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USER'S MANUAL FOR THE GENERALIZED RADIATION TRANSFER CODE (RAD/EQUIL)

by

W. E. Nicolet

Prepared for

National Aeronautics and Space Administrtion
Langley Research Center
Hampton, Virginia

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Technical Management

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FOREWORD

This report describes a radiation transport program which has evolved over a span of two contracts to its present state. The initial effort was performed under Contract NAS-6719 for the NASA Manned Spacecraft Center, Structures and Mechanics Division. This effort included the basic computational procedures for the radiation properties and transport models. These were extended and generalized under the current contract (NAS1-9399) for the NASA Langley Research Center, Applied Material and Physics Division. On this effort the program was generalized to include the equilibrium chemistry capability and interaction with boundary (wall) fluxes. In addition, certain revisions were made to the structure of the program to increase computing speed.

ABSTRACT

This report describes the use and structure of the RAD/EQUIL program, a computational procedure for predicting nongrey radiative fluxes or intensities at any point within a plane-parallel slab (for the flux calculation) or at any point on a ray (for the intensity calculation). The program was developed for the study of radiation heating phenomena in the mass injected, hypersonic boundary layer environment; however, it is not limited to such studies. The radiative properties model assumes local thermodynamic equilibrium and considers the continuun transitions, molecular bands and atomic lines of the species of the C-H-O-N elemental system. The bandless model for the molecular bands is the only approximation which is an integral part of the properties model employed in the program. Other aspects of the model can be made to include as much (or little) detail as desired through changes to the input data or simple modifications to the program, itself. This allows a wide range of trade-offs to be made between accuracy and computational effort.

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USER'S MANUAL FOR THE GENERALIZED RADIATION TRANSFER CODE (RAD/EQUIL)

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SECTION 1

INTRODUCTION

This report describes the RAD/EQUIL computer code, a combination of the radiation transfer code (RAD) and a simplified version of the Aerotherm Chemical Equilibrium Code (EQUIL). The motivation for developing the code was to study hypersonic, mass injected shock layer environments during entry into planetary atmospheres and during reentry from deep space missions; however, it is not limited to such studies. Indeed, its most attractive feature is its versatility.

The C-H-O-N elemental system is considered. This system is representative of shock layers adjacent to ablating bodies. Local thermodynamic equilibrium is assumed to exist at all times. Molecular, atomic and ionic species are all considered with those which appear in the 3000°K to 15000°K temperature range (.1 to 10 atmospheres, pressure range) being given primary consideration. A complete description of the properties and transport models has been given in Ref. 1.

The RAD/EQUIL code requires as input information sufficient to describe the spatial distribution of the thermodynamic state. This information can be obtained in a variety of forms, e.g., pressure, temperature, concentrations of base species (or elements), or enthalpy can replace temperature and/or mole fractions can replace the base species concentrations. Alternatively, the conditions ahead of an oblique (or normal) shock wave can be

specified and the program will compute the thermodynamic state distributions. From these data it calculates the intensities along a ray; or if the gas is confined in a plane - parallel slab, it can calculate radiant fluxes directly. If the radiation is to be observed behind a window, frequency dependent transmission factors are included which can be used to simulate its transmittance. The wall radiation can also be included and allowed to interact with the gases.

The following six sections describe the operating aspects of the code in terms of INPUT, OUTPUT, SAMPLE CASES, OPERATING PROCEDURES, PROGRAM DESCRIPTION, and A LIST OF FORTRAN VARIABLES. A listing is available under a separate cover.

SECTION 2

INPUT

The program uses punched cards as the input media. Two data decks are required, A and B. Deck A contains basic radiation and spectroscopic data, e.g., f-numbers, line widths and centers, definition of line groups, energies and statistical weights of levels, etc. Deck A is not changed unless changes to the basic radiation model are to be performed; consequently, it is often referred to as permanent data. Deck B contains case data such as path length, temperatures, pressures, etc. A complete description of the two data decks is given in Table 2.1.

2.1 DATA DECK SETUP

Figure 2.1 shows a typical data deck setup. Permanent data is always read in first, followed by case data. The first set of case data must be complete; that is, it must include a setup of the spatial nodes and the boundary conditions. The following cases can be read, in abbreviated form. Each case starts with a control card (KR, Title) and ends with a C4 card. Successive cases are read in and run until a 1. appears on the C4 card. This terminates the run.

TABLE 2.1

INPUT CARDS

DECK A — PERMANENT DATA

Group 1 — Basic Radiation Data

Card 1, Format (40I2)

Field 1, (Columns 1-2), NHV

This is the number of line groups to be included in the calculation (maximum of 25). A discussion of the judgements involved in selecting the appropriate number of line groups is given in the discussion of the FHVM and FHVP values.

Field 2, (Columns 3-4), NAES

This is the number of atomic and ionic energy levels. Normally 56 are used to describe the CHON system - 8 levels each being assigned to C, H, O, N, C+, O+ and N+. Some lumping of levels is usually required. This is done using normal quantum mechanical weighting and a table of energy levels such as Moore's (Ref. 3).

Field 3, (Columns 5-6), NXI

This is the number of special hydrogen lines for which no (half) half width data is read in. When the hydrogen lines are to be included, NXI = 4. Otherwise, it equals zero. The four lines given special treatment are the Lyman α and β and the Balmer α and β. Half width information (a GAMP value) is read in for each of the remaining hydrogen lines.*

*The half width information for the Lyman γ and Paschen α is used to set up the frequency coordinate system only. For the lines which are still higher than these, the input (half) half width is used throughout the transport calculation.

Group 2 — Statistical Weights of Absorbing Levels

Cards 1,2..., Format (6E12.4)

Field 1, (Columns 1-12, 13-24, etc.), GEE

These are the statistical weights of the atomic and ionic levels. For unlumped levels GEE = 2J+1 where J is the inner quantum number of the level and can be obtained from tabulations (Ref. 3). For lumped levels, GEE is obtained by summing the contributions of the individual levels.

Group 3 — Energy Levels

Cards 1,2..., Format (6E12.4)

Field 1, (Columns 1-12, 13-24, etc.), EPS

These are the energies of the levels (in eV), for unlumped levels, values can be obtained from tabulations (Ref. 3). For lumped values the equation

$$\mathrm{EPS}\Big|_{\mathrm{Lumped}} = \frac{\sum \mathrm{GEE*EPS}}{\sum \mathrm{GEE}}$$

is applicable where the summations are taken over all the levels to be lumped.

Group 4 — Line Group Specification

Cards 1, 2..., N1, Format (6E12.4)

Field 1, (Columns 1-12, 13-24, etc.), FHVM

These are the low frequency boundaries on the line groups. An FHVM value along with an FHVP value defines a frequency increment. All the lines with their centers within that increment define a line group. The continuum properties and the black body functions are evaluated at only one frequency point for each line group. Therefore, the frequency boundaries on the line group should not be so wide as to allow appreciable changes in these quantities. In addition, contributions to the transport from sources outside the

boundaries of the line group are not taken into account. Therefore, the boundaries on a line group should never to too close to the center of a line within the group.

Cards N1+1, N1+2...N2, Format (6E12.4)

Field 1, (Columns 1-12, 13-24, etc.), FHVP

These are the high frequency boundaries on the line groups.

Cards N2+1, N2+2...N3, Format (6E12.4)

Field 1, (Columns 1-12, 13-24, etc.), FHV

These are the frequencies at which the continuum properties and the black body function are evaluated for each line group. They are usually taken to be roughly midway between FHVP and FHVM. Thus FHV is often referred to as the "average" frequency of the line group.

Group 5 – Hydrogen Index (Skip this Group if NXI = 0)

Card 1, Format (40I2)

Field 1 (Columns 1-2, 3-4, etc), IA

These are the indices on the line groups which contain the special hydrogen lines (one per line group, maximum). The line groups are always numbered sequentially starting with those at the lowest frequency.

Group 6 – Number of Lines Per Line Group

Card 1, Format (40I2)

Field 1, (Columns 1-2, 3-4, etc.), NU

This is the number of lines which are situated within each line group and which are treated individually. This number must equal the number of line data cards read in for each group. Whenever a line is incorrectly assigned to a line group the program will stop and write out the message "LINE CENTER OUT OF GROUP FREQUENCY RANGE."

Group 7 — Base Data on Line Transitions

Cards 1,2,... No. of Lines, Format (I2, IOX, 2E12.1, 3E12.2)

Field 1, (Columns 1-2), ND

Each of these is the index on the lower (abosrbing) level of each line. It identifies the radiating atomic and ionic species and its level according to the scheme

ND	Species
1 - 8	N
9 - 16	O
17 - 24	C
25 - 32	H
33 - 40	N+
41 - 48	O+
49 - 56	C+

where the indices increase (for each species) with increasing energy of the levels.

Field 2, (Columns 13-24), HVL

Frequency of the center of the line (in eV).

Field 3, (Columns 25-36), FF

This is the f number of the line when the lower level of the transition is unlumped. When it is lumped

$$FF = \frac{GEE * f}{GEE \big|_{\text{lumped}}}$$

where GEE is the statistical weight of the unlumped lower level of the transition.

Field 4, (Columns 37-48), GAMP

This is the (half) half width per free electron of each line due to Stark Broadening, evaluated at 10,000°K.

Field 5, (Columns 49-60), XNOL

Each of these is the number of lines in a given line group which have identical properties. It is used only when the properties of several lines are to be averaged and transport calculated for the averaged line, then multiplied by the number of original lines to obtain the total. Only lines in the low frequency region (less than 5 ev, roughly) should be averaged in this manner.

Field 6, (Columns 61-72), GUP

Each of these is the statistical weight of the upper level of the line (used in resonance broadening calculation,only).

Group 8 – Frequency Nodes for the Continuum

Card 1, Format (24I3)

Field 1, (Columns 1-3) NIHVC

This is the number of continuum frequency points (a maximum of 50 is allowed).

Cards 2,3..., Format (6E12.1)

Field 1, (Columns 1-12, 13-24, etc.), FHVC

These are the continuum frequency points which are selected. Care must be taken to insure that the photoionization edges in the ultraviolet are adequately resolved.

DECK B – CASE DATA

Group 1 – Control Card and Title

Card 1, (Format (20I1, 15A4)

Field 1, (Columns 1-20) KR

Column 1 - Determines whether intensities or fluxes will be calculated

0 Calculates intensities

1 Calculates fluxes

Column 2 - Sets the conditions of the radiating layer.

0 Allows arbitrary specification of thermodynamic state across the layer

1 Allows arbitrary specification of thermodynamic state but requires that the layer have uniform properties

2 Allows the thermodynamic state to be determined from specified shock wave conditions, but requires that these conditions be uniform across the radiating layer. (KR(7) and KQ(5) must both equal 1)

Column 3 - Determines if molecules are to be included in the calculation

0 Molecules can be included (see also the NCRC variable which overrides this control)

1 Molecules are not included (irrespective of what NCRC is)

Column 4 - Determines how the line contributions are calculated

0 Include lines but allow weak lines to be treated approximately

1 Include lines in full detail

2 Exclude lines

Column 5 - Determines the optical conditions of the wall

0 Requires a cold, black wall

1 Requires a black wall but allows it an arbitrary temperature

2 Allows a wall with an arbitrarily specified temperature, emittance and/or transmittance.

Column 6 - Specifies the type of flux (or intensity) calculated at NICN(1) - The surface node

0	Incident flux (or intensity)
1	Flux (or intensity) transmitted through the surface

Column 7 - Determines how the thermodynamic state conditions of the radiating species are obtained

0	Uses the resident values
1	Performs chemistry calculation
2	Reads in mole fractions, temperature and pressures

Column 8 - Determines whether frequency or wave length is used in output

0	Uses frequency, $h\nu$ (eV)
1	Uses wavelength, λ (A)

Column 9 - Determines if the program is to check the validity of the continuum frequency grid.

0	The grid is checked - use for energy transfer calculations
1	The grid is not checked - use when only a selected part of the spectrum is of interest

Column 10 - Determines where the program obtains (1) normalized spatial nodes, (2) index on spatial nodes to determine where fluxes or intensities are to be calculated and (3) the optical properties of the wall

0	Uses resident values
1	Reads in new values

Column 11 - Determines which radiation subroutines are to be used.

0 Uses standard radiation package (best for most calculations)

1 Uses accelerated radiation package (this package is much faster and should be used if the RAD/EQUIL program is to be used as a subroutine)

Column 12 - Determines if the chemistry input package is to be read

0 Read in new data for element and molecular, atomic, and ionic species - input data will not appear in output

1 Use resident elemental and species data

2 Same as KR (12) = 0 except that data will appear in output

Column 13 - Determines where program obtains optical path length

0 Reads it in

1 Takes it equal to the stand off distance of the bow shock of a sphere (the spherical radius (in CM) is read in))

2 Same as KR(13) = 1 except that the spherical radius is in feet

Column 14
Column 15
Column 16
} Not used

Column 17 - Determines the amount of radiative output

0 Normal radiative output

1 Extensive radiative output

Column 18 - Determines chemistry debug output

0	None
1	Dumps chemistry iterations

Column 19 } Not used
Column 20 }

Field 2, (Columns 21-80), CASE

This is the title of the case (alphanumeric) used for identification of printed output.

Group 2 - Chemistry Control Card (Skip this group if KR(7) = 0)

Card 1, Format (20I1, 5E10.3)

Field 1, (Columns 1-10) KQ

Column 1 - Determines which variables are used to specify the thermodynamic state

0	Temperature
1	Do not use this value
2	Enthalpy

Column 2 - Determines if chemistry package is to be read in (see KR(12), also)

0	Use resident data
1	Read in new data

Column 3 - Must be the same as Column 2

Column 4 - Not used

Column 5 - Determines if shock wave option is to be utlized

0	It is not utilized
1	A shock wave solution will be calculated

Columns 6-20 - Do not use

Field 2, (columns 21-30), THETA

This is the angle of the shock wave. An entry here has meaning only when the shock wave option is to be used. This is also true for the next three fields.

Field 3, (Columns 31-40), SV1

This is the velocity (ft/sec) upstream of the shock wave.

Field 4, (Columns 41-50) SP1

This is the pressure (atm) upstream of the shock wave.

Field 5, (Columns 51-60) SR1

This is the density (lb/ft^3) upstream of the shock wave.

Field 6, (Columns 61-70), HS

This is the enthalpy (Btu/lb) upstream of the shock wave.

Group 3 - Chemistry Input (Skip this if KR(7) $\neq$ 1 or KR(12) = 1)

Card 1, Format (I3,F7.0)

Field 1, (Columns 1-3), IS

Number of elements in the system including electrons if considered.

Cards 2,3...,IS, (One for each element, see Card 1, Field 1 of this group), Format I3, 3A4, 4F10.5)

Field 1, (Columns 1-3), KAT(K)

Atomic number of element (99 for electron), cards must be ordered with this number ascending with electron last (when considered)

Field 2, (Columns 4-15) ATA(K), ATB(K), ATC(K)

Name of element (used for output only). For best looking output, elements with 3 or 4 letters (e.g., iron) should start in Column 6, elements with 5, 6, or 7 letters (e.g., carbon) should start in Column 5, and elements with 8 or more letters (e.g., nitrogen) should start in Column 4.

Field 3, (Columns 16-25), WAT(K)

Atomic weight of element.

Group 4 – Thermodynamic Data (Skip this if KR(17)≠1 or KR(12)=1)

There are three cards for each molecular, atomic, condensed, or ionic species. A total of 60 species of all types are allowed. The number of allowable condensed-phase materials is (12-IS). A blank card after the last set concludes the thermodynamic data. The arrangement of these cards sets is of consequence in so far as it determines the base species upon which mass balances are performed, the first independent set of base species being selected. Singular matrices can result from certain sets of theoretically-acceptable base species due to round-off errors. Furthermore, mass balances, etc. for the (NSP)th base species is obtained by difference. Therefore, the element represented by this base species should be present in appreciable quantities. For example, for air, molecular nitrogen is a good choice for the (NSP)TH base species. Except for these considerations, atomic, molecular, and condensed species can be arranged in any order. When ionized flows are considered, the atomic, molecular, and condensed species data must appear first and be followed by, first, electron species data, and then the ionic species data (which can be in any order). The data format accepted by the program (described below) are as generated by the Aerotherm TCDATA program and are the same as that used in NAVWEPS Report 7043. Thermochemical data decks have been generated for about 600 species, based mostly on curve fits of JANAF data.

Cards 1, 4, 7,..., One for each molecule, Format (7(F3.0, I3), 30X, 2A4

Fields 1, 3, 5,..., One for each element in molecule (Columns 1-3, 7-9, 13-15,...), ALPT(N) in each field

Number of atoms (of atomic number given in subsequent field in a molecule of this species. If field one is zero this card is presumed to be end of thermodynamic data.

Fields 2,4,6,..., One for each element in molecule, (Columns 4-6, 10-12, 16-18,...), JAT(N) in each field

Atomic numbers of elements in molecules (listed in ascending sequence).

Last Field, (Columns 73-80)

Molecular designation (e.g., SIO2) for output

Cards 2,5,8,..., One for each molecule, Format (6E9.6, 6X, F6.0, I1)

Field 1, (Columns 1-9), RA(J)

Heat of formation of molecule at 298°K from JANAF base state (elements in most natural form at 298°K), cal/mole.

Fields 2-6, (Columns 10-18, 19-27, 28-36, 37-45, and 46-54), CH(J,1), RC(J,1), RD(j,1), RE(j,1), RF(J,1)

Constants appropriate to lower temperature range of thermdynamic data. Taking F2, F3,..., as Fields 2, 3, etc., the curve fits are as follows with T in °K, H in cal/mole, and S in cal/mole °K.

Heat capacity, CP = F3 + F4* T + F5/T**2

Enthalpy, H - H298 = F2 + F3*(T - 3000) + 0.5*F4*
(T**2 - 3000**2) - F5*(1/T - 1/3000)

Entropy, S = F6 + F3*LN(T/3000) + F4*(T - 3000)
- 0.5*F5*(1/T**2 - 1/3000**2)

Field 7, (Columns 61-66), TU(J,1)

Upper limit of lower temperature range in °K. (For condensed-phase materials which melt, it is appropriate to use melt temperatures).

Field 8, (Column 67), KPHA(1)

1 signifies gaseous species
2 signifies solid species
3 signifies liquid species

Cards 3,6,9,..., One for each molecule, Format (6E9.6, 6X, F6.0, I1)

Fields 1-8, (Columns 1-67)

Same as Cards 2,5,8,..., except use constants for upper temperature range and Field 7 is ignored.

Last Card - A blank card is used to signify end of thermodynamic data.

Group 5 – Nodal Input and Surface Properties

(Skip this group if KR(10) ≠ 1)

Card 1, Format (24I3)

Field 1, (Columns 1-3), NIC

This is the number of spatial stations at which transport is to be calculated. This number must be equal to or less than 7. (20 for updimensioned versions)

Card 2, Format (24I3)

Field 1, (Columns 1-3, 4-6,...), NICN

These are the indices on the spatial stations where transport is to be calculated. The nodal points usually start with 1 at the wall and increase away from the wall.

Card 3, Format (5I3)

Field 1, (Columns 1-3), NY

This is the number of spatial nodes used to describe the slab (or ray). It must be equal to or less than 10. (20 for updimensional versions).

Field 2, (Columns 4-6), NI

This is the index on the spatial point at which the line frequency coordinate system is to be evaluated. For a layer in which the elemental composition does not vary greatly, use the high temperature boundary. When the elemental concentration does vary significantly, select a point where the temperatures are the highest but all the elements are still present.

Cards 4,...N5, Format (6E12.4)

Field 1, (Columns 1-12, 13-24,...), (YY(I), I=1,NY)

This is the normalized distance to each spatial station from the wall. Select these so that the thermodynamic variation of the slab (or ray) is well described.

----------Skip the Rest of Group 5 if KR(5) < 2----------

Cards N5+1, N5+2,...,N6, Format (6E12.1)

Field 1, (Columns 1-12, 13-24,...), AHV

These are the absorptances or emittances of the wall - one for each continuum frequency point.

Cards N6+1, N6+2,...,N7, Format (6E12.1)

Field 1, (Columns 1-12, 13-24,...), AHVL

These are the absorptances or emittances of the wall - one for each line group center frequency.

Cards N7+1, N7+2,...,N8, Format (6E12.1)

Field 1, (Columns 1-12, 13-24,...), TMSW

Continuum transmittances of the wall - one for each continuum frequency point

Cards N8+1, N8+2,...,N9, Format (6E12.1)

Field 1, (Columns 1-12, 13-24,...), TMSWL

Line group transmittances of the wall - one for each line group center frequency.

Group 6 — Uniform conditions input

(Skip this group if KR(2) = 0)

Card 1, Format (6E12.8)

Field 1, (Columns 1-12), DELTA

If KR(13) = 0, DELTA is the radiation path length (CM). If KR(13) = 1, DELTA is the radius of a spherical body (CM). If KR(13) = 2, DELTA is the same as for KR(13) = 1, except that it is in feet.

---------- Skip Fields 2 and 3 if KR(7) = 0 ----------

Field 2, (Columns 13-24), PRES(1)

This is the pressure (atm)

Field 3, (Columns 25-36), TEE(1)

If KQ(1) = 0, TEE is the temperature (°K). If KQ(1) = 2, TEE is the enthalpy (Btu/lb). TEE is a first guess temperature (°K) for shock wave solutions. (KQ(5) = 1)

Card 2, Format (6E12.8)

Field 1, (Columns 1-12), TW

The temperature (°K) which is used to calculate the emission from the wall.

Card 3, Format (24I3)

Field 1, (Columns 1-3, 4-6,...), NCRC

These values determine which continuum contributions are to be included in the absorption coefficients and which are not. When NCRC(I) = 1, the source is included; when NCRC(I) = 0, it is not included. The following scheme is used to relate NCRC(I) values to the sources.

I	Source
1	Nitrogen High Line Series
2	Oxygen High Line Series
3	N_2^+ (1-) Band System
4	N^- Photodetachment
5	H^- Photodetachment
6	O^- Photodetachment
7	NO Band Systems and Photoionization
8	N Atomic Photoionization
9	O Atomic Photoionization
10	N^+ Photoionization

11	O_2 Band Systems and Photodissociation
12	N_2 Band Systems
13	CO Band Systems
14	H_2 Band Systems and Photoionization
15	C_2 Band Systems
16	CN Band Systems
17	C Atomic Photoionization
18	C^+ Photoionization
19	H Photoionization
20	C^- Photodetachment

----------If KR(7) $\neq$ 1 Skip the Next Card----------

Card 4, Format (8E10.3)

Field 1, (Columns 1-10, 11-20, etc.), (SP(I), I = 1, ISM)

These are the mass fractions of the base species. They are read in the same order that the species were read in the chemistry input (Group 3).

----------If KR(7) $\neq$ 2 Skip the Next Card Set----------

Cards 5,6,...,N10, Format (6E12.8)

Field 1, (Columns 1-12, 13-24, etc.), (FR(J,1), J =1,15)

These are the mole fractions of the radiating species. Species must always be read in, in the following order: O^+, O, N^+, N, E^-, O_2, N_2, CO, H_2, C_2, CN, C, C^+, H, NO. The program will automatically obtained the mole fractions of the species N_2^+, N^-, O^-, C^-, and H^-.

Group 7 – Nonuniform Conditions Input

(Skip this group if KR(2) ≠ 0)

Card 1, Format (1E12.)

Field 1, (Columns 1-12), DELTA

This is the radiation path length (CM).

---------- Skip the next two card sets if KR((7) = 0----------

Cards 2,...,N11, Format (6E12.8)

Field 1, (Columns 1-12, 13-24, etc.) (PRES(I), I = 1, NY)

These are the pressures (atm) at each spatial node.

Cards N11+1,...,N12, Format (6E12.4)

Field 1, (Columns 1-12, 13-24, etc),(TEE(I), I = 1, NY)

If KQ(1) = 0, these are the temperatures (°K) at each node. If KQ(1) = 2, they are the enthalpies (Btu/lb).

Card N12+1, Format (6E12.4)

Field 1, (Columns 1-12), TW

This quantity was described previously in Group 6.

Card N12+2, Format (24I3), NCRC

This quantity was also described in Group 5.

----------If (KR(7) ≠ 1, Skip this card----------

Cards N12+3,...N13, Format (8E10.3)

Fields 4, (Columns 1-10, 11-20, etc.) DO - I = 1, NY; (SP(1, I, J), J = 1, ISM)

These are the mass fractions of the base species at each spatial node (I). The ordering of the species must be the same as the ordering the species data were read in, in Group 3.

----------IF KR(7) $\neq$ 2 Skip this Card Set----------

Cards N13+1,...,N14, Format (6E12.4)

Field 1, (Columns 1-12, 13-24, etc.)((FR(J,I), I = 1,NY) J = 1,15)

These are the mole fractions of the radiating species at each spatial node (I). The ordering of the species was discussed in Group 3.

Group 8 — Termination of Run

Card 1, Format (6E12.4)

Field 1, (Columns 1-12), C4

If C4 = 0, begin reading in a new case starting with Group 1 of Deck B. If C4 = 1., stop calculations.

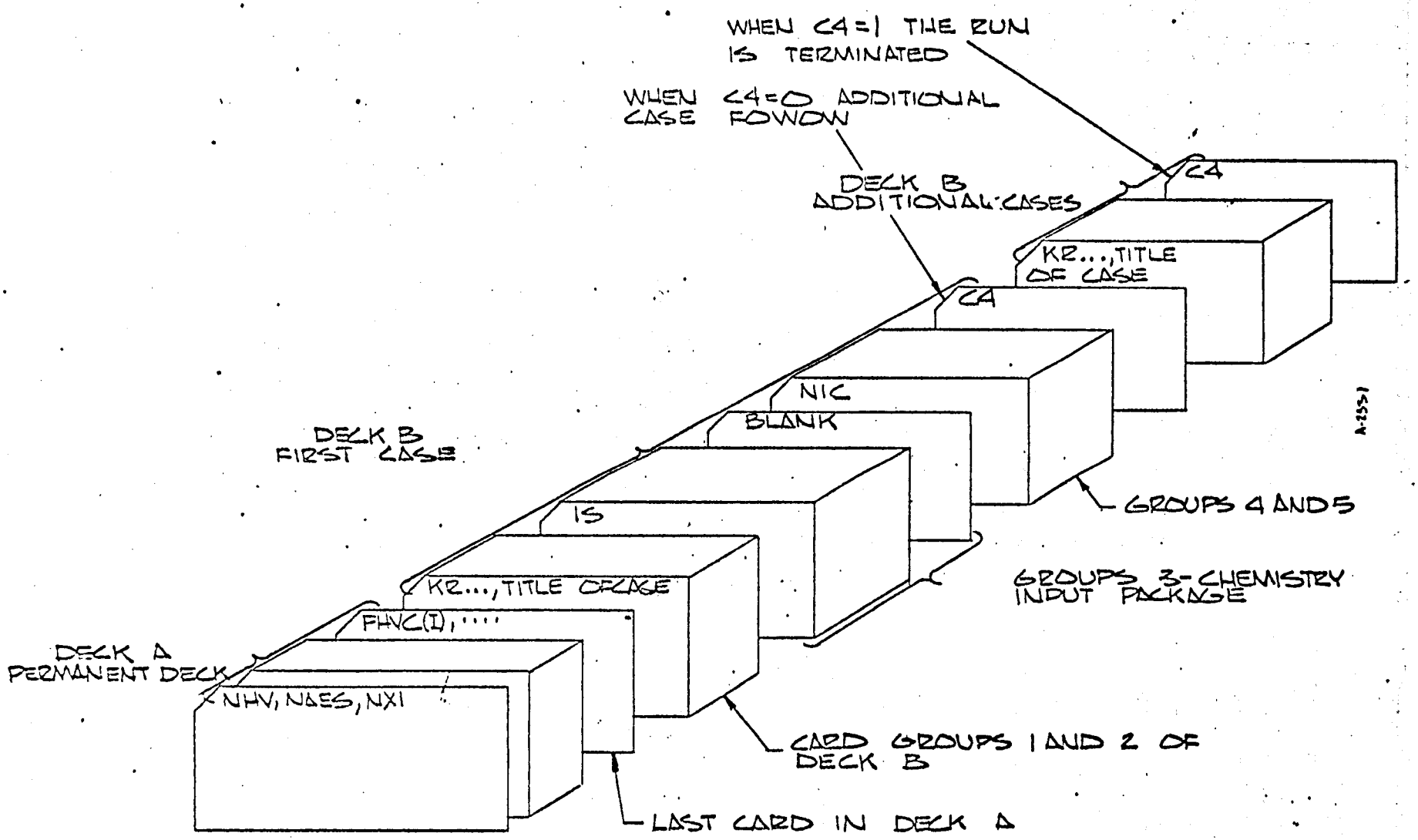


FIGURE 2.1 — DATA DECK SETUP

SECTION 3

OUTPUT

3.1 NORMAL OUTPUT

For a given case, the normal output consists of five sets of data, each approximately one page in length. The first set summarizes the permanent data deck being used. The second set gives the radiation and chemistry control numbers and defines the radiative boundary conditions for the case being run. The third set defines the spatial variations of the thermodynamic state properties. The fourth set gives the results of the continuum transport calculations, and the fifth gives the results of the line transport calculations. When more than one case is calculated in a given run, the first set of data is printed out for the first case only. The other four sets are printed out for each case.

The first set of data is given the title "TABLE II." Ten columns of data are printed out under the following headings: GROUP, HV, HV+, HV-, N, K(I), HV(J), F(I), GAM(I), NOL(I). The first five columns define the properties of the line groups; the second five define the properties of the lines within each line group. These variables are the same as the input variables, although slightly different terminology is used. In terms of input variables the headings are the following:

LINE
GROUP
INDEX, FHV, FHVP, FHVM, NU, ND, HVL, FF, GAMP, XNOL

which were defined in Section 2.

The second set of data is titled "CASE - XXXX" where XXXX is the case title which was read in on the first card of Deck B. The radiation control numbers (KR(I)) and the chemistry

control numbers (KQ (I)) are given which describe the case. These are followed by the "RADIATIVE BOUNDARY CONDITIONS" given in terms of the emittance and transmittance of the wall and the outer boundary and as a function of both the continuum and line group frequencies (corresponding wave lengths are also given).

The third set of data is always given the title "TABLE 1." In the second row of the title, an S station is identified. This is for the identification of the case only and has no physical meaning. The third row in the title gives the overall thickness of the slab (or length of the ray) in centimeters. The other data printed out include the following: the normalized path lengths, temperatures (^{o}K), pressures (atm), enthalpies (Btu/lb), mean molecular weight, mole fractions of the radiating species (dimensionless), and the number densities of the radiating species (particles/cm^3).

The fourth and fifth sets of data have output formats which are dependent upon the version of the radiative programs being utilized. The output for the standard programs (KR(11) = 0) is discussed in Section 3.1.1 and that of the accelerated programs (KR(11) = 1) in Section 3.1.2.

3.1.1 Output of Standard Subroutines

The fourth set of data is given either the title "CONTINUUM CONTRIBUTION TO THE SPECTRAL FLUX" or "CONTINUUM CONTRIBUTION TO THE SPECTRAL INTENSITY" depending on the type of calculation being performed. The second row of the title gives the normalized spatial station specified for the transport calculation. The spectral points used for the continuum calculation are given in the first column. The next three columns give the continuum transport quantities in the negative direction (away from the wall). The spectral fluxes (or intensities) are given first; then the integral of the spectral flux (or intensity) over frequency is given as a function of frequency (each entry represents the integral from the first frequency point to the current frequency point); finally, the third column gives the same information as the second, except that its entries are normalized against the final value of the

integral. The information given in the last three columns is the same as in the three just described, except that the transport quantities in the positive direction are considered. When KR(8) = 1, the spectral quantities are presented as functions of wavelength instead of frequency.

The last set of data gives the results of the line calculation. It is given a title "TABLE X" where X equals the number of line groups plus three. The second row of the title identifies the S station number (for identification only - as before) and the spatial station specified for the transport calculation. Four columns of data are given. The indicies on the line groups are given in the first column. The "average" frequency of each group is given in the second column. The corrections to be added to the total flux (or intensity) to account for line effects are given in the third column (negative direction) and the fourth column (positive direction). The total corrections (sums over all line groups) are given at the bottom of the page. Again, wavelength variables instead of frequency variables are used when KR(8) = 1.

3.1.2 Output of Accelerated Subprograms

The fourth set of data is given either the title "CONTINUUM CONTRIBUTION TO THE SPECTRAL FLUX" or "CONTINUUM CONTRIBUTION TO THE SPECTRAL INTENSITY" depending on the type of calculation being performed. The next row gives the normalized distances to the nodes where the transport integrals were evaluated. The first column gives the nodal points in frequency used in the continuum calculation. When the transport integrals are to be evaluated at 6 points or less (NIC $\leq$ 6), the next 2 times NIC columns represent F_ν^- and F_ν^+ (or I_ν^- and I_ν^+) given alternately, one combination for each node at which the transport integrals were evaluated. When NIC > 6, there are two rows of output for each continuum frequency point. The top row is F_ν^- (or I_ν^-) and the bottom row (which is slightly displaced to the right) is F_ν^+ (or I_ν^+). Frequency integrated values are given at the bottom of the page for the NIC spatial nodes being considered.

The fifth set of data is given the title "LINE RADIATION". The next row gives the normalized distances to the nodes where the transport integrals were evaluated. The first column gives the index on the line group being considered. The next column gives the center frequency of the line group. Two rows of output are then given for each line group. The first row gives the line correction (F_ν^L or I_ν^L - see Equation 66 of Ref. 1) integrated over the frequency increment of the line group and in the negative direction. The second line is displaced slightly to the right and gives the corresponding value in the positive direction. The total line correction to the directional fluxes are given at the bottom of the page.

3.2 EXTENSIVE OUTPUT (STANDARD SUBPROGRAMS, ONLY)

For a given case the extensive output consists of seven sets of data, five of which are approximately one page in length. The other two sets can be very extensive. The first, second, fifth and seventh sets are identical (respectively) to the first, second, fourth and fifth sets of data which are printed out with the normal output option. The third set includes a set of electronic partition functions (as calculated by the code); otherwise, it is identical to the third set of data printed out with the normal output option.

The fourth set of data gives additional details about the continuum transport calculation. For each frequency point, values of B, FMU and TAU are printed out as a function of the spatial nodes. The function B is the black body emissive power for a flux calculation, the Planck function for an intensity calculation. The other two quantities are the absorption coefficients (1/cm) and the optical depths, respectively.

The sixth set of data gives additional details about the line group and the line transport calculation. For each line group the continuum absorption coefficients and the appropriate back body function at the "average" frequency of the line group are given as a function of the spatial points. The positive and negative continuum fluxes (or intensities) are given at the

spatial station specified for the transport calculation. At each of the frequency points within the line group (frequency interval), the total (line + continuum) absorption coefficients and optical depths are given as a function of the spatial points. The spectral flux (or intensity) is also given (at the one proper spatial point). An integral over the line group is then given. Finally, the quantity CFIL (the distance in frequency space covered by lines) is given for the line group. In terms of these variables the correction to the continuum transport to account for line effects is

line correction = total flux (intensity) - spectral continuum flux (intensity)*CFIL

and is printed out for each line group in the last set of data.

SECTION 4

SAMPLE CASES

Two sample cases are presented. In the first case, the radiative flux at the wall is obtained. The source is a plane parallel slab of air 1 cm thick at 14000°K and .1 atmosphere pressure. The data deck is shown in Figure 4.1. The five sets of output data for normal output are shown in Figures 4.2 to 4.6 and the additional sets for extensive output in Figures 4.7 and 4.8. In the second case, the flux at a boundary of a non-isothermal, plane parallel slab is obtained. Transport from the full CO_2-N_2 system is allowed. The data deck is shown in Figure 4.9. The five sets of data for normal output are shown in Figures 4.10 to 4.14.

Figure 4.1 Input Deck

```
2056
   0.40  +01   0.10  +02   0.60  +01   0.18  +02   0.54  +02   0.90  +02
   0.00  +00   0.00  +00   0.90  +01   0.50  +01   0.10  +01   0.50  +01
   0.30  +01   1.50  +01   0.90  +01   0.40  +02   0.90  +01   0.50  +01
   0.10  +01   0.50  +01   0.12  +02   0.15  +02   0.36  +02   0.00  +00
   0.20  +01   0.80  +01   0.18  +02   0.32  +02   0.00  +00   0.00  +00
   0.00  +00   0.00  +00   0.90  +01   0.00  +00   0.00  +00   0.00  +00
   0.00  +00   0.00  +00   0.00  +00   0.00  +00   0.40  +01   0.00  +00
   0.00  +00   0.00  +00   0.00  +00   0.00  +00   0.00  +00   0.00  +00
   0.60  +01   0.00  +00   0.00  +00   0.00  +00   0.00  +00   0.00  +00
   0.00  +00   0.00  +00   0.00  +00   0.00  +00   0.00  +00   0.00  +00
   0.00  +00   0.2384+01   0.3576+01   0.1045+02   0.1188+02   0.1300+02
   0.00  +00   0.00  +00   0.96  -02   0.1967+01   0.4189+01   0.9144+01
   0.9519+01   0.1074+02   0.1099+02   0.1208+02   0.00  +00   1.2639+00
   2.6839+00   4.1825+00   7.5351+00   7.9461+00   8.6442+00   0.00  +00
   0.00  +00   0.1020+02   0.1208+02   0.1274+02   0.00  +00   0.00  +00


   0.60  +00   0.85  +00   0.96  +00   0.12  +01   0.14  +01   0.162 +01
   0.24  +01   0.34  +01   0.62  +01   0.80  +01   0.86  +01   0.90  +01
   0.97  +01   0.1045+02   0.1080+02   0.1170+02   0.1210+02   0.1280+02
   0.1340+02   0.1380+02   0.00  +00   0.00  +00   0.00  +00   0.00  +00
   0.80  +00   0.95  +00   0.12  +01   0.14  +01   0.16  +01   0.24  +01
   0.3340+01   0.40  +01   0.80  +01   0.86  +01   0.90  +01   0.97  +01
   0.1045+02   0.1080+02   0.1170+02   0.1210+02   0.1280+02   0.1340+02
   0.1380+02   0.1450+02   0.00  +00   0.00  +00   0.00  +00   0.00  +00
   0.69  +00   0.89  +00   0.1080+01   0.1290+01   0.1460+01   0.1850+01
   0.2850+01   0.3700+01   0.7110+01   0.8302+01   0.8781+01   0.94  +01
   0.1007+02   0.1062+02   0.1120+02   0.1190+02   0.1241+02   0.1304+02
   0.1358+02   0.1420+02     .     +     .     +     .     +     .     +
 3 4 5 4 4 4 3 2 1 1 1 4 5 6 7 7 7 3 3 4
16          0.685       0.196          110E-21 6.
 6          0.689       0.1597         187E-20 6.
 5          0.7525      0.0149         446E-21
 5          0.875       0.0366         380E-21 4.
15          0.8840      0.1570         367E-21
 4          0.9158      0.00847        739E-22
 6          0.9304      0.0253         387E-20 2.
 6          0.965       0.0262         387E-20 4.
16          0.991       0.0805         309E-20 2.
 5          1.0355      0.0735         331E-21 7.
15          1.0980      0.7490         344E-21
14          1.1320      0.2010         367E-21
 5          1.2610      0.118          312E-21 3.
 4          1.3190      0.1833         984E-22
14          1.3380      0.9130         342E-21
 5          1.3677      0.0387         292E-21
 4          1.4380      0.256          824E-22 3.
13          1.4670      0.9500         865E-22
 5          1.5527      0.0030         293E-20
12          1.594       1.0300         709E-22
 4          1.6630      0.0923         958E-22
15          1.767       0.0226         275E-20 3.
 5          1.8357      0.00566        293E-20 5.
14          2.015       0.0258         275E-20 3.
 4          2.925       0.0070         106E-20 3.
13          3.0         0.010          810E-21 2.
```

Figure 4.1 (continued)

```
12          3.167       0.00826       520E-21
 4          3.4724      0.00861       452E-20  3.
12          3.7110      0.0143        110E-20
 3          07.111      0.0634        912E-22                6.
 2          08.302      0.0740        912E-22                6.
 3          08.781      0.0435        661E-22
 3          09.301      0.0166        446E-21
 3          09.394      0.0119        229E-21
 3          09.460      0.0360        336E-21
09          9.5010      0.0471        548E-22
 2          09.973      0.0890        661E-22
 3          10.102      0.0374        293E-20
11          10.182      0.1510        653E-22
 1          10.332      0.1840        621E-22                12.
 3          10.418      0.0225        532E-20
 2          10.493      0.0187        446E-20
 3          10.585      0.0131        796E-20
 2          10.619      0.0533        312E-21                14.
 3          10.682      0.00819       268E-19
 3          10.757      0.00518       437E-19
10          10.761      0.1200        653E-22
 1          10.927      0.4540        161E-23                12.
11          11.007      0.0185        367E-21
 3          11.200      0.0200        446E-21
 2          11.293      0.0418        293E-20
 3          11.310      0.0254        323E-21
33          11.424      0.2260        143E-23
 2          11.609      0.0250        532E-20
 2          11.776      0.0220        796E-20
11          11.806      0.0049        145E-20
09          11.852      0.0199        367E-21
 2          11.874      0.0091        268E-19
 2          11.948      0.00575       437E-19
 3          12.000      0.0269        299E-20
09          12.067      0.0218        344E-21
11          12.160      0.0019        128E-20
 3          12.316      0.0156        696E-20
10          12.404      0.0461        653E-22
 2          12.414      0.0574        390E-21
 2          12.511      0.0279        337E-21
09          12.521      0.0775        633E-22
09          12.651      0.00524       145E-20
 1          12.877      0.0230        446E-21
 1          13.004      0.1320        294E-21                12.
 2          13.190      0.0489        299E-20
 2          13.508      0.0291        696E-19
33          13.543      0.1610        950E-24
 1          13.677      0.0957        293E-20
 1          13.993      0.0584        532E-20
 1          14.160      0.0342        796E-20
 1          14.257      0.0212        268E-19
 1          14.332      0.0138        437E-19
 36
      .02         .1          .2          .5          .6          .8
  1.0         1.5         2.0         2.5         3.0         3.5
  4.0         4.5         5.0         6.0         7.0         8.0
 9.0         10.0        10.79       10.81       11.25       11.270
 11.990      12.010      13.390      13.410      13.590      13.610
 14.29       14.31       15.0        16.5        19.0        22.0
1100001001000001000  SAMPLE CASE
011000000
 3
 7 NITROGEN    14.008
 8 OXYGEN      16.0
 99 ELECTRON    0.00055
```

Figure 4.1 (concluded)

```
002007                                          JANAF 3/61                      N2
      0+0 224490+5 689313+1 856610-3-214051+5 638720+2  300. 2000.1    0.N2
      0+0 221654+5 883191+1 595750-4-140025+7 637653+2 2000. 5000.1    0.N2
  2008                                          JANAF 03/61                     O2
 000000-0 234460+5 804370+1 510872-3-152718+6 679730+2  500. 3000.1    0.O2
 000000-0 234460+5 103071+2 290991-4-783079+7 679730+2 3000. 5000.1    0.O2
  1007                                          JANAF 03/61                     N
 112965+6 134370+5 486944+1 383516-4 958460+5 480900+2  500. 3000.1    0.N
 112965+6 134370+5 428957+1 240844-3-417273+6 480900+2 3000. 5000.1    0.N
  1007 01 08                                    JANAF 06/63                     NO
 215800+5 227000+5 877623+1 899031-4-789656+6 688490+2  500. 3000.1    0.NO
 215800+5 227000+5 916260+1 657885-5-212519+7 688490+2 3000. 5000.1    0.NO
  1008                                          JANAF 06/62                     O
 595590+5 135220+5 497228+1 380768-5 154749+5 500960+2  500. 3000.1     =O
 595590+5 135220+5 657489+1-224268-3-891782+7 500960+2 3000. 5000.1    0.O
  1 99                                          CONVAIR ZPH-122 12/61           E-
         +149010+5+498851+1-272800-5-135900+6+164558+22000. 10000.1      E-
         +149010+5+498851+1-272800-5-135900+6+164558+22000. 10000.1      E-
  1  7 -1 99                                    CONVAIR ZPH-122 12/61           N+
+446641+6+151310+5+501751+1+617100-4-184100+7+496847+22000. 10000.1      N+
+446641+6+151310+5+501751+1+617100-4-184100+7+496847+22000. 10000.1      N
  1  7  1  8 -1 99                              CONVAIR ZPH-122 12/61           NO+
+232919+6+241970+5+910216+1+277400-4-316600+7+654379+22000. 10000.1      NO+
+232919+6+241970+5+910216+1+277400-4-316600+7+654379+22000. 10000.1      NO+
  1  8 -1 99                                    CONVAIR ZPH-122 12/61           O+
+371999+6+149290+5+336271+1+306710-3+590200+7+484849+22000. 10000.1      O+
+371999+6+149290+5+336271+1+306710-3+590200+7+484849+22000. 10000.1      O+

  1
  1
 10  6
  0.0000E+00  4.7192E-03  1.1826E-02  2.3679E-02  4.7192E-02  9.4838E-02
  2.1139E-01  4.7426E-01  7.3713E-01 10.0000E-01
  1.         .1           14000.

  1  1  1     1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  .7650       .2350
 1.0
```

Figure 4.2 Printout of Data

TABLE II

GROUP	HV	HV+	HV-	N	K(I)	HV(J)	F(I)	GAM(I)	NOL(I)
1	.490	.800	.600	3	16	.685	1.96E-01	1.10E-21	6.000
					6	.689	1.60E-01	1.87E-20	6.000
					5	.753	1.49E-02	4.46E-21	1.000
2	.890	.950	.850	4	5	.875	3.66E-02	3.80E-21	4.000
					15	.884	1.57E-01	3.67E-21	1.000
					4	.916	8.47E-03	7.39E-22	1.000
					6	.930	2.53E-02	3.87E-20	2.000
3	1.080	1.200	.960	5	6	.965	2.62E-02	3.87E-20	4.000
					16	.991	8.05E-02	3.09E-20	2.000
					5	1.035	7.35E-02	3.31E-21	7.000
					15	1.098	7.49E-01	3.44E-21	1.000
					14	1.132	2.01E-01	3.67E-21	1.000
4	1.290	1.400	1.200	4	5	1.261	1.18E-01	3.12E-21	3.000
					4	1.319	1.83E-01	9.84E-22	1.000
					14	1.338	9.13E-01	3.42E-21	1.000
					5	1.368	3.87E-02	2.92E-21	1.000
5	1.460	1.600	1.400	4	4	1.438	2.56E-01	8.24E-22	3.000
					13	1.467	9.50E-01	8.65E-22	1.000
					5	1.553	3.00E-03	2.93E-20	1.000
					12	1.594	1.03E+00	7.09E-22	1.000
6	1.850	2.400	1.620	4	4	1.663	9.23E-02	9.58E-22	1.000
					15	1.767	2.26E-02	2.75E-20	3.000
					5	1.836	5.66E-03	2.93E-20	5.000
					14	2.015	2.58E-02	2.75E-20	3.000
7	2.850	3.340	2.400	3	4	2.925	7.00E-03	1.06E-20	3.000
					13	3.000	1.00E-02	8.10E-21	2.000
					12	3.167	8.26E-03	5.20E-21	1.000
8	3.700	4.000	3.400	2	4	3.472	8.61E-03	4.52E-20	3.000
					12	3.711	1.43E-02	1.10E-20	1.000
9	7.110	8.000	6.200	1	3	7.111	6.34E-02	9.12E-22	1.000
10	8.302	8.600	8.000	1	2	8.302	7.40E-02	9.12E-22	1.000
11	8.781	9.000	8.600	1	3	8.781	4.35E-02	6.61E-22	1.000
12	9.400	9.700	9.000	4	3	9.301	1.66E-02	4.46E-21	1.000
					3	9.394	1.19E-02	2.29E-21	1.000
					3	9.460	3.60E-02	3.36E-21	1.000
					9	9.501	4.71E-02	5.48E-22	1.000
13	10.070	10.450	9.700	5	2	9.973	8.90E-02	6.61E-22	1.000
					3	10.102	3.74E-02	2.93E-20	1.000
					11	10.182	1.51E-01	6.53E-22	1.000
					1	10.332	1.84E-01	6.21E-22	1.000
					3	10.418	2.25E-02	5.32E-20	1.000
14	10.620	10.800	10.450	6	2	10.493	1.87E-02	4.46E-20	1.000
					3	10.585	1.31E-02	7.96E-20	1.000
					2	10.619	5.33E-02	3.12E-21	1.000
					3	10.682	8.19E-03	2.68E-19	1.000
					3	10.757	5.18E-03	4.37E-19	1.000
					10	10.761	1.20E-01	6.53E-22	1.000
15	11.200	11.700	10.800	7	1	10.927	4.54E-01	1.61E-23	1.000
					11	11.007	1.85E-02	3.67E-21	1.000
					3	11.200	2.00E-02	4.46E-21	1.000
					2	11.293	4.18E-02	2.93E-20	1.000
					3	11.310	2.54E-02	3.23E-21	1.000
					33	11.424	2.26E-01	1.43E-23	1.000
					2	11.609	2.50E-02	5.32E-20	1.000
16	11.900	12.100	11.700	7	2	11.776	2.20E-02	7.96E-20	1.000
					11	11.806	4.90E-03	1.45E-20	1.000
					9	11.852	1.99E-02	3.67E-21	1.000
					2	11.874	9.10E-03	2.68E-19	1.000
					2	11.948	5.75E-03	4.37E-19	1.000
					3	12.000	2.69E-02	2.99E-20	1.000
					9	12.067	2.18E-02	3.44E-21	1.000
17	12.410	12.800	12.100	7	11	12.160	1.90E-03	1.28E-20	1.000
					3	12.316	1.56E-02	6.96E-20	1.000
					10	12.404	4.61E-02	6.53E-22	1.000
					2	12.414	5.74E-02	3.90E-21	1.000
					2	12.511	2.79E-02	3.37E-21	1.000
					9	12.521	7.75E-02	6.33E-22	1.000
					9	12.651	5.24E-03	1.45E-20	1.000
18	13.040	13.400	12.800	3	1	12.877	2.30E-02	4.46E-21	1.000
					1	13.004	1.32E-01	2.94E-21	1.000
					2	13.190	4.89E-02	2.99E-20	1.000
19	13.580	13.800	13.400	3	2	13.508	2.91E-02	6.96E-19	1.000
					33	13.543	1.61E-01	9.50E-24	1.000
					1	13.677	9.57E-02	2.93E-20	1.000
20	14.200	14.500	13.800	4	1	13.993	5.84E-02	5.32E-20	1.000
					1	14.160	3.42E-02	7.96E-20	1.000
					1	14.257	2.12E-02	2.68E-19	1.000
					1	14.332	1.38E-02	4.37E-19	1.000

Figure 4.3 Transmission Factors

CASE - SAMPLE CASE

RADIATION CONTROL NUMBERS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	1	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0

CHEMISTRY CONTROL NUMBERS	1	2	3	4	5	6	7	8	9	10
	0	1	1	0	0	0	0	0	0	-0

RADIATIVE BOUNDARY CONDITIONS

CONTINUUM

FREQ. (EV)	WAVE LENGTH (A)	EMITTANCE WALL	EMITTANCE OUTER BOUND.	TRANSMITTANCE WALL	TRANSMITTANCE OUTER BOUND.
.020	.620E+06	1.000	0.000	0.000	1.000
.100	.124E+06	1.000	0.000	0.000	1.000
.200	.620E+05	1.000	0.000	0.000	1.000
.500	.248E+05	1.000	0.000	0.000	1.000
.600	.207E+05	1.000	0.000	0.000	1.000
.800	.155E+05	1.000	0.000	0.000	1.000
1.000	.124E+05	1.000	0.000	0.000	1.000
1.500	.827E+04	1.000	0.000	0.000	1.000
2.000	.620E+04	1.000	0.000	0.000	1.000
2.500	.496E+04	1.000	0.000	0.000	1.000
3.000	.413E+04	1.000	0.000	0.000	1.000
3.500	.354E+04	1.000	0.000	0.000	1.000
4.000	.310E+04	1.000	0.000	0.000	1.000
4.500	.276E+04	1.000	0.000	0.000	1.000
5.000	.248E+04	1.000	0.000	0.000	1.000
6.000	.207E+04	1.000	0.000	0.000	1.000
7.000	.177E+04	1.000	0.000	0.000	1.000
8.000	.155E+04	1.000	0.000	0.000	1.000
9.000	.138E+04	1.000	0.000	0.000	1.000
10.000	.124E+04	1.000	0.000	0.000	1.000
10.790	.115E+04	1.000	0.000	0.000	1.000
10.810	.115E+04	1.000	0.000	0.000	1.000
11.250	.110E+04	1.000	0.000	0.000	1.000
11.270	.110E+04	1.000	0.000	0.000	1.000
11.990	.103E+04	1.000	0.000	0.000	1.000
12.010	.103E+04	1.000	0.000	0.000	1.000
13.390	.926E+03	1.000	0.000	0.000	1.000
13.410	.925E+03	1.000	0.000	0.000	1.000
13.590	.912E+03	1.000	0.000	0.000	1.000
13.610	.911E+03	1.000	0.000	0.000	1.000
14.290	.868E+03	1.000	0.000	0.000	1.000
14.310	.867E+03	1.000	0.000	0.000	1.000
15.000	.827E+03	1.000	0.000	0.000	1.000
16.500	.752E+03	1.000	0.000	0.000	1.000
19.000	.653E+03	1.000	0.000	0.000	1.000
22.000	.564E+03	1.000	0.000	0.000	1.000

LINE GROUPS

FREQ. (EV)	WAVE LENGTH (A)	EMITTANCE WALL	EMITTANCE OUTER BOUND.	TRANSMITTANCE WALL	TRANSMITTANCE OUTER BOUND.
.690	.180E+05	1.000	0.000	0.000	1.000
.890	.139E+05	1.000	0.000	0.000	1.000
1.080	.115E+05	1.000	0.000	0.000	1.000
1.290	.961E+04	1.000	0.000	0.000	1.000
1.460	.849E+04	1.000	0.000	0.000	1.000
1.850	.670E+04	1.000	0.000	0.000	1.000
2.850	.435E+04	1.000	0.000	0.000	1.000
3.700	.335E+04	1.000	0.000	0.000	1.000
7.110	.174E+04	1.000	0.000	0.000	1.000
8.302	.149E+04	1.000	0.000	0.000	1.000
8.781	.141E+04	1.000	0.000	0.000	1.000
9.400	.132E+04	1.000	0.000	0.000	1.000
10.070	.123E+04	1.000	0.000	0.000	1.000
10.620	.117E+04	1.000	0.000	0.000	1.000
11.200	.111E+04	1.000	0.000	0.000	1.000
11.900	.104E+04	1.000	0.000	0.000	1.000
12.410	.999E+03	1.000	0.000	0.000	1.000
13.040	.951E+03	1.000	0.000	0.000	1.000
13.580	.913E+03	1.000	0.000	0.000	1.000
14.200	.873E+03	1.000	0.000	0.000	1.000

Figure 4.4 Thermodynamic State Quantities

TABLE 1

STATE QUANTITIES AT STATION S=1.00 CM

PATH LENGTH= 1.00E+00

PATH LENGTH (NORMALIZED)	0.	4.72E-03	1.18E-02	2.37E-02	4.72E-02	9.48E-02	2.11E-01	4.74E-01	7.37E-01	1.00E+00
TEMPERATURE (DEG-K)	1.40E+04	1.40E+04	1.40E+04	1.40E+04	1.40E+04	1.40E+04	1.40E+04	1.40E+04	1.40E+04	1.40E+04
PRESSURE (ATM)	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
ENTHALPY (BTU/LB)	6.10E+04	6.10E+04	6.10E+04	6.10E+04	6.10E+04	6.10E+04	6.10E+04	6.10E+04	6.10E+04	6.10E+04
MEAN MOLECULAR WT.	8.12E+00	8.12E+00	8.12E+00	8.12E+00	8.12E+00	8.12E+00	8.12E+00	8.12E+00	8.12E+00	8.12E+00
MOLE FRACTIONS										
SPECIES										
O+	8.38E-02	8.38E-02	8.38E-02	8.38E-02	8.38E-02	8.38E-02	8.38E-02	8.38E-02	8.38E-02	8.38E-02
O	3.55E-02	3.55E-02	3.55E-02	3.55E-02	3.55E-02	3.55E-02	3.55E-02	3.55E-02	3.55E-02	3.55E-02
N+	3.54E-01	3.54E-01	3.54E-01	3.54E-01	3.54E-01	3.54E-01	3.54E-01	3.54E-01	3.54E-01	3.54E-01
N	8.98E-02	8.98E-02	8.98E-02	8.98E-02	8.98E-02	8.98E-02	8.98E-02	8.98E-02	8.98E-02	8.98E-02
E-	4.37E-01	4.37E-01	4.37E-01	4.37E-01	4.37E-01	4.37E-01	4.37E-01	4.37E-01	4.37E-01	4.37E-01
O2	1.07E-09	1.07E-09	1.07E-09	1.07E-09	1.07E-09	1.07E-09	1.07E-09	1.07E-09	1.07E-09	1.07E-09
N2	1.15E-07	1.15E-07	1.15E-07	1.15E-07	1.15E-07	1.15E-07	1.15E-07	1.15E-07	1.15E-07	1.15E-07
NO	1.89E-08	1.89E-08	1.89E-08	1.89E-08	1.89E-08	1.89E-08	1.89E-08	1.89E-08	1.89E-08	1.89E-08
NUMBER DENSITIES										
O+	4.39E+15	4.39E+15	4.39E+15	4.39E+15	4.39E+15	4.39E+15	4.39E+15	4.39E+15	4.39E+15	4.39E+15
O	1.86E+15	1.86E+15	1.86E+15	1.86E+15	1.86E+15	1.86E+15	1.86E+15	1.86E+15	1.86E+15	1.86E+15
N+	1.85E+16	1.85E+16	1.85E+16	1.85E+16	1.85E+16	1.85E+16	1.85E+16	1.85E+16	1.85E+16	1.85E+16
N	4.71E+15	4.71E+15	4.71E+15	4.71E+15	4.71E+15	4.71E+15	4.71E+15	4.71E+15	4.71E+15	4.71E+15
E-	2.29E+16	2.29E+16	2.29E+16	2.29E+16	2.29E+16	2.29E+16	2.29E+16	2.29E+16	2.29E+16	2.29E+16
O2	5.62E+07	5.62E+07	5.62E+07	5.62E+07	5.62E+07	5.62E+07	5.62E+07	5.62E+07	5.62E+07	5.62E+07
N2	6.03E+09	6.03E+09	6.03E+09	6.03E+09	6.03E+09	6.03E+09	6.03E+09	6.03E+09	6.03E+09	6.03E+09
CO	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
H2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
C2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
C	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
C+	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
H	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
NO	9.93E+08	9.93E+08	9.93E+08	9.93E+08	9.93E+08	9.93E+08	9.93E+08	9.93E+08	9.93E+08	9.93E+08
N2+	2.48E+10	2.48E+10	2.48E+10	2.48E+10	2.48E+10	2.48E+10	2.48E+10	2.48E+10	2.48E+10	2.48E+10
N-	5.59E+09	5.59E+09	5.59E+09	5.59E+09	5.59E+09	5.59E+09	5.59E+09	5.59E+09	5.59E+09	5.59E+09
O-	1.09E+10	1.09E+10	1.09E+10	1.09E+10	1.09E+10	1.09E+10	1.09E+10	1.09E+10	1.09E+10	1.09E+10
H-	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
C-	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Figure 4.5 Continuum Output

CONTINUUM CONTRIBUTION TO THE SPECTRAL FLUX
Y/DELTA= 0.

HV (EV)	QMINUS (WATTS/ CM2 EV)	PARTIAL SPECTRAL INTEGRAL OF QMINUS (WATTS/CM2)	NORMALIZED QMINUS CONTRIBUTION (PERCENT TOTAL)	QPLUS (WATTS/ CM2 EV)	PARTIAL SPECTRAL INTEGRAL OF QPLUS (WATTS/CM2)	NORMALIZED QPLUS CONTRIBUTION (PERCENT TOTAL)
.020	0.	0.	IIIII	4.623E+00	0.	0.
.100	0.	0.	IIIII	6.808E+00	4.572E-01	4.060E-03
.200	0.	0.	IIIII	6.674E+00	1.131E+00	1.005E-02
.500	0.	0.	IIIII	6.074E+00	3.044E+00	2.702E-02
.600	0.	0.	IIIII	5.885E+00	3.642E+00	3.233E-02
.800	0.	0.	IIIII	5.522E+00	4.782E+00	4.246E-02
1.000	0.	0.	IIIII	4.951E+00	5.769E+00	5.123E-02
1.500	0.	0.	IIIII	3.515E+00	7.736E+00	6.869E-02
2.000	0.	0.	IIIII	2.743E+00	9.301E+00	8.258E-02
2.500	0.	0.	IIIII	2.164E+00	1.053E+01	9.347E-02
3.000	0.	0.	IIIII	1.647E+00	1.148E+01	1.019E-01
3.500	0.	0.	IIIII	1.402E+00	1.224E+01	1.087E-01
4.000	0.	0.	IIIII	9.946E-01	1.284E+01	1.140E-01
4.500	0.	0.	IIIII	1.173E+00	1.338E+01	1.188E-01
5.000	0.	0.	IIIII	9.138E-01	1.390E+01	1.235E-01
6.000	0.	0.	IIIII	5.880E-01	1.466E+01	1.301E-01
7.000	0.	0.	IIIII	3.265E-01	1.511E+01	1.342E-01
8.000	0.	0.	IIIII	2.063E-01	1.538E+01	1.366E-01
9.000	0.	0.	IIIII	1.271E-01	1.555E+01	1.380E-01
10.000	0.	0.	IIIII	7.680E-02	1.565E+01	1.389E-01
10.790	0.	0.	IIIII	4.978E-02	1.570E+01	1.394E-01
10.810	0.	0.	IIIII	1.210E+01	1.582E+01	1.405E-01
11.250	0.	0.	IIIII	9.470E+00	2.056E+01	1.826E-01
11.270	0.	0.	IIIII	9.364E+00	2.075E+01	1.843E-01
11.990	0.	0.	IIIII	6.209E+00	2.636E+01	2.340E-01
12.010	0.	0.	IIIII	2.640E+01	2.668E+01	2.369E-01
13.390	0.	0.	IIIII	1.166E+01	5.295E+01	4.701E-01
13.410	0.	0.	IIIII	1.895E+01	5.325E+01	4.728E-01
13.590	0.	0.	IIIII	1.699E+01	5.649E+01	5.016E-01
13.610	0.	0.	IIIII	1.678E+01	5.682E+01	5.045E-01
14.290	0.	0.	IIIII	1.106E+01	6.629E+01	5.886E-01
14.310	0.	0.	IIIII	2.707E+01	6.667E+01	5.920E-01
15.000	0.	0.	IIIII	1.760E+01	8.208E+01	7.288E-01
16.500	0.	0.	IIIII	6.758E+00	1.003E+02	8.910E-01
19.000	0.	0.	IIIII	1.300E+00	1.104E+02	9.804E-01
22.000	0.	0.	IIIII	1.680E-01	1.126E+02	1.000E+00

Figure 4.6 Line Output

TABLE 23

LINE TRANSPORT QUANTITIES AT STATION S=1.00 CM AND Y/DELTA=0.000

GROUP NO.	FREQUENCY (EV)	NEG CONTRIBUTION W/CM2	POS CONTRIBUTION W/CM2
1	.690	0.	1.12E+00
2	.890	0.	5.19E-01
3	1.080	0.	2.65E+00
4	1.290	0.	3.89E+00
5	1.460	0.	6.07E+00
6	1.850	0.	1.39E+00
7	2.850	0.	4.48E-01
8	3.700	0.	5.61E-01
9	7.110	0.	8.43E+00
10	8.302	0.	1.11E+01
11	8.781	0.	3.31E+00
12	9.400	0.	1.37E+01
13	10.070	0.	2.49E+01
14	10.620	0.	2.05E+01
15	11.200	0.	2.20E+01
16	11.900	0.	1.63E+01
17	12.410	0.	7.59E+00
18	13.040	0.	9.11E+00
19	13.580	0.	9.18E+00
20	14.200	0.	1.63E+01

TOTAL LINE CORRECTION TO FLUX DIRECTED AWAY FROM WALL= 0. WATTS/SQ.CM

TOTAL LINE CORRECTION TO FLUX DIRECTED TOWARD WALL= 1.79E+02WATTS/SQ.CM

Figure 4.7 Extensive Continuum Output

B				
7.580067E+00	7.580067E+00	7.580067E+00	7.580067E+00	7.580067E+00
7.580067E+00	7.580067E+00	7.580067E+00	7.580067E+00	7.580067E+00
FMU				
4.706243E-01	4.706243E-01	4.706243E-01	4.706243E-01	4.706243E-01
4.706243E-01	4.706243E-01	4.706243E-01	4.706243E-01	4.706243E-01
TAU				
1.000000E-08	4.441951E-03	1.113122E-02	2.228784E-02	4.441942E-02
8.926615E-02	1.989706E-01	4.463966E-01	6.938227E-01	9.412487E-01
B				
1.832731E+02	1.832731E+02	1.832731E+02	1.832731E+02	1.832731E+02
1.832731E+02	1.832731E+02	1.832731E+02	1.832731E+02	1.832731E+02
FMU				
1.892766E-02	1.892766E-02	1.892766E-02	1.892766E-02	1.892766E-02
1.892766E-02	1.892766E-02	1.892766E-02	1.892766E-02	1.892766E-02
TAU				
1.000000E-08	1.786568E-04	4.476871E-04	8.963862E-04	1.784478E-03
3.590133E-03	8.002247E-03	1.795328E-02	2.790430E-02	3.785533E-02
B				
7.027366E+02	7.027366E+02	7.027366E+02	7.027366E+02	7.027366E+02
7.027366E+02	7.027366E+02	7.027366E+02	7.027366E+02	7.027366E+02
FMU				
4.771077E-03	4.771077E-03	4.771077E-03	4.771077E-03	4.771077E-03
4.771077E-03	4.771077E-03	4.771077E-03	4.771077E-03	4.771077E-03
TAU				
1.000000E-08	4.504133E-05	1.128555E-04	2.259586E-04	4.503233E-04
9.049687E-04	2.017126E-03	4.525471E-03	7.033817E-03	9.542163E-03
B				
3.855553E+03	3.855553E+03	3.855553E+03	3.855553E+03	3.855553E+03
3.855553E+03	3.855553E+03	3.855553E+03	3.855553E+03	3.855553E+03
FMU				
7.883733E-04	7.883733E-04	7.883733E-04	7.883733E-04	7.883733E-04
7.883733E-04	7.883733E-04	7.883733E-04	7.883733E-04	7.883733E-04
TAU				
1.000000E-08	7.450983E-06	1.865661E-05	3.734578E-05	7.441983E-05
1.495455E-04	3.333185E-04	7.477979E-04	1.162277E-03	1.576757E-03
B				
5.309988E+03	5.309988E+03	5.309988E+03	5.309988E+03	5.309988E+03
5.309988E+03	5.309988E+03	5.309988E+03	5.309988E+03	5.309988E+03
FMU				
5.544127E-04	5.544127E-04	5.544127E-04	5.544127E-04	5.544127E-04
5.544127E-04	5.544127E-04	5.544127E-04	5.544127E-04	5.544127E-04
TAU				
1.000000E-08	5.242769E-06	1.312297E-05	2.626588E-05	5.233769E-05
1.051688E-04	2.344046E-04	5.258815E-04	8.173525E-04	1.108835E-03
B				
8.620340E+03	8.620340E+03	8.620340E+03	8.620340E+03	8.620340E+03
8.620340E+03	8.620340E+03	8.620340E+03	8.620340E+03	8.620340E+03
FMU				
3.203638E-04	3.203638E-04	3.203638E-04	3.203638E-04	3.203638E-04
3.203638E-04	3.203638E-04	3.203638E-04	3.203638E-04	3.203638E-04
TAU				
1.000000E-08	3.033722E-06	7.587245E-06	1.518179E-05	3.024722E-05
6.077533E-05	1.354534E-04	3.038815E-04	4.723095E-04	6.407376E-04
B				
1.227229E+04	1.227229E+04	1.227229E+04	1.227229E+04	1.227229E+04
1.227229E+04	1.227229E+04	1.227229E+04	1.227229E+04	1.227229E+04
FMU				
1.794415E-04	1.794415E-04	1.794415E-04	1.794415E-04	1.794415E-04
1.794415E-04	1.794415E-04	1.794415E-04	1.794415E-04	1.794415E-04

MANY PAGES OF OUTPUT HAVE

BEEN OMITTED

Figure 4.8 Extensive Line Output

```
                                    TABLE   3
                  LINE TRANSPORT QUANTITIES AT S=1.00 CM,Y/DELTA=0.000
LINE GROUP NO. 1
   PATH LENGTH
  (NORMALIZED)        0.      47.19E-0411.83E-0323.68E-0347.19E-0394.84E-0321.14E-0247.43E-0273.71E-0210.00E-01
CONTM. ABSORPTION
  COEFF. (1/CM)      42.42E-0542.42E-0542.42E-0542.42E-0542.42E-0542.42E-0542.42E-0542.42E-0542.42E-0542.42E-05
B.B.EMISSIVE POWER
(WATTS/ SQ.  CM-EV) 67.43E+0267.43E+0267.43E+0267.43E+0267.43E+0267.43E+0267.43E+0267.43E+0267.43E+0267.43E+02
                    POS. CONTM FLUX=57.19E-01 NEG. CONTM FLUX= 0.       BOTH IN WATTS/CM2

                                  ABSORPTION COEFFICIENTS, (1/CM)
                                       OPTICAL DEPTHS,AND
                                             FLUXES
   .68474          94.62E-0594.62E-0594.62E-0594.62E-0594.62E-0594.62E-0594.62E-0594.62E-0594.62E-0594.62E-05
                   10.00E-0989.41E-0722.39E-0644.82E-0689.32E-0617.95E-0540.01E-0589.75E-0513.95E-0418.92E-04
                    POSITIVE SPECTRAL FLUX=12.75E+00 NEGATIVE SPECTRAL FLUX= 0.       BOTH IN W/CM2-EV

   .68482          13.64E-0413.64E-0413.64E-0413.64E-0413.64E-0413.64E-0413.64E-0413.64E-0413.64E-0413.64E-04
                   10.00E-0912.88E-0632.27E-0664.60E-0612.87E-0525.87E-0557.66E-0512.94E-0420.11E-0427.28E-04
                    POSITIVE SPECTRAL FLUX=18.37E+00 NEGATIVE SPECTRAL FLUX= 0.       BOTH IN W/CM2-EV

   .68487          22.33E-0422.33E-0422.33E-0422.33E-0422.33E-0422.33E-0422.33E-0422.33E-0422.33E-0422.33E-04
                   10.00E-0921.09E-0652.82E-0610.58E-0521.08E-0542.36E-0594.41E-0521.18E-0432.92E-0444.66E-04
                    POSITIVE SPECTRAL FLUX=30.05E+00 NEGATIVE SPECTRAL FLUX= 0.       BOTH IN W/CM2-EV

   .68491          41.18E-0441.18E-0441.18E-0441.18E-0441.18E-0441.18E-0441.18E-0441.18E-0441.18E-0441.18E-04
                   10.00E-0938.87E-0697.40E-0619.50E-0538.86E-0578.10E-0517.41E-0439.06E-0460.70E-0482.35E-04
                    POSITIVE SPECTRAL FLUX=55.30E+00 NEGATIVE SPECTRAL FLUX= 0.       BOTH IN W/CM2-EV

   .68495          82.90E-0482.90E-0482.90E-0482.90E-0482.90E-0482.90E-0482.90E-0482.90E-0482.90E-0482.90E-04
                   10.00E-0978.25E-0619.61E-0539.26E-0578.24E-0515.72E-0435.05E-0478.63E-0412.22E-0316.58E-03
                    POSITIVE SPECTRAL FLUX=11.09E+01 NEGATIVE SPECTRAL FLUX= 0.       BOTH IN W/CM2-EV

   .68497          16.85E-0316.85E-0316.85E-0316.85E-0316.85E-0316.85E-0316.85E-0316.85E-0316.85E-0316.85E-03
                   10.00E-0915.91E-0539.86E-0579.80E-0515.90E-0431.96E-0471.24E-0415.98E-0324.84E-0333.70E-03
                    POSITIVE SPECTRAL FLUX=22.35E+01 NEGATIVE SPECTRAL FLUX= 0.       BOTH IN W/CM2-EV

   .68499          28.84E-0328.84E-0328.84E-0328.84E-0328.84E-0328.84E-0328.84E-0328.84E-0328.84E-0328.84E-03
                   10.00E-0927.22E-0568.22E-0513.66E-0427.22E-0454.71E-0412.19E-0327.36E-0342.52E-0357.69E-03
                    POSITIVE SPECTRAL FLUX=37.80E+01 NEGATIVE SPECTRAL FLUX= 0.       BOTH IN W/CM2-EV

   .68500          34.39E-0334.39E-0334.39E-0334.39E-0334.39E-0334.39E-0334.39E-0334.39E-0334.39E-0334.39E-03
                   10.00E-0932.46E-0581.34E-0516.29E-0432.46E-0465.23E-0414.54E-0332.62E-0350.70E-0368.78E-03
                    POSITIVE SPECTRAL FLUX=44.82E+01 NEGATIVE SPECTRAL FLUX= 0.       BOTH IN W/CM2-EV
```

MANY PAGES OF OUTPUT HAVE

BEEN OMITTED

Figure 4.9 Input Deck (Second Case)

```
2056 4
   0.40  +01   0.10  +02   0.60  +01   0.18  +02   0.54  +02   0.90  +02
   0.00  +00   0.00  +00   0.90  +01   0.50  +01   0.10  +01   0.50  +01
   0.30  +01   1.50  +01   0.90  +01   0.40  +02   0.90  +01   0.50  +01
   0.10  +01   0.50  +01   0.12  +02   0.15  +02   0.36  +02   0.00  +00
   0.20  +01   0.80  +01   0.18  +02   0.32  +02   0.00  +00   0.00  +00
   0.00  +00   0.00  +00   0.90  +01   0.00  +00   0.00  +00   0.00  +00
   0.00  +00   0.00  +00   0.00  +00   0.00  +00   0.40  +01   0.00  +00
   0.00  +00   0.00  +00   0.00  +00   0.00  +00   0.00  +00   0.00  +00
   0.60  +01   0.00  +00   0.00  +00   0.00  +00   0.00  +00   0.00  +00
   0.00  +00   0.00  +00   0.00  +00   0.00  +00   0.00  +00   0.00  +00
   0.00  +00   0.2384+01   0.3576+01   0.1045+02   0.1188+02   0.1300+02
   0.00  +00   0.00  +00   0.96  -02   0.1967+01   0.4189+01   0.9144+01
   0.9519+01   0.1074+02   0.1099+02   0.1208+02   0.00  +00   1.2639+00
   2.6839+00   4.1825+00   7.5351+00   7.9461+00   8.6442+00   0.00  +00
   0.00  +00   0.1020+02   0.1208+02   0.1274+02   0.00  +00   0.00  +00


   0.60  +00   0.81  +00   0.96  +00   0.12  +01   0.14  +01   0.162 +01
   0.24  +01   0.34  +01   0.40  +01   0.62  +01   0.80  +01   0.90  +01
   0.97  +01   0.1045+02   0.1080+02   0.1170+02   0.1210+02   0.1280+02
   0.1340+02   0.1380+02   0.00  +00   0.00  +00   0.00  +00   0.00  +00
   0.80  +00   0.95  +00   0.12  +01   0.14  +01   0.16  +01   0.24  +01
   0.3500+01   0.40  +01   0.60  +01   0.80  +01   0.90  +01   0.97  +01
   0.1045+02   0.1080+02   0.1170+02   0.1210+02   0.1280+02   0.1340+02
   0.1380+02   0.1450+02   0.00  +00   0.00  +00   0.00  +00   0.00  +00
   0.69  +00   0.89  +00   0.1050+01   0.1290+01   0.1460+01   0.1850+01
   0.2850+01   0.3700+01   0.5000+01   0.7110+01   0.8400+01   0.94  +01
   0.1007+02   0.1062+02   0.1120+02   0.1190+02   0.1241+02   0.1304+02
   0.1358+02   0.1420+02    .    +      .    +      .    +      .    +
 6 71316
 6 6 8 6 5 6 5 1 1 8101212 712 8 9 4 4 4
27          0.660        0.8421        5.67E   -20
16           0.685        0.196            110E-21 6.
22           0.6859       0.044            321E-21 3.
 6           0.689        0.1597           187E-20 6.
23           0.710        0.208            639E-18 4.
 5           0.7525       0.0149           446E-21
22           0.844        0.0808           412E-21 3.
21           0.852        0.0687           108E-21
 5           0.875        0.0366           380E-21 4.
15          0.8840       0.1570            367E-21
 4           0.9158       0.00847          739E-22
 6           0.9304       0.0253           387E-20 2.
 6           0.965        0.0262           387E-20 4.
16           0.991        0.0805           309E-20 2.
23           1.019        0.0329           205E-19 4.
 5           1.0355       0.0735           331E-21 7.
22           1.079        0.1008           320E-21 8.
15          1.0980       0.7490            344E-21
14          1.1320       0.2010            367E-21
21           1.163        0.474            108E-21
22           1.224        0.0245           262E-21
 5           1.2610       0.115            312E-21 3.
 4           1.3190       0.1833           984E-22
21           1.326        0.206            138E-21 3.
14          1.3380       0.9130            342E-21
 5           1.3677       0.0387           292E-21
```

Figure 4.9 (Continued)

4	1.4380	0.256	824E-22	3.
13	1.4670	0.9500	865E-22	
21	1.487	0.0405	218E-21	
5	1.5527	0.0030	293E-20	
12	1.594	1.0300	709E-22	
4	1.6630	0.0923	958E-22	
15	1.767	0.0226	275E-20	3.
22	1.814	0.0039	350E-20	5.
5	1.8357	0.00566	293E-20	5.
26	1.888	0.6407		
14	2.015	0.0258	275E-20	3.
26	2.549	0.1193		
4	2.925	0.0070	106E-20	3.
13	3.0	0.010	810E-21	2.
12	3.167	0.00826	520E-21	
4	3.4724	0.00861	452E-20	3.
12	3.7110	0.0143	110E-20	
19	5.002	0.0676	113E-21	
18	6.424	0.07290	113E-21	
19	7.013	0.01410	500E-21	
19	7.078	0.0748	262E-21	
3	07.111	0.0634	912E-22	
17	7.481	0.105	873E-22	
19	7.717	0.00534	220E-20	
19	7.721	0.0367	109E-19	
17	7.947	0.283	208E-22	
19	8.030	0.00457	690E-19	
19	8.191	0.0116	130E-18	
19	8.203	0.00147	119E-19	
19	8.302	0.00831	538E-18	
2	08.3021	0.0740	912E-22	
18	8.368	0.011	214E-21	
19	8.377	0.00501	677E-18	
18	8.433	0.0142	500E-21	
18	8.474	0.0625	248E-21	
3	08.781	0.0435	661E-22	
18	9.137	0.00526	220E-20	
18	9.141	0.0362	109E-19	
3	09.301	0.0166	446E-21	
17	9.332	0.203	557E-23	
3	09.394	0.0119	229E-21	
18	9.450	0.0218	690E-19	
3	09.460	0.0360	336E-21	
09	9.5010	0.0471	548E-22	
18	9.611	0.0114	130E-18	
18	9.623	0.00143	119E-19	
17	9.697	0.01950	500E-21	
17	9.698	0.0038	235E-21	
17	9.709	0.0767	235E-21	
18	9.722	0.0081	538E-18	
18	9.797	0.00488	677E-18	
17	9.834	0.026	293E-21	
2	09.973	0.0890	661E-22	
3	10.102	0.0374	293E-20	
11	10.182	0.1510	653E-22	
25	10.196	0.4162		
1	10.332	0.1840	621E-22	
17	10.401	0.00719	220E-20	
17	10.405	0.0495	109E-19	
3	10.418	0.0225	532E-20	
2	10.493	0.0187	446E-20	
3	10.585	0.0131	796E-20	
2	10.619	0.0533	312E-21	
3	10.682	0.00819	268E-19	
17	10.714	0.0298	690E-19	
3	10.757	0.00518	437E-19	

```
10          10.761      0.1200          653E-22
18          10.873      0.705           630E-21
17          10.875      0.0155          130E-18
17          10.887      0.00195         119E-19
 1          10.927      0.4540          161E-23
17          10.984      0.011           253E-19
11          11.007      0.0185          367E-21
17          11.061      0.00659         677E-18
 3          11.200      0.0200          446E-21
 2          11.293      0.0418          293E-20
 3          11.310      0.0254          323E-21
 7          11.424      0.2260          143E-23
 2          11.609      0.0250          532E-20
 2          11.776      0.0220          796E-20
11          11.806      0.0049          145E-20
09          11.852      0.0199          367E-21
 2          11.874      0.0091          268E-19
 2          11.948      0.00575         437E-19
 3          12.000      0.0269          299E-20
09          12.067      0.0218          344E-21
25          12.084      0.0791
11          12.160      0.0019          128E-20
19          12.181      1.05            159E-22
 3          12.316      0.0156          696E-20
10          12.404      0.0461          653E-22
 2          12.414      0.0574          390E-21
 2          12.511      0.0279          337E-21
09          12.521      0.0775          633E-22
09          12.651      0.00524         145E-20
25          12.745      0.02899      4.59E   -20
 1          12.877      0.0230          446E-21
 1          13.004      0.1320          294E-21
17          13.119      0.379           101E-21
 2          13.190      0.0489          299E-20
 2          13.508      0.0291          696E-19
 7          13.543      0.1610          950E-24
18          13.601      0.295           159E-22
 1          13.677      0.0957          293E-20
 1          13.993      0.0584          532E-20
 1          14.160      0.0342          796E-20
 1          14.257      0.0212          268E-19
 1          14.332      0.0138          437E-19
 35
  0.02       0.1        0.2        0.5        0.6        0.8
  1.00       1.50       2.00       2.5        2.75       3.0
  3.25       3.50       3.75       4.0        4.5        5.0
  6.0        7.0        8.0        10.79      10.81      11.0
  11.25      11.27      11.99      12.01      13.39      13.41
  13.59      13.61      14.29      14.31      15.0
1000001001000000000 SAMPLE CASE NO. 2
0110000000
  4
  6 CARBON      12.011
  7 NITROGEN    14.008    -
  8 OXYGEN      16.0
 99 ELECTRON     0.00055
001006002008                                JANAF 3/61                    CO2
-940539+5 370628+5 114722+2 151349-2-300936+6 800466+2  300. 2000.1   0.CO2
-940539+5 365358+5 147056+2 137959-3-223029+7 798482+2 2000. 5000.1   0.CO2
  2008                                      JANAF 03/61                   O2
 000000-0 234460+5 804370+1 510872-3-152718+6 679730+2  500. 3000.1   0.O2
 000000-0 234460+5 103071+2 290991-4-783079+7 679730+2 3000. 5000.1   0.O2
002007                                      JANAF 3/61                    N2
      0+0 224490+5 689313+1 856610-3-214051+5 638720+2  300. 2000.1   0.N2
      0+0 221654+5 883191+1 595750-4-140025+7 637653+2 2000. 5000.1   0.N2
003006                                      JANAF 12/60                   C3
```

Figure 4.9 (Continued)

```
 189699+6 371079+5 118636+2 127695-2-282238+6 800241+2  300. 2000.1    0.C3
 189699+6 366234+5 148489+2 868438-5-207743+7 798416+2 2000. 5000.1    0.C3
001006001008                                JANAF 3/61                    CO
-264170+5 226455+5 700344+1 834883-3-368400+5 654784+2  300. 2000.1    0.CO
-264170+5 223576+5 885673+1 586015-4-123975+7 653701+2 2000. 5000.1    0.CO
  1006                                      JANAF 03/61                   C
 170886+6 135500+5 444433+1 228125-3 409830+6 492870+2  500. 3000.1    0.C
 170886+6 135500+5 412212+1 261908-3 262886+7 492870+2 3000. 5000.1    0.C
  1006 01 07                                JANAF 12/62                  CN
 109000+6 232490+5 655906+1 115326-2 479517+6 669760+2  500. 3000.1    0.CN
 109000+6 232490+5 988013+1 313855-3-649453+7 669760+2 3000. 5000.1    0.CN
002006                                      JANAF 9/61                   C2
 198999+6 246990+5 776612+1 696081-3 185649+6 685519+2  500. 3000.1    0.C2
 198999+6 246990+5 104162+2 566841-4-640205+7 685519+2 3000. 5000.1    0.C2
  1007                                      JANAF 03/61                   N
 112965+6 134370+5 486944+1 383516-4 958460+5 480900+2  500. 3000.1    0.N
 112965+6 134370+5 428957+1 240844-3-417273+6 480900+2 3000. 5000.1    0.N
  1007 01 08                                JANAF 06/63                  NO
 215800+5 227000+5 877623+1 899031-4-789656+6 688490+2  500. 3000.1    0.NO
 215800+5 227000+5 916260+1 657885-5-212519+7 688490+2 3000. 5000.1    0.NO
  1008                                      JANAF 06/62                   O
 595590+5 135220+5 497228+1 380768-5 154749+5 500960+2  500. 3000.1     =O
 595590+5 135220+5 657489+1-224268-3-891782+7 500960+2 3000. 5000.1    0.O
  1 99                                      CONVAIR ZPH-122 12/61        E-
        +149010+5+498851+1-272800-5-135900+6+164558+22000. 10000.1      E-
        +149010+5+498851+1-272800-5-135900+6+164558+22000. 10000.1      E-
  1  8  1 99                                CONVAIR ZPH-122 12/61        O-
+245000+5+149430+5+216633+1+805240-3+532500+7+492947+22000. 10000.1      O-
+245000+5+149430+5+216633+1+805240-3+532500+7+492947+22000. 10000.1      O-
  2  8 -1 99                                CONVAIR ZPH-122 12/61       O2+
+279695+6+248730+5+594789+1+626340-3+103500+8+677731+22000. 10000.1     O2+
+279695+6+248730+5+594789+1+626340-3+103500+8+677731+22000. 10000.1     O2+
  2  8  1 99                                CONVAIR ZPH-122 12/61       O2-
-205250+5+267570+5+111480+2-656700-4-779100+7+699149+22000. 10000.1     O2-
-205250+5+267570+5+111480+2-656700-4-779100+7+699149+22000. 10000.1     O2-
  1  6 -1 99                                CONVAIR ZPH-122 12/61        C+
+428985+6+150120+5+489657+1+180700-4+340000+5+484232+22000. 10000.1      C+
+428985+6+150120+5+489657+1+180700-4+340000+5+484232+22000. 10000.1      C+
  1  7 -1 99                                CONVAIR ZPH-122 12/61        N+
+446641+6+151310+5+501751+1+617100-4-184100+7+496847+22000. 10000.1      N+
+446641+6+151310+5+501751+1+617100-4-184100+7+496847+22000. 10000.1      N+
  1  6  1  8 -1 99                          CONVAIR ZPH-122 12/61       CO+
+294283+6+243830+5+893619+1+378000-4-150900+7+666595+22000. 10000.1     CO+
+294283+6+243830+5+893619+1+378000-4-150900+7+666595+22000. 10000.1     CO+
  1  7  1  8 -1 99                          CONVAIR ZPH-122 12/61       NO+
+232919+6+241970+5+910216+1+277400-4-316600+7+654379+22000. 10000.1     NO+
+232919+6+241970+5+910216+1+277400-4-316600+7+654379+22000. 10000.1     NO+
  1  8 -1 99                                CONVAIR ZPH-122 12/61        O+
+371999+6+149290+5+336271+1+306710-3+590200+7+484849+22000. 10000.1      O+
+371999+6+149290+5+336271+1+306710-3+590200+7+484849+22000. 10000.1      O+

  1
  1
 10  6
  0.0000E+00  4.7192E-03  1.1826E-02  2.3679E-02  4.7192E-02  9.4838E-02
  2.1139E-01  4.7426E-01  7.3713E-01 10.0000E-01
  10.
  1.          1.          1.          1.          1.          1.
  1.          1.          1.          1.          1.
  5000.       6000.       7000.       8000.       9000.       10000.
  10500.      11000.      11500.      12000.

  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  0.25                0.75
  0.25                0.75
  0.25                0.75
```

Figure 4.9 (Continued)

Figure 4.9 (concluded)

```
  0.25                0.75
  0.25                0.75
  0.25                0.75
  0.25                0.75
  0.25                0.75
  0.25                0.75
  0.25                0.75
   1.
0000000000000000000000
```

Figure 4.10 Printout of Data (Second Case)

GROUP	HV	HV+	HV-	N
1	.690	.800	.600	6
2	.890	.950	.810	6
3	1.050	1.200	.960	8
4	1.290	1.400	1.200	6
5	1.460	1.600	1.400	5
6	1.850	2.400	1.620	6
7	2.850	3.500	2.400	5
8	3.700	4.000	3.400	1
9	5.000	6.000	4.000	1
10	7.110	8.000	6.200	8
11	8.400	9.000	8.000	10

TABLE II

K(I)	HV(J)	F(I)	GAM(I)	NOL(I)
27	.660	8.42E-01	5.67E-20	1.000
16	.685	1.96E-01	1.10E-21	6.000
22	.686	4.40E-02	3.21E-21	3.000
6	.689	1.60E-01	1.87E-20	6.000
23	.710	2.08E-01	6.39E-18	4.000
5	.753	1.49E-02	4.46E-21	1.000
22	.844	8.08E-02	4.12E-21	3.000
21	.852	6.87E-02	1.08E-21	1.000
5	.875	3.66E-02	3.80E-21	4.000
15	.884	1.57E-01	3.67E-21	1.000
4	.916	8.47E-03	7.39E-22	1.000
6	.930	2.53E-02	3.87E-20	2.000
6	.965	2.62E-02	3.87E-20	4.000
16	.991	8.05E-02	3.09E-20	2.000
23	1.019	3.29E-02	2.05E-19	4.000
5	1.035	7.35E-02	3.31E-21	7.000
22	1.079	1.01E-01	3.20E-21	8.000
15	1.098	7.49E-01	3.44E-21	1.000
14	1.132	2.01E-01	3.67E-21	1.000
21	1.163	4.74E-01	1.08E-21	1.000
22	1.224	2.85E-02	2.62E-21	1.000
5	1.261	1.18E-01	3.12E-21	3.000
4	1.319	1.83E-01	9.84E-22	1.000
21	1.326	2.06E-01	1.38E-21	3.000
14	1.338	9.13E-01	3.42E-21	1.000
5	1.368	3.87E-02	2.92E-21	1.000
4	1.438	2.56E-01	8.24E-22	3.000
13	1.467	9.50E-01	8.65E-22	1.000
21	1.487	4.05E-02	2.18E-21	1.000
5	1.553	3.00E-03	2.93E-20	1.000
12	1.594	1.03E+00	7.09E-22	1.000
4	1.663	9.23E-02	9.58E-22	1.000
15	1.767	2.26E-02	2.75E-20	3.000
22	1.814	3.90E-03	3.50E-20	5.000
5	1.836	5.66E-03	2.93E-20	5.000
26	1.888	6.41E-01	-0.	1.000
14	2.015	2.58E-02	2.75E-20	3.000
26	2.549	1.19E-01	-0.	1.000
4	2.925	7.00E-03	1.06E-20	3.000
13	3.000	1.00E-02	8.10E-21	2.000
12	3.167	8.26E-03	5.20E-21	1.000
4	3.472	8.61E-03	4.52E-20	3.000
12	3.711	1.43E-02	1.10E-20	1.000
19	5.002	6.76E-02	1.13E-21	1.000
18	6.424	7.29E-02	1.13E-21	1.000
19	7.013	1.41E-02	5.00E-21	1.000
19	7.078	7.48E-02	2.62E-21	1.000
3	7.111	6.34E-02	9.12E-22	1.000
17	7.481	1.05E-01	8.73E-22	1.000
19	7.717	5.34E-03	2.20E-20	1.000
19	7.721	3.67E-02	1.09E-19	1.000
17	7.947	2.83E-01	2.08E-22	1.000
19	8.030	4.57E-03	6.90E-19	1.000
19	8.191	1.16E-02	1.30E-18	1.000
19	8.203	1.47E-03	1.19E-19	1.000
19	8.302	8.31E-03	5.38E-18	1.000
2	8.302	7.40E-02	9.12E-22	1.000
18	8.368	1.10E-02	2.14E-21	1.000
19	8.377	5.01E-03	6.77E-18	1.000

Figure 4.10 (continued)

					18	8.433	1.42E-02	5.00E-21	1.000
					18	8.474	6.25E-02	2.48E-21	1.000
					3	8.761	4.35E-02	6.61E-22	1.000
12	9.400	9.700	9.000	12	18	9.137	5.26E-03	2.20E-20	1.000
					18	9.141	3.62E-02	1.09E-19	1.000
					3	9.301	1.66E-02	4.46E-21	1.000
					17	9.332	2.03E-01	5.57E-23	1.000
					3	9.394	1.19E-02	2.29E-21	1.000
					18	9.450	2.18E-02	6.90E-19	1.000
					3	9.460	3.60E-02	3.36E-21	1.000
					9	9.501	4.71E-02	5.48E-22	1.000
					18	9.611	1.14E-02	1.30E-18	1.000
					18	9.623	1.43E-03	1.19E-19	1.000
					17	9.697	1.95E-02	5.00E-21	1.000
					17	9.698	3.80E-03	2.35E-21	1.000
13	10.070	10.450	9.700	12	17	9.709	7.67E-02	2.35E-21	1.000
					18	9.722	8.10E-03	5.38E-18	1.000
					18	9.797	4.88E-03	6.77E-18	1.000
					17	9.834	2.60E-02	2.93E-21	1.000
					2	9.973	8.90E-02	6.61E-22	1.000
					3	10.102	3.74E-02	2.93E-20	1.000
					11	10.182	1.51E-01	6.53E-22	1.000
					25	10.196	4.16E-01	-0.	1.000
					1	10.332	1.84E-01	6.21E-22	1.000
					17	10.401	7.19E-03	2.20E-20	1.000
					17	10.405	4.95E-02	1.09E-19	1.000
					3	10.418	2.25E-02	5.32E-20	1.000
14	10.620	10.800	10.450	7	2	10.493	1.87E-02	4.46E-20	1.000
					3	10.585	1.31E-02	7.96E-20	1.000
					2	10.619	5.33E-02	3.12E-21	1.000
					3	10.682	8.19E-03	2.68E-19	1.000
					17	10.714	2.98E-02	6.90E-19	1.000
					3	10.757	5.18E-03	4.37E-19	1.000
					10	10.761	1.20E-01	6.53E-22	1.000
15	11.200	11.700	10.800	12	18	10.873	7.05E-01	6.30E-21	1.000
					17	10.875	1.55E-02	1.30E-18	1.000
					17	10.887	1.95E-03	1.19E-19	1.000
					1	10.927	4.54E-01	1.61E-23	1.000
					17	10.986	1.10E-02	2.53E-19	1.000
					11	11.007	1.85E-02	3.67E-21	1.000
					17	11.061	6.59E-03	6.77E-18	1.000
					3	11.200	2.00E-02	4.46E-21	1.000
					2	11.293	4.18E-02	2.93E-20	1.000
					3	11.310	2.54E-02	3.23E-21	1.000
					7	11.424	2.26E-01	1.43E-23	1.000
					2	11.609	2.50E-02	5.32E-20	1.000
16	11.900	12.100	11.700	8	2	11.776	2.20E-02	7.96E-20	1.000
					11	11.806	4.90E-03	1.45E-20	1.000
					9	11.852	1.99E-02	3.67E-21	1.000
					2	11.874	9.10E-03	2.68E-19	1.000
					2	11.948	5.75E-03	4.37E-19	1.000
					3	12.000	2.69E-02	2.99E-20	1.000
					9	12.067	2.18E-02	3.44E-21	1.000
					25	12.084	7.91E-02	-0.	1.000
17	12.410	12.800	12.100	9	11	12.160	1.90E-03	1.28E-20	1.000
					19	12.181	1.05E+00	1.59E-22	1.000
					3	12.316	1.56E-02	6.96E-20	1.000
					10	12.404	4.61E-02	6.53E-22	1.000
					2	12.414	5.74E-02	3.90E-21	1.000
					2	12.511	2.79E-02	3.37E-21	1.000
					9	12.521	7.75E-02	6.33E-22	1.000
					9	12.651	5.24E-03	1.45E-20	1.000
					25	12.745	2.90E-02	4.59E-20	1.000
18	13.040	13.400	12.800	4	1	12.877	2.30E-02	4.46E-21	1.000
					1	13.004	1.32E-01	2.94E-21	1.000
					17	13.119	3.79E-01	1.01E-21	1.000

Figure 4.10 (concluded)

					2	13.190	4.89E-02	2.99E-20	1.000
19	13.580	13.800	13.400	4	2	13.508	2.91E-02	6.96E-19	1.000
					7	13.543	1.61E-01	9.50E-24	1.000
					18	13.601	2.95E-01	1.59E-22	1.000
					1	13.677	9.57E-02	2.93E-20	1.000
20	14.200	14.500	13.800	4	1	13.993	5.04E-02	5.32E-20	1.000
					1	14.160	3.42E-02	7.96E-20	1.000
					1	14.257	2.12E-02	2.68E-19	1.000
					1	14.332	1.38E-02	4.37E-19	1.000

Figure 4.11 Transmission Factors (Second Case)

CASE - SAMPLE CASE NO. 2

RADIATION CONTROL NUMBERS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0

CHEMISTRY CONTROL NUMBERS	1	2	3	4	5	6	7	8	9	10
	0	1	1	0	0	0	0	0	0	0

RADIATIVE BOUNDARY CONDITIONS

CONTINUUM						LINE GROUPS					
FREQ. (EV)	WAVE LENGTH (A)	EMITTANCE WALL	EMITTANCE OUTER BOUND.	TRANSMITTANCE WALL	TRANSMITTANCE OUTER BOUND.	FREQ. (EV)	WAVE LENGTH (A)	EMITTANCE WALL	EMITTANCE OUTER BOUND.	TRANSMITTANCE WALL	TRANSMITTANCE OUTER BOUND.
.020	.620E+06	1.000	0.000	0.000	1.000	.690	.180E+05	1.000	0.000	0.000	1.000
.100	.124E+06	1.000	0.000	0.000	1.000	.890	.139E+05	1.000	0.000	0.000	1.000
.200	.620E+05	1.000	0.000	0.000	1.000	1.050	.118E+05	1.000	0.000	0.000	1.000
.500	.248E+05	1.000	0.000	0.000	1.000	1.290	.961E+04	1.000	0.000	0.000	1.000
.600	.207E+05	1.000	0.000	0.000	1.000	1.460	.849E+04	1.000	0.000	0.000	1.000
.800	.155E+05	1.000	0.000	0.000	1.000	1.850	.670E+04	1.000	0.000	0.000	1.000
1.000	.124E+05	1.000	0.000	0.000	1.000	2.850	.435E+04	1.000	0.000	0.000	1.000
1.500	.827E+04	1.000	0.000	0.000	1.000	3.700	.335E+04	1.000	0.000	0.000	1.000
2.000	.620E+04	1.000	0.000	0.000	1.000	5.000	.248E+04	1.000	0.000	0.000	1.000
2.500	.496E+04	1.000	0.000	0.000	1.000	7.110	.174E+04	1.000	0.000	0.000	1.000
2.750	.451E+04	1.000	0.000	0.000	1.000	8.400	.148E+04	1.000	0.000	0.000	1.000
3.000	.413E+04	1.000	0.000	0.000	1.000	9.400	.132E+04	1.000	0.000	0.000	1.000
3.250	.382E+04	1.000	0.000	0.000	1.000	10.070	.123E+04	1.000	0.000	0.000	1.000
3.500	.354E+04	1.000	0.000	0.000	1.000	10.620	.117E+04	1.000	0.000	0.000	1.000
3.750	.331E+04	1.000	0.000	0.000	1.000	11.200	.111E+04	1.000	0.000	0.000	1.000
4.000	.310E+04	1.000	0.000	0.000	1.000	11.900	.104E+04	1.000	0.000	0.000	1.000
4.500	.276E+04	1.000	0.000	0.000	1.000	12.410	.999E+03	1.000	0.000	0.000	1.000
5.000	.248E+04	1.000	0.000	0.000	1.000	13.040	.951E+03	1.000	0.000	0.000	1.000
6.000	.207E+04	1.000	0.000	0.000	1.000	13.580	.913E+03	1.000	0.000	0.000	1.000
7.000	.177E+04	1.000	0.000	0.000	1.000	14.200	.873E+03	1.000	0.000	0.000	1.000
8.000	.155E+04	1.000	0.000	0.000	1.000						
10.790	.115E+04	1.000	0.000	0.000	1.000						
10.810	.115E+04	1.000	0.000	0.000	1.000						
11.000	.113E+04	1.000	0.000	0.000	1.000						
11.250	.110E+04	1.000	0.000	0.000	1.000						
11.270	.110E+04	1.000	0.000	0.000	1.000						
11.990	.103E+04	1.000	0.000	0.000	1.000						
12.010	.103E+04	1.000	0.000	0.000	1.000						
13.390	.926E+03	1.000	0.000	0.000	1.000						
13.410	.925E+03	1.000	0.000	0.000	1.000						
13.590	.912E+03	1.000	0.000	0.000	1.000						
13.610	.911E+03	1.000	0.000	0.000	1.000						
14.290	.868E+03	1.000	0.000	0.000	1.000						
14.310	.867E+03	1.000	0.000	0.000	1.000						
15.000	.827E+03	1.000	0.000	0.000	1.000						

Figure 4.12 Thermodynamic State Quantities (Second Case)

TABLE 1
STATE QUANTITIES AT STATION S=1.00 CM
PATH LENGTH= 1.00E+01

PATH LENGTH (NORMALIZED)	0.	4.72E-03	1.18E-02	2.37E-02	4.72E-02	9.48E-02	2.11E-0	4.74E-01	7.37E-01	1.00E+00
TEMPERATURE (DEG-K)	5.00E+03	6.00E+03	7.00E+03	8.00E+03	9.00E+03	1.00E+04	1.05E+04	1.10E+04	1.15E+04	1.20E+04
PRESSURE (ATM)	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
ENTHALPY (BTU/LB)	.31E+04	.52E+04	.11E+05	.17E+05	.20E+05	.22E+05	.23E+05	.25E+05	.26E+05	.29E+05
MEAN MOLECULAR WT.	.26E+02	.24E+02	.18E+02	.15E+02	.14E+02	.14E+02	.14E+02	.13E+02	.13E+02	.12E+02
MOLE FRACTIONS										
SPECIES										
O+	.46E-07	.26E-05	.30E-04	.17E-03	.67E-03	.20E-02	.33E-02	.50E-02	.74E-02	.11E-01
O	.14E+00	.14E+00	.16E+00	.16E+00	.16E+00	.15E+00	.15E+00	.15E+00	.14E+00	.13E+00
N+	.52E-08	.26E-05	.92E-04	.88E-03	.43E-02	.15E-01	.24E-0	.38E-01	.56E-01	.79E-01
N	.27E-01	.17E+00	.48E+00	.69E+00	.73E+00	.72E+00	.70E+00	.67E+00	.63E+00	.59E+00
E-	.29E-04	.16E-03	.10E-02	.44E-02	.13E-01	.32E-01	.47E-0	.67E-01	.92E-01	.12E+00
O2	.40E-03	.51E-04	.16E-04	.54E-05	.22E-05	.10E-05	.75E-06	.54E-06	.39E-06	.28E-06
N2	.68E+00	.55E+00	.25E+00	.58E-01	.12E-01	.29E-02	.15E-02	.81E-03	.44E-03	.24E-03
CO	.15E+00	.13E+00	.42E-01	.50E-02	.69E-03	.13E-03	.59E-04	.28E-04	.14E-04	.67E-05
C2	.78E-08	.35E-05	.30E-04	.13E-04	.41E-05	.13E-05	.76E-06	.43E-06	.24E-06	.13E-06
CN	.45E-04	.11E-02	.24E-02	.91E-03	.26E-03	.83E-04	.48E-04	.28E-04	.16E-04	.93E-05
C	.11E-03	.82E-02	.58E-01	.76E-01	.72E-01	.63E-01	.57E-0	.51E-01	.45E-01	.38E-01
C+	.13E-07	.20E-04	.72E-03	.32E-02	.80E-02	.15E-01	.20E-0	.24E-01	.28E-01	.32E-01
NO	.83E-02	.38E-02	.18E-02	.60E-03	.20E-03	.75E-04	.48E-04	.31E-04	.20E-04	.13E-04
NUMBER DENSITIES										
O+	.68E+11	.31E+13	.31E+14	.15E+15	.54E+15	.15E+16	.23E+16	.34E+16	.47E+16	.65E+16
O	.20E+18	.17E+18	.17E+18	.15E+18	.13E+18	.11E+18	.11E+18	.97E+17	.89E+17	.80E+17
N+	.77E+10	.32E+13	.97E+14	.81E+15	.35E+16	.11E+17	.17E+17	.25E+17	.36E+17	.48E+17
N	.40E+17	.21E+18	.51E+18	.63E+18	.60E+18	.53E+18	.49E+18	.45E+18	.40E+18	.36E+18
E-	.43E+14	.20E+15	.11E+16	.40E+16	.11E+17	.23E+17	.33E+17	.45E+17	.59E+17	.75E+17
O2	.58E+15	.63E+14	.17E+14	.50E+13	.18E+13	.76E+12	.52E+1	.36E+12	.25E+12	.17E+12
N2	.10E+19	.67E+18	.26E+18	.53E+17	.98E+16	.21E+16	.11E+16	.54E+15	.28E+15	.14E+15
CO	.22E+18	.15E+18	.44E+17	.46E+16	.56E+15	.94E+14	.41E+14	.19E+14	.87E+13	.41E+13
H2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
C2	.11E+11	.42E+13	.31E+14	.12E+14	.33E+13	.98E+12	.53E+1	.29E+12	.16E+12	.82E+11
CN	.67E+14	.13E+16	.26E+16	.84E+15	.21E+15	.61E+14	.33E+14	.19E+14	.10E+14	.57E+13
C	.17E+15	.10E+17	.61E+17	.70E+17	.58E+17	.46E+17	.40E+17	.34E+17	.29E+17	.24E+17
C+	.19E+11	.25E+14	.76E+15	.29E+16	.65E+16	.11E+17	.14E+17	.16E+17	.18E+17	.20E+17
H	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
NO	.12E+17	.46E+16	.19E+16	.55E+15	.16E+15	.55E+14	.33E+14	.20E+14	.13E+14	.78E+13
N2+	.21E+11	.19E+13	.13E+14	.25E+14	.28E+14	.26E+14	.24E+14	.21E+14	.19E+14	.16E+14
N-	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
O-	.10E+12	.18E+12	.50E+12	.97E+12	.14E+13	.19E+13	.21E+13	.23E+13	.24E+13	.24E+13
H-	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Figure 4.13 Continuum Output (Second Case)

CONTINUUM CONTRIBUTION TO THE SPECTRAL FLUX
Y/DELTA= 0.

HV (EV)	QMINUS (WATTS/ CM2 EV)	PARTIAL SPECTRAL INTEGRAL OF QMINUS (WATTS/CM2)	NORMALIZED QMINUS CONTRIBUTION (PERCENT TOTAL)	QPLUS (WATTS/ CM2 EV)	PARTIAL SPECTRAL INTEGRAL OF QPLUS (WATTS/CM2)	NORMALIZED QPLUS CONTRIBUTION (PERCENT TOTAL)
.020	0.	0.	IIIII	5.289E+00	0.	0.
.100	0.	0.	IIIII	1.237E+02	5.159E+00	3.897E-03
.200	0.	0.	IIIII	2.249E+02	2.259E+01	1.706E-02
.500	0.	0.	IIIII	2.508E+02	9.390E+01	7.093E-02
.600	0.	0.	IIIII	2.455E+02	1.187E+02	8.967E-02
.800	0.	0.	IIIII	2.374E+02	1.670E+02	1.261E-01
1.000	0.	0.	IIIII	1.896E+02	2.097E+02	1.584E-01
1.500	0.	0.	IIIII	2.051E+02	3.084E+02	2.329E-01
2.000	0.	0.	IIIII	1.916E+02	4.075E+02	3.078E-01
2.500	0.	0.	IIIII	1.816E+02	5.008E+02	3.783E-01
2.750	0.	0.	IIIII	1.659E+02	5.468E+02	4.130E-01
3.000	0.	0.	IIIII	2.104E+02	5.963E+02	4.504E-01
3.250	0.	0.	IIIII	2.534E+02	6.543E+02	4.942E-01
3.500	0.	0.	IIIII	2.608E+02	7.185E+02	5.428E-01
3.750	0.	0.	IIIII	2.174E+02	7.783E+02	5.879E-01
4.000	0.	0.	IIIII	1.582E+02	8.253E+02	6.234E-01
4.500	0.	0.	IIIII	1.175E+02	8.942E+02	6.755E-01
5.000	0.	0.	IIIII	8.996E+01	9.461E+02	7.146E-01
6.000	0.	0.	IIIII	5.457E+01	1.018E+03	7.692E-01
7.000	0.	0.	IIIII	3.262E+01	1.062E+03	8.022E-01
8.000	0.	0.	IIIII	1.935E+01	1.088E+03	8.218E-01
10.790	0.	0.	IIIII	1.176E+02	1.279E+03	9.661E-01
10.810	0.	0.	IIIII	1.120E+02	1.281E+03	9.678E-01
11.000	0.	0.	IIIII	8.353E+01	1.300E+03	9.818E-01
11.250	0.	0.	IIIII	4.949E+01	1.316E+03	9.944E-01
11.270	0.	0.	IIIII	1.294E+01	1.317E+03	9.948E-01
11.990	0.	0.	IIIII	5.456E-03	1.322E+03	9.984E-01
12.010	0.	0.	IIIII	3.855E-03	1.322E+03	9.984E-01
13.390	0.	0.	IIIII	2.196E+00	1.323E+03	9.995E-01
13.410	0.	0.	IIIII	9.641E-01	1.323E+03	9.995E-01
13.590	0.	0.	IIIII	8.348E-01	1.323E+03	9.997E-01
13.610	0.	0.	IIIII	8.184E-01	1.323E+03	9.997E-01
14.290	0.	0.	IIIII	4.159E-01	1.324E+03	1.000E+00
14.310	0.	0.	IIIII	2.078E-02	1.324E+03	1.000E+00
15.000	0.	0.	IIIII	9.142E-03	1.324E+03	1.000E+00

Figure 4.14 Line Output (Second Case)

TABLE 23

LINE TRANSPORT QUANTITIES AT STATION S=0.00 CM AND Y/DELTA=0.000

GROUP NO.	FREQUENCY (EV)	NEG CONTRIBUTION W/CM2	POS CONTRIBUTION W/CM2
1	.690	0.	5.49E+01
2	.890	0.	4.19E+01
3	1.050	0.	1.71E+02
4	1.290	0.	1.29E+02
5	1.460	0.	8.39E+01
6	1.850	0.	4.48E+01
7	2.850	0.	5.41E+01
8	3.700	0.	1.77E+00
9	5.000	0.	2.46E+00
10	7.110	0.	1.50E+02
11	8.400	0.	5.11E+01
12	9.400	0.	1.29E+02
13	10.070	0.	-2.25E+01
14	10.620	0.	-1.95E+01
15	11.200	0.	-1.71E+01
16	11.900	0.	-2.28E-03
17	12.410	0.	2.71E-05
18	13.040	0.	-3.28E-01
19	13.580	0.	-8.18E-02
20	14.200	0.	-1.27E-01

TOTAL LINE CORRECTION TO FLUX DIRECTED AWAY FROM WALL= 0. WATTS/SQ.CM

TOTAL LINE CORRECTION TO FLUX DIRECTED TOWARD WALL= 8.54E+02 WATTS/SQ.CM

SECTION 5

OPERATING PROCEDURES

This program is written in FORTRAN V source language. It has been run on the UNIVAC 1108, the Philco 212, the CDC 6600 and various subroutines have been run on the IBM 1130, although some modifications to the source decks are required in this case. It easily fits within the 66K core capacity of the 1108 computer; consequently, an overlay procedure is usually not required.

Card input and tabular output are on units M and N, respectively, where M and N are defined in the main routine. No scratch tapes or other input/output devices are needed.

A control deck setup is shown in Figure 5.1 for the UNIVAC 1108. Compiled decks are often obtained from tape storage as shown in the figure. Drum storage is also commonly used for this machine, the deck setup being quite similar to that which is shown.

A control deck setup is shown in Figure 5.2 for the CDC 6600. Compiled decks are often obtained from common files as shown in the figure. Tapes and permanent files are also commonly used with this machine.

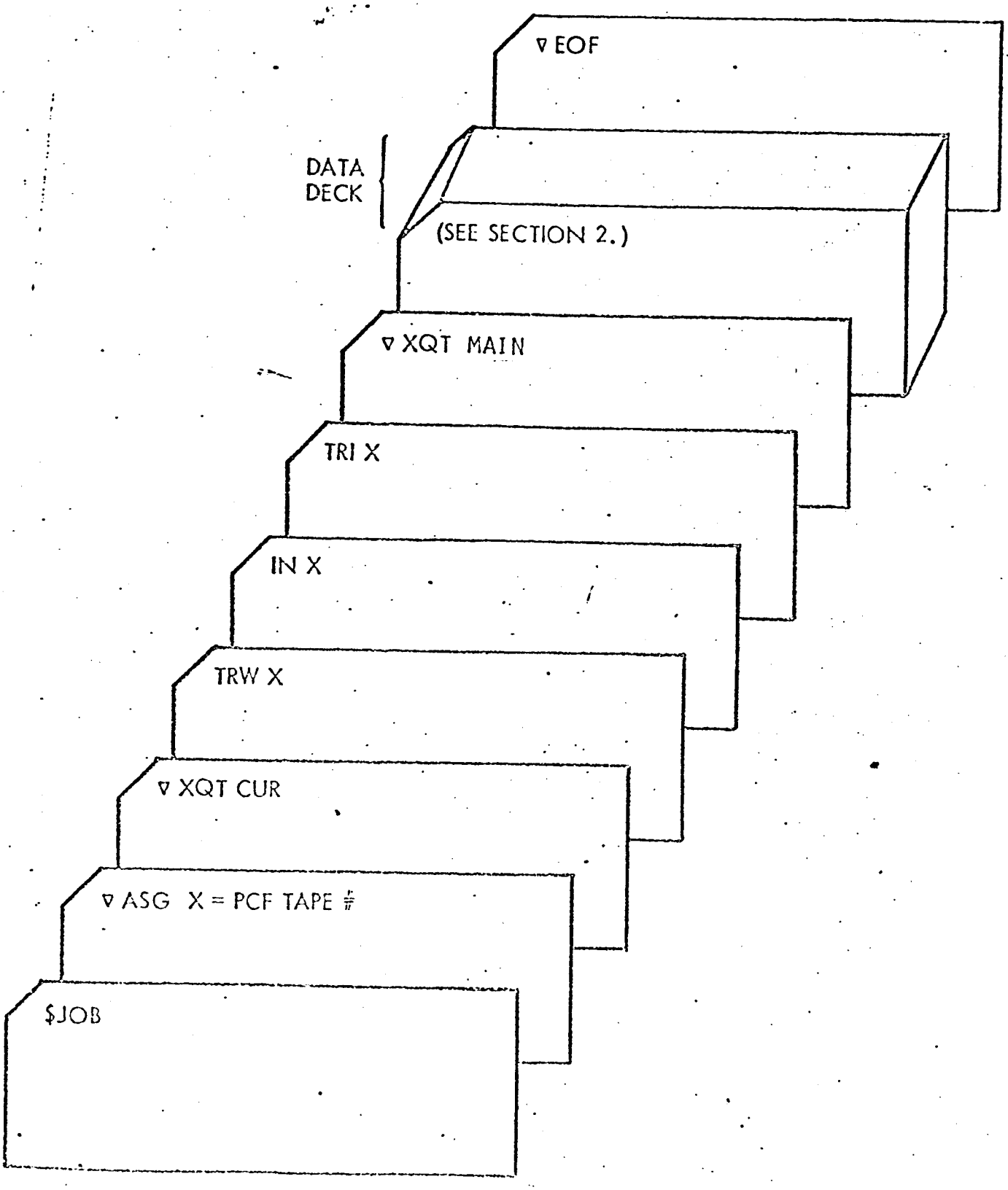
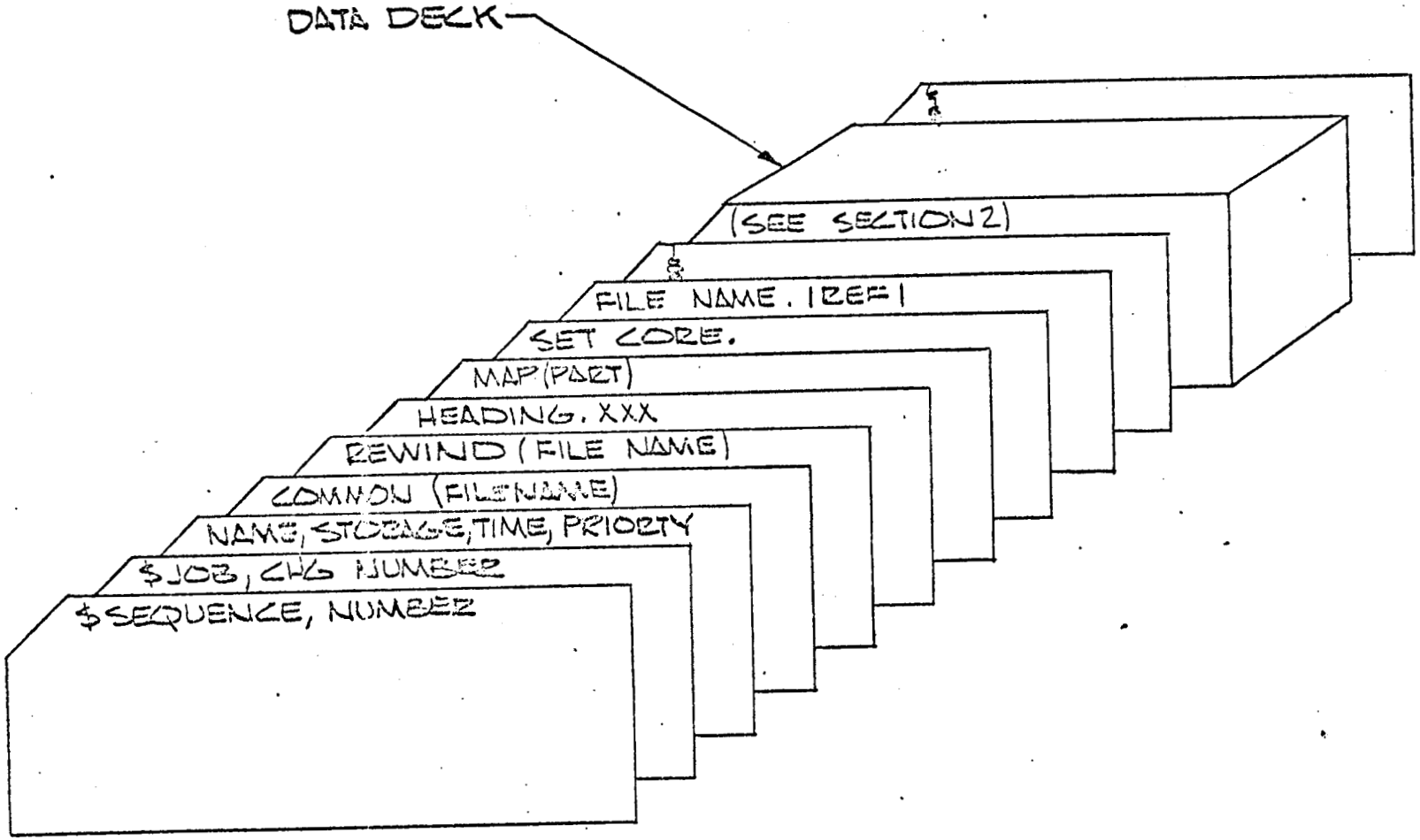


FIGURE 5.1 CONTROL DECK SETUP (UNIVAC 1108)



A-2330

FIGURE 5.2 CONTROL DECK SETUP (CDC 6600)

SECTION 6

CODE DESCRIPTION

The RAD/EQUIL code performs four nearly autonomous functions. These are:

(1) It obtains basic radiation property data, viz. frequency grid, line group properties and absorption coefficient data.

(2) It obtains the properties of the radiating layer, viz. its size, spatial grid, radiation boundary conditions and thermodynamic property distribution across the layer.

(3) It calculates continuum transport.

(4) It calculates line transport.

The code performs these functions through the use of three primary computational modules.

The first module performs function (2) and is driven by Subroutine DADIN. Its most important elements are Subroutine INPUT (Reads the chemistry input data), EQUIL (drives the equilibrium chemistry and shock wave calculations), THERM, CRECT, and MATER (all contribute to the chemistry calculation), RERAY (performs matrix inversions during chemistry calculation), NODEN (converts mole fractions to number densities) and DADIN (drives the module and calculates partition functions).

The second module calculates continuum transport and is driven by Subroutine CONTN. Its most important elements are Subroutines MU (calculates continuum absorption coefficients), TRANS (calculates optical depths and spectral fluxes or intensities) and CONTN (drives the calculation and performs frequency integration to obtain total transport quantities.

The third module calculates the line correction to be added

to the continuum transport and is driven by Subroutine LINT. Its most important elements are Subroutine FREQ (sets up the nodal grid in frequency), MULE (calculates the line absorption coefficients), TRANS (calculates optical depths and spectral fluxes or intensities) and LINT (drives the calculation and performs a frequency integration to obtain total transport qualities). The line corrections are obtained by taking the difference between the combined (line + continuum) transport quantities and the continuum transport quantities evaluated at the "average" frequency of the line group. This calculation is also done in Subroutine LINT.

The flow of the logic is shown in Figure 6.1 to 6.9. Brief descriptions of the function of each subroutine are given in Section 6.1 to 6.22.

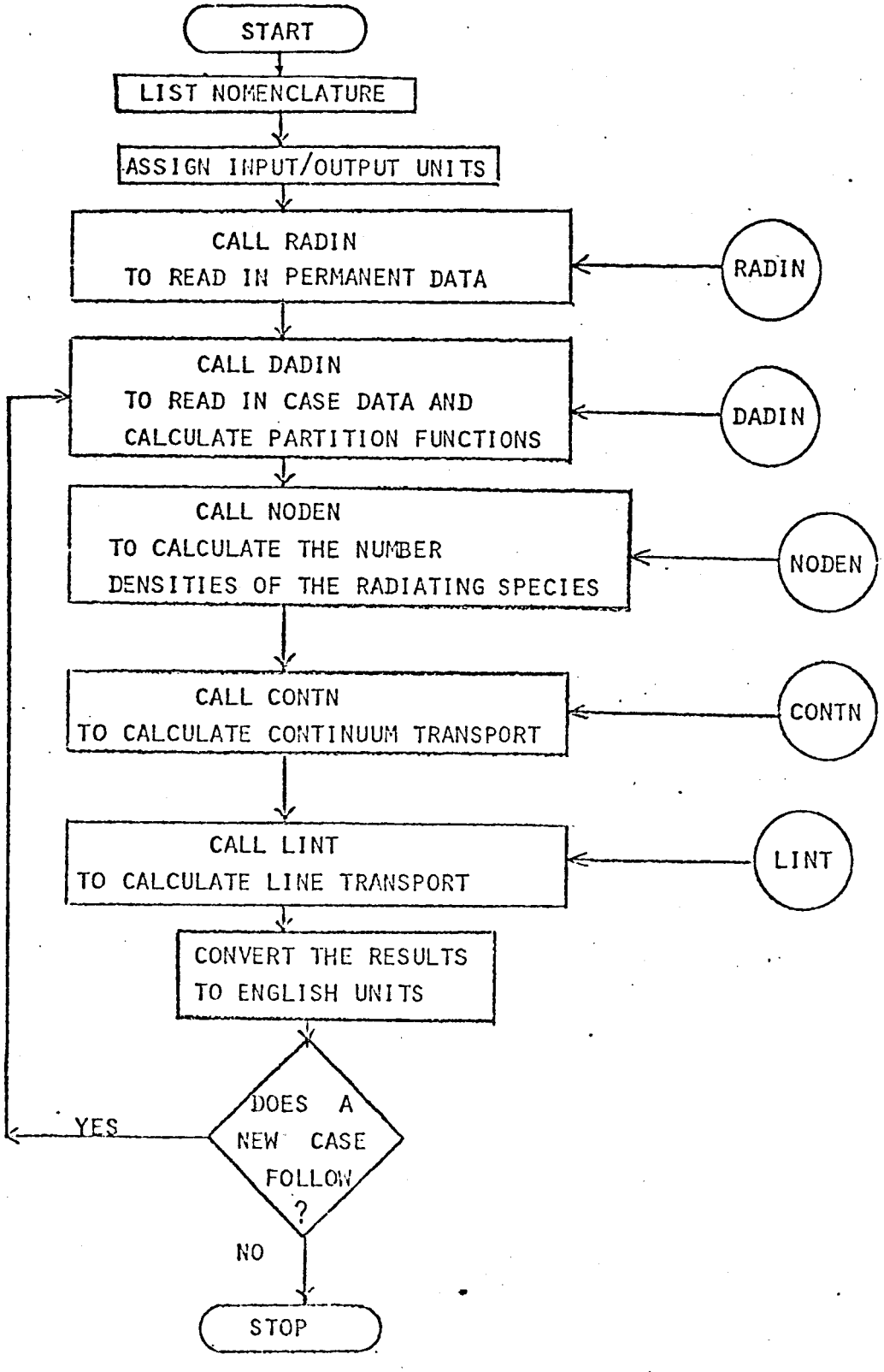


FIGURE 6.1. MAIN PROGRAM LOGIC DIAGRAM

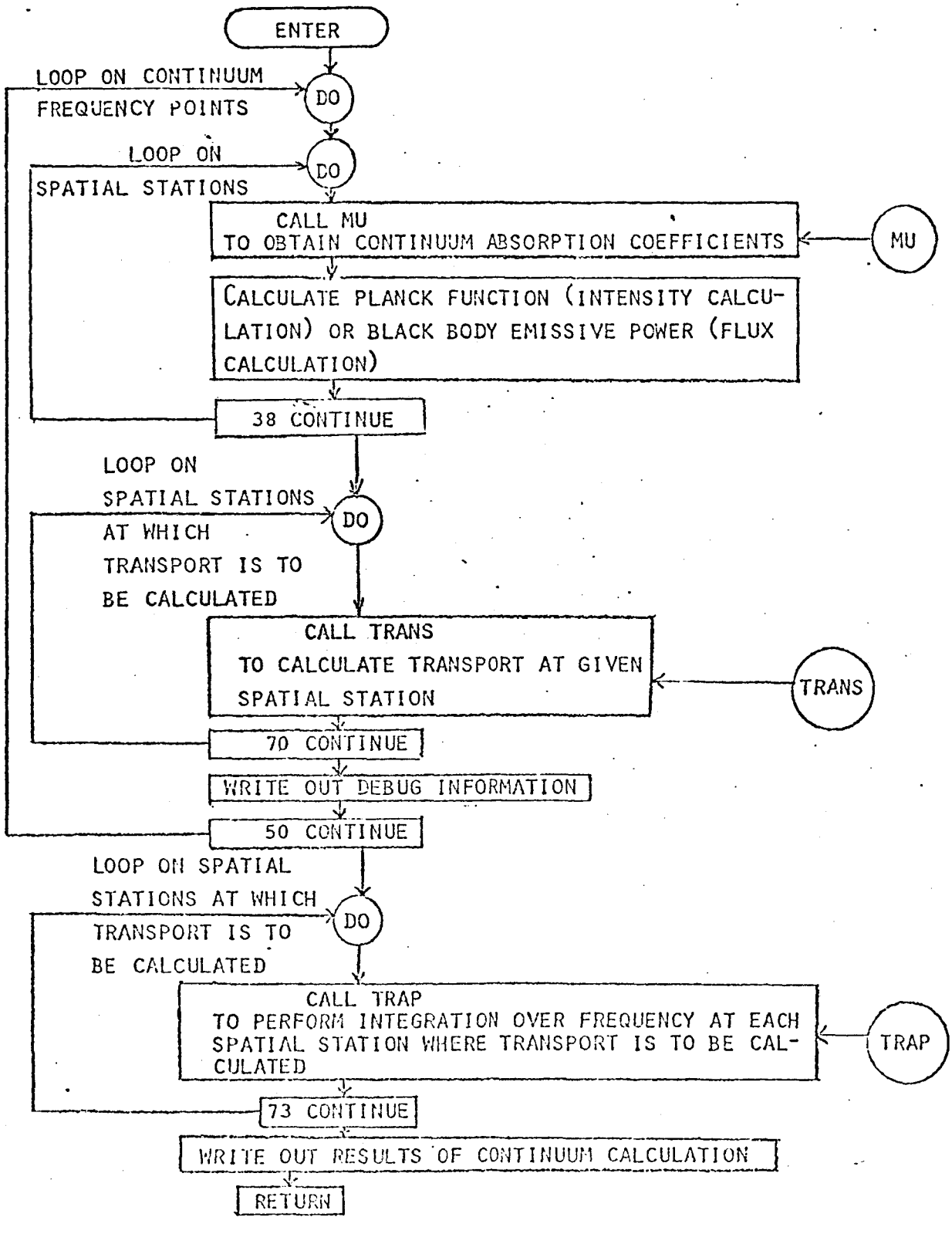


FIGURE 6.2. LOGIC DIAGRAM FOR SUBROUTINE CONTN

ENTER

CALL ZHV TO OBTAIN LOW FREQUENCY PHOTOIONIZATION CONTRIBUTIONS FOR THE C, O, N AND N^+ ABSORPTION COEFFICIENTS ← ZHV

CALCULATE CONTINUUM CONTRIBUTIONS TO THE ABSORPTION COEFFICIENTS, WHEN NCRC (I) = 1, THE CONTRIBUTION IS INCLUDED, WHEN NCRC (I) = 0, IT IS NOT.

THE CONTRIBUTIONS ARE ADDED LINEARLY IN THE FOLLOWING ORDER

INDEX ON NCRC(I)	CONTRIBUTOR	
1	NITROGEN HIGH LINE SERIES	
2	OXYGEN HIGH LINE SERIES	
3	N_2^+	(1-) BAND SYSTEM
4	N-	PHOTODETACHMENT
5	H-	PHOTODETACHMENT
6	O-	PHOTODETACHMENT
7	NO	BAND SYSTEMS AND PHOTO-IONIZATION
8	N	ATOMIC PHOTOIONIZATION EDGES
9	O	ATOMIC PHOTOIONIZATION EDGES
10	N^+	PHOTOIONIZATION
11	O_2	BAND SYSTEMS AND PHOTO-DISSOCIATION
12	N_2	BAND SYSTEMS
13	CO	BAND SYSTEMS
14	H_2	BAND SYSTEMS AND PHOTO-IONIZATION
15	C_2	BAND SYSTEMS
16	CN	BAND SYSTEMS
17	C	ATOMIC PHOTOIONIZATION EDGES
18	C^+	PHOTOIONIZATION
19	H	PHOTOIONIZATION
20	C-	PHOTODETACHMENT

OBTAIN TOTAL CONTRIBUTION

RETURN

FIGURE 6.3. LOGIC DIAGRAM FOR SUBROUTINE MU

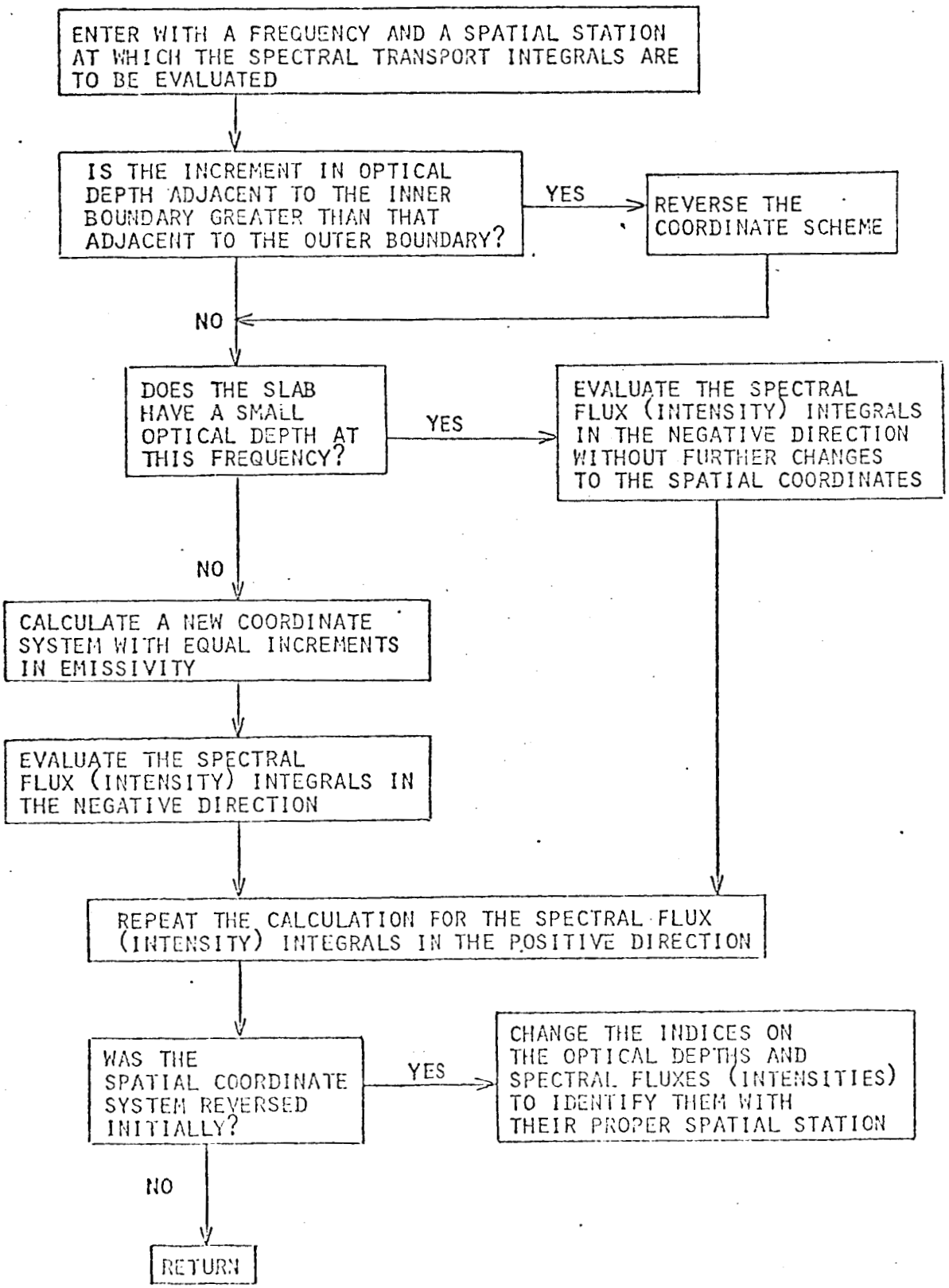


FIGURE 6.4. LOGIC DIAGRAM FOR SUBROUTINE TRANS

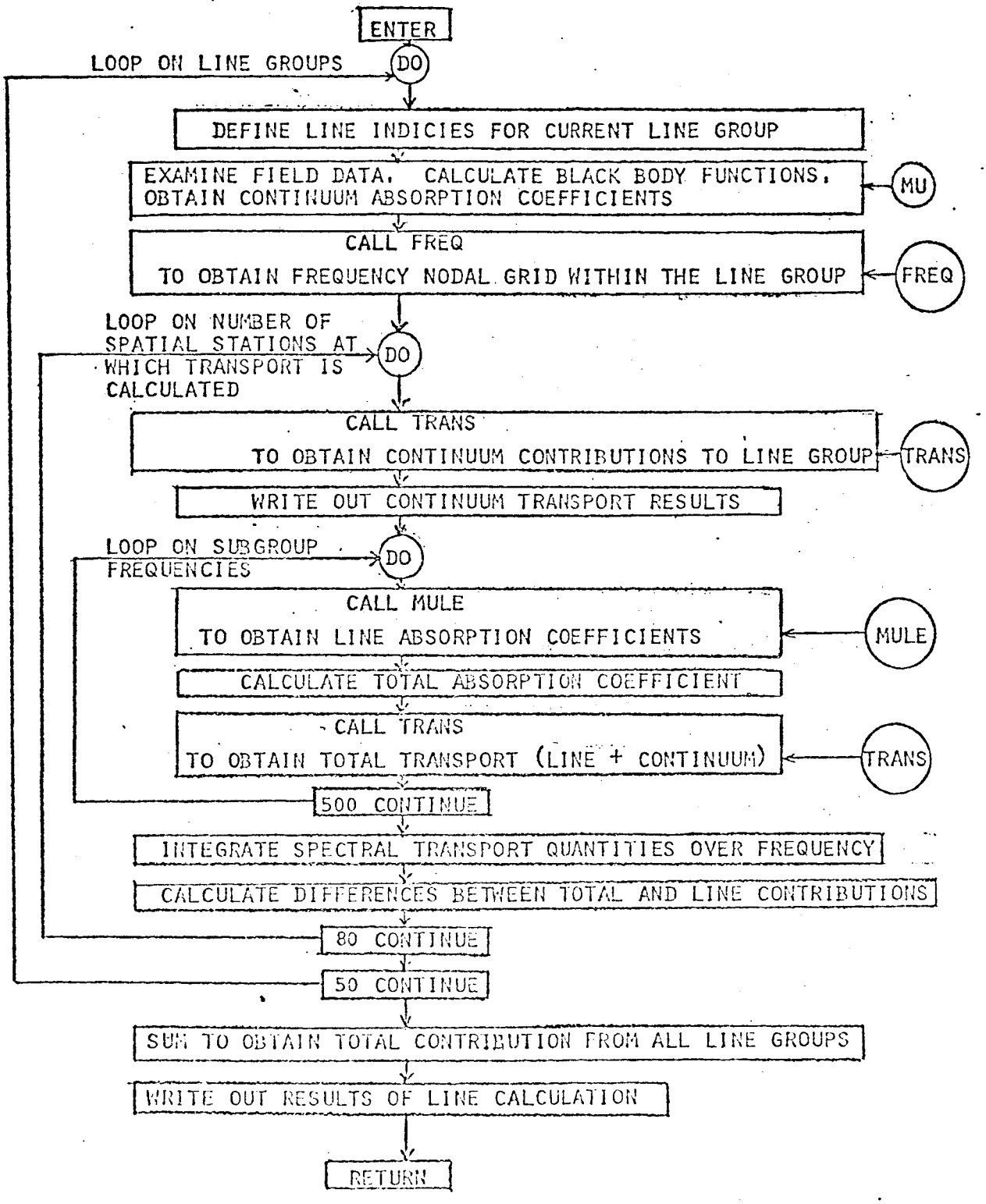


FIGURE 6.5. LOGIC DIAGRAM FOR SUBROUTINE LINT

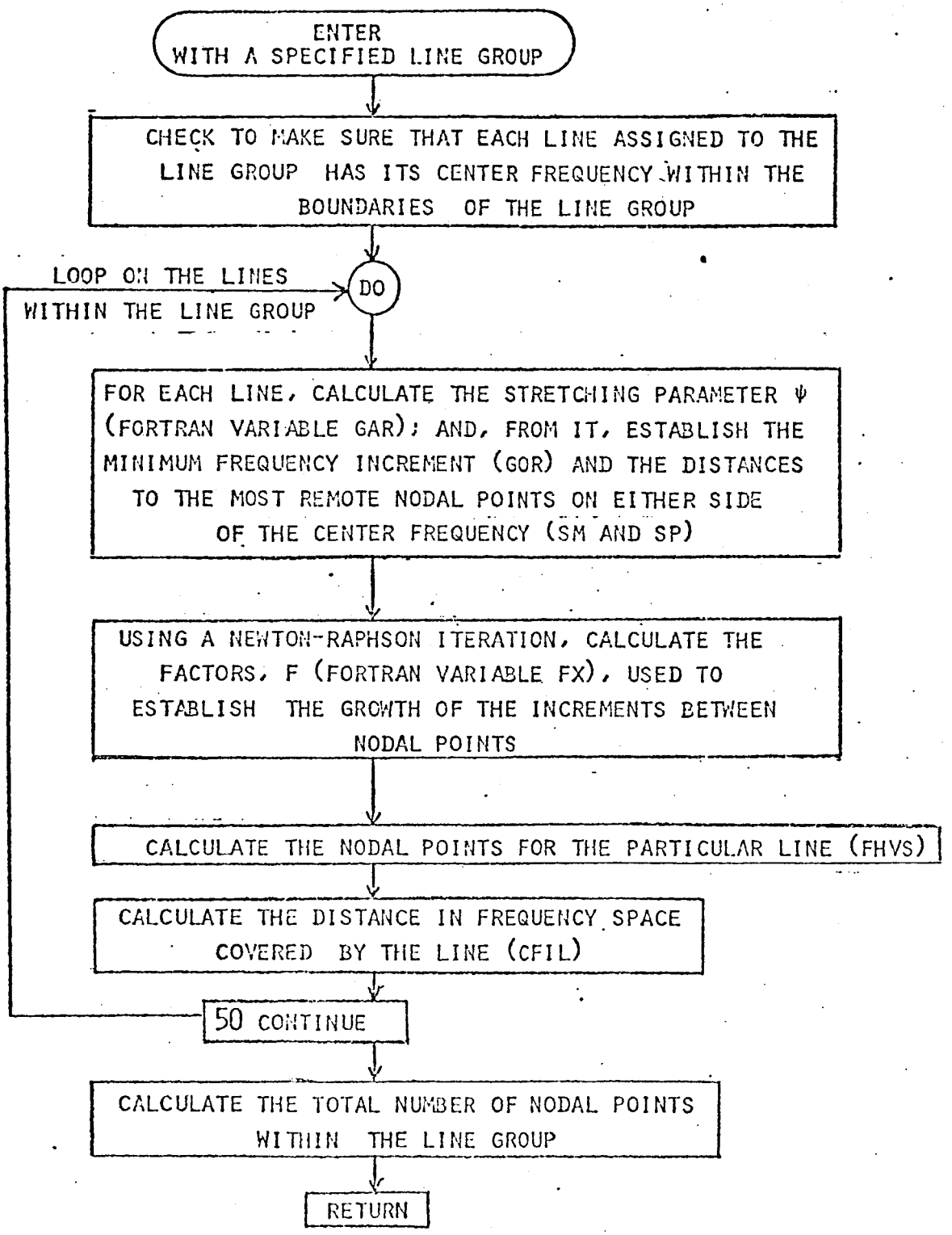


FIGURE 6.6. LOGIC DIAGRAM FOR SUBROUTINE FREQ

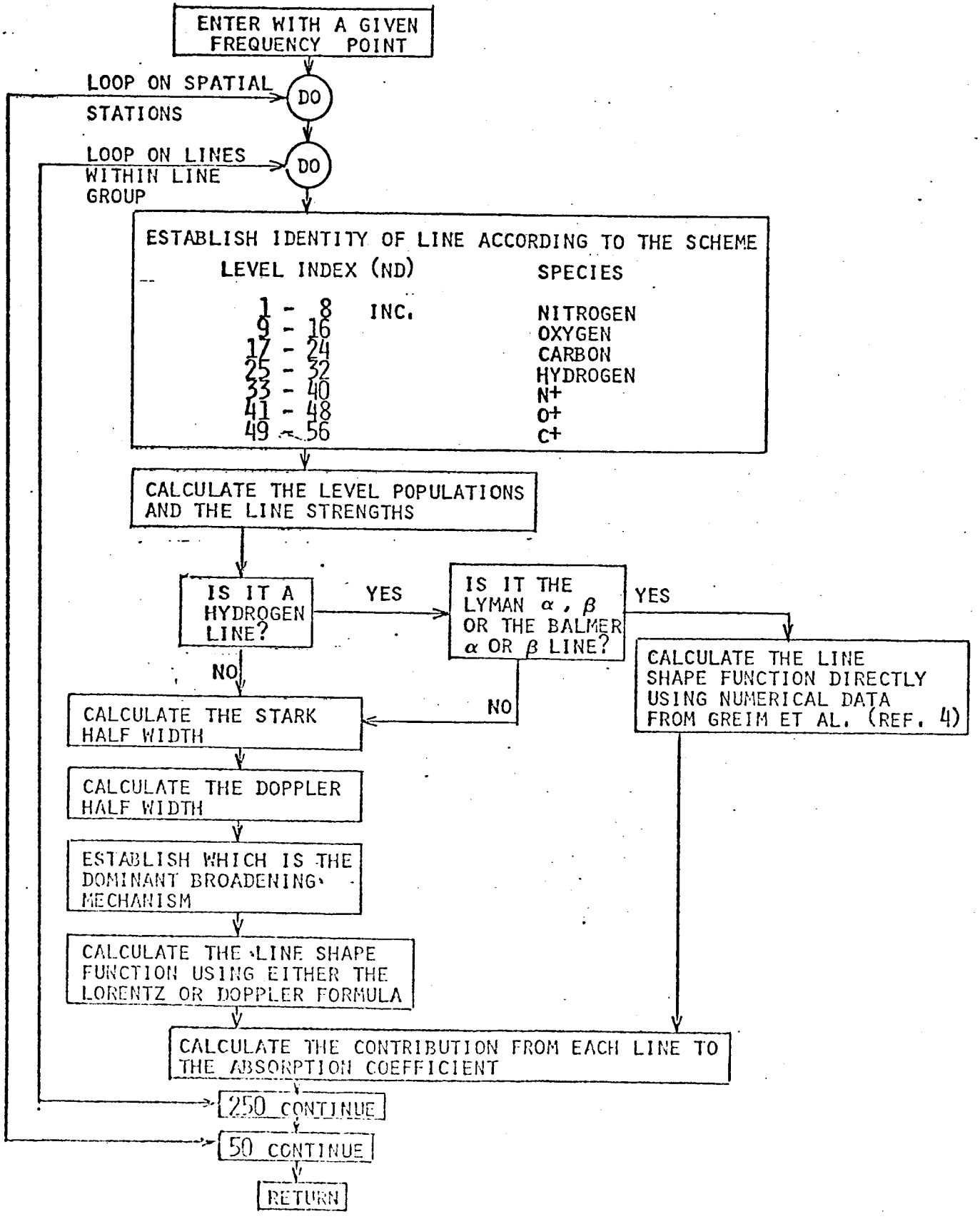


FIGURE 6.7. LOGIC DIAGRAM FOR SUBROUTINE MULE

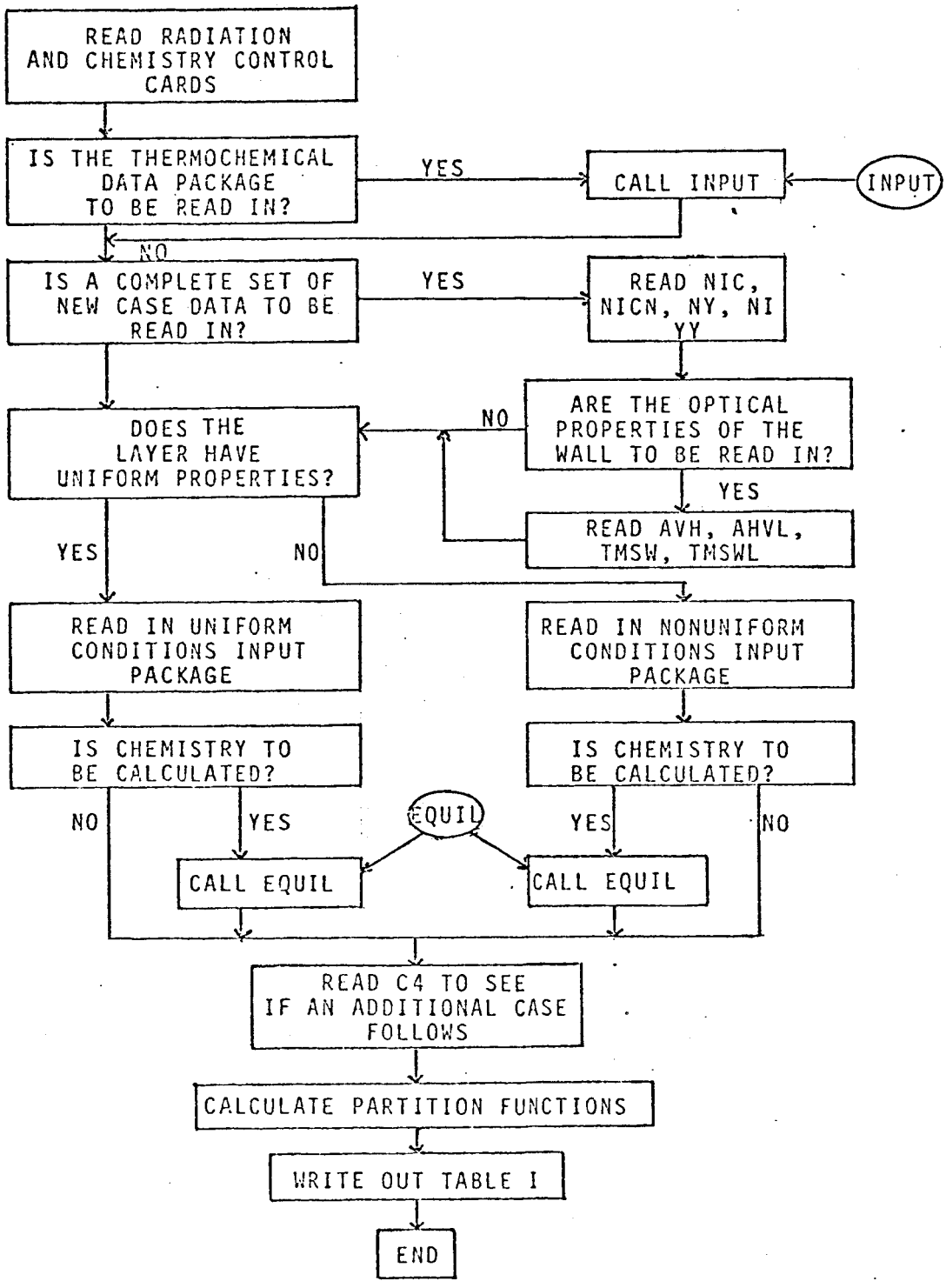


Figure 6.8 Logic Diagram for Subroutine DADIN

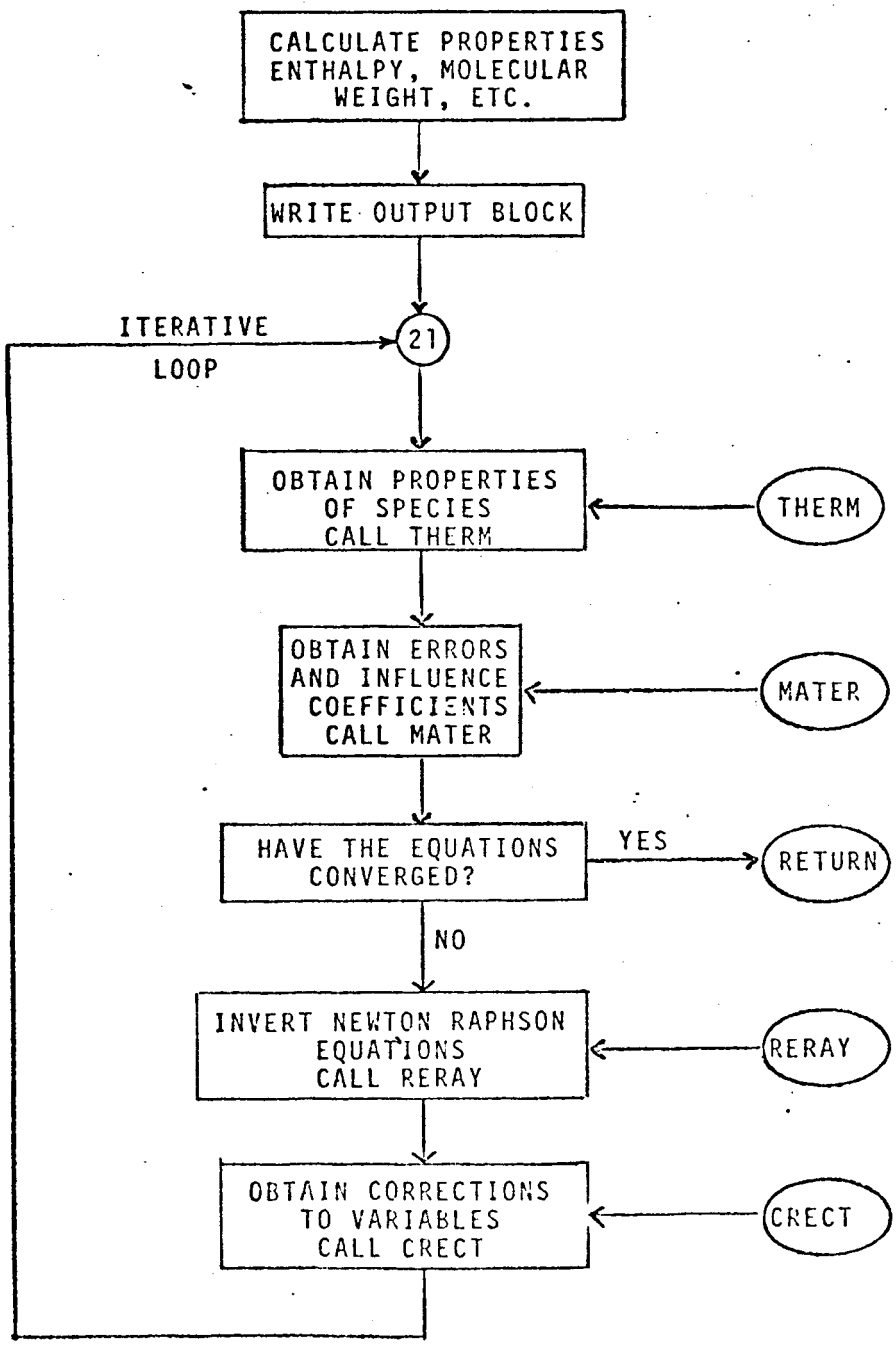


Figure 6.9 Logic Diagram for Subroutine EQUIL

6.1 MAIN

This routine is the program driver. It takes no part in the calculations except to convert units. A logic diagram is given in Figure 6.1.

6.2 SUBROUTINE RADIN

This subroutine reads in permanent data, viz, that data such as the continuum frequency points, the line group boundaries and center frequencies, the number of lines, f-numbers, line width functions, etc., which are associated with the physics of radiative transport.

6.3 SUBROUTINE DADIN

This subroutine reads in case data, viz. that data which defines the thermodynamic state (temperature, pressure, mole fraction distributions) of the slab or ray being considered. It also calculates electronic partition functions.

6.4 SUBROUTINE NODEN

This subroutine calculates the number densities of the radiating species.

6.5 SUBROUTINE TRANS

This subroutine evaluates the spectral transport integrals. This includes optical depths, positive and negative spectral fluxes (or intensities).

6.6 SUBROUTINE CONTN

This subroutine organizes and drives the continuum calculation. It also integrates the spectral transport quantities to obtain total quantities.

6.7 SUBROUTINE MU

This subroutine supplies continuum absorption coefficients.

6.8 SUBROUTINE ZHV

This subroutine does a particular calculation for Subroutine MU. It calculates the low frequency contributions to the continuum absorption coefficients from the N, O, N^+ and C atoms.

6.9 SUBROUTINE LINT

This subroutine organizes and drives the line calculation. It also integrates the spectral quantities to obtain total quantities.

6.10 SUBROUTINE FREQ

This subroutine calculates the nodal points in frequency used in the line transport calculation.

6.11 SUBROUTINE MULE

This subroutine supplies the line absorption coefficients.

6.12 SUBROUTINE SLOPQ

This is a general service subroutine. Given a single function of an independent variable, it will calculate slopes and/or integrals of the functions. Cubics are used as interpolation functions.

6.13 SUBROUTINE OGLE

This is a general service subroutine. Given a single function of an independent variable, it will obtain intermediate points by cubic interpolation.

6.14 SUBROUTINE LOGLE

This is a general service subroutine. It is essentially the same as Subroutine OGLE except that the interpolation is done on the logarithm of the variables.

6.15 SUBROUTINE ISLDV

This is a general service subroutine. It is essentially the same as SLOPQ except that the logarithms of the dependent variable are fitted to obtain the slopes and integrals, rather than the dependent variable directly. The resulting slopes and integrals are those of the function, however.

6.16 SUBROUTINE TRAP

This is a general service subroutine. It performs integrations using straight line interpolation formulas.

6.17 SUBROUTINE ITF

This is a special service subroutine. It is essentially the same as ISLDV except where subroutine ISLDV obtains slopes and integrals at all the points describing the function. Subroutine ITF considers those only within a specified range.

6.18 SUBROUTINE EQUIL

This subroutine is the program driver for the chemistry calculation. It contains the basic iterative logs for the Newton-Raphson procedure. When shock wave solutions are to be obtained the pressure and enthalpy specifications are replaced by the momentum and energy equations, respectively. The iteration proceeds as before, yielding the coupled solution automatically.

6.19 SUBROUTINE THERM

This subroutine evaluates molecular thermodynamic properties (e.g., enthalpy, entropy, free energy, specific heat) and the equilibrium constants appropriate to each formation reaction.

6.20 SUBROUTINE MATER

This subroutine evaluates the contributions of the base and non-base species contributions to the mass balance equations. It also calculates the matrix of partial derivatives of mass balance errors with respect to log of base species partial pressures.

6.21 SUBROUTINE CRECT

This subroutine calculates the corrections to log partial pressures of the non-base species. It scans all corrections and determines maximum damping factor which will permit all corrections to satisfy certain constraints. It then corrects the variables.

6.22 SUBROUTINE INPUT

This subroutine reads in the chemistry input package.

6.23 SUBROUTINE RERAY

This is a general purpose matrix inversion subroutine.

SECTION 7

FORTRAN VARIABLES LISTING

A list of nomenclature follows which defines the FORTRAN variables. The variables used primarily in the radiation aspects of the program are given in Figure 7.1; while those used primarily in the chemistry calculation are given in Figure 7.2

FORTRAN VARIABLES LIST

A(N,NN)	ERROR COEFFICIENT ARRAY IN CHEMISTRY SOLUTION, N PERTAINS TO EQUATION WHEREAS NN PERTAINS TO VARIABLE.	C EQTCOM
AA	PRODUCT OF PRESSURE TIMES MOLECULAR WEIGHT.	C EQTCOM
AAA	DEFUNCT VARIABLE, SET TO UNITY.	C EQPCOM
AB	LOCALLY DEFINED VARIABLE	L SLOPQ
ABB	LOCALLY DEFINED VARIABLE	L SLOPQ
ABER	ABSOLUTE VALUE OF RATIO OF A MASS BALANCE ERROR TO LARGEST TERM IN THAT MASS BALANCE.	L MATER
ABSVA	ABSOLUTE VALUE OF CONTRIBUTION OF A SPCIES TO A MASS BALANCE.	L MATER
ABX	ABSOLUTE VALUE OF LOG CORRECTION ON TEMPERATURE.	L CRECT
AC	LOCALLY DEFINED VARIABLE	L SLOPQ
ACC	LOCALLY DEFINED VARIABLE	L SLOPQ
ACH	MACH NUMBER	L OUTPUT
AHV	WALL EMMITTANCE FOR CONTINUUM SPECTRAL POINTS	C RAD
AHVL	WALL EMMITANCE FOR LINE GROUPS	C RAD
ALF	DERIVATIVE OF LOG MOLECULAR WEIGHT WITH RESPECT TO LOG TEMPERATURE AT CONSTANT PRESSURE	L EQUIL
ALPHA	ALPHANUMERIC NAMES OF RADIATING SPECIES	L DADIN
ALPT(N)	NUMBER OF ATOMS OF AN ELEMENT WITH ATOMIC NUMBER JAT(N) IN A SPECIES.	L INPUT
AMOA	ALPHANUMERIC VARIABLE, FIRST OF TWO PORTIONS OF SPECIES NAME.	L INPUT
AMOB	ALPHANUMERIC VARIABLE, SECOND OF TWO PORTIONS OF SPECIES NAME.	L INPUT
APE(N,NN)	SAVED ARRAY A(N,NN) DURING INVERSION.	L EQUIL

ARPH	ELEMENTAL MASS FRACTION OF ATOM.	L EQUIL
ARPHM	MAXIMUM CONTRIBUTION TO CALCULATION OF AN ARPH.	L EQUIL
ATA(K)	ALPHANUMERIC VARIABLE, FIRST OF THREE PORTIONS OF ELEMENT NAME.	C EQPCOM
ATB(K)	ALPHANUMERIC VARIABLE, SECOND OF THREE PORTIONS OF ELEMENT NAME.	C EQPCOM
ATC(K)	ALPHANUMERIC VARIABLE, THIRD OF THREE PORTIONS OF ELEMENT NAME.	C EQPCOM
B	LINE SHAPE FUNCTION (AS IT APPEARS IN EQUATION 42 OF REF. 1)	L MULE
BEE	PLANCK FUNCTION FOR INTENSITY CALCULATIONS, BLACK BODY EMISSIVE POWER FOR FLUX CALCULATIONS	L CONTN
BEE	PLANCK FUNCTION FOR INTENSITY CALCULATIONS, BLACK BODY EMISSIVE POWER FOR FLUX CALCULATIONS	L LINT
BEEW	PLANCK FUNCTION (FOR INTENSITY CALCULATION) OR BLACK BODY EMISSIVE POWER (FLUX CALCULATION) AT THE WALL	L CONTN
BEEW	PLANCK FUNCTION (FOR INTENSITY CALCULATION) OR BLACK BODY EMISSIVE POWER (FLUX CALCULATION) AT THE WALL	L LINT
BETA	ALPHANUMERIC NAMES OF ATOMIC AND IONIC RADIATING SPECIES	L DADIN
BETH	DERIVATIVE OF LOG MOLECULAR WEIGHT WITH RESPECT TO LOG PRESSURE AT CONSTANT TEMPERATURE.	L EQUIL
BS(N)	SAVED ARRAY OF B(N) DURING INVERSION.	L EQUIL
BULP	LOG (BUMP).	L CRECT
BUMP	10**4 * P, CONSTRAINTS ON CORRECTIONS ARE RELAXED FOR PARTIAL PRESSURES BELOW THIS VALUE.	L CRECT
C(K)	GRAM ATOMS OF ELEMENT K IN A MOLECULE.	L INPUT
C1	=1 FOR UNIFORM CONDITIONS, NOT=1 FOR NONUNIFORM CONDITIONS	C RAD
C2	= DELTA FOR INTENSITY CALCULATION, = 2*DELTA FOR FLUX CALCULATION	C RAD
C3	=0 IF A FULL SET OF NEW DATA IS TO BE READ, NOT =0, IF ONLY THERMODYNAMIC AND PATH LENGTH DATA IS TO BE READ IN	C RAD
C4	=0 WHEN A NEW CASE FOLLOWS, =1 FOR LAST CASE	C RAD

CASE	ALPHANUMERIC NAME OF CASE BEING RUN	C RAD
CFIL	TOTAL DISTANCE IN FREQUENCY SPACE COVERED BY LINES (SUMMED OVER LINE GROUP)	L FREQ
CFIL	TOTAL DISTANCE IN FREQUENCY SPACE COVERED BY LINES (SUMMED OVER LINE GROUP)	L LINT
CHFLUX	LESS THAN ZERO VALUE IMPLIES PRESENCE OF CHAR ELEMENTS IN SURFACE CHEMISTRY	L EQUIL
CH(N)	CURVE FIT CONSTANTS FOR THERMODYNAMIC DATA (THE QUANTITY F2 H298 DISCUSSED IN GROUP 12 OF INPUT INSTRUCTIONS N=1 FOR LOW AND N=2 FOR HIGH TEMPERATURE RANGE	C EQPCOM
CIJ(K,KK)	GRAM ATOM OF ELEMENT K IN BASE SPECIES KK.	E EQPCOM
CP(J)	SPECIFIC HEAT.	C EQTCOM
CPA	LOCALLY DEFINED VARIABLE	L MATER
CPF	FROZEN SPECIFIC HEAT, IDENTICAL TO CCPF .	C EQTCOM
CPG	FROZEN SPECIFIC HEAT OF GAS, IDENTICAL TO CCPG .	C EQTCOM
CSP	EQUILIBRIUM SPECIFIC HEAT OF GAS.	L EQUIL
DELTA	SLAB THICKNESS (CM) FOR FLUX CALCULATION, OVERALL LENGTH OF RAY (CM) FOR INTENSITY CALCULATION	C RAD
DIM	THE DIFFERENCE BETWEEN FIIMT AND THE CORRESPONDING CONTINUUM FLUX (OR INTENSITY)	L LINT
DIP	THE DIFFERENCE BETWEEN FIIPT AND THE CORRESPONDING CONTINUUM FLUX (OR INTENSITY)	L LINT
DIV	ROW NORMALIZING FACTOR IN GAUSSIAN ELIMINATION.	L RERAY
DIVC	PRODUCT OF 'DIV' AND ELEMENT OF ROW.	L RERAY
DTD	DOWNWARD TEMPERATURE STEP USED IN SEEKING SURFACE EQUILIBRIUM SOLUTION.	L EQUIL
DTM	LIMIT VALUE OF DELTA (1./T) IN CHEMISTRY SOLUTION.	L CRECT
DTU	UPWARD TEMPERATURE STEP USED IN SEEKING SURFACE EQUILIBRIUM SOLUTION.	L EQUIL
DUB2		L INPUT
DUB3	LOCALLY INPUT VARIABLES, IF NON-ZERO ASSIGNED TO FITMOL, BASMOL, SIGMA AND EPOVRK, RESPECTIVELY	L INPUT
DUB4		L INPUT
DUB5		L INPUT

DUM	LOCALLY DEFINED VARIABLE	L EQUIL
DUM1	LOCALLY DEFINED VARIABLE	L CRECT
DUM1	LOCALLY DEFINED VARIABLE	L EQUIL
DUM1	LOCALLY DEFINED VARIABLE	L MATER
DUM2	LOCALLY DEFINED VARIABLE	L EQUIL
DUM2	LOCALLY DEFINED VARIABLE	L MATER
DUMP	P * 10**7, LIMIT PRESSURE IN CONTROLLING DAMPING OF CHEMISTRY SOLUTION.	L CRECT
DY(J)	CORRECTION ON VARIABLE Y(J)* IN CHEMISTRY SOLUTION.	C EQTCOM
E(N)	ERRORS IN CHEMISTRY EQUATIONS (MASS BALANCE ERRORS FOR N EQUAL TO OR LESS THAN IS*, EQUILIBRIUM ERRORS FOR N GREATER THAN IS*, WHERE IS* IS NUMBER OF ELEMENTS INCLUDING ELECTRON).	C EQTCOM
EB(K)	MAGNITUDE OF LARGEST CONTRIBUTION TO K TH MASS BALANCE.	C EQTCOM
EBL(K)	MINIMUM CONTRIBUTION ACCEPTED TO K TH MASS BALANCE, +EB/(10**8)	C EQTCOM
ECD(N)	RESIDUAL ERROR IN CONDENSED EQUILIBRIUM IMPOSED IN CHEMISTRY SOLUTION AS A CONSEQUENCE OF BOUNDARY LAYER DAMPING.	L MATER
ECRP	LIMIT CHANGE OF CONDENSED SPECIES QUANTITIES DURING CHEMISTRY ITERATION.	C EQTCOM
EER	EQUILIBRIUM ERROR OF CONDENSED SPECIES BEING INTRODUCED DURING CURRENT ITERATION.	L MATER
EESE(N)	RESIDUAL ERROR IN MASS BALANCE IMPOSED IN CHEMISTRY SOLUTION AS A CONSEQUENCE OF BOUNDARY LAYER DAMPING.	L MATER
EHS	ERROR IN ENTHALPY OR ENTROPY FOR ASSIGNED ENTHALPY OR ENTROPY CHEMISTRY SOLUTIONS.	L MATER
EL	MAXIMUM EQUILIBRIUM ERROR, IDENTICAL TO EEL .	C EQTCOM
EMSB	NOT CURRENTLY USED	L DADIN
EMSBL	NOT CURRENTLY USED	L DADIN
EMSW	SAME AS AHV	L DADIN
EMSWL	SAME AS AHVL	L DADIN
EMT	NEGATIVE EMISSIVITY OF THE LAYER (EQUATION 65 OF REF. 1)	L TRANS

ENL	MAXIMUM MASS BALANCE ERROR	
EP	ERROR IN OVERALL PRESSURE BALANCE.	L MATER
EPOVRK	EPSILON/K, OF REFERENCE SPECIES IN DIFFUSION CALCULATIONS	C EQTCOM
EPS	ELECTRONIC ENERGY LEVEL	C RAD
EPT	POSITIVE EMISSIVITY OF THE LAYER (EQUATION 64 OF REF. 1)	L TRANS
ER	ERROR IN MASS BALANCE RELATION.	L MATER
EX	TEMPERATURE EXPONENT FOR STARK BROADENING (AS USED IN EQUATION 44 OF REF. 1)	L MULE
FF	F NUMBER OF INDIVIDUAL LINE IF AN UNLUMPED LOWER LEVEL IS USED. OTHERWISE IT = G(I)*F/GEE(L) WHERE G(I) IS THE STATISTICAL WT OF THE ABSORBING LEVEL AND GEE(L) IS THE STATISTICAL WT OF THE COMBINED LEVEL USED IN THE CALCULATION	C RAD
FF(J)	DIFFUSION FACTOR INTRODUCED BY THE APPROXIMATION FOR DIFFUSION COEFFICIENTS BY EQ(19) OF NASA CR-1062.	C EQPCOM
FFA	POWER ON MOLECULAR WEIGHT IF IT IS ASSUMED THAT THE DIFFUSION FACTORS, FF(J), ARE PROPORTIONAL TO SPECIES MOLECULAR WEIGHTS, WTM(J), RAISED TO A POWER.	C EQPCOM
FFF	RATIO OF GAS MOLECULAR WEIGHT TO 'VMU2'.	L MATER
FFIN(J)	DIFFUSION FACTOR, FF(J), WHICH IS READ IN.	L INPUT
FHV	MEAN FREQUENCY OF LINE GROUP	C RAD
FHVC	FREQUENCY OF A CONTINUUM SPECTRAL POINT	C RAD
FHVM	LOWER FREQUENCY LIMIT OF LINE GROUP	C RAD
FHVP	UPPER FREQUENCY LIMIT OF LINE GROUP	C RAD
FHVS	VALUES OF LINE FREQUENCIES WITHIN LINE GROUPS	L LINT
FIIM	INTEGRAL OVER THE SPECTRUM OF THE FLUX (OR INTENSITY) DIRECTED AWAY FROM THE WALL	L CONTN
FIIMT	THE TOTAL (LINE AND CONTINUUM) FLUX (OR INTENSITY) ASSIGNED TO A PARTICULAR LINE GROUP AND DIRECTED AWAY FROM THE WALL	L LINT
FIIP	INTEGRAL OVER THE SPECTRUM OF THE FLUX (OR INTENSITY) DIRECTED TOWARD THE WALL	L CONTN

FIIPT	THE TOTAL (LINE AND CONTINUUM) FLUX (OR INTENSITY) ASSIGNED TO A PARTICULAR LINE GROUP AND DIRECTED TOWARD THE WALL	L LINT
FIM	CONTINUUM SPECTRAL FLUX (OR INTENSITY) DIRECTED AWAY FROM THE WALL	L CONTN
FIM	CONTINUUM SPECTRAL FLUX (OR INTENSITY) DIRECTED AWAY FROM WALL	L LINT
FIMI	CONTINUUM RADIATIVE FLUX AWAY FROM WALL (WATTS/CM2)	C RAD
FIMO	THE SAME AS FIM, EXCEPT THAT IT IS AT THE NEXT LOWER SPECTRAL POINT	L CONTN2
FIMO	THE SAME AS FIM, EXCEPT THAT IT IS AT THE NEXT LOWER SPECTRAL POINT	L LINT2
FIP	CONTINUUM SPECTRAL FLUX (OR INTENSITY) DIRECTED TOWARD THE WALL	L CONTN
FIP	CONTINUUM SPECTRAL FLUX (OR INTENSITY) DIRECTED TOWARD THE WALL	L LINT
FIPI	CONTINUUM RADIATIVE FLUX TOWARD WALL (WATTS/CM2)	C RAD
FIPO	THE SAME AS FIP, EXCEPT THAT IT IS AT THE NEXT LOWER SPECTRAL POINT	L CONTN2
FIPO	THE SAME AS FIP, EXCEPT THAT IT IS AT THE NEXT LOWER SPECTRAL POINT	L LINT2
FL1	=1 FOR INTENSITY CALC., =2 FOR FLUX CALC	C RAD
FL2	SAME AS FL1	C RAD
FLG	=0 FOR NORMAL PRINT-OUT, NOT=0 FOR EXTENSIVE PRINT-OUT	C RAD
FLG1	=0 FOR INTENSITY CALC, NOT=0 FOR FLUX CALC	C RAD
FMU	CONTINUUM ABSORPTION COEFFICIENT	L CONTN
FMU	CONTINUUM ABSORPTION COEFFICIENT	L LINT
FMU	THE CONTRIBUTION TO THE ABSORPTION DUE TO A PARTICULAR LINE	L MULE
FNU(K)	VNU(J,K) FOR CURRENT J.	C EQTCOM
FR	SPECIES MOLE FRACTION	C RADCOM
FRM	THE SAME AS FIM	L CONTN

FRP	THE SAME AS FIP	L CONTN
GAM	ISENTROPIC EXPONENT.	L EQUIL
GAM	LORENTZ HALF WIDTH AT HALF INTENSITY	L MULE
GAMF(K)	DEFINED BY EQ(79) OF NASA CR-1064.	C EQTCOM
GAMH(K)	DEFINED BY EQ(80) OF NASA CR-1064.	C EQTCOM
GAMP	HALF LINE BREDTH PER ELECTRON AT 10,000 DEG K	C RAD
GAR	LINE STRETCHING PARAMETER (DEFINED BY EQ. 71, REF 1)	L FREQ
GEE	STATISTICAL WEIGHTS OF ABSORBING (LOWER) LEVELS	C RAD
GOR	FREQUENCY INCREMENT BETWEEN LINE CENTER AND ADJACENT NODE	L FREQ
GUP	STATISTICAL WEIGHTS OF THE UPPER LEVELS OF THE LINE TRANSITIONS	C LINE
H(J)	ENTHALPY, IDENTICAL TO HH .	C EQTCOM
HCH	CHAMBER (OR STAGNATION) ENTHALPY.	L EQUIL
HCWAL	ENTHALPY OF SURFACE SPECIES DURING KR(9) + 3 OR 4 OPTIONS.	C EQPCOM
HG	ENTHALPY OF GAS, IDENTICAL TO HHG .	C EQTCOM
HH	ENTHALPY OF MIXTURE (BTU/LB)	C RADCOM
HH(J)	ENTHALPY, IDENTICAL TO H(J)*.	C EQTCOM
HIP	ENTHALPY INPUT.	C EQTCOM
HMELT	HM(J) IF J TH SPECIES IS CHANGING PHASE, OTHERWISE 0.	C EQTCOM
HOS	ENTHALPY OR ENTROPY OF SPECIES IN ASSIGNED ENTHALPY OR ENTROPY CHEMISTRY SOLUTION.	L MATER
HS	ENTHALPY UPSTREAM OF SHOCKWAVE (BTU/LB)	C RADCOM
HV	CONTINUUM FREQUENCY POINT	L MU
HVL	FREQUENCY OF AN INDIVIDUAL LINE CENTER	C LINE
IA	LINE GROUPS IN WHICH SPECIAL H LINES ARE LOCATED (ONE PER GROUP)	C LINE
IB(K)	INDEX ON SPECIES WITH LARGEST CONTRIBUTION TO K TH MASS BALANCE, SUBSEQUENTLY ORDERED ON IB WITH DUPLICATES SET TO 1000.	C EQTCOM
IC(K)	NEGATIVE INDEX OF ELEMENT CORRESPONDING TO KTH BASE SPECIES	L INPUT

ICT	CYCLE COUNTER ON POST INVERSION MODIFICATION IN CHEMISTRY SOLUTION	L EQUIL
IE	EQUATION INDEX FOR CONDENSED SPECIES.	L MATER
IER	EQUATION NUMBER TO REPRESENT NEWLY APPEARING CONDENSED SPECIES	C EQTCOM
IFC(J)	CONTROL FLAG (0 GAS, -1 NONPRESENT CONDENSED, 1 PRESENT CONDENSED, PRIOR FLAGS DECREMENTED BY 3 IF SPECIES CONTAINS NONPRESENT ELEMENT OR INCREMENTED BY 3 IF IT IS A BASE SPECIES REPRESENTING A NONPRESENT ELEMENT).	C EQPCOM
IG	NOMINALLY ZERO, EQUALS ONE ON FIRST SET OF BOUNDARY LAYER CHEMISTRY SOLUTIONS. FIRST GUESS AT I IS SOLUTION AT I-IG.	L EQUIL
IG	ELIMINATION INDEX IN BASE SPECIES-ELEMENT CORRESPONDENCE LOGIC.	L INPUT
IL	INDEX ON FIRST CHEMISTRY EQUATION TO BE SOLVED (1 FOR UNKNOWN T AND 2 FOR KNOWN T).	C EQTCOM
IM(K)	ROW AND COLUMN INDEX IN INVERSION OF CIJ TO UM.	L INPUT
IMI	LOCAL INDEX	L INPUT
IMJ	LOCAL INDEX	L INPUT
IML	LOCAL INDEX	L INPUT
IN	NUMBER OF EQUATIONS BEING SOLVED (HAS THE VALUE OF THE LOCAL VARIABLE ISPQ IF TEMPERATURE IS UNKNOWN OR ISPQ-1 IF TEMPERATURE IS KNOWN).	C EQTCOM
INP	IN 2	L CRECT
INV	FLAG ON RESTART OF CHEMISTRY (PERMITS ONLY ONE RESTART)	L EQUIL
IQ	FOR EACH NON-BASE GASEOUS SPECIES INITIALIZED TO ZERO, SET TO ONE IF SPECIES IS SIGNIFICANT IN ANY MASS BALANCE.	L MATER
IQQ	DEBUG(-2) AND NONCONVERGENT(-1) FLAG ON CALL TO AND RETURN FROM RERAY, RESPECTIVELY.	L EQUIL
IR(K)	CORRESPONDENCE VECTOR BETWEEN BASE SPECIES AND ELEMENTS.	C EQPCOM
IRE	INDEX ON NEWLY APPEARING CONDENSED SPECIES.	C EQTCOM
ISP	SAME AS ISP IN INPUT.	L EQUIL
ISP	(IS*) 1 WHERE IS* IS THE NUMBER OF ELEMENTS INCLUDING ELECTRON.	L INPUT

ISPQ	NUMBER OF EQUATIONS SOLVED IN CHEMISTRY SOLUTIONS, IS 2 NUMBER OF PRESENT CONDENSED SPECIES.	L EQUIL
ITFF	NEGATIVE COUNT ON SUCCEEDING CHEMISTRY SOLUTIONS WHICH WILL ACCEPT RESIDENT SOLUTION AS FIRST GUESS	L EQUIL
ITS	COUNTER FOR CHEMISTRY ITERATIONS	
IX	DEBUG FLAG.	L RERAY
IZ	NUMBER OF ELEMENTS INCLUDING ELECTRON, IDENTICAL TO IS*.	C EQPCOM
J	LOCAL INDEX	L CRECT
J	LOCAL INDEX	L EQUIL
J	LOCAL INDEX	L INPUT
J	LOCAL INDEX	L MATER
J	LOCAL INDEX	L THERM
JM	J-1, WHERE 'J' IS BASE SPECIES COUNT.	L INPUT
JT	LOCAL INDEX	L EQUIL
K1,K2	LOWEST INDEX (K1) AND HIGHEST INDEX (K2) ON THE LINES IN A GIVEN LINE GROUP	C LINE
KAT(K)	ATOMIC NUMBER.	C EQPCOM
KK	LOCAL INDEX	L INPUT
KPHA(N)	PHASE INDEX FOR A SPECIES, 1+GAS, 2+SOLID, 3+LIQUID.	L INPUT
KQ	CHEMISTRY CONTROL NUMBERS	L DADIN
KR	RADIATION CONTROL NUMBERS	C INTCOM
L(N)	INDEX ON COLUMNS DURING INVERSION.	L RERAY
LC	LINE COUNT INDEX (FOR OUTPUT PURPOSES ONLY)	L LINT
LEFUP	UPDATE LEF IF EQUAL TO ZERO (+MITS II-2 FOR BOUNDARY LAYER SOLUTION, OTHERWISE+1).	L EQUIL
LL(N)	ROW INDEX OF PIVOT FOR NTH COLUMN.	L RERAY
LLL(N)	COLUMN INDEX OF PIVOT FOR NTH ROW.	L RERAY
LS	INDEX USED TO REARRANGE COLUMNS IN RERAY (SEE LAR)	L RERAY

L2	INDEX ON PYROLYSIS GAS COMPONENT	C EQTCOM
L3	INDEX ON CHAR COMPONENT	C EQTCOM
M	DESIGNATES INPUT UNIT (E.G., TAPE)	C INTCOM
M	LOCAL INDEX	L CRECT
M	LOCAL INDEX	L INPUT
M1,M2	ALPHANUMERIC NAMES OF THE RADIATING SPECIES	C RAD
MELT	INDEX ON PHASE CHANGING SPECIES.	C EQTCOM
MODE	STORED VALUE FOR KR(1)*.	C EQTCOM
MOE	FLAG SET IN EQUIL AND USED IN CRECT. ZERO RESULTS IN EMPHASIZING EQUILIBRIUM EQUATIONS DURING CHEMISTRY CONVERGENCE, ONE RESULTS IN EMPHASIZING MASS BALANCES.	L EQUIL
N	DESIGNATES OUTPUT UNIT (E.G.,TAPE)	C INTCOM
N7	ITERATION AT WHICH DIAGNOSTIC OUTPUT WILL COMMENCE	L EQUIL
NAES	NUMBER OF ATOMIC ELECTRONIC LEVELS (SUM OVER ALL SPECIES)	C RAD
NBLP	NUMBER OF SPATIAL NODES ACROSS THE BOUNDARY LAYER (NOT NECESSARILY EQUAL TO NY)	C RAD
NCRC	USED TO DETERMINE WHICH CONTINUUM CONTRIBUTERS WILL BE INCLUDED. =1 INCLUDES, =0 EXCLUDES	C CONTM
NCV	NONCONVERGENCE COUNT, INITIALLY ZERO, INCREMENTED BY ONE FOR EACH NONCONVERGENT CHEMISTRY SOLUTION.	L EQUIL
ND	INDEX ON GROUND LEVEL OF TRANSITION	C RAD
NFM	NUMBER OF SIGNIFICANT SPECIES PLUS NUMBER OF NONPRESENT ELEMENTS.	L MATER
NHV	NUMBER OF LINE GROUPS	C RAD
NI	YY INDEX WHERE LINE COORDINATES ARE EVALUATED	C LINE
NIC	NUMBER OF Y/DELTA POINTS WHERE TRANSPORT IS CALCULATED	C RAD
NICK	NUMBER OF SPECIES CONSIDERED IN CHEMISTRY CALCULATION	C EQPCOM
NICN	INDICIES ON Y/DELTA VALUES WHERE TRANSPORT IS CALCULATED	C RAD
NIHVC	TOTAL NUMBER OF CONTINUUM SPECTRAL POINTS	C RAD

NK	THE NUMBER OF FREQUENCY POINTS ASSIGNED TO EACH LINE EQUALS 2*NK+1	L FREQ
NLG	THE SAME AS FLG EXCEPT THAT IT IS A FIXED POINT VARIABLE	L CONTN
NLG	THE SAME AS FLG EXCEPT THAT IT IS A FIXED POINT VARIABLE	L LINT
NLG1	THE SAME AS FLG1 EXCEPT THAT IT IS A FIXED POINT VARIABLE	L CONTN
NLG1	THE SAME AS FLG1 EXCEPT THAT IT IS A FIXED POINT VARIABLE	L LINT
NM	NUMBER OF ROWS LESS ONE	L RERAY
NN	NUMBER BY WHICH COLUMNS EXCEED ROWS IN PRINCIPAL ARRAY	L RERAY
NNN	NUMBER OF COLUMN VECTORS IN SECONDARY ARRAY	L RERAY
NOL	SAME AS XNOL	OUTPUT
NP	NUMBER OF COLUMNS IN PRIMARY ARRAY.	L RERAY
NR	INDEX WHICH INDICATES IF THE COORDINATE SYSTEM IS TO BE REVERSED DURING THE EVALUATION OF THE TRANSPORT INTEGRALS	L TRANS
NSHV	NUMBER OF FREQUENCY POINTS PER LINE GROUP	L LINT
NU	NUMBER OF LINES IN EACH LINE GROUP	C RAD
NXI	NUMBER OF SPECIAL H LINES (GAMP OF ZERO)	C LINE
NY	NUMBER OF Y/DELTA POINTS	C RAD
OT	INDEX WHICH INDICATES IF THE COORDINATE SYSTEM IS SUITABLE. OT=1 FOR AN OPTICALLY THIN LAYER, OT NOT EQUAL TO 1 FOR OPTICALLY THICK LAYER	L TRANS
P	PRESSURE.	C EQPCOM
PIN	P * (10**(-5)) USED TO INITIALIZE PARTIAL PRESSURES.	L EQUIL
PIN	SAME AS IN EQUIL.	L MATER
PINL	LOG (PIN).	L EQUIL
PLM	SUMMATION VN(J)*WTM(J) FOR ALL CONDENSED SPECIES.	L EQUIL
PNUS(K)	SUMMATION VNU(J,K) * VN(J) OVER ALL GASES J.	L MATER
PRES	PRESSURE (ATM)	C RAD
QR	NET RADIATIVE FLUX(BTU/FT2-SEC)	L MAIN
RA(N)	HEAT OF FORMATION OF MOLECULE AT 298 DEG K FROM JANAF BASE STATE, CAL/MOLE, N+1 OR 2 FOR LOW AND HIGH TEMPERATURE RANGES, RESPECTIVELY.	L INPUT

RC(J,N)	CURVE FIT CONSTANT FOR THERMODYNAMIC DATA (THE QUANTITY F3 DISCUSSED IN GROUP 4 OF INPUT INSTRUCTIONS), N+1 OR 2 FOR LOW AND HIGH TEMPERATURE RANGES,RESPECTIVELY.	C EQPCOM
RD(J,N)	CURVE FIT CONSTANT FOR THERMODYNAMIC DATA (THE QUANTITY F4 DISCUSSED IN GROUP 4 OF INPUT INSTRUCTIONS), N+1 OR 2 FOR LOW AND HIGH TEMPERATURE RANGES,RESPECTIVELY.	C EQPCOM
RE(J,N)	CURVE FIT CONSTANT FOR THERMODYNAMIC DATA (THE QUANTITY F5 DISCUSSED IN GROUP 4 OF INPUT INSTRUCTIONS), N+1 OR 2 FOR LOW AND HIGH TEMPERATURE RANGES,RESPECTIVELY.	C EQPCOM
RHR	DENSITY.	L EQUIL
RMMG	RATIO OF MOLECULAR WEIGHT (OBTAINED BY SUMMING PARTIAL PRESSURES OVER ALL SPECIES) TO THE MOLECULE WEIGHT (OBTAINED BY SUMMING OVER GAS PHASE SPECIES)	L MATER
RMMGS	RMMG * RMMG	L MATER
RSQA	RMMGS*FFF/AA	L MATER
S	AN ARRAY USED FOR LOCAL STORAGE IN MANY SUBROUTINES	
S1	AN ARRAY USED FOR LOCAL STORAGE IN MANY SUBROUTINES	
S1	THE LINE ABSORPTION COEFFICIENT INCLUDING THE CONTRIBUTIONS DUE TO OVERLAPPING LINES AND ACCOUNTING FOR INDUCED EMISSION	L MULE
S2	AN ARRAY USED FOR LOCAL STORAGE IN MANY SUBROUTINES	
S(N)	LARGEST CONTRIBUTION TO TERM IN N TH COLUMN	L RERAY
SB(J)	ENTROPY.	C EQTCOM
SHIP	SAVED VALUE OF INPUT ENTHALPY.	L EQUIL
SIGMA	COLLISION CROSS SECTION FOR REFERENCE SPECIES	C EQTCOM
SIP	ENTROPY INPUT.	C EQTCOM
SL	LINE STRENGTH	L MULE
SLAM(K)	DEFINED BY EQ(83) OF NASA CR-1064.	C EQTCOM
SM	FREQUENCY INCREMENT BETWEEN LINE CENTER AND LOWEST FREQUENCY NODE ASSIGNED TO THAT LINE	L FREQ
SM(J)	ENTROPY OF FUSION.	C EQPCOM
SMELT	SM(J) IF J TH SPECIES IS CHANGING PHASE, OTHERWISE 0.	C EQTCOM
SP	FREQUENCY INCREMENT BETWEEN LINE CENTER AND HIGHEST FREQUENCY NODE ASSIGNED TO THAT LINE	L FREQ

SP	ELEMENTAL MASS FRACTIONS	C RADCOM
SP1	PRESSURE UPSTREAM OF SHOCKWAVE (ATM)	C RADCOM
SPEASE	SAVED VALUE OF PIEASE	L EQUIL
SR1	DENSITY UPSTREAM OF SHOCKWAVE (LB/CUBIC FT)	C RADCOM
SS	LOCALLY DEFINED VARIABLE	L SLOPQ
SSIP	SAVED VALUE OF INPUT ENTROPY.	L EQUIL
SUMG	OFF-DIAGONAL COLUMN SUMS OF GAMK USED TO STRENGTHEN DIAGONAL DOMINANCE OF ARRAY	L EQUIL
SUML	LOG (SUMN/P)	C EQTCOM
SUMN	SUMMATION OF PARTIAL PRESSURES FOR ALL GAS PHASE SPECIES.	C EQTCOM
SV1	VELOCITY UPSTREAM OF SHOCKWAVE (FT/SEC)	
T	STATIC TEMPERATURE IN DEG K, IDENTICAL TO Z .	C EQPCOM
T1	TEMPERATURE IN UNITS OF KT(EV)	L CONTN
T1	TEMPERATURE IN UNITS OF KT(EV)	L LINT
T1	TEMPERATURE IN UNITS OF KT(EV)	L MU
TAU	CONTINUUM OPTICAL DEPTH FOR INTENSITY CALCULATION, TWICE THAT FOR A FLUX CALCULATION	L CONTN
TAU	CONTINUUM OPTICAL DEPTH FOR INTENSITY CALCULATION, TWICE THAT FOR A FLUX CALCULATION	L LINT
TAU(K,KK)	INTERMEDIATE ARRAY USED IN FORMING UM.	L INPUT
TAUC	OPTICAL DEPTH AT THE LINE CENTER FOR INTENSITY CALCULATION, TWICE THAT FOR A FLUX CALCULATION	L FREQ
TAUT	TOTAL (LINE AND CONTINUUM) OPTICAL DEPTH FOR INTENSITY CALCULATION, TWICE THAT FOR A FLUX CALCULATION	L LINT
TEE	TEMPERATURE (DEG. K)	C RAD
TF(J)	FAIL TEMPERATURE OF SPECIES J.	E EQPCOM
TFMAX	MAXIMUM FAIL TEMPERATURE OF CANDIDATE SURFACE SPECIES.	L INPUT
THETA	ANGLE OF SHOCKWAVE	C RADCOM
TION	TEMPERATURE BELOW WHICH IONIZATION WILL BE SUPPRESSED	L EQUIL
TK(K,N)	GRAM ATOMS OF ELEMENT K PER UNIT MASS OF COMPONENT N.	C EQPCOM

TLCM	LINE CORRECTION TO FLUX (OR INTENSITY) AWAY FROM WALL	C LINE
TLCP	LINE CORRECTION TO FLUX (OR INTENSITY) TOWARD WALL	C LINE
TM	MAXIMUM OR MINIMUM TEMPERATURE IF DELTA T IS POSITIVE OR NEGATIVE, RESPECTIVELY.	L CRECT
TMAX	MAXIMUM TEMPERATURE ALLOWED FOR CURRENT ITERATION.	C EQTCOM
TMIN	MINIMUM TEMPERATURE ALLOWED FOR CURRENT ITERATION.	C EQTCOM
TMSW	TRANSMITTANCE OF WALL AT CONTINUUM FREQUENCIES	C RAD
TMSWL	TRANSMITTANCE OF WALL AT AVERAGE FREQUENCIES OF LINE GROUPS	C RAD
TMU	TOTAL (LINE AND CONTINUUM) ABSORPTION COEFFICIENT	L LINT
TQ(K,N)	GRAM ATOMS OF BASE SPECIES K PER UNIT MASS OF COMPONENT N. (SEE W(N) FOR DEFINITION OF COMPONENTS).	C EQPCOM
TS	PHASE CHANGE TEMPERATURE.	L INPUT
TT	TEMPERATURE (DEG. R)	C RADCOM
TTMAX	MAXIMUM TEMPERATURE ALLOWED FOR THIS SOLUTION.	C EQTCOM
TTMIN	MINIMUM TEMPERATURE ALLOWED FOR THIS SOLUTION.	C EQTCOM
TU(J,N)	UPPER TEMPERATURE OF TEMPERATURE RANGE FOR INPUTTING THERMODYNAMIC PROPERTY DATA FOR SPECIES J, N=1 OR 2 FOR LOWER AND UPPER TEMPERATURE RANGES, RESPECTIVELY	C EQPCOM
TW	WALL TEMPERATURE (DEG. K)	C RAD
UGH	NORMALIZING FACTOR IN GAUSSIAN ELIMINATION.	L INPUT
UM(K,KK)	MOLECULES OF BASE SPECIES K IN ELEMENT KK.	L INPUT
V	LOCALLY DEFINED VARIABLE	L INPUT
VA	LOCALLY DEFINED VARIABLE	L CRECT
VA	LOCALLY DEFINED VARIABLE	L INPUT
VA	LOCALLY DEFINED VARIABLE	L MATER
VA	LOCALLY DEFINED VARIABLE	L THERM
VB	LOCALLY DEFINED VARIABLES	L INPUT
VB	LOCALLY DEFINED VARIABLES	L THERM

VC	LOCALLY DEFINED VARIABLES	L INPUT
VC	LOCALLY DEFINED VARIABLES	L THERM
VD	LOCALLY DEFINED VARIABLES	L INPUT
VD	LOCALLY DEFINED VARIABLES	L THERM
VE	LOCALLY DEFINED VARIABLES	L INPUT
VE	LOCALLY DEFINED VARIABLES	L THERM
VEL	VELOCITY.	L EQUIL
VELSQ	SQUARE OF VELOCITY.	L EQUIL
VINT	P * 10**(-6)	L INPUT
VLNK(J)	LOG KP FOR FORMATION REACTION OF J TH SPECIES.	C EQTCOM
VMACH	MACH NUMBER	L EQUIL
VMU2	SAME AS VMU2 IN PROPS.	L MATER
VMW	MEAN MOLECULAR WEIGHT OF MIXTURE	C RADCOM
VN(J)	PARTIAL PRESSURE.	C EQPCOM
VNU(J,K)	STOICHIOMETRIC COEFFICIENT ON K TH BASE SPECIES IN FORMATION OF J TH SPECIES.	C EQPCOM
WAT(K)	ATOMIC WEIGHT.	C EQPCOM
WD	DOPPLER HALF WIDTH AT HALF INTENSITY	L MULE
WM	MOLECULAR WEIGHT OF MIXTURE.	C EQPCOM
WOL	NUMBER DENSITY OF N2+	C RAD
WT	MOLECULAR WEIGHT AS SUMMED.	L INPUT
WTG	PRESSURE * GAS MOLECULAR WEIGHT.	L MATER
WTL	SUMMATION OF VN(J) * WTM(J) FOR ALL CONDENSED SPECIES.	L MATER
WTM(J)	MOLECULAR WEIGHT OF SPECIES J.	C EQPCOM
X(N)	CORRECTIONS OF NONLINEAR VARIABLES IN CHEMISTRY SOLUTION.	E EQTCOM
X1	DAMPED VALUE OF DELTA LN T.	L CRECT
XAPNU	CONTINUUM ABSORPTION COEFFICIENT CORRECTED FOR INDUCED EMISSION	L MU
XD	LOCALLY DEFINED VARIABLE	L SLOPQ

XF	GROWTH FACTOR FOR LINE FREQUENCY NODES (DEFINED BY EQUATIONS 69 AND 70 OF REF 1)	L FREQ
XIM	NEGATIVE SPECTRAL FLUX (OR INTENSITY)	L TRANS
XIP	POSITIVE SPECTRAL FLUX (OR INTENSITY)	L TRANS
XJW	CONTINUUM FLUX (OR INTENSITY) LEAVING WALL AND INCLUDING REFLECTED AND EMITTED COMPONENTS	L CONTN
XJWL	LINE FLUX (OR INTENSITY) LEAVING WALL AND INCLUDING REFLECTED AND EMITTED COMPONENTS	L CONTN
XMOL	=1 MOLECULAR CONTRIBUTIONS TO THE ABSORPTION COEFF ARE INCLUDED, =0 THEY ARE NOT INCLUDED	C RAD
XNOL	WEIGHT FACTOR TO BE APPLIED TO THE CONTRIBUTION OF A LINE TO ACCOUNT FOR THE CONTRIBUTIONS OF OTHER LINES WITH IDENTICAL PROPERTIES, WHICH ARE ALSO WITHIN THE LINE GROUP.	C LINE
XNN	NUMBER DENSITIES OF RADIATING SPECIES	C LINE
XOT	LOCALLY DEFINED VARIABLE	L SLOPQ
XOTT	LOCALLY DEFINED VARIABLE	L SLOPQ
XP	NUMBER DENSITY OF THE ABSORBING LEVEL	L MULE
XQ	ELECTRONIC PARTITION FUNCTION	C RAD
XTO	LOCALLY DEFINED VARIABLE	L SLOPQ
XTT	LOCALLY DEFINED VARIABLE	L SLOPQ
XXN	NUMBER DENSITIES OF RADIATING SPECIES (DUPLICATE MEANING)	C LINE
Y(J)	NATURAL LOG OF PARTIAL PRESSURE (+0 FOR PRESENT CONDENSED SPECIES), IDENTICAL TO YYY(J).	C EQPCOM
YC	INITIAL VALUE OF Y(J).	L INPUT
YINT	ALOG(VINT)	L INPUT
YS	LOCALLY DEFINED VARIABLE	L SLOPQ
YW(K)	VALUE OF YYY(J) AT WALL (SAVED).	C EQPCOM
YY	VALUES OF Y/DELTA POINTS	C RAD
Z	STATIC TEMPERATURE IN DEG K, IDENTICAL TO T*.	C EQPCOM

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