

AD-A137 162

A COMPUTER CODE TO CALCULATE EMISSION AND TRANSMISSION
OF INFRARED RADIAT. (U) AIR FORCE GEOPHYSICS LAB
HANSCOM AFB MA R D SHARMA ET AL. 08 JUL 83

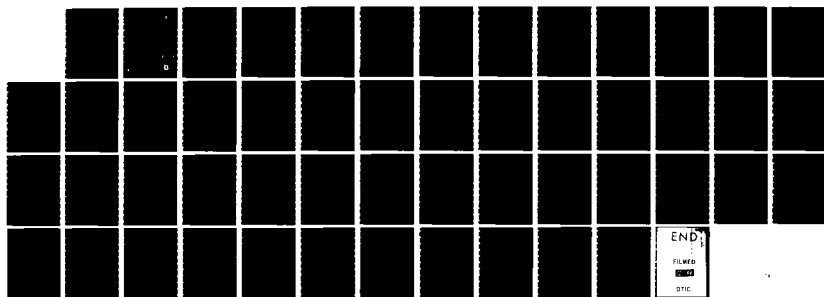
1/1

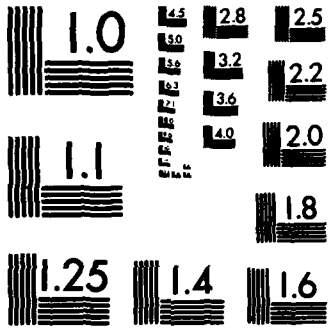
UNCLASSIFIED

AFGL-TR-83-0168

F/G 9/2

NL

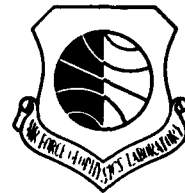




MICROCOPY RESOLUTION TEST CHART
 NATIONAL BUREAU OF STANDARDS-1963-A

10

AFGL-TR-83-0168
ENVIRONMENTAL RESEARCH PAPERS, NO. 842



AD A137162

A Computer Code to Calculate Emission and Transmission of Infrared Radiation Through Non-Equilibrium Atmospheres

R. D. SHARMA
R. D. SIANI
M. K. BULLITT
P. P. WINTERSTEINER

8 July 1983

Approved for public release; distribution unlimited.

DTIC
ELECTRONIC
S JAN 24 1984 D

OPTICAL PHYSICS DIVISION PROJECT 2310
AIR FORCE GEOPHYSICS LABORATORY
HANSCOM AFB, MASSACHUSETTS 01731

AIR FORCE SYSTEMS COMMAND, USAF




DTIC FILE COPY

84 01 23 045

This report has been reviewed by the ESD Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS).

"This technical report has been reviewed and is approved for publication"

FOR THE COMMANDER


(Signature)
RANDALL E. MURPHY
Branch Chief


(Signature)
JOHN S. GARING
Division Director

Qualified requestors may obtain additional copies from the Defense Technical Information Center. All others should apply to the National Technical Information Service.

If your address has changed, or if you wish to be removed from the mailing list, or if the addressee is no longer employed by your organization, please notify AFGL/DAA, Hanscom AFB, MA 01731. This will assist us in maintaining a current mailing list.

Do not return copies of this report unless contractual obligations or notices on a specific document requires that it be returned.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFGL-TR-83-0168	2. GOVT ACCESSION NO. AD-A137162	RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A COMPUTER CODE TO CALCULATE EMISSION AND TRANSMISSION OF INFRARED RADIATION THROUGH NON-EQUILIBRIUM ATMOSPHERES		5. TYPE OF REPORT & PERIOD COVERED Scientific. Interim.
7. AUTHOR(s) R. D. Sharma M. K. Bullitt† R. D. Siani P. P. Wintersteiner*		6. PERFORMING ORG. REPORT NUMBER ERP, No. 842
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Geophysics Laboratory (OPR) Hanscom AFB Massachusetts 01731		8. CONTRACT OR GRANT NUMBER(s)
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Geophysics Laboratory (OPR) Hanscom AFB Massachusetts 01731		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61102F 2310G415
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE 8 July 1983
		13. NUMBER OF PAGES 51
		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES † AFGL Scholar, supported through Southeast Center for Electrical Engineering Education, 1101 Massachusetts Avenue, St. Cloud, FL 32769 * Arcon Corporation, 260 Bear Hill Road, Waltham, MA 02154 <u>This research was supported by AFOSR</u>		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Infrared emission Band radiance Transmission Doppler Voigt Line-by-line		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A computer code that calculates infrared radiance in the upper atmosphere has been developed. The code, for limb-looking geometry and conditions where local thermodynamic equilibrium may not hold, utilizes individual ro-vibration- al transitions to calculate the optical thicknesses along each segment of the line-of-sight path. The formulation of the problem is given, as is the means of using the program and the procedure for obtaining input data from certain data bases. Appendices contain program listings and two examples.		

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	



Contents

1. INTRODUCTION	5
2. FORMULATION	6
3. USE OF THE PROGRAM	10
4. A PROCEDURE FOR THE ATMOSPHERIC PROFILES	12
5. THE AFGL ATMOSPHERIC ABSORPTION LINE PARAMETERS COMPILATION	14
5.1 Obtaining Files From the Disk Pack	15
5.2 Obtaining Files From the Magnetic Tapes	18
REFERENCES	21
APPENDIX A: Program Listings	23
APPENDIX B: Example of Program Output for a Single Line	37
APPENDIX C: Example of Program Output for All Lines of a Band	43

Illustrations

1. The Line-of-Sight Path Through a Layered Atmosphere	6
--	---

Tables

1. Miscellaneous Program Information on Unit 1	11
2. Atmospheric Profile Information on Unit 2	12
3. Input Data for the Procedure, ATMOS	13
4. Line-File Data for Each Transition	15
5. Input Data for the Procedure, WRITE	16
6. Parameters for the Procedure, WRITE	16

A Computer Code to Calculate Emission and Transmission of Infrared Radiation Through Non-Equilibrium Atmospheres

1. INTRODUCTION

The Air Force Geophysics Laboratory is in the process of developing a comprehensive computer code, NLTE, for calculating the radiance due to infrared-active species in the upper atmosphere. In particular, the code deals with atmospheric conditions in which local thermodynamic equilibrium (LTE) cannot be assumed; that is, conditions under which the populations of vibration-rotation states cannot (necessarily) be given by a Boltzman-distribution with the kinetic temperature. Moreover, it does a line-by-line calculation, rather than a band calculation, using the properties of individual rotational lines obtained from the AFGL Atmospheric Absorption Line Parameters Compilation.^{1, 2, 3, 4} The output is the integrated radiance from each line under consideration. The individual lineshapes can also be obtained, if necessary.

At present, the non-LTE conditions are simulated by the use of a vibrational temperature profile. Work is in progress to incorporate into the program computations of the direct physical mechanisms that are responsible for the populations of the excited states. That is, the excitation of infrared-emitting species by sunshine, earthshine, collisions, and photochemical reactions will be used to directly calculate

(Received for publication 6 July 1983)

(Due to the large number of references cited above, they will not be listed here. See References, page 21.)

the populations of vibrational states rather than using the vibrational temperature profile as input.

The looking geometry is assumed to be horizon-to-horizon. It is therefore parameterized by a tangent height, the lowest altitude along the line-of-sight path.

2. FORMULATION

We consider the path through which a photon has to pass to reach the observer to be made up of a series of slabs. In each of the slabs the kinetic temperature, the vibrational temperature, and the density of the atmospheric constituents in the ground and excited states is assumed to be constant. The altitude of the end points of each slab may not differ by more than 1 km (Figure 1).

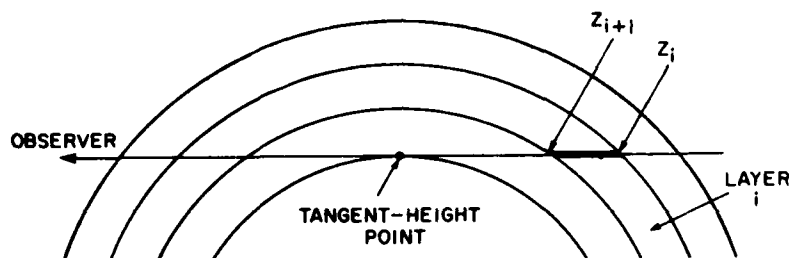


Figure 1. The Line-of-Sight Path Through a Layered Atmosphere, the enhanced segment showing its intersection with the i th layer over a distance $\Delta Z_i = Z_{i+1} - Z_i$

At first glance, it might appear that we are constructing a model for a one-dimensional atmosphere. This, however, is not the case. One can make the slabs as small as desired—so small in fact that the errors may be determined principally by the uncertainties in the input model atmosphere. Nor is there any requirement that the two slabs corresponding to a given altitude on either side of the tangent height point have the same composition.

In the equations that we derive, we will assume that lines for which the intensity is calculated are non-overlapping. That this is a reasonable assumption can be seen from the following argument. The two closest lines in the $15\text{-}\mu\text{m}$ band of the $\text{C}^{12}\text{O}_2^{16}\text{O}^1\text{O}-\text{OO}^0\text{O}$ transition are Q(2) and Q(4) which are 0.0145 cm^{-1} apart.

Recalling that the Doppler linewidth at 200 K, corresponding roughly to 70 km in altitude, is about 0.0005 cm^{-1} , it can be seen that the separation between the Q(2) and Q(4) lines corresponds to about 30 linewidths. Apart from the accidental overlap of lines of different bands, that may occur rather infrequently, we expect most of the lines to be spaced several linewidths apart. The assumption of non-overlapping lines thus appears reasonable.

We express the radiance in terms of n_ν , the number of photons (of frequency $\nu \text{ cm}^{-1}$) per wavenumber per unit area per steradian which are observed at a point z along the line-of-sight path per unit time. The change in n_ν in a path length dz is described by

$$\frac{dn_\nu}{dz} = \left[-n_\nu \frac{h\nu_0}{c} (n_\ell B(\ell \rightarrow u) - n_u B(u \rightarrow \ell)) + \frac{A}{4\pi} n_u \right] f(\nu - \nu_0) \quad (1)$$

where h and c are Planck's constant and the speed of light, n_ℓ and n_u are the number densities of the lower and upper radiating states, $B(\ell \rightarrow u)$ and $B(u \rightarrow \ell)$ are Einstein coefficients for absorption and induced emission, A is the Einstein coefficient for spontaneous emission and f is the normalized lineshape function such that

$$\int_{-\infty}^{\infty} f(\nu - \nu_0) d\nu = 1. \quad (2)$$

In Eq. (1), $n_\nu n_\ell B(\ell \rightarrow u)$ is the term for the absorption of incident photons. $n_\nu n_u B(u \rightarrow \ell)$ is the induced emission term. The factor $(h\nu_0/c)$, which is commonly absent in derivations of this equation, appears because of the fact that n_ν is a photon flux rather than an energy flux, and because ν is in units of cm^{-1} instead of sec^{-1} .

The Einstein coefficients⁵ are connected by

$$g_\ell B(\ell \rightarrow u) = g_u B(u \rightarrow \ell) \quad (3)$$

and

$$A = 8\pi h\nu_0^3 B(u \rightarrow \ell) \quad (4)$$

where g_ℓ and g_u are the statistical weights of the lower and upper radiating states. Through use of Eqs. (3) and (4), the definition

5. Penner, S. S. (1959) Quantitative Molecular Spectroscopy and Gas Emissivities, Addison-Wesley, Reading, Massachusetts.

$$\gamma \equiv \frac{g_\ell n_u}{g_u n_\ell} \quad (5)$$

and some algebraic manipulation we see that Eq. (1) can be cast in the form

$$\frac{dn_\nu}{dz} = \frac{h\nu_0}{c} B(\ell \rightarrow u) n_\ell \left[-n_\nu (1 - \gamma) + 2c\nu_0^2 \gamma \right] f(\nu - \nu_0). \quad (6)$$

One can readily see that the $(1 - \gamma)$ factor corrects the simple absorption term (which is proportional to $n_\ell n_\nu$) for stimulated emission; the other term in the brackets is the spontaneous emission.

Next we connect the Einstein coefficient to the line strength which is available on the AFGL Line Parameters Compilation.¹ The tabulated line strengths $S(T_s)$ are given for conditions of LTE at the standard temperature T_s , which is 296 K, and are related to $B(\ell \rightarrow u)$ by

$$\frac{h\nu_0}{c} B(\ell \rightarrow u) = \frac{S(T_s)}{P_\ell(T_s)} (1 - \exp(-C_2 \nu_0/T_s))^{-1} \quad (7)$$

where $C_2 = 1.4388 \text{ K/cm}^{-1}$ is the second radiation constant and $P_\ell(T_s)$ is the probability of finding the lower vibration-rotation state occupied. In general, $P_\ell = n_\ell/n$ where n is the total number density of the specie.

The exponential term in Eq. (7) takes into account the stimulated emission at 296 K, and in fact is simply γ evaluated under conditions of LTE at T_s .

We now define the optical depth, τ_ν , by

$$\frac{d\tau_\nu}{dz} = \frac{h\nu_0}{c} B(\ell \rightarrow u) f(\nu - \nu_0) n_\ell (1 - \gamma) = \frac{S(T_s)}{P_\ell(T_s)} f(\nu - \nu_0) n_\ell \frac{1 - \gamma}{1 - \exp(-C_2 \nu_0/T_s)}. \quad (8)$$

Since the quantities f , n_ℓ , and γ are (by assumption) constant within the confines of each slab, the optical depth of the i th slab is

$$\Delta\tau_{\nu i} = \tau_\nu(Z_{i+1}) - \tau_\nu(Z_i) = \frac{S(T_s)}{P_\ell(T_s)} f(\nu - \nu_0) n_\ell \frac{Z_{i+1} - Z_i}{1 - \exp(-C_2 \nu_0/T_s)} (1 - \gamma). \quad (9)$$

(The subscript i is implied for f , n_ℓ , and γ .) Expressing n_ℓ in terms of the total number density, this becomes

$$\Delta \tau_{\nu i} = \left[S(T_s) \frac{P_\ell(T)}{P_\ell(T_s)} \frac{1 - \gamma}{1 - \exp(-C_2 \nu_0 / T_s)} \right] f(\nu - \nu_0) n_\ell \Delta Z_i . \quad (10)$$

The term in square brackets now represents the line strength for conditions prevailing in the slab, including corrections for stimulated emission, and this times $f(\nu - \nu_0)$ is the conventional absorption coefficient $k(\nu)$. $P_\ell(T)$ must be evaluated with the understanding that non-LTE conditions prevail, in general; the same applies to γ . Both these quantities therefore actually depend on the vibrational temperature as well as the kinetic temperature of the slab.

To complete the analysis one combines Eqs. (6) and (8) to give

$$\frac{dn_\nu}{d\tau_\nu} = \left[-n_\nu + 2c\nu_0^2 \frac{\gamma}{1-\gamma} \right]. \quad (11)$$

This equation can easily be integrated across a slab. The solution is

$$n_\nu(Z_{i+1}) = n_\nu(Z_i) e^{-\Delta \tau_{\nu i}} + 2c\nu_0^2 \frac{\gamma_i}{1-\gamma_i} (1 - e^{-\Delta \tau_{\nu i}}) \quad (12)$$

where the slab-dependence of γ is finally made explicit with the subscript. In Eq. (12), the first term represents the absorption within the i th slab of radiance incident upon it at Z_i ; and the second term represents the contribution from the i th slab alone. The strategy of the program is now clear. The boundary condition at the far horizon is $n_\nu(Z_i) = 0$ for all frequencies. Using that as the starting point, one calculates the radiance at the near end of each slab from Eq. (12) until the observer's end of the line-of-sight path is reached. One thus obtains a line profile for the observed radiance. This profile is integrated over frequency to get the radiance for the line in question. At the end the result is converted to units of W/cm^2 -steradian.

NLTE also calculates the integrated radiance to be expected if the line is thin—that is, if $\Delta \tau_{\nu i}$ is always much less than unity for that line. The determination of whether a line actually is thin is made by comparing this result with the integral over the computed lineshape. Agreement within 5 percent defines a "thin" line.

The program adds the integrated radiance from all the lines it selects from the line-file provided by the user. It performs this operation for each looking geometry specified, starting with the lowest tangent height. For each tangent height after the first, as the computation proceeds it checks to see whether the line under consideration has been found to be thin for paths characterized by a lower tangent height. If it has, it is also assumed to be thin for the current path and all paths characterized

by greater tangent heights. The lengthy profile calculations are thereby avoided for this line, and the integrated intensity is taken to be the "thin" result.

3. USE OF THE PROGRAM

NLTE has been written in ANSI-standard FORTRAN '77. It is still in the process of being developed and made more efficient, and many changes are anticipated. A listing appropriate for radiance from CO_2 is given in the Appendix. At present NLTE requires 65,000 words to compile and execute on the CDC-6600 at AFGL. A high-optimization option should be selected at compile time (OPT = 2) unless changes are being made and the debug package is required. Except for a few seconds of overhead required for initialization, the execute time is nearly proportional to the number of lines used. It is usually also proportional to the number of tangent heights selected, but if many of the lines are thin the execute time can be reduced since fewer computations are required. Selecting the Doppler lineshape instead of the Voigt profile can cut the run time by a factor of three.

NLTE requires information from three data files, one of which is the input stream. These files, which are associated with units 1, 2, and 3, contain miscellaneous program input, an atmospheric profile, and a coded AFGL line file, respectively.

Table 1 lists the miscellaneous program input on unit 1. Three card-images are required, and they are read with list-directed reads. This means that comma or blank delimiters separate the data elements, and there is no need to align the latter in particular columns. All variables of type character must be enclosed in quotes ('). Default values result from blank fields. These are defined by consecutive commas or, in the case of the last fields on a card, by a single slash (/). Example 1 gives a possible data record for Unit 1.

The first of these three cards gives the specie of interest, and three energies which are required. The latter are the energy of the vibrational transition in question, which is needed to calculate γ ; the vibrational energy of the lower state, needed for $P_\ell(T)$; and the energy of the lowest-energy vibrational transition, needed to calculate the vibrational partition function. The program does not recognize defaults for any of these quantities.

The second card identifies the lines which are used to calculate the radiance, assuming they can be found on the line file. That is, the required frequency range, band, branch, and rotational line designations are specified, and all lines satisfying these requirements are used. The frequency range is given by VMIN and VMAX. The band is specified by the upper- and lower-state quantum numbers, UST and LST; the branch, by BR; and the rotational line by NRQL. Acceptable values of BR are

'P', 'Q', 'R', and 'A', where 'A' implies all branches. Acceptable values of NRQL are integer numbers identifying single lines of a branch; and 999, implying all lines of the selected branch(es).

NDP is a code specifying the lineshape to be used in the computation. A value of 0 causes the Voigt profile to be used; 1 gives the Doppler lineshape.

The program recognizes defaults of 0, 0, and 50000 for NDP, VMIN, and VMAX respectively.

The third card gives the tangent heights which define the looking geometry for each desired case. TANIN is the lowest tangent height, TANF the highest, and INTRVL is the spacing.

Table 1. Miscellaneous Program Information on Unit 1

Quantity	Description	Units	Type	Example
(CARD 1A)				
MOL	Molecular formula		Character	'CO2'
ISO	Isotope code		Integer	626
VIBE	Vib energy of the transition	cm ⁻¹	Real	667.3
VIBL	Vib energy of lower state	cm ⁻¹	Real	0
VIBQ	Vib energy for partition fn	cm ⁻¹	Real	667.3
(CARD 1B)				
BR	Branch (P, Q, or R)		Character	'R'
NRQL	Rotational quantum line		Integer	999
UST	Upper vib state (AFGL not 'n)		Character	'01101'
LST	Lower vib state (AFGL not 'n)		Character	'00001'
NDP	Lineshape option		Integer	0
VMIN	Lowest wavenumber desired	cm ⁻¹	Real, int	600
VMAX	Highest wavenumber desired	cm ⁻¹	Real, int	750
(CARD 1C)				
TANIN	Initial tangent height	km	Integer	70
TANF	Final tangent height	km	Integer	80
INTRVL	Examination height	km	Integer	5
Example 1 Example of an Input Data Record on Unit 1				
'CO2', 626, 667.3, 0, 667.3				
'R', 999, '01101', '00001'/				
70, 80, 5				

Unit 2 contains the atmospheric profile which is to be used in the radiance calculation. The file providing this information is headed by a single card-image containing identifying comments. Each succeeding card-image contains the information

listed in Table 2, in the format given there. No more than 250 cards, which correspond to successively higher altitudes with a 1-km spacing, may be read in. The lowest altitude must be less than or equal to TANIN. The highest must be greater than or equal to TANF + 50, since the calculations are done using 50 layers.

A procedure for obtaining the atmospheric-profile data files in the form required by NLTE for input on Unit 2 is described in the next section

Unit 3 contains the coded line file. This is needed to determine the absorption and reradiation of energy by each line in the wavelength range under consideration. The contents of such files, and the means of obtaining them from the complete data base which has been developed at AFGL, are given in Section 5.

Table 2. Atmospheric Profile Information on Unit 2

Quantity	Description	Units	Format
A (integer)	Altitude	km	I5
TRTMP	Kinetic temperature	Kelvin	F10.3
ALCOR	Atmospheric pressure	atmos	E12.5
RHO	Density of radiating molecule	cm ⁻³	E12.5
VTMP	Vibrational temperature	Kelvin	F10.3

4. A PROCEDURE FOR THE ATMOSPHERIC PROFILES

A procedure, called ATMOS, is available at AFGL for the purpose of allowing users to create databases in the format required to input to NLTE on Unit 2. The data presently built into ATMOS are profiles very much like those in the 1976 U. S. Standard Atmosphere. The vibrational profiles can either be read as input to this procedure, or derived in a very simple (but contrived) way from the kinetic temperature. The alternative to reading vibrational temperatures directly is to add or subtract a fixed number of degrees to or from the kinetic temperature. Interpolation procedures are built in so that input data for the vibrational temperature are not needed at intervals as closely spaced (1 km) as they are on output.

The procedure, ATMOS, is in a very preliminary stage of development. In the future, its data base will be expanded to include various standard atmospheric profiles and some other features as well. However, it can be used in its present form on the AFGL central computer system, as shown in Example 2.

ATMOS requires user input at two places: the BEGIN card and the data card following the end-of-record in the input stream. Also, if vibrational profiles are to be read in, a logical file called TAPE4 must be attached. The BEGIN card has two parameters which, if selected, cause the output data file to be cataloged as a

permanent file. The parameters are PFN and NAME, and are used in the example. It is acceptable to omit them completely, in which case the form is simply BEGIN, ATMOS, P, and the data are not saved on a permanent file. In either case, the first ATTACH card should be used exactly as in the example.

The data card should contain six quantities, listed in Table 3. They are read with a list-directed read, discussed above. Most of them are variables of type character, and must therefore be enclosed in quotes. MOL specifies the radiating molecule. Acceptable values of DORN are 'DAY' or 'NIGHT', reflecting the fact that some species' density profiles have diurnal variations. HMIN and HMAX are the minimum and maximum altitudes of interest.

Table 3. Input Data for the Procedure, ATMOS

Variable	Description	Type	Default
MOL	Molecular Formula	Character	
DORN	Day or night profile	Character	'NIGHT'
HMIN	Lowest altitude (km)	Integer	0
HMAX	Highest altitude (km)	Integer	250
CODE	Code for vib temp	Character	'ADD'
FMT	Format for read, or number of degrees to add	Character	'(I5, F10. 3)' '0'

EXAMPLE 2 Use of the Procedure, ATMOS			
USER1, T30.		1234	USER
ATTACH(P, PROCFILE, ID=WINTERS, MR=1)			
ATTACH(TAPE4, USERSFILE, ID=USER, MR=1)			
BEGIN(ATMOS, P, PFN=OUTPUTFILE, NAME=USER)			
EOR			
'CO2', 'NIGHT', 70, 190, 'READ', '(I5, 34X, F10. 3)'			

CODE and FMT have different forms depending on whether the vibrational temperature profile is to be read from TAPE4, or the vibrational temperature profile is to be determined from the kinetic temperature profile. Meaningful values for CODE are 'READ' and 'ADD'. Anything else causes the vibrational temperature to be set equal to the kinetic temperature everywhere.

If CODE is read as 'READ', the vibrational temperature is read in a user-selected format, given by FMT. Each card-image on TAPE4, except for a header card containing identifying information, should contain an altitude and a vibrational temperature in that order. FMT should then specify two fields, one integer and one real, for reading these quantities. The default value of FMT is '(I5, F10. 3)', but inside the quotes and parentheses, which are required, any format is acceptable.

If CODE is read as 'ADD', FMT must be a character representation of the number of degrees to add to the kinetic temperature. Possible values are '+10', '50', '0', and '-50'. Default is '0'.

5. THE AFGL ATMOSPHERIC ABSORPTION LINE PARAMETERS COMPILATION

For many years, AFGL has maintained and continually updated its own compilation of atmospheric absorption line parameters for transitions from the millimeter region through the visible. These are described in various publications.¹⁻⁴ The compilation is the responsibility of Dr. L. S. Rothman, AFGL/OPI.

For users of the AFGL computer system, the data reside on a disk pack in the CDC-6600 computer center. For workers at other installations, the compilation is available on two magnetic tapes. (It is also accessible on two CC tapes at AFGL, but use of the disk pack is preferable.) The compilation was originally developed in two parts. The "Main" compilation contained data from the principal sources of atmospheric infrared absorption. These molecules, corresponding to a gas code of 1 through 7, are H₂O, CO₂, O₃, N₂O, CO, CH₄, and O₂ respectively. The trace-gas file contained data for the molecules whose codes are 8 through 28.³ In fact, this division still exists on the magnetic tape compilations. A merged line file was recently written to a single disk pack, however, making all the data available (at AFGL) by use of simple procedures.

The data exist in card-images on the pack and tapes, with one card-image corresponding to each transition. There are almost 300,000 transitions (lines) in all, arranged in order of increasing wavenumber. They are grouped in files spanning 100 wavenumbers, each one divided into records containing up to 250 lines (pack) or 40 lines (tapes). On the pack the files are in buffered binary form; on the tapes, buffered BCD.

The data available for each transition are given in Table 4.¹ There are several programs available for accessing subsets of the complete compilation and making them available in particular formats for specific purposes (for example, input to the LTE radiance program, FASCODE⁶). The formatting listed in Table 4 is the output specification of a procedure, WRITE, written by Dr. Rothman to obtain a coded line file from the disk pack. Generally, subsets of the complete data set are located according to particular (1) frequency ranges, (2) molecules, (3) isotopes, and

6. Clough, S. A., Kneizys, F. X., Rothman, L. S., and Gallery, W. O. (1981) Atmospheric Spectral Transmittance and Radiance: FASCOD1B, AFGL-TR-81-0269, AD A104832; also SPIE 277 (Atmos Transmission) 152-166.

(4) vibrational bands. However, by reading the line file and checking any of the parameters given, one can make a selection based on other criteria as well.

Table 4. Line-File Data for Each Transition

Format	Symbol	Line-File Datum
F10.4	ν	Resonant frequency (cm-1)
E10.3	S	Line intensity at 296 K (cm-1/(molecule-cm ²))
F5.4	α	Halfwidth (air broadening) (cm-1/atmos)
F10.3	E''	Energy of the lower state (cm-1)
2A8, A10, A9		Quantum numbers, line identifiers
I3		Entry code for these data
I4	ISO	Isotope code
I3	MOL	Gas code

The meaning of the physical data (frequency, and so on) listed in Table 1 is self-evident. The quantum numbers are discussed in Reference 1 (and, to a small extent, below). The entry code is usually irrelevant for the user. The gas code is an integer between 1 and 28, as mentioned above. The isotope code is also explained in Reference 1. It is a string of integers representing the last digit in the atomic weight of each atom, given in the order in which the atoms exist in the molecule. For example, the main isotope of CO₂ is identified by the code 626, since the molecule consists of atoms of atomic weight 16, 12, and 16.

5.1 Obtaining Files From the Disk Pack

The procedure WRITE, mentioned above, is the easiest way for users at AFGL to obtain data from this compilation. Example 3 gives a control-card sequence which obtains, catalogs on permanent file, and lists all ozone lines between 2000 and 2020 cm⁻¹. For any job using this procedure, the first three cards must be prepared exactly as in the example, except for the user's name and problem number, the specification of the logical file name (P) and possibly the time allocated to the job. The BEGIN card contains optional parameters, described below, which determine the disposition of the information acquired from the compilation. The data card(s) following the end-of-record (EOR) provide the information the procedure requires to identify the desired lines.

The information to be taken from the data cards is listed in Table 5. Each card is read with a list-directed read, which means that the data fields (eight in number) should be separated by comma delimiters and no attention need be paid to the columns used for each field. Default values result from blank fields (consecutive commas). After the last field containing a non-default value, a slash (/) can be used

to terminate data input for that card. Either the slash or a sufficient number of commas to define each field must be used. All input data of type character must be surrounded by quotes, like 'O3' in Example 1. Leading blanks inside the quotes will give unpredictable results. Anywhere else, blanks are irrelevant.

EXAMPLE 3 Use of the Procedure WRITE

```

USER1, T30, CM50000, STMFA, PK.                1234  USER
ATTACH(P, PROCEDURES, ID=ROTHMAN, MR=1)
MNT(VSN=FAS53, SN=FASPK)
BEGIN(WRITE, P, PFN=OZONELINES, NAME=USER, COPFIL=YES)
EOR
2000, 2020, 'O3',,,,,,'PFILE'

```

Table 5. Input Data for the Procedure, WRITE

Datum	Quantity	Type	Default
V1, V2	Frequency range (cm-1)	Integer or real	
MOL	Molecular formula	Character	All molecules
ISO	Isotope code (Reference 1)	Integer	All isotopes
UST, LST	Band quantum numbers	Character	All branches
SCRIT	Threshold strength	Real	All strengths
DISPOS	File disposition code	Character	List only

V1 and V2 must be specified, as there is no default. MOL is an alphanumeric symbol giving the molecular formula. ISO is the isotope code explained earlier, UST and LST are the upper- and lower-state quantum numbers of the vibrational band desired. The quantum numbers are different for different molecules, and their meaning is discussed in Reference 1. For the purposes of WRITE, one enters consecutive digits inside the quotes, for example '11101'.

SCRIT is an intensity threshold. Lines which are weaker than this threshold are ignored. Because of the small magnitudes involved, an E descriptor should be used.

The data selected by the program can either be listed on OUTPUT or written to TAPE8, which is later made into a permanent file. DISPOS is a code used to select the desired disposition. Entering either 'PFILE' or 'PUNCH' in this field causes TAPE8 to be written. Anything else invokes the list option. One can list some data and save other data by entering different disposition codes on different cards.

Lines satisfying the requirements of each separate data card are frequency-ordered on whichever file they are directed to, OUTPUT or TAPE8. However, lines from one data card will always follow those from preceding cards. If the frequency ranges are increasing and do not overlap, frequency-ordering is preserved.

Otherwise, for TAPE8 only, a SORT/MERGE option (see below) can be specified on the BEGIN card to restore frequency-ordering.

The BEGIN card invokes the procedure WRITE (which is found on logical file P in our example). It allows up to four optional parameters which are used for three separate purposes: to preserve the frequency-ordering on TAPE8, as mentioned above; to give the permanent file name and user identification required for cataloging TAPE8; and to cause the information on TAPE8 to be copied to OUTPUT. The form of each of these parameters is KEYWORD=VALUE, where KEYWORD is fixed and VALUE is supplied by the user. Table 6 describes these parameters. PFN and NAME should be either both be specified, or neither. The parameters can be entered in any order following the logical file name. Parameters which are omitted assume default values, the effect of which is given in Table 6.

Table 6. Parameters for the Procedure, WRITE

Keyword	Value	Default
SORTM	YES	No SORT/MERGE
PFN	Permanent File Name	No catalog is done even if PFILE is specified on some data cards
NAME	User's ID	
COPFIL	YES	No list of TAPE8

It is possible to invoke WRITE more than once in a single job, with different parameters, so long as TAPE8 is returned after each usage and so long as one data record is provided for each usage.

The WRITE output specification given in Table 4 is that used on TAPE8. It may change slightly for certain frequency ranges, since sometimes more significant figures are available than this particular format allows. The field widths are always the same, however. On OUTPUT, when the list option is selected, the fields are spread out for ease in reading and to make space for annotation.

Example 4 contains a small subset of lines from the 11101-00001 band of CO₂, in the format assigned by WRITE and described above. Example 5 gives a possible, albeit unusual, set of requirements for linefiles, with many different forms used on the data cards. Only three sets of lines are written to TAPE8, and these are then ordered before being cataloged and copied. The second call to WRITE produces the lines of which Example 4 is a subset.

EXAMPLE 4 Portion of a Coded File from WRITE

2075.2960	7.868E-24.0770	2.341	11101	00001	P	2	482	626	2
2076.8632	3.363E-23.0770	2.341	11101	00001	Q	2	482	626	2
2076.8788	5.894E-23.0770	7.804	11101	00001	Q	4	482	626	2
2076.9034	8.166E-23.0760	16.389	11101	00001	Q	6	482	626	2
2076.9369	1.009E-22.0750	28.095	11101	00001	Q	8	482	626	2
2076.9793	1.160E-22.0750	42.922	11101	00001	Q	10	482	626	2
2077.0308	1.265E-22.0740	60.871	11101	00001	Q	12	482	626	2
2077.0912	1.325E-22.0740	81.940	11101	00001	Q	14	482	626	2
2077.1607	1.340E-22.0730	106.130	11101	00001	Q	16	482	626	2
2077.2393	1.316E-22.0720	133.439	11101	00001	Q	18	482	626	2
2077.3270	1.258E-22.0720	163.868	11101	00001	Q	20	482	626	2
2077.4239	1.173E-22.0710	197.416	11101	00001	Q	22	482	626	2
2077.5299	1.069E-22.0710	234.083	11101	00001	Q	24	482	626	2
2077.6373	1.252E-23.0780	0.000	11101	00001	R	0	482	626	2

EXAMPLE 5 Possible Usage of the Procedure WRITE

```

USER2, T30, CM50000, STMFA, PK.                                1234      USER
ATTACH(P, PROCEDURES, ID=ROTHMAN, MR=1)
MNT(VSN=FAS53, SN=FASPK)
BEGIN(WRITE, P, SORTM=YES, PFN=MISCLINES, NAME=USER, COPFIL=YES)
RETURN(TAPE8)
BEGIN(WRITE, P, PFN=CO2LINES, NAME=USER)
EOR
1220.000, 1221.000/
1220,1221,'H2O'/
1220 , 1221, 'H2O ' ,181 /
1220, 1221,,,'100','000'/
1220,1221,,,,,5.E-22/
1220,1221,,,,,5.E-22,'PFILE'
1220,1221,,,'00000111',00000000',,'PUNCH'
1220., 1221.,211,,,,,'PFILE'/
EOR
2000,2173,'CO2',626,'11101','00001',,'PFILE'
    
```

5.2 Obtaining Files From the Magnetic Tapes

Users who do not have access to the disk pack can obtain the line-file data from the two magnetic tapes. The tapes contain files spanning 100 wavenumbers and each file is split into records containing up to 40 transitions (the last record generally being shorter). Each card-image consists of eight 60-bit words, and there is a single word at the beginning of each record specifying the number of transitions on the record. The typical record therefore consists of 321 words.

The data on the tapes are the same as is given in Table 4, and in fact the format appropriate for decoding the record is exactly that given in Table 4 except for the 35 characters specifying the quantum numbers and line identifiers. The format for this portion of the card-image depends on the molecule in question and is described in Reference 1. In this context (magnetic tapes) the ordering and formatting given

in Reference 1 is correct, unlike that of the new disk pack where uniformity dictated certain changes.

In order to obtain a line file the coded records containing the data must somehow be read into arrays, and the data must be checked to see if they are included in the user's desired subset. In other words, a program to serve the function of procedure WRITE is required. On CDC systems, each record can be read with a BUFFER IN statement. One can then use the internal file feature of FORTRAN '77 as a means of converting character information to numerical information. This feature utilizes a variable or array of type character as the internal file. Formatted read and write operations, to and from this region of memory, perform the conversion. This approach is superior to the use of DECODE for several reasons, one of which is that it is ANSI-standard and hence available to all FORTRAN '77 users.

Example 6 gives a small portion of a possible FORTRAN program which could be used to examine the line-file data on a CDC system. The tape is identified with TAPE5. After the record is buffered in, the first word, A(1), is checked to determine the number of transitions on the record. The internal file used here is the variable C. Then, using array B as the internal file, the data for all transitions are read into arrays according to FORMAT statement 102. All the information is now in numerical form and can be manipulated with normal arithmetic operations, except the 35 characters of identifying information which are left in character form and can therefore be compared only with other character variables.

The loop DO 300 performs simple comparisons for each line to see if the data satisfy the user's criteria. The third and fourth IF statements compare substrings of the Ith element of CH with the codes for the desired branch, defined in the DATA statement.

This sketchy example, with its data and formats "hardwired" in, is obviously insufficient to duplicate the capability of procedure WRITE, but the basic idea can be developed into something considerably more general. Note that there is no need to dump all of the 35 characters of identifying information into a character array. Some of that information, such as the upper- and lower-state quantum numbers, is in the form of digits and could be converted to integers for arithmetic comparisons. Alternatively, any or all of it could be ignored altogether.

This also neglects the matter of file positioning—that is, skipping files and records until the record containing the lowest desired frequency is in position to be read. This is obviously desirable, to avoid reading and simply discarding hundreds or thousands of records. Since files span 100-wavenumber regions, the number of files to skip is easily determined. For example, to get lines in the region $650\text{-}750\text{ cm}^{-1}$, six complete files are skipped: SKIPF(TAPE5,6,17,C). If, in addition, the lines at 650 cm^{-1} are known to be in the (N+1)st record, N records can then also be

skipped within the seventh file): SKIPF(TAPE5, N, 1, C). Otherwise, as is generally the case, one must read each record of the correct file to discover its range of wavenumbers.

For users at installations without CDC equipment, the procedures for reading the coded tape are likely to be quite different. In particular, the different word sizes and character codes have to be accounted for.

EXAMPLE 6 Portions of a possible FORTRAN code for reading magnetic tape line files.

```
PROGRAM X
CHARACTER*80 B(40)
CHARACTER*35 CH(40)
CHARACTER*10 C, BRDES(2)
DIMENSION A(321), V(40), STS(40), ALF(40), EDP(40), ISO(40), MOL(40)
DATA BRDES/' 0 1 1 0 1', ' 0 0 0 0 1'/
OPEN(5)
100 FORMAT(8A10)
101 FORMAT(I10)
102 FORMAT(F10.4, E10.3, F5.3, F10.3, A35, 3X, 14, I3)
.
.
MDES = 2
IDES = 626
150 BUFFER IN (5, 0) (A(1), A(321))
IF(UNIT(5))200, 900, 900
C
C CHECK N, THE NUMBER OF LINES ON THIS RECORD
C
200 WRITE(C, 100)A(1)
READ(C, 101)N
C
C DECODE THE REST OF THE RECORD
C
M = 8*N + 1
WRITE(B, 100)(A(I), I=2, M)
READ(B, 102)(V(I), STS(I), ALF(I), EDP(I), CH(I), ISO(I), MOL(I), I=1, N)
C
C CHECK FOR THE DESIRED MOLECULE (MDES), ISOTOPE (IDES) AND
C BRANCH (BRDES)
C
DO 300 I = 1, N
IF(MOL(I).NE.MDES)GO TO 300
IF(ISO(I).NE.IDES)GO TO 300
IF(BRDES(1).NE.CH(I) (3:12))GO TO 300
IF(BRDES(2).NE.CH(I) (18:27))GO TO 300
C
C STORE THE DATA FOR THIS LINE
C
.
.
300 CONTINUE
GO TO 150
.
.
C ERROR BRANCHES
C
900 CONTINUE
.
.
.
```

References

1. McClatchey, R. A., Benedict, W. S., Clough, S. A., Burch, D. E., Calfee, R. F., Fox, K., Rothman, L. S., and Garing, J. S. (1973) AFCRL Atmospheric Absorption Line Parameters Compilation, AFCRL-TR-73-0096, AD762904.
2. Rothman, L. S. (1981) AFGL Atmospheric Absorption Line Parameters Compilation: 1980 Version, AFGL-TR-81-0112, AD A098387 also Appl. Opt., 20:791-795. Rothman, L. S., Gamache, R. R., Barbe, A., Goldman, A., Gillis, J. R. Brown, L. R., Toth, R. A., Flaud, J. M., and Camy-Peyret, C. AFGL atmospheric absorption line parameters compilation: 1982 edition, to be submitted to Applied Optics.
3. Rothman, L. S., Goldman, A., Gillis, J. R., Tipping, R. H., Brown, L. R., Margolis, J. S., Maki, A. G., and Young, L. D. G. (1981) AFGL Trace Gas Compilation: 1980 Version, AFGL-TR-81-0159, AD A100357, also Appl. Opt. 20:1323-1328. Rothman, L. S., Goldman, A., Gillis, J. R., Gamache, R. R., Pickett, H. M., Poynter, R. L., Husson, N., and Chedin, A. AFGL trace gas compilation: 1982 version, submitted to Applied Optics.
4. Park, J. H., Rothman, L. S., Ringland, C. P., Smith, M. A. H., Richardson, D. J., and Larsen, J. C. (1981) Atlas of Absorption Lines From 0 to 17900 cm⁻¹, NASA RP-1084, National Aeronautics and Space Administration, Scientific and Technical Information Branch.
5. Penner, S. S. (1959) Quantitative Molecular Spectroscopy and Gas Emissivities, Addison-Wesley, Reading, Massachusetts.
6. Clough, S. A., Kneizys, F. X., Rothman, L. S., and Gallery, W. O. (1981) Atmospheric Spectral Transmittance and Radiance: FASCOD1B, AFGL-TR-81-0269, AD A104832; also SPIE 277 (Atmos Transmission) 152-166.

Appendix A

Program Listings

```

1 PROGRAM ALTE
2 REAL NVZ
3 INTEGER TANIN, TANF, A, RGL, HTS, DEGV, FLAG
4 CHARACTER*1 GR, BRNCH(546), BCH
5 CHARACTER*5 XX(3), PCL
6 CHARACTER*10 USE, LST, US, LS, MSC(4)
7 DIMENSION NVZ(101, 4), DVV(101)
8 DIMENSION TRTMP(250), WETMP(250), RHO(250), CRAT(250), ALCCR(250)
9 DIMENSION ZZ(250, 4), GBB(250), S(250), CWID(250), VGT(250)
10 DIMENSION JT(546), SQL(546)
11 DIMENSION V(546), STS(546), ALF(546), EDP(546)
12 DIMENSION RAD(4), SUMRAD(4), HTS(4), THINR(4), FLAG(4)
13
14 C
15 OPEN(1, FILE='INPUT')
16 OPEN(2)
17 OPEN(3)
18 OPEN(4, FILE='OUTPUT')
19 C
20 1 FORMAT(//)
21 2 FORMAT(1X)
22 C
23 C *****
24 C DEFINE ALL CONSTANTS AND INITIAL VALUES
25 C EARTH = EARTH'S RADIUS (KM)
26 C TS = STANDARD LINE STRENGTH TEMPERATURE (K) FOR AFGL TAPE
27 C BOLTZ = BOLTZMAN'S CONSTANT (ERGS/DEG)
28 C BK = BOLTZMAN'S FACTOR (CM-1/DEG). THIS FACTOR IS NEEDED IN
29 C EXPRESSIONS LIKE EXP(-H*CV/(BOLTZ*B)) WHERE V IS IN CM-1
30 C AND T IS SOME TEMPERATURE. LATER THE TEMPERATURE PROFILES
31 C ARE PREMULTIPLIED BY BK TO SAVE SOME OPERATIONS.
32 C BST = BOLTZ*TS/(H*CM)
33 C C = SPEED OF LIGHT (CM/SEC)
34 C H = PLANCK'S CONSTANT (ERG-SEC). AFTER ITS INITIAL USE, MULTIPLY BY
35 C 10**7 TO GET MKS UNITS, WHICH GIVES THE EVENTUAL RADIANCES IN
36 C TERMS OF WATTS RATHER THAN ERGS/SEC.
37 C
38 A2 = SQRT(ALOG(2.0))
39 EARTH = 6361.
40 TS = 296.0
41 BOLTZ = 1.381E-16
42 C = 2.9979E+10
43 H = 6.626E-27
44 BK = BOLTZ/(H*CM)
45 BST = TS*BK
46 H = H*1.0E-07
47 NLVR = 50
48 XX(1) = '(ALL)'
49 XX(2) = ' '
50 XX(3) = ' '
51 C
52 C *****
53 C
54 C READ IN MODELLING DATA FROM CARDS---UNIT 1
55 C
56 C CARD 1A SPECIES CARD---LIST-DIRECTED READ, NO BLANK DEFAULTS
57 C PCL = RADIATING MOLECULE (INPUT AS 'CO2', ETC.

```

```

58 C INCLUDING CLOVES)
59 C ISO = ISOTOPE CCCE
60 C VIRE = VIBRATIONAL ENERGY (CM-1) OF THE RADIATIVE
61 C TRANSITION
62 C VIBL = VIBRATIONAL ENERGY (CM-1) OF THE LOWER STATE
63 C VIBQ = VIBRATIONAL QUANTUM (CM-1) WHICH ENTERS
64 C THE EXPRESSION FOR THE PARTITION FUNCTION
65 C
66 C CARD 16 SPECIES CARD
67 C BR = BRANCH (E, D, OR R)
68 C NRQL = ROTATIONAL QUANTUM LINE
69 C NST = THE UPPER STATE INDICES (AFGL LINE FILE NOTATION)
70 C LST = THE LOWER STATE INDICES (AFGL LINE FILE NOTATION)
71 C NDP = LINEShape OPTION 0 (DEFAULT) = VCIGT, 1 = DOPPLER
72 C VMIN = LOWER LIMIT ON THE WAVENUMBER OF THE DESIRED LINES
73 C VMAX = UPPER LIMIT ON THE WAVENUMBER OF THE DESIRED LINES
74 C
75 C WHEN BR = A, ALL P, Q, AND R BRANCHES ARE EVALUATED
76 C WHEN NRQL = 999 ALL QUANTUM LINES ARE EVALUATED
77 C
78 C DEFAULT ON VMIN IS ZERO; THAT IS, THE LOWEST-WAVENUMBER LINES ON
79 C THE FILE ARE EVALUATED. DEFAULT ON VMAX IS A NUMBER GREATER THAN
80 C ANY CONCEIVABLE WAVENUMBER ON A LINE FILE, 50000 CM-1.
81 C
82 C INDIVIDUAL LINES CAN BE SELECTED BY SETTING BR TO P, Q, OR R
83 C AND NRQL TO THE DESIRED LINE NUMBER.
84 C
85 C CARD 10 TANGENT HEIGHT CARD---UNIT 1---LIST-EXPECTED READ, NO DEFAULTS
86 C TANIN = INITIAL TANGENT HEIGHT (MM)
87 C TANE = FINAL TANGENT HEIGHT (MM)
88 C INTRVL = EXAMINATION INTERVAL (MM)
89 C
90 C*****1A
91 C*****
92 READ (1,*) MCL,ISO,VIRE,VIBL,VIBQ
93 WRITE (4,11) MCL,ISO,VIRE,VIBL,VIBQ
94 11 FORMAT(1H1,4X,'MOL = ',A3,/,5X,'ISO = ISOTOPE CCCE = ',I4,/,5X,
95 1'VIRE = VIBRATIONAL ENERGY (CM-1) OF THE TRANSITION = ',F9.3,/,
96 25X,'VIBL = VIBRATIONAL ENERGY (CM-1) OF THE LOWER STATE = ',F9.3,/,
97 3/,5X,'VIBQ = VIBRATIONAL QUANTUM (CM-1) (FOR PARTITION FUNCTION) = ',
98 4' ',F9.3)
99 WRITE (4,2)
100 C
101 C CALL MOLEC TO ESTABLISH THE MOLECULAR WEIGHT AND OTHER PARAMETERS
102 C ASSOCIATED WITH THE RADIATING MOLECULE
103 C
104 C CALL MOLEC (MOL,ISO,POLWT,DEGV,FRCT,TEXP)
105 C
106 WRITE (4,12) POLWT,DEGV,PROT,TEXP
107 12 FORMAT(5X,'MOLWT = ',I3,/,5X,
108 1'DEGV = ',I3,/,5X,
109 2'FRCT = ',F4.1,/,5X,
110 3'TEXP = ',F4.2)
111 C
112 WGT = FLCAT (MOLWT) / 6.02486E+23
113 C
114 NDP = 0

```

```

115          VMIN = 0.C
116          VMAX = 5.CE+04
117          C*****1B
118          C*****
119          READ(1,*) BR,NRQL,LST,LST,NDF,VMIN,VMAX
120          WRITE(4,1)
121          IF(BR.EQ.'A')XX(2) = XX(1)
122          IF(NRQL.EQ.999)XX(2) = XX(1)
123          I = INT(VMIN)
124          N = INT(VMAX)
125          MSG(1) = 'VCIGY'
126          IF(NDF.EQ.1)MSG(1) = 'COPPLER'
127          WRITE(4,2)I,N,MOL,ISO,UJT,LST,BR,XX(2),NRQL,XX(2),MSG(1)
128          21 FORMAT(5X,'PROGRAM WILL SEARCH THE LINE FILE BETWEEN',I5,' AND',
129             1I6,' CM-1 FOR LINES OF ',A3,'/5X,
130             2'ISCTOPE =',I4,'/5X,
131             3'BAND =',I1X,A5,' - ',I1X,A5,'/5X,
132             4'BRANCH =',I1X,A1,I1X,A5,'/5X,
133             5'LINE # =',I2,I1X,A5,'/5X,
134             6A6,'= LINESHAPE OPTION SELECTED')
135          WRITE(4,1)
136          C
137          C*****1C
138          C*****
139          READ(1,*) TANIN,TANF,INTRVL
140          WRITE(4,61) TANIN,TANF,INTRVL
141          61 FORMAT(5X,'INITIAL TANGENT HEIGHT (KMS) =',I5,'/5X,
142             5'FINAL TANGENT HEIGHT (KMS) =',I5,'/5X,
143             5'EXAMINATION INTERVAL (KMS) =',I5)
144          WRITE(4,1)
145          C
146          C *****
147          C
148          C CARD 2 ATMOSPHERE CARDS---UNIT 2
149          C
150          C THE FIRST CARD IS AN 81-CHARACTER IDENTIFYING MESSAGE WHICH IS
151          C SIMPLY READ AND PRINTED. SUCCESSIVE CARDS EACH CONTAIN, IN FOR-
152          C MATS GIVEN BELOW:
153          C
154          C          A          = ALTITUDE (KMS) LINEAR VARIABLE) I5
155          C          TRTMP(A) = TRANSLATIONAL TEMPERATURE (K) F10.3
156          C          ALQOP(A) = ATMOSPHERIC PRESSURE (ATMOSPHERES) F12.5
157          C          RHO(A) = DENSITY OF RADIATING MOLECULE (CM-3) E12.5
158          C          VETMP(A) = VIBRATIONAL TEMPERATURE (K) F10.3
159          C
160          C*****2
161          C*****
162          READ(2,62)MSG
163          WRITE(4,64)MSG
164          WRITE(4,62)MOL
165          62 FORMAT(7X,'ALT',5X,'TR TEMP',6X,'TOT PRESS',3X,A5,
166             1'DENSITY',1/26X,'(KM)',2(7X,'(K)'),5X,'(ATMOS)',7X,'(CM-3)',/
167          63 FORMAT(8A10)
168          64 FORMAT(/,4X,'ATMOSPHERE---',A10,'',/
169          C
170          C*****2
171          C*****

```

```

172      70 READ (2,80,END=99) A,TRTMP(A),ALCOR(A),R+C(A),VBTHF(A)
173      80 FORMAT(1E,10,2,2E12,5,10,3)
174      WRITE (4,81) A,TRTMP(A),VBTHF(A),ALCOR(A),RHO(A)
175      81 FORMAT(5X,15,2X,2E10,3,2X,2E14,6)
176      GC TO 70
177      C
178      C THE ARRAY RHO IS CONVERTED TO THE GEOMETRIC MEAN DENSITY IN THE
179      C LAYER WHOSE BOUNDARIES ARE A AND A + 1 AND STORED WITH INDEX A.
180      C
181      C THE ARRAYS TRTMP AND VBTHF ARE CONVERTED TO AVERAGE TEMPERATURES IN
182      C THE LAYER WHOSE BOUNDARIES ARE A AND A + 1. THESE AVERAGE TEMPERATURES
183      C ARE ALSO MULTIPLIED BY BK (SEE COMMENT AT BEGINNING). THIS FACTOR
184      C APPEARS EVERY TIME THE TEMPERATURES ARE USED) AND STORED IN THE
185      C SAME ARRAYS. AS WITH RHO(A), THE INDEX FOR THE LAYER WHOSE BOUNDARIES
186      C ARE A AND A+1 KM ABOVE THE EARTH'S SURFACE IS A.
187      C
188      C THE PROGRAM ASSUMES THE LAYERING OF THE ATMOSPHERE IS IN 1 KM STRATA.
189      C
190      C QVAT IS AN ARRAY STORING THE PRODUCT OF TWO RATIOS:
191      C THE VIBRATIONAL PARTITION FUNCTION AT IS (296 K) (QV) TO
192      C THE VIBRATIONAL PARTITION FUNCTION AT VBTHF (Z1)
193      C AND
194      C THE ROTATIONAL PARTITION FUNCTION AT IS (296 K) TO
195      C THE ROTATIONAL PARTITION FUNCTION AT TRTMP
196      C THE LATTER RATIO IS JUST A POWER OF THE RATIO OF TEMPERATURES,
197      C QV/TRTMP, WHERE TRTMP IS THE ACTUAL TRANSLATIONAL TEMPERATURE.
198      C
199      C ALCOR(A) IS READ IN AS THE TOTAL PRESSURE. AT STATEMENT 95 IT
200      C BECOMES AN ARRAY STORING THE FACTOR BY WHICH THE LORENTZ LINEWIDTH
201      C PARAMETER (GIVEN ON THE LINE FILE AT IS AND 1 ATMOSPHERE) IS MULTI-
202      C PLIED TO CORRECT FOR PRESSURE AND TEMPERATURE AT VARIOUS ALTITUDES.
203      C
204      C 90 QV = 1.0 / (1.2 - EXF1 - VIBQ/BST)) ** DEGV
205      C I = A - 1
206      C Y = 1.0 - TEXP
207      C DC 95 A = YANIM, I
208      C R+C(A) = SCRT(RHO(A)*RHO(A+1))
209      C TRTMP(A) = 0.5*(TRTMP(A) + TRTMP(A+1))*BK
210      C VBTHF(A) = 0.5*(VBTHF(A) + VBTHF(A+1))*BK
211      C Z1 = 1.0 / (1.2 - EXP(-VIBQ/(VBTHF(A)))) ** DEGV
212      C QVAT(A) = (QV/Z1)*(BST/TRTMP(A)) ** PROT
213      C 95 ALCOR(A) = ALCOR(A)*(BST/TRTMP(A)) ** Y
214      C WRITE(4,1)
215      C *****
216      C
217      C CARD 3 AFGL LINE FILE CARDS---UNIT 3
218      C
219      C THIS SECTION READ THE AFGL LINE FILE AND
220      C SELECTS LINES OF INTEREST BASED ON TRANSITION STATES (LST,LST),
221      C BRANCH (BR) AND LINE (NL) PARAMETERS SET IN CARD 18. MOST OF
222      C THE VARIABLES READ IN (VINIT, Z1, Z2...) ARE STORED IN ARRAYS
223      C (W, STS, ALF...) PRIOR TO STATEMENT 131. THE VARIABLES THEM-
224      C SELVES ARE LATER USED FOR MISCELLANEOUS OTHER PURPOSES.
225      C VINIT (W) = FREQUENCY OF VIBRATIONAL TRANSITION (CM-1)
226      C Z1 (STS) = LINE INTENSITY (CM-1/MOLECULE-CM2)
227      C Z2 (ALF) = LORENTZ HALF-WIDTH AT 296 K AND 1 ATMOSPHERE
228      C (CM-1/ATPCS)

```

```

229 C Y (EDP) = ENERGY OF THE LOWER STATE (CM-1)
230 C US, LS = UPPER AND LOWER STATE TRANSITIONS, RESPECTIVELY
231 C BCH (BRNCH) = BRANCH (P, Q, CA R)
232 C N (RCL) = ROTATIONAL QUANTUM LINE
233 C I = ISOTOPE CODE
234 C
235 WRITE(4,91) UST,LST
236 91 FORMAT(5X,'AFGL LINE FILE OF INTEREST FOR TRANSITION ',
237 1A5,' TO ',A5,/)
238 WRITE(4,92)
239 92 FORMAT(5X,'BRANCH',2X,'LINE',2X,'FREQ. ((M-1)*.2Y,
240 1'LINE STRENGTH',2X,'LINE WIDTH',3X,'LOWER STATE ENERGY',/)
241 C
242 C JMAX COUNTS THE TOTAL NUMBER OF LINES TO BE EXAMINED
243 C
244 JMAX = 0
245 C*****
246 C*****
247 100 READ(3,110,END=115)VINIT,Z1,Z2,Y,US,LS,BCH,N,I
248 110 FORMAT(F10.5,E10.3,F5.3,F10.3,3X,A5,3X,A5,14X,*,1,12,4X,I4)
249 C
250 C PROGRAM EXAMINES AND RETURNS CORRECT TRANSITION STATE, LINE(S),
251 C AND BRANCH(ES) FOR THE GIVEN ISOTOPE. IF THE DOPPLER OPTIC
252 C (NCP = 1) IS SELECTED, THE LORENTZ LINEWIDTHS ARE SET TO ZERO.
253 C
254 IF(VINIT.LT.VMIN)GC TO 100
255 IF(VINIT.GT.VMAX)GC TO 110
256 IF(ISC.NE.1) GO TO 100
257 IF(UST.NE.LS) GO TO 100
258 IF(LST.NE.LS) GO TO 100
259 IF(BR.NE.'*' AND BR.NE.BCH) GC TO 100
260 IF(NRQL.NE.N AND NRQL.NE.999)GC TO 100
261 C
262 JMAX = JMAX + 1
263 V(JMAX) = VINIT
264 SYS(JMAX) = Z1
265 ALF(JMAX) = Z2
266 IF(NDF.EQ.1)ALF(JMAX) = 0.0.
267 EDP(JMAX) = Y
268 BRNCH(JMAX) = BCH
269 RCL(JMAX) = N
270 WRITE(4,131) BCH,N,VINIT,Z1,Z2,Y
271 131 FORMAT(7X,A1,5X,I3,4X,F10.5,4X,E10.3,6X,F5.3,7Y,F10.3)
272 C
273 GC TO 100
274 135 IF(JMAX.EQ.0)GC TO 990
275 WRITE(4,1)
276 C
277 C AT THIS POINT THE DATA HAVE ALL BEEN READ IN AND STORED IN THE
278 C APPROPRIATE AREAYS. NOW DO SOME FURTHER INITIALIZATION AND THEN
279 C PROCEED WITH THE LCOPS WHICH PERFORM THE ACTUAL CALCULATIONS.
280 C
281 C *****
282 C
283 C PRESET THE LINESHAP ORDINATE. DVM IS THE "DISTANCE" IN CM-1
284 C FROM THE CENTER OF THE LINE IN QUESTION.
285 C

```

```

286      DC 138 L = 1,101
287      138 DMV(I) = FLCAT(I-1)*1.CE-04
288      C
289      C PRESET THE OPTICALLY THIN TEST ARRAY TO ZERO.
290      C
291      DC 139 J = 1, JMAX
292      139 JT(J) = 0
293      C
294      C THE TOTAL NUMBER OF DIFFERENT LINE-OF-SIGHT PATHS TO BE CONSIDERED IN
295      C ALL IS (TANE-TANIA)/INTRVL + 1. THESE CASES ARE DONE IN GROUPS OF
296      C FOUR (POSSIBLY LESS, IN THE CASE OF THE LAST GROUP) TO MAKE THE
297      C PRINTED OUTPUT MANAGEABLE AND TO REDUCE THE SIZE OF CERTAIN
298      C ARRAYS. THE LOOP DC 300 IS ENTERED ONCE FOR EACH GROUP. THE INTEGER
299      C ARRAY HTS STORES THE TANGENT HEIGHTS (IN KM) WHICH PARAMETERIZE EACH
300      C PATH. NREPS BECOMES THE NUMBER OF GROUPS WHICH MUST BE HANDLED. IMAX
301      C BECOMES THE NUMBER OF CASES IN THE CURRENT GROUP.
302      C
303      NREPS = (TANE-TANIA)/INTRVL + 1
304      NR = MOD(NREPS,4)
305      NREPS = NREPS/4
306      IF (NR.GT.0) NREPS = NREPS+1
307      C
308      C* *****
309      C*
310      C* LOOP TO SELECT GROUPS OF (4 OR LESS) TANGENT HEIGHTS. CALCULATE
311      C* THESE CASES SIMULTANEOUSLY. WHEN THIS LOOP ENDS, EXECUTION
312      C* TERMINATES.
313      C*
314      DC 300 NR = 1,NREPS
315      IPAX = 1
316      DC 140 I = 1,4
317      HTS(I) = TANIN + 14*(NR-1) + I - 1)*INTRVL
318      IF (HTS(I).GT.TANF) GO TO 140
319      IPAX = I
320      140 CONTINUE
321      C*
322      C* SUMRAD IS AN ARRAY THAT STORES THE SUM OF RADIANCES FROM ROTATIONAL
323      C* TRANSITIONS FOR A GIVEN TANGENT HEIGHT. PRESET THIS ARRAY TO ZERO.
324      C* ALSO CALCULATE THE ARRAY OF PATH LENGTHS Z2, FOR EACH LAYER (N)
325      C* AND EACH PATH (TANGENT HEIGHT) IN THIS GROUP. ACTUALLY, Z2 IS THE PRODUCT
326      C* OF THE TOTAL NUMBER DENSITY AT THE ALTITUDE IN QUESTION AND THE GEO-
327      C* METRICAL PATH LENGTH IN THE SLAB. THE FACTOR 10**5 CONVERTS
328      C* KM TO CM.
329      C*
330      DC 145 I = 1, IPAX
331      SUMRAD(I) = 0.0
332      DC 145 N = 1, NLYR
333      A = NLYR * HTS(I) - N
334      Z1 = SQRT(FLOAT(A - HTS(I))*(2.0*EARTH + FLOAT(A + HTS(I))))
335      Z2 = SQRT(FLOAT(A + HTS(I)+1)*(2.0*EARTH + FLCAT(A+HTS(I)+1)))
336      145 Z2(A,I) = AHO(A)*(Z2 - Z1)*1.CE+05
337      IF (IMAX.GT.1) WRITE (4,140) (HTS(I),HTS(I),I=1,IPAX)
338      WRITE (4,2)
339      140 FORMAT (//,5X,'RADIANCE (WATT/CM**2*STR) AT VARIOUS TANGENT HEIGHTS',
340      1//,5X,'LINE',3X,4(I3,' KM (THIN)',I5,' KM',5X))
341      C*
342      C* *****

```

```

343 C**
344 C** LOOP TO PERFORM CALCULATIONS ON ALL SELECTED ROTATIONAL LINES.
345 C** DC CORRECTS FOR THE STIMULATED EMISSION AT TS (296 K).
346 C** THE DOPPLER LINEWIDTH IS
347 C**  $ALFD = \sqrt{2 * ALOG(2) * ECLTZ * TRTMP / (MCLWT * C * C)} * VINIT$ 
348 C** WHERE TRTMP IS THE ACTUAL TRANSLATIONAL TEMPERATURE.
349 C**
350 C** DC 200 J = 1, JMAX
351 C**  $VINIT = V(J)$ 
352 C**  $QG = 1.0 - EXP(-VINIT / BST)$ 
353 C**  $DCPP = A2 * \sqrt{2.0 * ROLTZ / (BK * GT * C * C)} * VINIT$ 
354 C *
355 C * *****
356 C *
357 C * * THE LOOP DC 150 CALCULATES PATH-INDEPENDENT QUANTITIES WHICH
358 C * * DEPEND ONLY ON ALTITUDE. ALTITUDES RUN FROM THE LOWEST REQUIRED FOR
359 C * * THE FIRST (LOWEST) LINE-OF-SIGHT PATH TO THE HIGHEST REQUIRED FOR THE
360 C * * LAST ONE IN THE CURRENT GRCLP. NMAX IS THE NUMBER OF SUCH REQUIRED
361 C * * ALTITUDES.
362 C * *
363 C * * STS(J) GIVES THE LINE STRENGTH UNDER CONDITIONS OF LTE AT TEMPERATURE
364 C * * TS, WHICH WE REFER TO AS "STANDARD CONDITIONS". THE QUANTITY
365 C * *  $QRAT * EXP(Z1)$  GIVES THE RATIO OF THE PROBABILITY OF FINDING THE
366 C * * MOLECULE IN THE LOWER RADIATING STATE AT ALTITUDE A (WHERE VIBL
367 C * * AND TRTMP CHARACTERIZE THE DISTRIBUTION OF POPULATED STATES) TO THE
368 C * * PROBABILITY OF FINDING IT IN THE LOWER STATE UNDER STANDARD CONDITIONS.
369 C * * THE RATIO  $(1 - GAM) / QG$  CORRECTS FOR STIMULATED EMISSION AT ALTITUDE
370 C * * A AND FOR STANDARD CONDITIONS. THE PRODUCT OF THESE THREE FACTORS
371 C * * GIVES THE LINE STRENGTH AT ALTITUDE A, S(A).  $S(A) * F(A)$  GIVES
372 C * * THE CONVENTIONAL ABSORPTION COEFFICIENT AT FREQUENCY A.
373 C * *
374 C * *  $NMAX = HTS(IMAX) - HTS(1) + NLYR$ 
375 C * * DC 150 N = 1, NMAX
376 C * *  $A = HTS(1) + N - 1$ 
377 C * *  $GAM = EXP(-(VINIT - VIBE) / TRTMP(A)) * EXP(-VIBE / VBTMP(A))$ 
378 C * *  $GRB(A) = (GAM / (1.0 - GAM)) * 2.0 * C * VINIT ** 2$ 
379 C * *  $Z1 = EDP(J) / BST - (EDP(J) - VIBL) / TRTMP(A) - VIBL / VBTMP(A)$ 
380 C * *  $S(A) = STS(J) * QRAT(A) * (1.0 - GAM) * EXP(Z1) / QG$ 
381 C * * 150 ONID(A) = [DCPP * SQRT(TRTMP(A))]
382 C * * IF (JI(J), GE, 1) GO TO 180
383 C * *
384 C * * *****
385 C * *
386 C * *
387 C * * THE LOOP DC 170 L = 101, 1, -1 VARIES THE FREQUENCY BETWEEN THE CENTER
388 C * * OF THE LINE AND THE WINGS. THE INTEGRATION OVER THE LINE-OF-SIGHT
389 C * * PATH (THE Z-INTEGRATION) IS THEREFORE COMPLETELY CARRIED OUT FOR ONE
390 C * * FREQUENCY FOR EACH TANGENT HEIGHT IN THE CURRENT GRCLP BEFORE THE
391 C * * NEXT FREQUENCY IS CONSIDERED.
392 C * *
393 C * * FOR SOME LINES, THERE MAY BE FREQUENCIES NEAR THE CENTER OF THE LINE
394 C * * WHERE THE LINE IS VERY THICK---THAT IS, FREQUENCIES FOR WHICH ALL
395 C * * RADIATION FROM SLAB (N-1) IS COMPLETELY ABSORBED IN SLAB (N), SO
396 C * * THAT AT THE END OF SLAB (N) THE RADIANCE IS ENTIRELY FROM THAT SLAB.
397 C * * FOR SUCH CASES, THE INTEGRATION THROUGH THE FIRST HALF OF THE LINE-
398 C * * OF-SIGHT PATH IS UNNECESSARY. BY SELECTING FREQUENCIES IN "BACKWARDS"
399 C * * ORDER---STARTING IN THE WING, WITH L = 101---WE CAN FLAG THE FRE-

```



```

400 C ** QUENCIES NEAR THE LINE CENTER FOR WHICH THIS EXTRA CORP CAN BE
401 C ** AVOIDED.
402 C **
403 DC 155 I = 1, I
404 155 FLAG(I) = 0
405 DC 170 I = 1, I, I
406 C **
407 C ** THE LOOP DO 160 CALCULATES, FOR ALL ALTITUDES REQUIRED, THE VALUES
408 C ** OF THE VCIGY PROFILE AT THE "DISTANCE" FROM THE CENTER OF THE LINE
409 C ** INDEXED BY THE CURRENT VALUE OF L--THAT IS, DIVIDED BY I FROM THE
410 C ** CENTER.
411 C **
412 DC 160 N = 1, NPAX
413 A = HYS(I) + N - 1
414 ALFO = D*IF(A)
415 Y = DVV(L)/ALFO
416 RAT = A2*(ALF(J)*ALCOR(A))/ALFO
417 160 VGT(A) = WBERF(Y, RAT)/ALFO
418 C **
419 C ** *****
420 C ***
421 C *** THE LOOP DO 170 I = 1, IPAX VARIES THE TANGENT HEIGHTS. THE PROFILE ARRAY,
422 C *** NVZ, IS ALSO INITIALIZED, AND THE FLAG IS CHECKED AND POSSIBLY RESET.
423 C ***
424 DC 170 I = 1, IPAX
425 NVZ(I, I) = 0.0
426 IF(FLAG(I).EQ.1)GO TO 169
427 A = HYS(I)
428 Z1 = S(A)*ZZ(A, I)*VGT(A)
429 IF(Z1.GE.35.)FLAG(I) = 1
430 C ***
431 C *** START THE Z-INTEGRATION ALONG THE LINE-OF-SIGHT AT THE FAR
432 C *** HORIZON. THE LOOP DO 165 CARRIES THE CALCULATION TO THE TANGENT
433 C *** HEIGHT POINT. IN THIS LOOP, AND IN THE NEXT ONE, Z1 BECOMES THE
434 C *** OPTICAL DEPTH OF THE CURRENT SLAB AT THE FREQUENCY IN QUESTION.
435 C ***
436 DC 165 N = 1, NLVR
437 A = NLVR + HYS(I) - N
438 Z1 = S(A)*ZZ(A, I)*VGT(A)
439 Z2 = 0.0
440 IF(Z1.LT.35.)Z2 = EXP(-Z1)
441 NVZ(I, I) = NVZ(I, I)*Z2 + (1.0 - Z2)*GBR(A)
442 C ***
443 C *** COMPLETE THE Z-INTEGRATION BY CARRYING IT FROM THE TANGENT HEIGHT
444 C *** POINT THROUGH NLVR SLABS TO THE OBSERVATION POINT.
445 C ***
446 DC 170 A = 1, NLVR
447 A = HYS(I) + N - 1
448 Z1 = S(A)*ZZ(A, I)*VGT(A)
449 Z2 = 0.0
450 IF(Z1.LT.35.)Z2 = EXP(-Z1)
451 170 NVZ(I, I) = NVZ(I, I)*Z2 + (1.0 - Z2)*GBR(A)
452 C ***
453 C *** END THE LOOP (INDEX I) THAT VARIES THE FREQUENCY. THE LINE PROFILE, NVZ,
454 C *** HAS BEEN FOUND AS A FUNCTION OF FREQUENCY (INDEXED BY L) FOR EACH TAN-
455 C *** GENT HEIGHT (INDEXED BY I) IN THE CURRENT GROUP.
456 C ***

```

```

457 C * .....
458 C * .....
459 C * .....
460 C * *
461 C * * THE LOOP DC 190 RJNS THROUGH THE TANGENT HEIGHTS IN THE CURRENT GROUP.
462 C * * INTEGRATE OVER THE OPTICAL LINE, USING SIMPSON'S RULE WITH 50 PANELS
463 C * * Z2 IS THE SUM OF OF EVEN TERMS (THE ENDS OF EACH PANEL); Z1, OF ODD TERMS
464 C * * THE RESULT, RAD(I), HAS UNITS OF MATZ/CM2*STR
465 C * *
466 DC 190 I = 1, IPAX
467 THINR(I) = 0.0
468 DC 105 N = 1, NLYR
469 A = NLYR * HTS(I) - N
470 185 THINR(I) = THINR(I) + GB(A)*S(A)*ZZ(A, I)
471 THINR(I) = 2.0*THINR(I)*H*C*VINIT
472 RAD(I) = THINR(I)
473 IF(JT(J).GE.1)GO TO 190
474 Z2 = 0.0
475 Z1 = 0.0
476 DC 100 L = 2, 99, 2
477 Z2 = Z2 + NVZ(L, I)
478 Z1 = Z1 + NVZ(L+1, I)
479 188 CCNTINUE
480 Z2 = Z2 + NVZ(100, I)
481 RAD(I) = (NVZ(1, I) + 4.0*Z2 + 2.0*Z1 + NVZ(101, I))/3.0
482 RAD(I) = RAD(I)*2.0E-04*H*C*VINIT
483 IF((AES(THINR(I)-RAD(I))).LT.(RAD(I)*.05)) JT(J) = I
484 190 SUMRAD(I) = SUMRAD(I) + RAD(I)
485 C * *
486 C * * END THE LAST LOOP (INDEX I) THAT VARIES THE TANGENT HEIGHT
487 C * *
488 C * * .....
489 C * *
490 C * * IF ONLY ONE LINE IS CALCULATED, PRINT OUT THE LINESHAPE
491 C * *
492 N = JT(J)
493 IF(N.EQ.0)N = IMAX
494 IF(JMAX.AE.1)GO TO 195
495 IF(N.EQ.5)GO TO 194
496 WRITE(4,191)BR,NRQL,(HTS(I),I=1,IMAX)
497 191 FORMAT(///, ' RADIANCE (PHOTONS/CM2*STR*SEC*CM-1) FOR LINE ',
498 'A1, I3, ' VS FREQUENCY (CM-1) AT VARIOUS TANGENT HEIGHTS', //
499 '27X, 'FREQ', 2X, 4(2X, I9, ' KM')')
500 192 FORMAT(F13.4, 2X, 4E14.5)
501 WRITE(4, 2)
502 DO 193 L = 1, 101
503 IF(NVZ(L, N).EQ.0.0)GO TO 194
504 Z1 = VINIT + TVV(L)
505 193 WRITE(4, 192)Z1, (NVZ(L, I), I=1, N)
506 194 WRITE(4, 1)
507 WRITE(4, 140)(HTS(I), HTS(I), I=1, IMAX)
508 WRITE(4, 2)
509 C *
510 C * * PRINT OUT THE RADIANCES
511 C * *
512 195 WRITE(4, 196)BRNCH(J), RGL(J), (THINR(I), I=1, IMAX)
513 IF(N.LT.5)WRITE(4, 197) (RAD(I), I=1, N)

```

```

514          196 FORMAT(5X,A1,I4,4(2X,E12.5,12X))
515          197 FORMAT(1H4,9X,A(14X,E12.5))
516          IF(JT(J).GT.0)JT(J) = 5
517          C**
518          200 CCNTINUE
519          C**
520          C** END THE LCCP (INDEX J) THAT CHOOSES DIFFERENT LINES
521          C**
522          C* *****
523          C*
524          WRITE(4,1)
525          IF(JMAX.GT.1)WRITE(4,201)JMAX,(SLHEAD(I),I=1,IPAX)
526          201 FORMAT(' TOTAL FCR',I4,' LINES =',4(E12.5,14X))
527          WRITE(4,1)
528          300 CCNTINUE
529          C*
530          C* END THE LCCP (INDEX NR) SELECTING DIFFERENT GROUPS OF LINE-OF-SIGHT PAIRS
531          C**
532          C* *****
533          C*
534          998 IF(JMAX.EQ.0)WRITE(4,990)
535          990 FORMAT(///,' ***** NO LINES FOUND *****',///)
536          CLOSE (UNIT=1)
537          CLOSE (UNIT=2)
538          CLOSE (UNIT=3)
539          CLOSE (UNIT=4)
540          END

```

```

1      FUNCTION VWERF (XX,A)
2
3      C      THE METHOD IS DUE TO RYBICKI. THE FORTRAN LISTING WAS
4      C      PUBLISHED AS AN APPENDIX TO E. M. AVRETT AND R. L. GEESE,
5      C      "FORMATION OF LINE AND CONTINUOUS SPECTRA," SPECIAL REPORT 303,
6      C      SMITHSONIAN ASTROPHYSICAL OBSERVATORY, CAMBRIDGE, MASS. (1970)
7
8      C      THE METHOD OF CALCULATION IS DESCRIBED BY B. H. AMSTRONG,
9      C      AND R. W. NICHOLS, "EMISSION, ABSORPTION AND TRANSFER OF
10     C      RADIATION IN HEATED ATMOSPHERES," PERGAMON PRESS, NEW YORK,
11     C      (1972) - PP. 225-237.
12     C      COMPLEX Z
13     DIMENSION C(121)
14     DATA NTRY,NMAX,PI,C2,Q2 /1,15,3.141592653589793,
15     1 5.6418952354776E-01,0.979356102563E-02/
16     IF (NTRY .EQ. 1) GO TO 170
17     110 CONTINUE
18     X = RTLN2*XX
19     IF (A .EQ. 0.0) GO TO 160
20     IF ((X + A) .GT. 25.0) GO TO 190
21     C      NO COMPUTATION FOR GENERAL CASE
22     A1 = RH*A
23     A2 = A*A
24     IF (A .LT. 0.1) GO TO 120
25     Z = CEXP(CMPLX(-Q1*A,C1*X))
26     VWERF = 0.0
27     GO TO 130
28     120 CONTINUE
29     Z = CGCS(CMPLX(Q1*X,Q1*A))
30     VWERF = C2*XF(A2 - X*X)*COS(2.*(A*X)
31     130 CONTINUE
32     E1 = (1.0 - REAL(Z))*A*0.5*RH
33     E2 = -AIMAG(Z)
34     S = -0.5*(FLCAT(EF1) + RH*X)
35     T = S*S + 0.25*RH*SQ*A2
36     DO 150 N = 1, NPN1
37     T = T + S + 0.25
38     S = S + 0.5
39     B1 = A1 - B1
40     B2 = -B2
41     IF (T .GT. 2.6E-12) GO TO 140
42     VWERF = VWERF - C(N)*A/RH
43     GO TO 150
44     140 CONTINUE
45     VWERF = VWERF + C(N)*(B2*S + B1)/T
46     150 CONTINUE
47     155 CONTINUE
48     VWERF = VWERF*RTLN2
49     RETURN
50     160 CONTINUE
51     VWERF = RTLN2*Q2*EXP(-X*X)
52     RETURN
53     170 CONTINUE
54     NTRY = C
55     NPN1 = NMAX + 1
56     NPN1 = NPN1 + NP1
57     RHSQ = R1*RH

```

```

58      K = -NP1
59      DC 18, N = 1, NP1
60      K = K + 1
61      CINI = C3*EXP(-FLCAT(K*K)/R+SC)
62      18C CONTINUE
63      C1 = RM*E1
64      RVLNC = SORT(ALOG(2.))
65      GO TO 11C
66      19C CONTINUE
67      C
68      C USE ASYMPTOTIC EXPANSION FOR COMPLEX ERROR FUNCTION
69      C FOR LARGE X AND A
70      C
71      AN = 2.5
72      CENP = A
73      ENI = -1
74      DC 20, I = 1, 5
75      DEN = AN/(CENP*ENR + CENI*ENI)
76      CENP = CENP*ENR + A
77      CENI = -CENI*ENI - X
78      AN = AN - 0.5
79      20C CONTINUE
80      DEN = 02/(CENP*ENR + CENI*ENI)
81      VWERF = RVLN2*02*CENP*ENR
82      RETURN
83      END

```

```

1  SUBROUTINE MOLEC(MCL,ISO,MCLWT,DEGV,PROT,TEXP)
2
3  C
4  C THIS SUBROUTINE, GIVEN THE MOLECULE CODE (MCL) AND THE ISOTOPE CODE
5  C (ISO), RETURNS PARAMETERS WHICH ARE UNIQUELY ASSOCIATED WITH THE
6  C MOLECULE IN QUESTION: MCLWT, THE MOLECULAR WEIGHT
7  C DEGV, THE DEGENERACY OF THE VIBRATIONAL MANIFOLD
8  C PROT, THE EXPONENT OF TEMPERATURE IN THE
9  C VIBRATIONAL PARTITION FUNCTION
10 C TEXP, THE EXPONENT OF TEMPERATURE IN
11 C THE LOGRENZ-LINNETT CORRECTION
12 C
13 C FOR CH4 THE CORRECT PARTITION FUNCTION RESULTS (TO WITHIN
14 C 1% UP TO 400 K) IF A SINGLE LEVEL AT 1370 CM-1 WITH A DE-
15 C GENERACY OF 5 IS CHOSEN.
16 C
17 C DEGV IS 2 FOR LINEAR TRIATOMIC MOLECULES, 1 OTHERWISE (XC CH4)
18 C PROT IS 1 FOR ALL LINEAR MOLECULES, 1.5 OTHERWISE
19 C TEXP IS .25 FOR CO2, .5 OTHERWISE
20 C
21 C INTEGER DEGV
22 C CHARACTER*8 MOLCOD(7),POL
23 C DIMENSION POLMWT(2),MOLISO(2)
24 C DATA (MOLCOD(I),I=1,7)/'H2O','CO2','O3 ','N2O','CO ','CH4','O2 '/
25 C DATA (MOLISO(I),I=1,2)/161,676,666,446,28,211,66/
26 C DATA (MCLWT(I),I=1,7)/18,44,48,44,28,16,32/
27 C
28 MCLWT = 0
29 IC = 1
30 PROT = 1.5
31 DEGV = 1
32 TEXP = 0.5
33 DC 10, I = 1,7
34 100 IF (MOLCOD(I).EQ.MOL) IC = I
35 IF (IC.EQ.0) RETURN
36 IF (IC.EQ.1.OR.IC.EQ.3) GO TO 120
37 IF (IC.EQ.2) TEXP = .25
38 IF (IC.EQ.7) PROT = 1.0
39 IF (IC.EQ.5) DEGV = 2
40 IF (IC.EQ.7) DEGV = 5
41 120 MDIFF = ISC - MOLISO(IC)
42 IF (MDIFF) 130,140,150
43 130 ISC = MOLISO(IC)
44 140 MCLWT = MCLMGT(IC)
45 RETURN
46 C
47 150 M1 = MDIFF/100
48 M2 = (MDIFF - 100*M1)/10
49 M3 = (MDIFF - 100*M1 - 10*M2)
50 MCLWT = MCLMGT(IC) + M1 + M2 + M3
51 IF (M1.GT.2.OR.M2.GT.2.OR.M3.GT.2) MCLWT = 0
52 RETURN
53 END

```

Appendix B

Example of Program Output for a Single Line of the
01101-00001 Band of CO₂. The Voigt Lineshape
is Used. The Spectral Lineshape and the Integrated
Radiance is Calculated for Four Tangent Heights

MCL = CC2
 ISO = ISOTOPE CODE = 626
 WIRE = VIBRATIONAL ENERGY (CM-1) OF THE TRANSITION = 667.300
 WIBL = VIBRATIONAL ENERGY (CM-1) OF THE LOWER STATE = 0.000
 WIBQ = VIBRATIONAL QUANTUM (CM-1) (FOR PARTITION FUNCTION) = 667.300

MCLMT = 44
 DEGV = 2
 PROT = 1.0
 TEMP = .25

PROGRAM WILL SEARCH THE LINE FILE BETWEEN 0 AND 50000 CM-1 FOR LINES OF CO2
 ISOTOPE = 626
 BANC = 01131 - 00J01
 BRANCH = R
 LINE # = 2
 WIGT = LINESHAPE OPTION SELECTED

INITIAL TANGENT HEIGHT (KMS) = 70
 FINAL TANGENT HEIGHT (KMS) = 45
 EXAMINATION INTERVAL (KMS) = 5

ATMOSPHERE---" CO2,NIGHT, 70-150 KM; T, F = US STD76; WIE TEMP = CO2,NIGHT, 70-150 K 05/12/83 "

ALT (KM)	TR TEMP (K)	WB TEMP (K)	TOI PRESS (ATMOS)	CO2 DENSITY (CM-3)
70	219.590	211.760	.515260E-04	.542350E+12
71	216.925	208.526	.441680E-04	.470690E+12
72	214.260	205.223	.378610E-04	.408490E+12
73	212.305	201.843	.323500E-04	.352280E+12
74	210.350	198.393	.276420E-04	.303000E+12
75	208.390	194.869	.235520E-04	.261250E+12
76	206.430	191.464	.200670E-04	.224730E+12
77	204.475	188.136	.171620E-04	.192750E+12
78	202.520	184.602	.147210E-04	.165320E+12
79	200.565	181.190	.127910E-04	.141380E+12
80	198.610	177.799	.103970E-04	.123910E+12
81	196.655	174.452	.876010E-05	.103050E+12
82	194.710	171.220	.740200E-05	.879010E+11
83	192.760	168.144	.622880E-05	.747140E+11
84	190.780	165.253	.524100E-05	.635050E+11
85	188.825	162.555	.439670E-05	.538020E+11
86	186.870	160.017	.366500E-05	.458200E+11
87	184.870	155.329	.304520E-05	.381540E+11
88	182.870	150.397	.258310E-05	.319360E+11
89	180.870	157.124	.218340E-05	.267340E+11
90	186.870	156.400	.181190E-05	.223000E+11
91	187.115	156.054	.151810E-05	.187170E+11
92	187.360	155.924	.127190E-05	.156530E+11
93	187.845	156.007	.106620E-05	.130850E+11
94	188.330	156.292	.893750E-06	.109380E+11
95	188.820	156.809	.749970E-06	.915240E+10
96	189.310	157.279	.629320E-06	.765830E+10
97	190.755	157.845	.529300E-06	.638850E+10

98	192.200	158.500	.444680E-06	.532923E+10
99	193.640	159.235	.374820E-06	.445800E+10
100	195.080	160.514	.315330E-06	.372930E+10
101	197.640	161.965	.268630E-06	.311360E+10
102	200.200	163.340	.228410E-06	.259960E+10
103	202.755	164.816	.195080E-06	.218060E+10
104	205.310	166.330	.166610E-06	.182910E+10
105	205.415	166.365	.143110E-06	.153170E+10
106	213.520	170.947	.122910E-06	.128260E+10
107	216.750	173.256	.106320E-06	.107670E+10
108	223.980	175.584	.919700E-07	.903870E+09
109	231.990	177.826	.803310E-07	.703326E+09
110	240.000	180.738	.701130E-07	.547270E+09
111	252.440	194.252	.615970E-07	.427590E+09
112	264.000	187.580	.548210E-07	.334090E+09
113	276.000	190.715	.490530E-07	.266740E+09
114	288.000	193.654	.438920E-07	.212990E+09
115	300.000	196.865	.396610E-07	.173140E+09
116	312.000	200.369	.358370E-07	.140760E+09
117	324.000	203.701	.326520E-07	.116220E+09
118	336.000	206.862	.297500E-07	.959550E+08
119	348.000	209.852	.272990E-07	.802870E+08
120	360.000	212.379	.250500E-07	.671780E+08
121	372.445	214.442	.231270E-07	.561350E+08
122	382.890	216.214	.213520E-07	.482540E+08
123	394.335	217.924	.198160E-07	.412990E+08
124	405.780	219.243	.183910E-07	.353400E+08
125	416.710	220.579	.171450E-07	.305380E+08
126	427.640	221.845	.159830E-07	.263880E+08
127	438.645	222.952	.149570E-07	.229540E+08
128	448.450	223.909	.139970E-07	.200360E+08
129	458.860	224.727	.131430E-07	.175700E+08
130	469.270	225.533	.123410E-07	.154070E+08
131	478.305	226.346	.116230E-07	.136230E+08
132	487.340	227.053	.109470E-07	.120450E+08
133	497.375	227.662	.103370E-07	.106590E+08
134	505.410	228.177	.976140E-08	.951280E+07
135	514.450	228.601	.923970E-08	.847630E+07
136	522.490	229.068	.874590E-08	.756070E+07
137	532.525	229.427	.829620E-08	.677060E+07
138	541.560	229.723	.786360E-08	.606200E+07
139	551.595	229.959	.747350E-08	.544540E+07
140	559.630	230.139	.710870E-08	.489790E+07
141	567.105	230.274	.676920E-08	.442630E+07
142	574.580	230.368	.644400E-08	.403380E+07
143	582.055	230.423	.614530E-08	.362960E+07
144	589.530	230.441	.586040E-08	.329630E+07
145	597.010	230.426	.559700E-08	.299200E+07
146	604.490	230.385	.534540E-08	.271750E+07
147	611.965	230.319	.511210E-08	.247560E+07
148	619.440	230.230	.488900E-08	.225520E+07
149	626.915	230.119	.468150E-08	.205510E+07
150	634.390	229.979	.448280E-08	.188000E+07
151	640.580	229.814	.430630E-08	.172920E+07
152	646.770	229.636	.413670E-08	.159050E+07
153	652.960	229.445	.397380E-08	.146290E+07
154	659.150	229.242	.381730E-08	.134560E+07
155	665.340	229.033	.366700E-08	.123760E+07
156	671.530	228.760	.352260E-08	.113840E+07
157	677.720	228.401	.338390E-08	.104710E+07
158	683.910	228.098	.325070E-08	.963070E+06
159	690.100	227.790	.312270E-08	.885220E+06
160	696.290	227.460	.299970E-08	.814770E+06
161	701.418	227.138	.289370E-08	.755630E+06
162	706.546	226.757	.279140E-08	.700780E+06
163	711.674	226.406	.269280E-08	.649920E+06

164	716.802	226.355	.259760E-08	.602740E+06
165	721.930	225.705	.250580E-08	.552690E+06
166	727.058	225.356	.241730E-08	.518420E+06
167	732.186	225.008	.233190E-08	.480790E+06
168	737.314	224.662	.224950E-08	.445890E+06
169	742.442	224.318	.217000E-08	.413530E+06
170	747.570	223.955	.209330E-08	.383510E+06
171	751.633	223.575	.202570E-08	.35750E+06
172	755.696	223.199	.196020E-08	.333910E+06
173	759.759	222.827	.189690E-08	.311570E+06
174	762.822	222.460	.183560E-08	.290720E+06
175	767.885	222.096	.177620E-08	.271270E+06
176	771.948	221.737	.171880E-08	.253120E+06
177	776.011	221.382	.166330E-08	.236190E+06
178	780.074	221.032	.160950E-08	.220380E+06
179	784.137	220.687	.155750E-08	.205640E+06
180	788.200	220.331	.150720E-08	.191880E+06
181	791.766	219.965	.146200E-08	.179780E+06
182	795.332	219.605	.141820E-08	.168440E+06
183	799.898	219.251	.137570E-08	.158210E+06
184	802.464	218.901	.133450E-08	.147850E+06
185	806.030	218.557	.129450E-08	.138530E+06
186	809.596	218.219	.125570E-08	.129790E+06
187	813.162	217.885	.121810E-08	.121600E+06
188	816.728	217.558	.118160E-08	.113930E+06
189	820.294	217.235	.114610E-08	.106740E+06
190	823.860	216.905	.111180E-08	.100010E+06

AFGL LINE FILE OF INTEREST FOR TRANSITION U1101 TO 30031

BRANCH	LINE	FREQ. (CM-1)	LINE STRENGTH	LINE WIDTH	LOWER STATE ENERGY
R	2	669.72630	.597E-19	.077	2.341

RADIANCE (PHOTONS/CM²*STR*SEC*CM-1) FOR LINE R 2 VS FREQUENCY (CM-1) AT VARIOUS TANGENT HEIGHTS

FREQ	70 KM	75 KM	80 KM	85 KM
669.7263	.91444E+14	.64348E+14	.56036E+14	.99414E+14
669.7264	.90971E+14	.63855E+14	.56127E+14	.98891E+14
669.7265	.89580E+14	.62391E+14	.54816E+14	.97342E+14
669.7266	.87315E+14	.60010E+14	.52353E+14	.94813E+14
669.7267	.84284E+14	.56807E+14	.48933E+14	.91393E+14
669.7268	.80623E+14	.52931E+14	.45002E+14	.87223E+14
669.7269	.76561E+14	.48605E+14	.40472E+14	.82507E+14
669.7270	.72035E+14	.44150E+14	.35746E+14	.77526E+14
669.7271	.68774E+14	.40056E+14	.31265E+14	.72665E+14
669.7272	.66455E+14	.37160E+14	.27696E+14	.68464E+14
669.7273	.64978E+14	.34572E+14	.24606E+14	.65631E+14
669.7274	.62710E+14	.31500E+14	.21882E+14	.64741E+14
669.7275	.60338E+14	.28259E+14	.174627E+14	.64826E+14
669.7276	.50961E+15	.10007E+15	.84943E+14	.58821E+14
669.7277	.14193E+15	.12446E+15	.87978E+14	.43047E+14
669.7278	.17935E+15	.14212E+15	.71123E+14	.25134E+14
669.7279	.21241E+15	.13135E+15	.44816E+14	.12570E+14
669.7280	.22197E+15	.97991E+14	.24600E+14	.58502E+13
669.7281	.20829E+15	.66541E+14	.13410E+14	.27554E+13
669.7282	.18250E+15	.47346E+14	.80768E+13	.14356E+13

669.7283	.16007E+15	.36511E+14	.56365E+13	.88276E+12
669.7284	.14236E+15	.30407E+14	.44562E+13	.64027E+12
669.7285	.13076E+15	.26572E+14	.37996E+13	.51992E+12
669.7286	.12063E+15	.23225E+14	.33657E+13	.44287E+12
669.7287	.11200E+15	.21651E+14	.30368E+13	.39948E+12
669.7288	.10428E+15	.19825E+14	.27669E+13	.36119E+12
669.7289	.97532E+14	.18246E+14	.25365E+13	.32963E+12
669.7290	.91219E+14	.16858E+14	.23359E+13	.30274E+12
669.7291	.85657E+14	.15628E+14	.21593E+13	.27939E+12
669.7292	.80441E+14	.14531E+14	.20027E+13	.25885E+12
669.7293	.75739E+14	.13547E+14	.18630E+13	.24063E+12
669.7294	.71387E+14	.12662E+14	.17377E+13	.22436E+12
669.7295	.67385E+14	.11861E+14	.16250E+13	.20971E+12
669.7296	.63652E+14	.11135E+14	.15231E+13	.19651E+12
669.7297	.60296E+14	.10475E+14	.14306E+13	.18454E+12
669.7298	.57151E+14	.98715E+13	.13465E+13	.17365E+12
669.7299	.54238E+14	.93196E+13	.12697E+13	.16371E+12
669.7300	.51527E+14	.88131E+13	.11993E+13	.15462E+12
669.7301	.49027E+14	.83470E+13	.11347E+13	.14627E+12
669.7302	.46692E+14	.79172E+13	.10752E+13	.13859E+12
669.7303	.44516E+14	.75200E+13	.10205E+13	.13151E+12
669.7304	.42486E+14	.71521E+13	.96977E+12	.12496E+12
669.7305	.40599E+14	.68108E+13	.92280E+12	.11890E+12
669.7306	.38813E+14	.64934E+13	.87919E+12	.11327E+12
669.7307	.37150E+14	.61979E+13	.83963E+12	.10803E+12
669.7308	.35589E+14	.59223E+13	.80082E+12	.10315E+12
669.7309	.34124E+14	.56643E+13	.76556E+12	.98602E+11
669.7310	.32748E+14	.54232E+13	.73259E+12	.94348E+11
669.7311	.31447E+14	.51972E+13	.70171E+12	.90361E+11
669.7312	.30224E+14	.49851E+13	.67276E+12	.86631E+11
669.7313	.29070E+14	.47857E+13	.64556E+12	.83127E+11
669.7314	.27980E+14	.45981E+13	.62003E+12	.79831E+11
669.7315	.26949E+14	.44214E+13	.59597E+12	.76731E+11
669.7316	.25974E+14	.42547E+13	.57329E+12	.73866E+11
669.7317	.25050E+14	.40973E+13	.55190E+12	.71048E+11
669.7318	.24174E+14	.39485E+13	.53168E+12	.68442E+11
669.7319	.23342E+14	.38077E+13	.51256E+12	.65978E+11
669.7320	.22553E+14	.36742E+13	.49446E+12	.63641E+11
669.7321	.21802E+14	.35477E+13	.47731E+12	.61435E+11
669.7322	.21088E+14	.34277E+13	.46102E+12	.59338E+11
669.7323	.20408E+14	.33136E+13	.44559E+12	.57348E+11
669.7324	.19761E+14	.32052E+13	.43099E+12	.55456E+11
669.7325	.19143E+14	.31020E+13	.41693E+12	.53657E+11
669.7326	.18553E+14	.30037E+13	.40344E+12	.51945E+11
669.7327	.17991E+14	.29100E+13	.39097E+12	.50313E+11
669.7328	.17453E+14	.28207E+13	.37890E+12	.48758E+11
669.7329	.16939E+14	.27354E+13	.36737E+12	.47273E+11
669.7330	.16447E+14	.26539E+13	.35637E+12	.45856E+11
669.7331	.15976E+14	.25760E+13	.34585E+12	.44502E+11
669.7332	.15525E+14	.25016E+13	.33580E+12	.43207E+11
669.7333	.15092E+14	.24302E+13	.32618E+12	.41968E+11
669.7334	.14677E+14	.23620E+13	.31696E+12	.40781E+11
669.7335	.14280E+14	.22965E+13	.30814E+12	.39644E+11
669.7336	.13898E+14	.22337E+13	.29968E+12	.38558E+11
669.7337	.13530E+14	.21735E+13	.29156E+12	.37510E+11
669.7338	.13178E+14	.21157E+13	.28377E+12	.36501E+11
669.7339	.12839E+14	.20602E+13	.27629E+12	.35545E+11
669.7340	.12512E+14	.20068E+13	.26910E+12	.34621E+11
669.7341	.12198E+14	.19555E+13	.26219E+12	.33730E+11
669.7342	.11896E+14	.19061E+13	.25554E+12	.32874E+11
669.7343	.11604E+14	.18586E+13	.24914E+12	.32051E+11
669.7344	.11323E+14	.18128E+13	.24299E+12	.31251E+11
669.7345	.11052E+14	.17687E+13	.23705E+12	.30495E+11
669.7346	.10791E+14	.17262E+13	.23133E+12	.29759E+11
669.7347	.10539E+14	.16852E+13	.22582E+12	.29049E+11
669.7348	.10295E+14	.16457E+13	.22050E+12	.28365E+11

669.7349	.10060E+14	.16079E+13	.21537E+12	.27704E+11
669.7350	.58322E+13	.15706E+13	.21142E+12	.27057E+11
669.7351	.96132E+13	.15390E+13	.20563E+12	.26451E+11
669.7352	.94108E+13	.15106E+13	.20101E+12	.25956E+11
669.7353	.91953E+13	.14746E+13	.19654E+12	.25281E+11
669.7354	.89655E+13	.14322E+13	.19222E+12	.24726E+11
669.7355	.88140E+13	.14041E+13	.18904E+12	.24187E+11
669.7356	.86177E+13	.13740E+13	.18608E+12	.23666E+11
669.7357	.84370E+13	.13449E+13	.18308E+12	.23162E+11
669.7358	.82621E+13	.13166E+13	.17929E+12	.22679E+11
669.7359	.80925E+13	.12892E+13	.17628E+12	.22207E+11
669.7360	.79282E+13	.12627E+13	.17306E+12	.21747E+11
669.7361	.77685E+13	.12370E+13	.16961E+12	.21300E+11
669.7362	.76133E+13	.12121E+13	.16226E+12	.20871E+11
669.7363	.74636E+13	.11879E+13	.15902E+12	.20452E+11

RADIANCE (WATT/CM2*STR) AT VARIOUS TANGENT HEIGHTS

LINE	70 KP (TFIN)	73 KM	75 KM (THIN)	75 KM	80 KM (THIN)	80 KM	85 KP (THIN)	85 KM
R 2	.77307E-05	.13544E-07	.25310E-05	.59142E-08	.27663E-06	.75667E-06	.23102E-06	.31254E-08

Appendix C

Example of Program Output for All Lines of the
01101-00001 Band of CO₂. The Doppler Lineshape
is Used. The Integrated Radiance is Printed Out for
a Single Tangent Height

NOL = CO2
 ISO = ISOTOPE CODE = 6.6
 VIDE = VIBRATIONAL ENERGY (CM-1) OF THE TRANSITION = 667.300
 VIDL = VIBRATIONAL ENERGY (CM-1) OF THE LOWER STATE = 0.000
 VIBU = VIBRATIONAL QUANTUM (CM-1) (FOR PARTITION FUNCTION) = 667.300
 NOLM1 = 44
 DELV = 2
 PROY = 1.0
 TLAP = 0.5

PROGRAM WILL SEARCH IN LINE FILE BETWEEN 1 AND 5.000 CM-1 FOR LINES OF CO2
 ISOTOPE = 6.6
 SANC = 11.1 - 1.0
 BRANCH = A (ALL)
 LINE # = ** (ALL)
 COPPLER = LINESHAPE OF ION SELECTED

INITIAL TANGENT HEIGHT (KMS) = 70
 FINAL TANGENT HEIGHT (KMS) = 70
 EXAMINATION INTERVAL (KMS) = 5

ATMOSPHERE --- CO2, NIGHT, 70-190 KM; T, P = US STC76; VIB TEMP = CO2, NIGHT, 70-190 K 05/12/67

AL (KM)	IR TEMP (K)	VS TEMP (K)	TOT PRESS (ATMOS)	CO2 DENSITY (CM-1)
7	209.590	210.760	.515260E-04	.54235E+12
71	216.925	207.526	.441680E-04	.477697E+12
72	214.260	209.223	.37610E-04	.46049E+12
73	212.305	207.843	.32350E-04	.35228E+12
74	210.350	198.333	.27626E-04	.30380E+12
75	208.390	197.069	.235520E-04	.26129E+12
76	206.430	197.404	.20070E-04	.22473E+12
77	204.475	187.336	.177620E-04	.19275E+12
78	202.520	187.602	.157210E-04	.16532E+12
79	200.565	187.130	.12779E-04	.14138E+12
80	198.610	177.799	.103570E-04	.12091E+12
81	196.655	177.450	.87059E-05	.10309E+12
82	194.700	177.220	.74280E-05	.87901E+11
83	192.740	167.144	.62080E-05	.74716E+11
84	190.780	165.253	.52410E-05	.63505E+11
85	188.825	167.555	.43976E-05	.53802E+11
86	186.870	167.827	.36800E-05	.45582E+11
87	186.870	159.329	.304520E-05	.39154E+11
88	186.870	150.197	.254310E-05	.319360E+11
89	186.870	157.124	.216340E-05	.26734E+11
90	186.870	150.408	.181190E-05	.22380E+11
91	187.115	150.054	.15110E-05	.18717E+11
92	187.360	150.924	.127190E-05	.15653E+11
93	187.605	150.007	.106620E-05	.13085E+11
94	188.330	150.292	.893750E-06	.10436E+11
95	184.823	150.809	.749970E-06	.51524E+10
96	189.310	157.279	.629320E-06	.76583E+10

97	190.755	157.045	.524000E-06	.63885 E+10
98	192.205	155.505	.444680E-06	.53292 E+10
99	193.640	155.035	.374320E-06	.44580 E+10
100	195.080	160.514	.315930E-06	.37293 E+10
101	197.640	160.905	.267730E-06	.31136 E+10
102	200.200	165.340	.220610E-06	.25996 E+10
103	202.755	164.816	.195180E-06	.21866 E+10
104	205.310	160.335	.166610E-06	.18291 E+10
105	209.415	160.305	.143100E-06	.15317 E+10
106	213.520	170.047	.122910E-06	.12926 E+10
107	218.750	175.256	.106320E-06	.10767 E+10
108	224.300	175.504	.91970E-07	.90307 E+09
109	231.990	177.826	.80310E-07	.78332 E+09
110	240.000	180.738	.701130E-07	.64727 E+09
111	252.000	184.252	.619970E-07	.42759 E+09
112	264.000	180.580	.548210E-07	.33409 E+09
113	276.000	190.715	.490330E-07	.26674 E+09
114	288.000	190.054	.438920E-07	.21296 E+09
115	300.000	195.865	.396510E-07	.17314 E+09
116	312.000	200.369	.35370E-07	.14076 E+09
117	324.000	200.771	.320520E-07	.11622 E+09
118	336.000	200.862	.29750E-07	.95955 E+08
119	348.000	200.052	.27490E-07	.80287 E+08
120	360.000	212.579	.25300E-07	.67178 E+08
121	371.445	214.422	.231270E-07	.56935 E+08
122	382.090	215.214	.213520E-07	.48254 E+08
123	394.335	217.824	.198160E-07	.41295 E+08
124	405.780	210.243	.18310E-07	.35340 E+08
125	416.710	220.579	.17150E-07	.30538 E+08
126	427.640	220.045	.15930E-07	.26300 E+08
127	438.045	220.952	.149570E-07	.22994 E+08
128	448.450	220.909	.139470E-07	.20326 E+08
129	458.860	224.727	.131430E-07	.17570 E+08
130	469.270	225.533	.123410E-07	.15407 E+08
131	478.305	225.346	.116230E-07	.13623 E+08
132	487.340	227.053	.109470E-07	.12045 E+08
133	496.375	227.662	.103370E-07	.10699 E+08
134	505.410	225.177	.976140E-08	.95028 E+07
135	514.450	220.041	.920470E-08	.84763 E+07
136	523.490	225.068	.874590E-08	.75607 E+07
137	532.525	224.427	.829020E-08	.67706 E+07
138	541.560	225.723	.786360E-08	.60630 E+07
139	550.595	220.959	.747350E-08	.54494 E+07
140	559.630	230.239	.711870E-08	.48979 E+07
141	567.185	230.274	.678920E-08	.44283 E+07
142	574.580	230.368	.648400E-08	.40338 E+07
143	582.055	230.423	.614530E-08	.36296 E+07
144	589.530	230.441	.58640E-08	.32103 E+07
145	597.010	230.426	.55970E-08	.29902 E+07
146	604.490	230.385	.534540E-08	.27175 E+07
147	611.965	230.319	.511210E-08	.24756 E+07
148	619.440	230.230	.48830E-08	.22552 E+07
149	626.915	230.219	.468150E-08	.20591 E+07
150	634.390	225.979	.449280E-08	.18880 E+07
151	640.580	225.814	.431630E-08	.17292 E+07
152	646.770	225.636	.413670E-08	.15905 E+07
153	652.960	220.445	.397380E-08	.14629 E+07
154	659.150	225.242	.381730E-08	.13456 E+07
155	665.340	225.993	.36670E-08	.12376 E+07
156	671.530	225.700	.352260E-08	.11384 E+07
157	677.720	228.401	.338190E-08	.10471 E+07
158	683.910	225.098	.325170E-08	.96307 E+06
159	690.100	227.790	.312270E-08	.88582 E+06
160	696.290	227.460	.299470E-08	.81477 E+06
161	701.410	227.100	.289370E-08	.75563 E+06
162	706.540	226.757	.279140E-08	.70078 E+06

160	711.674	225.456	.269280E-08	.64992E+06
161	716.842	225.55	.254760E-08	.60276E+06
162	721.930	225.705	.251580E-08	.55899E+06
163	727.058	225.856	.247380E-08	.51842E+06
164	732.186	225.968	.243190E-08	.48079E+06
165	737.314	226.062	.23950E-08	.44589E+06
166	742.442	226.318	.21700E-08	.41353E+06
167	747.570	226.355	.209330E-08	.38351E+06
168	751.633	226.575	.202570E-08	.35785E+06
169	755.696	226.199	.196120E-08	.33391E+06
170	759.759	226.827	.189690E-08	.31157E+06
171	763.822	226.460	.183560E-08	.29072E+06
172	767.885	226.36	.17780E-08	.27127E+06
173	771.948	226.737	.172480E-08	.25312E+06
174	776.011	226.382	.166330E-08	.23619E+06
175	780.074	226.32	.160550E-08	.22038E+06
176	784.137	226.537	.155750E-08	.20564E+06
177	788.200	226.331	.151220E-08	.19188E+06
178	791.763	219.965	.146200E-08	.17977E+06
179	795.326	219.695	.141520E-08	.16944E+06
180	798.889	219.251	.137570E-08	.15781E+06
181	802.452	219.91	.133550E-08	.14705E+06
182	806.015	219.557	.129450E-08	.13851E+06
183	809.578	219.219	.12570E-08	.12979E+06
184	813.141	219.885	.121810E-08	.12180E+06
185	816.704	219.558	.117160E-08	.11393E+06
186	820.267	219.235	.112810E-08	.10674E+06
187	823.830	219.909	.11180E-08	.10001E+06

AFGL LINE FILE OF INTEREST FOR TRANSITION 01101 TO 0001

BRANCH	LINE	FREQ. (CM-1)	LINE STRENGTH	LINETHICK	LOWER STATE ENERGY
P	100	593.8370	.666E-26	.348	3927.621
P	98	595.2130	.138E-25	.049	3773.364
P	96	596.5950	.284E-25	.049	3622.166
P	94	597.9590	.572E-25	.050	3476.030
P	92	599.3730	.114E-24	.050	3328.959
P	90	600.7675	.222E-24	.051	3186.955
P	88	602.1654	.428E-24	.052	3048.021
P	86	603.5670	.811E-24	.052	2912.158
P	84	604.9740	.151E-23	.053	2779.369
P	82	606.3860	.278E-23	.053	2649.656
P	80	607.7945	.504E-23	.054	2523.022
P	78	609.2110	.897E-23	.055	2399.468
P	76	610.6360	.157E-22	.055	2278.996
P	74	612.0598	.272E-22	.056	2161.609
P	72	613.4808	.462E-22	.056	2047.308
P	70	614.9160	.773E-22	.057	1936.095
P	68	616.3530	.127E-21	.058	1827.572
P	66	617.7970	.206E-21	.058	1722.941
P	64	619.2380	.329E-21	.059	1621.003
P	62	620.6880	.517E-21	.059	1522.160
P	60	622.1360	.798E-21	.060	1426.414
P	58	623.5802	.121E-20	.061	1333.767
P	56	625.0406	.181E-20	.061	1244.219
P	54	626.5067	.267E-20	.062	1157.773
P	52	627.9760	.386E-20	.062	1074.430
P	50	629.4430	.549E-20	.063	994.190
P	48	630.9158	.768E-20	.064	917.056
P	46	632.3931	.106E-19	.064	843.829
P	44	633.8740	.143E-19	.065	772.110
P	42	635.3588	.198E-19	.065	704.388
P	40	636.8473	.248E-19	.066	639.600

P	38	638.33350	.319E-19	.067	579.811
P	36	639.83540	.402E-19	.067	519.534
P	34	641.33500	.497E-19	.068	464.171
P	32	642.80330	.603E-19	.068	411.922
P	30	644.34530	.718E-19	.069	362.788
P	28	645.85000	.839E-19	.070	316.769
P	26	647.37300	.959E-19	.070	273.868
P	24	648.88020	.107E-18	.071	234.883
P	22	650.40770	.118E-18	.071	197.416
P	20	651.93390	.125E-18	.072	163.868
P	18	653.46300	.131E-18	.073	133.439
P	16	654.99390	.132E-18	.073	106.130
P	14	656.53370	.129E-18	.074	81.940
P	12	658.07110	.121E-18	.074	60.871
P	10	659.61400	.108E-18	.075	42.922
P	8	661.16300	.909E-19	.076	29.095
P	6	662.71110	.609E-19	.076	16.389
P	4	664.26330	.432E-19	.077	7.804
P	2	665.82100	.148E-19	.077	2.341
Q	2	667.38020	.743E-19	.077	2.341
Q	4	667.40770	.136E-18	.077	7.804
Q	6	667.42350	.181E-18	.076	16.389
Q	8	667.45600	.223E-18	.075	29.095
Q	10	667.49290	.256E-18	.075	42.922
Q	12	667.54250	.280E-18	.074	60.871
Q	14	667.59740	.293E-18	.074	81.940
Q	16	667.66050	.296E-18	.073	106.130
Q	18	667.73390	.291E-18	.072	133.439
Q	20	667.81450	.278E-18	.072	163.868
Q	22	667.90340	.259E-18	.071	197.416
Q	24	668.00040	.236E-18	.071	234.883
Q	26	668.10570	.211E-18	.070	273.868
R	0	668.16300	.331E-19	.078	0.000
Q	28	668.21020	.184E-18	.069	316.769
Q	30	668.34600	.150E-18	.069	362.788
Q	32	668.47700	.132E-18	.068	411.922
Q	34	668.60400	.109E-18	.068	464.171
Q	36	668.75470	.881E-19	.067	519.534
Q	38	668.99900	.699E-19	.066	578.811
Q	40	669.27300	.545E-19	.066	639.600
Q	42	669.24160	.418E-19	.065	704.300
Q	44	669.42110	.315E-19	.065	772.110
Q	46	669.60050	.233E-19	.064	843.029
R	2	669.72030	.597E-19	.077	2.341
Q	48	669.80000	.170E-19	.063	917.056
Q	50	670.00000	.122E-19	.063	994.190
Q	52	670.21380	.850E-20	.062	1074.430
Q	54	670.43220	.593E-20	.062	1157.773
Q	56	670.65440	.404E-20	.061	1244.219
Q	58	670.88250	.271E-20	.060	1333.767
Q	60	671.13440	.179E-20	.060	1426.414
R	4	671.29470	.874E-19	.077	7.804
Q	62	671.38010	.116E-20	.059	1522.160
Q	64	671.604160	.740E-21	.059	1621.803
Q	66	671.90090	.465E-21	.058	1722.941
Q	68	672.17180	.287E-21	.057	1827.972
Q	70	672.46040	.175E-21	.057	1936.095
Q	72	672.74070	.105E-21	.056	2047.308
R	6	672.86040	.112E-18	.076	16.389
Q	74	673.04450	.619E-22	.056	2161.609
Q	76	673.34790	.359E-22	.055	2278.996
Q	78	673.65080	.205E-22	.054	2399.468
Q	80	673.97720	.116E-22	.054	2523.022
Q	82	674.30290	.640E-23	.053	2649.656
R	8	674.44300	.133E-18	.075	28.095
Q	84	674.63010	.349E-23	.053	2779.369

Q	86	674.97669	.188E-23	.052	2912.158
Q	88	675.3244	.992E-24	.051	3048.021
Q	90	675.67340	.517E-24	.051	3186.955
R	10	676.0115	.149E-18	.075	42.922
Q	92	676.04180	.265E-24	.050	3328.959
Q	94	676.41190	.134E-24	.050	3474.030
Q	96	676.78730	.666E-25	.049	3622.166
Q	98	677.17180	.326E-25	.048	3773.364
Q	100	677.56210	.157E-25	.048	3927.621
P	12	677.60190	.159E-18	.074	60.871
Q	102	677.95350	.747E-26	.047	4084.936
R	14	679.18550	.165E-18	.074	81.940
R	16	680.77320	.165E-18	.073	106.130
R	18	682.36400	.161E-18	.072	133.439
R	20	683.95790	.153E-18	.072	163.868
R	22	685.55180	.143E-18	.071	197.416
R	24	687.15180	.130E-18	.071	234.083
R	26	688.75700	.115E-18	.070	273.868
R	28	690.36370	.101E-18	.069	316.769
P	30	691.97150	.859E-19	.069	362.788
R	32	693.58110	.721E-19	.069	411.922
R	34	695.19170	.594E-19	.068	464.171
R	36	696.81000	.480E-19	.067	519.534
R	38	698.43000	.381E-19	.066	578.011
P	40	700.05180	.298E-19	.066	639.600
R	42	701.68430	.228E-19	.065	704.300
R	44	703.31740	.172E-19	.065	772.110
R	46	704.94600	.128E-19	.064	843.029
P	48	706.57130	.929E-20	.063	917.056
R	50	708.21180	.666E-20	.063	994.190
P	52	709.85210	.463E-20	.062	1074.430
R	54	711.49180	.326E-20	.062	1157.773
R	56	713.13080	.222E-20	.061	1244.219
R	58	714.77110	.149E-20	.060	1333.767
P	60	716.42060	.984E-21	.060	1426.414
R	62	718.07040	.639E-21	.059	1522.160
R	64	719.72140	.409E-21	.059	1621.003
R	66	721.38150	.257E-21	.058	1722.941
R	68	723.04160	.159E-21	.057	1827.872
R	70	724.69100	.972E-22	.057	1936.095
R	72	726.35090	.583E-22	.056	2047.308
R	74	728.01100	.344E-22	.056	2161.609
R	76	729.68090	.200E-22	.055	2278.996
P	78	731.34060	.115E-22	.054	2399.468
R	80	733.01000	.646E-23	.054	2523.022
P	82	734.68010	.359E-23	.053	2649.656
R	84	736.35090	.196E-23	.053	2779.369
P	86	738.02200	.105E-23	.052	2912.158
P	88	739.70200	.558E-24	.051	3048.021
R	90	741.37720	.291E-24	.051	3186.955
P	92	743.05780	.150E-24	.050	3328.959
R	94	744.73180	.757E-25	.050	3474.030
R	96	746.41100	.377E-25	.049	3622.166
R	98	748.09130	.185E-25	.048	3773.364
R	100	749.77280	.893E-26	.048	3927.621
R	102	751.45530	.425E-26	.047	4084.936

RADIANCE (WATT/CM²·SR) AT VARIOUS TANGENT HEIGHTS

LINE 70 KM (THIN) 70 KM

P 10: .98726E-15 .98726E-15

P 9b	.25597E-14	.25597E-14
P 9b	.66005E-14	.66005E-14
P 9c	.16847E-13	.16847E-13
P 9c	.42436E-13	.42436E-13
P 9d	.10533E-12	.10533E-12
P 8d	.25736E-12	.25736E-12
P 8d	.61044E-12	.61044E-12
P 8c	.14489E-11	.14489E-11
P 8c	.33415E-11	.33415E-11
P 8c	.75533E-11	.75533E-11
P 7c	.16736E-10	.16736E-10
P 7c	.36321E-10	.36321E-10
P 7c	.77222E-10	.77222E-10
P 7c	.16479E-09	.16479E-09
P 7c	.32787E-09	.32787E-09
P 6c	.65444E-09	.65444E-09
P 6c	.14740E-08	.14740E-08
P 6c	.29468E-08	.29468E-08
P 6c	.45827E-08	.45827E-08
P 6c	.83975E-08	.83975E-08
P 5c	.15063E-07	.15063E-07
P 5c	.20443E-07	.20443E-07
P 5c	.45368E-07	.45368E-07
P 5c	.76241E-07	.76241E-07
P 5c	.12517E-06	.12517E-06
P 4c	.20106E-06	.20106E-06
P 4c	.30584E-06	.30584E-06
P 4c	.48546E-06	.48546E-06
P 4c	.74761E-06	.74761E-06
P 4c	.11671E-05	.11671E-05
P 3c	.15231E-05	.15231E-05
P 3c	.21391E-05	.21391E-05
P 3c	.29215E-05	.29215E-05
P 3c	.39943E-05	.39943E-05
P 3c	.54632E-05	.54632E-05
P 2c	.64111E-05	.64111E-05
P 2c	.79106E-05	.79106E-05
P 2c	.95045E-05	.95045E-05
P 2c	.11606E-04	.11606E-04
P 2c	.12546E-04	.12546E-04
P 1c	.13766E-04	.13766E-04
P 1c	.14574E-04	.14574E-04
P 1c	.14843E-04	.14843E-04
P 1c	.14461E-04	.14461E-04
P 1c	.13335E-04	.13335E-04
P 1c	.11447E-04	.11447E-04
P 1c	.88364E-05	.88364E-05
P 1c	.56103E-05	.56103E-05
P 1c	.19303E-05	.19303E-05
Q 1c	.90794E-05	.90794E-05
Q 1c	.16794E-04	.16794E-04
Q 1c	.22894E-04	.22894E-04
Q 1c	.27674E-04	.27674E-04
Q 1c	.30954E-04	.30954E-04
Q 1c	.32651E-04	.32651E-04
Q 1c	.32874E-04	.32874E-04
Q 1c	.31801E-04	.31801E-04
Q 1c	.29672E-04	.29672E-04
U 2c	.20045E-04	.20045E-04
Q 2c	.43481E-04	.43481E-04
Q 2c	.11989E-04	.11989E-04
Q 2c	.16554E-04	.16554E-04
R 1c	.39343E-05	.39343E-05
Q 2c	.13350E-04	.13350E-04
C 3c	.10487E-04	.10487E-04
Q 3c	.20364E-05	.20364E-05

Q 3-	.6092E-05	.7505E-08
Q 3c	.43801E-05	.0000E-0
Q 3o	.31258E-05	.55469E-08
G 4-	.21761E-05	.04938E-08
G 4c	.24002E-05	.54839E-08
Q 4-	.98413E-06	.05147E-08
Q 4b	.63962E-06	.06119E-08
R 4-	.77307E-05	.04918E-08
Q 4c	.40647E-06	.07511E-08
U 5-	.25043E-06	.09221E-08
Q 5-	.19345E-06	.00932E-08
G 5-	.41222E-07	.02130E-08
Q 5b	.53052E-07	.02118E-08
Q 5c	.31192E-07	.00123E-08
Q 6-	.16010E-07	.04792E-08
R 6-	.11644E-04	.06913E-08
G 6c	.01632E-06	.05033E-08
Q 6-	.40801E-08	.52265E-08
Q 6b	.25522E-06	.00319E-08
Q 6c	.13045E-08	.11576E-08
G 7-	.65301E-09	.01466E-09
Q 7c	.30413E-09	.1173E-09
R 7-	.14031E-04	.08343E-09
Q 7-	.15357E-09	.05139E-09
Q 7c	.72181E-10	.71697E-10
Q 7-	.30242E-10	.03144E-10
G 8-	.14994E-10	.14973E-10
U 8c	.60334E-11	.06294E-11
R 8-	.16189E-04	.09357E-08
G 8-	.28759E-11	.08752E-11
Q 8b	.00230E-11	.0234E-11
Q 8c	.51040E-12	.01188E-12
Q 9-	.00967E-12	.00967E-12
R 9-	.17567E-04	.00022E-08
Q 9c	.84679E-13	.4670E-13
Q 9c	.30711E-13	.3711E-13
G 9c	.13274E-13	.13274E-13
Q 9-	.52054E-14	.1854E-14
G 10-	.20188E-14	.01088E-14
R 10-	.00143E-04	.00375E-08
Q 10c	.78860E-15	.78860E-15
R 14-	.17978E-04	.00454E-08
R 1b	.17173E-04	.00294E-08
R 1c	.15856E-04	.09847E-08
R 2-	.14204E-04	.09304E-08
R 2c	.12349E-04	.08550E-08
R 24-	.10443E-04	.07081E-08
R 2c	.85950E-05	.06716E-08
R 2b	.68987E-05	.05711E-08
R 3-	.53902E-05	.04710E-08
R 3c	.41176E-05	.03773E-08
R 3+	.30604E-05	.02993E-08
R 3b	.22239E-05	.02423E-08
R 3c	.003836E-05	.02133E-10
R 4-	.10990E-05	.02214E-08
R 4c	.74515E-06	.02724E-08
R 4-	.49383E-06	.03092E-08
R 4b	.32008E-06	.05046E-08
R 4c	.20201E-06	.06611E-08
R 5-	.12569E-06	.08042E-08
R 5c	.76195E-07	.0923E-08
R 5+	.45108E-07	.08832E-08
R 5b	.26214E-07	.06694E-08
R 5b	.14003E-07	.05273E-08
R 6-	.82677E-08	.41867E-08
R 6c	.44958E-08	.00051E-08

R 0-	.25927E-08	.49106E-08
R 0-	.22468E-08	.1155E-08
R 0	.65604E-09	.3772E-09
R 7	.3725E-09	.779E-09
R 7-	.15529E-09	.5094E-09
R 7-	.7379E-10	.341E-10
R 7-	.34798E-10	.4779E-10
R 7	.2604E-10	.614E-10
R 8	.72242E-11	.2194E-11
R 8-	.1992E-11	.1002E-11
R 8-	.58.7E-11	.346E-11
R 8-	.55675E-12	.8672E-12
R 8-	.4459E-12	.488E-12
R 9	.2046E-12	.104E-12
R 9-	.4.6.6E-13	.6.6E-13
R 9-	.2196E-13	.146E-13
R 9-	.6377E-14	.3977E-14
R 9-	.2512E-14	.52E-14
R 10-	.9603E-15	.603E-15
R 10-	.0919E-15	.8919E-15

TOTAL FOR 99 LINES = .0040E-0

FILMED

02 - 84