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ANTI - A SCALING CODE FOR NEUTRON TRANSPORT THROUGH THE ATMOSPHERE

James G. Bevelock, et al

Picatinny Arsenal
Dover, New Jersey

August 1972

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13 ABSTRACT
ANT-1 is a computer program which uses existing transport data given at sea level to determine the energy spectrum of neutrons transported from a given source to a receptor. As an option, the program can list in a convenient format the complete set of transport data build into the program and also the transport data at the equivalent sea level distance between the given source and receptor.

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ANTI - A Scaling Code for Neutron Transport Through the Atmosphere

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MANAGEMENT INFORMATION SYSTEMS DIRECTORATE

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DOVER, NEW JERSEY

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ABSTRACT

ANTI is a computer program which scales existing neutron transport data given at sea level to determine the energy spectrum of neutrons transported from a given source to a receptor. The energy spectrum can be determined over wide ranges of altitude and distances of separation between source and receptor. The basic transport data was obtained from Moments Methods runs by Kaman Sciences Corporation and Monte Carlo results reported by Braddock, Dunn and McDonald.

INTRODUCTION

The computer program ANTI was written at the request of the Nuclear Effects Branch[1], Engineering Sciences Laboratory, (ESL), Feltman Research Laboratory. The model was formulated by Dr. F. J. Jankowski who was a consultant to ESL.

The code was developed to provide an inexpensive but reliable means of obtaining the flux distribution caused by a neutron source in the atmosphere. ANTI results were compared against the original source of the transport data (ref 1), as well as against various other air transport studies. These checks gave quite acceptable agreement.

ANTI computes the flux and energy spectrum of neutrons transported from a given source to a receptor. The difficult problem of neutron transport is handled by scaling existing transport data given at sea level (see ref 1). The transport table provides the code with previously calculated flux data out to a distance of 6500 feet at sea level (approx. 17 mean free paths for a 14 Mev neutron). The flux data is tabulated for 33 discrete ranges from 0 to 6500 feet. Interpolation techniques make it possible to find the flux at any given range less than 6500 feet. For longer distances an extrapolation procedure is employed.

The program can list in a convenient format the complete set of transport data built into the program. The transport table may be expanded or replaced to include additional data should it become available.

ANTI is written in FORTRAN IV for the IBM 360/65 and the CDC 6500 computers.

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[1]Nuclear Effects Br. is now the Threat and Susceptibility Br., Concepts and Effectiveness Division, Nuclear Development and Engineering Directorate (NDED).

MATHEMATICAL MODEL

The computer program ANTI is used to calculate the flux and energy spectrum of neutrons which a target (receptor) receives from a given nuclear detonation (source). The geometry is illustrated in Figure 1.

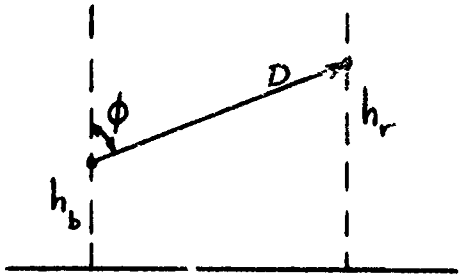


FIGURE 1 (Geometry of Problem)

where

h_b is the altitude of the source.

h_r is the altitude of the receptor.

D is the distance between the source and receptor.

ϕ is the angle between the vertical axis and the vector from the source to the receptor.

The source spectrum is specified for a set of discrete energy levels $\{SL(i), i = 1,n\}$. The number of neutrons $\{N_S(i)\}$ is specified at each energy level or within each interval of the given spectrum.

As the neutrons travel from the source to the receptor, they interact with the atmosphere; this interaction is a function of the distance traveled and the density of air along the trajectory of the neutrons. The program assumes the attenuation along the given path (not including the inverse square attenuation) is the same as the attenuation the neutrons encounter in traveling a distance D_0 at sea level. From reference (1) D_0 is computed as

$$D_o = \frac{1}{\rho_o} \int_0^D \rho(r)dr \tag{1}$$

where

ρ_o is the density of air at sea level.

$\rho_{(r)}$ is the density of air at the distance r from the source.

In ANTI, the density of air is a function of altitude only.

(1) is computed as

$$D_o = \frac{1}{\rho_o \cos\phi} \int_{h_b}^{h_r} \rho(h)dh \tag{2}$$

using the transformation

$$r = \frac{h}{\cos\phi} \tag{3}$$

The density of air is built into the program for discrete values of altitude which range from 0 ft to 200,000 ft in increments of 10,000 ft (reference 2). Between two adjacent altitudes, the density is assumed to be of the form

$$\rho(h) = \rho(h_i) \text{ EXP } \{\frac{h - h_i}{S_i}\} \tag{4}$$

where

$\rho(h)$ is the density of air at the altitude h.

i denotes the interval in the table of air densities in which h lies.

h_i is the lower altitude of the i^{th} interval.

S_i is inverse of the slope of log (h) in the i^{th} interval.

In general, the source and receptor may be located in different intervals. Therefore, it is necessary to carry out the integration in (3) as the sum of integrals over each interval. That is

$$(5) \quad D_o = \frac{1}{\rho_o \cos \phi} \left[\int_{h_b}^{h_{i+1}} \rho(h)dh + \sum_{j=i+1}^{N_K-1} \int_{h_j}^{h_{j+1}} \rho(h)dh + \int_{h_{N_K}}^{h_r} \rho(h)dh \right]$$

where N_K is the interval in which the receptor lies and the source is in the i^{th} interval.

Within the j^{th} interval, equation (4) can be integrated analytically as

$$(6) \quad D_o\,(j) = \frac{\rho(h_j)\,S_j}{\rho_o \cos \phi} \left[\mathrm{EXP}\left\{\frac{h_{j+1}-h_j}{S_j}\right\} - 1 \right]$$

It is obvious that in an actual case, the only variable in equation (6) which changes if the integration is over a full interval is ϕ. Therefore, COS $D_o(j)$ was computed for each interval in the air density table and built into the program as a table. For a given engagement, ANTI first determines which intervals the source and receptor are located within and evaluates the first and last integrals in (5). The integrals in the sum are obtained by multiplying the tabular values of $D_o(j)$ cosϕ by $\frac{1}{\cos\phi}$.

Transport data from reference 1 and 2 are built into the program in the form of tables. The tables give the probability of neutrons (flux multiplied by $4\pi D_o^2$) being transported from the source to the receptor as a function of source energy* ST(j), receptor energy interval** RT(i), and distance between the source and receptor R. The values for R = 1042 m are illustrated in Table 1. Data is given for 33 values for R between 0 ft and 6500 ft. The distances were selected so that the spacing was fine close to zero and increased at the distances close to 6500 ft. The reason for this is that the D_o will not necessarily be one of the tabulated R values and logarithmic interpolation is used to determine the transport at D_o, if D_o is less than 6500 ft. If D_o is greater than 6500 feet, logarithmic extrapolation is used to determine the transport table at D_o.

Once D_o and the corresponding table of receptor flux (function of source and receptor energy interval) are calculated, it remains to determine the transport of the given source. In general, the given source spectrum is not the same as the source spectrum in the transport table. This is overcome by the following interpolation scheme. Let

{SL(i) i = 1,n} be the energy levels in the given source spectrum (or the upper bound of the energy level, for continuous spectra).

{ST(j) j = 1,m} be the source energy levels in the transport table (or the upper bound of the energy level for continuous spectra).

$N_s(i)$ be the number of neutrons within the i^{th} energy level.

---

*ST(j) is the upper bound of the interval if continuous spectrum is specified.

**RT(i) is the upper bound of the energy interval in which the neutron appears at the receptor.

TABLE 1

RC = 104230.94 CM

	14.-12.	12.-10.	10.-8.	8.-5.	5.-3.	3.-1.4	1.4-.75	.75-.4	.4-.1	.1-.025	.025-.01	.01-.004
14.000-12.000	.54E-02	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12.000-10.000	.21E-02	.55E-02	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10.000- 8.000	.24E-02	.17E-02	.72E-02	0.	0.	0.	0.	0.	0.	0.	0.	0.
8.000- 6.300	.27E-02	.16E-02	.28E-02	.12E-01	0.	0.	0.	0.	0.	0.	0.	0.
6.300- 5.000	.29E-02	.35E-02	.20E-02	.74E-02	0.	0.	0.	0.	0.	0.	0.	0.
5.000- 3.000	.46E-02	.11E-01	.91E-02	.90E-02	.17E-03	0.	0.	0.	0.	0.	0.	0.
3.000- 2.500	.50E-02	.57E-02	.59E-02	.73E-02	.12E-01	.28E-02	0.	0.	0.	0.	0.	0.
2.500- 1.400	.18E-01	.15E-01	.18E-01	.18E-01	.51E-01	.25E-01	0.	0.	0.	0.	0.	0.
1.400- 1.000	.72E-02	.97E-02	.14E-01	.89E-02	.25E-01	.19E-01	.78E-03	0.	0.	0.	0.	0.
1.000- .750	.12E-01	.15E-01	.12E-01	.15E-01	.26E-01	.19E-01	.11E-02	0.	0.	0.	0.	0.
.750- .400	.23E-01	[illegible]	.23E-01	.25E-01	.55E-01	.60E-01	.76E-02	[illegible]	0.	0.	0.	0.
.400- .200	.14E-01	.21E-01	.20E-01	.18E-01	.49E-01	.54E-01	.87E-02	.18E-02	.81E-04	0.	0.	0.
.200- .100	.18E-01	.23E-01	.23E-01	.22E-01	.44E-01	.48E-01	.13E-01	.46E-02	.13E-03	0.	0.	0.
.100- .025	.35E-01	.39E-01	.51E-01	.47E-01	.87E-01	.87E-01	.25E-01	.73E-02	.11E-03	.91E-05	0.	0.
.025- .010	.21E-01	.27E-01	.27E-01	.30E-01	.50E-01	.59E-01	.17E-01	.52E-02	.18E-02	.92E-05	.10E-05	0.
.010- .004	.19E-01	.24E-01	.25E-01	.37E-01	.51E-01	.52E-01	.23E-01	.10E-01	.10E-02	.80E-07	.20E-05	.21E-07

The following conventions are required in the program:

$SL(1) > SL(2) > . . . > SL(n)$

$ST(1) > ST(2) > . . . > ST(m)$

SL(1) = ST(1) (=14 Mev in the initial program)

SL(2) = ST(2) (=12 Mev in the initial program)

$SL(n) \geq ST(m)$

The maximum and minimum energy bounds that a neutron may have are 14 Mev and .004 Mev respectively. That is:

$$.004 < SL(i) \leq 14 \text{ MEV}$$

Neutrons with energies below .004 Mev are ignored.

From the given source data, the program generates a curve which gives the number of neutrons with energy greater than a given energy level {NGS(i)} as a function of energy level. From the restrictions above, the number greater than 14 Mev must be 0. NGS(i) is computed as

$$NGS(i) = \sum_{K=1}^{i} N_S(K) \qquad (7)$$

In equation (7) i, the index of NGS, refers to the lower bound of the i^{th} energy interval.

The number of neutrons greater than the j^{th} energy level in the transport table NGT(j) is obtained by the following interpolation formula

$$NGT(j) = NGS(i-1) + \frac{NGS(i)-NGS(i-1)}{SL(i)-SL(i-1)} \cdot \{ST(j)-SL(i-1)\} \qquad (8)$$

if

$$SL(i-1) > ST(j) \geq SL(i) \quad i = 2,3,\ldots,n \quad j = 2,3,\ldots,m$$

The number and intensity of neutrons at the source in terms of the source spectrum in the transport tables is calculated as

$$N_{ST}(j) = NGT(j) - NGT(j-1) \quad j = 2,3,\ldots,m \tag{9}$$

$$N_{ST}(1) = NGT(1) = NGS(1) = N_S(1)$$

Equations (7), (8), and (9) are used to convert the given source data to correspond to the source spectrum in the transport table. The neutron flux received by the target from the given source is then calculated as

$$\phi_T(j) = \frac{1}{4\pi D^2} \sum_{K=1}^{n-1} N_{ST}(K)\, \phi(K,j) \tag{10}$$

$\phi(k,j)$ is the previously mentioned probability of a neutron starting out in energy interval K ending up in energy interval j after traversing an equivalent sea level distance D_o.

D is the distance R between burst point and receptor.

$\phi_T(j)$ is the neutron flux at the receptor with energies in the j^{th} interval. The energy intervals correspond to the receptor spectrum in the transport table. Equations (7), (8), and (9) can be used to convert this data to any desired spectrum for output purposes.

SUMMARY OF PROGRAM CAPABILITY

(1) The source spectrum may have up to 25 energy intervals (ranging from 14 Mev to .004 Mev).

(2) For each energy interval, the program will accept either the number of neutrons, the number of neutrons per kiloton or the fraction of the total number of neutrons at the source having the given energy.

(3) If this data is normalized to one kiloton, then the number of kilotons at the source must be specified.

(4) The altitude of the source (h_b), the altitude of the receptor (h_r) the distance between the source and the receptor (D) and the number of kilotons (nkt) at the source can be parameterized respectively while reading the source spectrum once. The maximum number of variations are 20 values of hb, 20 values of hr, 30 values of D, and 10 values of nkt.

(5) The maximum number of cases handled can be easily increased by increasing the dimension of the appropriate variable array.

(6) The transport data at sea level is built into the program and can be modified in a straight-forward manner as more accurate data is obtained.

(7) An option exists in the program to print the transport data at sea level which is built into the program.

(8) An option exists in the program to print the transport data at sea level for the given source and receptor conditions.

(9) The given source spectrum does not have to be the same as the source spectrum in the transport table.

(10) The spectrum, printed out, does not have to be the same as the given source spectrum in the transport table.

DESCRIPTION OF INPUT

This section describes the input procedure necessary to use ANTI. The column headed "Card Set" refers to one or more cards of the same type and the cards are arranged in the order of card sets. The column headed "Symbol" gives the variable name used in the program. The column headed "Card Column" gives the column(s) in which the numerical value is punched. The column headed "Definition" describes the meaning of the symbol in the program. The column headed "Units" defines the units that the program assumes for the variable. Some symbols refer to an array name. In this instance a subscript is printed after the symbol and the "Conversion" Column describes the field width of the card. If more than one card is necessary to describe the array, additional cards are added using the same format as the first card.

CARD SET	SYMBOL	CARD COL.	CONVERSION	DEFINITION	UNITS
1	JTABS	1	I1	Control to print transport data JTABS= 0 do not print JTABS= 1 print	-
1	NTRT	2	I1	Control to print transport data for specified equivalent sea level ranges NTRT= 0 do not print NTRT= 1 print	-
1	NRANGE	3	I1	Option to determine range for a specified flux value NRANGE= 0 do not use option NRANGE= 1 use option	-
2	PHI	1-10	E10.3	Only use if NRANGE=1. Value of specified 1-Mev equivalent flux.	-
3	NSOR	1-3	I3	Number of source altitudes to be considered (maximum of 20)	-
3	NREC	4-6	I3	Number of receptor altitudes to be considered per source altitude (maximum of 20)	-
3	NDSR	7-9	I3	Number of distances between each source and each receptor (Maximum of 30)	-

EXAMPLE: If NSOR=2, NREC=3, NDSR=4, then 24 separate cases will be calculated.

CARD SET	SYMBOL	CARD COL.	CONVERSION	DEFINITION	UNITS
3	NSIT	10-12	I3	Number of source energy levels (maximum of 25)	-
3	NSST	13-15	I3	Control to specify source energy levels different than that of transport data NSST= 0 energy levels are the same as transport data. NSST = 1 energy levels are different than transport data.	-

CARD SET	SYMBOL	CARD COL.	CONVERSION	DEFINITION	UNITS
3	NOPD	16-18	I3	Control to print energy levels at the receptor different than transport data NOPD= 0 Output spectrum is the same as the transport data. NOPD= 1 output spectrum is different than the transport data.	-
3	NNTSD	19-21	I3	If source is normalized to 1KT, NNTSD is the number of sources to consider with number of KT≠1.	-

EXAMPLE: If the source is 3KT, then the energy is determined by 3x(results for 1KT).

CARD SET	SYMBOL	CARD COL.	CONVERSION	DEFINITION	UNITS
3	NPCT	22-24	I3	Option to specify the fraction of the total neutron flux. NPCT= 0 source spectrum is specified as the neutrons per energy level. NPCT= 1 source spectrum is specified as the fraction of the total neutron flux.	-
4	AHSØRC(I)	1-70	7F10.3	The altitudes of the source to be considered (I=1, NSOR)	ft.
5	SSPCTR(I)	1-70	7F10.3	The energy levels of the given source in decreasing order (I=1,NSIT).	Mev

NOTE: Omit card sets 6 and 7 if NOPD=0

CARD SET	SYMBOL	CARD COL.	CONVERSION	DEFINITION	UNITS
6	NOSS	1-3	I3	The number of energy intervals in the output spectrum plus 1.	-
7	OSRID(I)	1-70	7F10.3	The energy levels of the output spectrum (I=1, NOSS)	Mev

CARD SET	SYMBOL	CARD COL.	CONVERSION	DEFINITION	UNITS

NOTE: Card sets 8 and 9 have two options.

Option 1: If NPCT=1

8	TNNTS	1-10	F10.3	The total number of neutrons at the source	-
9	PCTNT(I)	1-70	7F10.3	The fraction of the total flux in the Ith energy interval at the source (I=1,NSIT-1)	-

Option 2: If NPCT=0

8	ANNTS(I)	1-70	7F10.3	The neutron flux at the source having energy in the Ith interval (I=1, NSIT-1)	-

Card set 9 is omitted.

NOTE: Card set 10 used only if NNTSD > 0

10	SSNKT(I)	1-70	7F10.3	The number of kilotons for the Ith source (I=1, NNTSD)	Kt
11	AHREC(I)	1-70	7F10.3	The altitude of the Ith receptor (I=1, NREC)	ft
12	DRSR(I)	1-70	7F10.3	The Ith distance between the source and receptor (I=1, NREC)	cm

NOTE: Card sets 11 and 12 are repeated for each source altitude to be considered (i.e. repeat NSOR times).

13	RATS	1-4	A4	"RATS" is punched in columns 1 through 4 and signifies the end of all input data	-

SAMPLE INPUT

```
CARD FIELD   1         2         3         4         5         6         7
CARD COLUMN  1234567890123456789012345678901234567890123456789012345678901234567890   CARD NO.

             010                                                                     1
               2  2  2  6  1  1  2  1                                                2
             10000.    20000.                                                        3
             14.       12.       8.3       3.0       1.0       0.1                   4
              6                                                                      5
             14.       12.       8.3       3.0       1.0       0.1                   6
             1.0    E20                                                              7
             .5        .3        .1        .1                                        8
             1.        100.                                                          9
             10000.    15000.                                                        10
             1.8    E05 2.0   E06                                                    11
             20000.    15000.                                                        12
             1.8    E05 2.0   E06                                                    13
             RATS                                                                    14
```

DESCRIPTION OF OUTPUT

Basically ANTI computes the flux and energy spectrum of neutrons which a receptor receives from a given source. In addition to this data, ANTI also prints a listing of all the input parameters, the complete transport data as an option, and the transport table for the equivalent sea level range (D_o).

The initial output is a complete listing of all the input data (card images). This is done by first storing an input card onto a disk and then printing the card before a new card is read. Then the data for an individual case are read from the disk.

If the option to print the complete transport table is selected, this data will appear next (JTABS=1). The transport data for one value of range is printed on each page. The first line contains the range value in feet. The next line contains the source of the receptor spectrum. The entries in the table are then the fraction of neutrons (flux multiplied by $4\pi D_o{}^2$) transported from the source to the receptor. This data is repeated for each range value (33 pages of output).

A second option (NTRT=1) is to print the transport table for the equivalent sea level distance (D_o). The format for this output is the same as above except R_o is printed on the first line of the page.

Finally the basic output is printed. This consists of the neutron spectra for each set of source (burst) altitude, receptor altitude, source-to-receptor slant range and yield (KT).

A row of summary information is listed. This includes values for each of the parameters above and the equivalent sea level range (D_0). Next tables of flux (nt/cm^2) and total neutrons by energy group are printed. These are supplemented by tables of direct flux (if NSST equals zero) or scattered flux (if NSST equals zero and output energy boundaries correspond to all twelve source energy **boundaries).**

NOTE: NET FLUX = DIRECT + SCATTERED

The final output consists of summations over all energy groups of total fluence, one-Mev equivalent flux, and RADS.

SAMPLE OUTPUT

HO = 132946.36 CM

	14.-12.	12.-10.	10.-8.	8.-5.	5.-3.	3.-1.4	1.4-.75	.75-.4	.4-.1	.1-.025	.025-.01	.01-.004
14,000-12,000	.12E-02	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12,000-10,000	.49E-03	.13E-02	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10,[illegible]-[illegible],000	.57E-03	.47E-03	.19E-02	0.	0.	0.	0.	0.	0.	0.	0.	0.
8,000- [illegible]	.92E-03	.36E-03	.10E-02	.35E-02	0.	0.	0.	0.	0.	0.	0.	0.
6,300- 5,000	.86E-03	.11E-02	.46E-03	.22F-02	0.	0.	0.	0.	0.	0.	0.	0.
5,000- 3,000	.94E-03	.33F-02	.34E-02	.35F-02	.47E-07	0.	0.	0.	0.	0.	0.	0.
3,000- 2,500	.17E-02	.17E-02	.18E-02	.34E-02	.34E-02	.29E-03	0.	0.	0.	0.	0.	0.
2,500- 1,400	.52E-02	.44E-02	.68E-02	.51E-02	.22E-01	.66F-02	0.	0.	0.	0.	0.	0.
1,400- 1,000	.21E-02	.27E-02	.42E-02	.18E-02	.58E-02	.59E-02	.54E-04	0.	0.	0.	0.	0.
1,000- .750	.49E-02	.50E-02	.38E-02	.46E-02	.88E-02	.45E-02	.13E-03	0.	0.	0.	0.	0.
.750- .400	.83E-02	.46E-02	.74E-02	.83E-02	.21E-01	.14E-01	.83E-03	.23E-05	0.	0.	0.	0.
.400- .200	.44E-02	.55E-02	.56E-02	.53E-02	.11E-01	.13E-01	.14E-02	.18E-03	.39E-05	0.	0.	0.
.200- .100	.55E-02	.20E-02	.65E-02	.61E-02	.16E-01	.13E-01	.15E-02	.66E-03	.57E-05	0.	0.	0.
.100- .025	.13E-01	.12E-01	.22E-01	.18E-01	.35E-01	.24E-01	.20E-02	.75E-03	.96F-07	.17E-06	0.	0.
.025- .010	.11E-01	.11E-01	.10E-01	.11E-01	.22E-01	.21E-01	.33E-02	.41E-03	.16F-03	.15E-06	.13E-07	0.
.010- .004	.76F-02	.12E-01	.10E-01	.14F-01	.26E-01	.13E-01	.28E-02	.19E-02	.65F-04	.22F-11	.25F-07	.59E-10

RESULTS

SOURCE HT = 10000.0 FT. TARGET HT = 10000.0 FT. SLANT RANGE = 180000. CM. STP RANGE = 132946. CM. = OF KTON = 1.0

(ENERGY IN MEV. FLUX IN NT/SQCM)

ENERGY RANGE		NET FLUX	FLUX*AREA	DIRECT	SCATTERED
12.000	14.000	.153E+06	.622E+17		
8.300	12.000	.245E+06	.997E+17		
3.000	8.300	.844E+06	.344E+18		
1.000	3.000	.240E+07	.106E+19		
.100	1.000	.635E+07	.258E+19		

TOTAL FLUENCE = .10194E+08 NT/SQCM

TOTAL EQUIV = .34941E+08 NT/SQCM

TOTAL RADS = .11816E+00

RESULTS

OURCE HT = 10000.0 FT, TARGET HT = 10000.0 FT, SLANT RANGE = 180000. CM, STP RANGE = 132946. CM, = OF KTON = 100.0

ENERGY RANGE		NET FLUX	FLUX*AREA	DIRECT	SCATTERED	(ENERGY IN MEV, FLUX IN NT/SQCM)
12.000	14.000	.153E+08	.622E+19			
8.300	12.000	.245E+08	.997E+19			
3.000	8.300	.844E+08	.344E+20			
1.000	3.000	.260E+09	.106E+21			
.100	1.000	.635E+09	.258E+21			

TOTAL FLUENCE = .10194E+10 NT/SQCM

TOTAL EQUIV = .34941E+10 NT/SQCM

TOTAL RADS = .11816E+02

REFERENCES

1. J. P. George and A. Lavagnino, Time Dependent Neutron Transport from A Point Isotropic Source, DASA REPORT Nos. 1820-1, 1830-2, 1820-3, Braddock, Dunn, and McDonald, 1966

2. R. L. Berger, Neutron Transport and Applications, NWEF REPORT No. 8303, Naval Weapons Evaluation Facility, 1966

3. Unpublished notes of Dr. F. J. Jankowski

APPENDIX A

BRIEF DESCRIPTION OF THE TRANSPORT TABLES

The air transport tables are built into the program as data statements. The data is normalized to one neutron per source group. They are very dependent on the 13 flux levels at the source, 17 flux levels at the receptor and 33 values of range. If any of these numbers are changed, the dimension statements, equivalence statements, and data statements which describe the new air transport table must be consistent with the new numbers.

Each data statement gives the transport data as a function of range for a given source energy group and receptor energy group. The ranges are defined in increasing order and the energy intervals are in decreasing order. The data statements are ordered such that the receptor energy varies for each source energy level.

These data statements were generated by a separate program which is available to generate an entirely different table.

APPENDIX B

PROGRAM SYMBOLS AND UNITS

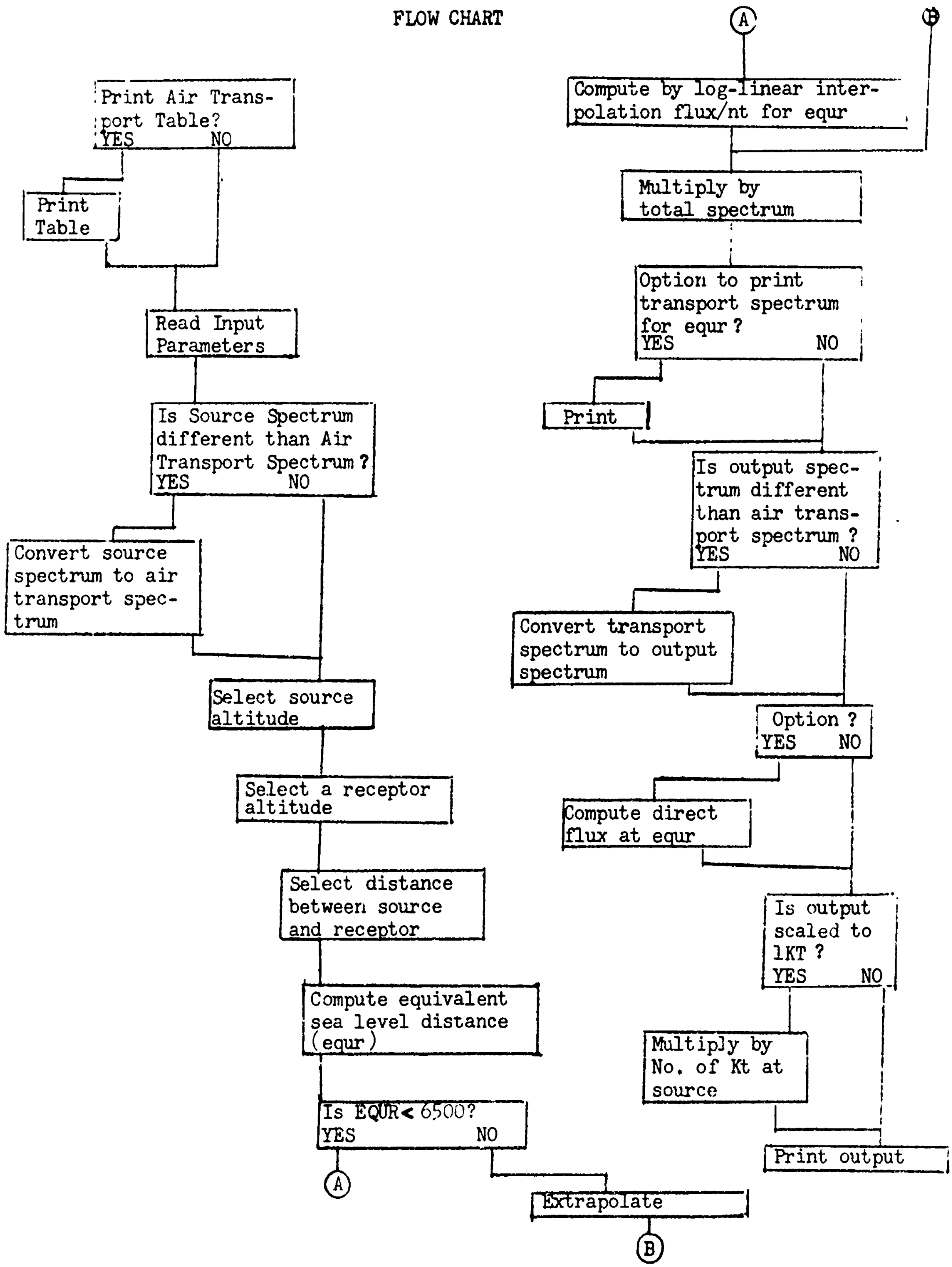
Symbol	Definition	Units
ADENS(I)	Altitudes at which density of air has been tabulated in the program. (21 values from 0 to 200,000 ft)	ft
AHREC(I)	Altitude of receptor. (Maximum of 20 values)	ft
AHSORC(I)	Altitude of source. (Maximum of 20 values)	ft
ANNTR	Neutron flux at receptor for a given energy group. (Partial summation)	nt/ft^2
ANNTS(I)	Number of neutrons in the I^{th} energy group of source spectrum.	
BNNTS(I)	Number of neutrons in the I^{th} energy group in terms of source spectrum of the transport table.	
CSI	Cos ϕ (see figure 1)	
DBRS	Distance between source and receptor being evaluated	ft, cm
DENS(I)	Density of air at altitude ADENS(I)	lb/ft^3
DIRECT(I)	Unscattered flux in I^{th} energy group	nt/cm^2
DNR(I)	$\int \rho(h)\, dh$ from h = ADENS(I) to h = ADENS(I+1), where ρ is the density of air (20 values)	lb/ft^2
DRSR(I)	Distance between source and receptor (maximum of 30 values)	cm
EQUIV(I)	One-Mev Equivalent weighting factors (for each of 16 output energy groups of the transport table spectrum)	
EQUR	Equivalent DRSR(I) distance at sea level	ft, cm
FLUXR(I)	Rads equivalent of flux in the I^{th} output energy group.	Rads

Symbol	Definition	Units
FLUX1(I)	One-Mev equivalent of flux in the I^{th} output energy group	
FRPE	$4\pi D^2$, where D is the distance from source to receptor	ft^2
HA(I)	Slope of curve of log(ρ) vs. altitude from h = ADENS(I) to h = ADENS(I+1)	1/ft
FTCMSQ	Conversion from ft^2 to cm^2	cm^2/ft^2
HREC	Altitude of receptor being evaluated	ft
HSORC	Altitude of source being evaluated	ft
IHRI	Receptor is located between ADENS(IHRI) and ADENS(IHRI+1)	
IHSI	Source is located between ADENS(IHSI) and ADENS(IHSI+1)	
NDNS	Number of altitudes at which the density of air is specified. (21 altitudes from 0 to 200,000 ft)	
NDSR	Number of distances between source and receptor to be investigated.	
NNTSD	Option to specify the number of kilotons in the source.	
NOPD	Option to specify the output energy spectrum	
NOSS	Number of energy intervals in the output spectrum.	
NR	Number of range points at which the transport table flux is specified. (33 points from 0 to 6500 ft.	
NRANGE	Option to compare flux at a distance to a specified one-Mev equivalent flux.	
NREC	Number of receptor altitudes.	
NRLS	Number of energy levels in the output spectrum of the transport table (NRLS = 17).	
NRSI	Same as NRLS	

Symbols	Definition	Units
NSIT	Number of energy levels in the source spectrum.	
NSLS	Number of energy levels in the source spectrum of the transport table. (NSLS = 13)	
NSOR	Number of source altitudes.	
NSSI	Same as NSLS	
NSST	Option to specify input source spectrum different from transport table.	
NTRS	Same as NR	
NUTS	Checks to see if output and input spectra have coincident energy boundaries.	
ONNTR(I)	The neutron flux in the I^{th} energy group of the output spectrum	nt/ft^2
OSRID(I)	The upper boundary of the I^{th} output energy group	Mev
PCTNT(I)	Fraction of neutrons in the I^{th} energy group of the source spectrum	
PHI	Given one-Mev equivalent flux value, it is desired to find the range at which this flux occurs.	
PNTR(I)	The number of neutrons in the I^{th} energy group of the output spectrum.	
PSI(K, I, J)	The fraction of neutrons scattered from the I^{th} energy group at the source to the J^{th} energy group at the receptor, which are separated by a distance RGD(K). (This information is stored in the transport tables).	
RADS(I)	Response factors, nt/cm^2 to Rads for the I^{th} energy group	$RADS/(nt/cm^2)$
RDEN	Density of air at the receptor	lbs/ft^3
RGD(I)	The I^{th} distance in the transport table	ft
SDEN	Density of air at the source	lbs/ft^3

Symbols	Definition	Units
SDNR	$\int \rho \, dr$ from source to receptor	lbs/ft^2
SLOPE(I)	Used to calculate direct flux. It is the slope of log (flux) vs range for the Ith energy group.	1/ft
SNKT	Number of kilotons being investigated	kT
SNNTR(I)	Neutron flux at receptor in the Ith energy group of the transport table spectrum.	nt/ft^2
SRID(I)	Ith value of transport table receptor energy groups	Mev
SSID(I)	Ith value of transport table source energy groups	Mev
SSPCTR(I)	Ith value of input source energy groups	Mev
TANNTR(M,N)	Intermediate flux calculation.	
TNNTS	The total number of source neutrons.	

FLOW CHART


Print Air Transport Table? YES NO
Print Table
Read Input Parameters
Is Source Spectrum different than Air Transport Spectrum? YES NO
Convert source spectrum to air transport spectrum
Select source altitude
Select a receptor altitude
Select distance between source and receptor
Compute equivalent sea level distance (equr)
Is EQUR< 6500? YES NO
A
Extrapolate
B
A
B
Compute by log-linear interpolation flux/nt for equr
Multiply by total spectrum
Option to print transport spectrum for equr? YES NO
Print
Is output spectrum different than air transport spectrum? YES NO
Convert transport spectrum to output spectrum
Option? YES NO
Compute direct flux at equr
Is output scaled to 1KT? YES NO
Multiply by No. of Kt at source
Print output