)NAMNUC(I),VG(I),VD(I),SC(I)
```

```
356  FORMAT(' ',T21,A8,T37,F10.3,T61,F10.5,T85,F10.3)
357  CONTINUE
     WRITE(51,360)
360  FORMAT('1',T36,'FREQUENCIES OF WIND DIRECTIONS AND RECIPROCAL-AVER
    1AGED WIND SPEEDS')
     WRITE(51,301)
     WRITE(51,361)
361  FORMAT('0',T20,'WIND TOWARD',T50,'FREQUENCY',T82,'WIND SPEEDS FOR
    1EACH STABILITY CLASS')
     WRITE(51,366)
366  FORMAT(' ',T94,'(METERS/SEC)')
     WRITE(51,367)
367  FORMAT('0',T73,'A',T81,'B',T90,'C',T99,'D',T108,'E',T116,'F',T124,
    1'G')
     WRITE(51,301)
     DO 368 I=1,16
     WRITE(51,363)I,PERD(I),UDCAT(1,I),UDCAT(2,I),UDCAT(3,I),
    1UDCAT(4,I),UDCAT(5,I),UDCAT(6,I),UDCAT(7,I)
363  FORMAT(' ',T25,I2,T52,F5.3,T71,F5.2,T79,F5.2,T88,F5.2,T97,F5.2,
    1T106,F5.2,T114,F5.2,T122,F5.2)
368  CONTINUE
     WRITE(51,365)
365  FORMAT('0',T20,'WIND DIRECTIONS ARE NUMBERED COUNTERCLOCKWISE STA
    1RTING AT 1 FOR DUE NORTH')
     WRITE(51,202)
202  FORMAT('1',T38,'FREQUENCIES OF WIND DIRECTIONS AND TRUE-AVERAGE WI
    1ND SPEEDS')
     WRITE(51,301)
     WRITE(51,361)
     WRITE(51,366)
     WRITE(51,367)
     WRITE(51,301)
     DO 206 I=1,16
     WRITE(51,207)I,PERD(I),UDAV(1,I),UDAV(2,I),UDAV(3,I),UDAV(4,I),
    1UDAV(5,I),UDAV(6,I),UDAV(7,I)
207  FORMAT(' ',T25,I2,T52,F5.3,T71,F5.2,T79,F5.2,T88,F5.2,T97,F5.2,
    1T106,F5.2,T114,F5.2,T122,F5.2)
206  CONTINUE
     WRITE(51,365)
     WRITE(51,1154)
1154 FORMAT('1',T46,'ESTIMATED RADIONUCLIDE CONCENTRATIONS')
     WRITE(51,651)
651  FORMAT('0',T20,'AREA',T40,'NUCLIDE',T70,'AIR CONCENTRATION',T100,
    1'GROUND DEPOSITION RATE')
     WRITE(51,652)
652  FORMAT(' ',T75,'(PCI/CC)',T101,'(PCI/SQUARE CM-SEC)')
     IF(LCRT.EQ.0)GO TO 1310
     WRITE(51,1311)
1311 FORMAT(' ',T13,'WIND TOWARD',T25,'DISTANCE')
     WRITE(51,1312)
1312 FORMAT(' ',T25,'(METERS)')
     WRITE(51,301)
     GO TO 1149
1310 WRITE(51,653)
653  FORMAT(' ',T16,'COLUMN',T26,'ROW')
     WRITE(51,301)
1149 CONTINUE
     NEND=29
```

```
      IF(LORT.EQ.1)NEND=16
      LRUN=0
      DO 552 NO=1,NEND
      DO 553 NR=1,20
      IF(LORT.EQ.1)GO TO 1313
      GO TO 3000
 3050 DO 3070 NO=1,10
      DO 3071 NR=1,10
      LRUN=1
      IF(NO.GT.5.AND.NR.GT.5)XO=NO-5
      IF(NO.GT.5.AND.NR.GT.5)YO=NR-5
      IF(NO.LE.5.AND.NR.GT.5)XO=NO-6
      IF(NO.LE.5.AND.NR.GT.5)YO=NR-5
      IF(NO.LE.5.AND.NR.LE.5)XO=NO-6
      IF(NO.LE.5.AND.NR.LE.5)YO=NR-6
      IF(NO.GT.5.AND.NR.LE.5)XO=NO-5
      IF(NO.GT.5.AND.NR.LE.5)YO=NR-6
      X=SQRT((ABS(XO*SQSD2)-.5*SQSD2)**2+(ABS(YO*SQSD2)-.5*SQSD2)**2)
      NOK=NO+5
      NRK=NR+5
      MO=NSPTMO(NOK,NRK)
      GO TO 3001
 3000 IF(NO.GT.10.AND.NR.GT.10)XO=NO-10
      IF(NO.GT.10.AND.NR.GT.10)YO=NR-10
      IF(NO.LE.10.AND.NR.GT.10)XO=NO-11
      IF(NO.LE.10.AND.NR.GT.10)YO=NR-10
      IF(NO.LE.10.AND.NR.LE.10)XO=NO-11
      IF(NO.LE.10.AND.NR.LE.10)YO=NR-11
      IF(NO.GT.10.AND.NR.LE.10)XO=NO-10
      IF(NO.GT.10.AND.NR.LE.10)YO=NR-11
      X=SQRT((ABS(XO*SQSD)-.5*SQSD)**2+(ABS(YO*SQSD)-.5*SQSD)**2)
      MO=NSPTMO(NO,NR)
 3001 PERW=PERD(MO)
 1313 IF(LORT.EQ.0)GO TO 1156
      PERW=PERD(NO)
      MO=NO
      X=IDIST(NR)
 1156 FRA=FRAW(1,MO)
      FRB=FRAW(2,MO)
      FRC=FRAW(3,MO)
      FRD=FRAW(4,MO)
      FRE=FRAW(5,MO)
      FRF=FRAW(6,MO)
      FRG=FRAW(7,MO)
      DO 7050 I=1,NNUCS
      TGD(I)=0
 7050 TAI(I)=0
      DO 1159 J=1,NUMST
      UD=UDCAT(1,MO)
      U=UDAV(1,MO)
      FF2=(1.167-U/6.-1./UD)/(1.167-U/6.-1./U)
      FF3=U/5.-.2+FF2/5.-(FF2*U)/5.
      FF1=1.-FF2-FF3
      IF(FRA.EQ.0)U=1.0
      ADH(J)=(1.6*((3.7*(1.E-5)*QH(J))**0.333)*((10.*PH(J))**0.666))/U
      BDH(J)=(1.6*((3.7*(1.E-5)*QH(J))**0.333)*(X**0.666))/U
      IF(X.GT.(10.*PH(J)))DH(J)=ADH(J)
      IF(X.LE.(10.*PH(J)))DH(J)=BDH(J)
```

```
      IF(LCNT.EQ.1)DH(J)=(1.5*VEL(J)*DIA(J))/U
      IF(LUDT.EQ.1)DH(J)=PRA
      H(J)=PH(J)+DH(J)
      LIDI=LIDAI
      IAF=(LIDI/100)+1
      RIAF=IAF
      A=.6294
      C=.2083
      IF(X.LE.10000)A=.866
      IF(X.LE.10000)C=1.841
      IF(X.LE.1000)A=.9757
      IF(X.LE.1000)C=3.928
      D=1.00
      F=5.02
      DO 7000 I=1,NNUCS
      IF(I.EQ.1.OR.J.GT.1)GO TO 223
      IEN=I-1
      DO 221 M=1,IEN
      NOT1=0
      NOT2=0
      IF(VG(I).EQ.VG(M).AND.VD(I).EQ.VD(M))NOT1=1
      IF(SC(I).EQ.SC(M))NOT2=1
      IF(EXP(-((ANLAM(I)*DISTG)/(8.64E4*2.1))).LT.0.95)NOT2=0
      IF(NOT1.EQ.1.AND.NOT2.EQ.1)NOMA(I)=M
      IF(NOT1.EQ.1.AND.NOT2.EQ.1)GO TO 7000
221   CONTINUE
223   CONTINUE
      IF(FRA.EQ.0)GO TO 7000
      CALL ALFDD(D,F,VG(I),U,LIDI,XLIDD)
      IF(X.LE.XLIDD)GO TO 5030
      QREDLR=EXP(-((X-XLIDD)*(VD(I)/(LIDI*U))))
      CALL QXA(XLIDD,H(J),VD(I),U,UD,VG(I),QFDD)
      FDD=QREDLR*QFDD
      GO TO 5031
5030  CALL QXA(X,H(J),VD(I),U,UD,VG(I),FDD)
5031  QRED=REL(J,I)*FDD*EXP(-(SC(I)*X/U))
     1*(FF1*EXP(-((ANLAM(I)*X)/(8.64E4*1.)))+FF2*EXP(-((ANLAM(I)*X)/(8.6
     24E4*U)))+FF3*EXP(-((ANLAM(I)*X)/(8.64E4*6.))))
      CHAD=QRED/(6.2832*((X**A)/C)*((X**D)/F)*UD)
      TVAL=0
      DO 6000 IA=1,IAF
      ZA=(IA-1)*100
      IF((.5*((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)).GT.50)VAL=0
      IF((.5*((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)).GT.50)GO TO 701
      IF(((VG(I)*X)/U).GE.H(J))H(J)=(VG(I)*X)/U
      VAL=CHAD*(EXP(-.5*(((((VG(I)*X)/U)+ZA-H(J))/((X**D)/F))**2))+
     1EXP(-.5*(((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)))
701   IF(IA.EQ.1)BX=VAL
      TVAL=VAL+TVAL
6000  CONTINUE
      VERT=TVAL/RIAF
      IF(X.LE.XLIDD)
     1AT=BX
      IF(X.LE.XLIDD)
     1BU=0
      IF(X.GT.XLIDD)
     1AT=QRED/(2.5066*((X**A)/C)*LIDI*UD)
      IF(X.GT.XLIDD)
```

```
      IRU=AT
       IF(X.GT.XLIDD)
      IVERT=0
       DO 260 IER=1,12
       AI=IER
       THETA=AI*0.02454
       Y=X*TAN(THETA)
260    AMULT(IER)=EXP(-.5*((Y/((X**A)/C))**2))
       TOTA=1.0
       DO 261 JER=1,12
261    TOTA=AMULT(JER)+TOTA
       FRAC=TOTA/9.
       IF(LOST.EQ.1)FRAC=1.0
       SAF=FRAC*PERW*4.
       VERT=(SAF*VERT)/4.
       RU=(SAF*RU)/4.
       AT=(SAF*AT)/4.
       TGD(I)=VD(I)*AT*FRA+SC(I)*LID1*VERT*FRA+SC(I)*LID1*RU*FRA+TGD(I)
       TAI(I)=AT*FRA+TAI(I)
9072   CONTINUE
7000   CONTINUE
1157   IF(FRB.EQ.0)GO TO 21
       UD=UDCAT(2,MD)
       U=UDAV(2,MD)
       FF2=(1.167-U/6.-1./UD)/(1.167-U/6.-1./U)
       FF3=U/5.-.2+FF2/5.-(FF2*U)/5.
       FF1=1.-FF2-FF3
       ADH(J)=(1.6*((3.7*(1.E-5)*QH(J))**0.333)*((10.*PH(J))**0.666))/U
       BDH(J)=(1.6*((3.7*(1.E-5)*QH(J))**0.333)*(X**0.666))/U
       IF(X.GT.(10.*PH(J)))DH(J)=ADH(J)
       IF(X.LE.(10.*PH(J)))DH(J)=BDH(J)
       IF(LCNT.EQ.1)DH(J)=(1.5*VEL(J)*DIA(J))/U
       IF(LCUT.EQ.1)DH(J)=PRB
       H(J)=PH(J)+DH(J)
       LID1=LIDA1
       IAF=(LID1/100)+1
       RIAF=IAF
       A=.5303
       C=.2946
       IF(X.LE.10000)A=.8493
       IF(X.LE.10000)C=2.213
       IF(X.LE.1000)A=.9986
       IF(X.LE.1000)C=6.205
       D=1.00
       F=9.35
       DO 7001 I=1,NNICS
       IF(NOMA(I).GT.0)GO TO 7001
       CALL ALFDC(D,F,VG(I),U,LID1,XLIDD)
       IF(X.LE.XLIDD)GO TO 5040
       QREDLR=EXP(-((X-XLIDD)*(VD(I)/(LID1*U))))
       CALL QXB(XLIDD,H(J),VD(I),U,UD,VG(I),QFDD)
       FDD=QREDLR*QFDD
       GO TO 5041
5040   CALL QXB(X,H(J),VD(I),U,UD,VG(I),FDD)
5041   QRED=REL(J,I)*FDD*EXP(-(SC(I)*X/U))
      1*(FF1*EXP(-((ANLAM(I)*X)/(8.64E4*1.)))+FF2*EXP(-((ANLAM(I)*X)/(8.6
      2E4*U)))+FF3*EXP(-((ANLAM(I)*X)/(8.64E4*6.))))
       CHAD=QRED/(6.2832*((X**A)/C)*((X**D)/F)*UD)
```

```
      TVAL=0
      DO 6001 IA=1,IAF
      ZA=(IA-1)*100
      IF((.5*((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)).GT.50)VAL=0
      IF((.5*((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)).GT.50)GO TO 70?
      IF(((VG(I)*X)/U).GE.H(J))H(J)=(VG(I)*X)/U
      VAL=CHAD*(EXP(-.5*(((((VG(I)*X)/U)+ZA-H(J))/((X**D)/F))**2))+
     1EXP(-.5*(((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)))
70?   IF(IA.EQ.1)BX=VAL
      TVAL=VAL+TVAL
6001  CONTINUE
      VERT=TVAL/RIAF
      IF(X.LE.XLIO?)
     1BT=BX
      IF(X.LE.XLIO?)
     1BU=C
      IF(X.GT.XLIOD)
     1BT=QREO/(2.5066*((X**A)/C)*LIO1*UO)
      IF(X.GT.XLIO?)
     1BU=BT
      IF(X.GT.XLIO?)
     1VERT=0
      DO 262 IER=1,12
      AI=IER
      THETA=AI*0.02454
      Y=X*TAN(THETA)
262   AMULT(IER)=EXP(-.5*((Y/((X**A)/C))**2))
      TOTA=1.0
      DO 263 JER=1,12
263   TOTA=AMULT(JER)+TOTA
      FRAC=TOTA/9.
      IF(LOST.EQ.1)FRAC=1.0
      SAF=FRAC*PFRB*4.
      VERT=(SAF*VERT)/4.
      BU=(SAF*BU)/4.
      BT=(SAF*BT)/4.
      TGD(I)=VG(I)*BT*FRB+SC(I)*LIO1*VERT*FRB+SC(I)*LIO1*BU*FRB+TGD(I)
      TAI(I)=BT*FRB+TAI(I)
4074  CONTINUE
7001  CONTINUE
21    IF(FRC.EQ.0)GO TO 22
      UD=UDCAT(3,MO)
      U=UDAV(3,MO)
      FF2=(1.167-U/6.-1./UD)/(1.167-U/6.-1./U)
      FF3=U/5.-.2+FF2/5.-(FF2*U)/5.
      FF1=1.-FF2-FF3
      ADH(J)=(1.6*((3.7*(1.E-5)*QH(J))**0.333)*((10.*PH(J))**0.666))/U
      BDH(J)=(1.6*((3.7*(1.E-5)*QH(J))**0.333)*(X**0.666))/U
      IF(X.GT.(10.*PH(J)))DH(J)=ADH(J)
      IF(X.LE.(10.*PH(J)))DH(J)=BDH(J)
      IF(LONT.EQ.1)DH(J)=(1.5*VEL(J)*DIA(J))/U
      IF(LOST.EQ.1)DH(J)=PRC
      H(J)=PH(J)+DH(J)
      LIO1=LIOA1
      IAF=(LIO1/100)+1
      RIAF=IAF
      A=.0?54
      C=.397X
```

```
      IF(X.LE.10000)A=.854
      IF(X.LE.10000)C=3.266
      IF(X.LE.1000)A=.9767
      IF(X.LE.1000)C=7.623
      D=.5524
      F=.332
      IF(X.LE.10000)D=.833
      IF(X.LE.10000)F=4.4
      IF(X.LE.1000)D=.954
      IF(X.LE.1000)F=10.015
      DO 7002 I=1,NNUCS
      IF(NUMA(I).GT.0)GO TO 7002
      CALL ALFDD(D,F,VG(I),U,LID1,XLIDD)
      IF(X.LE.XLIDD)GO TO 5050
      QREDLR=EXP(-((X-XLIDD)*(VD(I)/(LID1*U))))
      CALL QXC(XLIDD,H(J),VD(I),U,UD,VG(I),QFDD)
      FDD=QREDLR*QFDD
      GO TO 5051
5050  CALL QXC(X,H(J),VD(I),U,UD,VG(I),FDD)
5051  QRED=REL(J,I)*FDD*EXP(-(SC(I)*X/U))
     1*(FF1*EXP(-((ANLAM(I)*X)/(8.64E4*1.)))+FF2*EXP(-((ANLAM(I)*X)/(3.5
     2E4*U)))+FF3*EXP(-((ANLAM(I)*X)/(3.64E4*6.))))
      CHAD=QRED/(6.2832*((X**A)/C)*((X**D)/F)*UD)
      TVAL=0
      DO 6002 IA=1,IAF
      ZA=(IA-1)*100
      IF((.5*(((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)).GT.50)VAL=0
      IF((.5*(((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)).GT.50)GO TO 703
      IF(((VG(I)*X)/U).GE.H(J))H(J)=(VG(I)*X)/U
      VAL=CHAD*(EXP(-.5*(((((VG(I)*X)/U)+ZA-H(J))/((X**D)/F))**2))+
     1EXP(-.5*(((((VG(I)*X)/U)+ZA+H(J))/((X**Q)/F))**2)))
703   IF(IA.EQ.1)BX=VAL
      TVAL=VAL+TVAL
6002  CONTINUE
      VERT=TVAL/RIAF
      IF(X.LE.XLIDD)
     1CT=BX
      IF(X.LE.XLIDD)
     1BU=U
      IF(X.GT.XLIDD)
     1CT=QRED/(2.5066*((X**A)/C)*LID1*UD)
      IF(X.GT.XLIDD)
     1BU=CT
      IF(X.GT.XLIDD)
     1VERT=0
      DO 264 IER=1,12
      AI=IER
      THETA=AI*0.02454
      Y=X*TAN(THETA)
264   AMULT(IER)=EXP(-.5*((Y/((X**A)/C))**2))
      TOTA=1.0
      DO 265 JER=1,12
265   TOTA=AMULT(JER)+TOTA
      FRAC=TOTA/9.
      IF(LCST.EQ.1)FRAC=1.0
      SAF=FRAC*PERW*4.
      VERT=(SAF*VERT)/4.
      BU=(SAF*BU)/4.
```

```
      CT=(SAF*CT)/4.
      TGD(I)=VD(I)*CT*FRC+SC(I)*LID1*VFRT*FRC+SC(I)*LID1*PU*FRC+TGD(I)
      TAI(I)=CT*FRC+TAI(I)
9076  CONTINUE
7002  CONTINUE
22    IF(FRD.EQ.0)GO TO 23
      UD=UDCAT(4,MO)
      U=UDAV(4,MO)
      FF2=(1.167-U/6.-1./UD)/(1.167-U/6.-1./U)
      FF3=U/5.-.2+FF2/5.-(FF2*U)/5.
      FF1=1.-FF2-FF3
      ADH(J)=(1.6*((3.7*(1.E-5)*QH(J))**0.333)*((10.*PH(J))**0.666))/U
      BDH(J)=(1.6*((3.7*(1.E-5)*QH(J))**0.333)*(X**0.666))/U
      IF(X.GT.(10.*PH(J)))DH(J)=ADH(J)
      IF(X.LE.(10.*PH(J)))DH(J)=BDH(J)
      IF(LONT.EQ.1)DH(J)=(1.5*VEL(J)*DIA(J))/U
      IF(LOOT.EQ.1)DH(J)=PRD
      H(J)=PH(J)+DH(J)
      LID1=LIDA1
      IAF=(LID1/100)+1
      RIAF=IAF
      A=.6342
      C=.6156
      IF(X.LE.10000)A=.867
      IF(X.LE.10000)C=5.261
      IF(X.LE.1000)A=.96
      IF(X.LE.1000)C=10.0
      D=.5251
      F=.93
      IF(X.LE.10000)D=.5099
      IF(X.LE.10000)F=.81
      IF(X.LE.3000)D=.6715
      IF(X.LE.3000)F=2.55
      IF(X.LE.1000)D=.8061
      IF(X.LE.1000)F=7.48
      DO 7003 I=1,NNUCS
      IF(NOMA(I).GT.0)GO TO 7003
      CALL ALFOD(D,F,VG(I),U,LID1,XLIDO)
      IF(X.LE.XLIDO)GO TO 5060
      DREDLR=EXP(-((X-XLIDO)*(VD(I)/(LID1*U))))
      CALL DXD(XLIDO,H(J),VD(I),U,UD,VG(I),QFDD)
      FDD=DREDLR*QFDD
      GO TO 5061
5060  CALL DXD(X,H(J),VD(I),U,UD,VG(I),FDD)
5061  DRED=RFL(J,I)*FDD*EXP(-(SC(I)*X/U))
     1*(FF1*EXP(-((ANLAM(I)*X)/(8.64E4*1.)))+FF2*EXP(-((ANLAM(I)*X)/(5.6
     2E4*U)))+FF3*EXP(-((ANLAM(I)*X)/(8.64E4*6.))))
      CHAD=DRED/(6.2832*((X**A)/C)*((X**D)/F)*UD)
      TVAL=0
      DO 6003 IA=1,IAF
      ZA=(IA-1)*100
      IF((.5*((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)).GT.50)VAL=0
      IF((.5*((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)).GT.50)GO TO 704
      IF(((VG(I)*X)/U).GE.H(J))H(J)=(VG(I)*X)/U
      VAL=CHAD*(EXP(-.5*(((((VG(I)*X)/U)+ZA-H(J))/((X**D)/F))**2))+
     1EXP(-.5*(((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)))
704   IF(IA.EQ.1)BX=VAL
      TVAL=VAL+TVAL
```

```
6003 CONTINUE
     VERT=TVAL/RIA.
      IF(X.LE.XLIDO)
     1DT=BX
      IF(X.LE.XLIDO)
     1BU=0
      IF(X.GT.XLIDO)
     1DT=QRED/(2.5066*((X**A)/C)*LID1*UD)
      IF(X.GT.XLIDO)
     1BU=DT
      IF(X.GT.XLIDO)
     1VERT=0
      DO 266 IER=1,12
      AI=IER
      THETA=AI*0.02454
      Y=X*TAN(THETA)
266   AMULT(IER)=EXP(-.5*((Y/((X**A)/C))**2))
      TOTA=1.0
      DO 267 JER=1,12
267   TOTA=AMULT(JER)+TOTA
      FRAC=TOTA/9.
      IF(LOST.EQ.1)FRAC=1.0
      SAF=FRAC*PERW*4.
      VERT=(SAF*VERT)/4.
      BU=(SAF*BU)/4.
      DT=(SAF*DT)/4.
      TGD(I)=VD(I)*DT*FRD+SC(I)*LID1*VERT*FRD+SC(I)*LID1*BU*FRD+TGD(I)
      TAI(I)=DT*FRD+TAI(I)
9078 CONTINUE
7003 CONTINUE
23    IF(FRE.EQ.0)GO TO 24
      UD=UDCAT(5,MO)
      U=UDAV(5,MO)
      FF2=(1.167-U/6.-1./UD)/(1.167-U/6.-1./U)
      FF3=U/5.-.2+FF2/5.-(FF2*U)/5.
      FF1=1.-FF2-FF3
      S=(9.80665/TA)*(TGE+0.0098)
      DH(J)=2.9*(((3.7*(1.E-5)*QH(J))/(U*S))**0.333)
      IF(X.GT.((2.4*U)/SQRT(S)))GO TO 805
      DH(J)=(1.6*((3.7*(1.E-5)*QH(J))**0.333)*(X**0.666))/U
805   IF(LOOT.EQ.1)DH(J)=PRE
      IF(LONT.EQ.1)DH(J)=(1.5*VEL(J)*DIA(J))/U
      H(J)=PH(J)+DH(J)
      LID1=LIDA1
      IAF=(LID1/100)+1
      RIAF=IAF
      A=.626
      C=.8042
      IF(X.LE.10000)A=.867
      IF(X.LE.10000)C=7.357
      IF(X.LE.1000)A=.9615
      IF(X.LE.1000)C=14.13
      D=.111
      F=.0349
      IF(X.LE.10000)D=.4054
      IF(X.LE.10000)F=.524
      IF(X.LE.3000)D=.629
      IF(X.LE.3000)F=3.15
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```
      IF(X.LE.1000)D=.86
      IF(X.LE.1000)F=15.5
      DO 7004 I=1,NNUCS
      IF(NOMA(I).GT.0)GO TO 7004
      CALL ALFDD(D,F,VG(I),U,LID1,XLIDD)
      IF(X.LE.XLIDD)GO TO 5070
      QREDLR=EXP(-((X-XLIDD)*(VD(I)/(LID1*U))))
      CALL QXE(XLIDD,H(J),VD(I),U,UD,VG(I),QFDD)
      FDD=QREDLR*QFDD
      GO TO 5071
 5070 CALL QXE(X,H(J),VD(I),U,UD,VG(I),FDD)
 5071 QRED=REL(J,I)*FDD*EXP(-(SC(I)*X/U))
     1*(FF1*EXP(-((ANLAM(I)*X)/(8.64E4*1.)))+FF2*EXP(-((ANLAM(I)*X)/(8.6
     24E4*U)))+FF3*EXP(-((ANLAM(I)*X)/(8.64E4*6.))))
      CHAD=QRED/(6.2832*((X**A)/C)*((X**D)/F)*UD)
      TVAL=0
      DO 6004 IA=1,IAF
      ZA=(IA-1)*100
      IF((.5*((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)).GT.50)VAL=0
      IF((.5*((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)).GT.50)GO TO 705
      IF(((VG(I)*X)/U).GE.H(J))H(J)=(VG(I)*X)/U
      VAL=CHAD*(EXP(-.5*(((((VG(I)*X)/U)+ZA-H(J))/((X**D)/F))**2))+
     1EXP(-.5*(((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)))
 705  IF(IA.EQ.1)BX=VAL
      TVAL=VAL+TVAL
 6004 CONTINUE
      VERT=TVAL/RIAF
      IF(X.LE.XLIDD)
     1ET=BX
      IF(X.LE.XLIDD)
     1BU=0
      IF(X.GT.XLIDD)
     1ET=QRED/(2.5066*((X**A)/C)*LID1*UD)
      IF(X.GT.XLIDD)
     1BU=ET
      IF(X.GT.XLIDD)
     1VERT=0
      DO 268 IER=1,12
      AI=IER
      THETA=AI*0.02454
      Y=X*TAN(THETA)
 268  AMULT(IER)=EXP(-.5*((Y/((X**A)/C))**2))
      TOTA=1.0
      DO 269 JER=1,12
 269  TOTA=AMULT(JER)+TOTA
      FRAC=TOTA/9.
      IF(LCST.EQ.1)FRAC=1.0
      SAF=FRAC*PERW*4.
      VERT=(SAF*VERT)/4.
      BU=(SAF*BU)/4.
      ET=(SAF*ET)/4.
      TGD(I)=VD(I)*ET*FRE+SC(I)*LID1*VERT*FRE+SC(I)*LID1*BU*FRE+TGD(I)
      TAI(I)=ET*FRE+TAI(I)
 9080 CONTINUE
 7004 CONTINUE
 2    IF(FRE.EQ.0)GO TO 1158
      UD=UDCAT(6,MO)
      U=UDAV(6,MO)
```

```
      FF2=(1.167-U/6.-1./UD)/(1.167-U/6.-1./U)
      FF3=U/5.-.2+FF2/5.-(FF2*U)/5.
      FF1=1.-FF2-FF3
      S=(9.8066/TA)*(TGF+0.0098)
      DH(J)=2.9*(((3.7*(1.E-5)*QH(J))/(U*S))**0.333)
      IF(X.GT.((2.4*U)/SQRT(S)))GO TO 806
      DH(J)=(1.6*((3.7*(1.E-5)*QH(J))**0.333)*(X**0.666))/U
806   IF(LONT.EQ.1)DH(J)=PRF
      IF(LONT.EQ.1)DH(J)=(1.5*VEL(J)*DIA(J))/U
      H(J)=PH(J)+DH(J)
      LID1=LIDA1
      IAF=(LID1/100)+1
      RIAF=IAF
      A=.6342
      C=1.233
      IF(X.LE.10000)A=.854
      IF(X.LE.10000)C=9.333
      IF(X.LE.1000)A=.9733
      IF(X.LE.1000)C=21.28
      D=.1106
      F=.0694
      IF(X.LE.10000)D=.371
      IF(X.LE.10000)F=.764
      IF(X.LE.3000)D=.6321
      IF(X.LE.3000)F=6.132
      IF(X.LE.1000)D=.8823
      IF(X.LE.1000)F=34.7
      DO 7005 I=1,NNUCS
      IF(NOMA(I).GT.0)GO TO 7005
      CALL ALFDD(D,F,VG(I),U,LID1,XLIDD)
      IF(X.LE.XLIDD)GO TO 5080
      QREDLR=EXP(-((X-XLIDD)*(VD(I)/(LID1*U))))
      CALL QXF(XLIDD,H(J),VD(I),U,UD,VG(I),QFDD)
      FDD=QREDLR*QFDD
      GO TO 5081
5080  CALL QXF(X,H(J),VD(I),U,UD,VG(I),FDD)
5081  QRED=REL(J,I)*FDD*EXP(-(SC(I)*X/U))
     1*(FF1*EXP(-((ANLAM(I)*X)/(8.64E4*1.)))+FF2*EXP(-((ANLAM(I)*X)/(8.6
     2E4*U)))+FF3*EXP(-((ANLAM(I)*X)/(8.64E4*6.))))
      CHAD=QRED/(6.2832*((X**A)/C)*((X**D)/F)*UD)
      TVAL=0
      DO 6005 IA=1,IAF
      ZA=(IA-1)*100
      IF((.5*(((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)).GT.50)VAL=0
      IF((.5*(((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)).GT.50)GO TO 706
      IF(((VG(I)*X)/U).GE.H(J))H(J)=(VG(I)*X)/U
      VAL=CHAD*(EXP(-.5*(((((VG(I)*X)/U)+ZA-H(J))/((X**D)/F))**2))+
     1EXP(-.5*(((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)))
706   IF(IA.EQ.1)BX=VAL
      TVAL=VAL+TVAL
6005  CONTINUE
      VERT=TVAL/RIAF
      IF(X.LE.XLIDD)
     1FT=BX
      IF(X.LE.XLIDD)
     1HU=0
      IF(X.GT.XLIDD)
     1FT=QRED/(2.5066*((X**A)/C)*LID1*UD)
```

```
      IF(X.GT.XLIDD)
     1RU=FT
      IF(X.GT.XLIDD)
     1VERT=0
      DO 270 IER=1,12
      AI=IER
      THETA=AI*0.02454
      Y=X*TAN(THETA)
 270  AMULT(IER)=EXP(-.5*((Y/((X**A)/C))**2))
      TOTA=1.0
      DO 271 JER=1,12
 271  TOTA=AMULT(JER)+TOTA
      FRAC=TOTA/9.
      IF(LOST.EQ.1)FRAC=1.0
      SAF=FRAC*PERW*4.
      VERT=(SAF*VERT)/4.
      RU=(SAF*RU)/4.
      FT=(SAF*FT)/4.
      TGD(I)=VD(I)*FT*FRF+SC(I)*LID1*VERT*FRF+SC(I)*LID1*RU*FRF+TGD(I)
      TAI(I)=FT*FRF+TAI(I)
9062  CONTINUE
7005  CONTINUE
1155  IF(FRG.EQ.0)GO TO 9888
      UD=UDCAT(7,MD)
      U=UDAV(7,MD)
      FF2=(1.167-U/6.-1./UD)/(1.167-U/6.-1./U)
      FF3=U/5.-.2+FF2/5.-(FF2*U)/5.
      FF1=1.-FF2-FF3
      S=(9.8066/TA)*(TGG+0.0098)
      DH(J)=2.9*(((3.7*(1.E-5)*QH(J))/(U*S))**0.333)
      IF(X.GT.((2.4*U)/SQRT(S)))GO TO 807
      DH(J)=(1.6*((3.7*(1.E-5)*QH(J))**0.333)*(X**0.666))/U
 807  IF(LOST.EQ.1)DH(J)=PRG
      IF(LONT.EQ.1)DH(J)=(1.5*VEL(J)*DIA(J))/U
      H(J)=PH(J)+DH(J)
      LID1=LIDA1
      IAF=(LID1/100)+1
      P IAF=IAF
      A=.836
      C=10.093
      IF(X.LE.1000)A=.9986
      IF(X.LE.1000)C=31.03
      D=.1106
      F=.1739
      IF(X.LE.10000)D=.3818
      IF(X.LE.10000)F=2.115
      IF(X.LE.3000)D=.6547
      IF(X.LE.3000)F=18.8
      IF(X.LE.1000)D=.8257
      IF(X.LE.1000)F=61.25
9888  DO 7006 I=1,NNUCS
      IF(NUMA(I).GT.0)GO TO 9889
      CALL ALFDD(D,F,VG(I),U,LID1,XLIDD)
      IF(X.LE.XLIDD)GO TO 5090
      QREDLR=EXP(-((X-XLIDD)*(VD(I)/(LID1*U))))
      CALL QXG(XLIDD,H(J),VD(I),U,UD,VG(I),QFDD)
      FDD=QREDLR*QFDD
      GO TO 5091
```

```
5090 CALL QXG(X,H(J),VD(I),U,UD,VG(I),FDD)
5091 QRED=RFL(J,I)*FDD*EXP(-(SC(I)*X/U))
    1*(FF1*EXP(-((ANLAM(I)*X)/(8.64E4*1.)))+FF2*EXP(-((ANLAM(I)*X)/(8.6
    24E4*U)))+FF3*EXP(-((ANLAM(I)*X)/(8.64E4*6.))))
     CHAD=QRED/(6.2832*((X**A)/C)*((X**D)/F)*UD)
     TVAL=0
     DO 6006 IA=1,IAF
     ZA=(IA-1)*100
     IF((.5*(((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)).GT.50)VAL=0
     IF((.5*(((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)).GT.50)GO TO 707
     IF(((VG(I)*X)/U).GE.H(J))H(J)=(VG(I)*X)/U
     VAL=CHAD*(EXP(-.5*(((((VG(I)*X)/U)+ZA-H(J))/((X**D)/F))**2))+
    1EXP(-.5*(((((VG(I)*X)/U)+ZA+H(J))/((X**D)/F))**2)))
707  IF(IA.EQ.1)BX=VAL
     TVAL=VAL+TVAL
6006 CONTINUE
     VERT=TVAL/RIAF
     IF(X.LE.XLIDD)
    1GT=BX
     IF(X.LE.XLIDD)
    1BU=0
     IF(X.GT.XLIDD)
    1GT=QRED/(2.5066*((X**A)/C)*LID1*UD)
     IF(X.GT.XLIDD)
    1BU=GT
     IF(X.GT.XLIDD)
    1VERT=0
     DO 272 IER=1,12
     AI=IER
     THETA=AI*0.02454
     Y=X*TAN(THETA)
272  AMULT(IER)=EXP(-.5*((Y/((X**A)/C))**2))
     TOTA=1.0
     DO 273 JER=1,12
273  TOTA=AMULT(JER)+TOTA
     FRAC=TOTA/9.
     IF(LOST.EQ.1)FRAC=1.0
     SAF=FRAC*PERW*4.
     VERT=(SAF*VERT)/4.
     BU=(SAF*BU)/4.
     GT=(SAF*GT)/4.
     TGD(I)=VD(I)*GT*FRG+SC(I)*LID1*VERT*FRG+SC(I)*LID1*BU*FRG+TGD(I)
     TAI(I)=GT*FRG+TAI(I)
9084 CONTINUE
9389 M=NOMA(I)
     IF(NOMA(I).GT.0)TGD(I)=TGD(M)*(RFL(J,I)/RFL(J,M))
     IF(NOMA(I).GT.0)TAI(I)=TAI(M)*(RFL(J,I)/RFL(J,M))
7006 CONTINUE
1159 CONTINUE
     IF(LORT.EQ.1)GO TO 7799
     IF(LRUN.EQ.1)GO TO 3005
     DO 7999 I=1,NNUCS
     CALL AKA(I,NU,NR)
7999 CONTINUE
     GO TO 553
7799 DO 7998 I=1,NNUCS
7998 CALL AKKA(I,NQ,NR)
     GO TO 553
```

```
3005 DO 3006 I=1,NNUCS
     FSTR(I,NO,NR)=TAI(I)*1.E-6
3006 FSTRG(I,NO,NR)=TGD(I)*1.E-4
3071 CONTINUE
3070 CONTINUE
     IF(LRUN.EQ.1)GO TO 3072
553  CONTINUE
552  CONTINUE
3072 CONTINUE
     IF(LRUN.EQ.0)GO TO 3050
     IF(LOKT.EQ.1)GO TO 7997
     ASQSD=((SQSD**2)*400.)/1.E6
     WRITE(51,301)
     WRITE(51,301)
     WRITE(51,5000)
5000 FORMAT('0',T35,'NOTE-  THE AREA SURROUNDING THE PLANT IS A SQUARE
    1WITH AN AREA')
     WRITE(51,5001)ASQSD
5001 FORMAT(' ',T35,'OF',F7.1,1X,'SQUARE KILOMETERS WITH THE PLANT LOCA
    1TED AT THE CENTER.')
     WRITE(51,5002)
5002 FORMAT(' ',T35,'THE SQUARE AREA IS ALIGNED DUE NORTH-SOUTH AND EAS
    1T-WEST. THE')
     WRITE(51,5003)SQSD
5003 FORMAT(' ',T35,'400 SMALLER SQUARES, WHICH ARE EACH ',F7.1,1X,'MET
    1ERS ON A SIDE,')
     WRITE(51,5004)
5004 FORMAT(' ',T35,'ARE IDENTIFIED BY COLUMN AND ROW. COLUMNS ARE NUMB
    1ERED FROM')
     WRITE(51,5005)
5005 FORMAT(' ',T35,'1 TO 20 FROM WEST TO EAST. ROWS ARE NUMBERED FROM
    11 TO 20 FROM')
     WRITE(51,5006)
5006 FORMAT(' ',T35,'SOUTH TO NORTH.')
     IF(LOPT.EQ.1)GO TO 7997
     READ(50,556)((NOBCT(I,J),J=1,20),I=1,20)
556  FORMAT(16I5)
     READ(50,557)((NOMCT(I,J),J=1,20),I=1,20)
557  FORMAT(16I5)
     READ(50,1001)((INTEC(I,J),J=1,20),I=1,20)
1001 FORMAT(80I1)
     READ(50,1002)((INTPA(I,J),J=1,20),I=1,20)
1002 FORMAT(8F10.1)
     READ(50,558)((INTWA(I,J),J=1,20),I=1,20)
558  FORMAT(40I2)
     READ 10,WRTHRT,DILFAC,USEFAC
10   FORMAT(3F10.3)
     READ 150, A,ASURG,DSURF,DSURG,SMALLD,D1,D2,D3,D4
     READ 150, KSURB,MSURB,RHO,S1,S2,S3,TAUREF,TAUMLK,TAURM,TAUCM
     READ 150, TAUES,TAUGR,TAURD,TAURD,TAURG,TAUSP,U,V,VSURC,VSURM
150  FORMAT (10F8.4)
     READ(50,162)PFIV
162  FORMAT(F10.2)
     READ(50,162)PFIC
     READ(50,162)PFIB
     S10 = S1
     S20 = S2
     S30 = S3
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      WRITE(51,860)
  860 FORMAT('1')
      WRITE(51,301)
      WRITE(51,301)
      WRITE(51,1200)
 1200 FORMAT('0',T48,'SUMMARY OF AREA SURROUNDING PLANT')
      WRITE(51,1201)
 1201 FORMAT('0',T20,'AREA',T40,'NO. BEEF CATTLE',T60,'NO. MILK CATTLE'
     1,T80,'FOOD CROPS',T95,'WATER AREA',T113,'POPULATION')
      WRITE(51,1202)
 1202 FORMAT('0',T16,'COLUMN',T26,'ROW')
      WRITE(51,301)
      DO 1204 NO=1,20
      DO 1205 NR=1,20
      WRITE(51,1206)NO,NR,NOBCT(NO,NR),NOMCT(NO,NR),INTFC(NO,NR),
     1INTWA(NO,NR),INTPA(NO,NR)
 1206 FORMAT(' ',T18,I2,T27,I2,T45,I5,T64,I5,T85,I2,T100,I2,T110,F10.1)
 1205 CONTINUE
 1204 CONTINUE
      WRITE(51,1207)
 1207 FORMAT('0',T20,'FOR FOOD CROPS--0= NONE OR MINIMAL AND 1= FOOD CRO
     1PS PRODUCED')
      WRITE(51,1208)
 1208 FORMAT(' ',T20,'FOR WATER AREAS--0= NONE OR MINIMAL AND 1= MAJOR W
     1ATER AREA PRESENT')
      PRINT 871
  871 FORMAT('1',T36,'LIST OF INPUT VALUES FOR RADIONUCLIDE-INDEPENDENT
     1VARIABLES')
      PRINT 880,NNUCS
  880 FORMAT('0',T13,'NUMBER OF NUCLIDES CONSIDERED',T110,I12)
      PRINT 881,BRTHRT
  881 FORMAT('0',T13,'INHALATION RATE OF MAN (CUBIC CENTIMETERS/HR)',
     1T110,E12.4)
      PRINT 883,DILFAC
  883 FORMAT('0',T13,'DILUTION FACTOR FOR WATER FOR SWIMMING (CM)',T110,
     1F12.4)
      PRINT 884,USEFAC
  884 FORMAT('0',T13,'FRACTION OF TIME SPENT SWIMMING',T110,F12.4)
      PRINT 900,A
  900 FORMAT('0',T13,'SOIL SURFACE AREA REQUIRED TO FURNISH FOOD CROPS F
     1OR ONE MAN (SQUARE METERS)',T110,E12.4)
      PRINT 901,ASUBG
  901 FORMAT('0',T13,'PASTURE AREA PER COW (SQUARE METERS)',T110,F12.4)
      PRINT 902,DSUBF
  902 FORMAT('0',T13,'DRY WEIGHT AREAL DENSITY OF MANS ABOVE-SURFACE FOO
     1D (KGS PER SQUARE METER)',T110,F12.4)
      PRINT 903,DSUBG
  903 FORMAT('0',T13,'DRY-WEIGHT AREAL GRASS DENSITY (KGS PER SQUARE MET
     1ER)',T110,F12.4)
      PRINT 904,SMALLD
  904 FORMAT('0',T13,'DEPTH OF PLOW LAYER (CM)',T110,F12.4)
      PRINT 909,KSUBB
  909 FORMAT('0',T13,'RATE OF INCREASE OF STEER MUSCLE MASS (KG PER DAY)
     1',T110,E12.4)
      PRINT 910,MSUBB
  910 FORMAT('0',T13,'MUSCLE MASS OF STEER AT SLAUGHTER (KG)',T110,F12.4
     1)
      PRINT 911,RHO
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911  FORMAT('0',T13,'SOIL DENSITY (GRAMS PER CUBIC CENTIMETER)',T110,E1
    12.4)
     PRINT 912,S1
912  FORMAT('0',T13,'FALLOUT CORRECTION FACTOR FOR ABOVE-SURFACE FOOD',
    1T110,E12.4)
     PRINT 913,S2
913  FORMAT('0',T13,'FALLOUT CORRECTION FACTOR FOR SOIL SURFACE BELOW F
    1OOD',T110,E12.4)
     PRINT 914,S3
914  FORMAT('0',T13,'FALLOUT CORRECTION FACTOR FOR PASTURE',T110,E12.4)
     PRINT 915,TAUBEF
915  FORMAT('0',T13,'FRACTION OF BEEF HERD SLAUGHTERED PER DAY',T110,E1
    12.4)
     PRINT 916,TAUMLK
916  FORMAT('0',T13,'TRANSFER RATE OF MILK FROM UDDER (PER DAY)',T110,E
    112.4)
     PRINT 917,TAUBM
917  FORMAT('0',T13,'BEEF CONSUMPTION OF MAN (KG/DAY)',T110,E12.4)
     PRINT 918,TAUCM
918  FORMAT('0',T13,'MILK CONSUMPTION OF MAN (LITERS/DAY)',T110,E12.4)
     PRINT 919,TAUES
919  FORMAT('0',T13,'TRANSFER RATE--ABOVE-SURFACE FOOD TO SOIL SURFACE
    1(PER DAY)',T110,E12.4)
     PRINT 920,TAUGR
920  FORMAT('0',T13,'TRANSFER RATE--PASTURE GRASS TO PASTURE SOIL (PER
    1DAY)',T110,E12.4)
     PRINT 921,TAUPD
921  FORMAT('0',T13,'TRANSFER RATE--SOIL POOL TO SOIL SINK (PER DAY)',T
    1110,E12.4)
     PRINT 922,TAUPO
922  FORMAT('0',T13,'TRANSFER RATE--PASTURE SOIL TO SOIL SINK (PER DAY
    1',T110,E12.4)
     PRINT 923,TAURG
923  FORMAT('0',T13,'TRANSFER RATE--PASTURE SOIL TO PASTURE GRASS (PER
    1DAY)',T110,E12.4)
     PRINT 924,TAUSP
924  FORMAT('0',T13,'TRANSFER RATE--SOIL SURFACE TO SOIL POOL (PER DAY)
    1',T110,E12.4)
     PRINT 925,U
925  FORMAT('0',T13,'MILK CAPACITY OF THE UDDER (LITERS)',T110,E12.4)
     PRINT 926,V
926  FORMAT('0',T13,'VEGETABLE FOOD CONSUMPTION OF MAN (KG/DAY)',T110,
    1E12.4)
     PRINT 927,VSUBC
927  FORMAT('0',T13,'GRASS CONSUMPTION OF COW (KG/DAY)',T110,E12.4)
     PRINT 928,VSUBM
928  FORMAT('0',T13,'MILK PRODUCTION OF COW (LITERS/DAY)',T110,E12.4)
     TPOP=0
     TNOBCT=0
     TNOMCT=0
     TSOVG=0
     DO 4002 NO=1,20
     DO 4003 NR=1,20
     TPOP=INTPA(NO,NR)+TPOP
     TNOBCT=NOBCT(NO,NR)+TNOBCT
     TNOMCT=NOMCT(NO,NR)+TNOMCT
4003 IF(INTFC(NO,NR).EQ.1)TSOVG=TSOVG+1.
4002 CONTINUE
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      ANUMM=(TSQVG*(SQSD**2))/A
      IF(TPOP.GT.ANUMM)D1=(ANUMM/TPOP)*D1
      IF(TPOP.GT.ANUMM)D2=(ANUMM/TPOP)*D2
      TKGBCA=TAUBM*365.*TPOP
      ANOBCT=TNOBCT
      TKGBPA=ANOBCT*TAUBEF*365.*MSUBB
      IF(TKGBCA.GT.TKGBPA)D3=(TKGBPA/TKGBCA)*D3
      CONMK=TAUCM*TPOP
      ANOMCT=TNOMCT
      PRNMK=VSUBM*ANOMCT
      IF(CONMK.GT.PRNMK)D4=(PRNMK/CONMK)*D4
      TAREC=TSQVG*(SQSD**2)
      PAREC=(TSQVG/400.)*100.
      YCONMK=CONMK*365.
      YPRNMK=PRNMK*365.
      PFCY=DSUBF*TAREC
      CFCY=TPOP*V*365.
      WRITE(51,4004)
 4004 FORMAT('1',T51,'COMPUTED VALUES FOR THE AREA')
      WRITE(51,4005)TPOP
 4005 FORMAT('0',T13,'TOTAL POPULATION',T110,F12.1)
      WRITE(51,4006)TNOBCT
 4006 FORMAT('0',T13,'TOTAL NUMBER OF BEEF CATTLE',T110,I12)
      WRITE(51,4007)TNOMCT
 4007 FORMAT('0',T13,'TOTAL NUMBER OF MILK CATTLE',T110,I12)
      WRITE(51,4008)TAREC
 4008 FORMAT('0',T13,'TOTAL AREA OF VEGETABLE FOOD CROPS (SQUARE METERS)
     1',T110,F12.4)
      WRITE(51,4009)PAREC
 4009 FORMAT('0',T13,'PERCENT OF AREA USED TO PRODUCE VEGETABLE FOOD CRO
     1PS',T110,F12.1)
      WRITE(51,4010)TKGBCA
 4010 FORMAT('0',T13,'TOTAL BEEF CONSUMPTION (KG PER YEAR)',T110,F12.4)
      WRITE(51,4011)TKGBPA
 4011 FORMAT('0',T13,'TOTAL BEEF PRODUCTION (KG PER YEAR)',T110,F12.4)
      WRITE(51,4012)YCONMK
 4012 FORMAT('0',T13,'TOTAL MILK CONSUMPTION (LITERS/YEAR)',T110,F12.4)
      WRITE(51,4013)YPRNMK
 4013 FORMAT('0',T13,'TOTAL MILK PRODUCTION (LITERS/YEAR)',T110,F12.4)
      WRITE(51,4014)CFCY
 4014 FORMAT('0',T13,'TOTAL VEGETABLE FOOD CONSUMPTION (KG PER YEAR)',
     1T110,F12.4)
      WRITE(51,4015)PFCY
 4015 FORMAT('0',T13,'TOTAL VEGETABLE FOOD PRODUCED (KG PER YEAR)',T110,
     1F12.4)
      PRINT 905,D1
  905 FORMAT('0',T13,'DIETARY CORRECTION FACTOR FOR ABOVE-SURFACE FOOD',
     1T110,F12.4)
      PRINT 906,D2
  906 FORMAT('0',T13,'DIETARY CORRECTION FACTOR FOR UPTAKE FROM SOIL',T1
     110,F12.4)
      PRINT 907,D3
  907 FORMAT('0',T13,'DIETARY CORRECTION FACTOR FOR BEEF',T110,F12.4)
      PRINT 908,D4
  908 FORMAT('0',T13,'DIETARY CORRECTION FACTOR FOR MILK',T110,F12.4)
C CONTRIBUTION OF 50 YEARS EXPOSURE
      T = 18250.
      DO 100 I = 1, NNUCS
```

```
      AMAN=0
      READ 20, NUMORG,LAMRR,CFSBA,CFSHW,CFSUR
 20   FORMAT(I10,4F10.3)
      READ 30,  CSUBB,CSUBP,CSUBS,FSURM,LAME,CSURBR,HSJRFQ,TAUFXC
 30   FORMAT(8E10.3)
      READ 175,LAMSUR,LAMH2O
 175  FORMAT(2E10.3)
      DO 200 J = 1, NUMORG
      READ 40,  NAMORG(J),CFINHA(J),CFINGA(J)
 40   FORMAT(A8,F12.3,E10.4)
 200  CONTINUE
      TBCTGC=0
      TMCTGC=0
      TVCA=0
      AMAX=0
      TTMR=0
      TAVGCN=0
      PRINT 9255,NAMNUC(I)
 9255 FORMAT('1',T42,'RESULTS OF DOSE COMPUTATIONS FOR NUCLIDE ',A8)
      WRITE(51,301)
      PRINT 9256
 9256 FORMAT('0',T15,'AREA',T26,'ORGAN',T60,'DOSE THROUGH EACH PATHWAY (
     1REMS/YEAR)')
      PRINT 9257
 9257 FORMAT('0',T11,'COLUMN',T20,'ROW')
      WRITE(51,301)
      PRINT 9259
 9259 FORMAT('0',T40,'INHALATION',T55,'SUBMERSION',T70,'SURFACE',T85,
     1'INGESTION',T100,'SUBMERSION',T117,'TOTAL')
      PRINT 9260
 9260 FORMAT(' ',T57,'IN AIR',T69,'EXPOSURE',T102,'IN WATER')
      WRITE(51,301)
 8021 NOM=1
      NRM=1
      DO 4000 NO=1,20
      DO 4001 NR=1,20
      ACN=ACCN(I,NO,NR)
      GCN=GCON(I,NO,NR)
      TBCTGC=NOBCT(NO,NR)*GCN+TBCTGC
      TMCTGC=NOMCT(NO,NR)*GCN+TMCTGC
      IF(INTFC(NO,NR).EQ.1)TVCA=GCN+TVCA
      TAVGCN=GCN+TAVGCN
      IF(INTPA(NO,NR).GT.0.AND.ACN.GT.AMAX)AMAX=ACN
      IF(INTPA(NO,NR).GT.0.AND.ACN.EQ.AMAX)NOM=NO
      IF(INTPA(NO,NR).GT.0.AND.ACN.EQ.AMAX)NRM=NR
      GCNM=GCON(I,NOM,NRM)
 4001 CONTINUE
 4000 CONTINUE
      AVGCBC=TBCTGC/TNOBCT
      AVGCMC=TMCTGC/TNOMCT
      AVSOVG=TVCA/TSOVG
      ACONCM=AMAX*1.E-6*8760.
      GCONCM=(GCNM/(LAMRR*1.1574E-5+LAMSUR*1.1574E-5))*
     11.E-6*8760.
      GCONCW=GCONCM
      GCONCF=(AVSOVG/(LAMRR*1.1574E-5+LAMSUR*1.1574E-5))*1.E-6*8760.
      GCONCP=(((AVGCBC+AVGCMC)/2.)/(LAMRR*1.1574E-5+LAMSUR*1.1574E-5))*
     11.E-6*8760.
```

```
      IF(NAMNUC(I)-NADEC1)430,440,430
430   NTRIT = 0
      GO TO 450
440   NTRIT = 1
450   CONTINUE
      LLRUN=0
      DO 4050 NO=1,20
      DO 4051 NR=1,20
      GO TO 3002
 3004 DO 3060 NO=1,10
      DO 3061 NR=1,10
      LLRUN=1
      ACN=FSTR(I,NO,NR)
      GCN=FSTRG(I,NO,NR)
      GO TO 3003
 3002 ACN=ACON(I,NO,NR)
      GCN=GCON(I,NO,NR)
 3003 DO 9230 J=1,11
      X=LAMRP+LAMSUR
      DO 9290 N=1,NUMORG
      IF (NAMES(J) - NAMORG(N)) 9290,9291,9290
 9290 CONTINUE
      L=1
      GO TO 9292
 9291 L=N
 9292 CFINH=CFINHA(L)
      CFING=CFINGA(L)
      IF(ACN.EQ.0)DOS1=0
      IF(ACN.EQ.0)DOS2=0
      IF(ACN.EQ.0)DOS3=0
      IF(ACN.EQ.0)GO TO 4080
      DOS1=ACN*1.E-6*BRTHRT*8760.*CFINH
      DOS2=ACN*1.E-6*8760.*CFSBA
      DOS3=ACN*1.E-6*8760.*CFSUR*(GCN /ACN)*(1-EXP(-X*T))/X*3600.*24.
      IF(NTRIT.EQ.1)DOSING(J)=((TAVGCN/400.)/PR)*E.3434E2
      IF(NTRIT.EQ.1)GO TO 5012
 4080 IF(NO.GT.1.OR.NR.GT.1)GO TO 5012
      FZERO=AMAX*1.E-6*8760.*(GCNM/AMAX)*3600.*10000.
      IF(GCONCF.EQ.0.AND.GCONCP.EQ.0)DOSING(J)=0
      IF(GCONCF.EQ.0.AND.GCONCP.EQ.0)GO TO 5012
      S1 = S10* GCONCF / GCONCM
      S2 = S20* GCONCF / GCONCM
      S3 = S30* GCONCP / GCONCM
C CALCULATES MSUBEQ IF IT IS NOT GIVEN
      IF (MSUBEQ) 403, 17, 403
17    MSUBEQ = CSUBBH * 70. * 10.**(-3.)
403   CONTINUE
15    VSUBS = A * 10.**4. * SMALLD * RHO
16    PSUBEQ =(CSUBS / 10.**6.) * VSUBS
14    TAUPM = (MSUBEQ / PSUBEQ) * LAMF
18    TAUGC = FSUBM * VSUBM * VSUBC / (U * DSUBG)
C CALCULATES FSUBB WITH EQ. 25 OR 21 DEPENDING IF TAUEXC GIVEN OR NOT
      IF(TAUEXC)1500,1500,25
 1500 FSUBB=KSUBB*CSUBB/(4.*VSUBC*CSUBP)
      GO TO 404
25    FSUBB = MSUBB * TAUEXC * CSUBB / (4. * CSUBP * VSUBC)
404   CONTINUE
19    TAUGB = FSUBB * (VSUBC / DSUBG) / MSUBB
```

```
26    TAUFM = V / USUBF
C EQUILIBRIUM EQUATIONS OF CONSTANT INPUT CASE (F(T) = FZERO)
1     F = S1 * FZERO / (LAMRR + TAUFM/A + TAUFS)
2     S = (TAUFS * F + S2 * FZERO) / (LAMRR + TAUSP)
3     P = A * TAUSP * S / (LAMRR + TAUPM + TAUPD)
C CALCULATE EQUATIONS 4 AND 5 SIMULTANEOUSLY
      G = -S3*FZERO*ASUBG*USUBG*(LAMRR+TAURG+TAURD)/(TAUFG*TAUGR*ASUBG*
     1USUBG-(ASUBG*USUBG*(LAMRR+TAUGR)+VSUBG)*(LAMRR+TAURG+TAURD))
5     R = TAUGR * G / (LAMRR + TAURG + TAURD)
6     D = (TAURD * R + (TAUPD/A) * P) / LAMRR
7     C = TAUGC * G / (LAMRR + TAUMLK)
8     B = TAUGB * G / (LAMRR + TAUBEF)
9     EQI = D1*TAUFM*F + D2*TAUPM*P + D3*TAUBM*B + D4*TAUCM*C
      IF(NAMNUC(I).NE.NADFC2)GO TO 8090
      EQI=D1*TAUFM*F*PFIV+D2*TAUPM*P*PFIV+D3*TAUBM*B*PFIH+D4*TAUCM*C*PFI
     1C
8090  DOSING(J)=EQI*CFING
9012  X=LAMRR+LAMH2O
1250  IF(GCONC*.EQ.0)DOS5=0
      IF(GCONC*.EQ.0)GO TO 1251
      IF(ACN.EQ.0)DOS5=0
      IF(ACN.EQ.0)GO TO 1251
      DOS5=ACN*1.E-6*8760.*CFSPW*(GCN/ACN)*USLFAC/DILFAC*(1-EXP(-X*T))/X
     1*GCONC*/GCONCM*3600.*24.
1251  TDOS=DOS1+DOS2+DOS3+DOSING(J)+DOS5
      IF(LLRUN.EQ.1)GO TO 3085
      IF(I.GT.3)GO TO 8020
      WRITE(51,9261)NO,NR,NAMES(J),DOS1,DOS2,DOS3,DOSING(J),DOS5,TDOS
9261  FORMAT(' ',T13,I2,T20,I2,T25,A8,T40,E10.3,T55,E10.3,T70,E10.3,T85,
     1E10.3,T100,E10.3,T115,E10.3)
8020  CONTINUE
      DOSP(1,J,I)=DOS1*INTPA(NO,NR)+DOSP(1,J,I)
      DOSP(2,J,I)=DOS2*INTPA(NO,NR)+DOSP(2,J,I)
      DOSP(3,J,I)=DOS3*INTPA(NO,NR)+DOSP(3,J,I)
      DOSP(4,J,I)=DOSING(J)*INTPA(NO,NR)+DOSP(4,J,I)
      DOSP(5,J,I)=DOS5*INTPA(NO,NR)+DOSP(5,J,I)
      IF(TDOS.GT.DOSIN(J,I))NOMM(I)=NO
      IF(TDOS.GT.DOSIN(J,I))NRMM(I)=NR
      IF(TDOS.GT.DOSIN(J,I))DOSIN(J,I)=TDOS
      IF(LLRUN.EQ.0)GO TO 9280
3085  NOTE3=0
      NOTE4=0
      IF(NO.GT.(5-INT(PLBW/SGSD2)).AND.NO.LT.(6+INT(PLBE/SGSD2)))NOTE3=1
      IF(NR.GT.(5-INT(PLBS/SGSD2)).AND.NR.LT.(6+INT(PLBN/SGSD2)))NOTE4=1
      IF(NOTE3.EQ.1.AND.NOTE4.EQ.1)GO TO 9280
      IF(TDOS.GT.DOSON(J,I))NOMM2(I)=NO
      IF(TDOS.GT.DOSON(J,I))NRMM2(I)=NR
      IF(TDOS.GT.DOSON(J,I))DOSON(J,I)=TDOS
9280  CONTINUE
      IF(LLRUN.EQ.0)GO TO 4051
3061  CONTINUE
3060  CONTINUE
      IF(LLRUN.EQ.1)GO TO 3062
4051  CONTINUE
4050  CONTINUE
3062  CONTINUE
      IF(LLRUN.EQ.0)GO TO 3004
752   PRINT 931,NAMNUC(I)
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931  FORMAT('1',T47,'LIST OF INPUT DATA FOR NUCLIDE ',A8)
     IF(NTRIT.EQ.1)GO TO 155
     PRINT 933,CSUBBB
933  FORMAT('0',T13,'CONCENTRATION OF THE ELEMENT IN MAN (PPM)',T110,F1
    12.4)
     IF(NAMNUC(I).NE.NADEC2)GO TO 160
     PRINT 161,PFIV
161  FORMAT('0',T13,'DOSE REDUCTION FACTOR FOR VEGETABLE CONSUMPTION',
    1T110,F12.4)
     PRINT 163,PFIC
163  FORMAT('0',T13,'DOSE REDUCTION FACTOR FOR MILK CONSUMPTION',
    1T110,F12.4)
     PRINT 164,PFIB
164  FORMAT('0',T13,'DOSE REDUCTION FACTOR FOR BEEF CONSUMPTION',
    1T110,F12.4)
160  PRINT 934,CSUBP
934  FORMAT('0',T13,'CONCENTRATION OF THE ELEMENT IN MEAT (PPM)',T110,F
    112.4)
     PRINT 935,CSUBP
935  FORMAT('0',T13,'CONCENTRATION OF THE ELEMENT IN FORAGE (PPM)',T110
    1,F12.4)
     PRINT 936,CSUBS
936  FORMAT('0',T13,'CONCENTRATION OF THE ELEMENT IN SOIL (PPM)',T110,F
    112.4)
155  CONTINUE
     PRINT 937,LAMRR
937  FORMAT('0',T13,'RADIOACTIVE DECAY CONSTANT (PER DAY)',T110,F12.4)
     PRINT 938,LAMSUP
938  FORMAT('0',T13,'ENVIRONMENTAL DECAY CONSTANT--SURFACE (PER DAY)',
    1T110,F12.4)
     PRINT 939,LAMH2O
939  FORMAT('0',T13,'ENVIRONMENTAL DECAY CONSTANT--WATER (PER DAY)',T11
    10,F12.4)
     IF(NTRIT.EQ.1)GO TO 156
     PRINT 940,LAME
940  FORMAT('0',T13,'TURNOVER RATE OF THE STABLE ISOTOPE IN MAN (PER DA
    1Y)',T110,E12.4)
     PRINT 941,FSUBM
941  FORMAT('0',T13,'FRACTION OF ISOTOPE INGESTED BY A COW AND SECRETED
    1 (DAYS/LITER)',T110,F12.4)
     PRINT 942,MSUBEO
942  FORMAT('0',T13,'EQUILIBRIUM MASS OF STABLE ELEMENT IN MAN (GRAMS)'
    1,T110,F12.4)
     PRINT 943,TAUEXC
943  FORMAT('0',T13,'EXCRETION RATE OF STABLE ISOTOPE FROM MUSCLE OR ST
    1EER (PER DAY)',T110,F12.4)
156  CONTINUE
     PRINT 944,GCONCM
944  FORMAT('0',T13,'EQUILIBRIUM GROUND CONCENTRATION AT MAN (MICROCURI
    1E-HR/SQUARE CM)',T110,E12.4)
     PRINT 945,ACONCM
945  FORMAT('0',T13,'EQUILIBRIUM AIR CONCENTRATION AT MAN (MICROCURIE-H
    1R/CUBIC CM)',T110,F12.4)
     PRINT 946,GCONCW
946  FORMAT('0',T13,'EQUILIBRIUM CONCENTRATION AT WATER SURFACE (MICROC
    1URIE-HR/SQUARE CM)',T110,F12.4)
     PRINT 947,GCONCF
947  FORMAT('0',T13,'EQUILIBRIUM GROUND CONCENTRATION AT FOOD GROUP [illegible]
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     1CROCURIE-HR/SQUARE CM)',T110,F12.4)
      PRINT 948,GCONCP
948  FORMAT('0',T13,'EQUILIBRIUM GROUND CONCENTRATION AT PASTURE (MIC
     1CURIE-HR/SQUARE CM)',T110,F12.4)
      WRITE(51,301)
      PRINT 950
950  FORMAT('0',T55,'DOSE CONVERSION FACTORS')
      PRINT 951
951  FORMAT('0',T5,'ORGAN',T20,'INHALATION',T38,'INGESTION',T58,
     1'SUBMERSION IN AIR',T83,'SURFACE EXPOSURE',T107,'SUBMERSION IN WAT
     1ER')
      PRINT 952
952  FORMAT(' ',T17,'(REMS/MICROCURIE)',T34,'(REMS/MICROCURIE)',T59,
     1'(REMS-CUBIC CM/',T83,'(REMS-SQUARE CM/',T109,'(REMS-CUBIC CM/')
      PRINT 953
953  FORMAT(' ',T60,'MICROCURIE-HR)',T84,'MICROCURIE-HR)',T110,'MICROCU
     1RIE-HR)')
      WRITE(51,301)
      DO 201 J=1,NUMORG
      PRINT 955,NAMORG(J),CFINHA(J),CFINGA(J),CFSBA,CFSUR,CFSBW
955  FORMAT(' ',T4,A8,T21,E10.3,T38,E10.3,T61,E10.3,T85,E10.3,T111,E10.
     13)
201  CONTINUE
100  CONTINUE
9999 DO 2032 I=1,NNUCS
2032 TBDOS(I)=DOSP(1,1,I)+DOSP(2,1,I)+DOSP(3,1,I)+DOSP(4,1,I)+DOSP(5,1,
     1I)
      AMOD=1.E60
      ICNT=1
      DO 2033 JRM=1,36
      AMX=0
      DO 2034 I=1,36
      IF(TBDOS(I).GT.AMX.AND.TBDOS(I).LT.AMOD)IRANK(I)=ICNT
      IF(TBDOS(I).GT.AMX.AND.TBDOS(I).LT.AMOD)AMX=TBDOS(I)
2034 CONTINUE
      AMOD=AMX-(AMX*1.E-4)
      ICNT=ICNT+1
2033 CONTINUE
      DO 2055 I=1,36
      DO 2056 MD=1,5
      DO 2057 J=1,11
      JO=IRANK(I)
      NANUC(JO)=NAMNUC(I)
2057 DOSPA(MD,J,JO)=DOSP(MD,J,I)
2056 CONTINUE
2055 CONTINUE
      WRITE(51,242)
242  FORMAT('1',T27,'DOSE TO EACH ORGAN THROUGH EACH PATHWAY FOR EACH R
     1ADIONUCLIDE (MAN-REMS/YEAR)')
      WRITE(51,301)
      WRITE(51,2060)
2060 FORMAT(' ','RANK',T7,'NUCLIDE',T16,'PATHWAY',T25,'TOT.BODY',T34,
     1'GI TRACT',T45,'BONE',T52,'THYROID',T62,'LUNGS',T71,'MUSCLE',
     2T79,'KIDNEYS',T89,'LIVER',T96,'SPLEEN',T107,'TESTES',T115,'OVARIES
     3')
      WRITE(51,301)
      DO 2062 JO=1,NNUCS
      DO 245 MD=1,5
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      IF(MD.EQ.1)GO TO 2063
      WRITE(51,244)(MODE(MD),(DOSPA(MD,J,JO),J=1,11))
244   FORMAT(' ',T16,A8,T24,11F9.2)
      GO TO 245
2063  WRITE(51,2064)(JO,NANUC(JO),MODE(MD),(DOSPA(MD,J,JO),J=1,11))
2064  FORMAT(' ',T1,I4,T7,A8,T16,A8,T24,11F9.2)
245   CONTINUE
2062  CONTINUE
      DO 2080 J=1,11
      WRITE(51,2081)NAMES(J)
2081  FORMAT('0',T36,'PERCENT OF ',A3,' DOSE BY EACH PATHWAY')
      WRITE(51,2070)
2070  FORMAT('0',T20,'NUCLIDE',T35,'PATHWAY',T50,'DOSE(MAN-REMS)',
     1T70,'PERCENT OF TOTAL')
      WRITE(51,301)
      DO 2065 JO=1,NNUCS
      SUMA=0
      DO 2066 MD=1,5
2066  SUMA=DOSPA(MD,J,JO)+SUMA
      PCT(1)=(DOSPA(1,J,JO)/SUMA)*100.
      PCT(2)=(DOSPA(2,J,JO)/SUMA)*100.
      PCT(3)=(DOSPA(3,J,JO)/SUMA)*100.
      PCT(4)=(DOSPA(4,J,JO)/SUMA)*100.
      PCT(5)=(DOSPA(5,J,JO)/SUMA)*100.
      MD=1
      WRITE(51,2068)NANUC(JO),MODE(MD),DOSPA(MD,J,JO),PCT(MD)
      DO 2067 MD=2,5
2067  WRITE(51,2069)MODE(MD),DOSPA(MD,J,JO),PCT(MD)
2069  FORMAT(' ',T35,A8,T52,F10.3,T75,F6.1)
2068  FORMAT(' ',T20,A8,T35,A8,T52,F10.3,T75,F6.1)
2065  CONTINUE
2080  CONTINUE
      WRITE(51,2094)
2094  FORMAT('1',T48,'DOSE TO EACH ORGAN FROM ALL PATHWAYS')
      WRITE(51,2095)
2095  FORMAT('0',T30,'NUCLIDE',T60,'ORGAN',T90,'DOSE(MAN-REMS)')
      WRITE(51,301)
      DO 2090 JO=1,NNUCS
      DO 2091 J=1,11
      SUMA=0
      DO 2092 MD=1,5
2092  SUMA=DOSPA(MD,J,JO)+SUMA
      IF(J.EQ.1)GO TO 241
      WRITE(51,240)NAMES(J),SUMA
240   FORMAT(' ',T59,A8,T92,F10.3)
      GO TO 2091
241   WRITE(51,2093)NANUC(JO),NAMES(J),SUMA
2093  FORMAT(' ',T30,A8,T59,A8,T92,F10.3)
2091  CONTINUE
2090  CONTINUE
      WRITE(51,2044)
2044  FORMAT('1',T52,'TOTAL DOSE FOR EACH PATHWAY')
      WRITE(51,2045)
2045  FORMAT('0',T20,'ORGAN',T50,'PATHWAY',T80,'DOSE(MAN-REMS)',
     1T100,'PERCENT')
      WRITE(51,301)
      DO 2040 J=1,11
      DO 2041 MD=1,5
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```
      SUMT(MD)=0
      PCT(MD)=0
      DO 2042 JD=1,NNUCS
 2042 SUMT(MD)=DOSPA(MD,J,JD)+SUMT(MD)
 2041 CONTINUE
      SUMR=0
      DO 2043 MD=1,5
 2043 SUMR=SUMT(MD)+SUMR
      DO 5010 MD=1,5
      PCT(MD)=(SUMT(MD)/SUMR)*100.
      IF(MD.GT.1)GO TO 246
      WRITE(51,5011)NAMES(J),MODE(MD),SUMT(MD),PCT(MD)
 5011 FORMAT(' ',T19,A8,T50,A8,T82,E10.3,T101,F5.1)
      GO TO 5010
  246 WRITE(51,243)MODE(MD),SUMT(MD),PCT(MD)
  243 FORMAT(' ',T50,A8,T82,E10.3,T101,F5.1)
 5010 CONTINUE
 2040 CONTINUE
      WRITE(51,9321)
 9321 FORMAT('1',T42,'HIGHEST INDIVIDUAL DOSES IN AREA FOR EACH NUCLIDE'
     1)
      WRITE(51,9320)
 9320 FORMAT('0',T20,'NUCLIDE',T47,'ORGAN',T70,'DOSE (REMS)',T97,
     1'LOCATION')
      WRITE(51,1050)
 1050 FORMAT('0',T90,'GRID',T100,'COLUMN',T110,'ROW')
      DO 9311 I=1,NNUCS
      IGRID(I)=1
      DO 9312 J=1,11
      IF(DOSIN(J,I).GT.DOSON(J,I))IGRID(I)=2
      IF(IGRID(I).EQ.2)DOSON(J,I)=DOSIN(J,I)
      IF(IGRID(I).EQ.2)NOMM2(I)=NOMM(I)
      IF(IGRID(I).EQ.2)NRMM2(I)=NRMM(I)
      IF(J.EQ.1)GO TO 9313
      WRITE(51,9310)NAMES(J),DOSON(J,I),IGRID(I),NOMM2(I),NRMM2(I)
      GO TO 9312
 9313 WRITE(51,9314)NAMNUC(I),NAMES(J),DOSON(J,I),IGRID(I),NOMM2(I),
     1NRMM2(I)
 9312 CONTINUE
 9311 CONTINUE
 9314 FORMAT('0',T21,A8,T46,A8,T70,E10.3,T91,I2,T102,I2,T111,I2)
 9310 FORMAT('0',T46,A8,T70,E10.3,T91,I2,T102,I2,T111,I2)
      WRITE(51,1051)SQSD2
 1051 FORMAT('0',T20,'NO. 1 IS A 10 BY 10 SQUARE WITH THE SIDE OF EACH G
     1RID',F10.1,' METERS')
      WRITE(51,1052)SQSD
 1052 FORMAT(' ',T20,'NO. 2 IS A 20 BY 20 SQUARE WITH THE SIDE OF EACH G
     1RID',F10.1,' METERS')
      WRITE(51,9099)
 9099 FORMAT('1',T50,'HIGHEST INDIVIDUAL DOSES IN AREA')
      WRITE(51,9097)
 9097 FORMAT('0',T55,'ORGAN',T67,'DOSE (REMS)')
      DO 9096 J=1,11
      DOSIJ(J)=0
      DO 9095 I=1,NNUCS
 9095 DOSIJ(J)=DOSON(J,I)+DOSIJ(J)
 9096 CONTINUE
      WRITE(51,9094)((NAMES(J),DOSIJ(J)),J=1,11)
 9094 FORMAT(' ',T55,A8,T67,E10.3)
 7997 CONTINUE
      STOP
      END
```

```
C
      SUBROUTINE AKKA(I,NO,NR)
      COMMON ACON(36,20,20),GCON(36,20,20),TAI(36),TGD(36),NAMNUC(36),
     1IDIST(20)
      REAL*8 NAMNUC(36)
      ACON(I,NO,NR)=TAI(I)*1.E-6
      GCON(I,NO,NR)=TGD(I)*1.E-4
      WRITE(51,1161)NO,IDIST(NR),NAMNUC(I),ACON(I,NO,NR),GCON(I,NO,NR)
 1161 FORMAT(' ',T10,I10,I8,T41,A8,T73,F10.3,T106,F10.3)
 1    CONTINUE
      RETURN
      END


      SUBROUTINE AKA(I,NO,NR)
      COMMON ACON(36,20,20),GCON(36,20,20),TAI(36),TGD(36),NAMNUC(36),
     1IDIST(20)
      REAL*8 NAMNUC(36)
      ACON(I,NO,NR)=TAI(I)*1.E-6
      GCON(I,NO,NR)=TGD(I)*1.E-4
2     WRITE(51,1161)NO,NR,NAMNUC(I),ACON(I,NO,NR),GCON(I,NO,NR)
1161  FORMAT(' ',T10,I10,I8,T41,A8,T73,F10.3,T106,F10.3)
1     CONTINUE
      RETURN
      END


      SUBROUTINE ALFDD(D,F,VG,U,LIDI,XLIDD)
      DO 1 IX1=1,10
      Y=10000*IX1
1     IF(((Y**D)-(.47*F*Y*(VG/U))).GT.(.47*F*LIDI))GO TO 2
2     DO 3 IX2=1,10
      Y=(IX1*10000-10000)+IX2*1000
3     IF(((Y**D)-(.47*F*Y*(VG/U))).GT.(.47*F*LIDI))GO TO 4
4     DO 5 IX3=1,10
      Y=(IX1*10000-10000)+(IX2*1000-1000)+IX3*100
5     IF(((Y**D)-(.47*F*Y*(VG/U))).GT.(.47*F*LIDI))GO TO 6
6     XLIDD=2*Y
      RETURN
      END
```

```
C
C   SIMPSON'S RULE SUBROUTINE FOR DEPLETION FRACTION CALCULATION
C
      SUBROUTINE QXR(D,F,HS,NM,INTL,VG,U,NPRT,SIMP)
      FUNC(D,F,HH,X)=F*EXP(-(HH**2*F**2)/(2.*X**(2*D)))/X**D
      FUNC1=0.0
      FUNC2=0.0
      IPRT=(NM-INTL)/NPRT
      IF(IPRT.LT.1)IPRT=1
      JPRT=2*IPRT
      NN=NM-IPRT
      JNTL=INTL+2*IPRT
      DO 1 I=JNTL,NN,JPRT
      X1=I-IPRT
      HZ=HS-VG*X1/U
      IF (HZ.LT.0.0) HZ=0.0
      FUNC1=FUNC1+FUNC(D,F,HZ,X1)
      X2=I
      HZ=HS-VG*X2/U
      IF (HZ.LT.0.0) HZ=0.0
    1 FUNC2=FUNC2+FUNC(D,F,HZ,X2)
      XM=NM
      HM=HS-VG*XM/U
      IF (HM.LT.0.0) HM=0.0
      IF(INTL.EQ.0)GO TO 2
      XNTL=INTL
      HI=HS-VG*XNTL/U
      IF (HI.LT.0.0) HI=0.0
      SIMP=FUNC(D,F,HI,XNTL)+FUNC1*4.0+FUNC2*2.0+FUNC(D,F,HM,XM)
      SIMP=SIMP*IPRT/3.0
      GO TO 3
    2 SIMP=(FUNC1*4.0+FUNC2*2.0+FUNC(D,F,HM,XM))*IPRT/3.0
    3 RETURN
      END
```

```
C
C   DEPLETION FRACTION SUBROUTINE FOR STABILITY CATEGORY A
C
      SUBROUTINE QXA(X,H,VD,U,UD,VG,QAX)
      NM=X
      CALL QXR(1.00,5.02,H,NM,0,VG,U,25,SIMPA)
 1    QAX=EXP(SIMPA*(-.79788)*VD/UD)
      RETURN
      END
```

```
C
C   DEPLETION FRACTION SUBROUTINE FOR STABILITY CATEGORY B
C
      SUBROUTINE QXB(X,H,VD,U,UD,VG,QBX)
      NM=X
      CALL QXR(1.00,8.35,H,NM,0,VG,U,25,SIMPB)
 1    QBX=EXP(SIMPB*(-.79788)*VD/UD)
      RETURN
      END


C
C   DEPLETION FRACTION SUBROUTINE FOR STABILITY CATEGORY C
C
      SUBROUTINE QXC(X,H,VD,U,UD,VG,QCX)
      NM=1000
      IF(X.LT.1000)NM=X
      CALL QXR(.954,10.015,H,NM,0,VG,U,20,SIMPC1)
      IF(X.LE.1000)SIMPC=SIMPC1
      IF(X.LE.1000)GO TO 1
      NM=10000
      IF(X.LT.10000)NM=X
      CALL QXR(.833,4.4,H,NM,1000,VG,U,15,SIMPC2)
      IF(X.LE.10000)SIMPC=SIMPC1+SIMPC2
      IF(X.LE.10000)GO TO 1
      NM=X
      CALL QXR(.5524,.332,H,NM,10000,VG,U,15,SIMPC3)
      SIMPC=SIMPC1+SIMPC2+SIMPC3
 1    QCX=EXP(SIMPC*(-.79788)*VD/UD)
      RETURN
      END


C
C   DEPLETION FRACTION SUBROUTINE FOR STABILITY CATEGORY D
C
      SUBROUTINE QXD(X,H,VD,U,UD,VG,QDX)
      NM=1000
      IF(X.LT.1000)NM=X
      CALL QXR(.8061,7.48,H,NM,0,VG,U,20,SIMPD1)
      IF(X.LT.1000)SIMPD=SIMPD1
      IF(X.LT.1000)GO TO 1
      NM=3000
      IF(X.LT.3000)NM=X
      CALL QXR(.6715,2.95,H,NM,1000,VG,U,5,SIMPD2)
      IF(X.LE.3000)SIMPD=SIMPD1+SIMPD2
      IF(X.LE.3000)GO TO 1
      NM=10000
      IF(X.LT.10000)NM=X
      CALL QXR(.5099,0.31,H,NM,3000,VG,U,5,SIMPD3)
      IF(X.LE.10000)SIMPD=SIMPD1+SIMPD2+SIMPD3
      IF(X.LE.10000)GO TO 1
      NM=X
      CALL QXR(.5251,.93,H,NM,10000,VG,U,15,SIMPD4)
      SIMPD=SIMPD1+SIMPD2+SIMPD3+SIMPD4
 1    QDX=EXP(SIMPD*(-.79788)*VD/UD)
      RETURN
      END
```

```
C
C  DEPLETION FRACTION SUBROUTINE FOR STABILITY CATEGORY E
C
      SUBROUTINE QXE(X,H,VD,U,UD,VG,QEX)
      NM=1000
      IF(X.LT.1000)NM=X
      CALL QXR(.86,15.5,H,NM,0,VG,U,20,SIMPE1)
      IF(X.LE.1000)SIMPE=SIMPE1
      IF(X.LE.1000)GO TO 1
      NM=3000
      IF(X.LT.3000)NM=X
      CALL QXR(.629,3.15,H,NM,1000,VG,U,5,SIMPE2)
      IF(X.LE.3000)SIMPE=SIMPE1+SIMPE2
      IF(X.LE.3000)GO TO 1
      NM=10000
      IF(X.LT.10000)NM=X
      CALL QXR(.4054,.524,H,NM,3000,VG,U,5,SIMPE3)
      IF(X.LE.10000)SIMPE=SIMPE1+SIMPE2+SIMPE3
      IF(X.LE.10000)GO TO 1
      NM=X
      CALL QXR(.111,.0349,H,NM,10000,VG,U,15,SIMPE4)
      SIMPE=SIMPE1+SIMPE2+SIMPE3+SIMPE4
    1 QEX=EXP(SIMPE*(-.79788)*VD/UD)
      RETURN
      END
```

```
C
C  DEPLETION FRACTION SUBROUTINE FOR STABILITY CATEGORY F
C
      SUBROUTINE QXF(X,H,VD,U,UD,VG,QFX)
      NM=1000
      IF(X.LT.1000)NM=X
      CALL QXR(.8623,34.7,H,NM,0,VG,U,20,SIMPF1)
      IF(X.LE.1000)SIMPF=SIMPF1
      IF(X.LE.1000)GO TO 1
      NM=3000
      IF(X.LT.3000)NM=X
      CALL QXR(.6321,6.132,H,NM,1000,VG,U,20,SIMPF2)
      IF(X.LE.3000)SIMPF=SIMPF1+SIMPF2
      IF(X.LE.3000)GO TO 1
      NM=10000
      IF(X.LT.10000)NM=X
      CALL QXR(.371,.764,H,NM,3000,VG,U,20,SIMPF3)
      IF(X.LE.10000)SIMPF=SIMPF1+SIMPF2+SIMPF3
      IF(X.LE.10000)GO TO 1
      NM=X
      CALL QXR(.1106,.0694,H,NM,10000,VG,U,20,SIMPF4)
      SIMPF=SIMPF1+SIMPF2+SIMPF3+SIMPF4
    1 QFX=EXP(SIMPF*(-.79788)*VD/UD)
      RETURN
      END
```

```
C
C   DEPLETION FRACTION SUBROUTINE FOR STABILITY CATEGORY G
C
      SUBROUTINE QXG(X,H,VD,U,UD,VG,QGX)
      NM=1000
      IF(X.LT.1000)NM=X
      CALL QXR(.8257,61.25,H,NM,0,VG,U,20,SIMPG1)
      IF(X.LE.1000)SIMPG=SIMPG1
      IF(X.LE.1000)GO TO 1
      NM=3000
      IF(X.LT.3000)NM=X
      CALL QXR(.6547,18.8,H,NM,1000,VG,U,10,SIMPG2)
      IF(X.LE.3000)SIMPG=SIMPG1+SIMPG2
      IF(X.LE.3000)GO TO 1
      NM=10000
      IF(X.LT.10000)NM=X
      CALL QXR(.3818,2.115,H,NM,3000,VG,U,10,SIMPG3)
      IF(X.LE.10000)SIMPG=SIMPG1+SIMPG2+SIMPG3
      IF(X.LE.10000)GO TO 1
      NM=X
      CALL QXR(.1106,.1739,H,NM,10000,VG,U,20,SIMPG4)
      SIMPG=SIMPG1+SIMPG2+SIMPG3+SIMPG4
    1 QGX=EXP(SIMPG*(-.79788)*VD/UD)
      RETURN
      END
```

END

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