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FUSECRAC: MODIFICATIONS OF CRAC FOR FUSION APPLICATION

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ABSTRACT

The CRAC Code (Calculation of Reactor Accident Consequences), which was developed for fission reactors has been modified for use in fusion reactor safety assessments. This report details the changes, and describes the needed input data to allow use of the modified code, FUSECRAC. This report is meant for those already familiar with CRAC, and the information is complementary to the CRAC User's Manual.

A major difference between fission and fusion is the higher magnitude of the potential for tritium release from a fusion reactor. Since tritium behaves fundamentally differently in the environment from the dominant isotopes in a fission reactor release, a new tritium model was incorporated into the code.

A model for estimating the environmental transfer of fusion-specific isotopes, not studied for fission, is given.

The appropriate isotope-specific dose factor values for inhalation, ingestion, groundshine and cloudshine exposure are examined. Except for ingestion, these does factors are incorporated in a new health data file, FUSEDOSE, to be used with the code.

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1. INTRODUCTION

1.1 Purpose

The CRAC (Calculation of Reactor Accident Consequences) Code [1] is an outgrowth of the (Fission) Reactor Safety Study [2]. The code, given the necessary parameters concerning the release of a radioactive plume following a hypothetical accident and the site of the accident, calculates the probability-dependent public health effects. As such, CRAC is a very valuable tool in fission reactor safety assessments. It is continuously being updated and modified, the version used here is that currently (Spring '81) available from the Argonne code center.

A similar consequence analysis tool is needed for fusion safety assessments. The MIT-modified version of AIRDOS [3] can calculate effects from continuous emissions of tritium and other gases. A fusion version of CRAC is needed to determine accident consequences. For CRAC to be used for fusion it should be modified to properly treat tritium, and to include the relevant data for fusion-specific isotopes. This report details the work performed in modifying CRAC for fusion applications.

1.2 CRAC and FUSECRAC Structure

Fortunately the CRAC code is very flexible and thus is fairly easy to adapt for this new purpose. The fusion-modified CRAC is called FUSECRAC. Figure 1 shows the inputs to the code which may be different for fusion from fission and how they are handled. Most of the relevant data is directly input to the code which is easily changed for each

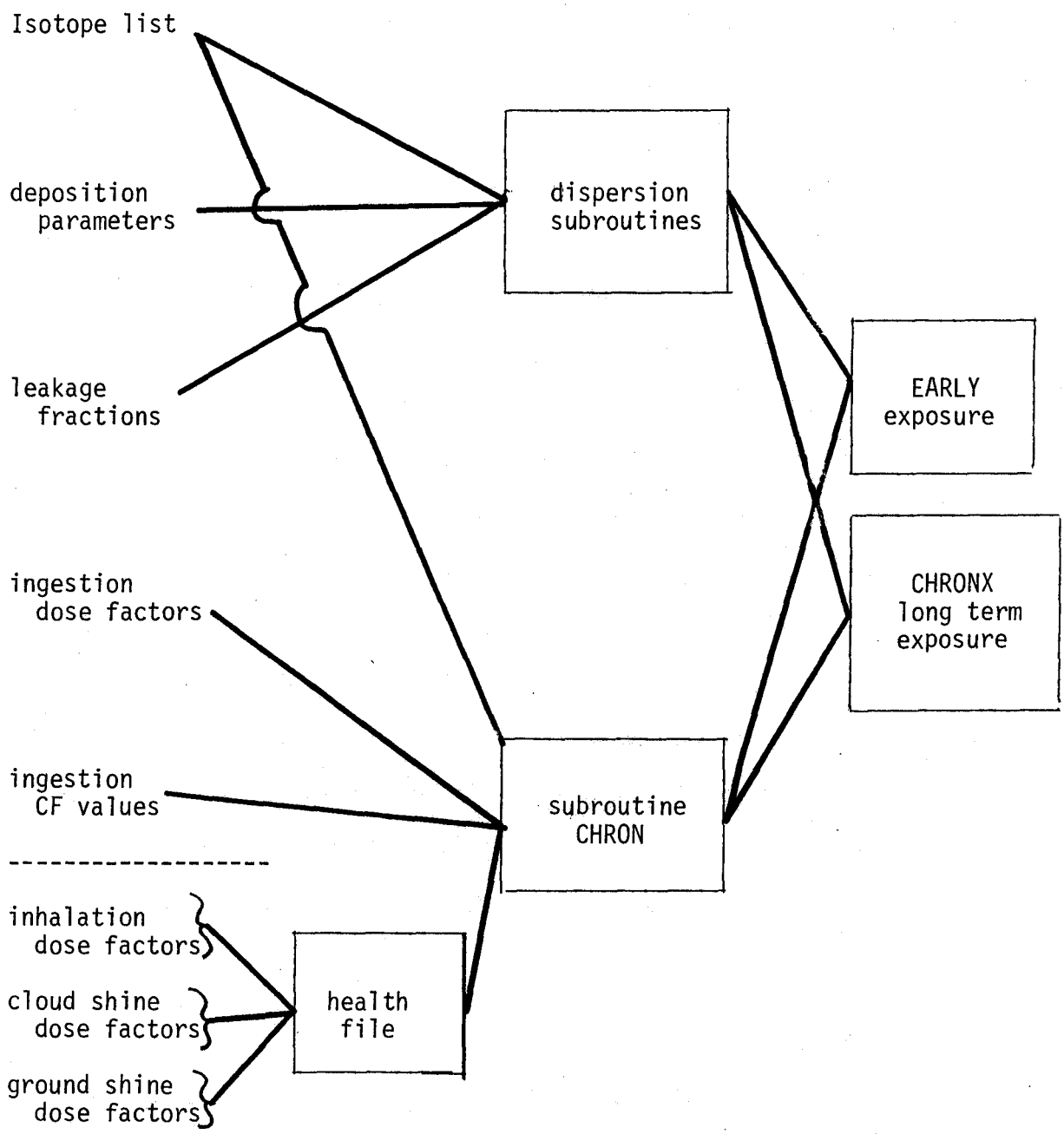


Figure 1: Data Pathways

execution. The inhalation and external dose factors are stored in a health file which the subroutine CHRON reads in. The subroutine CHRONX calculates the long term effects due to resuspension, ingestion, and groundshine. The incorporation of tritium, which behaves fundamentally differently in terms of ingestion pathways, caused some changes in CHRONX. In addition, there were cases where some dose factors would have been zero which leads to division by zero in CHRON. This necessitated another code revision. These changes are discussed in Chapter 2. The only important code changes were in the subroutines CHRON and CHRONX.

The incorporation of fusion-specific isotopes not studied for fission means that a variety of input data (as shown in Fig. 1) is needed. Table 1 lists the isotopes which are fission-specific and for which input data exists. The health file CRACDOSE includes the dose factors (except ingestion) for all of these. An isotope can not be in the input isotope list unless it is also listed in the health file. Table 2 lists the fusion isotopes which have been incorporated into the new health file FUSEDOSE. These isotopes are those shown to be important for fusion blankets made of 316SS, TZM, or V-15 Cr-5 Ti [4]. Thus, the current input data allows the code to be used for Fe-Cr-Ni alloys, Mo-based and V-based alloys. This current health file is an expanded update of an earlier work by Sawdye [5].

Other materials may be used and these would in some cases require a further expanded health file. Table 3 lists some of the isotopes which may be needed for assessments of other materials. The alloying elements and various impurities often determine if a given isotope is important. isotopes with half lives <15 min. are not included as they would decay before substantial accidental exposure (isotopes with

TABLE 1

Fission Isotopes:
Found in Health File CRACDOSE

1.	CO-58	28.	SB-127
2.	CO-60	29.	SB-129
3.	KR-85	30.	I-131
4.	KR-85M	31.	I-132
5.	KR-87	32.	I-133
6.	KR-88	33.	I-134
7.	RB-86	34.	I-135
8.	SR-89	35.	XE-133
9.	SR-90	36.	XE-135
10.	SR-91	37.	CS-134
11.	Y-90	38.	CS-136
12.	Y-91	39.	CS-137
13.	ZR-95	40.	BA-140
14.	ZR-97	41.	LA-140
15.	NB-95	42.	CE-141
16.	MO-99	43.	CE-143
17.	TC-99M	44.	CE-144
18.	RU-103	45.	PR-143
19.	RU-105	46.	ND-147
20.	RU-106	47.	NP-239
21.	RH-105	48.	PU-238
22.	TE-127	49.	PU-239
23.	TE-127M	50.	PU-240
24.	TE-129	51.	PU-241
25.	TE-129M	52.	AM-241
26.	TE-131M	53.	CM-242
27.	TE-132	54.	CM-244

TABLE 2

Fusion Isotopes:
Currently in Health File FUSEDOSE

1.	H-3	19.	SR-89
2.	CA-45	20.	Y-88
3.	SC-46	21.	Y-90
4.	SC-47	22.	Y-91
5.	SC-48	23.	ZR-89
6.	TI-45	24.	ZR-95
7.	V-49	25.	ZR-97
8.	CR-49	26.	NB-91M
9.	CR-51	27.	NB-92M
10.	MN-54	28.	NB-93M
11.	MN-56	29.	NB-95M
12.	FE-55	30.	NB-95
13.	FE-59	31.	NB-96
14.	CO-57	32.	NB-97
15.	CO-58	33.	MO-93
16.	CO-60	34.	MO-99
17.	NI-57	35.	TC-99M
18.	NI-63	36.	TA-182

TABLE 3

Additional Isotopes which May Be Required for Various Materials*

Aluminum-based alloys
^{24}Na, ^{26}Al, ^{64}Cu, ^{65}Zn

Titanium-based alloys
^{24}Na, ^{26}Al, ^{31}Si, ^{47}Ca, ^{64}Cu, ^{65}Ni,
^{111}Sn, ^{113}Sn, ^{121}Sn, ^{123}Sn, ^{125}Sn

Ferritic Steels (having W)
^{185}W

Nickel-based alloys
--

Niobium-based alloys
^{90m}Y, ^{93}Zr, ^{92}Nb, ^{94}Nb

Copper-based alloys
^{64}Cu, ^{65}Ni

Lead (Li-Pb tritium breeder or Zr-Pb multiplier)
^{205}Pb, ^{204}Tl, ^{207}Bi

First wall coatings
^{10}Be (Be coating)
^{14}C (C or SiC coating)

*dependent on alloying elements and impurities - list is for illustrative purposes

$T_{1/2}$ <30 min. were excluded from WASH-1400). Furthermore, the health file does not include isotopes which appear to represent < 0.1% of the dose from each pathway (inhalation, ingestion, cloudshine, and groundshine) [4]. The isotopes in Table 3 have not been screened to determine if they are indeed significant contributors to exposure. Instead, they have been mentioned in previous reports listing isotopes that will be present [6,7,8,9]. They represent potential additional information needs.

The required ingestion data for the various isotopes is presented in Chapter 3. Other fusion relevant input data, primarily the health file data, are discussed in Chapter 4.

2. CODE MODIFICATIONS

Required code changes include those to incorporate tritium and those to solve fusion related problems. The new listing for the modified subroutines, CHRONX and CHRON, are given in appendices A and B.

2.1 Tritium Models

Due to its mobility in the assumed form HTO, (more dangerous and mobile than HT) tritium behavior is fundamentally different from most isotopes. This necessitates some code modifications. C-14, if included, would require similar changes. Both $^{3}H(T)$ and ^{14}C are generally modeled by the specific activity model [10]: the radioisotopes are in equilibrium with non-radioactive isotopes.

2.1.1 Exposure Pathways and Interdiction Levels

Once a plume has been released, deposition occurs and isotopes collect on the ground and vegetation. Long term exposure can occur by groundshine from deposited activity, inhalation or resuspended activity, and ingestion of contaminated food. The subroutine CHRONX calculates long term exposure for six pathways (See Table 4). The division between milk (feed animals) and crops is to allow for differences in land use between grazing and crop cultivation. The division between direct and indirect (soil) is due to the different mechanisms of contamination, time scales, and rates of removal.

Furthermore, if the dose from a pathway is higher than a given input value, interdiction is established. Different levels of interdiction (Table 5) correspond to different pathways. The code is based on the assumptions that 1) population dose for land interdiction is dominated by groundshine, not resuspension, 2) land interdiction automatically

TABLE 4

Long Term DSCOM† (Dose Commitment) Pathways*

1. Ground shine

   External exposure from deposited activity

2. Inhalation

   Inhalation dose due to resuspension of radioactive species

3. Ingestion dose - direct milk

   Dose from ingestion of milk, milk products, and crops due to feed animals ingested activity directly deposited on grass

4. Ingestion dose - direct crops

   Dose from ingestion of milk products and crops from activity directly deposited on crops

5. Ingestion dose - indirect milk

   Dose from ingestion of milk and milk products due to feed animals ingesting grass contaminated through root uptake (soil transfer)

6. Ingestion dose - indirect crops

   Dose from ingestion of crops contaminated through root uptake (soil transfer)

†Code array name for dose committment categories.

*Pathways as incorporated in the code in subroutine CHRONX.

TABLE 5

Interdiction Levels

5	Permanent (>10 years) land interdiction (population exclusion)
4	Land Interdiction (<10 years) (population exclusion)
3	Milk and crop interdiction
2	Crop interdiction
1	Milk interdiction

interdicts food, 3) the various food interdiction levels are dominated by the direct pathways and not soil transfer.

The required input data is divided as is shown in Table 6. The four ingestion input pathways require values for CF (1) and CF (2), where the first relates to crops and the second to feed animal (milk). Both are units of ($\frac{\text{Ci ingested}}{\text{Ci/m}^2 \text{ deposited}}$) and represent cumulative ecological transfer.

2.1.2 External Exposure

For tritium, there is no external gamma, so that the groundshine dose is zero. For cases with only tritium released, an infinite amount would be allowed for land interdiction purposes; the division by zero occurs in subroutine CHRON (see Section 2.2). This means that population exclusion will not occur for a tritium-only release. Population exclusion is a long-term ($\gtrsim$ months) problem. Short term evacuation is handled separately, controlled by the user by direct input criteria and is independent of the isotopes involved.

2.1.3 Inhalation of Resuspended Tritium

Land interdiction for a tritium-only release would thus be set by inhalation of resuspended tritium. The code uses the model in WASH-1400 and is controlled by f(t), the fraction resuspended $\left(\frac{\text{Ci/m}^3 \text{ resuspended}}{\text{Ci/m}^2 \text{ deposited}}\right)$

where

$$f(t) = [K_o \exp(-\lambda t) + K_\ell] \exp(-\lambda_{1/2} t)$$

$K_o = 10^{-5}\ m^{-1}$

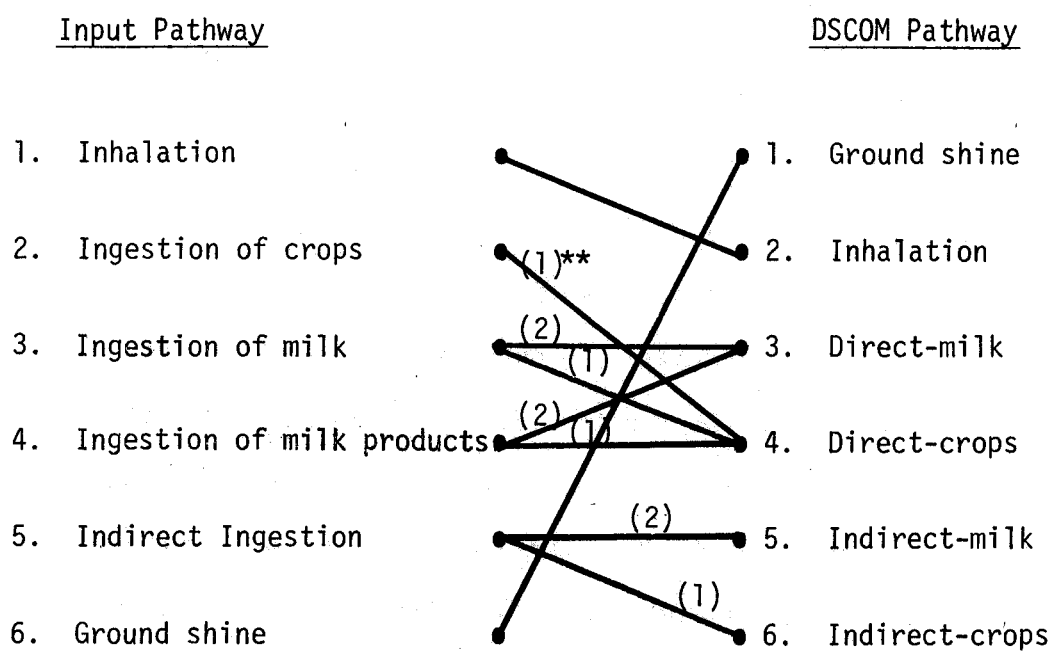
$K_\ell = 10^{-9}\ m^{-1}$

$\lambda = 0.677\ yr^{-1}$

$\lambda_{1/2}$ = decay constant

TABLE 6

Connection between Input* Pathways and DSCOM Pathways



*Input refers to the organization of pathway data supplied by the user, the input and DSCOM numbers are those used in the code.

**(1) = dose commitment based on amount of crops available.

(2) = dose commitment based on amount of milk available.

This is used for all types of land-use and release chemical forms. This model is unlikely to be very good for tritium, except in cases where tritium is in a particulate form. In most cases the existing model should over-estimate resuspension. The T/H equilibrium in the air will be controlled by the greater hydrogen pool on the surface in such forms as vegetation. The faster surface water transfer and dilution would then be expected to result in a faster decay than that incorporated into the model. This, however, is likely to be fairly site dependent and strongly influenced by the occurrence of rain.

At the present state of knowledge, it would be difficult to justify a new resuspension model; this represents an area for additional research. Limited use of the code with the current model suggests that land interdiction would not be required for long time periods due to resuspension. Interdiction, if it occurred, might be expected for short times, perhaps until the first rain. The lack of an interdiction check is conservative in that doses are included from areas that might have been interdicted. Thus, a future need for FUSECRAC is an improved resuspension model for tritium and an interdiction check. At present the existing model and lack of resuspension interdiction appears to produce conservative results.

2.1.4 Ingestion Dose

Ingestion doses from tritium required some code changes. First the dose due to non-direct transfer is more important than the direct deposition, necessitating a shift in interdiction control. Second, the contamination level for direct exposure is better related to the air concentration during the plume passage rather than the actual Ci/m^2 deposited.

The first change means that the CF input values for direct and indirect must be switched. Thus, the input pathways 2-4 are indirect rather than direct.

The second change involves the direct pathway. For tritium, the dose due to direct contamination of crops is better related to the air concentration during the plume passage [10] rather than the resulting ground concentration. Crops directly absorb tritium (HTO) from the air. However, the two are related by

$$AC \sim GC/V$$

where AC = air concentration x exposure time of plume passage ($Ci\text{-}sec/m^3$)

GC = ground concentration (Ci/m^2)

V = deposition velocity (m/s)

Normally the CF factor relates Ci-ingested to Ci/m^2-deposited, and the dose (Rem) = dose factor (Rem/Ci) x CF x GC.

For tritium, we define AF = Ci ingested/($Ci\text{-}sec/m^3$) so that the dose is calculated by

$$\text{dose (Rem)} = \text{dose factor (Rem/Ci)} \times AF \times AC$$

so that the dose is related to the air concentration during the plume passage. To minimize code changes, this is rewritten,

$$\text{dose} = DF \times (AF/V) \times (V \times AC/GC) \times GC \quad (\text{where DF = dose factor})$$

The factor V x AC/GC is incorporated into the code (subroutine CHRONX, see Appendix A). The factor AF/V now has the same units as CF and must be input to the code. Thus we have defined a CF (direct) for tritium as AF/V.

To account for the passage of time required by any interdiction, the pathway 5 exposures (direct for tritium) are multiplied by

$$\exp(-\text{TIDEC} \times 0.693/T_{eff})$$

where TIDEC = interdiction period for either crop or milk

T_{eff} = effective decay half-life for tritium

for DSCOM(5) - indirect milk, TIDEC = TIMEK

for DSCOM(6) - indirect crops, TIDEC = TWAIT

where TIMEK is the milk interdiction time

and TWAIT is the crop interdiction time.

2.1.5. Tritium Input Values

The inhalation and ingestion input for tritium must be calculated. All data is discussed in Reference 10, based on ref. 10a. The inhalation dose is calculated by

$$\text{Inhalation Dose} = DF \times BREATH \times AC$$

where DF = dose factor input (rem/Ci)

BREATH = breathing rate (m^3/s)

AC = Ci-sec/m^3

$\int_0^T \chi \, dt$ = cumulative air exposure $\sim\chi$(Ci/m^3 in plume) x T(passage time)

The DF is read in directly from the health file and no modifications are needed.

For direct ingestion, the dose is given by

$$\text{dose} = DF \times AF \times (T + 1/\lambda_p)$$

where T = plume passage time

λ_p = plant HTO decay constant

$\lambda_p = 16.6\ \text{day}^{-1}$ $\quad T < 1$ hr

$\quad T/\ln 2 \quad 1\ \text{hr} < T < 1\ \text{day}$

$\quad 0.7\ \text{day}^{-1} \quad 1\ \text{day} < T$

We now define the factor $PF = \left(\frac{1}{1 + \frac{1}{\ln 2}}\right)\left(\frac{T + \frac{1}{\lambda_p}}{T}\right)$

$PF = 0.409 + 0.591/T \quad T < 1$ hr (T in hours)

$\quad = 1.0 \quad 1\ \text{hr} < T < 1\ \text{day}$

$\quad = 0.409 + 0.591/T \quad 1\ \text{day} < T$ (T in days)

Then

$$\text{dose} = DF \times AF \times PF \times T \times \chi \times \left(1 + \frac{1}{\ln 2}\right) \quad (T \times \chi = AC)$$

$$= DF \times \frac{AF}{V} \times PF \times \left(1 + \frac{1}{\ln 2}\right) \times \left(\frac{V \times AC}{GC}\right) \times GC$$

$\left[\frac{U \times AC}{GC}\right.$ included in code$\left.\right]$

For most cases of interest the release time ($\lesssim$ plume passage time) will be $\gtrsim$ 1 hour and PF $\to$ 1. For other cases PF = 1 is conservative, but one can adjust the input if desired. As noted above, the required input is CF = AF/V x PF x $\left(1 + \frac{1}{\ln 2}\right)$, which will now be calculated (in the manner of ref. 10). For vegetation, CF = AF/V x PF x $\left(1 + \frac{1}{\ln 2}\right)$,

$$CF = \frac{(0.521\ \text{kg/day intake})}{(2)(8\ \text{g/m}^3\ \text{absolute humidity})} \left(\frac{10^3\ \text{g}}{\text{kg}}\right)\left(\frac{1\ \text{day}}{86400\ \text{sec}}\right)\left(\frac{1}{10^{-3}\ \text{m/s}}\right)$$

$$\times \left(1 + \frac{1}{\ln 2}\right)$$

with $V = 10^{-3}$ m/s

$CF = 0.92\ m^2 (x\ PF)$

For meat,

$$CF = \frac{(0.649)(300\ g/day)(1 + \frac{1}{\ln 2})}{(2)(8\ g/m^3)(10^{-3}\ m/s)} \left(\frac{1\ day}{86400\ sec}\right) x\ PF$$

$$= 0.344\ m^2\ (x\ PF)$$

For milk,

$$CF = \frac{(0.534)(300\ g/day)(1 + \frac{1}{\ln 2})}{(2)(8\ g/m^3)(10^{-3}\ m/s)} \left(\frac{1\ day}{86400\ sec}\right) x\ PF$$

$$= 0.283\ m^2 (x\ PF)$$

where 0.649 and 0.534 are the transfer fractions that account for passage of tritium through the feed animal from both breathing and food intake of the feed animal [10].

To complete the tritium discussion, the indirect ingestion CF values are calculated. Here the HTO is assumed to contaminate the root zone. Unlike other isotopes, this would occur very fast.

For soil→crop

$$CF = \frac{0.521\ kg/day}{(0.5\ m)(0.105\ kg/m^3)(0.0693\ day^{-1})}$$

where 0.5 m = root zone depth

$0.105\ kg/m^3$ = average soil moisture

$0.0693\ day^{-1}$ = 10 day soil moisture decay half-life

then $CF_{crop} = 143\ m^2$

For soil→meat,

$$CF = \frac{(0.300\ kg/day)(0.604)}{(0.5)(0.105)(0.0693)} = 49.8\ m^2$$

For soil→milk,

$$CF = \frac{(0.300\ kg/day)(0.507)}{(0.5)(0.105)(0.0693)} = 41.8\ m^2$$

where 0.604 and 0.507 are the transfer fractions due to passage through feed animal from the animal food intake (but not animal inhalation). Note that these are very site and crop mixture dependent. The weathering (used as input to calculate T_{eff}) would in like fashion be 10 days. WASH-1400 [2] used a 14 day weathering half-life for the above surface wash-off. For case where tritium is run with other isotopes, one should be conservative and use the 14 day value (slower weathering).

2.2 Zero Dose Factors and Minor Problems

The previous section indicated that for the tritium-only releases there is no groundshine dose. The subroutine CHRON calculates the maximum permissible deposited activity based on the maximum permissible dose. For tritium the zero dose factor led to division by zero. Furthermore, as will be discussed in Chapter 4, the health file currently lacks some inhalation data and has zeroes for some isotopes.

To prevent overflow errors for all these cases the subroutine CHRON has been modified. For critical organs the dose factors are checked against 10^{-20} and set to 10^{-20} if it is below. This has no effect on results and prevents division by zero (see Appendix B).

Finally there are a few other aspects to the code which the fusion user should be aware of. The health file is read by the subroutine CHRON to set up the inhalation and external dose factor arrays. This only occurs on the first reference case. Thus one should not alter the number or order of isotopes (group ISOTOPE) in any modification case as the arrays will not agree with the isotope numbers. The leakage (group LEAKAGE) fraction may be changed.

Although CHRON has been modified to protect against zero dose factors, it does not screen out zero input for CF values, care should be taken to avoid inputting zero for any of these.

Two detailed output options will slightly malfunction for fusion. The detailed health output (NPH) will try to calculate the percentage thyroid dose due to Iodine species when thyroid effects are desired. For fusion cases, Iodine is not present and the numbers for percentage effects are meaningless. The detailed output (NPD) will try to use Cesium as an example to show air concentration. For fusion cases, these numbers are meaningless. Finally, for tritium-only cases, tritium obviously represents 100% of the acute dose. For the detailed health output (NPH=20), the isotopes percentage contribution to dose will be calculated. For tritium-only cases, the 100% value overflows the formatted output field.

3. INGESTION INPUT DATA

Depending on the release considered the ingestion contribution to long term dose can be dominant. The code requires two sets of ingestion parameters -- CF and ingestion dose factor. The former is a measure of the ecological transfer to man (Ci ingested/ Ci/m^2 deposited). The latter indicates the damage done internally after the isotope enters the body.

3.1 Problem Organization

The primary food stuffs in which people could ingest deposited radionuclides are typically divided into milk, beef, and crops. The current model incorporates these three separate but associated pathways. Once ingested, it is assumed that the metabolization of the nuclide is independent of the process by which it was transferred to man. This permits the radiological hazard assessment to be divided into two independent factors (dose factor and CF value). These are identical to those discussed in Appendix 6, section E of WASH-1400 [2]. Thus, the problem is to acquire dose factors and calculate CF values for fusion isotopes.

The CF factor is a measure of the amount of activity that is ingested from an initial deposition and has units of Ci ingested/ Ci deposited/m^2. This factor incorporates all of the environmental transfer modeling. Both the CF and dose factor are functions of chemical behavior and radiological decay. Since many of these fusion isotopes have not been relevant in fission or medical application, little environmental related data has been published for them. As a result, the overall modeling is limited in its accuracy. Here conservative estimates have been used where needed. The results can be used with some confidence (within an order of magnitude)

especially in determining relative ingestion health effects from various structural alloys (with different sets of isotopes).

Modeling of the pathways was kept as simple as possible while incorporating all the major environmental "compartments" that the nuclide travels through. Increasing the complexity of the model would not have added any accuracy to the results due to the large lack of certainty in the additional transfer parameters. (In fact added complexity may compound the errors in data and cause the results to be less accurate [11].)

The results of this work have been used to show that certain nuclides are dominant in terms of dose to people [4]. Therefore, further study and effort can be focused on fewer nuclides without any loss in relevant accuracy. The list of isotopes studied in this section is more comprehensive than that used in implementing CRAC for precisely the above reason. (The elements considered are listed in Table 7.)

3.2 Environmental Modeling

In the past decade several models have been developed in order to determine the radioactive intake by man from an initial deposition in a terrestrial environment. WASH-1400 in 1975 developed a methodology for estimating ingestion doses but was very isotope specific and not easily utilized for the fusion related isotopes presently considered. The WASH-1400 analysis centered on three dominant elements (I, Cs, Sr) and much of it is only applicable for these elements, especially the crop pathway.

TABLE 7

Elements Considered in Environmental Models

(A check indicates that an isotope of the listed elements was studied.)

Element	ORNL [Ref. 12]	WASH-1400 [Ref. 2]	Present Study
H	✓		✓
C			✓
P	✓		
Ca			✓
Sc	✓		✓
Ti			✓
V			✓
Cr			✓
Mn			✓
Re			✓
Co			✓
Ni			✓
Cu			✓
Zn	✓		
Sr	✓	✓	✓
Y			✓
Zr			✓
Nb			✓
Mo	✓		✓
Tc			✓
Ru	✓		
Te	✓		
I	✓	✓	
Cs	✓	✓	
Ta	✓		✓
W	✓		✓
Hg	✓		
Tl	✓		
Pb	✓		

See Appendices C and D for individual isotopes considered in present study.

A 1971 Oak Ridge report by researchers Boothe and Kaye [12] presented a systems analysis from which much of the modeling and notation is used in this report. Several changes have been made in order to obtain CF values consistent with CRAC input requirements.

The CF values used in CRAC are separated into "indirect" and "direct" components. The direct component of the CF (herein referred to as CF direct) is defined as that amount of radioactivity that is transferred to man without having entered the soil compartment (see Fig. 2). All radioactivity that is not deposited directly onto the crop or pasture grass is excluded from CF_{direct}. Part of the activity that is deposited on crop or pasture grass will be transferred to the soil by weathering and also will not contribute to the CF_{direct}. The $CF_{indirect}$ is defined as that part of the ingested activity that has at some point passed through the soil compartment, either by weathering or by direct deposition onto soil. (See Fig. 3.) From these definitions it is clear that $CF = CF_{total} = CF_{indirect} + CF_{direct}$, and the CF components are appropriate for use with CRAC.

CRAC also requires that the CF values be input in terms of pathway. The CF values should be for crop, beef, and milk pathways (designated CF_{crops}, CF_{beef}, CF_{milk} respectively). The total CF for a given nuclide would be the sum of the indirect and direct components of the three pathways.

The model allows for initial depositions of radioactivity onto foodcrops ($S_1 \times F_o$), pasture grass ($S_3 \times F_o$), and pasture soil ($S_4 \times F_o$), (see Fig. 4). The factors S_1, S_3, and S_4 are independent and are used to approximate initial levels of retention and distributions of deposited radionuclides. Radioactivity can be transferred to man from the pasture

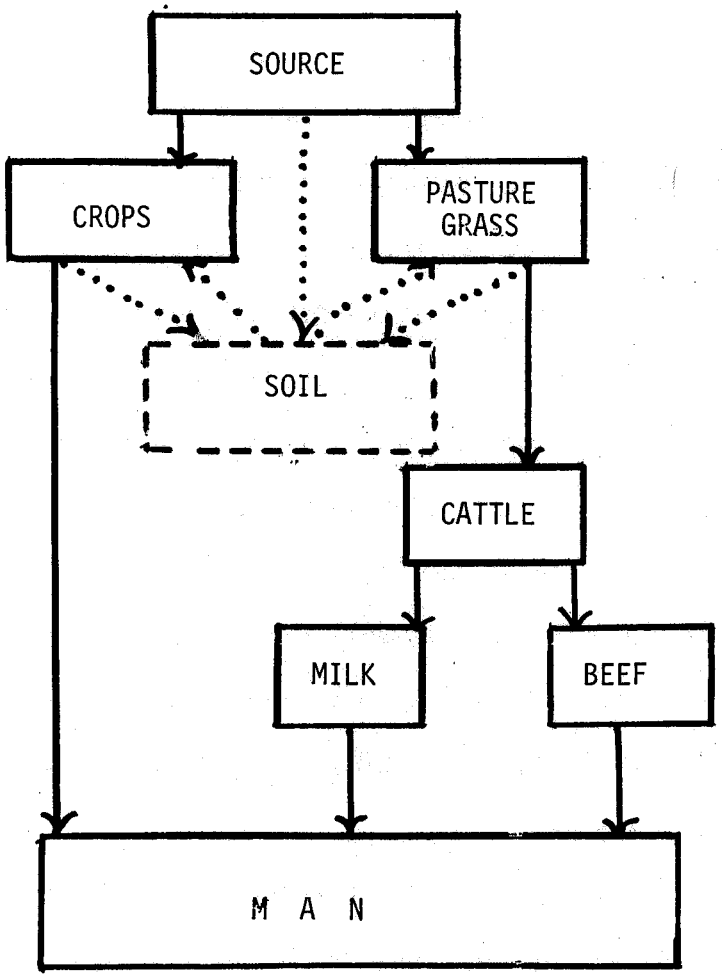


Figure 2: Diagram of Direct Pathway to Man (dashed line indicates pathway excluded in CF direct determination)

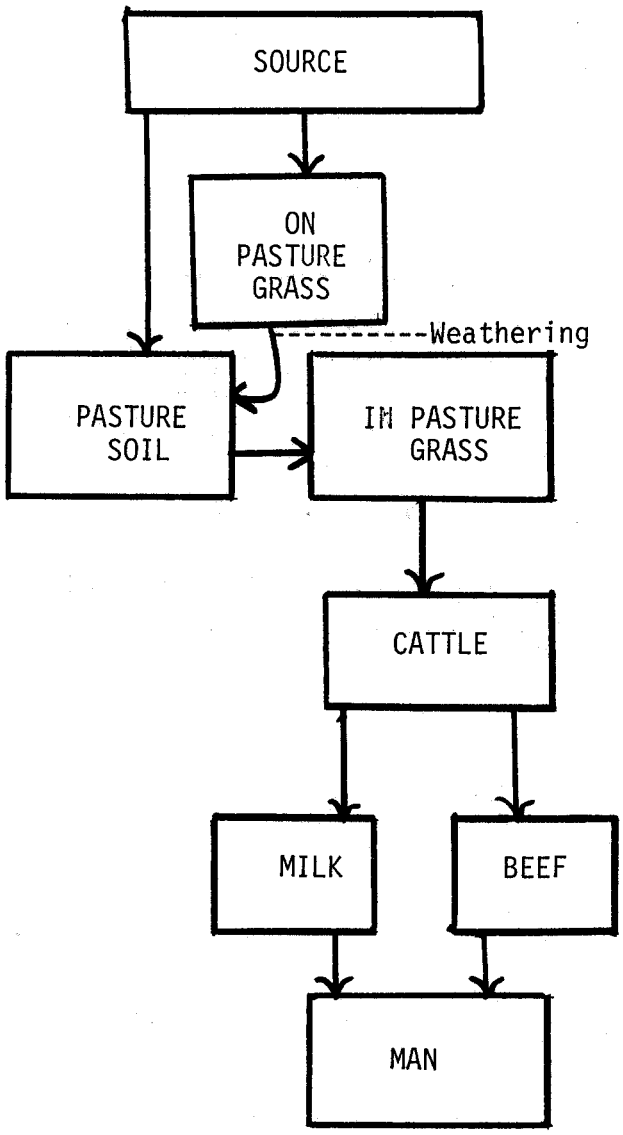


Figure 3: Diagram of "Indirect" Pathways to Man (Milk and Beef Pathways Only)

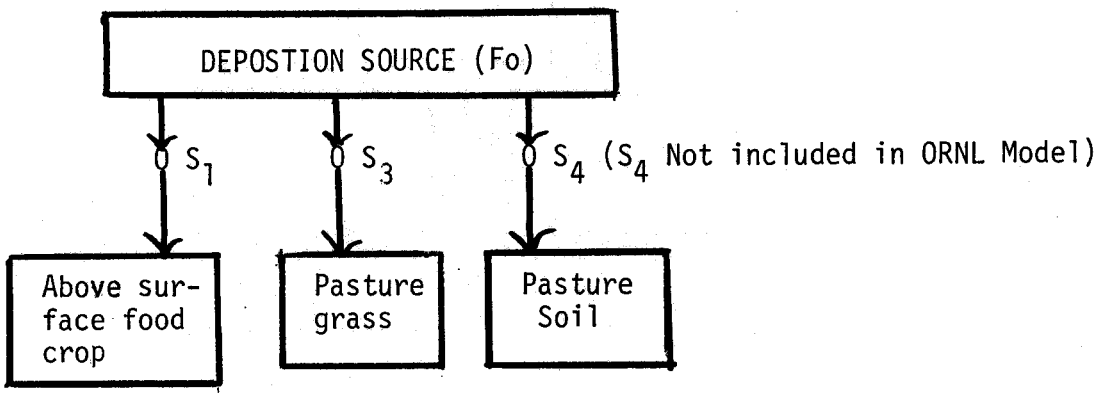


Figure 4: Initial Deposition Distribution

grass through consumption of milk or beef. Both pathways allow for the transfer of the radionuclides from the pasture grass to the soil by weathering (see Fig. 5). There is also a feedback loop that allows for the root uptake of the radionuclide from the pasture soil to the pasture grass, where it can then be consumed by the cow. The model used in this report also allows direct deposition onto pasture soil to be eventually incorporated into the pasture grass, a factor that was not present in the ORNL model (see Fig. 4).

Movement of the radionuclide from the pasture soil to a soil sink where it is unavailable for root uptake is also considered (see Fig. 6). The transfer of the radionuclide through the cow is considered separately in the beef and milk pathways ($\tau_{g,b}$ and $\tau_{g,c}$ of Fig. 6). A list of symbols used in environmental modeling is given in Table 8.

The milk compartment follows the passage of the radionuclide through the cow's udder. The radioactivity is modeled as passing directly from the grass to the milk and is a very simplified simulation (see Fig. 5). The only loss mechanism for activity in the milk is radioactive decay. This is necessitated by a lack of data for transfer parameters of many radionuclides that would be needed in a more detailed milk pathway model. Furthermore, none of the other models studied were able to model the milk or beef pathways in greater detail than was done in the present study.

The beef compartment models the transfer of radioactivity directly from grass to the meat or muscle of cattle grazing on the contaminated pasture (see Fig. 5). Radioactivity is allowed to leave the compartment through radioactive decay, biological elimination and slaughter of cattle. The mass of the beef remains constant, because uncontaminated cattle added to the herd and growth of the cattle were assumed to balance the

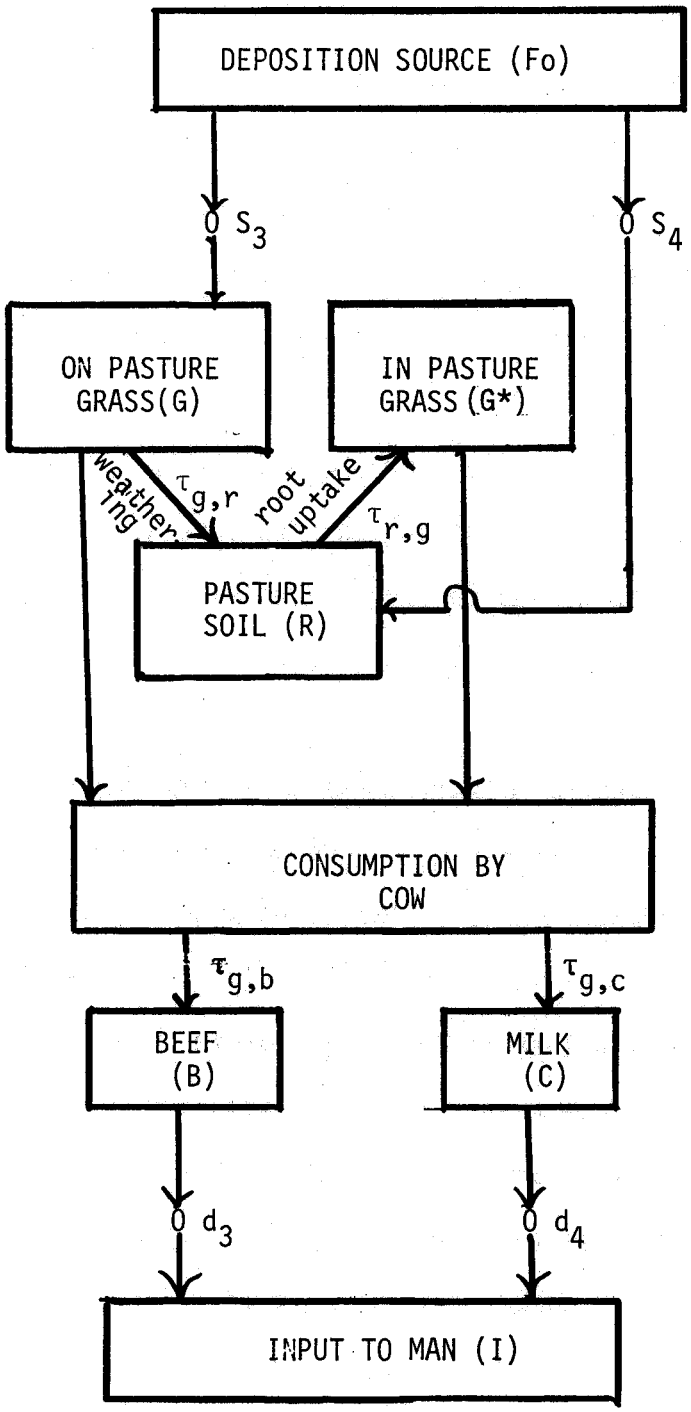
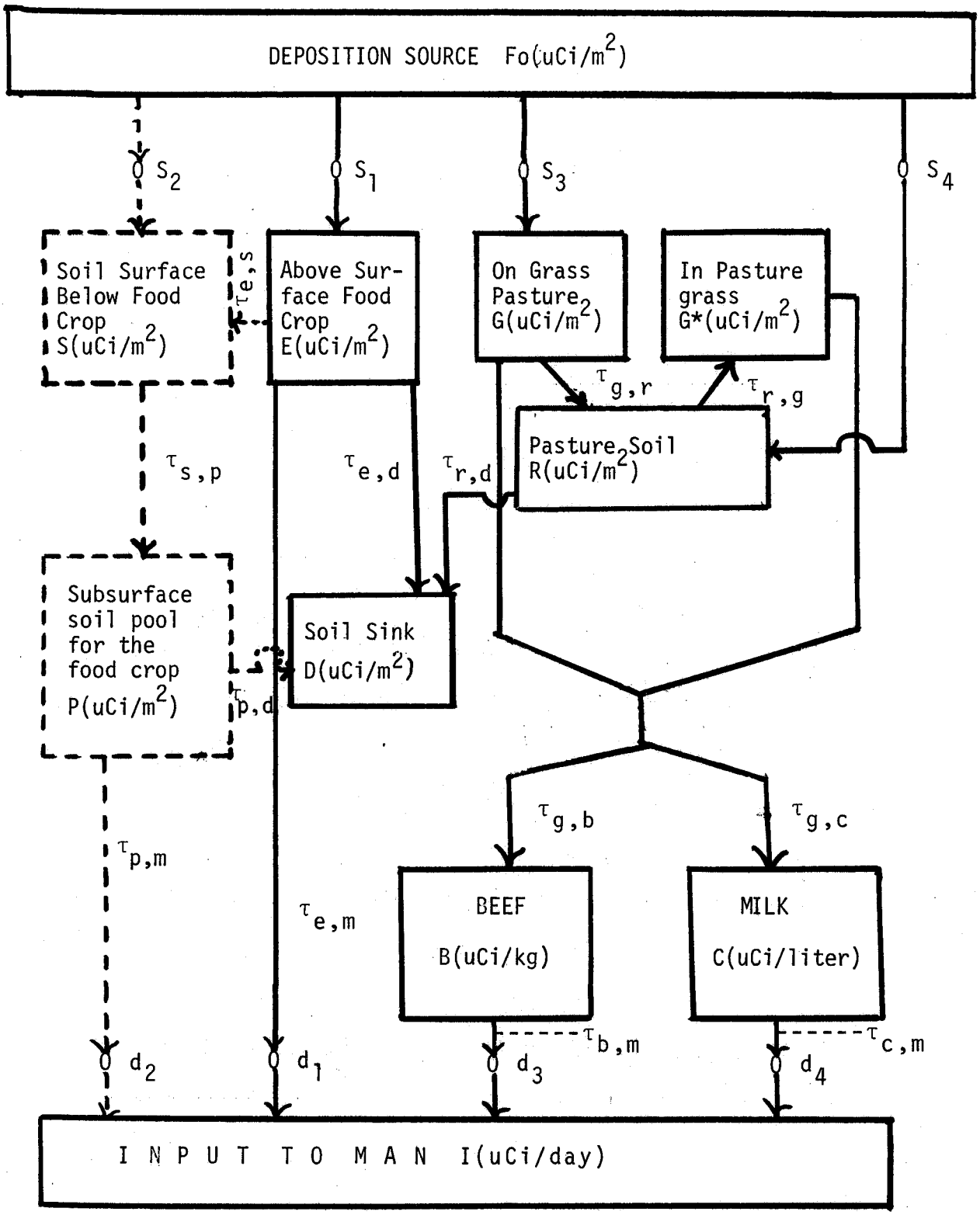


Figure 5: Beef and Milk Pathways

losses from the herd. These assumptions are the same as those presented in the ORNL model.

The crop direct pathway is modeled independent of the $milk_{direct}$ and $beef_{direct}$ pathways (see Fig. 2). The direct deposition of radioactivity onto crops is explicitly modeled and simulates the eventual ingestion of foodstuffs other than milk or beef. The crop was assumed to be continuously harvested during and after deposition, with biomass loss balanced by crop growth. If an accurate depiction of the manner in which the crops are harvested is known, the transfer parameter between surface food crop and man ($\tau_{p,m}$ of Fig. 6) can be changed to reflect this greater accuracy. The ORNL model allowed for the transfer of radioactivity from the crop directly to man or to the soil subsurface below the crop. This latter radioactivity could then enter man by travelling through a subsurface pool to plants roots and eventually be ingested as part of the crop. The weakness of this modeling was due to the lack of information about the final transfer parameter ($\tau_{p,m}$) (see Fig. 6) in the crop or pool-root-man pathway. The value for this transfer parameter was determined from the ratio of equilibrium concentrations of stable nuclides in man and soil. This ignores the effect of milk and beef contributions to a nuclide's concentration in men. It also has the additional disadvantage of incorporating an equilibrium (see Ref. 12, p. 6) transfer value into a dynamic system and might not accurately indicate which radionuclides might be major contributors in a dynamic environment.

The WASH-1400 [2] report did not model the transfer of radionuclides through the crop soil but determined the $CF_{crop\ indirect}$ values by radioisotope specific comparisons to the other pathways or by experimental



CF is defined by $CF \equiv \int_0^{\infty} I(t)dt$ CF_{0-1} is defined by $CF \equiv \int_0^{365} I(t)dt$

Figure 6: Block Diagram Comparing Terrestrial Pathways Modeled

TABLE 8

List of Symbols
for Environmental Modeling

A*	Soil surface area required to furnish food crops for one man ($10^3 m^2$)
Ag*	Pasture area per cow ($10^4 m^2$)
α_i	Ratio of $CF_{indirect}$ to CF_{direct} for the i^{th} nuclide
B	Concentration of radioactivity in beef ($\mu Ci/kg$)
C	Concentration of radioactivity in milk ($\mu Ci/liter$)
CF_i	Ratio of ingested radioactivity to radioactivity deposited per area for the i^{th} pathway ($Ci/Ci/m^2$)
D	Radioactivity present in soil below the root depth ($\mu Ci/m^2$)
Dg*	Dry weight density of pasture grass ($0.15 kg/m^2$)
d_1, d_3, d_4	Dietary factors that allow for the correction of transfer coefficients to man in order to model populations other than that of reference man - set equal to one for reference man (dimensionless)
E	Radioactivity present in above surface food ($\mu Ci/m^2$)
F	Radioactivity deposition rate ($\mu Ci/m^2$-day)
F_0	Ground deposition source ($\mu Ci/m^2$)
G	Radioactivity in grass compartment that is deposited on the surface of the grass ($\mu Ci/m^2$)
G*	Radioactivity in the grass compartment that is from root uptake of radioactivity in the soil ($\mu Ci/m^2$)
I	Input source (rate) to man (μCi/day)
λ_B	Biological decay rate for turnover of the stable isotope of the nuclide in man ($days^{-1}$)
λ_R	Radioactive decay rate of the nuclide under study ($days^{-1}$)

Table 8 Continued

M	Radioactivity present in man (μCi)
R	Radioactivity present in the soil from the ground surface to the root depth of the grass ($\mu Ci/m^2$)
S_1, S_3, S_4	Falloout correction factor to account for different depositions to the above surface food (S_1) pasture grass (S_3) and pasture soil (S_4) (dimensionless)
ts,i	Storage time of foodstuff between production and consumption for the i^{th} pathway
τ_{beef}	Fraction of beef herd slaughtered per day (.00381 day^{-1})
τ_{milk}	Transfer rate of milk from the udder (2.0 $days^{-1}$)
$\tau_{i,j}$	Transfer coefficient from compartment i to compartment j
$\tau_{b,m}$	Amount of meat eaten by a man each day (.3kg/day)
$\tau_{c,m}$	Amount of milk consumed by a man each day (.3 liter/day) (Note: This value differs from ORNL report)
$\tau_{e,m}^*$	Amount of surface area of crop consumed by man each day (2.5 m^2/day) (See ORNL-TM 3135 for derivation)
$\tau_{e,s}^*$	Transfer rate from crop surface to crop soil (14 day environmental half life assumed) (.0495 day^{-1})
$\tau_{g,b}$	Transfer rate from pasture grass to beef (m^2/kg day)
$\tau_{g,c}$	Transfer rate from pasture grass to milk (m^2/liter day)
$\tau_{g,r}^*$	Transfer rate from deposition on surface of pasture grass to pasture soil (14 day environmental half life assumed) (.0495 day^{-1})
$\tau_{r,d}^*$	Transfer rate from pasture soil to soil sink (1.096×10^{-4} day^{-1}) (assumed to be 4%/year)
$\tau_{r,g}$	Transfer rate from pasture soil through roots to pasture grass (day^{-1})
V_c	Dry weight grass consumption per day by a cow (10 g/day)
*	Value of marked parameters obtained from reference 12

data available for a few select nuclides. The method used to estimate $CF_{\text{crop indirect}}$ in this report is based on the expected similarity of root uptake by pasture grass and crops. The following relationship was found to be true for CF values of each radionuclide:

$$\frac{CF_{\text{beef indirect}}}{CF_{\text{beef direct}}} = \frac{CF_{\text{milk indirect}}}{CF_{\text{milk direct}}} = \alpha$$

The value of α was different for each radionuclide. (A derivation of the ratio α is given in Appendix C.) The ratio was then extended to include the crop pathway by setting:

$$\frac{CF_{\text{crop indirect}}}{CF_{\text{crop direct}}} = \alpha \ .$$

Since the $CF_{\text{crop direct}}$ is determined in the present modeling, the $CF_{\text{crop indirect}}$ value is obtained from the product of α and $CF_{\text{crop direct}}$. Estimating $CF_{\text{crop indirect}}$ in this manner utilizes the dynamic modeling of the beef and milk pathways. The major weakness lies in equating the transfer parameter between soil and crop to the transfer parameter between soil and pasture grass ($\tau_{r,g}$ of Fig. 6). However, the crop pathway represents a lumping together of many different types of vegetation and, until there is enough information to treat each type separately, a single valued estimation is necessary.

The model also includes dietary and decontamination factors (d_1,d_3,d_4) (see Fig. 6). Since the present analysis is being done for a standard man these factors allow for the variations in a population's diet from that of standard man. They also allow for the possible interdiction

of a given pathway by setting to zero the d factor for the associated pathway. They can also include decontamination through radiological decay of stored crops, milk, or beef by multiplying them by $\exp(-\lambda_r t_s)$ where t_s is the storage time in days and λ_r is the radiological decay constant. When used with CRAC, the CRAC code automatically accounts for decay due to interdiction. Other factors that influence the value of the dietary factors would be processing and working methods involved in the preparation of the milk, beef, or crops.

There has also been one subtle, but very important change made to the ORNL model. That report made no distinction between an "in grass" component of the pasture grass compartment and an "on grass" component (see Fig. 7). The importance of making the distinction is due to the assumption of a 14 day weathering effective half life in which the radionuclides present in the grass compartment are transferred to the soil compartment. "Weathering" is only effective for radionuclides deposited on the pasture grass. The activity that is incorporated into the plant by root uptake does not get "weathered" to any great extent and certainly not at a 14 day effective half life. The principle mechanism by which radionuclides are transferred to pasture soil from within the grass is through ingestion of the grass by the cow and then excretion onto the pasture soil. This mechanism is a much slower transfer to the soil than weathering, hence it was not expected to add appreciably to the $CF_{indirect}$ values and was not included in the present analysis.

The WASH-1400 Report dismissed the contribution to the $CF_{indirect}$ from weathering transfer to the soil as secondary compared to the direct deposition on soil. However it was found that for the longer lived

a - Present modeling of transfer through grass compartment

b ORNL (12) modeling

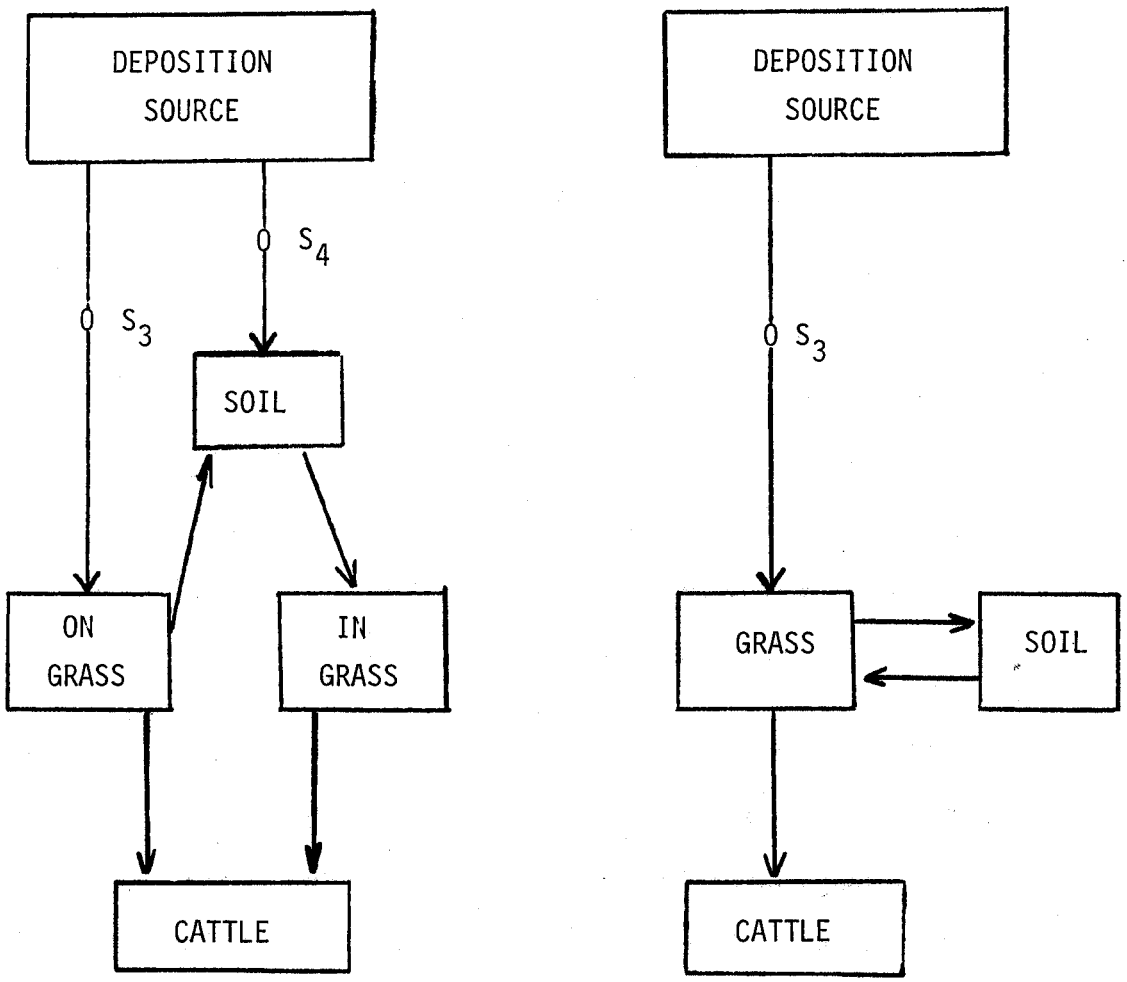


Figure 7: Comparison of the Grass-Soil Pathways

radioisotopes the effect is not neglible (see Ref. 12, pages 14-16) and an estimate has been included in the present model and will be presented later in this chapter. A comparison of the conservatism of each model with respect to indirect CF will also be considered at that time.

The basic assumptions not already stated are summarized as follows: (and are consistent with the ORNL model).

1. There is no radioactivity transported out of the contaminated area by environmental effects (such as water runoff, wind, etc.) other than the inclusion of a soil sink.
2. The entire food needs of the cattle were derived from contaminated pasture.
3. The only loss mechanisms considered were radiological decay, metabolic processing in cattle and movement to the soil sink.

These assumptions are thought to be conservative. The nonconservative assumptions include lack of a feedback loop from the cattle to a pasture soil (through excretions) as well as the crude estimation of the CF crop indirect values. (There is no way to determine whether these values are conservative or not without detailed knowledge of the transfer parameters from the soil to the crops. Also radioactive intake by the cattle from inhalation and water consumption was ignored. Researchers [12] AT Oak Ridge have found this to be of second order importance due to the much larger amounts of radioactivity transferred to the cow by ingestion (although the inhalation intake was included for ^{3}H in Chapter 2).

Ideally, each of the transfer parameters would be determined for each nuclide. Lack of detailed information precludes this possibility. As a result, the transfer parameters $\tau_{g,b}$, $\tau_{g,c}$ and $\tau_{r,g}$

were considered to be functions of the element under study. Derivations of $\tau_{g,b}$ and $\tau_{g,c}$ are given in the ORNL report [12] and are not reproduced here.

The value of $\tau_{r,g}$ was derived independent of Ref. 12, which had assumed a constant value of $2.74 \times 10^{-5} day^{-1}$ for all nuclides. The WASH-1400 report [2] listed in Section E, Table VI, p. 32, the relative concentration factors (ppm in dry plant material/ppm in dry soil) of elements in first-crop plants compared with soil. The elements were separated into groups having similar concentration factors. The total range for these factors was from 10-1000 (strongly concentrated) to less than .01 (strongly excluded). Each of these groups were assigned transfer values, $\tau_{r,g}$, consistent with their relative standing as well as the values quoted for specific isotopes (i.e. $\tau_{r,g}(Sr) = 1.41 \times 10^{-4}\ day^{-1}$ and $\tau_{r,g}(Cs) = 6.31 \times 10^{-6} day^{-1}$). Elements that were not in in WASH-1400 were grouped by their expected chemical behavior. This was estimated by associating elements in the same column of the periodic table of the elements with the same transfer coefficient. This method was expected to be conservative as a whole since all but one of the elements so estimated were assigned the second highest transfer value. (see Table 9).

The values of the radiological decay constant (λ_r) were taken from the CRC Handbook of Chemistry and Physics 58th Edition. The values of λ_β were taken from UCRL-50163. p. 32 [13] and are for whole body distribution only.

The parameters S_1, S_3, S_4, d_1, d_3, d_4, were considered to be independent of the nuclide in question. In the present study (done for reference man) d_1, d_3 and d_4 are unity by definition. The S factors were assigned the following values: $S_1 = .1$; $S_3 = .5$; $S_4 = .5$. The initial retention of 50% of the fallout on the pasture grass ($S_3 = .5$) is the same as that implicitly assumed by WASH-1400 [2] (In WASH-1400

TABLE 9

Classes of Elements of
Similar Concentration Factors and
Associated $\tau_{r,g}$ Values

Concentration Factor*	Assigned Value of $\tau_{r,g}$ (day^{-1})	Element
10 - 1000 (strongly concentrated)	7.25×10^{-4}	C
1 - 100 (slightly concentrated)	1.50×10^{-4}	Ca,Sr,Mn,Mo, V,Cr,Nb,Tc
0.1 - 10 (not concentrated)	2.80×10^{-5}	Co,Ni,Cu
0.01 - 1 (slightly excluded)	6.30×10^{-6}	Fe
< 0.01 (strongly excluded)	1.00×10^{-6}	Se,Y,Zr, Ta,W,Ti

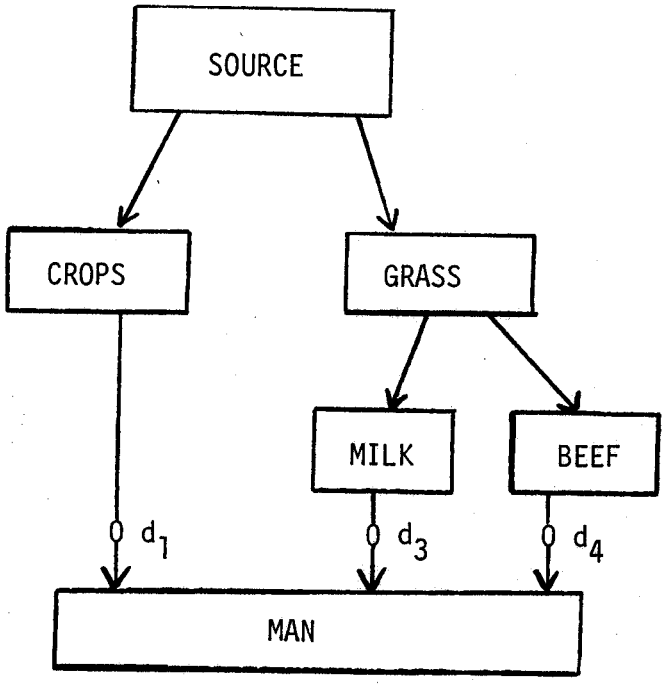
* From reference 2, Appendix E. Additional elements were assigned to classes on the basis of location in periodic table, and are underlined in chart.

the CF contributions from direct and indirect pathways were weighted equally). The initial retention of 10% on crop (S_1 = .1) is the same value as in ORNL [12] and is lower than S_3 because it is assumed that the food from crops can undergo many forms and stages of processing which have not otherwise been taken into account). The pasture grass is eaten directly by the cow without any other handling and/or processing. The value of .1 for S_1 appears to give values consistent with available data on CF values. It should be noted that the CF values presented are linearly dependent on the S and d factors and therefore only apply to the values used in this report.

3.3 CF Value Calculation

In order to calculate the required values for CRAC of CF_{beef}, CF_{crop}, CF_{milk} (both direct and indirect) and not affect the dynamic modeling of the combined pathways it was necessary to isolate the various components using the dietary factors d_1, d_3, d_4. To calculate the beef contribution to the CF, d_1 and d_4 were set = 0. (See Fig. 8a). To calculate the direct component of CF it was necessary to set $\lambda_{r,g} = 0$ (see Fig. 8b). This implied that any radioactivity that entered the soil did not reach man and is consistent with the definition of direct dose. Setting the value of $\tau_{r,g}$ to zero also altered the values of $\lambda_r, \lambda_1, \lambda_2$, and λ_g in the solution of I(t). In trying to calculate the indirect dose an approximation had to be used due to the inability of attaining an analytical solution for I(t) when the compartments G and G* are separated. In calculating the indirect dose for milk and beef pathways it was necessary to set $\tau_{g,r}$ (weathering) equal to zero (see Fig. 8b). This was done because there should be almost no weathering of the radionuclide once it has entered the pasture grass through the roots.

a

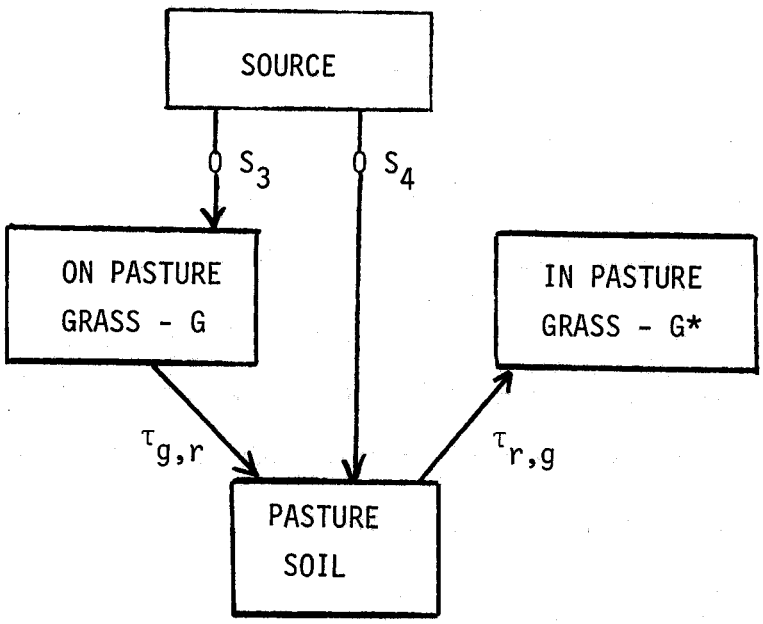


$d_3 = d_1 = 0$ for beef pathway

$d_1 = d_4 = 0$ for milk pathway

$d_3 = d_4 = 0$ for crop pathway

b



$\tau_{r,g} = 0$ for direct dose

$\tau_{g,r} = 0$ for indirect dose

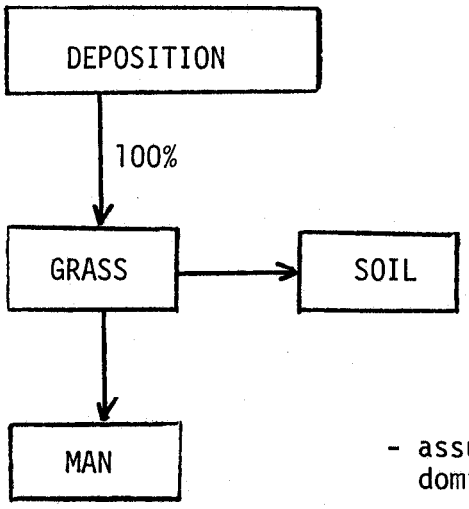
Figure 8: Diagram of Model Alterations to Isolate Pathways
a) Dietary Factors; b) Soil Transfer Parameters

Setting $\tau_{g,r}$ to zero causes difficulty when tracing the indirect component from the direct deposition (S_3) (see Fig. 8b). Since the weathering effect has been deleted and compartments G and G* have not been separated there can be no cycling of the radionuclide from deposition on grass to soil then to grass again. As a result, part of the indirect dose will be lost. In order to make up for this deficiency when estimating the indirect dose the value of S_4 is assumed to be 1.0 (see Fig. 9). This estimation assumes that all of the radionuclides are deposited on the soil and is conservative when calculating the CF indirect values only. It is not considered to be overly conservative however, since the transfer rate through the soil is much slower than for the direct to man pathway. This has the effect of not adding appreciably to the $CF_{indirect}$ value for nuclides with half lives equal to 50 days or less. It is important when the half lives are much longer but these are precisely the radionuclides of interest in the indirect pathway. Also estimating the indirect dose in this manner makes up for some nonconservatism in the weathering assumption of the direct dose calculation. This nonconservatism is due to the 14 day weathering half life assumed for all time.

In WASH-1400 [2] it is stated that this weathering half life has been determined to be valid for periods ranging from 7 to 30 days. After this time the weathering time period slows to around 40 days. The nonconservatism in the weathering coefficient is only significant for those isotopes with half lives comparable to or greater than the period of validity, i.e., approximately 30 days. As stated before it is just these isotopes that are overestimated in the indirect CF determination. There is also a general conservatism introduced in each CF because of the integration of the intake from zero to infinity.

a

CF_{direct}



$CF_{indirect}$

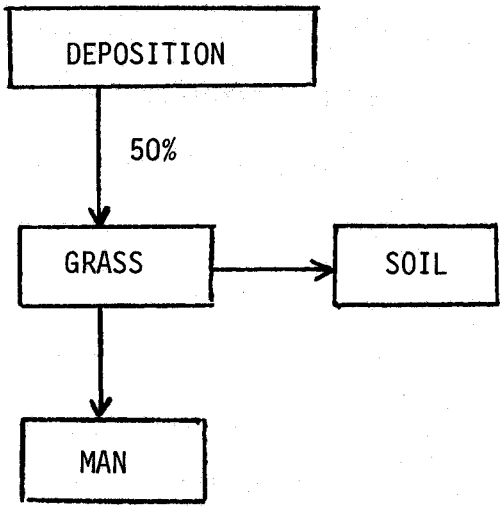
Not able to calculate indirect CF; no initial deposition on soil

- assumption of 100% overestimates dominant CF_{direct} by ~ 2

Figure 9.a: Comparison and Summary of Direct and Indirect Pathways for ORNL Model

b

CF_{direct}



$CF_{indirect}$

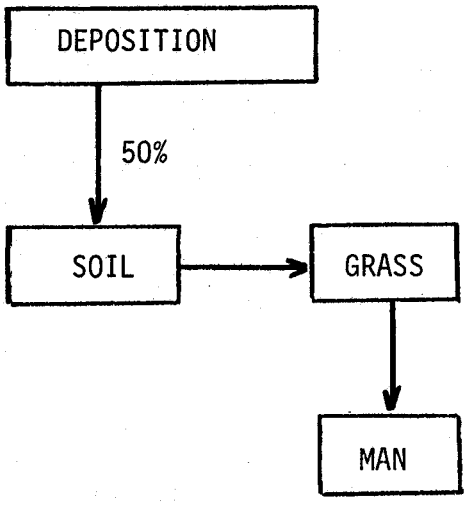


Figure 9.b: Comparison and Summary of Direct and Indirect Pathways for WASH-1400 Model

- Underestimates CF_{direct} for long-lived isotopes due to weathering half life.
- Underestimates $CF_{indirect}$ for all isotopes since model does not account for weathering contribution to $CF_{indirect}$ (i.e., deposition to grass, then washed to soil, then uptake by grass roots)

(Continued)

c

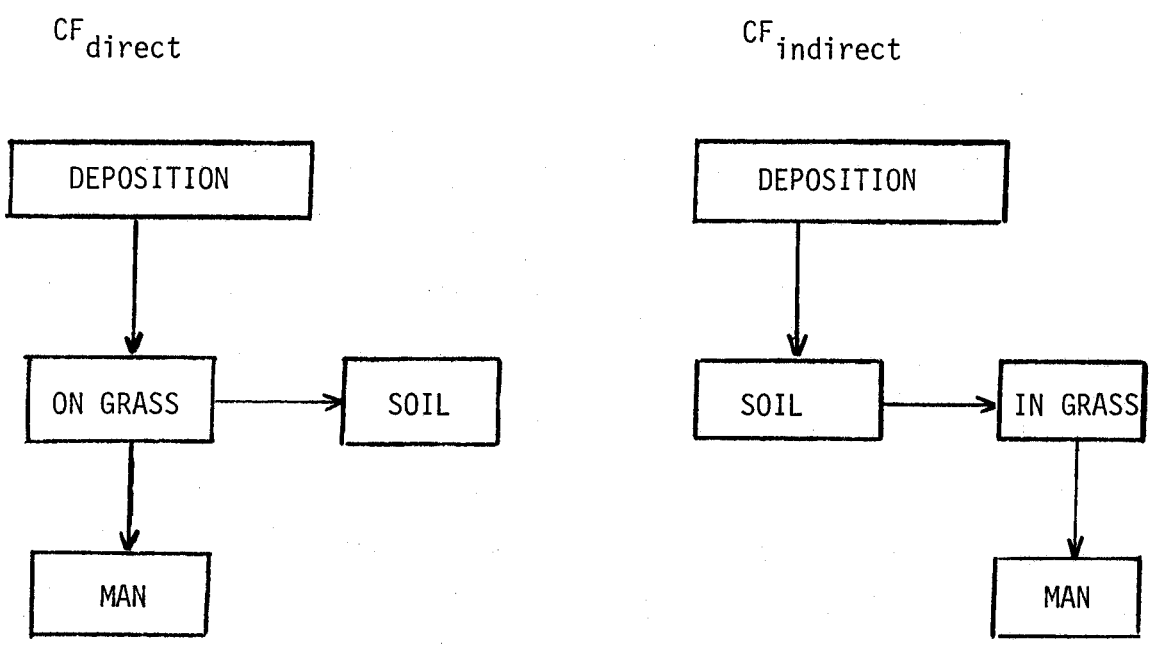


Figure 9.c: Comparison and Summary of Direct and Indirect Pathways for Present Study

- Slightly underestimates CF_{direct} for long lived isotopes due to weathering half life.
- Slightly overestimates $CF_{indirect}$ for long lived isotopes due to added 50% deposition to soil which accounts for weathering of direct deposition from grass.

In comparison, the ORNL model [12] does not allow for deposition onto pasture soil (see Fig. 9). The direct dose would then be doubled (in present report S_3 = .5; ORNL report used S_3 = 1.0) and would be considered overly conservative. Their indirect dose would be much lower as a result of no deposition onto soil and weathering of the radionuclide even after it has entered the pasture grass. However, these nonconservatisms tend to be secondary since they enter through the indirect dose, which in most cases is much less than the direct dose.

WASH-1400 [2] did not allow for the weathered isotopes to be cycled through the soil to the grass, and indicated that this was of second order importance (see Fig. 9). However for long lived isotopes (half lives greater than 750 days) the indirect dose is of primary importance and it's also these radionuclides that tend to have higher CF values. See Table 10 for a comparison of the CF values obtained from the different methodologies.

The importance of the indirect CF values is due to the incorporation of the possibility of interdiction of CROP milk and beef in the CRAC code. If interdiction is allowed the CF_{direct} is greatly reduced and as a result the CF values are dominated by the indirect CF values.

3.4 Ingestion Dose Factors

The ingestion dose factor relates the dose in terms that an individual receives to the amount of radioactivity in Ci that the individual has ingested (units of Rem/Ci).

The biological metabolization in man of radionuclides depends almost exclusively on the elemental and chemical form of the nuclide. Very complex and extensive computer codes and models have been developed to estimate the dose using biological information as well as nuclear decay data. The results

TABLE 10

Comparison of CF Values from Reports:
(A) ORNL [Ref. 12]; (B) WASH-1400 [Ref. 2]; (C) Present Study

Note: The intake rates by man of milk and beef differed in the above reports. For comparison purposes they are normalized to the same values as those used in the present study. These values are given in NRC guide 1.109 Table E-4 (ref. 14) and are: milk - 110 liters/year, and beef and poultry - 95 kg/year.

Sr-89	CF_{milk}	
	direct	indirect
A	~.707	—
B	.123	.003
C	.286	.022

Sr-89	CF_{crop}	
	direct	indirect
A	~1.29	—
B	.171	.0123
C	.400	.0136

Mo-99	CF_{milk}	
	direct	indirect
A	~.750	—
C	.218	.0003

Ta-182	CF_{beef}	
	direct	indirect
A	~77.1	—
C	64.4	.102

(Continued)

Table 10 Continued

Ta-182	CF_{milk}	
	direct	indirect
A	6.43	—
C	4.00	.0063

Notes:

Values for (A) were estimated from the intake rates presented for the different pathways in ref. 12.

The above isotopes were the only ones presented in both reports A and C. Sr-89 was also included in Wash-1400 and is included in the comparison.

of these studies have been published in two forms: (1) ingestion dose factors and (2) S factors. The form of (1) is identical to the definition above and whenever available for nuclides of interest these values were used. The S factors relate Rems/Ci-(ingested) days. The information required to relate the S factor to the dose factor (DF) is the residence time (U) of the radionuclide in the organ of interest. By definition the DF = U x S. Whenever there were models available for retention of the radionuclide they were used to estimate U, otherwise a simple biological half life estimation was used.

If DF or S factors were lacking for a given nuclide, the DF was estimated using the method presented by Smith [15]. This latter method is very crude compared to the other two yet the results appeared to be within the same range for similar decay and residence properties as well as conservative.

Due to the lack of data, the current input is limited to whole body dose factors as these are most commonly available and easiest to estimate where published data does not exist. Thus the comparisons resulting from the data is consistently based only on whole body effects (for ingestion only).

3.5 Conclusions

From the data it is seen that the most critical parameter for differentiating CF values was the radiological decay rate (λ_R). This is especially true of the indirect pathways since the transfer through the soil is at a much slower rate than direct transfer to man: The only isotopes that had large indirect contributions to the CF are ^{14}C ($T_{1/2}$ = 2.09 x 10^6 days), ^{63}Ni ($T_{1/2}$ = 4.56 x 10^4 days), ^{59}Ni ($T_{1/2}$ = 2.92 x 10^7 days), ^{53}Mn ($T_{1/2}$ = 7.3 x 10^8 days), ^{93}Mo ($T_{1/2}$ = 73.65 x 10^4 days), ^{99}Tc ($T_{1/2}$ = 7.74 x 10^7 days).

These are the longest lived isotopes considered. On the other hand the indirect dose was negligible compared to direct dose for nuclides of half lives on the order of 30 days or less.

For medium lived radionuclides the importance of the value of $\tau_{r,g}$ was clearly seen. The fact that α was proportional to $\tau_{r,g}$ (see appendix C) indicates that for medium lived isotopes the value of $\tau_{r,g}$ will determine α and therefore the ratio of direct to indirect contributions to the CF. This shows the importance of determining $\tau_{r,g}$ for each crop type rather than as a group parameter as was done in the present study.

The value of CF is also proportional to the parameters $\tau_{g,c}$ or $\tau_{g,b}$ for the milk or beef pathways respectively.

These factors need to be studied in greater detail and should, wherever possible, be determined from dynamic experimental results rather than equilibrium conditions. A recent work in this area is UCRL-51939 [16].

The consumption behavior of man also linearly relates to CF and the values cited in this report were default values from the NRC guide [14] since no specific population was under study. However, consumption varies greatly in the many segments of society and as a result the CF values could change by a factor of 5 (up or down) just from this effect.

The modeling of the weathering of the radionuclides is still very approximate. However, the data in this area would have to be elementally specific as well as geographical and plant species dependent to effect major improvement. The wealth of data that is required to accurately model this effect precludes any real increase in the accuracy of the model at this time.

Another concern is the lack of consideration of daughters in the CF values. A recent report [17] has stated that an analysis including daughters has yielded significant contributions to the CF for certain isotopes. This indicates a potential for non-conservatism in the present model whenever daughters are significant (i.e., comparable half lives to parent). The CF values were adjusted for use with FUSECRAC due to daughters, discussed in Chapter 4.

Due to uncertainties in the data (especially for the nuclides not important in fission) the uncertainty in the individual CF's can easily vary as much as an order of magnitude from the values given in Appendix D. The overall level of conservatism introduced into the parameters and modeling should put the stated value on the high side.

Similar problems exist in the calculation of the DF. For the isotopes that were estimated, daughters were not taken into account, and even when they are in the other reports it is only in approximate manner. The data for the isotopes found in fission or those that are important in medical applications is fairly well collated.

The analysis presented here is at least a rough indication of the relative radiological dose to man for the different isotopes studied. The most immediate use of this information is in comparison studies between material candidates for first wall and blanket structures in fusion power plants. The present methodology is adequate for such comparison purposes but certainly, as the actual dose to people becomes the principle function, the model should incorporate the improvements already mentioned.

4. Input Data

As indicated in previous sections, a variety of input is required for FUSECRAC. Chapter 3 contains the input relevant for the ingestion pathway. The deposition data (group ISOTOPE) can be specified as in Table 11. As usual tritium is a special case. [Except for ^{14}C other isotopes are expected to behave similar (for deposition) to species released from a fission reactor accident (small particles and gases)]. Future research will be needed to better quantify release chemical and physical form and specific behavior as a function of accident conditions. Even today there is continued research on the form for a fission release.

The remaining fusion-specific information are dose factors for pathways inhalation, cloud shine and groundshine. These are incorporated into a health file, FUSEDOSE. The specific numbers are influenced by the chemical form (for inhalation) and by daughter build-up.

4.1 Sources of Dose Factors

As noted in Chapter 1, the present study focused on the isotopes caused by the activation of 316 SS, V-15Cr-5Ti, and TZM. The dose factor had to be compiled from a variety of sources as indicated in Table 12. The inhalation dose factors are set in the array INCON (body organ, time period, nuclide) with units rem/Ci inhaled. There are 7 time periods. The daughter product buildup (for parent decay after inhalation takes place) is incorporated directly in the dose factors as presented in the references (ultimately calculated by the INREM code).

The inhalation dose factors are also a function of lung clearance class and particle size. The lung classes are in turn a function

TABLE 11

Deposition Parameters

	Deposition Velocity V_d (m/sec)	Rain Scavenging Coefficient ϕ (sec^{-1})
Tritium assumed HTO (ref. 10)	10^{-3}	10^{-5}
all others (ref. 2)	10^{-2}	10^{-4}

TABLE 12

Sources of Dose Factors**

(Reference Numbers)

Isotope	Inhalation	External	Isotope	Inhalation	External
H-3	10	18	SR-89	21	22
CA-45	*	18	Y-88	19	18
SC-46	*	18	Y-90	21	18
SC-47	*	18	Y-91	21	22
SC-48	*	18	ZR-89	19	18
TI-45	*	18	ZR-95	21	22
V-49	*	18	ZR-97	21	22
Cr-49	*	18	NB-91m	19	18
Cr-51	*	18	NB-92m	19	18
MN-54	19	18	NB-93m	*	18
MN-56	19	18	NB-95m	19	18
FE-55	19	18	NB-95	19	18
FE-59	19	18	NB-96	*	18
CO-57	19	18	NB-97	19	18
CO-58	21	22	MO-93	19	22
CO-60	21	22	MO-99	21	22
NI-57	19	18	TC-99m	21	22
NI-63	19	18	TA-182	*	20

* Unavailable

** Inhalation dose factors based on 1 μm particle size

of chemical species and are discussed in Section 4.2. Typical particle size in the Reactor Safety Study was 1 μm which was adopted here for all isotopes. As one sees in the table, the required input is non-existent for 11 isotopes, mainly those associated with the V alloy. Results using this health file must be adjusted for a V structure as discussed in Ref. 4. The tritium dose factor assumes uniform body burden [10].

The cloudshine dose factors are kept in the array CLCON (body organ, nuclide) in units Rem/Ci-sec/m^3 exposure. The other external mode, groundshine, is kept in the array GRCON (body organ, time period, nuclide) in units Rem/Ci/m^2. In all cases the daughter buildup in transport is discussed in Section 4.3.

The health file, FUSEDOSE, includes these 3 arrays. In generating the health file the data must be adjusted in two ways. First, the numbers must be converted to proper units, depending on the source units. Second, the time period effects on groundshine must be calculated. The required groundshine input is the dose rate at t = 0. This is stored as time period = 3, GRCON 3, and is used for chronic dose calculations. The time period 1 (8 hr) dose is given by

$$GRCON(1) = GRCON(3)/8760 \times \frac{T_{1/2}}{.6932} \times (1 - \exp(-.693 \times 8/T_{1/2}))$$

and the time period 2 (168 hr) dose is given by

$$GRCON(2) = GRCON(3)/8760 \times \frac{T_{1/2}}{.6932} \times (1 - \exp(-.693 \times 168/T_{1/2}))$$

where $T_{1/2}$(hr) = radiological half-life.

For some cases (see Section 4.3) these are further adjusted to include caughter effects.

4.2 Lung Clearance Classes

The chemical form of the isotopes influences its absorption and transport characteristics in the lung. The model handles this variance by the variable lung clearance class. There are 3 possible conditions: D-day, W-week, Y-year, which correspond to the speed of clearance from the lung to the rest of the body. The class D species would then tend to have a lower lung dose function, but higher doses to other organs. Table 13 lists the elements and the corresponding chemical forms which are found in Ref. 21. It is seen that elements in the same column on the periodic table behave the same as one would expect (these are all low-to-moderate atomic number).

The Reactor Safety Study had to determine the likely chemical species of released isotopes. This is complicated by the elements present (e.g. Cs, I) and the processes involved in release. Table 14 shows the lung clearance class assigned as a result.

The release chemistry for fusion is likely to be different. Both chemical elements and release mechanisms differ. The primary release mechanisms appear to be oxidation and corrosion (4). Thus one would expect the released material to generally be in the oxide or hydroxide form.

In addition, there are no halides and fewer other elements which could lead to different species. A major exception to this could be the case of a flibe (or other molten salt) reactor which would then greatly complicate the possible released chemical forms (F, Be present).

TABLE 13

Elements and Possible Lung Clearance Classes

Element	Class	Chemical Species
Mn	W	oxides, hydroxides, halides, nitrates
	D	all others
Fe	Y	oxides, hydroxides, halides
	W	all others
Co	Y	oxides, hydroxides
	W	all others
Sr	Y	$SrTiO_2$
	D	all others
Y	W	all
Zr	Y	oxides, hydroxides
	W	all others
Nb	Y	all
Mo	Y	oxides
	D	molybdates
Tc	W	oxides, hydroxides
	D	all others

For the present purposes it is assumed that the isotopes are released in an oxide or hydroxide form which leads to the assignment of lung clearance class given in Table 14. Hydrogen is assigned class D based on the 10 day biological half life of tritium in man. The lung clearance class had less than a factor of 2 effect on the whole body dose factor.

4.3 Daughter Contributions

For each of the pathways involved, the daughters had to be examined to check for a possible contribution to the dose (see Table 15).

For inhalation, the problem breaks into two parts. First is the daughter buildup in the body after intake. All the dose factors used have this included. The second part is the daughter buildup in the environment during transport. In the early exposure case, the code automatically calculates daughter buildup and thus accounts for decay/buildup. For the long term, the resuspension case is more complex.

The code presently loops for daughter buildup after deposition for some long-term fission isotopes (^{241}Pu, ^{242}Cm, ^{244}Cm) in subroutine CHRONX. The code always accounts for decay and buildup in plume transport. Further, long term resuspension is dominated by very long (many years) lived isotopes. Thus, the only potential case is Mo^{93}. At present, since resuspension is a small ($\sim$1%) of the chronic dose and the inhalation dose factor for Nb^{93m} (daughter) is unavailable, this effect has not been included. This should be of very small effect.

For ingestion, the problem breaks into the same two pieces -- internal and external. Internal buildup should be incorporated into the dose factor. As indicated in Appendix E, some do not. An approximate modified dose factor was used as given by

TABLE 14

Lung Clearance Classes

Elements	H	Ca	Sc	Ti	V	Cr	Mn	Fe,Co,Ni
	Li	Sr	Y	Zr	Nb	Mo	Tc	
	Na	Ba	La		Ta	W	Re	
WASH-1400 class	—	D	W	Y	Y	D(Y*)	D	Y
Present study**	D	D	W	Y	Y	Y	W	Y

* Mo assumed present in a mixture of forms, mainly D

** Assumes oxide or hydroxide form

TABLE 15

Parent-Daughter Relationships

Parent	Daughter
CR-49	V-49
NI-57	CO-57
ZR-95	NB-95m, NB-95
ZR-97	NB-97
NB-95m	NB-95
MO-93	NB-93m
MO-99	TC-99m

$$DF = DF_p + DF_D(T_p/T_D) \text{ for } T_D < T_p$$

where DF_p = parent-only dose factor (Rem/Ci)

DF_D = daughter dose factor

T_p = parent half life

T_D = daughter half life

The factor T_p/T_D is the ratio of number of atoms of daughter per atoms of parent. Thus this assumes all parent atoms ingested decay within the body before removal. This maximizes the potential daughter effect and is thus conservative.

The CF factor can be approximately adjusted in similar fashion

$$\begin{aligned} CF &= CF_p \text{ if } T_p >> T_D \\ &= CF_p + CF_D \qquad T_p \sim T_D \\ &= CF_p + CF_D\,(T_p/T_D)(DF_D/DF_{total}) \quad T_p < T_D \end{aligned}$$

In the last case the first term represents the parent contribution, whereas the second represents the daughter contribution. The factor (DF_D/DF_{total}) is present since the total CF is eventually multiplied by the total DF. The only two significant cases were $^{95}ZR \rightarrow {}^{95m}Nb$, ^{95}Nb increase by (factor of 2.04) and $^{95m}Nb \rightarrow {}^{95}Nb$ (factor of 1.24) among significant contributors to the total ingestion dose. This modification was used [4] in the initial screening for dominant isotopes. As the CF modeling and data improves, so should the incorporation of daughters. The present model is adequate for the current state of knowledge.

For external exposure, only daughter buildup in environmental transport is relevant. For cloudshine, the code automatically keeps track of decay/buildup in the plume. For groundshine, the buildup after deposition must be calculated. There are two cases. First, the 8 hr. and 168 hr. dose (GRCON 1 & 2) must be increased to include daughters. Second, the chronic dose ($0 \rightarrow \infty$) dose (GRCON 3) must be adjusted.

For short times the only processes are radiological decay. One wants to calculate the 8 hr. and 168 hr. dose due to some initial deposition of a parent isotope.

Let

C_p, C_d = concentration of parent, daughter

λ_p, λ_d = decay constant of parent, daughter

$\lambda_p C_p$, $\lambda_d C_d$ = activity of parent, daughter

R_p, R_D = dose factor rate $\left(\frac{\text{Rem/yr}}{\text{Ci/m}^2}\right)$ for parent, daughter

D_t, D_p, D_D = time integrated dose (total, parent-only, daughter-only)

The concentration of the parent is then given by

$$C_p(t) = C_o\, e^{-\lambda p t}$$

The daughter rate equation is given as

$$\frac{dC_d(t)}{dt} = -\lambda_d C_d(t) + \lambda_p C_p(t)$$

Since we only desire daughter contributions resulting from parent decay, set $C_d(t=0) = 0$.

Then,

$$C_d(t) = \left(\frac{\lambda_p}{\lambda_d - \lambda_p}\right) C_o \left(e^{-\lambda_p t} - e^{-\lambda_d t}\right)$$

then we have

$$D_T = D_p + D_D$$

$$D_p = \int_o^T dt\ R_p \lambda_p\ C_p(t)$$

$$D_D = \int_o^T dt\ R_D \lambda_D\ C_D(t)$$

Where T is the assessment time (8 hr. or 168 hr.). Using the expressions for $C_d(t)$ and $C_p(t)$,

$$D_T = R_p \lambda_p C_o \int_o^T e^{-\lambda_p t} + R_D \lambda_d C_o \left(\frac{\lambda_p}{\lambda_d - \lambda_p}\right) \int_o^T \left(e^{-\lambda_p t} - e^{-\lambda_d t}\right) dt$$

$$= R_p C_o \left(1 - e^{-\lambda_p T}\right) + R_D C_o \left(1 - \frac{(\lambda_d) e^{-\lambda_p T} - (\lambda_p) e^{-\lambda_d t}}{\lambda_d - \lambda_p}\right)$$

or,

$$D_T = D_p \left[1 + \frac{R_D}{R_p} \frac{\left(1 - \frac{\lambda_d \exp(-\lambda_p T) - \lambda_p \exp(-\lambda_d T)}{(\lambda_d - \lambda_p)}\right)}{\left(1 - e^{-\lambda_p T}\right)}\right]$$

Of the isotopes involved, only ^{95}Zr, ^{97}Zr, ^{95m}Nb, and ^{99}Mo exhibit significant daughter contributions. Note that daughters that do not have gamma decay are automatically excluded. The dose factors for three of these (^{95}Zr, ^{97}Zr, ^{99}Mo) already incorporated daughter contributions as

these where obtained from the fission file, CRACDOSE. The remaining isotope (^{95m}Nb) must be adjusted when one generates fusion health files. The above term in brackets represents the correction factor. For the times and isotopes, this factor is found to be 1.21 (8 hr) and 5.96 (168 hr).

For long term exposure, there is the additional loss mechanism of weathering. The Reactor Safety Study models the decay of surface activity as follows:

$$C_p = C_o W(t)\, e^{-\lambda_p T}$$

where $W(t) = f_1 \exp(-\lambda_1 t) + f_2 \exp(-\lambda_2 t)$

and $f_1 = 0.63$

$f_2 = 0.37$

$\lambda_1 = .693/0.612 = 1.13\ yr^{-1}$

$\lambda_2 = .693/92.6 = 0.0075\ yr^{-1}$

Thus one obtains

$$C_p(t) = C_o\, f_1 \exp(-(\lambda_1 + \lambda_p)t) + C_o\, f_2 \exp(-(\lambda_2 + \lambda_p)t)$$

this is equivalent to the rate equation

$$\frac{dC_p(t)}{dt} = -\lambda_p C_p(t) - \lambda_1 C_{p1}(t) - \lambda_2 C_{p2}(t)$$

where C_{pi} are the two components of parent activity,

$$C_{P1} + C_{p2} = C_p \text{ and } C_{Pi} = C_o f_i \exp(-(\lambda_i + \lambda_p)t).$$

In similar fashion, write $C_d = C_{d1} + C_{d2}$, and

$$\frac{dC_d}{dt} = \lambda_d C_d - \lambda_1 Cd_1 - \lambda_2 Cd_2 + \lambda_p C_p$$

$$= -(\lambda d + \lambda_1)C_{d1} - (\lambda_d + \lambda_2)Cd_2 + \lambda_p C_o \left[f_1 e^{-(\lambda_1+\lambda_p)t} + f_2 e^{-(\lambda_2+\lambda_p)t} \right]$$

with again $C_{di}(t = 0) = 0$.

The solution is

$$C_{d1}(t) = \left(\frac{\lambda_p}{\lambda_d - \lambda_p}\right) C_o f_1 \left(e^{-(\lambda_1+\lambda_p)t} - e^{-(\lambda_d+\lambda_1)t} \right)$$

$$C_{d2}(t) = \left(\frac{\lambda_p}{\lambda_d - \lambda_p}\right) C_o f_2 \left(e^{-(\lambda_2+\lambda_p)t} - e^{-(\lambda_d+\lambda_2)t} \right)$$

and

$$C_d(t) = \left(\frac{\lambda_p}{\lambda_d - \lambda_p}\right) C_o \left[-f_1 e^{-(\lambda_d+\lambda_1)t} - f_2 e^{-(\lambda_d+\lambda_2)t} + f_1 e^{-(\lambda_p+\lambda_1)t} + f_2 e^{-(\lambda_p+\lambda_2)t} \right]$$

Then,

$$D_p = \int_o^\infty R_p \lambda_p C_p(t) dt = R_p \lambda_p C_o \left[\frac{f_1}{\lambda_1 + \lambda_p} + \frac{f_2}{\lambda_2 + \lambda_p} \right]$$

TABLE 16

Important Parent/Daughter Combinations

Pathway	How Incorporated	Parent	Daughter
Inhalation	Already directly in source dose factors	several	several
Ingestion	Multiply input value of CF	^{95}Zr	^{95m}Nb, ^{95}Nb
		^{95m}Nb	^{95}Nb
Ground shine (short term)	Already directly in source dose factors	^{95}Zr	^{95m}Nb, ^{95}Nb
		^{97}Zr	^{97}Nb
		^{99}Mo	^{99m}Tc
	Multiply dose factor when making health file	^{95m}Nb	^{95}Nb
Ground shine (long term)	Multiply dose factor when making health file	^{95}Zr	^{95m}Nb, ^{95}Nb
		^{95m}Nb	^{95}Nb
		^{93}Mo	^{93m}Nb
		^{99}Mo	^{99m}Tc

$$D_R = \int_o^\infty R_D \lambda_D C_d(t)\, dt = R_D \lambda_D C_o \left(\frac{\lambda_p}{\lambda_d - \lambda_p}\right)\left[\frac{-f_1}{\lambda_d+\lambda_2} + \frac{-f_2}{\lambda_d+\lambda_2} + \frac{f_1}{\lambda_1+\lambda_2} + \frac{f_2}{\lambda_2+\lambda_p}\right]$$

$$D_T = D_p + D_p$$

$$= D_p \left[1 + \left(\frac{R_D}{R_p}\right)\left(\frac{\lambda_d}{\lambda_p}\right)\frac{-f_1/\lambda_d+\lambda_1 + -f_2/\lambda_d+\lambda_d+\lambda_2 + f_1/\lambda_1+\lambda_p + f_2/\lambda_2+\lambda_p}{f_1/\lambda_1+\lambda_p + f_2/\lambda_2+\lambda_p}\left(\frac{\lambda_d}{\lambda_d-\lambda_p}\right)\right]$$

$$= D_p \left[1 + \left(\frac{R_D}{R_p}\right)\frac{\lambda_d \{f_1(\lambda_d+\lambda_2)(\lambda_p+\lambda_2) + f_2(\lambda_1+\lambda_p)(\lambda_d+\lambda_1)\}}{(\lambda_d+\lambda_1)(\lambda_d+\lambda_2)(\lambda_p+f_2\lambda_1+f_1\lambda_2)}\right]$$

$$= D_p \left[1 + \left(\frac{R_D}{R_p}\right)\frac{\lambda_d \{f_1(\lambda_d+\lambda_2)(\lambda_p+\lambda_2) + f_2(\lambda_1+\lambda_p)(\lambda_d+\lambda_1)\}}{(\lambda_d+\lambda_1)(\lambda_d+\lambda_2)(\lambda_p+f_2\lambda_1+f_1\lambda_2)}\right]$$

Note for cases where λ_1, $\lambda_2 \to 0$ (no weathering)
this reduces to

$$D_T/D_p = 1 + \frac{R_D}{R_p}$$

which agrees with the case ($T \to \infty$) from the previous expression. Of the parent/daughter combinations involved, only 4 parents exhibit a significant daughter contribution (contribution = D_T/D_p). These are ^{95}Zr (2.06), ^{95m}Nb (57.6), ^{93}Mo (1.20), and ^{99}Mo (1.79). For fission (original CRAC) no daughter contributions are included in the long-term dose, here we find that four fusion isotopes necessitate daughter corrections. The situation is complicated since the code checks the groundshine dose to set interdiction levels for various time periods, at end 1 or 2 years, or between 2 and 30. Thus, ideally, the daughter contribution would be added as a function of time as is currently done for resuspension.

However, the incorporation of interdiction makes this extremely more difficult. Fortunately, the four isotopes divide into those who will have most of their contribution $\lesssim$ 1 year (^{95}Zn, ^{95m}Nb, ^{99}Mo) and one which is very long term (^{93}Mo). Thus, for the cases of interest, the addition of interdiction has a small effect, since the correction takes place either before the first time period, or after the last. Therefore, the chronic dose is calculated by simply using an effective groundshine dose factor given by

$$\text{GRCON } (t = 3) = \text{GRCON } (t = 3) \times (D_T/D_p)$$

as the health file is created. Table 16 summarizes the cases where daughter decay is important.

5. Summary

The modified version of CRAC, FUSECRAC, is now capable of estimating the public health effects of potential fusion reactor releases. The bulk of the input isotope-specific data resides in the health file, FUSEDOSE. The isotope-specific data is available for releases of 316 SS, V-15Cr-5Ti, TZm, and ^{3}H. For extended comparison ability, future research should acquire:

1) Additional isotope data related to other alloys (see Table 3)

2) The missing inhalation data for isotopes already in the health file

Eventually, as fusion workers need more precise accident assessment tools which go beyond comparison studies to detailed investigations of specific sites, future work should include:

1) Improved models and data for ingestion

2) Site-specific tritium data

3) Improved resuspension and interdiction modeling for tritium

4) Incorporation of non-radiological chemical toxicity hazards, e.g., Be.

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APPENDIX A

Modified CHRONX Listing

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FORTRAN IV G LEVEL  21                CHRONX            DATE = 81183          09/12/20

0001                  SUBROUTINE CHRONX(MONTH)
                C
0002                  COMMON /ISO/ NAME(54), PARENT(54), HALF(54), RLAM(54), TYPE(54),
                     1             VD(54), IGRP(54), ITYPE(54), NGRP, NGPCLD, NIS,NISCLD
0003                  REAL*8 NAME, PARENT
0004                  REAL*8 NUCLID(6,10),PF(54)                                        MOD
0005                  COMMON /EXPO/ CF(5,10,2), DAYS1(6), DAYS2(6), DCINH(10,8,6),
                     1             CSING(10,8,6), SRING(10,8,6), RIING(10,8,6),
                     1             RTING(10,8,6), DSCOM(6,8,6), NUCLID, DEC,
                     2             PROFAC(6), RELIM(6,2), TAGE(6), TEFF(6,10),
                     3             TIMEK, SDEE(6,10,2), NIE(6), NEXP, INDEX(6,10),ICOST
                     4              ,TOTIME,NCRIT(6),INHAL(6)
0006                  COMMON /INPT/ AMAG(50), BRATE, EVACON(7), P(20,4), PERM,
                     1              PARMOD, SHFAC(4), SUBGRP, IC(18), IREST,
                     2              NPB(4), NP(5), NAT, NIT, NOT, NCT,
                     3              NPL, NPD, NPH, NPP, NPA, NRE,
                     4              NTAPE, NUM
0007                  COMMON /HLTH/ AORG(13),ERLORG(8),LAORG(8),LAEFF(8),
                     1             DL(4,8),FATFAC(8),PL(2,8),MRCON(8,10),
                     2             INCON(8,7,54),GRCON(8,3,54),CLCON(8,54),
                     3             TOTLAT(8,10),TOTORG(8),TOTLE,FATAL,ERLINJ,
                     4             INDERL(8),INCLA(8),JORG(8),KORG(13),
                     5             NLA,NEARLY,NCRGUS,NHLTH,NDL,INTIME,ORGDOS,
                     6             FACT(2),FACTOR(8),ORGFAC(8),THRESH(2),IBEST
0008                  REAL*8 AORG,ERLORG,LAORG,LAEFF
0009                  REAL INHAL,INCON,MRCON,FATFAC
0010                  COMMON /PROPDM/ K,LSEC,ISEC,EFLEAK,FLIP1,FLIP2,XLMDMC
0011                  COMMON /ISOSPA/ AC(54,34), GC(54,34), DECAY(54,34)
0012                  COMMON /PRTDEP/ DEPC,DEPCW,DEPM,DEPMW
                C
0013                  REAL*8 CPU238,CPU240,CPU241,CAM241,CCM242,CCM244,CH3              MOD
0014                  DATA CPU238/'PU-238'/,CPU240/'PU-240'/,CPU241/'PU-241'/,
                     1       CAM241/'AM-241'/,CCM242/'CM-242'/,CCM244/'CM-244'/,       MOD
                     2       CH3/'H-3   '/                                             MOD
                C
                C*************** ************************************************************
                C
                C  THIS SUBROUTINE COMPUTES THE CHRONIC EXPOSURE FOR DEPOSITED
                C    RADIOACTIVITY.
                C
                C
                C  MIT MODIFICATION 1979-81                                            MOD
                C  INCORPORATES A NEW MODEL FOR TRITIUM WHICH ALTERS THE INGESTION     MOD
                C  PATHWAYS                                                           MOD
                C                                                                     MOD
                C  ONLY THE RESUSPENDED DOSE INCORPORATES DAUGHTER CONTRIBUTION       MOD
                C  FOR FISSION ISOTOPES (ORIGINAL CODE)                               MOD
                C                                                                     MOD
                C  FOR FUSION, ADDITIONAL DAUGHTER INVESTIGATIONS MAY BE NEEDED.      MOD
                C
                C*************************************************************************
                C
0015                   TIDEC=0.0
0016                   DEC=1.0
0017                   RDEC=1.0
0018                   TOTIME=0.0
0019                   ICOST = 0
0020                    DO 50 I=1,NEXP
```

```
FORTRAN IV G LEVEL  21                CHRONX              DATE = 81183          09/12/20

0021                DO 50 J=1,8
0022                DO 50 L=1,6
0023             50 DSCOM(I,J,L)=0.0
                 C
                 C      OBTAIN DEPOSITED ACTIVITY FOR PROPERTY ISOTOPES
                 C
0024                NI = NIE(NEXP)
0025                TIMEK = 0.
                 C
                 C      LAND INTERDICTION
                 C      J = 1, CONSIDERATION OF FIRST YEAR DOSE ONLY
                 C      J=2, CONSIDERATION OF DOSE COMMITMENT ONLY
                 C
0026                J=2
                 C
                 C      CALCULATE CONTRIBUTION OF ISOTOPES
                 C
0027                DEPSUM = 0.
0028                DO 200 I = 1,NI
0029                II = INDEX(NEXP,I)
                 C
                 C      SUM RATIO OF ACTUAL TO ALLOWABLE ACTIVITY
                 C
0030             200 DEPSUM = DEPSUM + GC(II,K) / SDEE(NEXP,I,J)
                 C
                 C      CHECK TO SEE IF TOTAL EXPOSURE IS LESS THAN MAX ALLOWABLE
                 C
0031                IF(DEPSUM .LE. 1.) GO TO 800
                 C
                 C      SET COST FLAG FOR LAND INTERDICTION
                 C
0032                ICOST = 4
0033                DEC=DEPSUM
0034                DEPSUM = 0.
                 C
                 C       CALCULATE RATIO AFTER 10 YEARS ASSUMING NO DECONTAMINATION
                 C
0035                TDOSE = DAYS1(NEXP) / 365.0
0036                IF ( J.EQ.2 ) TDOSE = DAYS2(NEXP) / 365.0
0037                DO 300 I = 1,NI
0038                II = INDEX(NEXP,I)
0039                RES1 = 1.13 + 253.0/HALF(II)
0040                RES2 = 0.0075 + 253.0/HALF(II)
0041                EX1 = AMAX1(-RES1*TDOSE,-35.0)
0042                EX2 = AMAX1(-RES1*10.0,-35.0)
0043                EX3 = AMAX1(-RES2*TDOSE,-35.0)
0044                EX4 = AMAX1(-RES2*10.0,-35.0)
                 C
                 C      0.693  * 365. DAYS/YEARS = 253
                 C
0045             300 DEPSUM = DEPSUM + GC(II,K ) * PROFAC(NEXP)*GRCON(NCRIT(NEXP),3,II)
                    1          * (( 0.63 / (RES1)) * (1.0-
                    2           EXP ( EX1)) *
                    3          EXP ( EX2) +
                    4          ( 0.37 / ( RES2)) *
                    5          ( 1.0 - EXP ( EX3)) *
                    6          EXP( EX4)) / RCLIM(NEXP,J)
                 C
```

```
FORTRAN IV G LEVEL  21                  CHRONX              DATE = 81183          09/12/20

              C       CALCULATE RATIO AFTER 1 AND 2 YEARS ASSUMING NO DECONTAMINATION
              C
 0046                 N=1
 0047           350   DEP1 = 0.0
 0048                 TEM = N
 0049                 DO 400 I = 1,NI
 0050                 II = INDEX(NEXP,I)
 0051                 RES1 = 1.13 + 253.0/HALF(II)
 0052                 RES2 = 0.0075 + 253.0/HALF(II)
 0053                 EX1 = AMAX1(-RES1*TDOSE,-35.0)
 0054                 EX2 = AMAX1(-RES1*TEM,-35.0)
 0055                 EX3 = AMAX1(-RES2*TDOSE,-35.0)
 0056                 EX4 = AMAX1(-RES2*TEM,-35.0)
              C
              C      253. = .693 * 365
              C
 0057           400   DEP1 = DEP1 + GC(II,K) * PROFAC(NEXP)*GRCON(NCRIT(NEXP),3,II)
                     1          * (( 0.63 / (RES1)) * (1.0-
                     2           EXP ( EX1)) *
                     3          EXP ( EX2) +
                     4          ( 0.37 / ( RES2)) *
                     5          ( 1.0 - EXP ( EX3)) *
                     6          EXP( EX4)) / RDLIM(NEXP,J)
 0058                 IF(N.EQ.1) DEP1Y = DEP1
 0059                 IF(DEP1 .LT. 1.) GO TO 600
 0060                 IF(N.EQ.2) GO TO 450
 0061                 N = 2
 0062                 GO TO 350
              C
              C    EXPONENTIAL INTERPOLATION BETWEEN 2 AND 10 YEARS FOR  TOTAL TIME
              C
 0063           450   TOTIME = (2.+(8.0*ALOG(1./DEP1)/ALOG(DEPSUM/DEP1)))*365.
 0064                 GO TO 700
 0065           600   TOTIME = 365.* TEM
 0066           700   CONTINUE
              C
              C       AMAXDF IS MAXIMUM DECONTAMINATION FACTOR
              C
 0067                 AMAXDF=20.0
 0068                 IF(DEC.GT.AMAXDF.AND.TOTIME.GT.3650.00)ICOST=5
              C
              C      TIMEK IS AGING PERIOD WITH DECONTAMINATION
              C
 0069                 RDEC = DEC
              C
              C  IF DEC <= 20 CAN DECONTAMINATE IMMEDIATELY (TIMEK INIT TO 0.0)
 0070                 IF(DEC.LE.20.0) GO TO 800
              C
              C  IF DEPOSITION <= 20 AFTER 1 OR 2 YEARS CAN DECONTAMINATE AT THAT TIME
 0071                 IF(DEP1Y .LE. 20.) GO TO 750
 0072                 IF(DEP1.LE.20.0) GO TO 751
 0073                 TIMEK = (2.+(8.00*ALOG(AMAXDF/DEP1)/ALOG(DEPSUM/DEP1)))*365.
 0074                 IF(TIMEK .GT. 10950.) GO TO 1700
 0075                 DEC = AMAXDF
 0076                 GO TO 800
 0077           750   TIMEK = 365.0
 0078                 GO TO 800
 0079           751   TIMEK = 730.0
```

```
FORTRAN IV G LEVEL  21                CHRONX            DATE = 81183          09/12/20

 0080          800 CONTINUE
 0081              IF(NPH.GT.5) WRITE(NOT,810) DEP1,DEP1Y,DEPSUM,TIMEK,TOTIME
 0082          810 FORMAT(/,1X,'DEP1,DEP1Y,DEPSUM,TIMEK,TOTIME = ',1P5E12.4)
               C
               C     CALCULATE EXTERNAL IRRADIATION DOSE COMMITMENT
               C
               C     NOTE - NO DEPENDENCE ON TEFF FOR GROUNDSHINE DOSE,                MOD
               C     RDLIM SETS DECONTAMINATION AND INTERDICTION THROUGH SDEE           MOD
               C
 0083              DO 900 I = 1,NI
 0084              II = INDEX(NEXP,I)
               C
               C  CALCULATE REPEATED FACTORS IN EQUATIONS
               C
 0085              RES1=EXP(AMAX1(-35.0,-(1.13/365.0 + 0.693/HALF(II)) * TIMEK ))
 0086              RES2=EXP(AMAX1(-35.0,-(0.0075/365.0 + 0.693/HALF(II)) * TIMEK))
 0087              FAC1=0.63/(1.13 + 253.0/HALF(II))
 0088              FAC2=0.37/(0.0075 + 253.0/HALF(II))
               C
               C  EXTERNAL IRRADIATION DOSE COMMITMENT FOR FIRST YEAR
               C
 0089              EX1 = AMAX1(-(1.13 +253.0/HALF(II)), -35.0)
 0090              EX2 = AMAX1(-(0.0075 + 253.0/HALF(II)), -35.0)
 0091               IF(TIMEK .GT. 365.) GO TO 899
 0092              DO 895 N=1,NORGUS
 0093          895 DSCOM(1,N,1) = DSCOM(1,N,1) + PROFAC(NEXP)
                  1 *GRCON(N,3,II)*GC(II,K)*(FAC1*RES1*
                  2 (1.0-EXP(EX1)) + FAC2 * RES2 * (1.0-EXP(EX2)))
                  3 /DEC
               C
               C  EXTERNAL IRRADIATION DOSE COMMITMENT FOR ONE TO THIRTY YEARS
               C
 0094          899 CONTINUE
 0095              EX3 = AMAX1((-(0.0075+253.0/HALF(II))*30.0), -35.0)
 0096              DO 896 N=1,NORGUS
 0097          896 DSCOM(1,N,2)=DSCOM(1,N,2) + PROFAC(NEXP) *
                  1  GRCON(N,3,II) * GC(II,K) * (FAC1*RES1 * EXP(EX1) +
                  2  FAC2 *RES2 * (EXP(EX2)-EXP(EX3)))/DEC
               C
               C  EXTERNAL IRRADIATION DOSE COMMITMENT FOR 30 TO 60 YEARS
               C
 0098              EX1 = AMAX1((-(0.0075 + 253.0/HALF(II)) * 60.0), -35.0)
 0099              DO 897 N=1,NORGUS
 0100          897 DSCOM(1,N,3) = DSCOM(1,N,3) + PROFAC(NEXP) *
                  1  GRCON(N,3,II) * GC(II,K) * FAC2 * RES2 *
                  2  (EXP(EX3) - EXP(EX1))/DEC
               C
               C  EXTERNAL IRRADIATION DOSE COMMITMENT FOR 60 TO INFINITY
               C
 0101              DO 898 N=1,NORGUS
 0102          898 DSCOM(1,N,4) = DSCOM(1,N,4) + PROFAC(NEXP) *
                  1  GRCON(N,3,II) * GC(II,K) * FAC2 * RES2 * EXP(EX1)/DEC
               C
 0103          900 CONTINUE
               C
               C     CALCULATE DOSE COMMITMENT FROM INHALATION OF ISOTOPES
               C
               C     NOTE - NO DEPENDENCE ON TEFF, CF, RDLIM FOR THE                   MOD
```

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FORTRAN IV G LEVEL  21                CHRONX            DATE = 81183          09/12/20

            C     INHALATION DOSE                                                    MOD
            C                                                                        MOD
0104              NI = NIE(1)
0105              RFZERO = 1.0E-5
0106              RFLAST = 1.0E-9
0107              RFDEC = 0.677
            C
            C  RFZERO IS INITIAL RESUSPENSION FACTOR (1/M)
            C  RFLAST IS EQUILIBRIUM RESUSPENSION FACTOR (1/M)
            C  RFDEC IS DECAY CONSTANT FOR RESUSPENSION FACTOR (1/YEAR)
            C
0108              TPRIM=TIMEK/365.0
0109              DO 1000 I=1,NI
0110              IRET = 0
0111              DO 1005 M = 1,6
0112           1005 INHAL(M) = 0.0
0113              GCOEF = 1.0
0114              II = INDEX(1,I)
0115           1001 FAC1=(253.0/HALF(II)) + RFDEC
0116              FAC2 = 253.0/HALF(II)
            C
            C  7300 = YEARLY INHALATION RATE (M**3/YEAR)
            C
0117              EX1 = AMAX1(-FAC1*10.0, -35.0)
0118              EX2 = AMAX1(-FAC1*TPRIM, -35.0)
0119              EX3 = AMAX1(-FAC2*10.0, -35.0)
0120              EX4 = AMAX1(-FAC2*TPRIM, -35.0)
            C
            C     INHALATION DOSE COMMITMENT FOR THE FIRST 10 YEARS
            C
0121              INHAL(1) = INHAL(1) + GCOEF*7300.0 * GC(II,K) * ((RFZERO/FAC1) *
                 1  (1.0 - EXP(EX1)) * EXP(EX2) + (RFLAST/FAC2) *
                 2  (1.0 - EXP(EX3)) * EXP(EX4))
0122              EX5 = AMAX1(-FAC1*20.0,-35.0)
0123              EX6 = AMAX1(-FAC2*20.0,-35.0)
            C
            C     INHALATION DOSE COMMITMENT FOR 10 TO 20 YEARS
            C
0124              INHAL(2) = INHAL(2) + GCOEF* 7300.0 * GC(II,K) * ((RFZERO/FAC1) *
                 1  (EXP(EX1) - EXP(EX5)) * EXP(EX2) +
                 2  (RFLAST/FAC2) * (EXP(EX3) - EXP(EX6)) *
                 3  EXP(EX4))
0125              EX1 = AMAX1(-FAC2*30.0,-35.0)
            C
            C     INHALATION DOSE COMMITMENT FOR 20 TO 30 YEARS
            C
0126              INHAL(3) = INHAL(3) + GCOEF* 7300.0 * GC(II,K) * (RFLAST/FAC2) *
                 1  (EXP(EX6) - EXP(EX1)) * EXP(EX4)
0127              EX2 = AMAX1(-FAC2*40.0,-35.0)
            C
            C     INHALATION DOSE COMMITMENT FOR 30 TO 40 YEARS
            C
0128              INHAL(4) = INHAL(4) + GCOEF * 7300.0 * GC(II,K) * (RFLAST/FAC2) *
                 1  (EXP(EX1) - EXP(EX2)) * EXP(EX4)
0129              EX1 = AMAX1(-FAC2*50.0,-35.0)
            C
            C     INHALATION DOSE COMMITMENT FOR 40 TO 50 YEARS
            C
```

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FORTRAN IV G LEVEL  21                  CHRONX              DATE = 81183          09/12/20

0130                  INHAL(5) = INHAL(5) + GCOEF * 7300.0 * GC(II,K) * (RFLAST/FAC2) *
                     1  (EXP(EX2) - EXP(EX1)) * EXP(EX4)
                C
                C     INHALATION DOSE COMMITMENT FOR 50 TO INFINITY
                C
0131                  INHAL(6) = INHAL(6) + GCOEF * 7300.0 * GC(II,K) * (RFLAST/FAC2) *
                     1  EXP(EX1) * EXP(EX4)
                C
                C     CHECK TO SEE IF ANY RADIONUCLIDES HAVE PARENTS
                C
                C     MAY DESIRE TO ADD ADDITIONAL FUSION DAUGHTERS IF WARRANTED        MOD
                C
0132                  IF(IRET.GT.0) GO TO 1095
0133                  IF(NAME(II) .EQ. CPU238) GO TO 1010
0134                  IF(NAME(II) .EQ. CPU240) GO TO 1020
0135                  IF(NAME(II) .EQ. CAM241) GO TO 1030
0136                  GO TO 1095
                C
0137           1010 DO 1015 M=1,NIS
0138                  IF(NAME(M) .EQ. CCM242) GO TO 1040
0139           1015 CONTINUE
0140                  GO TO 1095
                C
0141           1020 DO 1025 M=1,NIS
0142                  IF(NAME(M) .EQ. CCM244) GO TO 1040
0143           1025 CONTINUE
0144                  GO TO 1095
                C
0145           1030 DO 1035 M=1,NIS
0146                  IF(NAME(M) .EQ. CPU241) GO TO 1040
0147           1035 CONTINUE
0148                  GO TO 1095
                C
                C     CALCULATE CONTRIBUTION DUE TO PARENT DECAY
                C
0149           1040 IRES=M
0150                  GCOEF = 1.0/((HALF(II)/HALF(IRES)) - 1.0)
0151                  DO 1041 M=1,6
0152                  IF(GC(II,K).EQ.0.0) GO TO 1041
0153                  INHAL(M) = INHAL(M) + GC(IRES,K) * GCOEF *
                     1       INHAL(M) / GC(II,K)
0154           1041 CONTINUE
0155                  GCOEF = -GCOEF
0156                  II = IRES
0157                  IRET = 1
0158                  GO TO 1001
                C
0159           1095 DO 1100 M=1,6
0160                  DO 1100 NORG=1,NORGUS
0161                  DO 1100 MREV=1,M
0162                  ITIM=M+1-MREV
0163                  IF(ITIM.GT.5) ITIM=5
0164           1100 DSCOM(2,NORG,M) = DSCOM(2,NORG,M) +
                     1  DCINH(I,NORG,ITIM) * INHAL(MREV)/DEC
                C
0165           1000 CONTINUE
                C
0166                  IF(DEC .GT. 1.) GO TO 1600
```

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FORTRAN IV G LEVEL  21                CHRONX          DATE = 81183          09/12/20

                C
                C       DSCOM ARRAY VALUES -                                                    MOD
                C       1 - GROUND SHINE DOSE                                                   MOD
                C       2 - INHALTION DOSE                                                      MOD
                C       3 - MILK, MILK PRODUCTS AND VEGETABLES THRU MILK CONSUMPTION             MOD
                C       4 - MILK PRODUCTS AND VEGETABLES THRU CROP CONSUMPTION                   MOD
                C       5 - MILK, ETC. FROM SOIL THRU MILK CONSUMPTION                          MOD
                C       6 - VEGETABLES, ETC. FROM SOIL THRU CROP CONSUMPTION                    MOD
                C                                                                               MOD
                C       DAYS1, RDLIM(1),SDEE(1) REFER TO CROP PATHWAYS                          MOD
                C       DAYS2,RDLIM(2), SDEE(2) REFER TO MILK PATHWAYS                          MOD
                C       PF = CORRECTION FACTOR TO ACCOUNT FOR CHANGES RN THE CRAC               MOD
                C       MODEL FOR THE TRITIUM CASE                                              MOD
                C                                                                               MOD
                C       CROP INTERDICTION
                C
                C       EXPOSED ORGANS TO INGESTION OF ISOTOPES
                C
                C       FOR THE TRITIUM CASE PATHWAYS 2 - 4 REFER TO DOSE FROM                  MOD
                C       CONTAMINATED SOIL WITH A PROVISION TO INTRODUCE PF IF                   MOD
                C       NEEDED LATER                                                            MOD
                C
0167                    TWAIT = 0.0
0168                    NM = NEXP - 3
0169                    DO 1350 I=2,NM
                C
                C  CONSIDERATION OF INGESTION VIA PATHWAYS OTHER
                C    THAN MILK (CROPS, MEAT, ETC.)
                C
0170                    NI = NIE(I)
0171                    DEPSUM = 0.
0172                    DO 1300 J = 1,NI
0173                    II = INDEX(I,J)
0174                    PF(II)=1.0                                                              MOD
0175             1300 DEPSUM = DEPSUM + GC(II,K)*PF(II)/SDEE(I,J,1)                             MOD
0176                    DEPC=DEPSUM
0177                    IF(DEPSUM .LT.1.) GO TO 1350
                C
                C  CALCULATE POSSIBLE DOSE AFTER WAITING PERIOD
                C
0178                    TWAIT = 60.0
0179                    IF (MONTH. EQ. 7) TWAIT = 30.0
0180                    DEPSUM = 0.0
0181                    DO 1305 J = 1,NI
0182                    II = INDEX(I,J)
0183                    PF(II)=1.0                                                              MOD
0184             1305 DEPSUM = DEPSUM + GC(II,K)*PF(II)*(0.85*                                  MOD
                       1 EXP(-0.693*TWAIT/TEFF(I,J)) + 0.15*
                       2 EXP(-0.693*TWAIT/HALF(II)))/SDEE(I,J,1)
0185                    DEPCW=DEPSUM
0186                    IF (DEPSUM. LE. 1.0) GO TO 1320
0187             1315 ICOST = 2
                C
                C  ICOST = 2 INDICATES COMPLETE LOSS OF CROPS
                C
                C       NOTE - INTERDICTION FOR CROPS IF ONLY TWAIT > 60 DAYS                   MOD
                C                                                                               MOD
0188                    GO TO 1400
```

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FORTRAN IV G LEVEL  21                CHRONX              DATE = 81183          09/12/20

0189        1320  CONTINUE
0190        1350  CONTINUE
            C
            C  CALCULATE DOSE COMMITMENTS FROM INGESTION
            C  OF CROPS
            C
0191              DO 1360 I = 2,NM
0192              NI = NIE (I)
0193              IGOTO=I-1
0194              GO TO (1370,1380), IGOTO
0195         1370 DO 1355 J=1,NI
0196              II = INDEX(I,J)
0197              PF(II)=1.0                                                    MOD
0198              DO 1355 L = 2,7
0199              M=L
0200              IF(M.GT.6)M=6
0201              DO 1355 N = 1,NORGUS
0202        1355  DSCOM(4,N,L-1)=DSCOM(4,N,L-1)+
                 1 CSING(J,N,M)*GC(II,K)*CF(I,J,1)*PF(II)*                     MOD
                 2 (0.85*EXP(-0.693*TWAIT/TEFF(I,J)) +0.15*
                 3 EXP(-0.693*TWAIT/HALF(II)))
0203              GO TO 1360
0204         1380 DO 1375 J=1,NI
0205              II = INDEX(I,J)
0206              PF(II)=1.0                                                    MOD
0207              DO 1375 L = 2,7
0208              M=L
0209              IF(M.GT.6)M=6
0210              DO 1375 N = 1,NORGUS
0211        1375  DSCOM(4,N,L-1)=DSCOM(4,N,L-1)+
                 1 SRING(J,N,M)*GC(II,K)*CF(I,J,1)*PF(II)*                     MOD
                 2 (0.85*EXP(-0.693*TWAIT/TEFF(I,J)) +0.15*
                 3 EXP(-0.693*TWAIT/HALF(II)))
0212        1360  CONTINUE
0213        1400  TIMEK = 0.0
0214              NM = NEXP-2
0215              DO 1405 I = 2,NM
            C
            C  CONSIDERATION OF INGESTION VIA DAIRY PRODUCTS
            C
0216              NI = NIE (I)
0217              DEPSUM = 0.0
0218              DO 1410 J = 1,NI
0219              II = INDEX(I,J)
0220              PF(II)=1.0                                                    MOD
0221         1410 DEPSUM = DEPSUM + GC(II,K)*PF(II)/SDEE(I,J,2)                 MOD
0222              DEPM=DEPSUM
0223              IF (DEPSUM. LT. 1.0) GO TO 1405
            C
            C  CALCULATE POSSIBLE DOSE AFTER 90 DAY
            C  MILK INTERDICTION PERIOD
            C
0224              DEP1 = 0.0
0225              DO 1415 J = 1,NI
0226              II = INDEX(I,J)
            C
            C  62.38 = 0.693 * 90.0 DAYS
            C
```

```
FORTRAN IV G LEVEL  21                CHRONX              DATE = 81183          09/12/20

0227                PF(II)=1.0                                                          MOD
0228          1415 DEP1 = DEP1 + GC(II,K) * PF(II) * (0.85*                             MOD
                  1 EXP(-62.38/TEFF(I,J)) + 0.15*
                  2 EXP(-62.38/HALF(II)))/SDEE(I,J,2)
0229                DEPMW=DEPSUM
                C
                C  EXPONENTIAL INTERPOLATION
                C
0230                TIMER = 90.0*ALOG(1.0/DEPSUM)/ALOG(DEP1/DEPSUM)
0231                IF(TIMER. GT. TIMEK) TIMEK = TIMER
0232          1405  CONTINUE
                C
                C  CALCULATE DOSE COMMITMENTS FROM MILK INGESTION
                C
0233                DO 1490 I = 2,NM
0234                NI = NIE (I)
0235                IGOTO=I-1
0236                GO TO (1440,1450,1460), IGOTO
0237           1440 DO 1420 J = 1,NI
0238                II = INDEX(I,J)
0239                PF(II)=1.0                                                          MOD
0240                DO 1420 L=2,7
0241                M=L
0242                IF(M.GT.6) M=6
0243                DO 1420 N=1,NORGUS
0244          1420  DSCOM(3,N,L-1) = DSCOM(3,N,L-1)+
                  1 CSING(J,N,M)*GC(II,K)*CF(I,J,2)*PF(II)*                           MOD
                  2 (0.85*EXP(-0.693*TIMEK/TEFF(I,J))+
                  3 0.15*EXP(-0.693*TIMEK/HALF(II)))
0245                GO TO 1490
0246           1450 DO 1455 J = 1,NI
0247                II = INDEX(I,J)
0248                PF(II)=1.0                                                          MOD
0249                DO 1455 L=2,7
0250                M=L
0251                IF(M.GT.6) M=6
0252                DO 1455 N=1,NORGUS
0253          1455  DSCOM(3,N,L-1) = DSCOM(3,N,L-1)+
                  1 SRING(J,N,M)*GC(II,K)*CF(I,J,2)*PF(II)*                           MOD
                  2 (0.85*EXP(-0.693*TIMEK/TEFF(I,J))+
                  3 0.15*EXP(-0.693*TIMEK/HALF(II)))
0254                GO TO 1490
0255           1460 DO 1465 J = 1,NI
0256                II = INDEX(I,J)
0257                PF(II)=1.0                                                          MOD
0258                DO 1465 L=2,7
0259                M=L
0260                IF(M.GT.6) M=6
0261                DO 1465 N=1,NORGUS
0262          1465  DSCOM(3,N,L-1) = DSCOM(3,N,L-1)+
                  1 RIING(J,N,M)*GC(II,K)*CF(I,J,2)*PF(II)*                           MOD
                  2 (0.85*EXP(-0.693*TIMEK/TEFF(I,J))+
                  3 0.15*EXP(-0.693*TIMEK/HALF(II)))
0263           1490 CONTINUE
                C
                C      NOTE - INTERDICTION IF THERE IS TIMEK = 0
                C                                                                     MOD
0264                IF(TIMEK.LE.0.0) GO TO 1600
```

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FORTRAN IV G LEVEL  21                  CHRONX              DATE = 81183          09/12/20

0265                IF(ICOST.GT.0) GO TO 1430
0266                ICOST = 1
0267                GO TO 1600
0268          1430  ICOST = 3
              C
              C  ICOST = 1 MILK INTERDICTION
              C  ICOST = 3 MILK AND CROP INTERDICTION
              C
0269          1600  CONTINUE
              C
              C  CALCULATE CONTRIBUTION TO DOSE COMMITMENT VIA
              C  PLANT ROOTS
              C
0270                NI = NIE(NEXP-1)
0271                IF (DEC.GT.1.0) TIDEC = 365.0
0272                DO 1610 J=1,NI
0273                II = INDEX(NEXP-1,J)
0274                PF(II)=1.0                                                    MOD
0275                CTID1=-0.693*TIDEC/HALF(II)                                   MOD
0276                CTID2=CTID1                                                   MOD
              C                                                                   MOD
0277                IF(NAME(II).NE.CH3)GO TO 1601                                 MOD
              C                                                                   MOD
              C     NEW TRITIUM MODEL FOR PATHWAY 5                               MOD
              C                                                                   MOD
              C     FOR TRITIUM PATHWAY 5 REFERS TODOSE FROM DIRECT AIR           MOD
              C     CONTAMINATION OF FCOD.  THIS VARIES WITH AC NOT GC            MOD
              C     THEREFORE PF = V(INCORPORATED INTO INPUT DATA) TIMES           MOD
              C     AC/GC.  ALSO THE MODEL TAKES INTO ACCOUNT TRITIUM MOVEMENT    MOD
              C     AWAY FROM CROPS BY USING TEFF HERE                            MOD
              C                                                                   MOD
0278                V=1.0/10.0**3                                                 MOD
0279                AEX=-20.0                                                     MOD
0280                ALIMIT=10.0**AEX                                              MOD
0281                IF(GC(II,K).LT.ALIMIT)GC(II,K)=ALIMIT                         MOD
0282                PF(II)=V*AC(II,K)/GC(II,K)                                    MOD
              C                                                                   MOD
0283                TIDEC1=TIDEC                                                  MOD
0284                IF(TIDEC1.LT.TWAIT)TIDEC1=TWAIT                               MOD
0285                CTID1=-0.693*TIDEC1/TEFF(NEXP-1,J)                            MOD
0286                TIDEC2=TIDEC                                                  MOD
0287                IF(TIDEC2.LT.TIMEK)TIDEC2=TIMEK                               MOD
0288                CTID2=-0.693*TIDEC2/TEFF(NEXP-1,J)                            MOD
              C                                                                   MOD
0289           1601 DO 1605 N=1,NORGUS                                            MOD
0290                DO 1605 L=1,6
0291                IF(CTID2.LE.-25.0)GO TO 1603                                  MOD
0292                DSCOM(5,N,L) = DSCOM(5,N,L) + RTING(J,N,L)*EXP(CTID2)/DEC*    MOD
                   1 GC(II,K)*CF(NEXP-1,J,2)*PF(II)                               MOD
0293           1603 IF(CTID1.LE.-25.0)GO TO 1605                                  MOD
0294                DSCOM(6,N,L) = DSCOM(6,N,L)+RTING(J,N,L)*EXP(CTID1)/DEC*      MOD
                   1 GC(II,K) * CF(NEXP-1,J,1)*PF(II)                             MOD
0295          1605  CONTINUE
0296          1610  CONTINUE
0297          1700  CONTINUE
0298                DEC=RDEC
0299                RETURN
0300                END
```

APPENDIX B

Modified CHRON Listing

```
FORTRAN IV G LEVEL  21          CHRON           DATE = 81183        09/12/20

0001                SUBROUTINE CHRON
                C
0002                COMMON /ISO/ NAME(54), PARENT(54), HALF(54), RLAM(54), TYPE(54),
                   1             VD(54), IGRP(54), ITYPE(54), NGRP, NGPOLD, NIS,NISOLD
0003                REAL*8 NAME, PARENT
0004                COMMON /INPT/ AMAG(50), BRATE, EVACON(7), P(20,4), PERM,
                   1              PARMOD, SHFAC(4), SUBGRP, ID(18), IREST,
                   2              NPB(4), NP(5), NAT, NIT, NOT, NCT,
                   3              NPL, NPD, NPH, NPP, NPA, NRE,
                   4              NTAPE, NUM
0005                REAL*8 NUCLID(6,10)
0006                COMMON /EXPO/ CF(5,10,2), DAYS1(6), DAYS2(6), DCINH(10,8,6),
                   1             CSING(10,8,6), SRING(10,8,6), RIING(10,8,6),
                   1             RTING(10,8,6), DSCOM(6,8,6), NUCLID, DEC,
                   2             PROFAC(6), RDLIM(6,2), TAGE(6), TEFF(6,10),
                   3             TIMEK, SDEE(6,10,2), NIE(6), NEXP, INDEX(6,10),ICOST
                   4              ,TOTIME,NCRIT(6),INHAL(6)
0007                COMMON /HLTH/ AORG(13),ERLORG(8),LAORG(8),LAEFF(8),
                   1             DL(4,8),FATFAC(8),PL(2,8),MRCON(8,10),
                   2             INCON(8,7,54),GRCON(8,3,54),CLCON(8,54),
                   3             TOTLAT(8,10),TOTORG(8),TOTLE,FATAL,ERLINJ,
                   4             INDERL(8),INCLA(8),JORG(8),KORG(13),
                   5             NLA,NEARLY,NORGUS,NHLTH,NDL,INTIME,ORGDOS,
                   6             FACT(2),FACTOR(8),ORGFAC(8),THRESH(2),IBEST
0008                REAL*8 AORG,ERLORG,LAORG,LAEFF
0009                REAL INHAL,INCON,MRCON,FATFAC
0010                DATA YES/3HYES/
               C
               C*********************************************************************
               C
               C  THIS SUBROUTINE READS IN THE REQUIRED GROUND, CLOUD, AND INHALATION
               C    DOSE CONVERSION FACTORS FROM THE HEALTH FILE DEPENDING ON THE
               C    ORGANS SPECIFIED BY SUBGROUPS ACCUTE AND LATENT.  IT THEN READS IN
               C    ADDITIONAL DATA USED IN COMPUTING THE LATENT EFFECTS FROM CHRONIC
               C    EXPOSURE, AND DOES SOME PRELIMINARY PROCESSING OF THIS DATA.
               C
               C
               C    MIT FUSION MODIFICATION 1981                                    MOD
               C    ELIMINATES DIVISION BY ZERO BY TESTING FOR ZERO VALUES OF       MOD
               C    DOSE FACTORS                                                    MOD
               C
               C
               C*********************************************************************
               C
               C GORG(13)          VALID ORGAN NAMES IN THE ORDER THAT THEY ARE STORED
               C                   ON THE HEALTH FILE
0011                REAL*8 AISO(54),GORG(13),ANAME
0012                DIMENSION TEMCLD(54),TEMGRD(3,54),TEMINH(7,54),INDISO(54)
               C
0013                DATA BLANK/4H    /
0014                DATA GORG /'LUNG','T MARROW','SKELETON','T E C L','ST WALL',
                   X 'SI+CONT','ULI WALL','LLI WALL','THYROID','OTHER','W BODY',
                   X 'TESTES','OVARIES'/
               C
0015                IF(IREST.NE.-1) GO TO 2800
               C
               C  NORGUS IS THE TOTAL NUMBER OF ORGANS USED THIS RUN
0016                NORGUS=0
```

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FORTRAN IV G LEVEL  21                  CHRON              DATE = 81183          09/12/20

                C  UNIT NUMBER OF MASTER FILE CONTAINING CLOUD, GROUND, & INHALATION
                C    DOSE CONVERSIONS
0017                 NHLTH=21
                C
                C  SET UP ARRAY OR INCICES FOR CRGANS TO BE USED THIS RUN
                C
0018                 NORG=13
0019                 DO 100 IORG=1,NORG
0020                 AORG(IORG)=GORG(IORG)
0021               100 KORG(IORG)=0
                C
                C  SET KORG(IORG)=1 FOR EACH ORGAN CONSIDERED UNDER LATENT EFFECTS
0022                 IF(NLA.EQ.0) GO TO 50
0023                 DO 101 ILA=1,NLA
0024                 DO 102 IORG=1,NORG
0025                 IF(LAORG(ILA).NE.AORG(IORG)) GO TO 102
0026                 KORG(IORG)=1
0027                 GO TO 101
0028               102 CONTINUE
0029               101 CONTINUE
                C
                C  SET KORG FOR EARLY EFFECTS
0030                50 IF(NEARLY.EQ.0) GO TO 51
0031                 DO 103 IEARLY=1,NEARLY
0032                 DO 104 IORG=1,NORG
0033                 IF(ERLORG(IEARLY).NE.AORG(ICRG)) GC TO 104
0034                 KORG(IORG)=1
0035                 GO TO 103
0036               104 CONTINUE
0037               103 CONTINUE
                C
                C  MAKE SURE THAT MARROW, THYROID, AND WHOLE BODY ARE READ IN
0038                51 IF(KORG(2).NE.1) KORG(2)=1
0039                 IF(KORG(9).NE.1) KORG(9)=1
0040                 IF(KORG(11).NE.1) KORG(11)=1
                C
                C  READ VALID ISOTOPE NAMES FROM HEALTH DATA FILE
0041                 READ(NHLTH) (AISO(I),I=1,54)
                C
                C  SET UP PROPER INDEXING FOR ISOTOPES BY MATCHING NAMES READ IN CN
                C    THE ISOTOPE CARDS WITH THE NAMES ON THE HEALTH FILE.
0042                 DO 60 I=1,NIS
0043                 INDISO(I)=0
0044                 DO 61 J=1,54
0045                 IF(NAME(I).NE.AISO(J)) GO TO 61
0046                 INDISO(I)=J
0047                 GO TO 60
0048                61 CONTINUE
0049                 PRINT 66, NAME(I)
0050                66 FORMAT('0',A8,' - INVALID ISOTOPE NAME.  RUN ABORTED.')
0051                 STOP
0052                60 CONTINUE
                C
                C  READ IN UP TO 8 ORGANS FROM MASTER FILE
                C
0053                 DO 105 IORG=1,NORG
0054                 IF(KORG(IORG).EQ.0) GO TO 110
0055                 NORGUS=NORGUS+1
```

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FORTRAN IV G LEVEL  21                 CHRON              DATE = 81183          09/12/20

0056                IF(NORGUS.LE.8) GO TO 109
0057                WRITE(NOT,1000)
0058             1000 FORMAT('0','***** MORE THAN 5 ORGANS (BESIDE MARROW, THYROID AND W
                    1HOLE BODY) WERE INPUT.  RUN ABORTED.')
0059                STOP
                 C
0060               109 KORG(IORG)=NORGUS
0061                JORG(NORGUS)=IORG
0062                READ(NHLTH) ANAME
0063                READ(NHLTH)  ((TEMGRD(ITIME,ISONUM),ITIME=1,3),ISONUM=1,54),
                    X (TEMCLD(ISONUM),ISONUM=1,54)
0064                READ(NHLTH) ((TEMINH(ITIME,ISONUM),ITIME=1,7),ISONUM=1,54)
0065                DO 70 I=1,NIS
0066                INDX=INDISO(I)
0067                CLCON(NORGUS,I)=TEMCLD(INDX)
0068                GRCON(NORGUS,1,I)=TEMGRD(1,INDX)
0069                GRCON(NORGUS,2,I)=TEMGRD(2,INDX)
0070                GRCON(NORGUS,3,I)=TEMGRD(3,INDX)
0071                DO 75 J=1,7
0072                INCON(NORGUS,J,I)=TEMINH(J,INDX)
0073              75 CONTINUE
0074              70 CONTINUE
0075                GO TO 105
                 C
                 C  SKIP UNUSED ORGANS
0076               110 READ(NHLTH)
0077                READ(NHLTH)
0078                READ(NHLTH)
0079               105 CONTINUE
                 C
                 C  SET UP ARRAYS OF ORGAN INDICES (INTO DOSE CONCENTRATION ARRAYS)
                 C    FOR LATENT AND EARLY EFFECTS.
                 C
0080                DO 120 ILA=1,NLA
0081                DO 125 IORG=1,NORG
0082                IF(LAORG(ILA).NE.AORG(IORG)) GO TO 125
0083                INDLA(ILA)=KORG(IORG)
0084                GO TO 120
0085               125 CONTINUE
0086               120 CONTINUE
                 C
                 C
0087                DO 130 IEARLY=1,NEARLY
0088                DO 135 IORG=1,NORG
0089                IF(ERLORG(IEARLY).NE.AORG(IORG)) GO TO 135
0090                INDERL(IEARLY)=KORG(IORG)
0091                GO TO 130
0092               135 CONTINUE
0093               130 CONTINUE
                 C
0094                IF(PARMOD .NE. YES) GO TO 2800
0095                WRITE(NOT,108)
0096               108 FORMAT(//,20X,'* * * INPUT CHRONIC EFFECTS DATA * * *',//)
0097                DO 107 ISONUM = 1,NIS
0098                WRITE(NOT,106) NAME(ISONUM),GRCON(1,1,ISCNUM),CLCON(1,ISONUM),
                   1                  (INCON(1,ITM,ISONUM),ITM=1,7)
0099               106 FORMAT(3X,A8,10(1X,1P1E9.3))
0100               107 CONTINUE
```

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FORTRAN IV G LEVEL  21                CHRON              DATE = 81183          09/12/20

0101          2800 CONTINUE
0102            90 FORMAT(A2,18X,I5,4X,A3,7X,A3)
0103           250 FORMAT(8E10.3)
0104               IF(IREST.NE.0) GO TO 2830
0105               WRITE(NAT,90) SUBGRP,NEXP,PARMOD
0106               DO 2810 I=1,NEXP
0107               WRITE(NAT,2805) NIE(I),NCRIT(I),PROFAC(I),
                  1 DAYS1(I),DAYS2(I),TAGE(I),(RDLIM(I,J),J=1,2)
0108               NI=NIE(I)
0109               DO 2810 J=1,NI
0110               IF(I.LT.NEXP) GO TO 2811
0111               WRITE(NAT,2820) NUCLID(I,J)
0112               GO TO 2810
0113          2811 WRITE(NAT,2820) NUCLID(I,J),(CF(I,J,K),K=1,2)
0114          2805 FORMAT(2I5,6E10.3)
0115          2820 FORMAT(A8,2X,2E10.3)
0116               IF(I.EQ.1) GO TO 2810
0117               DO 2809 N=1,NORGUS
0118               IGOTO=I-1
0119               GO TO (2816,2817,2818,2819), IGOTO
0120          2816 WRITE(NAT,2821)(CSING(J,N,M),M=1,6)
0121               GO TO 2809
0122          2817 WRITE(NAT,2821)(SRING(J,N,M),M=1,6)
0123               GO TO 2809
0124          2818 WRITE(NAT,2821)(RIING(J,N,M),M=1,6)
0125               GO TO 2809
0126          2819 WRITE(NAT,2821)(RTING(J,N,M),M=1,6)
0127          2809 CONTINUE
0128          2810 CONTINUE
              C
              C      NEXP IS THE NUMBER OF CHRONIC EXPOSURE LIMIT GROUPS
0129          2830 NEXP=NUM
0130               DO 2900 I = 1,NEXP
0131               READ(NIT,2805) NIE(I),NCRIT(I),PROFAC(I),DAYS1(I),DAYS2(I),
                  1                TAGE(I),(RDLIM(I,J),J=1,2)
0132               IF(IREST.EQ.1) GO TO 2899
0133               WRITE(NOT,2835)I,NIE(I),NCRIT(I),PROFAC(I),DAYS1(I),DAYS2(I),
                  1                TAGE(I),(RDLIM(I,J),J=1,2)
0134          2835 FORMAT(//,1X,'GROUP ',I2,2X,I2,' ISOTOPES - CRIT.ORGAN -',I2,
                  1 ' - PROFAC ',F5.3, ' - DAYS1,2 ',2(F6.0,1X),' AGING ',E10.3,
                  2 ' RDLIM(1,2) ',2(1X,E10.3),//,1X,'ISO I NAME  - ',
                  3       '  TEFF',11X,'  -  SDEE(1,2)',9X,'  -  CF(1,2)')
              C
0135               IORG=NCRIT(I)
0136               IF(KORG(IORG).NE.0) GO TO 2844
0137               WRITE(NOT,2846) NCRIT(I),(JORG(K),K=1,NCRGUS)
0138          2846 FORMAT(//,5X,'CRITICAL ORGAN NO.-',I3,'-NOT INCLUDED',
                  1  ' IN LIST OF ORGANS FOR CALCULATION-',//,5X,'JORG=',13I4)
0139               STOP
0140          2844 CONTINUE
              C
              C  LOOP ON THE NUMBER OF ISOTOPES IN THIS GROUP
              C                                                                    MOD
              C      I = PATHWAY GROUP NUMBER                                      MOD
              C      J = ISOTOPE NUMBER                                            MOD
              C      L = 1 INDICATES DATA FOR CROP PATHWAY                         MOD
              C      L = 2 INDICATES DATA FOR MILK PATHWAY                         MOD
              C      PATHWAYS FOR INGESTION DOSE                                   MOD
```

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FORTRAN IV G LEVEL  21                CHRON              DATE = 81183          09/12/20

            C      1 - INHALATION                                                          MOD
            C      2 - CROPS                                                               MOD
            C      3 - MILK PRODUCTS                                                       MOD
            C      4- MILK                                                                 MOD
            C      5 - SOIL CONTAMINATION                                                  MOD
            C      6 - GROUND SHINE                                                        MOD
            C                                                                              MOD
            C      MODIFICATION TO INSURE THAT DOSE FACTORS DO NOT EQUAL ZERO WHICH         MOD
            C      WOULD CAUSE UNDERFLOW ERRORS - NEVER SET PROFAC OR CF EQUAL              MOD
            C      TO ZERO EITHER                                                          MOD
            C                                                                              MOD
0141         2899 NI = NIE(I)
0142              AEX=-20.0                                                                MOD
0143               ALIMIT=10.0**AEX                                                        MOD
0144              NCRIT(I)=KORG(NCRIT(I))
0145              DO 2900 J = 1,NI
            C
            C  IF LAST GROUP (GROUND), DO NOT READ CF
0146              IF(I.EQ.NEXP) READ(NIT,2820) NUCLID(I,J)
0147              IF(I.LT.NEXP) READ(NIT,2820) NUCLID(I,J),(CF(I,J,L),L=1,2)
            C
            C      SEARCH FOR ISOTOPE INDEX
            C
0148              DO 2840 K = 1,NIS
0149              IF(NAME(K) .NE. NUCLID(I,J)) GO TO 2840
0150              INDEX(I,J) = K
0151              GO TO 2850
0152         2840 CONTINUE
0153              WRITE(NOT,2845) NUCLID(I,J)
0154         2845 FORMAT(//,5X,'ISOTOPE ',A8, ' NOT FOUND')
0155              STOP
            C
            C  SET UP DOSE CONVERSION DATA FOR EACH GROUP
            C
0156         2850 CONTINUE
            C
            C  TEST FOR GROUND GROUP
0157              IF(I.EQ.NEXP) GO TO 2859
            C
            C  TEST FOR INHALTION GROUP
0158                IF(I.EQ.1) GO TO 2854
            C
            C  READ IN DOSE CONVERSION DATA FOR INGESTION GROUP
0159              DO 2852 KING=1,13
0160              IF(KORG(KING).NE.0) GO TO 2853
0161              READ(NIT,2821)
0162              GO TO 2852
0163         2853 N=KORG(KING)
0164              IGOTO=I-1
0165              GO TO (2823,2824,2825,2826), IGOTO
0166         2823 READ(NIT,2821) (CSING(J,N,L), L=1,6)
0167              GO TO 2852
0168         2824 READ(NIT,2821) (SRING(J,N,L), L=1,6)
0169              GO TO 2852
0170         2825 READ(NIT,2821) (RIING(J,N,L), L=1,6)
0171              GO TO 2852
0172         2826 READ(NIT,2821) (RTING(J,N,L),L=1,6)
0173         2821 FORMAT(10X,7E10.3)
```

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FORTRAN IV G LEVEL  21                CHRON              DATE = 81183          09/12/20

0174          2852 CONTINUE
0175               GO TO 2859
                C
                C  COMPUTE DOSE CONVERSIONS FOR INHALATION GROUP
0176          2854 DO 2855 N=1,NORGUS
0177               DCINH(J,N,6)=0.0
0178               DO 2855 L=1,5
0179               IF(L.GT.1) GO TO 2856
0180               DCINH(J,N,L)=INCON(N,2,K) + INCON(N,3,K)
0181               GO TO 2855
0182          2856 DCINH(J,N,L)=INCON(N,L+2,K)
0183          2855 CONTINUE
                C
                C
                C      CALCULATE HALF-LIFE FOR WEATHERING OF ISOTOPES
                C
0184          2859 IF(IREST.EQ.1) GO TO 2900
0185               TEFF(I,J) = TAGE(I) * HALF(K) / (TAGE(I) + HALF(K))
0186               IF(I .LT. NEXP) GO TO 2860
                C
                C  GROUND GROUP
                C
                C      253. = .693 * 365 1011.99 = .693 * 365 * 4
0187               EX1 = AMAX1((-(1.13/365.+0.693/HALF(K))*DAYS1(I)),-40.)
0188               EX2 = AMAX1((-(0.0075/365.+0.693/HALF(K))*DAYS1(I)),-40.)
0189               EX3 = AMAX1((-(1.13/365.+0.693/HALF(K))*DAYS2(I)),-40.)
0190               EX4 = AMAX1((-(0.0075/365.+0.693/HALF(K))*DAYS2(I)),-40.)
0191               IF(GRCON(NCRIT(I),3,K).LT.ALIMIT)GRCON(NCRIT(I),3,K)=ALIMIT        MOD
0192               SDEE(I,J,1) = RDLIM(I,1) / (PROFAC(I)*GRCON(NCRIT(I),3,K)*
                  1      ((0.63/(1.13+253./HALF(K)))*(1.-EXP(EX1))
                  2       +(0.37/(0.0075+253./HALF(K)))*(1.-EXP(EX2))) )
0193               SDEE(I,J,2) = RDLIM(I,2) /(PROFAC(I)*GRCON(NCRIT(I),3,K)*
                  1    ((0.63/(1.13+253./HALF(K)))*(1.-EXP(EX3))
                  2     +(0.37/(0.0075+253./HALF(K)))*(1.-EXP(EX4)))  )
0194               IF(IREST.EQ.1) GO TO 2900
0195               WRITE(NOT,2890) J,K,NUCLID(I,J),TEFF(I,J),(SDEE(I,J,L),L=1,2)
0196               WRITE(NOT,2806) (L,JORG(L),GRCON(L,3,K),L=1,NORGUS)
0197          2806 FORMAT(2(4(5X,2I5,1PE10.3),/))
0198               GO TO 2900
                C
                C  INHALATION AND INGESTION GROUPS
0199          2860 CONTINUE
                C                                                                   MOD
                C      CHECK FOR ZERO VALUES                                        MOD
                C                                                                   MOD
0200               IF(CSING(J,NCRIT(I),1).LT.ALIMIT)CSING(J,NCRIT(I),1)=ALIMIT      MOD
0201               IF(SRING(J,NCRIT(I),1).LT.ALIMIT)SRING(J,NCRIT(I),1)=ALIMIT      MOD
0202               IF(RIING(J,NCRIT(I),1).LT.ALIMIT)RIING(J,NCRIT(I),1)=ALIMIT      MOD
0203               IF(RTING(J,NCRIT(I),1).LT.ALIMIT)RTING(J,NCRIT(I),1)=ALIMIT      MOD
0204               IF(DCINH(J,NCRIT(I),1).LT.ALIMIT)DCINH(J,NCRIT(I),1)=ALIMIT      MOD
0205               DO 2870 L = 1,2
0206               GO TO (2871,2872,2873,2874,2875), I
0207          2871 SDEE(I,J,L) = RDLIM(I,L)/(PROFAC(I)*DCINH(J,NCRIT(I),1)*CF(I,J,L))
0208               GO TO 2870
0209          2872 SDEE(I,J,L) = RDLIM(I,L)/(PROFAC(I)*CSING(J,NCRIT(I),1)*CF(I,J,L))
0210               GO TO 2870
0211          2873 SDEE(I,J,L) = RDLIM(I,L)/(PROFAC(I)*SRING(J,NCRIT(I),1)*CF(I,J,L))
0212               GO TO 2870
```

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0213          2874 SDEE(I,J,L) = RDLIM(I,L)/(PROFAC(I)*RIING(J,NCRIT(I),1)*CF(I,J,L))
0214               GO TO 2870
0215          2875 SDEE(I,J,L) = RDLIM(I,L)/(PROFAC(I)*RTING(J,NCRIT(I),1)*CF(I,J,L))
0216          2870 CONTINUE
0217          2880 IF(IREST .EQ. 1) GO TO 2900
0218               WRITE(NOT,2890) J,K,NUCLID(I,J),
                  1                TEFF(I,J),(SDEE(I,J,L),L=1,2),(CF(I,J,L),L=1,2)
0219          2890 FORMAT(2(1X,I2),2X,A8,7(2X,E12.4))
0220               DO 2895 L=1,NORGUS
0221               GO TO (2901,2902,2903,2904,2905), I
0222          2901 WRITE(NOT,2807) L,JORG(L),(DCINH(J,L,M),M=1,6)
0223               GO TO 2895
0224          2902 WRITE(NOT,2807) L,JORG(L),(CSING(J,L,M),M=1,6)
0225               GO TO 2895
0226          2903 WRITE(NOT,2807) L,JORG(L),(SRING(J,L,M),M=1,6)
0227               GO TO 2895
0228          2904 WRITE(NOT,2807) L,JORG(L),(RIING(J,L,M),M=1,6)
0229               GO TO 2895
0230          2905 WRITE(NOT,2807) L,JORG(L),(RTING(J,L,M),M=1,6)
0231          2807 FORMAT(1X,2I5,1P7E10.3)
0232          2895 CONTINUE
                  C
0233          2900 CONTINUE
                  C
                  C  MODIFY INCON DEPENDING ON THE NUMBER OF TIME PERIODS TO BE
                  C    PROCESSED FOR LATENT EFFECTS FROM EARLY EXPOSURE
0234                 IF(INTIME.EQ.10) RETURN
0235                 IT1=INTIME+1
0236                 IT2=INTIME+2
0237                 DO 80 IORG=1,NORG
0238                 DO 80 I=1,NIS
0239                 DO 80 J=IT2,11
0240                 INDX=J
0241                 IF(J.GT.7) INDX=7
0242                 INCON(IORG,IT1,I)=INCON(IORG,IT1,I)+INCON(IORG,INDX,I)
0243            80 CONTINUE
0244                 RETURN
0245                 END
```

APPENDIX C

Equations for Environmental Model

C.1 Governing Equations

These differential equations are associated with the block diagram of Fig. 6 (solid lines only). They are the same as those found in ORNL model (12) except for inclusion of the $S_4F(t)$ term in Equation 3 and the exclusion of the crop-soil-root equations (dotted lines in Fig. 6).

(Notation is same as Ref. 12 wherever possible.)

1) $$\frac{dE}{dt} = S_1F(t) - (\lambda_R + \frac{\tau_{e,m}}{A} + \tau_{e,s})\ E$$

2) $$\frac{dG}{dt} = S_3F(t) - (\lambda_R + \tau_{g,r} + \frac{V_c}{A_g D_g})\ G$$

3) $$\frac{dR}{dt} = S_4F(t) + \tau_{g,r}G - (\lambda_R + \tau_{r,g} + \tau_{r,d})\ R$$

4) $$\frac{dD}{dt} = \tau_{r,d}R + \tau_{e,s}E - \lambda_R D$$

5) $$\frac{dC}{dt} = \tau_{g,c}G - (\lambda_R + \tau_{milk})\ C$$

6) $$\frac{dB}{dt} = \tau_{g,b}G - (\lambda_R + \tau_{beef})\ B$$

7) $$I = d_1\ \tau_{e,m}E\ (1+\alpha_i) + d_3\tau_{b,m}B + d_4\tau_{c,m}C$$

8) $$\frac{dM}{dt} = I - (\lambda_R + \lambda_B)\, M$$

9) $$F(t) = F_o \delta(t)$$

C.2 Solution

The solution below differs significantly from ORNL (12) due to the S_4 terms.

$$I(t) = d_1 S_1 \tau_{e,m} F_o e^{-\lambda_a t}(1+\alpha)$$

$$+ \frac{d_3 \tau_{b,m} \tau_{g,b} F_o}{(\lambda_1-\lambda_2)(\lambda_b-\lambda_1)(\lambda_2-\lambda_b)} \left[S_3 \left[(\lambda_2-\lambda_b)(\lambda_1-\lambda_r)e^{-\lambda_1 t} \right.\right.$$

$$\left.\left. + (\lambda_b-\lambda_1)(\lambda_2-\lambda_r)e^{-\lambda_2 t} + (\lambda_1-\lambda_2)(\lambda_b-\lambda_r)e^{-\lambda_b t} \right] + \tau_{r,g} S_4 \right.$$

$$\left. \left[(\lambda_b-\lambda_2)e^{-\lambda_1 t} + (\lambda_1-\lambda_b)e^{-\lambda_2 t} + (\lambda_2-\lambda_1)e^{-\lambda_b t} \right] \right]$$

$$+ \frac{d_4 \tau_{c,m}\, \tau_{g,c}\, F_o}{(\lambda_1-\lambda_2)(\lambda_c-\lambda_1)(\lambda_2-\lambda_c)} \left[S_3 \left[(\lambda_2-\lambda_c)(\lambda_1-\lambda_r)e^{-\lambda_1 t} \right.\right.$$

$$\left.\left. (\lambda_c-\lambda_1)(\lambda_2-\lambda_r)e^{-\lambda_2 t} + (\lambda_1-\lambda_2)(\lambda_c-\lambda_r)e^{-\lambda_c t} \right] + \tau_{r,g} S_4 \right.$$

$$\left. \left[(\lambda_c-\lambda_2)e^{-\lambda_1 t} + (\lambda_1-\lambda_c)e^{-\lambda_2 t} + (\lambda_2-\lambda_1)e^{-\lambda_c t} \right] \right]$$

The CF values are obtained by integrating:

$$CF_{o,1} = \frac{1}{F_o} \int_o^{365} I(t)dt \qquad CF = \frac{1}{F_o} \int_o^{\infty} I(t)dt$$

The λ's in the solution are defined as follows:

$$\lambda_a = \lambda_R + \frac{\tau_{e,m}}{A} + \tau_{e,s} \qquad \lambda_R = \text{radiological decay constant}$$

$$\lambda_b = \lambda_R + \tau_{beef}$$

$$\lambda_c = \lambda_R + \tau_{milk}$$

$$\lambda_g = \lambda_R + \tau_{g,r} + \frac{V_c}{A_g D_g}$$

$$\lambda_r = \lambda_R + \tau_{r,g} + \tau_{r,d}$$

$$\lambda_1 = \frac{1}{2}\left[(\lambda_g + \lambda_r) + \sqrt{(\lambda_g + \lambda_r)^2 - 4(\lambda_g\lambda_r - \tau_{r,g}\,\tau_{g,r})}\right]$$

$$\lambda_2 = \frac{1}{2}\left[(\lambda_g + \lambda_r) - \sqrt{(\lambda_g + \lambda_r)^2 - 4(\lambda_g\lambda_r - \tau_{r,g}\,\tau_{g,r})}\right]$$

C.3 Derivation of $CF_{indirect}/CF_{direct}$ Ratio (α)

The derivation below is valid for CF values integrated from 0 to ∞ since only then does the time dependence disappear as do the decay constants λ_b, λ_c associated with the beef and milk pathways. The values of λ_1 and λ_2 in the solution I(t) become λ_2 and λ_r' respectively in the CF_{direct} calculation since $\tau_{r,g}$ is set to zero. The values of λ_1 and λ_2 become λ_g^* and λ_r respectively in the $CF_{indirect}$ calculation since $\tau_{g,r}$ is set to zero. Then we have from the results in Chapter 3

$$\alpha = \frac{CF_{milk\ indirect}}{CF_{milk\ direct}} = \frac{\dfrac{\tau_{r,g}\ S_4\ d_4\ F_o\ \tau_{c,m}\ \tau_{g,c}\left[\dfrac{(\lambda_c-\lambda_r)}{\lambda_g^*} + \dfrac{(\lambda_g^*-\lambda_c)}{\lambda_r} + \dfrac{(\lambda_r-\lambda_g^*)}{\lambda_c}\right]}{(\lambda_{g^*}-\lambda_r)(\lambda_c-\lambda_g^*)(\lambda_r-\lambda_c)}}{\dfrac{d_4\ F_o\ \tau_{c,m}\ \tau_{g,c}\ S_3}{(\lambda_g-\lambda_r')(\lambda_c-\lambda_g)(\lambda_r'-\lambda_c)}\left[\dfrac{(\lambda_r'-\lambda_c)(\lambda_g-\lambda_r')}{\lambda_g} + \dfrac{(\lambda_c-\lambda_g)(\lambda_r'-\lambda_r')}{\lambda_r'} + \dfrac{(\lambda_g-\lambda_r')(\lambda_c-\lambda_r')}{\lambda_c}\right]}$$

dividing out $\tau_{c,m}$, $\tau_{g,c}$, F_o, and d_4 we have

$$\alpha = \frac{\tau_{r,g}S_4}{S_3} \times \frac{\dfrac{\left[\dfrac{\lambda_c-\lambda_r}{\lambda_g^*} + \dfrac{\lambda_g^*-\lambda_c}{\lambda_r} + \dfrac{\lambda_r-\lambda_g^*}{\lambda_c}\right]}{(\lambda_g^*-\lambda_r)(\lambda_c-\lambda_g^*)(\lambda_r-\lambda_c)}}{\left[\dfrac{(\lambda_r'-\lambda_c)(\lambda_g-\lambda_r')}{\lambda_g} + \dfrac{(\lambda_g-\lambda_r')(\lambda_c-\lambda_r')}{\lambda_c}\right]}{(\lambda_g-\lambda_r')(\lambda_c-\lambda_g)(\lambda_r'-\lambda_c)}$$

dividing out $\lambda_g-\lambda_r'$ and $\lambda_c-\lambda_r'$ in denominator

$$\alpha = \frac{\tau_{r,g} S_4}{S_3} \times \frac{\left[\dfrac{\lambda_c-\lambda_r}{\lambda_g^*} + \dfrac{\lambda_g^*-\lambda_c}{\lambda_r} + \dfrac{\lambda_r-\lambda_g^*}{\lambda_c}\right]}{(\lambda_g^*-\lambda_r)\,(\lambda_c-\lambda_g^*)(\lambda_r-\lambda_c)}}{\left[\dfrac{\lambda_c}{\lambda_c\lambda_g(\lambda_c-\lambda_g)} - \dfrac{\lambda_g}{\lambda_g\lambda_c(\lambda_c-\lambda_g)}\right]}$$

$$\alpha = \frac{\tau_{r,g} S_4}{S_3} \lambda_g\lambda_c \left[\frac{\dfrac{\lambda_c-\lambda_r}{\lambda_g^*} \quad \dfrac{\lambda_g^*-\lambda_c}{\lambda_r} \quad \dfrac{\lambda_r-\lambda_g^*}{\lambda_c}}{[(\lambda_g^*-\lambda_r)(\lambda_c-\lambda_g^*)(\lambda_r-\lambda_c)]}\right]$$

multiplying top and bottom by $\lambda_g^*\lambda_r\lambda_c$ yields:

$$\alpha = \frac{\tau_{r,g} S_4}{S_3} \quad \frac{\lambda_g\lambda_c}{\lambda_g^*\lambda_r\lambda_c} \left[\frac{(\lambda_r\lambda_c)(\lambda_c-\lambda_r) + (\lambda_g^*\lambda_c)(\lambda_g^*-\lambda_c) + (\lambda_g^*\lambda_r)(\lambda_r-\lambda_g^*)}{(\lambda_g^*-\lambda_r)\,(\lambda_c-\lambda_g^*)\,(\lambda_r-\lambda_c)}\right]$$

multiplying out factors and rearranging terms,

$$\alpha = \frac{\tau_{r,g} S_4\ g}{S_3\lambda_g^*\lambda_r} \times \left[\frac{\lambda_r\lambda_c^2-\lambda_r^2\lambda_c+\lambda_g^{*2}\lambda_c-\lambda_g^*\lambda_c^2+\lambda_g^*\lambda_r^2-\lambda_g^{*2}\lambda_r}{\lambda_r\lambda_c^2-\lambda_r^2\lambda_c+\lambda_g^{*2}\lambda_c-\lambda_g^*\lambda_c^2+\lambda_g^*\lambda_r^2-\lambda_g^{*2}\lambda_r}\right]$$

so

$$\boxed{\alpha = \frac{\tau_{r,g} S_4\ g}{S_3\lambda_g^*\lambda_r}}$$

since $\tau_{r,g}$, λ_g , λ_g^* , λ_r do not depend on any milk parameters α is therefore independent of pathway.

A similar derivation yields the same result for α through the beef pathway. The factor α thus allows estimation of $CF_{0,\infty \text{ indirect crop}}$ from $CF_{0,\infty \text{ direct crop}}$. The factor β allows estimation of $CF_{0,1 \text{ indirect crop}}$ from $CF_{0,\infty \text{ indirect crop}}$. The ratio

$$\beta = \frac{CF_{0,1 \text{ indirect beef (or milk)}}}{CF_{0,\infty \text{ indirect beef (or milk)}}}$$

was used as a multiplier on the value of $CF_{0,\infty \text{ indirect crop}}$ to give $CF_{0,1 \text{ indirect crop}}$. The higher value of β from either the beef or milk pathway for a given nuclide was used as the more conservative estimate. Usually the values of β from beef and milk were very close, thus it was felt that using the ratio β for crops was a reasonable approximation.

APPENDIX D

Ingestion CF Values

Values of CF calculated from model presented in Chapter 3.

Isotopes included in present analysis are listed below:

^{14}C	^{59}Ni	^{89}Zr
^{45}Ti	^{63}Ni	^{95}Zr
^{45}Ca	^{65}Ni	^{97}Zr
^{46}Sc	^{57}Co	^{91m}Nb
^{47}Sc	^{58}Co	^{92m}Nb
^{48}Sc	^{60}Co	^{95m}Nb
^{49}Sc	^{61}Co	^{95}Nb
^{49}V	^{62}Co	^{96}Nb
^{49}Cr	^{62m}Co	^{97}Nb
^{51}Cr	^{62}Cu	^{93}Mo
^{53}Mn	^{64}Cu	^{99}Mo
^{54}Mn	^{66}Cu	^{99}Tc
^{56}Mn	^{88}Y	^{99m}Tc
^{55}Fe	^{90}Y	^{181}W
^{59}Fe	^{91}Y	^{185}W
^{57}Ni	^{89}Sr	^{182}Ta
	^{88}Zr	

Organization of the CF Values is as follows:

Pathway ↓	Isotope: First year CF (0-1)	Isotope: Total CF (0-∞)
direct beef	xxx	xxx
direct milk	xxx (+1)*	xxx
direct crop	xxx	xxx
		value of α = ( ) for given isotope
indirect beef	xxx	xxx
indirect milk	xxx	xxx
indirect crop	xxx	xxx

*number in parentheses is the value of the exponent to base ten (e.g. 1.4 (-1) is equal to 1.4×10^{-1}).

Units of CF are Curies ingested/(curies deposited/meter^2) = (Ci/(Ci/m^2))

^{14}C

		0-1	0-∞	
direct	b	2.65 (0)	3.61 (0)	
	m	2.67 (0)	2.67 (0)	
	c	5.02 (-1)	5.02 (-1)	
				α = 1.46 (+1)
indirect	b	3.53 (0)	5.28 (+1)	
	m	6.60 (0)	3.91 (+1)	
	c	1.24 (0)	7.34 (0)	

^{45}Ti

		0-1	0-∞	
direct	b	2.67 (-5)	2.67 (-5)	
	m	2.50 (-6)	2.50 (-6)	
	c	4.81 (-3)	4.81 (-3)	
				α = 3.76 (-7)
indirect	b	1.00 (-11)	1.00 (-11)	
	m	9.39 (-13)	9.39 (-13)	
	c	1.81 (- 9)	1.81 (- 9)	

^{45}Ca

		0-1	0-∞	
direct	b	1.94 (-1)	2.07 (-1)	
	m	2.64 (0)	2.64 (0)	
	c	4.64 (-1)	4.64 (-1)	
				α = 3.73 (-1)
indirect	b	3.62 (-2)	7.73 (-2)	
	m	6.69 (-1)	9.86 (-1)	
	c	1.18 (-1)	1.73 (-1)	

^{46}Sc

		0-1	0-∞	
direct	b	5.07 (-1)	5.15 (-1)	
	m	7.73 (-4)	7.73 (-4)	
	c	4.33 (-1)	4.33 (-1)	
				α = 1.03 (-3)
indirect	b	4.09 (-4)	5.30 (-4)	
	m	7.16 (-7)	7.97 (-7)	
	c	4.00 (-4)	4.46 (-4)	

^{47}Sc

		0-1	0-∞	
direct	b	7.53 (-3)	7.53 (-3)	
	m	1.76 (-4)	1.76 (-4)	
	c	1.03 (-1)	1.03 (-1)	
				α = 1.22 (-5)
indirect	b	9.21 (-8)	9.21 (-8)	
	m	2.15 (-9)	2.15 (-9)	
	c	1.26 (-6)	1.26 (-6)	

^{48}Sc

		0-1	0-∞	
direct	b	2.40 (-3)	2.40 (-3)	
	m	9.66 (-5)	9.66 (-5)	
	c	6.06 (-2)	6.06 (-2)	
				α = 5.96 (-6)
indirect	b	1.43 (-8)	1.43 (-8)	
	m	5.74 (-10)	5.74 (-10)	
	c	3.61 (-7)	3.61 (-7)	

^{49}V

		0-1	0-∞	
direct	b	1.46 (-1)	1.68 (-1)	
	m	1.71 (-1)	1.71 (-1)	
	c	4.82 (-1)	4.82 (-1)	
				α = 8.45 (-1)
indirect	b	3.43 (-2)	1.42 (-1)	
	m	6.30 (-2)	1.44 (-1)	
	c	1.78 (-1)	4.07 (-1)	

^{49}Cr

		0-1	0-∞
direct	b	4.51 (-8)	4.51 (-8)
	m	6.98 (-5)	6.98 (-5)
	c	1.09 (-5)	1.09 (-5)
			α = 2.95 (-5)
indirect	b	1.33 (-12)	1.33 (-12)
	m	8.83 (-10)	8.83 (-10)
	c	3.21 (-10)	3.21 (-10)

^{51}Cr

		0-1	0-∞
direct	b	2.57 (-2)	2.57 (-2)
	m	2.62 (-1)	2.26 (-1)
	c	3.39 (-1)	3.39 (-1)
			α= 3.06 (-2)
indirect	b	7.85 (-4)	7.87 (-4)
	m	8.01 (-3)	8.01 (-3)
	c	1.04 (-2)	1.04 (-2)

^{54}Mn

		0-1	0-∞	
direct	b	4.92 (-2)	5.60 (-2)	
	m	4.27 (-2)	4.27 (-2)	
	c	4.81 (-1)	4.81 (-1)	
				α = 7.68 (-1)
indirect	b	1.13 (-2)	4.30 (-2)	
	m	1.52 (-2)	3.28 (-2)	
	c	1.71 (-1)	3.69 (-1)	

^{56}Mn

		0-1	0-∞	
direct	b	4.71 (-7)	4.71 (-7)	
	m	9.02 (-5)	9.02 (-5)	
	c	4.00 (-3)	4.00 (-3)	
				α = 4.67 (-5)
indirect	b	2.20 (-11)	2.20 (-11)	
	m	4.21 (-9)	4.21 (-9)	
	c	1.87 (-7)	1.87 (-7)	

^{55}Fe

		0-1	0-∞	
direct	b	3.07 (0)	3.87 (0)	
	m	2.11 (-1)	2.11 (-1)	
	c	4.95 (-1)	4.95 (-1)	
				α = 1.15 (-1)
indirect	b	3.56 (-2)	4.44 (-1)	
	m	4.33 (-3)	2.42 (-2)	
	c	1.02 (-2)	5.68 (-2)	

^{59}Fe

		0-1	0-∞	
direct	b	7.28 (-1)	7.29 (-1)	
	m	1.67 (-1)	1.67 (-1)	
	c	3.87 (-1)	3.87 (-1)	
				α = 2.65 (-3)
indirect	b	1.85 (-3)	1.93 (-3)	
	m	4.33 (-4)	4.41 (-4)	
	c	1.00 (-3)	1.02 (-3)	

^{57}Ni

		0-1	0-∞	
direct	b	5.52 (-4)	5.52 (-4)	
	m	1.05 (-1)	1.05 (-1)	
	c	5.08 (-2)	5.08 (-2)	
				α = 1.34 (-4)
indirect	b	7.39 (-8)	7.39 (-8)	
	m	1.41 (-5)	1.41 (-5)	
	c	6.80 (-6)	6.80 (-6)	

^{63}Ni

		0-1	0-∞	
direct	b	4.58 (-1)	7.53 (-1)	
	m	1.20 (0)	1.45 (0)	
	c	5.00 (-1)	5.00 (-1)	
				α = 2.44 (0)
indirect	b	2.52 (-2)	1.84 (0)	
	m	1.25 (-1)	3.54 (0)	
	c	4.31 (-2)	1.22 (0)	

^{65}Ni

		0-1	0-∞	
direct	b	3.03 (-6)	3.03 (-6)	
	m	2.34 (-3)	2.34 (-3)	
	c	3.92 (-3)	3.92 (-3)	
				α = 8.55 (-6)
indirect	b	2.59 (-11)	2.59 (-11)	
	m	2.00 (-8)	2.00 (-8)	
	c	3.35 (-8)	3.35 (-8)	

^{57}Co

		0-1	0-∞	
direct	b	2.38 (+2)	2.67 (+2)	
	m	1.70 (-1)	1.70 (-1)	
	c	4.78 (-1)	4.78 (-1)	
				α = 1.32 (-1)
indirect	b	1.00 (+1)	3.52 (+1)	
	m	1.09 (-2)	2.23 (-2)	
	c	3.08 (-2)	6.30 (-2)	

^{58}Co

		0-1	0-∞	
direct	b	1.11 (+2)	1.12 (+2)	
	m	1.51 (-1)	1.51 (-1)	
	c	4.23 (-1)	4.23 (-1)	
				α = 2.29 (-2)
indirect	b	2.15 (0)	2.56 (0)	
	m	3.21 (-3)	3.44 (-3)	
	c	9.03 (-3)	9.67 (-3)	

^{60}Co

		0-1	0-∞	
direct	b	3.24 (+2)	4.24 (+2)	
	m	1.77 (-1)	1.77 (-1)	
	c	4.99 (-1)	4.99 (-1)	
				α = 9.06 (-1)
indirect	b	1.73 (+1)	3.84 (+2)	
	m	1.73 (-2)	1.59 (-1)	
	c	4.92 (-2)	4.52 (-1)	

^{61}Co

		0-1	0-∞	
direct	b	4.23 (-3)	4.23 (-3)	
	m	1.64 (-3)	1.64 (-3)	
	c	2.58 (-2)	2.58 (-2)	
				α = 1.30 (-6)
indirect	b	5.52 (-9)	5.52 (-9)	
	m	9.17 (-10)	9.17 (-10)	
	c	3.37 (-8)	3.37 (-8)	

^{62m}Co

		0-1	0-∞	
direct	b	2.55 (-7)	2.55 (-7)	
	m	5.10 (-8)	5.10 (-8)	
	c	4.18 (-5)	4.18 (-5)	
				α = 8.99 (-8)
indirect	b	2.29 (-14)	2.29 (-14)	
	m	4.59 (-15)	4.59 (-15)	
	c	3.76 (-12)	3.76 (-12)	

^{62}Co

		0-1	0-∞	
direct	b	1.96 (-5)	1.96 (-5)	
	m	3.80 (-6)	3.80 (-6)	
	c	3.65 (-4)	3.65 (-4)	
				α = 7.86 (-7)
indirect	b	1.54 (-11)	1.54 (-11)	
	m	2.98 (-12)	2.98 (-12)	
	c	2.87 (-10)	2.87 (-10)	

^{62}Cu

		0-1	0-∞	
direct	b	1.92 (-8)	1.92 (-8)	
	m	2.65 (-5)	2.65 (-5)	
	c	2.56 (-4)	2.56 (-4)	
				α = 5.51 (-7)
indirect	b	1.06 (-14)	1.06 (-14)	
	m	1.46 (-11)	1.46 (-11)	
	c	1.41 (-10)	1.41 (-10)	

^{64}Cu

		0-1	0-∞	
direct	b	1.14 (-4)	1.14 (-4)	
	m	6.33 (-2)	6.33 (-2)	
	c	1.94 (-2)	1.94 (-2)	
				α = 4.52 (-5)
indirect	b	5.15 (-9)	5.15 (-9)	
	m	2.85 (-6)	2.85 (-6)	
	c	8.76 (-7)	8.76 (-7)	

^{66}Cu

		0-1	0-∞	
direct	b	5.21 (-9)	5.21 (-9)	
	m	7.25 (-6)	7.25 (-6)	
	c	1.33 (-4)	1.33 (-4)	
				α = 2.86 (-7)
indirect	b	1.49 (-15)	1.49 (-15)	
	m	2.07 (-12)	2.07 (-12)	
	c	3.81 (-11)	3.81 (-11)	

^{88}Y

		0-1	0-∞	
direct	b	1.79 (-1)	1.79 (-1)	
	m	1.59 (-3)	1.59 (-3)	
	c	4.46 (-1)	4.46 (-1)	
				α = 1.44 (-3)
Indirect	b	1.69 (-4)	2.57 (-4)	
	m	1.89 (-6)	2.28 (-6)	
	c	4.21 (-4)	6.40 (-4)	

^{90}Y

		0.1	0-∞	
direct	b	1.38 (-3)	1.38 (-3)	
	m	2.02 (-4)	2.02 (-4)	
	c	8.37 (-3)	8.37 (-3)	
				α = 9.13 (-6)
indirect	b	1.26 (-8)	1.26 (-8)	
	m	1.84 (-9)	1.84 (-9)	
	c	7.64 (-8)	7.64 (-8)	

^{91}Y

		0-1	0-∞	
direct	b	1.09 (-3)	1.09 (-3)	
	m	1.46 (-3)	1.46 (-3)	
	c	4.09 (-1)	4.09 (-1)	
				α = 6.17 (-2)
indirect	b	6.08 (-5)	6.72 (-5)	
	m	9.00 (-5)	9.00 (-5)	
	c	2.52 (-2)	2.52 (-2)	

^{89}Sr

		0-1	0-∞	
direct	b	1.26 (-2)	1.26 (-2)	
	m	2.86 (-1)	2.86 (-1)	
	c	4.00 (-1)	4.00 (-1)	
				α = 7.67 (-2)
indirect	b	9.05 (-4)	9.66 (-4)	
	m	2.15 (-2)	2.19 (-2)	
	c	2.87 (-2)	3.07 (-2)	

^{88}Zr

		0-1	0-∞	
direct	b	1.10 (0)	1.12 (0)	
	m	7.75 (-4)	7.75 (-4)	
	c	4.34 (-1)	4.34 (-1)	
				α = 1.04 (-3)
indirect	b	8.98 (-4)	1.17 (-3)	
	m	7.29 (-7)	8.14 (-7)	
	c	4.06 (-4)	4.53 (-4)	

^{89}Zr

		0-1	0-∞	
direct	b	1.48 (-2)	1.48 (-2)	
	m	1.69 (-4)	1.69 (-4)	
	c	9.88 (-2)	9.88 (-2)	
				α = 1.16 (-5)
indirect	b	1.71 (-7)	1.71 (-7)	
	m	1.95 (-9)	1.95 (-9)	
	c	1.14 (-6)	1.14 (-6)	

^{95}Zr

		0-1	0-∞	
direct	b	8.83 (-1)	8.89 (-1)	
	m	7.44 (-4)	7.44 (-4)	
	c	4.17 (-1)	4.17 (-1)	
				α = 7.17 (-4)
indirect	b	5.55 (-4)	6.37 (-4)	
	m	5.06 (-7)	5.31 (-7)	
	c	2.84 (-4)	2.99 (-4)	

^{97}Zr

		0-1	0-∞	
direct	b	8.45 (-4)	8.45 (-4)	
	m	3.25 (-5)	3.25 (-5)	
	c	2.53 (-2)	2.53 (-2)	
				α = 2.14 (-6)
indirect	b	1.81 (-9)	1.81 (-9)	
	m	6.94 (-11)	6.94 (-11)	
	c	5.42 (-8)	5.42 (-8)	

$^{91m}_{Nb}$

		0-1	0-∞	
direct	b	6.90 (0)	6.94 (0)	
	m	3.69 (-1)	3.69 (-1)	
	c	4.13 (-1)	4.13 (-1)	
				α = 9.90 (-2)
indirect	b	5.48 (-1)	6.87 (-1)	
	m	3.23 (-2)	3.65 (-2)	
	c	3.62 (-2)	4.09 (-2)	

$^{92m}_{Nb}$

		0-1	0-∞	
direct	b	7.80 (-1)	7.80 (-1)	
	m	1.94 (-1)	1.94 (-1)	
	c	2.17 (-1)	2.17 (-1)	
				α = 7.26 (-3)
indirect	b	5.66 (-3)	5.66 (-3)	
	m	1.41 (-3)	1.41 (-3)	
	c	1.57 (-3)	1.57 (-3)	

^{95}Nb

		0-1	0-∞	
direct	b	3.92 (0)	3.92 (0)	
	m	3.26 (-1)	3.26 (-1)	
	c	3.64 (-1)	3.64 (-1)	
				α = 4.31 (-2)
indirect	b	1.68 (-1)	1.69 (-1)	
	m	1.41 (-2)	1.41 (-2)	
	c	1.57 (-2)	1.57 (-2)	

^{95m}Nb

		0-1	0-∞	
direct	b	9.87 (-1)	9.87 (-1)	
	m	1.76 (-1)	1.76 (-1)	
	c	2.00 (-1)	2.00 (-1)	
				α = 3.17 (-4)
indirect	b	3.13 (-4)	3.13 (-4)	
	m	5.58 (-5)	5.58 (-5)	
	c	6.34 (-5)	6.34 (-5)	

^{96}Nb

		0-1	0-∞	
direct	b	1.28 (-2)	1.28 (-2)	
	m	2.40 (-2)	2.40 (-2)	
	c	3.42 (-2)	3.42 (-2)	
				α = 4.50 (-4)
indirect	b	5.76 (-6)	5.76 (-6)	
	m	1.08 (-5)	1.08 (-5)	
	c	1.54 (-5)	1.54 (-5)	

^{97}Nb

		0-1	0-∞	
direct	b	3.62 (-5)	3.62 (-5)	
	m	2.26 (-4)	2.26 (-4)	
	c	1.88 (-3)	1.88 (-3)	
				α = 2.18 (-5)
indirect	b	7.89 (-10)	7.89 (-10)	
	m	4.93 (-9)	4.93 (-9)	
	c	4.10 (-8)	4.10 (-8)	

^{99}Mo

		0-1	0-∞	
direct	b	2.58 (-3)	2.58 (-3)	
	m	2.18 (-1)	2.18 (-1)	
	c	8.66 (-2)	8.66 (-2)	
				α = 1.43 (-3)
indirect	b	3.70 (-6)	3.70 (-6)	
	m	3.13 (-4)	3.13 (-4)	
	c	1.24 (-4)	1.24 (-4)	

^{99m}Tc

		0-1	0-∞	
direct	b	7.93 (-5)	7.93 (-5)	
	m	4.38 (-2)	4.38 (-2)	
	c	1.35 (-2)	1.35 (-2)	
				α = 9.29 (-5)
indirect	b	7.37 (-9)	7.37 (-9)	
	m	4.07 (-6)	4.07 (-6)	
	c	1.25 (-6)	1.25 (-6)	

^{49}Sc

		0-1	0-∞	
direct	b	1.33 (-6)	1.33 (-6)	
	m	2.97 (-7)	2.97 (-7)	
	c	1.50 (-3)	1.50 (-3)	
				α = 1.15 (-7)
indirect	b	1.53 (-13)	1.53 (-13)	
	m	3.43 (-14)	3.43 (-14)	
	c	1.73 (-10)	1.73 (-10)	

^{53}Mn

		0-1	0-∞	
direct	b	6.83 (-2)	9.32 (-2)	
	m	4.45 (-2)	4.45 (-2)	
	c	5.02 (-1)	5.02 (-1)	
				α = 9.74 (0)
indirect	b	2.00 (-2)	9.08 (-1)	
	m	2.47 (-2)	4.33 (-1)	
	c	2.79 (-1)	4.89 (0)	

^{59}Ni

		0-1	0-∞	
direct	b	4.56 (-1)	6.22 (-1)	
	m	1.19 (0)	1.19 (0)	
	c	5.02 (-1)	5.02 (-1)	
				α = 3.42 (0)
indirect	b	2.53 (-2)	2.13 (0)	
	m	1.26 (-1)	4.09 (0)	
	c	5.28 (-2)	1.72 (0)	

^{93}Mo

		0-1	0-∞	
direct	b	6.81 (-1)	9.27 (-1)	
	m	1.34 (0)	1.34 (0)	
	c	5.02 (-1)	5.02 (-1)	
				α = 9.05 (0)
indirect	b	1.99 (-1)	8.39 (0)	
	m	7.37 (-1)	1.21 (+1)	
	c	2.77 (-1)	4.54 (0)	

^{99}Tc

		0-1	0-∞	
direct	b	3.43 (+1)	4.68 (+1)	
	m	4.45 (0)	4.45 (0)	
	c	5.02 (-1)	5.02 (-1)	
				α = 9.72 (0)
indirect	b	1.00 (+1)	4.55 (+2)	
	m	2.48 (0)	4.37 (+1)	
	c	2.77 (-1)	4.88 (0)	

^{182}Ta

		0-1	0-∞	
direct	b	6.23 (+1)	6.44 (+1)	
	m	4.00 (0)	4.00 (0)	
	c	4.49 (-1)	4.49 (-1)	
				α = 1.58 (-3)
indirect	b	6.38 (-2)	1.02 (-1)	
	m	5.10 (-3)	6.30 (-3)	
	c	5.76 (-4)	7.11 (-4)	

$^{181}_{W}$

		0-1	0-∞	
direct	b	5.92 (-2)	6.22 (-2)	
	m	8.16 (-2)	8.16 (-2)	
	c	4.58 (-1)	4.58 (-1)	
				α = 2.07 (-3)
indirect	b	6.87 (-5)	1.29 (-4)	
	m	1.24 (-4)	1.70 (-4)	
	c	6.96 (-4)	9.50 (-4)	

$^{185}_{W}$

		0-1	0-∞	
direct	b	3.89 (-2)	3.94 (-2)	
	m	7.63 (-2)	7.63 (-2)	
	c	4.27 (-1)	4.27 (-1)	
				α = 8.91 (-4)
indirect	b	2.86 (-5)	3.51 (-5)	
	m	6.26 (-5)	6.81 (-5)	
	c	3.49 (-4)	3.80 (-4)	

APPENDIX E

Ingestion Dose Factors

Isotope	Total Body Dose Factors (Rem/Ci ingested)	Reference*
^{14}C	1.92×10^{3}	21
^{45}Ti	5.48×10^{1}	15,13
^{45}Ca	1.33×10^{4}	23
^{46}Sc	4.32×10^{4}	23
^{47}Sc	7.26×10^{2}	23
^{48}Sc	2.49×10^{3}	23
^{49}Sc	8.47×10^{1}	15,13
^{49}V	7.31×10^{3}	15,13
^{49}Cr**	$< 4 \times 10^{1}$	15,13
^{51}Cr	4.57×10^{2}	23
^{53}Mn	< 1	15,13
^{54}Mn	1.23×10^{3}	21
^{56}Mn	1.46×10^{2}	21,23
^{55}Fe	3.50×10^{2}	21
^{59}Fe	2.94×10^{3}	21
^{57}Ni**	9.60×10^{2}	15,13
^{59}Ni	2.15×10^{3}	20
^{63}Ni	1.18×10^{4}	23
^{65}Ni	8.86×10^{1}	23

Isotope	Total Body Dose Factors (Rem/Ci ingested)	Reference*
^{57}Co	1.84×10^{2}	21
^{58}Co	7.65×10^{2}	21
^{60}Co	4.37×10^{3}	21
^{61}Co	3.06×10^{1}	15,21
^{62}Co	1.83×10^{1}	15,21
^{62m}Co	1.93×10^{0}	15,21
^{62}Cu	2.20×10^{1}	15,13
^{64}Cu	1.14×10^{2}	23
^{66}Cu	3.10×10^{0}	15,13
^{88}Y	9.88×10^{4}	15,21
^{90}Y	5.07×10^{2}	21
^{91}Y	4.37×10^{2}	23
^{89}Sr	1.60×10^{3}	21
^{88}Zr**	7.53×10^{3}	15,21
^{89}Zr	2.73×10^{3}	15,21
^{95}Zr	5.45×10^{2}	21
^{97}Zr	7.22×10^{2}	21
^{91m}Nb**	1.47×10^{3}	15,21
^{92m}Nb	1.99×10^{3}	15,21
^{95m}Nb	7.75×10^{2}	23
^{95}Nb	5.04×10^{2}	21

Isotope	Total Body Dose Factors (Rem/Ci ingested)	Reference*
^{96}Nb	1.18×10^{3}	15,21
^{97}Nb	2.40×10^{1}	21
^{93}Mo**	7.65×10^{1}	15,13
^{99}Mo	1.18×10^{3}	21
^{99m}Tc	1.54×10^{1}	21
^{99}Tc	4.92×10^{1}	20
^{182}Ta	2.19×10^{4}	20
^{181}W	6.28×10^{1}	20
^{185}W	4.40×10^{1}	20

*Where reference 15 is sited, the model in that reference was used to calculate the dose factor. In those cases, the retention parameters come from the second reference number. The absorbed fraction in all such cases is from reference 23.

**Daughter decay and buildup after ingestion not included.

APPENDIX F

Sample Input Deck

The following is a sample case input deck with these features:

1) Reference case is 0.001% of the 316SS structural inventory which roughly corresponds to the total corrosion product inventory.

2) The modification case is a 10 g release of tritium.

3) The input to SITE describes an average weather condition for U.S. reactor sites (Ref. 4).

4) The input to TOPOGRAPHY, POPULATION, and ECONOMIC defines an average reactor site (Ref. 4).

```
        REFERENCE DATA
SPATIAL                  34
0.5       1.0       1.5       2.0       2.5       3.0       3.5       4.0
4.5       5.0       6.0       7.0       8.5       10.0      12.5      15.0
17.5      20.0      25.0      30.0      35.0      40.0      45.0      50.0
  55.0      60.0      65.0      70.0      85.0      100.0     150.0     200.0
350.0     500.0
SITE                      1
0                      1.0          9 0 0 0 0
    3     3     1
    1     4     6
  3.34      3.00      2.06
  0.12      0.00      0.00      0.00      0.52      0.00      0.00      0.00
  0.36
 1350.0     550.0
POPULATION                1
  1
 200.0     100.0
TOPOGRAPHY                0
  110
ECONOMIC                  1
  230.0     1700.0     0.2        17000.0    2900.0     37.0       240.0
AVERAGE       5     9  0.40       0.25       150.0      1000.0
ISOTOPE                  36
H-3       2              1.00E 84493.      0.001      0.00001
CA-45     1              2.54E 4163.0      0.01       0.0001
SC-46     1              4.06E 483.8       0.01       0.0001
SC-47     1              5.57E 43.4        0.01       0.0001
SC-48     1              8.36E 41.833      0.01       0.0001
TI-45     1              2.88E 30.1283     0.01       0.0001
V-49      1 CR-49        2.33E 6330.0      0.01       0.0001
CR-49     1              7.36E 50.029      0.01       0.0001
CR-51     1              1.35E 827.8       0.01       0.0001
MN-54     1              7.83E 7312.0      0.01       0.0001
MN-56     1              2.06E 80.1075     0.01       0.0001
FE-55     1              6.84E 8876.6      0.01       0.0001
FE-59     1              2.96E 545.0       0.01       0.0001
CO-57     1 NI-57        3.95E 7272.0      0.01       0.0001
CO-58     1              1.17E 871.0       0.01       0.0001
CO-60     1              2.59E 71914.0     0.01       0.0001
NI-57     1              7.06E 61.5        0.01       0.0001
NI-63     1              2.47E 533600.0    0.01       0.0001
SR-89     1         0.0        50.6        0.01       0.0001
Y-88      1         0.0        107.0       0.01       0.0001
Y-90      1         0.0        2.675       0.01       0.0001
Y-91      1         0.0        59.0        0.01       0.0001
```

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*
ZR-89     1                2.45E 53.267      0.01       0.0001
ZR-95     1                7.15E 465.0       0.01       0.0001
ZR-97     1                1.43E 40.708      0.01       0.0001
NB-91M    1           0.0       62.0         0.01       0.0001
NB-92M    1                5.51E 510.2       0.01       0.0001
NB-93M    1 MO-93          1.25E 44967.0     0.01       0.0001
NB-95M    1 ZR-95          1.06E 53.625      0.01       0.0001
NB-95     1 NB-95M         3.30E 535.0       0.01       0.0001
NB-96     1                1.52E 50.975      0.01       0.0001
NB-97     1 ZR-97          1.08E 50.05       0.01       0.0001
MO-93     1                6.74E 4  1.278E 60.01       0.0001
MO-99     1                1.01E 72.75       0.01       0.0001
TC-99M    1 MO-99     0.0       0.25         0.01       0.0001
TA-182    1           0.0       115.0        0.01       0.0001
LEAKAGE                    1
NORMAL      1.0       1.0       1.0          0.5        0.0        100.0
 0.00001  0.0
DISPERSION
  125.0    45.0            0
EVACUATE
 40225.0    0.536      0.0        8045.0     45.0       100.0      2.0
  1.0        0.75       0.50       0.33
2.660E-004
ACUTE                      6
T MARROW  320.       400.       510.       615.       .03        .5         1.
LLI WALL  2000.      5000.      5000.      5000.      1.         1.         1.
LUNG      5000.      14800.     22400.     24000.     .24        .73        1.
W BODY    55.        150.       280.       370.       .30        .8         0.
LUNG      3000.      3000.1     6000.      6000.      .05        1.0        0.
LLI WALL  1000.      1000.1     2500.      2500.      .05        1.0        0.
LATENT                     8
   10
T MARROW  LEUKEMIA  2.84E-   5  2.72E- 5  1.87E- 5  1.38E- 5   9.7E- 6  6.76E- 6
  4.03E- 6  1.69E- 6  4.8E-  7  0.          1.0
LUNG      LUNG         2.217E-5  2.217E-5  2.217E-5  1.453E-5  8.13E- 6  3.99E- 6
  1.5E-  6  2.2E-  7  0.         0.        1.0
LLI WALL  GI TRK       1.364E-5  1.364E-5  1.364E-5  8.940E-6  5.00E- 6  2.46E- 6
  9.20E- 7  1.4E-  7  0.         0.        1.
THYROID   THYROID      1.34E-04
                                          1.0
SKELETON  BONE         6.87E- 6  6.70E- 6  4.95E- 6  2.60E- 6  1.62E- 6  9.1E-  7
4.2E-    7  1.27E- 7   1.0E- 8  0.          1.0
W BODY    BREAST       2.558E-5  2.558E-5  2.558E-5  1.677E-5  9.35E- 6  4.6E-  6
  1.73E- 6  2.5E-  7  0.         0.        1.0
OTHER     OTHER        2.501E-5  2.317E-5  2.048E-5  1.343E-5  8.52E- 6  3.69E- 6
  1.39E- 6  2.0E-  7  0.         0.        1.
W BODY    W BODY    1.216E-0041.185E-0041.055E-0047.010E-0054.130E-0052.240E-005
1.000E-0052.600E-0065.000E-0070.0        1.0
CHRONIC                    6
    6    1  1.0       365.0      3650.0     0.001      5.0        50.0
H-3         0.001     0.001
MN-54       0.001     0.001
FE-55       0.001     0.001
CO-60       0.001     0.001
NI-63       0.001     0.001
MO-93       0.001     0.001
    5   11  1.0       365.0      365.0      14.0       5.0        5.0
H-3         143.2          1.0E-9
```

*

LUNG		
T MARROW		
SKELETON		
T E C L		
ST WALL		
SI+CONT		
ULI WALL		
LLI WALL		
THYROID		
OTHER		
W BODY	61.76	
TESTES		
OVARIES		
FE-55	0.50	1.0E-9
LUNG		
T MARROW		
SKELETON		
T E C L		
ST WALL		
SI+CONT		
ULI WALL		
LLI WALL		
THYROID		
OTHER		
W BODY	350.0	
TESTES		
OVARIES		
CO-57	0.48	1.0E-9
LUNG		
T MARROW		
SKELETON		
T E C L		
ST WALL		
SI+CONT		
ULI WALL		
LLI WALL		
THYROID		
OTHER		
W BODY	184.0	
TESTES		
OVARIES		
CO-58	0.42	1.0E-9
LUNG		
T MARROW		
SKELETON		
T E C L		
ST WALL		
SI+CONT		
ULI WALL		
LLI WALL		
THYROID		
OTHER		
W BODY	765.0	
TESTES		
OVARIES		
CO-60	0.50	1.0E-9
LUNG		
T MARROW		

```
*
   SKELETON
   T E C L
   ST WALL
   SI+CONT
   ULI WALL
   LLI WALL
   THYROID
   OTHER
   W BODY     4370.0
   TESTES
   OVARIES
        5   11  1.0      365.0      365.0      14.0       5.0        5.0
   H-3             1.0E-949.78
   LUNG
   T MARROW
   SKELETON
   T E C L
   ST WALL
   SI+CONT
   ULI WALL
   LLI WALL
   THYROID
   OTHER
   W BODY     61.76
   TESTES
   OVARIES
   FE-55           1.0E-93.87
   LUNG
   T MARROW
   SKELETON
   T E C L
   ST WALL
   SI+CONT
   ULI WALL
   LLI WALL
   THYROID
   OTHER
   W BODY     350.0
   TESTES
   OVARIES
   CO-57           1.0E-9267.0
   LUNG
   T MARROW
   SKELETON
   T E C L
   ST WALL
   SI+CONT
   ULI WALL
   LLI WALL
   THYROID
   OTHER
   W BODY     184.0
   TESTES
   OVARIES
   CO-58           1.0E-9112.0
   LUNG
   T MARROW
   SKELETON
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SI+CONT
ULI WALL
LLI WALL
THYROID
OTHER
W BODY     350.0
TESTES
OVARIES
CO-57      0.06       35.0
LUNG
T MARROW
SKELETON
T E C L
ST WALL
SI+CONT
ULI WALL
LLI WALL
THYROID
OTHER
W BODY     184.0
TESTES
OVARIES
CO-58      0.01       2.6
LUNG
T MARROW
SKELETON
T E C L
ST WALL
SI+CONT
ULI WALL
LLI WALL
THYROID
OTHER
W BODY     765.0
TESTES
OVARIES
CO-60      0.45       384.0
LUNG
T MARROW
SKELETON
T E C L
ST WALL
SI+CONT
ULI WALL
LLI WALL
THYROID
OTHER
W BODY     4370.0
TESTES
OVARIES
    6    11 0.333     365.0      3650.0     0.0        5.0        50.0
MN-54
FE-55
CR-51
CO-57
CO-58
CO-60
SCALE                  50
```

*

```
T E C L
ST WALL
SI+CONT
ULI WALL
LLI WALL
THYROID
OTHER
W BODY     765.0
TESTES
OVARIES
CO-60           1.0E-9424.0
LUNG
T MARROW
SKELETON
T E C L
ST WALL
SI+CONT
ULI WALL
LLI WALL
THYROID
OTHER
W BODY     4370.0
TESTES
OVARIES
    5   11  1.0      365.0      365.0      14.0       5.0        5.0
H-3             1.0E-941.80
LUNG
T MARROW
SKELETON
T E C L
ST WALL
SI+CONT
ULI WALL
LLI WALL
THYROID
OTHER
W BODY     61.76
TESTES
OVARIES
FE-55           1.0E-90.21
LUNG
T MARROW
SKELETON
T E C L
ST WALL
SI+CONT
ULI WALL
LLI WALL
THYROID
OTHER
W BODY     350.0
TESTES
OVARIES
CO-57           1.0E-90.17
LUNG
T MARROW
SKELETON
T E C L
```

```
*
   ST WALL
   SI+CONT
   ULI WALL
   LLI WALL
   THYROID
   OTHER
   W BODY     184.0
   TESTES
   OVARIES
   CO-58           1.0E-90.15
   LUNG
   T MARROW
   SKELETON
   T E C L
   ST WALL
   SI+CONT
   ULI WALL
   LLI WALL
   THYROID
   OTHER
   W BODY     765.0
   TESTES
   OVARIES
   CO-60           1.0E-90.18
   LUNG
   T MARROW
   SKELETON
   T E C L
   ST WALL
   SI+CONT
   ULI WALL
   LLI WALL
   THYROID
   OTHER
   W BODY     4370.0
   TESTES
   OVARIES
       5   11  1.0       365.0       365.0       14.0        5.0         5.0
   H-3        0.90        0.63
   LUNG
   T MARROW
   SKELETON
   T E C L
   ST WALL
   SI+CONT
   ULI WALL
   LLI WALL
   THYROID
   OTHER
   W BODY     61.76
   TESTES
   OVARIES
   FE-55      0.057       0.47
   LUNG
   T MARROW
   SKELETON
   T E C L
   ST WALL
```

```
*
1.0       2.0       3.0       5.0       7.0       10.0      20.0      30.0
50.0      70.0      100.0     200.0     300.0     500.0     700.0     1000.0
 2000.0    3000.0    5000.0    7000.0    10000.0   20000.0   30000.0   50000.0
70000.0   100000.0  200000.0  300000.0  500000.0  700000.0  1000000.0 2000000.0
3000000.0 5000000.0 7000000.0 10000000. 20000000. 30000000. 50000000. 70000000.
1.000E 0082.000E 0083.000E 0085.000E 0087.000E 0081.000E 0092.000E 0093.000E 009
5.000E 0097.000E 009
RESULTS                  28

TOTAL MAREM          1.0       1.0
ACUTE FATALITIES     1.0       1.0
ACUTE INJURIES
INITIAL LEUKEMIA
INITIAL LUNG
INITIAL GI TRK
INITIAL THYROID
INITIAL BONE
INITIAL BREAST
INITIAL OTHER
INITIAL W BODY
TOTAL F/INITIAL
TOTAL    LEUKEMIA
TOTAL    LUNG
TOTAL    GI TRK
TOTAL    THYROID
TOTAL    BONE
TOTAL    BREAST
TOTAL    OTHER
TOTAL    W BODY
TOTAL LATENT EFF
FATAL RADIUS (M)
INJ RADIUS (M)
INT MILK             1.0       1.0
INT CROPS            1.0       1.0
INT MILK&CROPS       1.0       1.0
INT POP <10 YRS      1.0       1.0
INT POP >10 YRS      1.0       1.0
OPTIONS
    0    0    0    0    0    0
END
    EXECUTE REFERENCE STAINLESS STEEL CASE
END
    EXECUTE REFERENCE TRITIUM CASE - 10 G
LEAKAGE                  1
NORMAL     1.0       1.0       1.0       0.5       0.0       100.0
 0.0     0.001
END
```

APPENDIX G

Sample FUSECRAC Output

The sample case input to FUSECRAC using the health file FUSECRAC using the health file FUSEDOSE results in the following output. The code first prints out the input in recognizable form and then prints results (dependent on which are desired).

* * * FREQUENCY DISTRIBUTIONS * * *
EXECUTE REFERENCE TRITIUM CASE - 10 G

MAGNITUDE	FATAL RADIUS (M) X 1.00E 00	INJ RADIUS (M) X 1.00E 00	INT MILK X 1.00E 00	INT CROPS X 1.00E 00	INT MILK&CROPS X 1.00E 00	INT POP <10 YRS X 1.00E 00	INT POP >10 YRS X 1.00E 00
1.00E 00	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
2.00E 00	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
3.00E 00	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
5.00E 00	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
7.00E 00	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
1.00E 01	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
2.00E 01	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
3.00E 01	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
5.00E 01	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
7.00E 01	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
1.00E 02	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
2.00E 02	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
3.00E 02	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
5.00E 02	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
7.00E 02	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
1.00E 03	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
2.00E 03	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
3.00E 03	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
5.00E 03	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
7.00E 03	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
1.00E 04	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
2.00E 04	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
3.00E 04	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
5.00E 04	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
7.00E 04	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
1.00E 05	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
2.00E 05	0.0	0.0	3.60E-01	0.0	8.80E-01	0.0	0.0
3.00E 05	0.0	0.0	3.60E-01	0.0	3.60E-01	0.0	0.0
5.00E 05	0.0	0.0	3.60E-01	0.0	3.60E-01	0.0	0.0
7.00E 05	0.0	0.0	3.60E-01	0.0	3.60E-01	0.0	0.0
1.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0

* * * FREQUENCY DISTRIBUTIONS * * *
EXECUTE REFERENCE TRITIUM CASE - 10 G

MAGNITUDE	TOTAL GI TRK X 1.00E 00	TOTAL THYROID X 1.00E 00	TOTAL BONE X 1.00E 00	TOTAL BREAST X 1.00E 00	TOTAL OTHER X 1.00E 00	TOTAL W BODY X 1.00E 00	TOTAL LATENT EFF X 1.00E 00
1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0

* * * FREQUENCY DISTRIBUTIONS * * *
EXECUTE REFERENCE TRITIUM CASE - 10 G

MAGNITUDE	INITIAL BONE X 1.00E 00	INITIAL BREAST X 1.00E 00	INITIAL OTHER X 1.00E 00	INITIAL W BODY X 1.00E 00	TOTAL F/INITIAL X 1.00E 00	TOTAL LEUKEMIA X 1.00E 00	TOTAL LUNG X 1.00E 00
1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0

* * * FREQUENCY DISTRIBUTIONS * * *
EXECUTE REFERENCE TRITIUM CASE - 10 G

MAGNITUDE	TOTAL MANREM X 1.00E 00	ACUTE FATALITIES X 1.00E 00	ACUTE INJURIES X 1.COE CO	INITIAL LEUKEMIA X 1.COE CO	INITIAL LUNG X 1.00E CO	INITIAL GI TRK X 1.00E 00	INITIAL THYRCID X 1.COE 00
1.00E 00	1.00E 00	0.0	0.0	0.C	0.0	0.0	0.0
2.00E 00	1.00E 00	0.0	0.0	0.C	0.C	C.0	C.0
3.00E 00	1.00E 00	0.0	C.0	0.C	0.0	C.0	C.C
5.00E 00	1.00E 00	0.0	0.0	0.0	0.0	C.0	C.0
7.00E 00	1.00E 00	0.0	0.0	0.0	0.0	C.0	C.0
1.00E 01	1.00E 00	0.0	0.C	0.C	0.C	C.0	C.C
2.00E 01	1.00E 00	0.0	0.0	0.0	0.0	0.0	C.C
3.00E 01	1.00E 00	0.0	0.0	0.0	0.0	0.0	C.C
5.00E 01	1.00E 00	0.0	0.0	0.0	0.C	C.0	C.C
7.00E 01	1.00E 00	0.0	C.0	0.C	0.0	0.0	C.C
1.00E 02	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 02	1.00E 00	0.0	C.0	0.0	0.C	C.0	C.C
3.00E 02	3.60E-01	0.0	0.0	0.C	0.C	0.0	C.C
5.00E 02	3.60E-01	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 02	3.60E-01	0.0	0.0	0.0	0.C	0.0	C.C
1.00E 03	0.0	0.0	C.0	0.0	0.C	C.0	C.C
2.00E 03	0.0	0.0	0.0	0.C	0.0	0.0	0.0
3.00E 03	0.0	0.0	0.0	0.C	C.0	C.0	C.0
5.00E 03	0.0	0.0	C.0	0.C	0.0	C.0	C.0
7.00E 03	0.0	0.0	0.0	0.0	0.C	0.0	0.0
1.00E 04	0.0	0.0	0.0	0.0	0.C	C.0	C.C
2.00E 04	0.0	0.0	C.0	0.C	0.0	C.0	C.0
3.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	C.C
7.00E 04	0.0	0.0	0.0	0.0	0.C	C.0	0.C
1.00E 05	0.0	0.0	0.0	0.C	0.C	0.0	C.C
2.00E 05	0.0	0.0	0.0	0.0	0.0	C.0	0.C
3.00E 05	0.0	0.0	0.0	0.0	0.C	C.0	C.C
5.00E 05	0.0	0.0	C.0	C.C	0.0	0.0	C.C
7.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 06	0.0	0.0	0.0	0.C	0.0	C.0	C.C
2.00E 06	0.0	0.0	0.C	0.C	0.C	C.0	C.C
3.00E 06	0.0	0.0	0.0	0.C	0.0	0.0	0.0
5.00E 06	0.0	0.0	0.0	0.0	0.C	C.0	C.C
7.00E 06	0.0	0.0	C.0	C.0	0.0	C.0	C.0
1.00E 07	0.0	0.0	0.0	0.C	0.C	0.0	0.0
2.00E 07	0.0	0.0	0.0	0.0	C.0	C.0	0.C
3.00E 07	0.0	0.0	C.0	C.C	0.C	C.0	C.C
5.00E 07	0.0	0.0	0.0	0.0	0.C	0.0	C.C
7.00E 07	0.0	0.0	0.0	0.0	0.0	C.0	C.0
1.00E 08	0.0	0.0	C.0	0.0	0.C	C.0	C.C
2.00E 08	0.0	0.0	C.0	0.C	0.0	0.0	C.C
3.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 08	0.0	0.0	C.0	0.0	C.C	C.0	C.C
7.00E 08	0.0	0.0	0.0	0.C	0.C	0.0	C.C
1.00E 09	0.0	0.0	0.0	0.0	0.C	0.0	0.0
2.00E 09	0.0	0.0	C.0	0.0	C.0	C.0	C.C
3.00E 09	0.0	0.0	0.0	0.0	0.C	C.0	C.C
5.00E 09	0.0	0.0	C.0	0.C	0.0	0.0	0.0
7.00E 09	0.0	0.0	0.0	0.C	0.C	C.0	C.0

*** * * * FINAL RESULTS * * * ***

EXECUTE REFERENCE TRITIUM CASE - 10 G

	** DESCRIPTION **	****** MEAN *****		**** VARIANCE ***		*** 3RD MOMENT **		*** 4TH MOMENT **		* P(0) *	* PEAK *	**** TRIAL **
1	TOTAL MANREM	5.22D 02	5.22D 02	1.12D 05	1.12D 05	2.14D 07	2.14D 07	1.69D 10	1.69D 10	1.00D 00	9.68D 02	101010110010
2	ACUTE FATALITIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
3	ACUTE INJURIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
4	INITIAL LEUKEMIA	2.23D-03	2.23D-03	2.11D-06	2.11D-06	1.77D-09	1.77D-09	5.99D-12	5.99D-12	1.00D 00	4.16D-03	101010110010
5	INITIAL LUNG	1.74D-03	1.74D-03	1.29D-06	1.29D-06	8.41D-10	8.41D-10	2.23D-12	2.23D-12	1.00D 00	3.25D-03	101010110010
6	INITIAL GI TRK	6.41D-04	6.41D-04	1.75D-07	1.75D-07	4.23D-11	4.23D-11	4.13D-14	4.13D-14	1.00D 00	1.20D-03	101010110010
7	INITIAL THYROID	1.05D-02	1.05D-02	4.70D-05	4.70D-05	1.86D-07	1.86D-07	2.97D-09	2.97D-09	1.00D 00	1.96D-02	101010110010
8	INITIAL BONE	5.38D-04	5.38D-04	1.24D-07	1.24D-07	2.50D-11	2.50D-11	2.05D-14	2.05D-14	1.00D 00	1.01D-03	101010110010
9	INITIAL BREAST	2.00D-03	2.00D-03	1.71D-06	1.71D-06	1.29D-09	1.29D-09	3.94D-12	3.94D-12	1.00D 00	3.75D-03	101010110010
10	INITIAL OTHER	1.96D-03	1.96D-03	1.64D-06	1.64D-06	1.21D-09	1.21D-09	3.60D-12	3.60D-12	1.00D 00	3.66D-03	101010110010
11	INITIAL W BODY	9.53D-03	9.53D-03	3.87D-05	3.87D-05	1.39D-07	1.39D-07	2.01D-09	2.01D-09	1.00D 00	1.78D-02	101010110010
12	TOTAL F/INITIAL	1.76D-02	1.76D-02	1.32D-04	1.32D-04	8.74D-07	8.74D-07	2.35D-08	2.35D-08	1.00D 00	3.29D-02	101010110010
13	TOTAL LEUKEMIA	3.10D-03	3.10D-03	4.06D-06	4.06D-06	4.69D-09	4.69D-09	2.21D-11	2.21D-11	1.00D 00	5.79D-03	101010110010
14	TOTAL LUNG	2.42D-03	2.42D-03	2.47D-06	2.47D-06	2.23D-09	2.23D-09	8.21D-12	8.21D-12	1.00D 00	4.52D-03	101010110010
15	TOTAL GI TRK	8.95D-04	8.95D-04	3.37D-07	3.37D-07	1.12D-10	1.12D-10	1.52D-13	1.52D-13	1.00D 00	1.67D-03	101010110010
16	TOTAL THYROID	1.09D-02	1.09D-02	5.07D-05	5.07D-05	2.08D-07	2.08D-07	3.45D-09	3.45D-09	1.00D 00	2.04D-02	101010110010
17	TOTAL BONE	7.51D-04	7.51D-04	2.37D-07	2.37D-07	6.63D-11	6.63D-11	7.57D-14	7.57D-14	1.00D 00	1.40D-03	101010110010
18	TOTAL BREAST	7.68D-03	7.68D-03	2.44D-05	2.44D-05	6.87D-08	6.87D-08	7.97D-10	7.97D-10	1.00D 00	1.43D-02	101010110010
19	TOTAL OTHER	2.73D-03	2.73D-03	3.15D-06	3.15D-06	3.20D-09	3.20D-09	1.33D-11	1.33D-11	1.00D 00	5.10D-03	101010110010
20	TOTAL W BODY	3.65D-02	3.65D-02	5.50D-04	5.50D-04	7.38D-06	7.38D-06	4.07D-07	4.07D-07	1.00D 00	6.78D-02	101010110010
21	TOTAL LATENT EFF	2.08D-02	2.08D-02	1.84D-04	1.84D-04	1.43D-06	1.43D-06	4.53D-08	4.53D-08	1.00D 00	3.89D-02	101010110010
22	FATAL RADIUS (M)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
23	INJ RADIUS (M)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
24	INT MILK	3.06D 05	8.50D 05	1.66D 11	-3.05D-05	3.96D 16	2.56D 02	3.71D 22	2.68D 08	3.60D-01	8.50D 05	101010110010
25	INT CROPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
26	INT MILK&CROPS	3.71D 05	4.22D 05	7.51D 10	6.41D 10	7.82D 15	6.00D 15	8.32D 21	4.67D 21	8.80D-01	7.26D 05	101010110010
27	INT POP <10 YRS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
28	INT POP >10 YRS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0

*** THIS RUN CONTAINS A TOTAL OF 3 RESULTS

*** THERE IS A TOTAL OF 3 START TIMES

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SUBGROUP END
PARAMETER       SET TC      0
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SUBGROUP LEAKAGE
PARAMETER NPB2 SET TO 1

* * * INPUT ISOTOPIC LEAKAGE FRACTIONS * * *

1	AL	PROB-P(J,2)	TIME TO RELEASE	EXPANSION FACTOR	WARNING TIME	SENSIBLE HEAT (CAL/SEC)	RELEASE HEIGHT
		1.000E 00	1.000E 00	1.260E 00	5.000E-01	0.0	1.000E 02

GROUP - LEAKAGE FRACTION 1-0.0 2-1.00E-03

* * * * CALCULATION OF REACTOR ACCIDENT CONSEQUENCES -- C R A C * * * *

EXECUTE REFERENCE TRITIUM CASE - 10 G 0

* * * FREQUENCY DISTRIBUTIONS * * *
EXECUTE REFERENCE STAINLESS STEEL CASE

MAGNITUDE	FATAL RADIUS (M) X 1.00E 00	INJ RADIUS (M) X 1.00E 00	INT MILK X 1.00E 00	INT CROPS X 1.00E 00	INT MILK&CROPS X 1.00E 00	INT POP <10 YRS X 1.00E 00	INT POP >10 YRS X 1.00E 00
1.00E 00	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
2.00E 00	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
3.00E 00	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
5.00E 00	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
7.00E 00	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
1.00E 01	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
2.00E 01	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
3.00E 01	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
5.00E 01	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
7.00E 01	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
1.00E 02	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
2.00E 02	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
3.00E 02	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
5.00E 02	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
7.00E 02	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
1.00E 03	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
2.00E 03	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
3.00E 03	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
5.00E 03	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
7.00E 03	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
1.00E 04	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
2.00E 04	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
3.00E 04	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
5.00E 04	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
7.00E 04	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
1.00E 05	0.0	0.0	1.00E 00	0.0	0.0	3.60E-01	0.0
2.00E 05	0.0	0.0	1.00E 00	0.0	0.0	0.0	0.0
3.00E 05	0.0	0.0	1.00E 00	0.0	0.0	0.0	0.0
5.00E 05	0.0	0.0	8.80E-01	0.0	0.0	0.0	0.0
7.00E 05	0.0	0.0	8.80E-01	0.0	0.0	0.0	0.0
1.00E 06	0.0	0.0	8.80E-01	0.0	0.0	0.0	0.0
2.00E 06	0.0	0.0	8.80E-01	0.0	0.0	0.0	0.0
3.00E 06	0.0	0.0	8.80E-01	0.0	0.0	0.0	0.0
5.00E 06	0.0	0.0	8.80E-01	0.0	0.0	0.0	0.0
7.00E 06	0.0	0.0	8.80E-01	0.0	0.0	0.0	0.0
1.00E 07	0.0	0.0	3.60E-01	0.0	0.0	0.0	0.0
2.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0

* * * FREQUENCY DISTRIBUTIONS * * *
EXECUTE REFERENCE STAINLESS STEEL CASE

MAGNITUDE	TOTAL GI TRK X 1.00E 00	TOTAL THYROID X 1.00E 00	TOTAL BONE X 1.00E 00	TOTAL BREAST X 1.00E 00	TOTAL OTHER X 1.00E 00	TOTAL W BODY X 1.00E 00	TOTAL LATENT EFF X 1.00E 00
1.00E 00	0.0	0.0	0.0	0.0	0.0	1.00E 00	1.00E 00
2.00E 00	0.0	0.0	0.0	0.0	0.0	1.00E 00	0.0
3.00E 00	0.0	0.0	0.0	0.0	0.0	6.40E-01	0.0
5.00E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0

* * * FREQUENCY DISTRIBUTIONS * * *
EXECUTE REFERENCE STAINLESS STEEL CASE

MAGNITUDE	INITIAL BONE X 1.00E 00	INITIAL BREAST X 1.00E 00	INITIAL OTHER X 1.COE CO	INITIAL W BODY X 1.COE 00	TOTAL F/INITIAL X 1.COE 00	TOTAL LEUKEMIA X 1.00E 00	TOTAL LUNG X 1.COE 00
1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0

* * * FREQUENCY DISTRIBUTIONS * * *
EXECUTE REFERENCE STAINLESS STEEL CASE

MAGNITUDE	TOTAL MANREM X 1.00E 00	ACUTE FATALITIES X 1.00E 00	ACUTE INJURIES X 1.00E 00	INITIAL LEUKEMIA X 1.00E 00	INITIAL LUNG X 1.00E 00	INITIAL GI TRK X 1.00E 00	INITIAL THYROID X 1.00E 00
1.00E 00	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 00	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 00	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 00	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 00	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 01	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 01	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 01	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 01	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 01	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 02	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 02	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 02	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 02	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 02	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 03	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 03	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 03	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 03	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 03	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 04	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 04	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 04	1.00E 00	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 04	6.40E-01	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.00E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0

* * * * FINAL RESULTS * * * *

EXECUTE REFERENCE STAINLESS STEEL CASE

	** DESCRIPTION **	****** MEAN *****		**** VARIANCE ***		*** 3RD MOMENT **		*** 4TH MOMENT **		* P(0) *	* PEAK *	**** TRIAL ***
1	TOTAL MANREM	4.95D 04	4.95D 04	3.42D 07	3.42D 07	2.66D 11	2.66D 11	4.85D 15	4.85D 15	1.00D 00	6.35D 04	1010101 4010
2	ACUTE FATALITIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
3	ACUTE INJURIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
4	INITIAL LEUKEMIA	2.79D-03	2.79D-03	2.84D-06	2.84D-06	3.32D-09	3.32D-09	2.36D-11	2.36D-11	1.00D 00	6.36D-03	1010101 4010
5	INITIAL LUNG	1.93D-02	1.93D-02	5.39D-05	5.39D-05	2.51D-07	2.51D-07	8.23D-09	8.23D-09	1.00D 00	3.46D-02	1010101 4010
6	INITIAL GI TRK	8.62D-04	8.62D-04	2.55D-07	2.55D-07	8.83D-11	8.83D-11	1.90D-13	1.90D-13	1.00D 00	1.93D-03	1010101 4010
7	INITIAL THYROID	9.85D-03	9.85D-03	3.70D-05	3.70D-05	1.51D-07	1.51D-07	3.96D-09	3.96D-09	1.00D 00	2.27D-02	1010101 4010
8	INITIAL BONE	6.50D-04	6.50D-04	1.59D-07	1.59D-07	4.41D-11	4.41D-11	7.43D-14	7.43D-14	1.00D 00	1.50D-03	1010101 4010
9	INITIAL BREAST	2.70D-03	2.70D-03	2.30D-06	2.30D-06	2.39D-09	2.39D-09	1.54D-11	1.54D-11	1.00D 00	5.91D-03	1010101 4010
10	INITIAL OTHER	2.85D-03	2.85D-03	3.00D-06	3.00D-06	3.62D-09	3.62D-09	2.65D-11	2.65D-11	1.00D 00	6.52D-03	1010101 4010
11	INITIAL W BODY	1.27D-02	1.27D-02	5.15D-05	5.15D-05	2.54D-07	2.54D-07	7.74D-09	7.74D-09	1.00D 00	2.79D-02	1010101 4010
12	TOTAL F/INITIAL	3.63D-02	3.63D-02	3.15D-04	3.15D-04	3.70D-06	3.70D-06	2.85D-07	2.85D-07	1.00D 00	7.36D-02	1010101 4010
13	TOTAL LEUKEMIA	2.38D-01	2.38D-01	8.35D-04	8.35D-04	3.22D-05	3.22D-05	2.89D-06	2.89D-06	1.00D 00	3.07D-01	1010101 4010
14	TOTAL LUNG	2.42D-01	2.42D-01	1.09D-03	1.09D-03	4.34D-05	4.34D-05	4.61D-06	4.61D-06	1.00D 00	3.19D-01	1010101 4010
15	TOTAL GI TRK	7.71D-02	7.71D-02	8.68D-05	8.68D-05	1.08D-06	1.08D-06	3.13D-08	3.13D-08	1.00D 00	9.93D-02	1010101 4010
16	TOTAL THYROID	3.37D-01	3.37D-01	1.91D-03	1.91D-03	1.06D-04	1.06D-04	1.47D-05	1.47D-05	1.00D 00	4.40D-01	1010101 4010
17	TOTAL BONE	5.80D-02	5.80D-02	4.94D-05	4.94D-05	4.64D-07	4.64D-07	1.01D-08	1.01D-08	1.00D 00	7.48D-02	1010101 4010
18	TOTAL BREAST	6.35D-01	6.35D-01	5.71D-03	5.71D-03	5.71D-04	5.71D-04	1.35D-04	1.35D-04	1.00D 00	8.15D-01	1010101 4010
19	TOTAL OTHER	2.57D-01	2.57D-01	9.68D-04	9.68D-04	4.02D-05	4.02D-05	3.89D-06	3.89D-06	1.00D 00	3.31D-01	1010101 4010
20	TOTAL W BODY	3.02D 00	3.02D 00	1.29D-01	1.29D-01	6.13D-02	6.13D-02	6.87D-02	6.87D-02	1.00D 00	3.87D 00	1010101 4010
21	TOTAL LATENT EFF	1.21D 00	1.21D 00	2.34D-02	2.34D-02	4.62D-03	4.62D-03	2.22D-03	2.22D-03	1.00D 00	1.57D 00	1010101 4010
22	FATAL RADIUS (M)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
23	INJ RADIUS (M)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
24	INT MILK	1.05D 07	1.05D 07	2.58D 13	2.58D 13	-5.93D 19	-5.93D 19	1.69D 27	1.69D 27	1.00D 00	1.63D 07	1010101100
25	INT CROPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
26	INT MILK&CROPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
27	INT POP <10 YRS	5.97D 04	1.66D 05	6.34D 09	-1.91D-06	2.95D 14	1.00D 00	5.40D 19	7.21D 05	3.60D-01	1.66D 05	101010110010
28	INT POP >10 YRS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0

*** THIS RUN CONTAINS A TOTAL OF 3 RESULTS

*** THERE IS A TOTAL OF 3 START TIMES

```
SUBGROUP END
PARAMETER      SET TC      0
```

**** CALCULATION OF REACTOR ACCIDENT CONSEQUENCES -- C R A C ****

EXECUTE REFERENCE STAINLESS STEEL CASE 0

```
SUBGROUP END
PARAMETER       SET TO      0
```

SUBGROUP OPTIONS
PARAMETER SET TC 0

* * * INPUT PRINT OPTIONS * * *

NPL=0 OR 1	PRINT OPTION FOR INTERDICT. & DECON.	0
NPD=0 OR 1	PRINT OPTION FOR DISPERSION	0
NPH=0,1,2,OR 3	PRINT OPTION FOR HEALTH EFFECTS	0
NPP=0 OR 1	PRINT OPTION FOR TRIAL RESULTS	0
NPA=0,1, OR 2	PRINT OPTION FOR ACTIVITY & AIR CONC.	0
NPE=0,1, OR 2	PRINT OPTION FOR ECONOMIC COSTS	0

SUBGROUP RESULTS
PARAMETER NRES SET TO 28

* * * INPUT NAMES OF FINAL RESULTS TO BE PRINTED * * *

NUMBER	NAME	FACTOR	SCALE
1	TOTAL MAIREM	1.000E 00	1.000E 00
2	ACUTE FATALITIES	1.000E 00	1.000E 00
3	ACUTE INJURIES	1.000E 00	1.000E 00
4	INITIAL LEUKEMIA	1.000E 00	1.000E 00
5	INITIAL LUNG	1.000E 00	1.000E 00
6	INITIAL GI TRK	1.000E 00	1.000E 00
7	INITIAL THYROID	1.000E 00	1.000E 00
8	INITIAL BONE	1.000E 00	1.000E 00
9	INITIAL BREAST	1.000E 00	1.000E 00
10	INITIAL OTHER	1.000E 00	1.000E 00
11	INITIAL W BODY	1.000E 00	1.000E 00
12	TOTAL F/INITIAL	1.000E 00	1.000E 00
13	TOTAL LEUKEMIA	1.000E 00	1.000E 00
14	TOTAL LUNG	1.000E 00	1.000E 00
15	TOTAL GI TRK	1.000E 00	1.000E 00
16	TOTAL THYROID	1.000E 00	1.000E 00
17	TOTAL BONE	1.000E 00	1.000E 00
18	TOTAL BREAST	1.000E 00	1.000E 00
19	TOTAL OTHER	1.000E 00	1.000E 00
20	TOTAL W BODY	1.000E 00	1.000E 00
21	TOTAL LATENT EFF	1.000E 00	1.000E 00
22	FATAL RADIUS (M)	1.000E 00	1.000E 00
23	ING RADIUS (M)	1.000E 00	1.000E 00
24	INT MILK	1.000E 00	1.000E 00
25	INT CROPS	1.000E 00	1.000E 00
26	INT MILK&CROPS	1.000E 00	1.000E 00
27	INT POP <10 YRS	1.000E 00	1.000E 00
28	INT POP >10 YRS	1.000E 00	1.000E 00

50 7.00E 09

SUBGROUP SCALE
PARAMETER NCT SET TO 50

* * * INPUT SCALE FOR PLOTTING THE COMPLEMENTARY CUMULATIVE DISTRIBUTIONS OF THE CONSEQUENCES * * *

NUMBER	MAGNITUDE
1	1.00E 00
2	2.00E 00
3	3.00E 00
4	5.00E 00
5	7.00E 00
6	1.00E 01
7	2.00E 01
8	3.00E 01
9	5.00E 01
10	7.00E 01
11	1.00E 02
12	2.00E 02
13	3.00E 02
14	5.00E 02
15	7.00E 02
16	1.00E 03
17	2.00E 03
18	3.00E 03
19	5.00E 03
20	7.00E 03
21	1.00E 04
22	2.00E 04
23	3.00E 04
24	5.00E 04
25	7.00E 04
26	1.00E 05
27	2.00E 05
28	3.00E 05
29	5.00E 05
30	7.00E 05
31	1.00E 06
32	2.00E 06
33	3.00E 06
34	5.00E 06
35	7.00E 06
36	1.00E 07
37	2.00E 07
38	3.00E 07
39	5.00E 07
40	7.00E 07
41	1.00E 08
42	2.00E 08
43	3.00E 08
44	5.00E 08
45	7.00E 08
46	1.00E 09
47	2.00E 09
48	3.00E 09
49	5.00E 09

	5	9	7.550E 04	6	10	1.310E 05	7	11	1.020E 05					
2	12	FE-55	0.0	0.1132E 00		0.4563E 00								
	1	1	1.650E 01	2	2	3.200E 01	3	3	3.020E 01	4	8	6.680E 00		
	5	9	8.330E 00	6	10	3.750E 03	7	11	2.020E 02					
3	9	CR-51	0.0	0.2490E-01		0.2490E 00								
	1	1	5.230E 03	2	2	8.920E 03	3	3	8.920E 03	4	8	3.270E 03		
	5	9	5.650E 03	6	10	7.390E 03	7	11	5.900E 03					
4	14	CO-57	0.0	0.1311E-02		0.9486E-02								
	1	1	1.890E 04	2	2	4.010E 04	3	3	4.010E 04	4	8	1.180E 04		
	5	9	2.750E 04	6	10	2.710E 04	7	11	2.260E 04					
5	15	CO-58	0.0	0.5354E-03		0.5260E-02								
	1	1	1.130E 05	2	2	1.340E 05	3	3	1.340E 05	4	8	7.970E 04		
	5	9	9.630E 04	6	10	1.540E 05	7	11	1.200E 05					
6	16	CO-60	0.0	0.6945E-04		0.1959E-03								
	1	1	2.910E 05	2	2	3.250E 05	3	3	3.240E 05	4	8	2.370E 05		
	5	9	2.730E 05	6	10	3.620E 05	7	11	3.070E 05					

```
    7   11 7.650E 02 0.0        0.0        0.0        0.0        0.0
 > 16  CO-60        0.1390E 02    0.1144E 07    0.6356E-02    0.1000E-08    0.180CE CC
    1    1 0.0        0.0        0.0        0.0        0.0        0.0
    2    2 0.0        0.0        0.0        0.0        0.0        0.0
    3    3 0.0        0.0        0.0        0.0        0.0        0.0
    4    8 0.0        0.0        0.0        0.0        0.0        0.0
    5    9 0.0        0.0        0.0        0.0        0.0        0.0
    6   10 0.0        0.0        0.0        0.0        0.0        0.0
    7   11 4.370E 03 0.0        0.0        0.0        0.0        0.0

GROUP  5   5 ISOTOPES - CRIT.ORGAN -11 - PROFAC 1.000 - DAYS1,2   365.   365.  AGING  0.140E 02 RDLIM(1,2)   0.500E 01  0.500E 01

ISO I NAME  -   TEFF            -  SDEE(1,2)          -  CF(1,2)
 1  1  H-3          0.1396E 02    0.8995E-01    0.1285E 00    0.900CE 00    0.6300E CO
    1    1 0.0        0.0        0.0        0.0        0.0        0.0
    2    2 0.0        0.0        0.0        0.0        0.0        0.0
    3    3 0.0        0.0        0.0        0.0        0.0        0.0
    4    8 0.0        0.0        0.0        0.0        0.0        0.0
    5    9 0.0        0.0        0.0        0.0        0.0        0.0
    6   10 0.0        0.0        0.0        0.0        0.0        0.0
    7   11 6.176E 01 0.0        0.0        0.0        0.0        0.0
 2 12  FE-55         0.1378E 02    0.2506E 00    0.3040E-01    0.570CE-01    0.470CE 00
    1    1 0.0        0.0        0.0        0.0        0.0        0.0
    2    2 0.0        0.0        0.0        0.0        0.0        0.0
    3    3 0.0        0.0        0.0        0.0        0.0        0.0
    4    8 0.0        0.0        0.0        0.0        0.0        0.0
    5    9 0.0        0.0        0.0        0.0        0.0        0.0
    6   10 0.0        0.0        0.0        0.0        0.0        0.0
    7   11 3.500E 02 0.0        0.0        0.0        0.0        0.0
 3 14  CO-57         0.1331E 02    0.4529E 00    0.7764E-03    0.6000E-01    0.350CE 02
    1    1 0.0        0.0        0.0        0.0        0.0        0.0
    2    2 0.0        0.0        0.0        0.0        0.0        0.0
    3    3 0.0        0.0        0.0        0.0        0.0        0.0
    4    8 0.0        0.0        0.0        0.0        0.0        0.0
    5    9 0.0        0.0        0.0        0.0        0.0        0.0
    6   10 0.0        0.0        0.0        0.0        0.0        0.0
    7   11 1.840E 02 0.0        0.0        0.0        0.0        0.0
 4 15  CO-58         0.1169E 02    0.6536E 00    0.2514E-02    0.1000E-01    0.260CE 01
    1    1 0.0        0.0        0.0        0.0        0.0        0.0
    2    2 0.0        0.0        0.0        0.0        0.0        0.0
    3    3 0.0        0.0        0.0        0.0        0.0        0.0
    4    8 0.0        0.0        0.0        0.0        0.0        0.0
    5    9 0.0        0.0        0.0        0.0        0.0        0.0
    6   10 0.0        0.0        0.0        0.0        0.0        0.0
    7   11 7.650E 02 0.0        0.0        0.0        0.0        0.0
 5 16  CO-60         0.1390E 02    0.2543E-02    0.2980E-05    0.450CE CO    0.384CE 03
    1    1 0.0        0.0        0.0        0.0        0.0        0.0
    2    2 0.0        0.0        0.0        0.0        0.0        0.0
    3    3 0.0        0.0        0.0        0.0        0.0        0.0
    4    8 0.0        0.0        0.0        0.0        0.0        0.0
    5    9 0.0        0.0        0.0        0.0        0.0        0.0
    6   10 0.0        0.0        0.0        0.0        0.0        0.0
    7   11 4.370E 03 0.0        0.0        0.0        0.0        0.0

GROUP  6   6 ISOTOPES - CRIT.ORGAN -11 - PROFAC 0.333 - DAYS1,2   365.  3650.  AGING  0.0       RDLIM(1,2)   0.500E 01  0.500E 02

ISO I NAME  -   TEFF            -  SDEE(1,2)          -  CF(1,2)
 1 10  MN-54         0.0          0.2774E-03    0.1696E-02
       1    1 9.510E 04          2    2 1.120E 05          3    3 1.120E 05          4    8 6.56CE C4
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    7   11 3.500E 02 0.0        0.0         0.0         0.0         0.0
 3 14   CO-57        0.1331E 02    0.2717E 08    0.1018E-03    0.1000E-08    0.2670E 03
    1    1 0.0         0.0         0.0         0.0         0.0         0.0
    2    2 0.0         0.0         0.0         0.0         0.0         0.0
    3    3 0.0         0.0         0.0         0.0         0.0         0.0
    4    8 0.0         0.0         0.0         0.0         0.0         0.0
    5    9 0.0         0.0         0.0         0.0         0.0         0.0
    6   10 0.0         0.0         0.0         0.0         0.0         0.0
    7   11 1.840E 02 0.0         0.0         0.0         0.0         0.0
 4 15   CO-58        0.1169E 02    0.6536E 07    0.5836E-04    0.1000E-08    0.1120E 03
    1    1 0.0         0.0         0.0         0.0         0.0         0.0
    2    2 0.0         0.0         0.0         0.0         0.0         0.0
    3    3 0.0         0.0         0.0         0.0         0.0         0.0
    4    8 0.0         0.0         0.0         0.0         0.0         0.0
    5    9 0.0         0.0         0.0         0.0         0.0         0.0
    6   10 0.0         0.0         0.0         0.0         0.0         0.0
    7   11 7.650E 02 0.0         0.0         0.0         0.0         0.0
 5 16   CO-60        0.1390E 02    0.1144E 07    0.2699E-05    0.1000E-08    0.4240E 03
    1    1 0.0         0.0         0.0         0.0         0.0         0.0
    2    2 0.0         0.0         0.0         0.0         0.0         0.0
    3    3 0.0         0.0         0.0         0.0         0.0         0.0
    4    8 0.0         0.0         0.0         0.0         0.0         0.0
    5    9 0.0         0.0         0.0         0.0         0.0         0.0
    6   10 0.0         0.0         0.0         0.0         0.0         0.0
    7   11 4.370E 03 0.0         0.0         0.0         0.0         0.0

GROUP  4   5 ISOTOPES - CRIT.ORGAN -11 - PROFAC 1.000 - DAYS1,2   365.   365.  AGING  0.140E 02 RCLIM(1,2)   0.5C0E C1  0.5C0E 01

ISO I NAME  -   TEFF          -  SDEE(1,2)          -  CF(1,2)
 1  1 H-3         0.1396E 02    0.8096E 08    0.1937E-02    0.1000E-08    0.418CE 02
    1    1 0.0         0.0         0.0         0.0         0.0         0.0
    2    2 0.0         0.0         0.0         0.0         0.0         0.0
    3    3 0.0         0.0         0.0         0.0         0.0         0.0
    4    8 0.0         0.0         0.0         0.0         0.0         0.0
    5    9 0.0         0.0         0.0         0.0         0.0         0.0
    6   10 0.0         0.0         0.0         0.0         0.0         0.0
    7   11 6.176E 01 0.0         0.0         0.0         0.0         0.0
 2 12   FE-55        0.1378E 02    0.1429E 08    0.6803E-01    0.1C00E-08    0.2100E CC
    1    1 0.0         0.0         0.0         0.0         0.0         0.0
    2    2 0.0         0.0         0.0         0.0         0.0         0.0
    3    3 0.0         0.0         0.0         0.0         0.0         0.0
    4    8 0.0         0.0         0.0         0.0         0.0         0.0
    5    9 0.0         0.0         0.0         0.0         0.0         0.0
    6   10 0.0         0.0         0.0         0.0         0.0         0.0
    7   11 3.500E 02 0.0         0.0         0.0         0.0         0.0
 3 14   CO-57        0.1331E 02    0.2717E 08    0.1598E 00    0.1000E-08    0.170CE CC
    1    1 0.0         0.0         0.0         0.0         0.0         0.0
    2    2 0.0         0.0         0.0         0.0         0.0         0.0
    3    3 0.0         0.0         0.0         0.0         0.0         0.0
    4    8 0.0         0.0         0.0         0.0         0.0         0.0
    5    9 0.0         0.0         0.0         0.0         0.0         0.0
    6   10 0.0         0.0         0.0         0.0         0.0         0.0
    7   11 1.840E 02 0.0         0.0         0.0         0.0         0.0
 4 15   CO-58        0.1169E 02    0.6536E 07    0.4357E-01    0.1000E-08    0.150CE CC
    1    1 0.0         0.0         0.0         0.0         0.0         0.0
    2    2 0.0         0.0         0.0         0.0         0.0         0.0
    3    3 0.0         0.0         0.0         0.0         0.0         0.0
    4    8 0.0         0.0         0.0         0.0         0.0         0.0
    5    9 0.0         0.0         0.0         0.0         0.0         0.0
    6   10 0.0         0.0         0.0         0.0         0.0         0.0
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ISO I NAME  -   TEFF              -  SDEE(1,2)            -  CF(1,2)
 1  1  H-3          0.1396E 02     0.5654E-03    0.8096E 08    0.1432E 03    0.1000E-08
    1    1 0.0        0.0          0.0           0.0           0.0           0.0
    2    2 0.0        0.0          0.0           0.0           0.0           0.0
    3    3 0.0        0.0          0.0           0.0           0.0           0.0
    4    8 0.0        0.0          0.0           0.0           0.0           0.0
    5    9 0.0        0.0          0.0           0.0           0.0           0.0
    6   10 0.0        0.0          0.0           0.0           0.0           0.0
    7   11 6.176E 01  0.0          0.0           0.0           0.0           0.0
 2 12  FE-55         0.1378E 02     0.2857E-01    0.1429E 08    0.5000E 00    0.1000E-08
    1    1 0.0        0.0          0.0           0.0           0.0           0.0
    2    2 0.0        0.0          0.0           0.0           0.0           0.0
    3    3 0.0        0.0          0.0           0.0           0.0           0.0
    4    8 0.0        0.0          0.0           0.0           0.0           0.0
    5    9 0.0        0.0          0.0           0.0           0.0           0.0
    6   10 0.0        0.0          0.0           0.0           0.0           0.0
    7   11 3.500E 02  0.0          0.0           0.0           0.0           0.0
 3 14  CO-57         0.1331E 02     0.5661E-01    0.2717E 08    0.4800E 00    0.1000E-08
    1    1 0.0        0.0          0.0           0.0           0.0           0.0
    2    2 0.0        0.0          0.0           0.0           0.0           0.0
    3    3 0.0        0.0          0.0           0.0           0.0           0.0
    4    8 0.0        0.0          0.0           0.0           0.0           0.0
    5    9 0.0        0.0          0.0           0.0           0.0           0.0
    6   10 0.0        0.0          0.0           0.0           0.0           0.0
    7   11 1.840E 02  0.0          0.0           0.0           0.0           0.0
 4 15  CO-58         0.1169E 02     0.1556E-01    0.6536E 07    0.4200E 00    0.1000E-08
    1    1 0.0        0.0          0.0           0.0           0.0           0.0
    2    2 0.0        0.0          0.0           0.0           0.0           0.0
    3    3 0.0        0.0          0.0           0.0           0.0           0.0
    4    8 0.0        0.0          0.0           0.0           0.0           0.0
    5    9 0.0        0.0          0.0           0.0           0.0           0.0
    6   10 0.0        0.0          0.0           0.0           0.0           0.0
    7   11 7.650E 02  0.0          0.0           0.0           0.0           0.0
 5 16  CO-60         0.1330E 02     0.2288E-02    0.1144E 07    0.5000E 00    0.1000E-08
    1    1 0.0        0.0          0.0           0.0           0.0           0.0
    2    2 0.0        0.0          0.0           0.0           0.0           0.0
    3    3 0.0        0.0          0.0           0.0           0.0           0.0
    4    8 0.0        0.0          0.0           0.0           0.0           0.0
    5    9 0.0        0.0          0.0           0.0           0.0           0.0
    6   10 0.0        0.0          0.0           0.0           0.0           0.0
    7   11 4.370E 03  0.0          0.0           0.0           0.0           0.0

GROUP  3   5 ISOTOPES - CRIT.ORGAN -11 - PROFAC 1.000 - DAYS1,2   365.   365.  AGING  0.140E 02 RDLIM(1,2)   0.500E 01  0.500E 01

ISO I NAME  -   TEFF              -  SDEE(1,2)            -  CF(1,2)
 1  1  H-3          0.1396E 02     0.8096E 08    0.1626E-02    0.1000E-08    0.4978E 02
    1    1 0.0        0.0          0.0           0.0           0.0           0.0
    2    2 0.0        0.0          0.0           0.0           0.0           0.0
    3    3 0.0        0.0          0.0           0.0           0.0           0.0
    4    8 0.0        0.0          0.0           0.0           0.0           0.0
    5    9 0.0        0.0          0.0           0.0           0.0           0.0
    6   10 0.0        0.0          0.0           0.0           0.0           0.0
    7   11 6.176E 01  0.0          0.0           0.0           0.0           0.0
 2 12  FE-55         0.1378E 02     0.1429E 08    0.3691E-02    0.1000E-08    0.3870E 01
    1    1 0.0        0.0          0.0           0.0           0.0           0.0
    2    2 0.0        0.0          0.0           0.0           0.0           0.0
    3    3 0.0        0.0          0.0           0.0           0.0           0.0
    4    8 0.0        0.0          0.0           0.0           0.0           0.0
    5    9 0.0        0.0          0.0           0.0           0.0           0.0
    6   10 0.0        0.0          0.0           0.0           0.0           0.0
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SUBGROUP CHRONIC
PARAMETER NEXP SET TG 6

GROUP 1 6 ISOTOPES - CRIT.ORGAN - 1 - PREFAC 1.000 - DAYS1,2 365. 3650. AGING 0.100E-02 RCLIM(1,2) 0.500E 01 0.500E 02

ISO	I	NAME	- TEFF.		- SDEE(1,2)		- CF(1,2)	
1	1	H-3	0.1000E-02	0.5495E 02	0.5495E 03	0.1000E-02	0.1000E-02	
	1	1	9.100E 01	0.0	0.0	0.0	0.0	
	2	2	9.100E 01	0.0	0.0	0.0	0.0	
	3	3	9.100E 01	0.0	0.0	0.0	0.0	
	4	8	5.460E 01	0.0	0.0	0.0	0.0	
	5	9	9.100E 01	0.0	0.0	0.0	0.0	
	6	10	9.100E 01	0.0	0.0	0.0	0.0	
	7	11	9.100E 01	0.0	0.0	0.0	0.0	
2	10	MN-54	0.1000E-02	0.2000E 00	0.2000E 01	0.1000E-02	0.1000E-02	
	1	1	2.500E 04	0.0	0.0	0.0	0.0	
	2	2	3.100E 03	0.0	0.0	0.0	0.0	
	3	3	2.700E 03	0.0	0.0	0.0	0.0	
	4	8	3.180E 03	0.0	0.0	0.0	0.0	
	5	9	3.100E 03	0.0	0.0	0.0	0.0	
	6	10	3.400E 03	0.0	0.0	0.0	0.0	
	7	11	3.600E 03	0.0	0.0	0.0	0.0	
3	12	FE-55	0.1000E-02	0.1852E 00	0.1852E 01	0.1000E-02	0.1000E-02	
	1	1	2.700E 04	0.0	0.0	0.0	0.0	
	2	2	2.500E 02	1.000E 01	0.0	0.0	0.0	0.0
	3	3	2.100E 02	1.000E 01	0.0	0.0	0.0	0.0
	4	8	4.080E 02	6.000E 00	0.0	0.0	0.0	0.0
	5	9	2.600E 02	1.000E 01	0.0	0.0	0.0	0.0
	6	10	2.600E 02	1.000E 01	0.0	0.0	0.0	0.0
	7	11	6.400E 02	2.000E 01	0.0	0.0	0.0	0.0
4	16	CO-60	0.1000E-02	0.4167E-02	0.4167E-01	0.1000E-02	0.1000E-02	
	1	1	1.200E 06	1.000E 05	0.0	0.0	0.0	0.0
	2	2	5.600E 04	1.000E 03	1.000E 03	0.0	0.0	0.0
	3	3	4.800E 04	2.000E 03	0.0	0.0	0.0	0.0
	4	8	1.624E 04	0.0	0.0	0.0	0.0	0.0
	5	9	5.800E 04	1.000E 03	1.000E 03	0.0	0.0	0.0
	6	10	6.400E 04	2.000E 03	1.000E 03	0.0	0.0	0.0
	7	11	7.900E 04	2.000E 03	1.000E 03	0.0	0.0	0.0
5	18	NI-63	0.1000E-02	0.3571E-01	0.3571E 00	0.1000E-02	0.1000E-02	
	1	1	1.400E 05	1.000E 04	1.000E 04	1.000E 04	1.000E 04	0.0
	2	2	9.500E 01	1.500E 01	0.0	0.0	0.0	0.0
	3	3	9.500E 01	1.500E 01	0.0	0.0	0.0	0.0
	4	8	1.140E 03	0.0	0.0	0.0	0.0	0.0
	5	9	9.500E 01	1.500E 01	0.0	0.0	0.0	0.0
	6	10	1.000E 02	2.000E 01	0.0	0.0	0.0	0.0
	7	11	2.100E 03	2.000E 02	2.000E 02	1.000E 02	1.000E 02	0.0
6	33	MO-93	0.1000E-02	0.4167E-01	0.4167E 00	0.1000E-02	0.1000E-02	
	1	1	1.200E 05	3.000E 04	1.000E 04	1.000E 04	2.000E 04	0.0
	2	2	2.300E 02	3.000E 01	3.000E 01	2.000E 01	2.000E 01	0.0
	3	3	3.500E 02	1.200E 02	7.000E 01	5.000E 01	6.000E 01	0.0
	4	8	6.000E 02	0.0	0.0	0.0	0.0	0.0
	5	9	7.500E 00	3.500E 00	2.000E 00	1.000E 00	2.000E 00	0.0
	6	10	6.300E 02	8.000E 01	6.000E 01	6.000E 01	5.000E 01	0.0
	7	11	2.300E 03	4.000E 02	3.000E 02	3.000E 02	2.000E 02	0.0

GROUP 2 5 ISOTOPES - CRIT.ORGAN -11 - PREFAC 1.000 - DAYS1,2 365. 365. AGING 0.140E 02 RCLIM(1,2) 0.500E 01 0.500E 01

SUBGROUP LATENT
PARAMETER NLAT SET TO 8

* * * INPUT LATENT HEALTH EFFECTS DATA * * *

ORGAN	EFFECT	MAN-RAD CONVERSION TO LATENT EFFECT FOR PERIODS (YEARS): <1	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	>80	ORGFAC
T MARROW	LEUKEMIA	2.840E-05	2.720E-05	1.870E-05	1.380E-05	9.700E-06	6.760E-06	4.030E-06	1.690E-06	4.800E-07	0.0	1.000E 00
LUNG	LUNG	2.217E-05	2.217E-05	2.217E-05	1.453E-05	8.130E-06	3.990E-06	1.500E-06	2.200E-07	0.0	0.0	1.000E 00
LLI WALL	GI TRK	1.364E-05	1.364E-05	1.364E-05	8.940E-06	5.000E-06	2.460E-06	9.200E-07	1.400E-07	0.0	0.0	1.000E 00
THYROID	THYROID	1.340E-04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000E 00
SKELETON	BONE	6.870E-06	6.700E-06	4.950E-06	2.600E-06	1.670E-06	9.100E-07	4.200E-07	1.270E-07	1.000E-08	0.0	1.000E 00
W BODY	BREAST	2.558E-05	2.558E-05	2.558E-05	1.677E-05	9.350E-06	4.600E-06	1.730E-06	2.500E-07	0.0	0.0	1.000E 00
OTHER	OTHER	2.501E-05	2.317E-05	2.048E-05	1.343E-05	8.520E-06	3.690E-06	1.390E-06	2.000E-07	0.0	0.0	1.000E 00
W BODY	W BODY	1.216E-04	1.185E-04	1.055E-04	7.010E-05	4.130E-05	2.240E-05	1.000E-05	2.600E-06	5.000E-07	0.0	1.000E 00

SUBGROUP ACUTE
PARAMETER NERL SET TO 6

* * * INPUT ACUTE HEALTH EFFECTS DATA * * *

ORGAN	DOSE BREAK-POINTS (RADS)				RESPECTIVE PROB. LIMITS		MORTALITY FACTOR
T MARROW	3.200E 02	4.000E 02	5.100E 02	6.150E 02	3.000E-02	5.000E-01	1.000E 00
LLI WALL	2.000E 03	5.000E 03	5.000E 03	5.000E 03	1.000E 00	1.000E 00	1.000E 00
LUNG	5.000E 03	1.480E 04	2.240E 04	2.400E 04	2.400E-01	7.300E-01	1.000E 00
W BODY	5.500E 01	1.500E 02	2.800E 02	4.700E 02	3.000E-01	8.000E-01	0.0
LUNG	3.000E 03	3.000E 03	6.000E 03	6.000E 03	5.000E-02	1.000E 00	0.0
LLI WALL	1.000E 03	1.000E 03	2.500E 03	2.500E 03	5.000E-02	1.000E 00	0.0

SUBGROUP EVACUATE
PARAMETER SET TO 0

* * * INPUT EMERGENCY ACTIONS DATA * * *

EVACON	MAXIMUM DISTANCE OF EVACUATION(M)	4.023E 04
EVACON	EVAC VEL (M/S) - ACCEL (NEG) (M/S/S)	5.360E-01
EVACON	TIME LAG BEFORE EVACUATION(DAYS)	0.0
EVACON	TRAVEL DISTANCE WHILE EVACUATING	8.045E 03
EVACON	ANGLE OF EVACUATED DOWNWIND SECTORS	4.500E 01
EVACON	EVACUATION DIRECT COST($/EVACUEE/DAY)	1.000E 02
EVACON	CRITERIA OF DURATION OF RELEASE FOR EVAC	2.000E 00
SHFAC	CLOUD SHIELDING WITH EVACUATION	1.000E 00
SHFAC	CLOUD SHIELDING WITHOUT EVACUATION	7.500E-01
SHFAC	GROUND SHIELDING WITH EVACUATION	5.000E-01
SHFAC	GROUND SHIELDING WITHOUT EVACUATION	3.300E-01
BRATE	BREATHING RATE	2.660E-04

SUBGROUP DISPERSE
PARAMETER SET TO 0

* * * INPUT BUILDING, WAKE, AND RAIN DATA * * *

BUILDL	REACTOR BUILDING LENGTH (M)	1.250E 02
BUILDH	REACTOR BUILDING HEIGHT (M)	4.500E 01
MWAKE	# OF INTERVALS FOR SPECIAL WAKE EFFECTS	0
LIRAIN	= 34, TURNS ON RAIN FOR THE LAST INTERVAL	0

SUBGROUP LEAKAGE
PARAMETER NPB2 SET TO 1

* * * INPUT ISOTOPIC LEAKAGE FRACTIONS * * *

1	AL	PROB-P(J,2)	TIME TO RELEASE	EXPANSION FACTOR	WARNING TIME	SENSIBLE HEAT (CAL/SEC)	RELEASE HEIGHT
		1.000E 00	1.000E 00	1.260E 00	5.000E-01	0.0	1.000E 02

GROUP - LEAKAGE FRACTION 1-1.00E-05 2-0.0

SUBGROUP ISOTOPE
PARAMETER NIS SET TO 36

* * * INPUT ISOTOPES * * *

NUMBER	NAME	GROUP	PARENT	INITIAL(CURIES)	HALF-LIFE(DAYS)	DEPOSITION VELOCITY(M/SEC)	RAIN COEF.(SEC-1)
1	H-3	2		1.000E 08	4.493E 03	1.000E-03	1.000E-05
2	CA-45	1		2.540E 04	1.630E 02	1.000E-02	1.000E-04
3	SC-46	1		4.060E 04	8.380E 01	1.000E-02	1.000E-04
4	SC-47	1		5.570E 04	3.400E 00	1.000E-02	1.000E-04
5	SC-48	1		8.360E 04	1.833E 00	1.000E-02	1.000E-04
6	TI-45	1		2.880E 03	1.283E-01	1.000E-02	1.000E-04
7	V-49	1	CR-49	2.330E 06	3.300E 02	1.000E-02	1.000E-04
8	CR-49	1		7.360E 05	2.900E-02	1.000E-02	1.000E-04
9	CR-51	1		1.350E 08	2.780E 01	1.000E-02	1.000E-04
10	MN-54	1		7.840E 07	3.120E 02	1.000E-02	1.000E-04
11	MN-56	1		2.060E 08	1.075E-01	1.000E-02	1.000E-04
12	FE-55	1		6.840E 08	8.766E 02	1.000E-02	1.000E-04
13	FE-59	1		2.960E 05	4.500E 01	1.000E-02	1.000E-04
14	CO-57	1	NI-57	3.950E 07	2.720E 02	1.000E-02	1.000E-04
15	CO-58	1		1.170E 08	7.100E 01	1.000E-02	1.000E-04
16	CO-60	1		2.590E 07	1.914E 03	1.000E-02	1.000E-04
17	NI-57	1		7.060E 06	1.500E 00	1.000E-02	1.000E-04
18	NI-63	1		2.470E 05	3.360E 04	1.000E-02	1.000E-04
19	SR-89	1		0.0	5.060E 01	1.000E-02	1.000E-04
20	Y-88	1		0.0	1.070E 02	1.000E-02	1.000E-04
21	Y-90	1		0.0	2.675E 00	1.000E-02	1.000E-04
22	Y-91	1		0.0	5.900E 01	1.000E-02	1.000E-04
23	ZR-89	1		2.450E 05	3.267E 00	1.000E-02	1.000E-04
24	ZR-95	1		7.150E 04	6.500E 01	1.000E-02	1.000E-04
25	ZR-97	1		1.430E 04	7.080E-01	1.000E-02	1.000E-04
26	NB-91M	1		0.0	6.200E 01	1.000E-02	1.000E-04
27	NB-92M	1		5.510E 05	1.020E 01	1.000E-02	1.000E-04
28	NB-93M	1	MO-93	1.250E 04	4.967E 03	1.000E-02	1.000E-04
29	NB-95M	1	ZR-95	1.060E 05	3.625E 00	1.000E-02	1.000E-04
30	NB-95	1	NB-95M	3.300E 05	3.500E 01	1.000E-02	1.000E-04
31	NB-96	1		1.520E 05	9.750E-01	1.000E-02	1.000E-04
32	NB-97	1	ZR-97	1.080E 05	5.000E-02	1.000E-02	1.000E-04
33	MO-93	1		6.740E 04	1.278E 06	1.000E-02	1.000E-04
34	MO-99	1		1.610E 07	2.750E 00	1.000E-02	1.000E-04
35	TC-99M	1	MO-99	0.0	2.500E-01	1.000E-02	1.000E-04
36	TA-182	1		0.0	1.150E 02	1.000E-02	1.000E-04

SUBGROUP ECONOMIC
PARAMETER SET TC 1

DCFLD	DECONTAM. COST OF FARM FIELDS ($/ACRE)	2.300E 02
DCRBP	DECONTAM. COST OF RESID.,BUSI.,PUB. AREA	1.700E 03
RATE	COMPENSATION RATE	2.000E-01
VRBP	VALUE OF RESIDENTIAL,BUSINESS,AND PUBLIC AREA	1.700E 04
CRELOC	RELOCATION COST ($/PERSON)	2.900E 03
CONMLK	COST OF MILK CONSUMPTION ($/PERSON)	3.700E 01
CONCRP	COST OF NON-DAIRY PRODUCTS CONSUMED ($/PERSON)	2.400E 02

* * * AGRICULTURAL DATA * * *

	STATE	SEEDING MONTH	HARVESTING MONTH	FARM LAND FRACTION	DAIRY PROD. FRACTION	ANNUAL SALES	VALUE OF FARM
1	AVERAGE	5	9	0.400	0.250	150.0000	1000.0000

```
                1 1.0     1 1.0     1 1.0     1 1.0
14              1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0
                1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0
                1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0
                1 1.0     1 1.0     1 1.0     1 1.0
15              1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0
                1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0
                1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0
                1 1.0     1 1.0     1 1.0     1 1.0
16              1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0
                1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0
                1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0     1 1.0
                1 1.0     1 1.0     1 1.0     1 1.0
```

SUBGROUP TOPOG
PARAMETER SET TO 0

* * * STATE CODE AND HABITABLE LAND FRACTION FOR EACH AREA ELEMENT * * *

SECTOR	STATE AND LAND FRACTION									
1	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0						
2	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0						
3	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0						
4	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0						
5	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0						
6	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0						
7	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0						
8	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0						
9	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0						
10	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0						
11	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0						
12	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0						
13	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0
	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0	1 1.0

SUBGROUP POP
PARAMETER NPB4 SET TC 1

1 SECTOR WITH UNIFORM POPULATION DENSITY = 2.00E 02 PEOPLE PER SQUARE MILE WILL BE RUN.
AN EXCLUSION RADIUS OF 1.00E 02 METERS IS SPECIFIED

* * * INPUT POPULATION DATA * * *

INDEX	SECTOR	PROBABILITY	POPULATION BY SPATIAL INTERVAL									
1	1	1.00E 00	9.82E 00	2.95E 01	4.91E 01	6.88E 01	8.84E 01	1.08E 02	1.28E 02	1.47E 02	1.67E 02	1.87E 02
			4.32E 02	5.11E 02	9.13E 02	1.09E 03	2.21E 03	2.70E 03	3.19E 03	3.68E 03	8.84E 03	1.08E 04
			1.28E 04	1.47E 04	1.67E 04	1.87E 04	2.06E 04	2.26E 04	2.46E 04	2.65E 04	9.13E 04	1.09E 05
			4.91E 05	6.88E 05	3.24E 06	5.01E 06						

```
 SUBGROUP SITE
 PARAMETER NPBJ SET TO      1


                    * * * INPUT SITE AND TRIAL DATA * * *

          SITE NUM      PROBABILITY      START CODE MO DA HR IPOP

** INVALID SITE NUMBER.  1ST SITE USED **
          SITE 1             1.0000                  9  0  0  0  0

NSTAB, NVEL, NRA (1=NO RAIN ONLY, 2=RAIN & NO RAIN)
     3    3    1

STABILITY CLASSES -
    1    4    6

VELOCITIES -
0.334E 01 0.300E 01 0.206E 01

PROBABILITY MATRIX FOR NSTAB*NVEL*NRA WEATHER TYPES
0.120E 00 0.0        0.0        0.0        0.520E 00 0.0        0.0        0.0
0.360E 00

MAX CLOUD HEIGHT - UNSTABLE AND STABLE     0.135E 04   0.550E 03
```

SUBGROUP SPATIAL
PARAMETER NNSI SET TC 34

* * * SPATIAL MESH DESCRIPTION * * *

REGION	OUTER RADIUS(M)	AVG. RADIUS(M)	AREA(M**2)	OUTER RADIUS(MI)	AVG. RADIUS(MI)	AREA(MI**2)
1	8.05E 02	4.02E 02	1.27E 05	5.00E-01	2.50E-01	4.91E-02
2	1.61E 03	1.21E 03	3.81E 05	1.00E 00	7.50E-01	1.47E-01
3	2.41E 03	2.01E 03	6.36E 05	1.50E 00	1.25E 00	2.46E-01
4	3.22E 03	2.82E 03	8.90E 05	2.00E 00	1.75E 00	3.44E-01
5	4.02E 03	3.62E 03	1.14E 06	2.50E 00	2.25E 00	4.42E-01
6	4.83E 03	4.43E 03	1.40E 06	3.00E 00	2.75E 00	5.40E-01
7	5.63E 03	5.23E 03	1.65E 06	3.50E 00	3.25E 00	6.38E-01
8	6.44E 03	6.04E 03	1.91E 06	4.00E 00	3.75E 00	7.37E-01
9	7.24E 03	6.84E 03	2.16E 06	4.50E 00	4.25E 00	8.35E-01
10	8.05E 03	7.64E 03	2.42E 06	5.00E 00	4.75E 00	9.33E-01
11	8.66E 03	8.85E 03	5.59E 06	6.00E 00	5.50E 00	2.16E 00
12	1.13E 04	1.05E 04	6.61E 06	7.00E 00	6.50E 00	2.55E 00
13	1.37E 04	1.25E 04	1.18E 07	8.50E 00	7.75E 00	4.57E 00
14	1.61E 04	1.49E 04	1.41E 07	1.00E 01	9.25E 00	5.45E 00
15	2.01E 04	1.81E 04	2.86E 07	1.25E 01	1.12E 01	1.10E 01
16	2.41E 04	2.21E 04	3.50E 07	1.50E 01	1.37E 01	1.35E 01
17	2.82E 04	2.62E 04	4.13E 07	1.75E 01	1.62E 01	1.60E 01
18	3.22E 04	3.02E 04	4.77E 07	2.00E 01	1.87E 01	1.84E 01
19	4.02E 04	3.62E 04	1.14E 08	2.50E 01	2.25E 01	4.42E 01
20	4.83E 04	4.43E 04	1.40E 08	3.00E 01	2.75E 01	5.40E 01
21	5.63E 04	5.23E 04	1.65E 08	3.50E 01	3.25E 01	6.38E 01
22	6.44E 04	6.04E 04	1.91E 08	4.00E 01	3.75E 01	7.37E 01
23	7.24E 04	6.84E 04	2.16E 08	4.50E 01	4.25E 01	8.35E 01
24	8.05E 04	7.64E 04	2.42E 08	5.00E 01	4.75E 01	9.33E 01
25	8.85E 04	8.45E 04	2.67E 08	5.50E 01	5.25E 01	1.03E 02
26	9.66E 04	9.25E 04	2.92E 08	6.00E 01	5.75E 01	1.13E 02
27	1.05E 05	1.01E 05	3.18E 08	6.50E 01	6.25E 01	1.23E 02
28	1.13E 05	1.09E 05	3.43E 08	7.00E 01	6.75E 01	1.33E 02
29	1.37E 05	1.25E 05	1.18E 09	8.50E 01	7.75E 01	4.57E 02
30	1.61E 05	1.49E 05	1.41E 09	1.00E 02	9.25E 01	5.45E 02
31	2.41E 05	2.01E 05	6.36E 09	1.50E 02	1.25E 02	2.46E 03
32	3.22E 05	2.82E 05	8.90E 09	2.00E 02	1.75E 02	3.44E 03
33	5.63E 05	4.43E 05	4.20E 10	3.50E 02	2.75E 02	1.62E 04
34	8.05E 05	6.84E 05	6.48E 10	5.00E 02	4.25E 02	2.50E 04

**** CALCULATION OF REACTOR ACCIDENT CONSEQUENCES -- C R A C ****

REFERENCE DATA

C