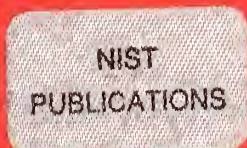


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NIST Technical Note 1402

RADCAL: A Narrow-Band Model for Radiation Calculations in a Combustion Environment

William L. Grosshandler

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NIST Technical Note 1402

RADCAL: A Narrow-Band Model for Radiation Calculations in a Combustion Environment

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April 1993



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ABSTRACT

Radiation within a medium containing products of combustion is dependent upon the temperature and concentrations throughout the entire field. The energy is distributed across the infrared spectrum in a highly nonlinear fashion, which greatly complicates modeling of the heat transfer within a burning environment. This report describes a numerical program, RADCAL, which predicts the radiant intensity leaving a nonisothermal volume containing nonuniform levels of carbon dioxide, water vapor, methane, carbon monoxide, nitrogen, oxygen, and soot. The absorption coefficient of the combined gases is calculated from a narrow-band model and a combination of tabulated spectral properties and theoretical approximations to the vibrational-rotational molecular bands. Soot is treated as a purely absorbing substance in the Rayleigh limit. Background on the development of the model, example calculations, and an explanation of input procedures are presented.

Key Words: models, radiation, radiative heat transfer, spectra, spectral absorptivity, spectral emissivity

TABLE OF CONTENTS

	Page
I. INTRODUCTION	1
II. DEVELOPMENT OF RADCAL	2
III. SAMPLE APPLICATIONS OF RADCAL	4
IV. PROGRAM STRUCTURE	5
A. Input Parameters	14
B. Output Parameters	16
V. GLOSSARY	23
VI. REFERENCES	25
VII. APPENDIX	27
A. Data Input File, RC.DAT	27
B. Fortran Listing of RADCAL	27
1. RCPART1.FOR	27
2. RCPART2.FOR	40
3. RCPART3.FOR	43
4. RCPART4.FOR	47

RADCAL: A NARROW-BAND MODEL FOR RADIATION CALCULATIONS IN A COMBUSTION ENVIRONMENT

I. INTRODUCTION

The transfer of energy from and within a burning environment is controlled by diffusive, convective, and radiative processes. Because the temperatures associated with combustion are high, a proper physical description needs to account for radiation unless the characteristic radiation-to-convection ratio of the system is small. Bhattacharjee and Grosshandler (1989) define the following radiation/convection parameter, Ψ , in terms of the flame, surrounding wall and inlet temperatures (T_f , T_w and T_i), the mass flux of material brought into the flame times its heat capacity, $\rho_i \mu_i c_p$, and the optical thickness of the system based upon the absorption coefficient, a , and a stream-wise dimension, L :

$$\Psi = \frac{\sigma a L (T_f^4 - T_w^4)}{\rho_i \mu_i c_p (T_f - T_i)} \quad (1)$$

σ is the Stefan-Boltzmann constant. For Ψ less than unity, radiation has little effect on the energy transfer.

The radiation/convection parameter can be recast in terms relevant to fires by using a typical flame temperature of 1500 K and by replacing the convective energy with the thermal input, Q , per unit area of burning surface, A . Equation (1) becomes

$$\Psi \sim 300 \frac{aV}{Q} \quad (2)$$

where V is the volume, LA , in cubic meters and Q is in kilowatts. Hence, highly absorbing fires in large volumes can be strongly influenced by radiation; conversely, a large thermal input can diminish the importance of radiation if the absorption properties, temperature and volume of interest remain about constant.

While Ψ is a useful global parameter, one must be able to estimate the absorption properties of the system and must recognize that the value of a can change substantially within the flow field. The absorption coefficient of the cool gases surrounding a fire can influence the transfer of energy from a burning object to a distant object. The absorption coefficient can also be used to analyze remotely the contents of the plume from a fire or an exhaust stack; and the absorption spectra of the pyrolysis and product gases formed during smoldering or shortly following ignition can be used for early detection of a fire.

For the above applications, a model which can predict the spectral structure of various

combustion products over a wide range of temperatures, pressures and pathlengths is required. The purpose of this report is to describe the development of one such model, RADCAL, to demonstrate its application, and to instruct others so that they can adapt it to their own needs.

II. DEVELOPMENT OF RADCAL

RADCAL computes the spectral intensity, i'_λ , from a non-isothermal mixture of combustion gases and soot incident upon a volume element within or external to the environment. The program solves the equation of transfer for an absorbing and emitting medium (no scattering) by breaking the line-of-sight into a number of uniform elements and by using molecular models and tabulated data for the spectral absorption coefficient, a_λ . Under these conditions the equation of transfer can be written as

$$i'_\lambda(l) = i'_{\lambda,w} e^{-\kappa_\lambda(l)} + \int_0^{\kappa_\lambda(l)} i_{b,\lambda}(l^*) \exp[-(\kappa_\lambda(l) - \kappa_\lambda(l^*))] d\kappa_\lambda(l^*) \quad (3)$$

$i_{b,\lambda}$ is the Planck blackbody function, κ_λ is the optical thickness defined by $\kappa_\lambda \equiv \int_0^l a_\lambda(l^*) dl^*$, λ is the wavelength, and the subscript w refers to a bounding wall condition.

The average spectral intensity incident on a differential volume from all directions is found by integrating eq (3) over solid angle, ω :

$$\overline{i'_\lambda(l)} = \frac{1}{4\pi} \int i'_\lambda(l) d\omega \quad (4)$$

Two different spectrally averaged absorption coefficients are useful to define: the incident-mean, a_i ,

$$a_i(l) \equiv \int_0^\infty \overline{i'_\lambda(l)} a_\lambda(l) d\lambda / \overline{i'_\lambda(l)} \quad (5)$$

and the Planck-mean, a_p ,

$$a_p(l) \equiv \int_0^\infty i_{b,\lambda}(l) a_\lambda(l) d\lambda / i_b(l) \quad (6)$$

The denominators in eqs (5) and (6) are, respectively, the average incident intensity (integral of eq (4) over wavelength) and the blackbody intensity, $\sigma T^4/\pi$. The l functionality persists because the medium is generally nonhomogeneous.

The divergence of the radiative flux vector, q_r , (which is equal to the source term in the generalized energy equation) can then be written in terms of the mean coefficients (Siegel and Howell, 1981) as

$$-\nabla \cdot q_r(l) = 4\pi a_i(l) i_i(l) - 4\pi a_p(l) i_b(l) . \quad (7)$$

The first version of RADCAL was developed to predict the enhancement in radiation caused by the addition of pulverized coal to a 60 kW methanol-fired furnace (Grosshandler, 1976). The program solved the equations for the single-line group model (SLG) as listed in Table 5-18 of the **Handbook of Infrared Radiation from Combustion Gases** (Ludwig, *et al.*, 1973). A combination of molecular models and data tables were used for the spectral properties of carbon dioxide, water vapor, and carbon monoxide, and contributions to the radiant intensity from the soot, ash and coal particles were handled with scattering neglected.

Validation of RADCAL was documented in a Factory Mutual Research Technical Report (Grosshandler, 1979), in which published experimental data were compared to the predictions of the numerical code for CO₂, H₂O, and CO individually and in mixtures. Spectral and total intensity experiments were examined, and the fidelity of the program for both isothermal and nonisothermal conditions was investigated. The spectrum between 1.25 and 12.5 μm was satisfactorily reproduced, although some of the data at particular wavelengths differed from the prediction by as much as 17%. Considerable disagreement occurred between the integrated emittance of CO₂ as predicted from RADCAL and that computed from the charts of Hottel (1954). No one source for this disagreement was identified, but it was thought to be a combination of the difficulty in obtaining high accuracy spectral measurements under the full range of conditions investigated, the uncertainty associated with extrapolating total transmittance results beyond the measured temperature and pressure-pathlengths, and the approximations associated with the narrow-band models.

RADCAL was used as the benchmark for a simplified, non-spectral model, TTNH, which was designed to estimate the radiant intensity from combustion gas mixtures (Grosshandler, 1980). The total transmittance nonhomogeneous gas model (TTNH) was able to reproduce the narrow-band results from RADCAL within an error band of about 10% for a range of pathlengths between 0.2 and 2 m, temperatures between 800 and 1800 K, CO₂/H₂O ratios between 1/2 and 2, and for a total pressure of 101 kPa. The advantage of TTNH over RADCAL is its two orders-of-magnitude faster computational time.

Methane was added to the data base of RADCAL (Grosshandler and Nguyen, 1985) and the spectral region over which the calculations could be made was extended to 200 μm . The current version of the program accounts for a radiating boundary, computes various absorption coefficients, has eliminated errors which were promulgated by the NASA report (Ludwig, *et al.*, 1973), and has a more convenient data input. Table 1 summarizes the species currently in RADCAL, which molecular bands are modeled, and how they are modeled. The accuracy of the calculations are limited to those of the individual models at temperatures, pressures, and

Table 1. Molecular bands included in RADCAL

<u>Species</u>	<u>Band</u>	<u>Method</u>	<u>Reference</u>
CO ₂	2.0 μm	modeled	9
CO ₂	2.7 μm	modeled	1
CO ₂	4.3 μm	modeled	2
CO ₂	10 μm	modeled	9
CO ₂	15 μm	tabulated	3
H ₂ O	1.38 μm	tabulated	3
H ₂ O	1.88 μm	tabulated	3
H ₂ O	2.7 μm	tabulated	3
H ₂ O	6.3 μm	tabulated	3
H ₂ O	20-200 μm	tabulated	3
CO	4.6 μm	modeled	4
CH ₄	2.4 μm	modeled	5,6
CH ₄	3.3 μm	tabulated	7,8
CH ₄	7.7 μm	tabulated	7,8
soot	0.4-2000 μm	modeled	10

- | | | |
|-------------------------------|-------------------------|---------------------------------|
| 1. Malkmus, 1963a | 2. Malkmus, 1963b | 3. Ludwig, <i>et al.</i> , 1973 |
| 4. Malkmus and Thomson, 1961 | 5. Vincent-Geisse, 1955 | 6. Gray and Penner, 1965 |
| 7. Brosmer and Tien, 1985 | 8. Lee and Happel, 1984 | 9. Leckner, 1971 |
| 10. Dalzell and Sarofim, 1969 | | |

pathlengths for which the models were originally developed. In general, RADCAL is likely to be less accurate at temperatures below 295 or greater than 2500 K, at pressures over 1.0 MPa, and at distances greater than 50 m.

Applications of the program are demonstrated in the next section, and details of data input and parameter definition are given in the last section. A full listing of the fortran code is included in the appendix.

III. SAMPLE APPLICATIONS OF RADCAL

Computational results from earlier versions of RADCAL have been presented in several references (e.g., Grosshandler, 1979; Grosshandler, 1980; Grosshandler and Modak, 1981; Grosshandler and Thurlow, 1992). Several of these calculations have been verified with the latest version of RADCAL and are included here as baseline cases.

Hottel's charts (1954) are often referenced as the source of total emittance data for

carbon dioxide and water vapor. Estimates of CO₂ emittance from the current version of RADCAL as a function of pressure-pathlength are compared to what one calculates from Hottel (1954) in Figure 1. The results are in better agreement than indicated in an earlier study (Grosshandler, 1979) because the 15 μm band is now included and an error in the tabulated data of Ludwig *et al.* (1973) has been corrected. From Figure 2, it can be seen that the two techniques diverge somewhat at the highest and lowest temperatures for a pressure-pathlength of 18.5 kPa-m. Discrepancies seen previously in the H₂O data remain, with RADCAL predicting greater emittance for all pressure-pathlengths at 1500 K, as shown in Figure 3. The open circles are data taken from Ludwig, *et al.* (1973), and indicate that, not surprisingly, RADCAL is in full agreement with the reference upon which it is based. Hottel and RADCAL are more consistent with each other at intermediate temperatures, as can be seen in Figure 4 for the case of a PL = 15.4 kPa-m. Ludwig (1973) pointed out that the earlier work by Hottel covered a more limited range of conditions and attempted to minimize the number of parameters for engineering estimates, and, thus, should not be expected to be as accurate as the narrow-band calculations.

Figure 5 is a spectral radiance calculation from a simulated 1.0 m diameter fire containing CO₂, H₂O and soot at the levels indicated in Table 2 (Grosshandler, 1979; Grosshandler and Modak, 1981). The total intensity integrates to 33.77 kW/m²/sr. The spectral transmittance is also plotted in the figure. The major water and carbon dioxide bands are easily identifiable within the continuous soot spectrum.

Figure 6 represents the spectral intensity radiated upstream in a premixed methane/N₂/O₂ flame at 606 kPa. Temperature and concentration profiles are listed in Table 3. In addition to carbon dioxide and water vapor, the molecular bands of CO and CH₄ are observable in this soot-free simulation. The program computes a total radiant intensity of 15.71 kW/m²/sr.

The spectral transmittance one might measure through a 320 K plume rising above material slowly pyrolyzing in atmospheric pressure air is shown in Figure 7. The concentrations of CO₂, H₂O, CH₄, and CO are uniform and equal 10 ppm (vol.) across the 0.5 m plume diameter, and it is assumed that smoke is present with a volume fraction of 10⁻⁸. Even at these low concentrations the spectral character is evident, but the transmittance is close to 1.0 everywhere but in 4.3 and 15 μm CO₂ bands.

IV. PROGRAM STRUCTURE

Figure 8 is a diagram of the structure of the program. The numerical code consists of a short main program which reads the temperature and concentration information from the data file, RC.DAT. SUBROUTINE RADCAL is called from the main program to perform all of the calculations listed in Table 5-18 of Ludwig, *et al.* (1973), and contains the instructions for printing the results into a file called RCOUT.DAT.

RADCAL relies upon four subroutines to compute the narrow-band parameters for the

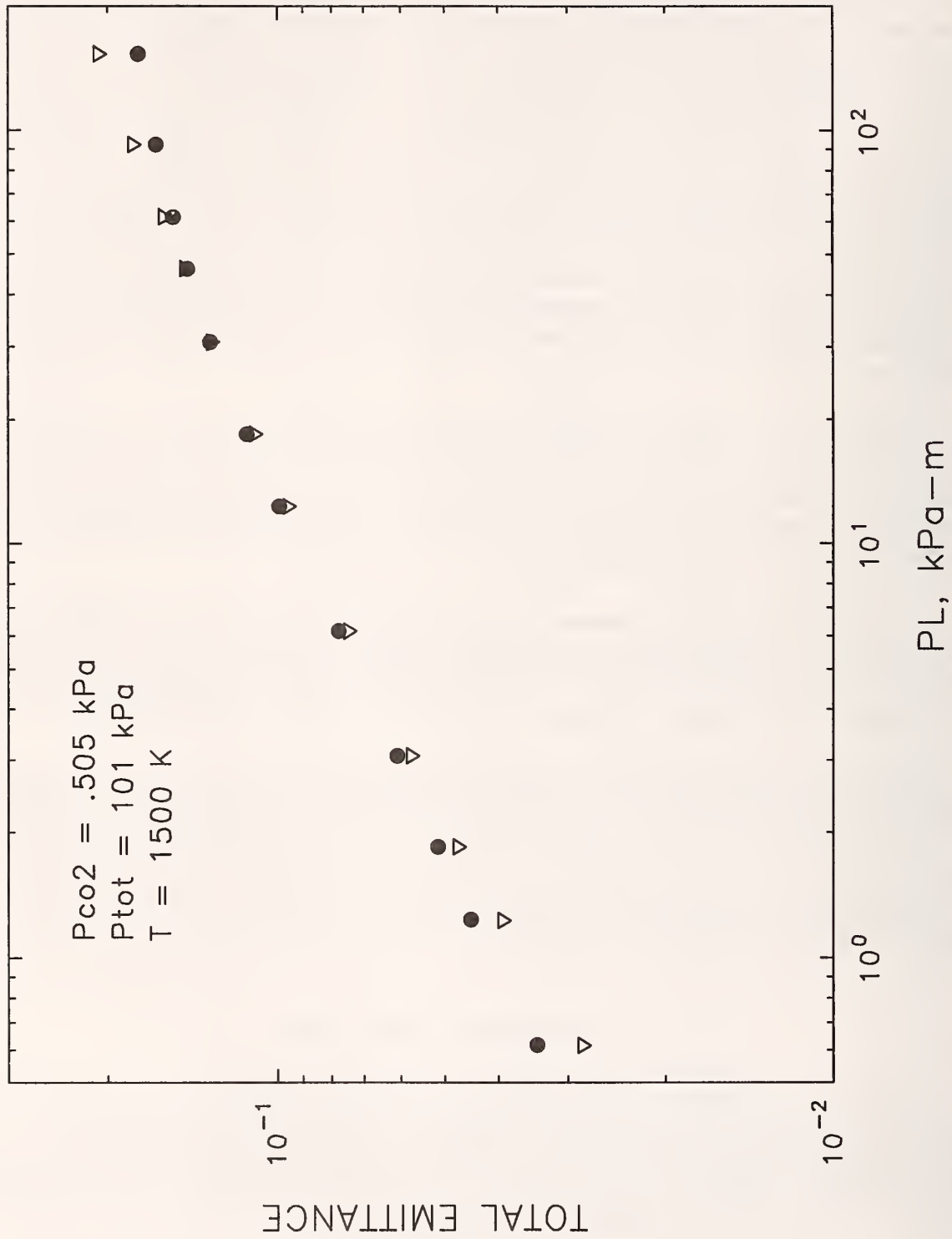


Figure 1. Total emittance of carbon dioxide/air mixtures as a function of pressure-pathlength, comparing RADCAL (filled circles) to the measurements of Hottel (1954) (triangles).

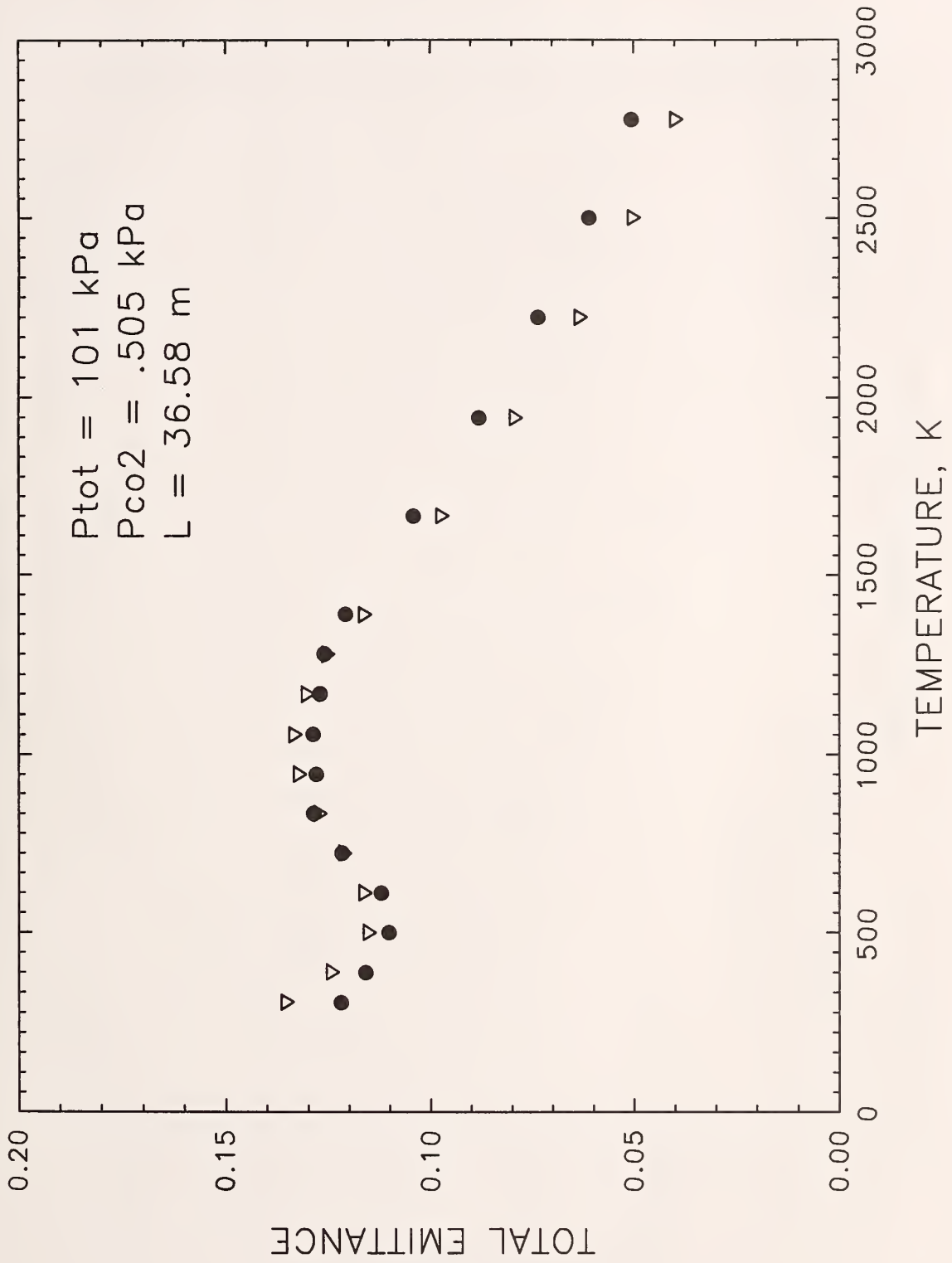


Figure 2. Total emittance of carbon dioxide/air mixtures as a function of temperature, comparing RADCAL (filled circles) to the measurements of Hottel (1954) (triangles).

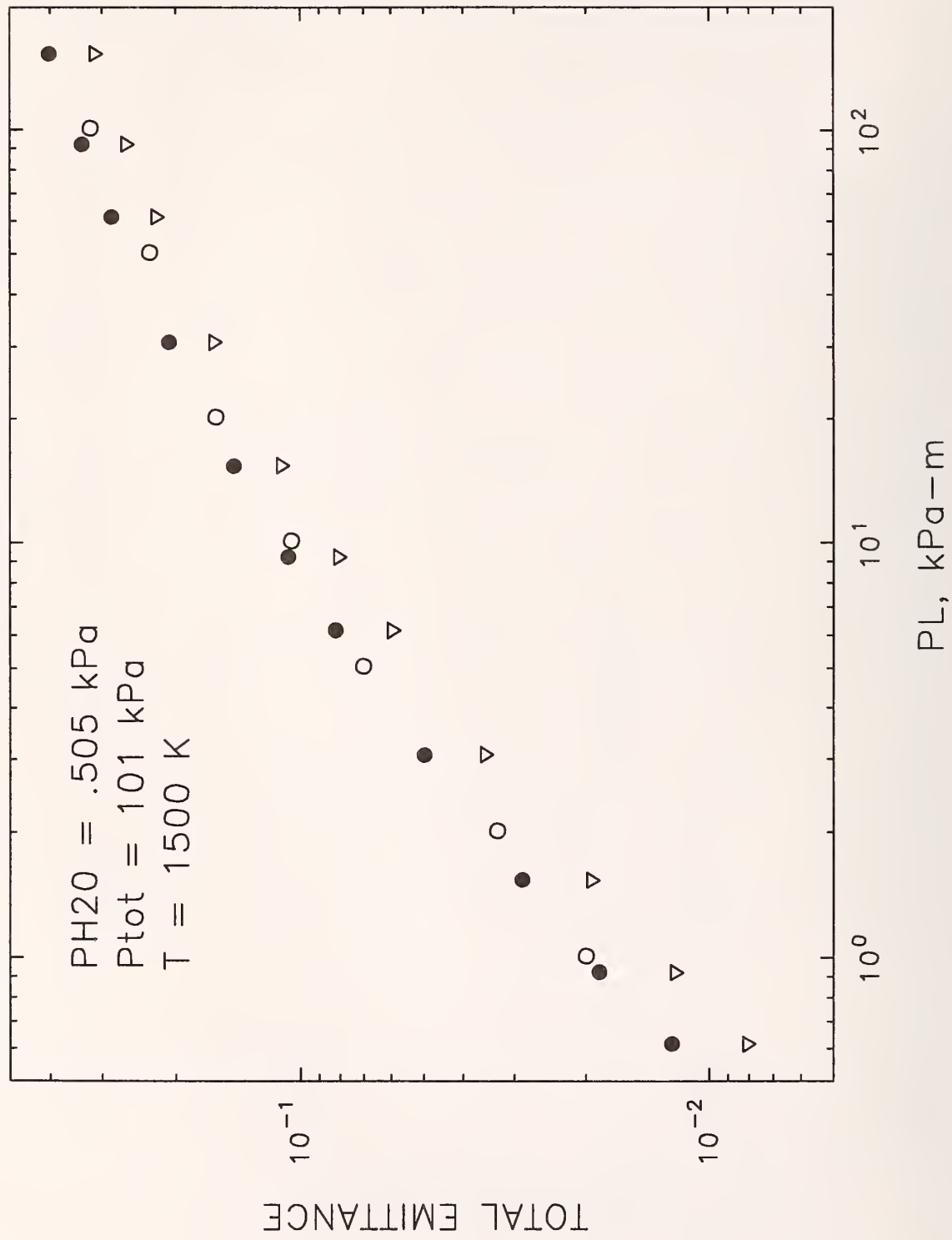


Figure 3. Total emittance of water vapor/air mixtures as a function of pressure-pathlength, comparing RADCAL (filled circles) to the measurements of Hottel (1954) (triangles). The open circles are taken from Fig. 6-33 of Ludwig, *et al.* (1973).

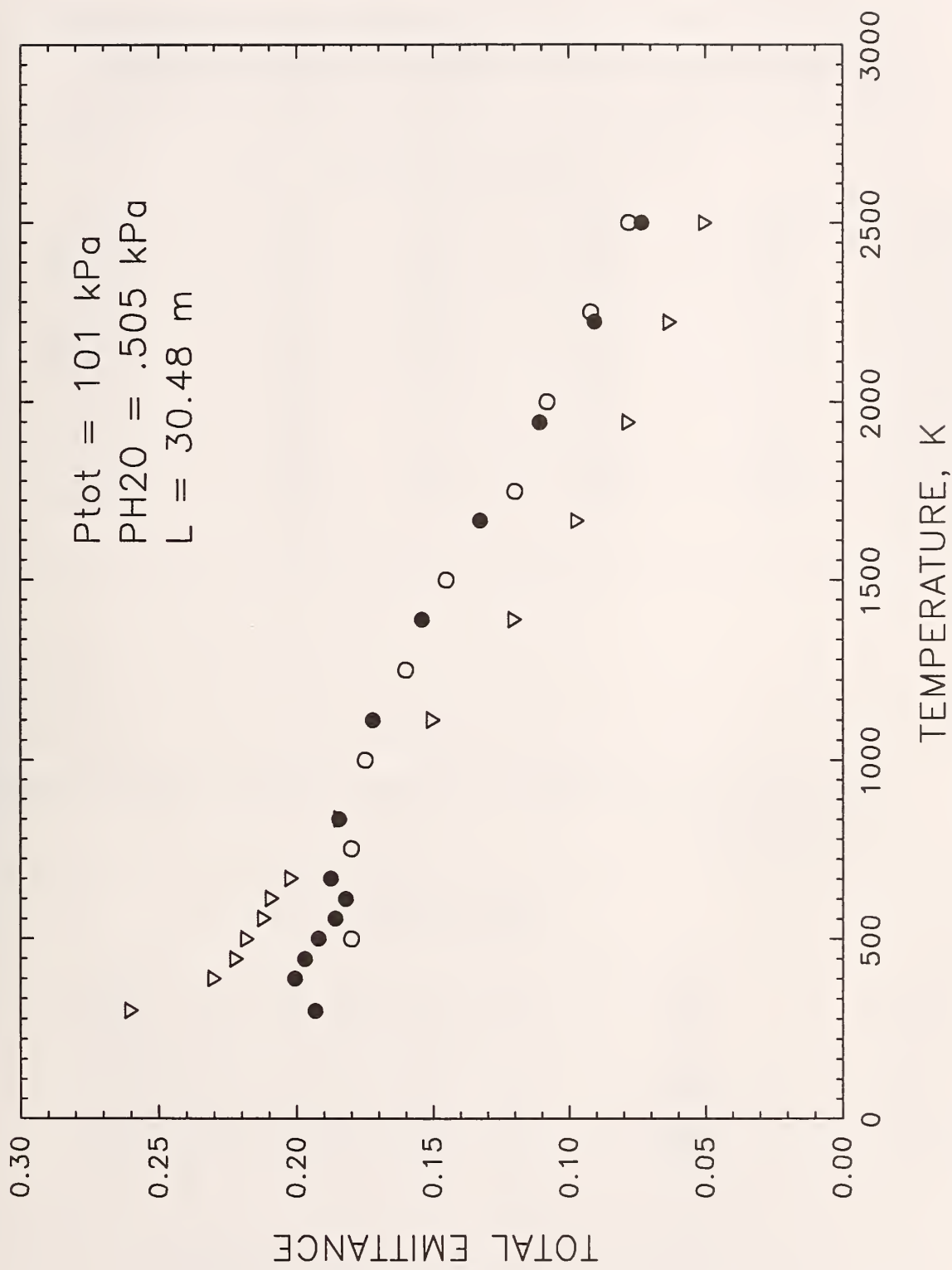


Figure 4. Total emittance of water vapor/air mixtures as a function of temperature, comparing RADCAL (filled circles) to the measurements of Hottel (1954) (triangles). The open circles are taken from Fig. 6-33 of Ludwig, *et al.* (1973).

Table 2. Radial profiles through simulated one meter diameter pool fire

Partial Pressures, kPa						
<u>Dist., m</u>	<u>Temp., K</u>	<u>CO₂</u>	<u>H₂O</u>	<u>N₂</u>	<u>Soot, f_v</u>	
0.05	899	7.07	7.07	86.8	5.55x10 ⁻⁸	
0.10	1158	10.0	10.0	81.0	5.55x10 ⁻⁸	
0.20	1438	13.1	13.1	74.7	5.55x10 ⁻⁸	
0.30	1637	15.4	15.4	70.3	5.55x10 ⁻⁸	
0.50	1770	16.9	16.9	67.3	5.55x10 ⁻⁸	
0.70	1637	15.4	15.4	70.3	5.55x10 ⁻⁸	
0.80	1438	13.1	13.1	74.7	5.55x10 ⁻⁸	
0.90	1158	10.0	10.0	81.0	5.55x10 ⁻⁸	
0.95	899	7.07	7.07	86.8	5.55x10 ⁻⁸	

Table 3. Line-of-sight profiles through 20 mm thick, simulated, fuel-rich premixed methane/O₂/N₂ flame

Partial Pressures, kPa							
<u>Dist., m</u>	<u>Temp., K</u>	<u>CO₂</u>	<u>H₂O</u>	<u>CH₄</u>	<u>CO</u>	<u>O₂</u>	<u>N₂</u>
0.001	300	0.0	0.0	122.2	0.0	185.8	298.0
0.003	725	0.0	58.6	92.9	29.3	139.4	285.8
0.005	1150	0.0	117.2	62.6	59.6	97.5	274.7
0.007	1575	0.0	181.8	31.3	98.0	49.5	264.6
0.009	2000	5.0	224.2	10.1	107.1	15.2	256.5
0.015	2525	5.0	244.4	0.0	117.2	0.0	254.5

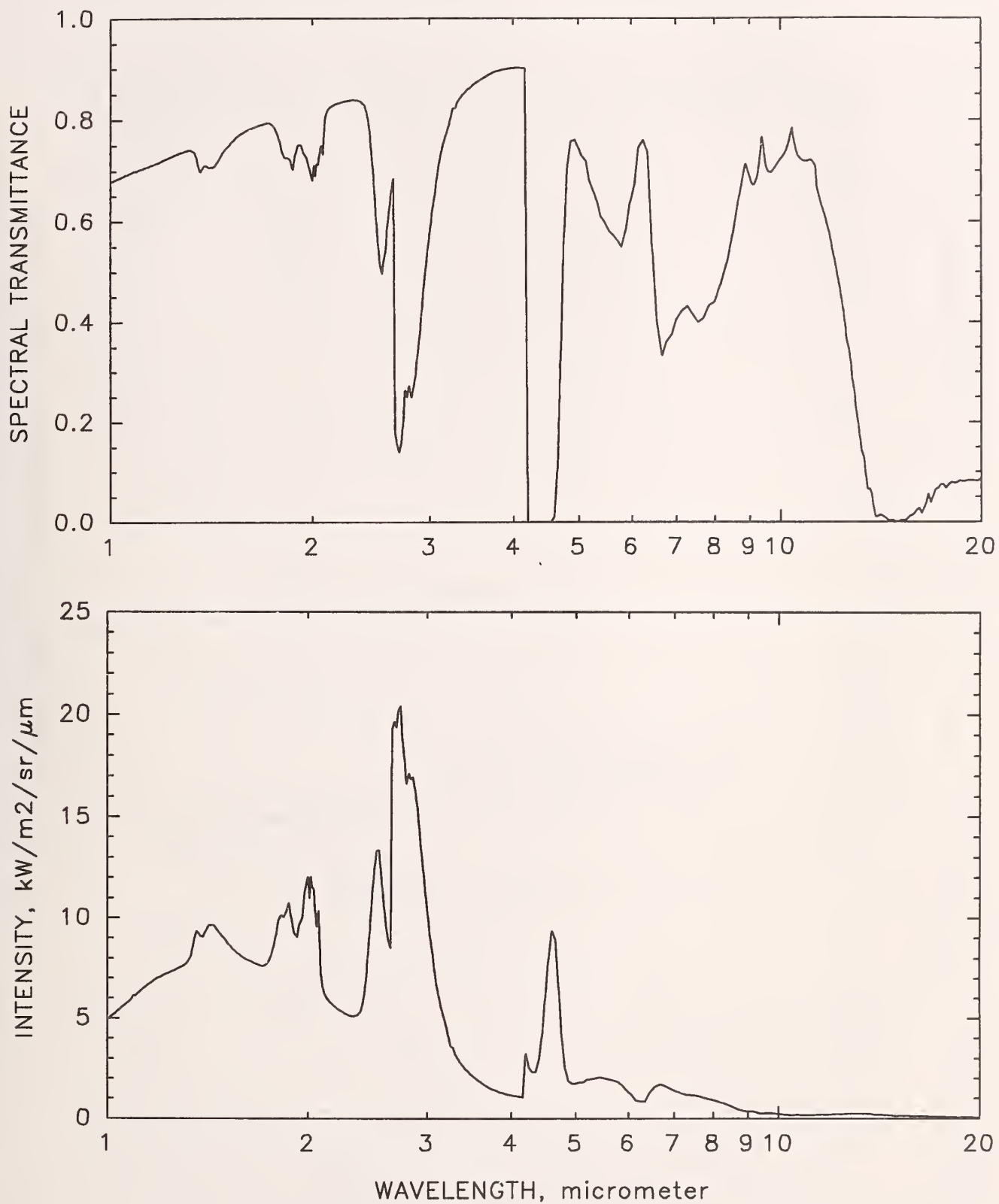


Figure 5. Spectral intensity and transmittance in simulated pool fire with profile as given in Table 2.

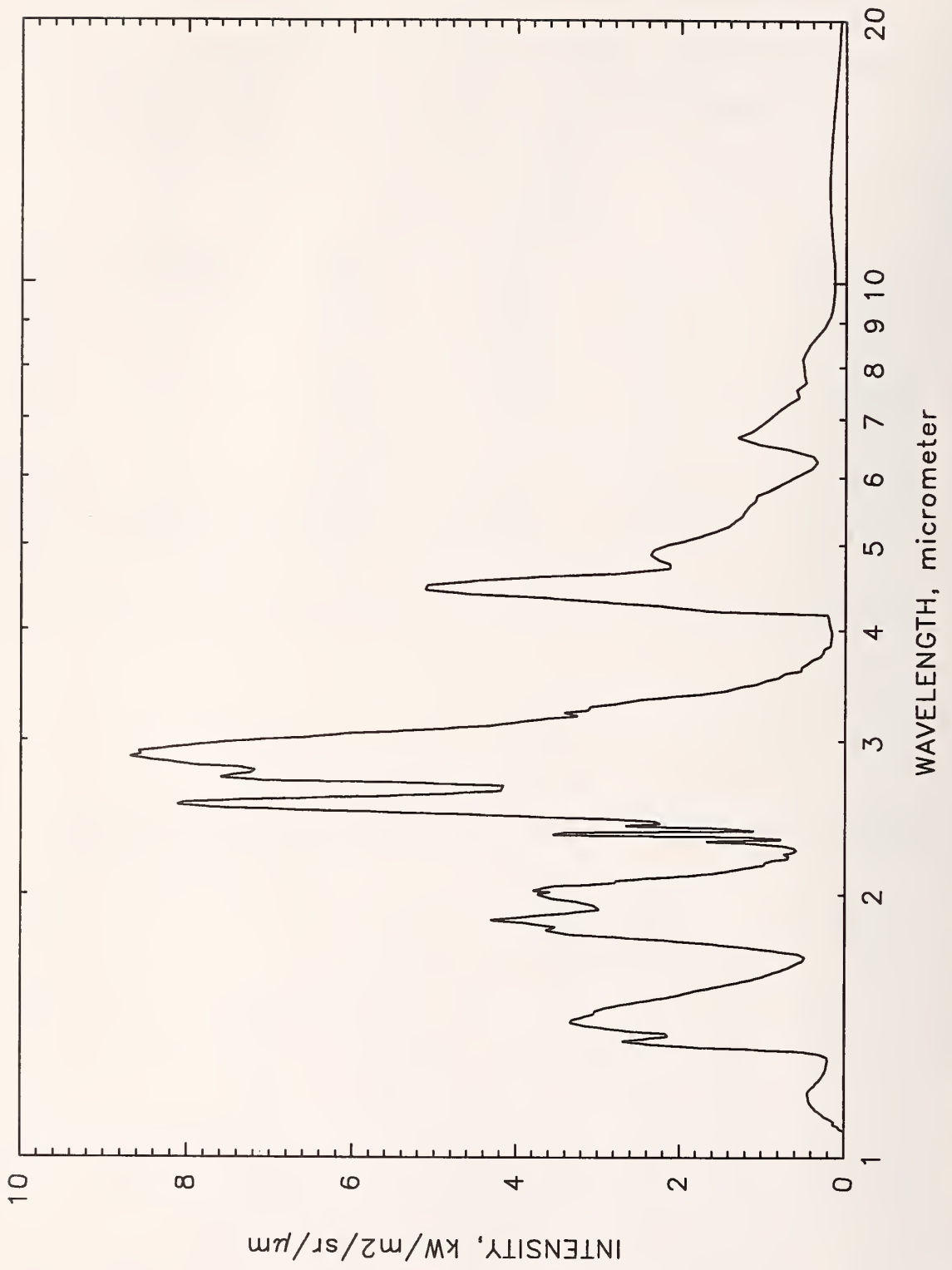


Figure 6. Spectral intensity from simulated premixed methane/oxygen/nitrogen flame with profile as given in Table 3.

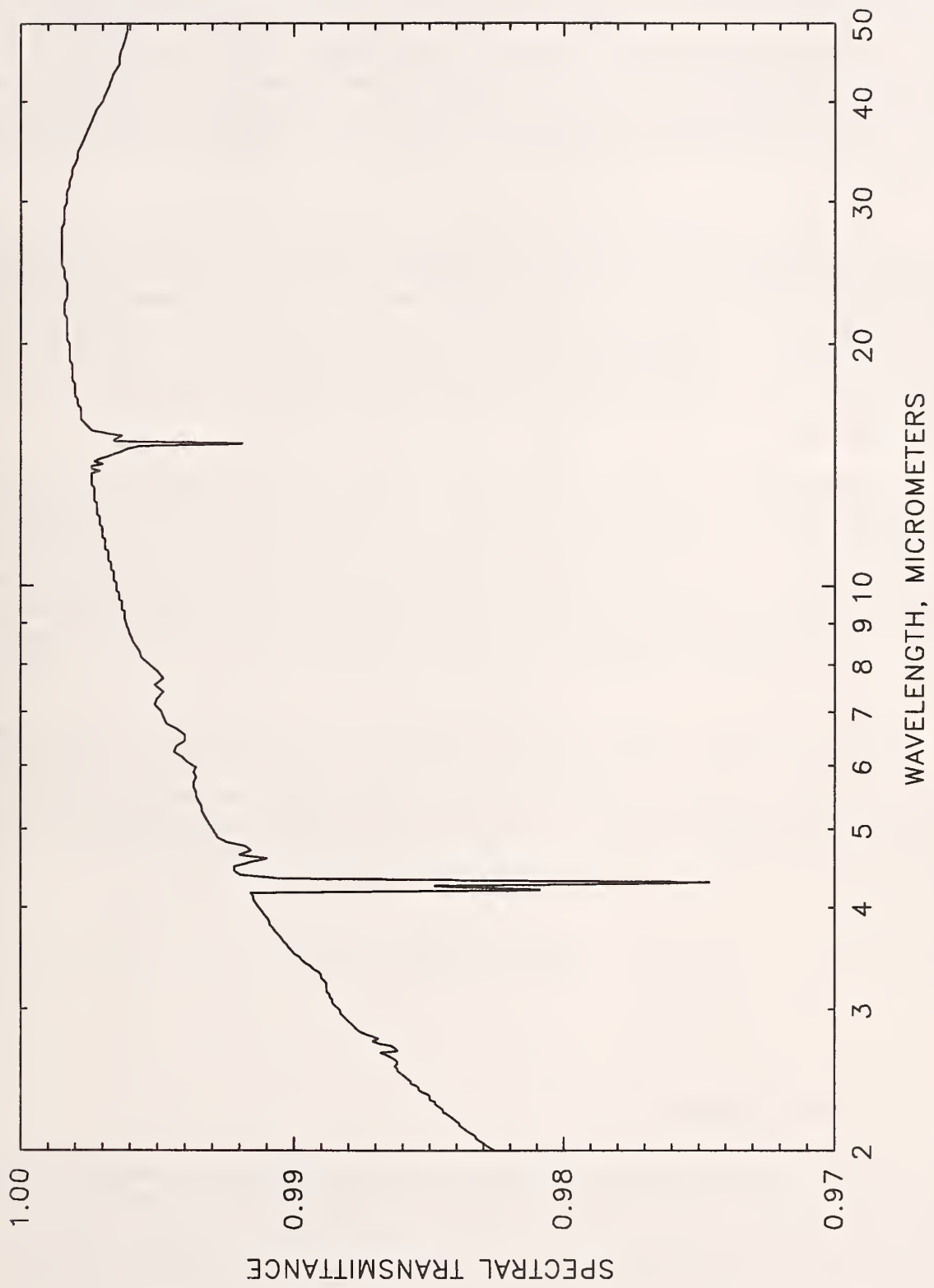


Figure 7. Spectral transmittance through simulated 1/2 meter diameter plume of pyrolysis gases consisting of 10 ppm (vol.) each of CO_2 , H_2O , CH_4 , and CO and .01 ppm soot in atmospheric pressure air. $T = 320 \text{ K}$.

carbon dioxide (SUBROUTINE CO2), water vapor (SUBROUTINE H2O), carbon monoxide (SUBROUTINE CO), and methane (SUBROUTINE FUEL). Two large block data files (BLOCK DATA BD1 and BLOCK DATA BD2) contain the absorption coefficient of water vapor as a function of temperature and wave number (Table A2-35 of Ludwig, *et al.* (1973)). A third data file, BLOCK DATA BD3, contains similar information for the 15.0 μm band of CO₂ (Table A2-28 of Ludwig, *et al.*, 1973), and the 3.3 and 7.4 μm bands of CH₄ (Brosmer and Tien, 1985). Line broadening parameters of Ludwig, *et al.* (1973) are listed at the beginning of BD3.

The spectral optical depth is calculated in SUBROUTINE RADCAL from the band-averaged absorption and line-width-to-line-spacing parameters (computed in the species subroutines), with a curve-of-growth based upon the particular species pressure-pathlength and with nonisothermal effects accounted for by the Curtis-Godson method. The particle optical depth is calculated in SUBROUTINE POD assuming the soot is in the Rayleigh limit with an albedo of zero. This value is added, in SUBROUTINE RADCAL, to the contributions from the gaseous species to determine the combined spectral optical depth.

SUBROUTINE RADCAL uses the optical depth to determine the spectral transmittance and intensity (calling FUNCTION PLANCK to evaluate the Planck blackbody intensity) as each new spatial element is added to the radiating path. Radiation from the far wall is counted after being attenuated by the calculated transmittance along the total length of the path. The spectral intensity is integrated across the spectrum to determine the total directional radiated energy flux. SUBROUTINE RADCAL separately computes the radiation from the soot for regions of the spectrum above and below the limits for the gas bands.

When the path contains only one element (*i.e.*, it is isothermal and of uniform composition) three different absorption coefficients are calculated: the Planck-mean based upon the gas temperature (eq (6)), the incident-mean based upon the wall temperature (eq (5)), and the effective absorption coefficient, a_e . The effective absorption coefficient is used to calculate the total radiant intensity, i , leaving a uniform gas bounded by a black wall; *i.e.*,

$$i = \frac{\sigma}{\pi} [(1 - e^{-a_e L}) T^4 + e^{-a_e L} T_w^4] \quad (8)$$

A. input parameters

The input data file, RC.DAT, is in free format, with the first line containing the number of elements (maximum of 50) into which the path is divided, NPT. The second line lists the size of the first element in meters, DD(1), its temperature in Kelvin, T(1), and the partial pressures in kilopascals of carbon dioxide, P(1,1), water vapor, P(1,2), methane, P(1,3), carbon monoxide, P(1,4), oxygen, P(1,5) and nitrogen, P(1,6). The last entry on the second line is the

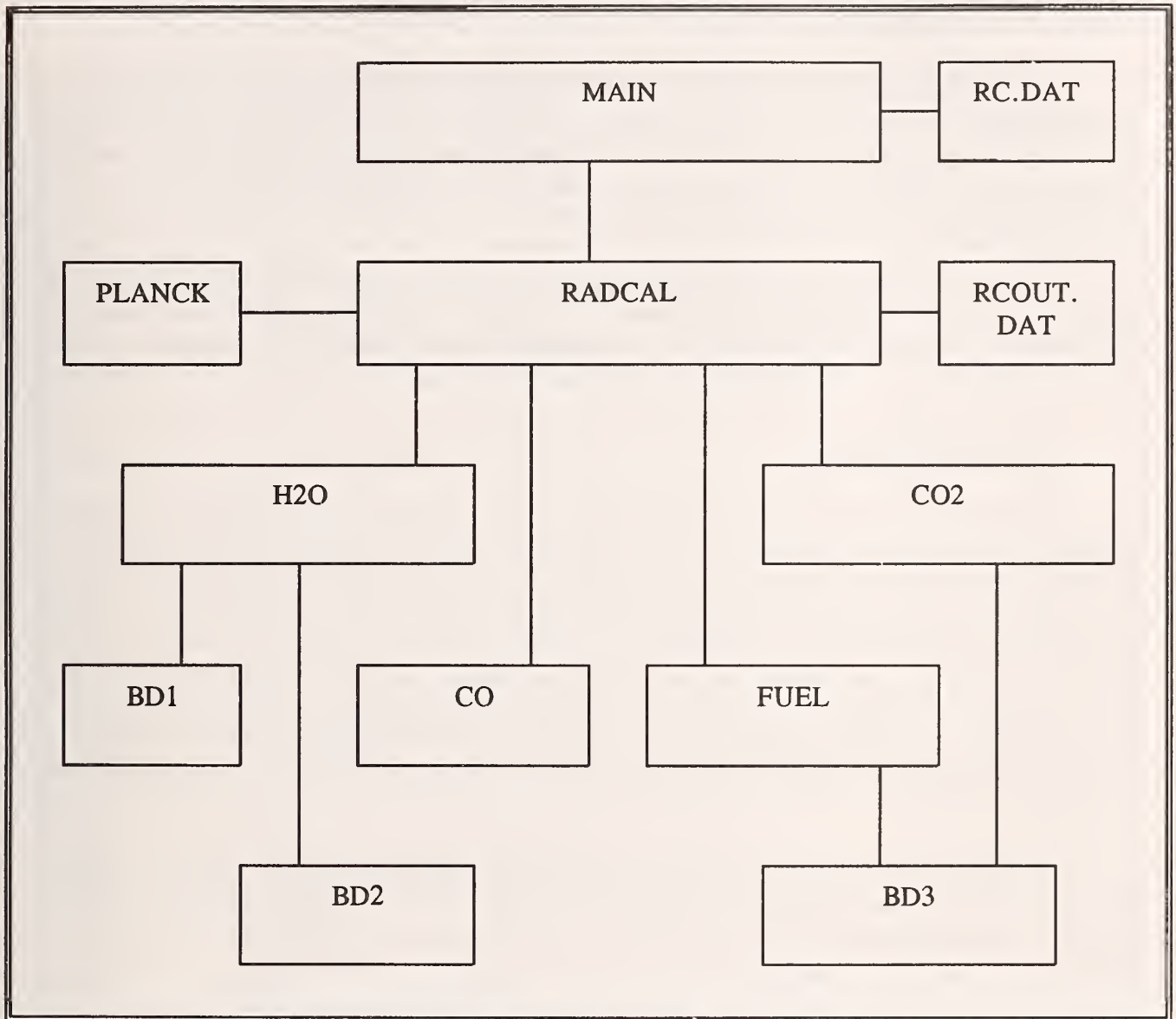


Figure 8. Structure of radiation calculation program RADCAL.

volume fraction of soot in the first element, $W(1)$. It is important to remember that the first element is located at the point in space for which the intensity is desired, and not at the far boundary of the computational volume.

The third line contains the size, temperature, species partial pressures, and soot volume fraction for the second element. Similar data is entered for the remainder of the NPT elements. Following this information is a line containing the wall temperature in Kelvin, $TWALL$, and the minimum and maximum wavenumbers in cm^{-1} , $OMMIN$ and $OMMAX$. Normally, there is no need to go below 50 cm^{-1} or above $10,000 \text{ cm}^{-1}$.

Additional cases can be stacked one upon another, but no data are carried over from the previous case even if they remain unchanged. The program terminates when it reads 0 for the value of NPT. Table 4 summarizes the input parameters and gives their limiting values.

B. output parameters

The results of the calculations can be found in the output file, $RCOUT.DAT$. The input conditions are summarized in tabular form, followed by the total directional radiated energy flux emanating outward from element one, Q . The spectral intensity, $QW(K)$, and transmittance, $TTAU(K)$, are listed for each wavelength, $AMBDA(K)$. The number of wavelengths computed is limited to 600, and the wavelength intervals vary between $0.005 \mu\text{m}$ (50 cm^{-1}) at $1.0 \mu\text{m}$ and $18.2 \mu\text{m}$ (5 cm^{-1}) at $200 \mu\text{m}$. For the special case of a uniform pathlength with only one element, the program also calculates the effective absorption coefficient, $AMEAN$, the Planck-mean absorption coefficient, APO , and the wall-incident-mean absorption coefficient, $AIWALL$. Additional parameters which are used within the different subroutines are defined in the Glossary.

Table 5 lists the output of the single uniform element case plotted in Figure 7. Only a few spectral entries are included for the sake of brevity. The output for the non-isothermal condition described in Table 2, and plotted over the full spectral range in Figure 5, is given in Table 6.

Table 4. Input data for RC.DAT

parameter	definition	units	range*	line numbers
NPT	number of spatial elements	none	1 to 50	1
DD(J)	length of Jth element	meters	10^{-4} to 10^3 m	2 to (NPT+1)
T(J)	temperature	Kelvin	270 to 2500 K	2 to (NPT+1)
P(1,J)	partial pressure of CO ₂	kilopascals	0 to 10 MPa	2 to (NPT+1)
P(2,J)	partial pressure of H ₂ O	kilopascals	0 to 10 MPa	2 to (NPT+1)
P(3,J)	partial pressure of CH ₄	kilopascals	0 to 10 MPa	2 to (NPT+1)
P(4,J)	partial pressure of CO	kilopascals	0 to 10 MPa	2 to (NPT+1)
P(5,J)	partial pressure of O ₂	kilopascals	0 to 10 MPa	2 to (NPT+1)
P(6,J)	partial pressure of N ₂	kilopascals	0 to 10 MPa	2 to (NPT+1)
W(J)	volume fraction of soot	m ³ /m ³	0 to 10^{-3}	2 to (NPT+1)
TWALL	far wall temperature	K	0 to 5000 K	(NPT+2)
OMMIN	minimum wavenumber	cm ⁻¹	50 cm ⁻¹	(NPT+2)
OMMAX	maximum wavenumber	cm ⁻¹	10,000 cm ⁻¹	(NPT+2)

*The accuracy of the program outside of the range where experimental data are available is limited to the accuracy of the original references.

Table 5. Sample output from RCOUT.DAT with isothermal, uniform path

Radial Profiles

Partial Pressures, kPa

J	dist,m	temp,K	CO2	H2O	CH4	CO	O2	N2	FV
1	.5000	320.	.001	.001	.001	.001	20.200	80.800	.1000E-07
wall		295.							

Total directional radiated energy flux = .136910E+03 Watts/m-2/strad

Spectral Intensity Distribution, Watts/m-2/ μ m/strad

wavelength	intensity	tau	wavelength	intensity	tau
3.125	.6838E-01	.9887	28.169	.1445E+01	.9984
3.175	.8059E-01	.9888	28.986	.1329E+01	.9984
3.200	.8745E-01	.9888	29.412	.1273E+01	.9984
3.252	.1029E+00	.9889	30.303	.1165E+01	.9983
3.361	.1417E+00	.9893	32.258	.9646E+00	.9981
3.419	.1660E+00	.9896	33.333	.8720E+00	.9980
3.448	.1795E+00	.9897	33.898	.8277E+00	.9979
3.509	.2098E+00	.9900	35.088	.7430E+00	.9978
3.540	.2266E+00	.9901	35.714	.7026E+00	.9977
3.636	.2852E+00	.9904	37.736	.5893E+00	.9974
3.704	.3318E+00	.9906	39.216	.5204E+00	.9972
3.738	.3577E+00	.9907	40.000	.4879E+00	.9970
3.846	.4468E+00	.9909	42.553	.3979E+00	.9967
3.922	.5170E+00	.9911	44.444	.3442E+00	.9964
3.960	.5558E+00	.9912	45.455	.3191E+00	.9964
4.040	.6413E+00	.9914	47.619	.2726E+00	.9962
4.082	.6884E+00	.9915	48.780	.2511E+00	.9961
4.167	.7919E+00	.9916	51.282	.2115E+00	.9960
4.211	.8621E+00	.9809	52.632	.1933E+00	.9960
4.301	.9969E+00	.9746	55.556	.1601E+00	.9960
4.348	.1043E+01	.9907	57.143	.1451E+00	.9960
4.444	.1190E+01	.9922	60.606	.1179E+00	.9961
4.494	.1271E+01	.9922	62.500	.1057E+00	.9961
4.598	.1449E+01	.9910	66.667	.8390E-01	.9963
4.651	.1543E+01	.9920	68.966	.7426E-01	.9964
4.819	.1861E+01	.9925	76.923	.4997E-01	.9969
4.878	.1977E+01	.9928	80.000	.4329E-01	.9970
5.000	.2229E+01	.9930	86.957	.3185E-01	.9975

The effective absorption coef. is .894161E-02/m
 The Planck-mean absorption coef. is .673106E-02/m
 The wall-incident mean is .632162E-02/m

Table 6. Sample output from RCOUT.OUT with nonhomogeneous input conditions

Radial Profiles

Partial Pressures, kPa

J	dist,m	temp,K	CO2	H2O	CH4	CO	O2	N2	FV
1	.0500	899.	7.070	7.070	.000	.000	.000	86.800	.5550E-07
2	.1000	1158.	10.000	10.000	.000	.000	.000	81.000	.5550E-07
3	.1000	1438.	13.100	13.100	.000	.000	.000	74.700	.5550E-07
4	.1000	1637.	15.400	15.400	.000	.000	.000	70.300	.5550E-07
5	.3000	1770.	16.900	16.900	.000	.000	.000	67.300	.5550E-07
6	.1000	1637.	15.400	15.400	.000	.000	.000	70.300	.5550E-07
7	.1000	1438.	13.100	13.100	.000	.000	.000	74.700	.5550E-07
8	.1000	1158.	10.000	10.000	.000	.000	.000	81.000	.5550E-07
9	.0500	899.	7.070	7.070	.000	.000	.000	86.800	.5550E-07
wall		0.							

Total directional radiated energy flux = .337731E+05 Watts/m-2/strad

Spectral Intensity Distribution, Watts/m-2/μm/strad

w.l.	intensity	tau	w.l.	intensity	tau	w.l.	intensity	tau	w.l.	intensity	tau
1.005	.4981E+04	.6794	6.061	.1187E+04	.6708	2.198	.5553E+04	.8340	16.000	.1248E+03	.0244
1.010	.5046E+04	.6807	6.154	.9046E+03	.7455	2.210	.5493E+04	.8349	16.129	.1220E+03	.0276
1.015	.5111E+04	.6820	6.250	.8433E+03	.7598	2.222	.5441E+04	.8355	16.260	.1151E+03	.0172
1.020	.5177E+04	.6834	6.349	.8481E+03	.7371	2.235	.5373E+04	.8366	16.393	.1132E+03	.0247
1.026	.5242E+04	.6847	6.452	.1305E+04	.5433	2.247	.5336E+04	.8369	16.529	.1118E+03	.0369
1.031	.5307E+04	.6860	6.557	.1582E+04	.3942	2.260	.5277E+04	.8378	16.667	.1082E+03	.0557
1.036	.5373E+04	.6874	6.667	.1717E+04	.3330	2.273	.5228E+04	.8384	16.807	.1047E+03	.0385
1.042	.5438E+04	.6887	6.780	.1607E+04	.3618	2.286	.5181E+04	.8389	16.949	.1014E+03	.0514
1.047	.5503E+04	.6900	6.897	.1499E+04	.3751	2.299	.5138E+04	.8393	17.094	.9767E+02	.0659
1.053	.5569E+04	.6914	7.018	.1368E+04	.4061	2.312	.5124E+04	.8391	17.241	.9467E+02	.0686
1.058	.5634E+04	.6927	7.143	.1272E+04	.4224	2.326	.5098E+04	.8390	17.391	.9110E+02	.0754
1.064	.5699E+04	.6941	7.273	.1184E+04	.4316	2.339	.5101E+04	.8384	17.544	.8796E+02	.0754
1.070	.5764E+04	.6954	7.407	.1155E+04	.4151	2.353	.5147E+04	.8366	17.699	.8539E+02	.0671
1.075	.5829E+04	.6968	7.547	.1120E+04	.3994	2.367	.5143E+04	.8359	17.857	.8187E+02	.0756
1.081	.5899E+04	.6980	7.692	.1058E+04	.4079	2.381	.5246E+04	.8322	18.018	.7857E+02	.0791
1.087	.5965E+04	.6993	7.843	.9627E+03	.4337	2.395	.5340E+04	.8289	18.182	.7570E+02	.0785
1.093	.6139E+04	.6980	8.000	.9147E+03	.4411	2.410	.5704E+04	.8177	18.349	.7289E+02	.0783
1.099	.6105E+04	.7016	8.163	.8186E+03	.4747	2.424	.6139E+04	.8042	18.519	.6994E+02	.0819
1.105	.6174E+04	.7028	8.333	.7143E+03	.5182	2.439	.6892E+04	.7804	18.692	.6737E+02	.0812
1.111	.6249E+04	.7038	8.511	.5970E+03	.5749	2.454	.8025E+04	.7452	18.868	.6491E+02	.0814
1.117	.6324E+04	.7048	8.696	.4628E+03	.6495	2.469	.9151E+04	.7037	19.048	.6230E+02	.0832
1.124	.6395E+04	.7059	8.889	.3522E+03	.7129	2.484	.1021E+05	.6586	19.231	.5993E+02	.0828
1.130	.6465E+04	.7070	9.091	.3632E+03	.6725	2.500	.1159E+05	.5996	19.417	.5753E+02	.0831
1.136	.6533E+04	.7082	9.132	.3553E+03	.6729	2.516	.1263E+05	.5503	19.608	.5531E+02	.0821
1.143	.6599E+04	.7095	9.174	.3451E+03	.6762	2.532	.1333E+05	.5110	19.802	.5310E+02	.0820
1.149	.6663E+04	.7107	9.217	.3322E+03	.6828	2.548	.1334E+05	.4961	20.000	.5065E+02	.0871
1.156	.6728E+04	.7120	9.259	.3162E+03	.6937	2.564	.1254E+05	.5222	20.202	.4863E+02	.0863
1.163	.6788E+04	.7133	9.302	.2961E+03	.7100	2.581	.1141E+05	.5399	20.408	.4667E+02	.0855
1.170	.6850E+04	.7146	9.346	.2720E+03	.7318	2.597	.1034E+05	.5943	20.619	.4478E+02	.0848
1.176	.6907E+04	.7160	9.390	.2363E+03	.7667	2.614	.9393E+04	.6261	20.833	.4296E+02	.0842
1.183	.6966E+04	.7173	9.434	.2460E+03	.7515	2.632	.8849E+04	.6607	21.053	.4120E+02	.0836
1.190	.7018E+04	.7189	9.479	.2626E+03	.7272	2.649	.8499E+04	.6840	21.277	.3946E+02	.0833

Table 6. (continued)

w.l.	intensity	tau	w.l.	intensity	tau	w.l.	intensity	tau	w.l.	intensity	tau
1.198	.7058E+04	.7207	9.524	.2703E+03	.7124	2.667	.1935E+05	.1753	21.505	.3778E+02	.0831
1.205	.7102E+04	.7224	9.569	.2737E+03	.7028	2.685	.1964E+05	.1533	21.739	.3616E+02	.0828
1.212	.7146E+04	.7240	9.615	.2737E+03	.6977	2.703	.1936E+05	.1395	21.978	.3460E+02	.0826
1.220	.7193E+04	.7255	9.662	.2711E+03	.6963	2.721	.2019E+05	.1566	22.222	.3310E+02	.0825
1.227	.7230E+04	.7273	9.709	.2666E+03	.6977	2.740	.2039E+05	.1936	22.472	.3163E+02	.0828
1.235	.7278E+04	.7288	9.756	.2606E+03	.7011	2.759	.1874E+05	.2632	22.727	.3022E+02	.0831
1.242	.7321E+04	.7303	9.804	.2541E+03	.7051	2.778	.1785E+05	.2504	22.989	.2886E+02	.0834
1.250	.7354E+04	.7321	9.852	.2470E+03	.7097	2.797	.1662E+05	.3301	23.256	.2755E+02	.0838
1.258	.7400E+04	.7335	9.901	.2397E+03	.7145	2.817	.1709E+05	.2502	23.529	.2628E+02	.0841
1.266	.7443E+04	.7349	9.950	.2322E+03	.7190	2.837	.1683E+05	.2693	23.810	.2505E+02	.0850
1.274	.7486E+04	.7363	10.000	.2248E+03	.7231	2.857	.1693E+05	.2894	24.096	.2387E+02	.0859
1.282	.7532E+04	.7376	10.050	.2182E+03	.7263	2.878	.1642E+05	.3301	24.390	.2273E+02	.0867
1.290	.7571E+04	.7390	10.101	.2114E+03	.7297	2.899	.1557E+05	.3713	24.691	.2163E+02	.0876
1.299	.7639E+04	.7395	10.152	.2043E+03	.7339	2.920	.1452E+05	.4191	25.000	.2058E+02	.0884
1.307	.7687E+04	.7407	10.204	.1964E+03	.7396	2.941	.1332E+05	.4673	25.316	.1956E+02	.0899
1.316	.7770E+04	.7405	10.256	.1873E+03	.7476	2.963	.1220E+05	.5105	25.641	.1858E+02	.0913
1.325	.7909E+04	.7386	10.309	.1777E+03	.7572	2.985	.1111E+05	.5500	25.974	.1763E+02	.0927
1.333	.8095E+04	.7366	10.363	.1658E+03	.7709	3.008	.1001E+05	.5905	26.316	.1673E+02	.0941
1.342	.8524E+04	.7261	10.417	.1550E+03	.7833	3.030	.9034E+04	.6246	26.667	.1586E+02	.0956
1.351	.9011E+04	.7089	10.471	.1643E+03	.7642	3.053	.8281E+04	.6515	27.027	.1502E+02	.0977
1.361	.9320E+04	.6979	10.526	.1701E+03	.7500	3.077	.7399E+04	.6840	27.397	.1422E+02	.0998
1.370	.9217E+04	.7029	10.582	.1744E+03	.7383	3.101	.6549E+04	.7158	27.778	.1345E+02	.1019
1.379	.9073E+04	.7100	10.638	.1766E+03	.7299	3.125	.6023E+04	.7352	28.169	.1271E+02	.1040
1.389	.9044E+04	.7091	10.695	.1771E+03	.7244	3.150	.5463E+04	.7546	28.571	.1200E+02	.1062
1.399	.9281E+04	.7063	10.753	.1762E+03	.7213	3.175	.5021E+04	.7703	28.986	.1132E+02	.1091
1.408	.9447E+04	.7073	10.811	.1742E+03	.7201	3.200	.4556E+04	.7861	29.412	.1066E+02	.1120
1.418	.9644E+04	.7063	10.870	.1723E+03	.7190	3.226	.4112E+04	.8023	29.851	.1004E+02	.1150
1.429	.9643E+04	.7106	10.929	.1697E+03	.7190	3.252	.3598E+04	.8217	30.303	.9439E+01	.1180
1.439	.9622E+04	.7161	10.989	.1666E+03	.7197	3.279	.3519E+04	.8229	30.769	.8867E+01	.1211
1.449	.9534E+04	.7218	11.050	.1633E+03	.7207	3.306	.3149E+04	.8365	31.250	.8320E+01	.1249
1.460	.9385E+04	.7291	11.111	.1600E+03	.7216	3.333	.2972E+04	.8423	31.746	.7798E+01	.1288
1.471	.9231E+04	.7369	11.173	.1593E+03	.7181	3.361	.2764E+04	.8494	32.258	.7300E+01	.1328
1.481	.9111E+04	.7416	11.236	.1587E+03	.7140	3.390	.2625E+04	.8539	32.787	.6825E+01	.1369
1.493	.8975E+04	.7468	11.299	.1584E+03	.7093	3.419	.2462E+04	.8597	33.333	.6373E+01	.1411
1.504	.8866E+04	.7511	11.364	.1802E+03	.6634	3.448	.2357E+04	.8631	33.898	.5938E+01	.1465
1.515	.8706E+04	.7563	11.429	.1820E+03	.6534	3.478	.2232E+04	.8674	34.483	.5525E+01	.1521
1.527	.8591E+04	.7606	11.494	.1866E+03	.6376	3.509	.2101E+04	.8722	35.088	.5133E+01	.1579
1.538	.8457E+04	.7649	11.561	.1876E+03	.6283	3.540	.2002E+04	.8753	35.714	.4760E+01	.1639
1.550	.8350E+04	.7687	11.628	.1898E+03	.6162	3.571	.1912E+04	.8781	36.364	.4407E+01	.1701
1.563	.8224E+04	.7726	11.696	.1908E+03	.6063	3.604	.1799E+04	.8825	37.037	.4075E+01	.1771
1.575	.8150E+04	.7752	11.765	.1925E+03	.5947	3.636	.1721E+04	.8851	37.736	.3761E+01	.1843
1.587	.8063E+04	.7780	11.834	.1955E+03	.5794	3.670	.1639E+04	.8877	38.462	.3464E+01	.1919
1.600	.8000E+04	.7802	11.905	.1996E+03	.5612	3.704	.1551E+04	.8910	39.216	.3184E+01	.1999
1.613	.7927E+04	.7826	11.976	.2032E+03	.5434	3.738	.1481E+04	.8934	40.000	.2920E+01	.2081
1.626	.7870E+04	.7846	12.048	.2060E+03	.5255	3.774	.1413E+04	.8956	40.816	.2673E+01	.2171
1.639	.7814E+04	.7865	12.121	.2076E+03	.5107	3.810	.1368E+04	.8968	41.667	.2441E+01	.2266
1.653	.7758E+04	.7884	12.195	.2098E+03	.4889	3.846	.1313E+04	.8984	42.553	.2224E+01	.2365
1.667	.7706E+04	.7901	12.270	.2144E+03	.4692	3.883	.1270E+04	.8993	43.478	.2020E+01	.2470
1.681	.7657E+04	.7917	12.346	.2164E+03	.4505	3.922	.1229E+04	.9003	44.444	.1829E+01	.2581
1.695	.7615E+04	.7932	12.422	.2205E+03	.4251	3.960	.1190E+04	.9011	45.455	.1651E+01	.2702
1.709	.7593E+04	.7943	12.500	.2258E+03	.3964	4.000	.1153E+04	.9019	46.512	.1485E+01	.2830
1.724	.7678E+04	.7932	12.579	.2317E+03	.3644	4.040	.1125E+04	.9022	47.619	.1331E+01	.2967
1.739	.7830E+04	.7905	12.658	.2313E+03	.3483	4.082	.1103E+04	.9019	48.780	.1187E+01	.3114
1.754	.8075E+04	.7849	12.739	.2336E+03	.3228	4.124	.1081E+04	.9017	50.000	.1054E+01	.3272
1.770	.8506E+04	.7743	12.821	.2405E+03	.2819	4.167	.1069E+04	.9007	51.282	.9335E+00	.3428
1.786	.9149E+04	.7574	12.903	.2411E+03	.2608	4.211	.3232E+04	.0002	52.632	.8224E+00	.3595
1.802	.9882E+04	.7363	12.987	.2452E+03	.2261	4.255	.2517E+04	.0000	54.054	.7201E+00	.3777
1.818	.1012E+05	.7257	13.072	.2454E+03	.2012	4.301	.2324E+04	.0000	55.556	.6262E+00	.3974
1.835	.1005E+05	.7260	13.158	.2471E+03	.1690	4.348	.2347E+04	.0000	57.143	.5402E+00	.4189
1.852	.1026E+05	.7215	13.245	.2469E+03	.1407	4.396	.2874E+04	.0000	58.824	.4672E+00	.4375
1.869	.1073E+05	.7024	13.333	.2444E+03	.1299	4.444	.4123E+04	.0000	60.606	.4009E+00	.4576
1.887	.1003E+05	.7319	13.423	.2432E+03	.0938	4.494	.5932E+04	.0000	62.500	.3410E+00	.4795
1.905	.9225E+04	.7506	13.514	.2388E+03	.0659	4.545	.7919E+04	.0002	64.516	.2868E+00	.5037

Table 6. (continued)

w.l.	intensity	tau	w.l.	intensity	tau	w.l.	intensity	tau	w.l.	intensity	tau
1.923	.9061E+04	.7501	13.605	.2328E+03	.0669	4.598	.9343E+04	.0099	66.667	.2381E+00	.5305
1.942	.9682E+04	.7339	13.699	.2282E+03	.0571	4.651	.8932E+04	.1075	68.966	.1997E+00	.5506
1.961	.9963E+04	.7259	13.793	.2209E+03	.0302	4.706	.6495E+04	.3408	71.429	.1656E+00	.5725
1.980	.1139E+05	.7044	13.889	.2030E+03	.0107	4.762	.3933E+04	.5764	74.074	.1355E+00	.5965
2.000	.1204E+05	.6812	13.986	.1979E+03	.0115	4.819	.2442E+04	.7117	76.923	.1091E+00	.6231
2.010	.1100E+05	.7105	14.085	.1952E+03	.0140	4.878	.1865E+04	.7577	80.000	.8594E-01	.6530
2.020	.1202E+05	.6897	14.184	.1895E+03	.0130	4.938	.1728E+04	.7601	83.333	.6909E-01	.6727
2.030	.1149E+05	.7135	14.286	.1819E+03	.0099	5.000	.1763E+04	.7443	86.957	.5464E-01	.6941
2.041	.1143E+05	.7123	14.388	.1721E+03	.0062	5.063	.1802E+04	.7279	90.909	.4235E-01	.7177
2.051	.1033E+05	.7317	14.493	.1603E+03	.0033	5.128	.1800E+04	.7186	95.238	.3199E-01	.7439
2.062	.9567E+04	.7486	14.599	.1542E+03	.0033	5.195	.1942E+04	.6779	100.000	.2334E-01	.7735
2.073	.1035E+05	.7321	14.706	.1537E+03	.0036	5.263	.1975E+04	.6584	105.263	.1746E-01	.7924
2.083	.8910E+04	.7692	14.815	.1351E+03	.0010	5.333	.1997E+04	.6395	111.111	.1270E-01	.8129
2.094	.7131E+04	.8055	14.925	.1142E+03	.0000	5.405	.2040E+04	.6082	117.647	.8894E-02	.8355
2.105	.6487E+04	.8176	15.038	.1234E+03	.0009	5.479	.2020E+04	.5972	125.000	.5920E-02	.8605
2.116	.6219E+04	.8225	15.152	.1391E+03	.0039	5.556	.1971E+04	.5800	133.333	.3649E-02	.8886
2.128	.6085E+04	.8249	15.267	.1331E+03	.0029	5.634	.1925E+04	.5718	142.857	.2470E-02	.9007
2.139	.5974E+04	.8269	15.385	.1296E+03	.0042	5.714	.1875E+04	.5617	153.846	.1600E-02	.9135
2.151	.5854E+04	.8291	15.504	.1320E+03	.0081	5.797	.1814E+04	.5491	166.667	.9796E-03	.9270
2.162	.5769E+04	.8305	15.625	.1320E+03	.0123	5.882	.1628E+04	.5807	181.818	.5543E-03	.9414
2.174	.5685E+04	.8319	15.748	.1290E+03	.0134	5.970	.1368E+04	.6365	200.000	.2782E-03	.9568
2.186	.5630E+04	.8327	15.873	.1267E+03	.0174						

V. GLOSSARY

The glossary lists the major program parameters in alphabetical order, and gives the subroutine where they are first introduced. Parameters which are common to several subroutines are so indicated.

AB(J)	spectral absorption coefficient through element J (RADCAL)
AC(J)	collision-broadened fine structure parameter in element J (RADCAL)
AD(J)	doppler-broadened fine structure parameter in element J (RADCAL)
AIWALL	wall temperature weighted mean absorption coefficient in uniform medium (RADCAL)
ALPHA	integrated band intensity (CO ₂ , CO)
AMBDA(KK)	wavelength (RADCAL)
AMEAN	effective absorption coefficient in uniform medium (RADCAL)
AP0	Planck-mean absorption coefficient in uniform medium (RADCAL)
DD(J)	length of Jth element (COMMON)
DINV	inverse line spacing parameter (CO ₂ , H ₂ O, CO, FUEL)
GAMMA(I,7)	line-broadening parameter of species I by individual gases (RADCAL, BD3)
GDDINV	line-width to line-spacing ratio for Doppler broadening (RADCAL)
GDINV	line-width to line-spacing ratio (RADCAL)
I	species index (COMMON)
J	element index (COMMON)
KK	spectral index (COMMON)
NOM	number of wavenumber intervals (600 maximum) (COMMON)
NPT	number of spatial elements (50 maximum) (COMMON)
NPRINT	controls output (COMMON)
OMEGA	wavenumber (COMMON)
OMMAX	maximum wavenumber (COMMON)
OMMIN	minimum wavenumber (COMMON)
P(1,J)	partial pressure of CO ₂ (COMMON)
P(2,J)	partial pressure of H ₂ O (COMMON)
P(3,J)	partial pressure of CH ₄ (COMMON)
P(4,J)	partial pressure of CO (COMMON)
P(5,J)	partial pressure of O ₂ (COMMON)
P(6,J)	partial pressure of N ₂ (COMMON)
PLANCK(A,B)	Planck blackbody distribution function at temperature A and wavelength B
Q	total radiant intensity leaving path (RADCAL)
QW(KK)	spectral intensity leaving path (RADCAL)
RIK	imaginary part of the index of refraction for soot (POD)
RIN	real part of the index of refraction for soot (POD)
RSL	long wavelength soot radiance (RADCAL)
RSS	short wavelength soot radiance (RADCAL)
SDWEAK	spectral absorption coefficient (COMMON)

SD(L,K) tabulated values of the absorption coefficient for the L th temperature of the K th wavenumber of water vapor (BD1, BD2)
SD7(L,K) tabulated values of the absorption coefficient for the L th temperature of the K th wavenumber of the 7.7 μm band of CH_4 (BD3)
SD15(L,K) tabulated values of the absorption coefficient for the L th temperature of the K th wavenumber of the 15 μm band of CO_2 (BD3)
SPECIE(I) if zero, particular species is absent (COMMON)
T(J) temperature of gas (COMMON)
TAU(J) spectral transmittance through element J (RADCAL)
TAUS(J) spectral transmittance through soot particles up to element J (RADCAL)
TTAU(K) spectral transmittance through entire path (RADCAL)
TWALL far wall temperature (COMMON)
U(I,J) pressure-pathlength of species I in element J (RADCAL)
UK pressure-pathlength times absorption coefficient (RADCAL)
W(J) volume fraction of soot (RADCAL)
X(I,J) optical depth of species I in element J (RADCAL)
XC optical depth for pure collision curve-of-growth (RADCAL)
XD optical depth for pure doppler curve-of-growth (RADCAL)
XPART(J) particle optical depth in element J (COMMON)
XSTAR(J) optical depth of species in the weak-line limit
XTOT(J) combined optical depth in element J of all gases and soot (RADCAL)

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VII. APPENDIX

A. Typical data input file, RC.DAT

```
1
36.58 306. .005 .0 .0 .0 .2 .795 .0
0. 400. 8000.
5
.30 1770. .1667 .1667 .0 .0 .0 .666 0.
.10 1637. .1520 .1520 .0 .0 .0 .696 0.
.10 1438. .1300 .1300 .0 .0 .0 .740 0.
.10 1158. .0992 .0992 .0 .0 .0 .802 0.
.05 899. .0705 .0705 .0 .0 .0 .859 0.
0. 50. 10000.
0
```

Data input file for RADCAL

line 1: number of homogeneous elements, n

line 2: pathlength (m), temperature (K), CO₂ (atm), H₂O, CH₄, CO, O₂, N₂, fv

lines 3 through n+1: same as line 2 for the rest of the elements

line n+2: wall temperature (K), minimum wavenumber (cm⁻¹), maximum wavenumber

line n+3: 0, or the number of homogeneous elements in the next case

B. Listing of RADCAL

RCPART1.FOR

```
C PROGRAM RADCAL (11/92)
C *****
C
C CONTROLLING PROGRAM FOR SUBROUTINE "RADCAL", A NARROW-BAND
C MODEL FOR CALCULATING SPECTRAL INTENSITY (W/M-2/SR/MICRON) AND
C SPECTRAL TRANSMITTANCE VERSUS WAVELENGTH (MICRONS) IN A NONISO-
C THERMAL, VARIABLE COMPOSITION MIXTURE OF CO2, H2O, CO, N2, O2,
C CH4, AND SOOT. FOR A HOMOGENEOUS PATH, THE PROGRAM ALSO COMPUTES
C THE PLANCK-MEAN ABSORPTION COEF., APO, THE INCIDENT-MEAN ABSORPTION
C COEFFICIENT, AIWALL, AND THE EFFECTIVE-MEAN ABSORPTION COEFFICIENT,
C AMEAN, ALL IN UNITS OF INVERSE METERS.
C
C INPUT PARAMETERS:
C NPT=NUMBER OF HOMOGENEOUS ELEMENTS
C DD(J)=THICKNESS OF J TH ELEMENT, M
C T(J)=TEMPERATURE OF J TH ELEMENT, K.
C P(I,J)=PARTIAL PRESSURE OF GASEOUS COMPONENTS, kPa:
C 1 GASEOUS SPECIES
C 1 CO2
C 2 H2O
C 3 CH4
C 4 CO
```

```

C          5      O2
C          6      N2
C      W(J)=SOOT VOLUME FRACTION OF J TH ELEMENT
C      OMMIN=MINIMUM WAVE NUMBER IN SPECTRUM, CM-1.
C      OMMAX=MAXIMUM WAVE NUMBER IN SPECTRUM, CM-1.
C
C
C      COMMON/CPART/W(50),XPART(50),T(50),DD(50),NPT
C      COMMON/CMAIN/OMMIN,OMMAX,NOM,TWALL,P(6,50),SPECIE(5),NPRINT
C
C      DATA ARE READ INTO UNIT 5 FROM DATA FILE "RC.DAT".
C      OPEN (5,FILE='RC.DAT')
C      OPEN (1,FILE='RCOUT.DAT')
C
C
40  CONTINUE
    READ(5,*)NPT
    IF(NPT.EQ.0)GO TO 3000
    SPECIE(1)=0.
    SPECIE(2)=0.
    SPECIE(3)=0.
    SPECIE(4)=0.
    SPECIE(5)=0.
    DO 50 J=1,NPT
    READ(5,*)DD(J),T(J),(P(I,J),I=1,6),W(J)
    DO 48 I=1,6
48  P(I,J)=P(I,J)/101.
    SPECIE(1)=P(1,J)+SPECIE(1)
    SPECIE(2)=P(2,J)+SPECIE(2)
    SPECIE(3)=P(3,J)+SPECIE(3)
    SPECIE(4)=P(4,J)+SPECIE(4)
    SPECIE(5)=W(J)+SPECIE(5)
50  CONTINUE
    READ(5,*)TWALL,OMMIN,OMMAX
    IF(OMMAX.LT.1100.)GO TO 101
    IF(OMMIN.GT.5000.)GO TO 102
    IF(OMMIN.LT.1100..AND.OMMAX.GT.5000.)GOTO 103
    IF(OMMIN.LT.1100.)GO TO 104
    IF(OMMAX.GT.5000.)GO TO 105
    NOM=IFIX((OMMAX-OMMIN)/25.)
    GO TO 106
101  NOM=IFIX((OMMAX-OMMIN)/5.)
    GO TO 106
102  NOM=IFIX((OMMAX-OMMIN)/50.)
    GO TO 106
103  NOM=IFIX((1100.-OMMIN)/5.)+IFIX((5000.-1100.)/25.)
    2      +IFIX((OMMAX-5000.)/50.)
    GO TO 106
104  NOM=IFIX((1100.-OMMIN)/5.)+IFIX((OMMAX-1100.)/25.)
    GO TO 106
105  NOM=IFIX((5000.-OMMIN)/25.)+IFIX((OMMAX-5000.)/50.)
106  NPRINT=1
    CALL RADCAL
    GO TO 40
3000 CONTINUE
    STOP
    END
C
C*****
C
C      SUBROUTINE RADCAL
C      DOUBLE PRECISION SDWEAK,GDINV,GDDINV,XC,AOM,Q,QW(600),TTAU(600),
C      2      XTOT(50),XT(600),XSTAR(50),X(4,50),UK,TAU(50)
C      COMMON/CMAIN/OMMIN,OMMAX,NOM,TWALL,P(6,50),SPECIE(5),NPRINT
C      COMMON/CPARAM/GAMMA(4,7)
C      COMMON/CPART/W(50),XPART(50),T(50),DD(50),NPT
C      DIMENSION U(4,50),AC(50),AD(50),GC(4,50),AMBDA(600),TAUS(50),
C      2      AB(600),PKPA(6)

```



```

C
C [NOTE: THE TOTAL INTENSITY CALCULATED IS THAT WHICH LEAVES INTERVAL J=1.
C P(I,J) IS PARTIAL PRESSURE, ATM, OF SPECIES I IN INTERVAL J.
C I=1,2,3,4,5, OR 6 IMPLIES SPECIES IS CO2, H2O, CH4, CO, O2, OR N2, RESP.]
C
  DOM=5.0
  OMEGA=OMMIN-DOM
  NM=NOM-1
C
C LOOP 1000 COMPUTES EACH SPECTRAL CONTRIBUTION
C *****
  DO 1000 KK=1,NOM
  OMEGA=OMEGA+DOM
  IF(OMEGA.LE.1100.)GO TO 109
  OMEGA=OMEGA+20.
  IF(OMEGA.LE.5000.)GO TO 109
  OMEGA=OMEGA+25.
109  AMBDA(KK)=10000./OMEGA
  ABGAS=0.
C
C LOOP 200 COMPUTES THE CONTRIBUTION OF EACH SPECIES TO TAU
C *****
  DO 200 I=1,4
  C IF SPECIE(I) IS SET TO 0., THAT PARTICULAR RADIATING SPECIES IS
  C NOT PRESENT. THE SPECIES CONSIDERED ARE
  C I SPECIES
  C 1 CO2
  C 2 H2O
  C 3 CH4
  C 4 CO
  C 5 PARTICULATES
  IF(SPECIE(I).EQ.0.) GO TO 200
C
C LOOP 100 IS FOR EACH ELEMENT ALONG PATH
C *****
  DO 100 J=1,NPT
  C (CALCULATION PROCEEDS IN ACCORDANCE WITH THE SLG MODEL, TABLE 5-18
  C IN NASA SP-3080.)
  IF(KK.GT.1) GO TO 107
  U(I,J)=273./T(J)*P(I,J)*100.*DD(J)
  GC(I,J)=0.
  PTOT=0.
  DO 105 II=1,6
  PTOT=P(II,J)+PTOT
105  GC(I,J)=GC(I,J)+GAMMA(I,II)*P(II,J)*(273./T(J))**.5
  GC(I,J)=GC(I,J)+GAMMA(I,7)*P(I,J)*273./T(J)
107  IF(P(I,J).EQ.0.) GO TO 121
  TEMP=T(J)
  GO TO(101,102,103,104),I
101  CALL CO2(OMEGA,TEMP,GC(1,J),SDWEAK,GDINV,GDDINV)
  GO TO 108
102  CALL H2O(OMEGA,TEMP,GC(2,J),SDWEAK,GDINV,GDDINV)
  GO TO 108
103  CONTINUE
  CALL FUEL(OMEGA,TEMP,P(3,J),PTOT,GC(3,J),SDWEAK,GDINV,GDDINV)
  GO TO 108
104  CONTINUE
  CALL CO(OMEGA,TEMP,GC(4,J),SDWEAK,GDINV,GDDINV)
108  UK=SDWEAK*U(I,J)
  IF(J.EQ.1) GO TO 110
  GKD=UK*GDINV
  GKDD=UK*GDDINV
  XSTAR(J)=XSTAR(J-1)+UK
  AD(J)=(XSTAR(J-1)*AD(J-1)+GKDD)/XSTAR(J)
  AC(J)=(XSTAR(J-1)*AC(J-1)+GKD)/XSTAR(J)
  GO TO 115
110  XSTAR(1)=UK+1.D-34

```

```

ABGAS=UK/DD(1)+ABGAS
AD(1)=GDDINV
AC(1)=GDINV
115 IF(XSTAR(J).LT.1.E-6) GO TO 125
XD=1.7*AD(J)*(DLOG(1.+(XSTAR(J)/1.7/AD(J)**2))**.5
YD=1.-(XD/XSTAR(J))**2
XC=XSTAR(J)/(1.+(XSTAR(J)/4./AC(J))**.5
C
C THE FOLLOWING LOOP COMPUTES THE OPTICAL THICKNESS, XC, FOR METHANE USING
C THE GODSON EQUATION AND AN APPROXIMATION TO THE LADENBERG-REICHE
C FUNCTION AS RECOMMENDED BY BROSNER AND TIEN (JQSRT 33,P 521). THE
C ERROR FUNCTION IS FOUND FROM ITS SERIES EXPANSION.
C
IF(I.NE.3.) GO TO 118
IF(XC.GT.10.)GO TO 118
AOM=XC
XX=.5*3.141593**.5*XC
IF(XX.LE.3.)GO TO 111
AOM=1.-EXP(-XX**2)/(3.141593**.5*XX)
GO TO 117
111 ENN=1.
DO 116 N=1,30
ENN=ENN*N
MM=2*N+1
ARG=1.128379*(-1.)**N*((.88622693*XC)**MM)/(MM*ENN)
ARGNEW=ARG+AOM
C IF(ABS(ARG/ARGNEW).LT..000001)N=30
116 AOM=ARGNEW
117 IF(AOM.GE.1.)AOM=.9999999
XC=-DLOG(1.-AOM)
C
C
118 YC=1.-(XC/XSTAR(J))**2
Y=1./YC**2+1./YD**2-1.
X(I,J)=XSTAR(J)*((1.-(Y**(-.5)))**.5)
GO TO 100
121 IF(J.GT.1) GO TO 123
XSTAR(1)=1.D-34
AC(1)=1.
AD(1)=1.
GO TO 125
123 XSTAR(J)=XSTAR(J-1)
AC(J)=AC(J-1)
AD(J)=AD(J-1)
125 X(I,J)=XSTAR(J)
100 CONTINUE
C
C
200 CONTINUE
C
C DETERMINE OPTICAL DEPTH OF SOOT
C
IF(SPECIE(5).EQ.0.) GO TO 250
CALL POD(OMEGA)
GO TO 260
250 DO 255 J=1,NPT
255 XPART(J)=0.
260 CONTINUE
AB(KK)=ABGAS+XPART(1)/DD(1)
C
C EVALUATE THE COMBINED SPECTRAL TRANSMITTANCE AND RADIANCE
C *****
DO 500 J=1,NPT
XTOT(J)=0.
DO 300 I=1,4
IF(SPECIE(I).EQ.0.) X(I,J)=0.
300 XTOT(J)=X(I,J)+XTOT(J)

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```

XTOT(J)=XTOT(J)+XPART(J)
IF(XTOT(J).GE.99.) GO TO 305
TAU(J)=DEXP(-XTOT(J))
GO TO 310
305 TAU(J)=0.
310 IF(J.EQ.1) GO TO 510
QW(KK)=QW(KK)-(TAU(J)-TAU(J-1))*PLANCK(T(J),AMBDA(KK))
GO TO 500
510 QW(KK)=-TAU(1-1.)*PLANCK(T(1),AMBDA(KK))
500 CONTINUE
XT(KK)=XTOT(NPT)
TTAU(KK)=TAU(NPT)
QW(KK)=QW(KK)+TTAU(KK)*PLANCK(TWALL,AMBDA(KK))
1000 CONTINUE
C
C INTEGRATE THE RADIANCE OVER THE SPECTRUM
C
Q=QW(1)*(AMBDA(1)-AMBDA(2))
DO 1100 KK=2,NM
1100 Q=Q+QW(KK)*(AMBDA(KK-1)-AMBDA(KK+1))/2.
Q=Q+QW(NOM)*(AMBDA(NOM-1)-AMBDA(NOM))
C
C DETERMINE SOOT RADIANCE FOR SHORT AND LONG WAVELENGTHS.
C
RSL=0.
RSS=0.
ABLONG=0.
ABSHRT=0.
ABIL=0.
ABIS=0.
IF(SPECIE(5).EQ.0..AND.TWALL.EQ.0.)GOTO 1090
KMAX=OMMIN/5*5
DO 1040 KK=5,KMAX,5
OMEGA=FLOAT(KK)
WL=10000./OMEGA
DAMBDA=10000./(OMEGA-2.5)-10000./(OMEGA+2.5)
CALL POD(OMEGA)
DO 1020 J=1,NPT
IF(XPART(J).GE.33.) GO TO 1010
TAUS(J)=EXP(-XPART(J))
GO TO 1012
1010 TAUS(J)=0.
1012 IF(J.EQ.1)GO TO 1021
RSL=RSL-(TAUS(J)-TAUS(J-1))*PLANCK(T(J),WL)*DAMBDA
GO TO 1020
1021 RSL=RSL-(TAUS(1)-1.)*PLANCK(T(1),WL)*DAMBDA
ABLONG=ABLONG+XPART(1)/DD(1)*PLANCK(T(1),WL)*DAMBDA*5.5411E7
2 /T(1)**4
ABIL=ABIL+XPART(1)/DD(1)*PLANCK(TWALL,WL)*DAMBDA*5.5411E7
2 /TWALL+.000001)**4
1020 CONTINUE
RSL=RSL+TAUS(NPT)*PLANCK(TWALL,WL)*DAMBDA
1040 CONTINUE
KMIN=OMMAX/100*100
DO 1080 KK=KMIN,25000,100
OMEGA=FLOAT(KK)
WL=10000./OMEGA
DAMBDA=10000./(OMEGA-50.)-10000./(OMEGA+50.)
CALL POD(OMEGA)
DO 1070 J=1,NPT
IF(XPART(J).GE.33.) GO TO 1050
TAUS(J)=EXP(-XPART(J))
GO TO 1060
1050 TAUS(J)=0.
1060 IF(J.EQ.1)GO TO 1071
RSS=RSS-(TAUS(J)-TAUS(J-1))*PLANCK(T(J),WL)*DAMBDA
GO TO 1070

```

```

1071 RSS=RSS-(TAUS(1)-1.)*PLANCK(T(1),WL)*DAMBDA
      ABSHRT=ABSHRT+XPART(1)/DD(1)*PLANCK(T(1),WL)*DAMBDA*5.5411E7
      2      /(T(1))**4
      ABIS=ABIS+XPART(1)/DD(1)*PLANCK(TWALL,WL)*DAMBDA*5.5411E7
      2      /(TWALL+.000001)**4
1070 CONTINUE
      RSS=RSS+TAUS(NPT)*PLANCK(TWALL,WL)*DAMBDA
1080 CONTINUE
1090 CONTINUE
      Q=Q+RSS+RSL
C
C
      IF(NPRINT.EQ.1) GO TO 2300
      IF(NPRINT.EQ.0)GO TO 3000
      GO TO 2400
2300 WRITE(1,4)
      NPRINT=2
      DO 2000 J=1,NPT
      DO 2001 I=1,6
2001 PKPA(I)=P(I,J)*101.
2000 WRITE(1,6)J,DD(J),T(J),(PKPA(I),I=1,6),W(J)
      WRITE(1,7)TWALL
2400 WRITE(1,8) Q
2401 WRITE(1,10)
      LMAX=NOM/2
      IF(LMAX*2.LT.NOM) LMAX=LMAX+1
      DO 2100 L=1,LMAX
      K=NOM-LMAX+1-L
      J=K+LMAX
      IF(K.LT.1) K=1
2100 WRITE(1,12)AMBDA(J),QW(J),TTAU(J),AMBDA(K),QW(K),TTAU(K)
3000 CONTINUE
C
C      THE FOLLOWING SECTION COMPUTES THE MEAN ABSORPTION COEFFICIENTS
C      IF THE SYSTEM IS HOMOGENEOUS (IE., NPT=1).
C
      IF(NPT.NE.1)GO TO 6109
      NM=NOM-1
      AIWALL=AB(1)*(AMBDA(1)-AMBDA(2))/2.*PLANCK(TWALL,AMBDA(1))
      AP0=AB(1)*(AMBDA(1)-AMBDA(2))/2.*PLANCK(T(1),AMBDA(1))
      DO 6100 KK=2,NM
      AIWALL=AIWALL+AB(KK)*(AMBDA(KK-1)-AMBDA(KK+1))/2.
      2      *PLANCK(TWALL,AMBDA(KK))
      AP0=AP0+AB(KK)*(AMBDA(KK-1)-AMBDA(KK+1))/2.
      2      *PLANCK(T(1),AMBDA(KK))
6100 CONTINUE
      AP0=(AP0+AB(NOM)*(AMBDA(NM)-AMBDA(NOM))/2.
      2      *PLANCK(T(1),AMBDA(NOM)))*5.5411E7/T(1)**4+ABSHRT+ABLONG
      IF(TWALL.EQ.T(1).OR.TWALL.EQ.0.)GO TO 6105
      AIWALL=(AIWALL+AB(NOM)*(AMBDA(NM)-AMBDA(NOM))/2.*
      2      PLANCK(TWALL,AMBDA(NOM)))*5.5411E7/TWALL**4
      AMEAN=-1./DD(1)*DLOG((5.5411E7*Q-T(1)**4)/(TWALL**4-T(1)**4))
      GO TO 6107
6105 AIWALL=AP0
      AMEAN=-1./DD(1)*DLOG((5.5411E7*Q-T(1)**4)/(-T(1)**4))
6107 WRITE(1,14) AMEAN,AP0,AIWALL
C
C
4   FORMAT(/,'          Radial Profiles'/
      1'          -----'//
      2'          Partial Pressures, kPa'/
      3' J dist,m  temp,K  CO2  H2O  CH4  CO   O2  N2
      4   FV')
6   FORMAT(1X,I2,F9.4,F7.0,6(F8.3),1X,E10.4)
7   FORMAT('wall',9X,F6.0)
8   FORMAT(/,' Total directional radiated energy flux =' ,E12.6,
      1' Watts/m-2/strad'//' ')

```

```

10  FORMAT(8X,'Spectral Intensity Distribution, Watts/m-2/micron/strad
1',/ 8X,'-----'
2',/,2X,'micron',4X,'intensity',6X,'tau',8X,'micron',4X,'intensity
3',6X,'tau')
12  FORMAT(2(F8.3,3X,E10.4,2X,F8.4,5X))
14  FORMAT(///'The effective absorption coef. is ', E12.6,'/m',/
2      'The Planck-mean absorption coef. is ', E12.6,'/m',/
3      'The wall-incident mean is ', E12.6,'/m',////)
C
C
6109 CONTINUE
      RETURN
      END
C
C*****
C
SUBROUTINE CO2(OMEGA,TEMP,GC1,SDWEAK,GDINV,GDDINV)
COMMON/CCO2/SD15(6,80)
DOUBLE PRECISION AA,BB,CC,DD,EE,FF,GG,SMINUS,SPLUS,SDWEAK,SDSTRG
1,DINV,GDINV,GDDINV
DIMENSION ATOT(3),BCNT(3)
IF(OMEGA.GT.5725.)GO TO 300
WM=44.
GD=5.94E-6*OMEGA*(TEMP/(273.*WM))**.5
IF(OMEGA.GT.4550.)GO TO 500
IF(OMEGA.GT.3800.)GO TO 300
IF(OMEGA.GT.3050.)GO TO 100
IF(OMEGA.GT.2474.)GO TO 300
IF(OMEGA.GT.1975.)GO TO 100
IF(OMEGA.GT.1100.)GO TO 300
IF(OMEGA.GT.880.)GO TO 600
IF(OMEGA.GT.500.)GO TO 400
GO TO 300
CONTRIBUTION TO 2.0 MICRON BAND FROM (000)-(041),(000)-(121),AND (000)
C -(201) TRANS.
500  OM1=1354.91
      OM2=673.0
      OM3=2396.49
      BCNT(1)=4860.5
      BCNT(2)=4983.5
      BCNT(3)=5109.0
      TO=300.
      C2=1.4388
      BE=0.391635
      COM1=4.*OM2+OM3
      COM2=OM1+2.*OM2+OM3
      COM3=2.*OM1+OM3
      ATOT(3)=0.426*TO/TEMP*(1.-EXP(-C2*COM3/TEMP)/(1.-EXP(-C2*OM1/TEMP)
1) )**2/(1.-EXP(-C2*OM3/TEMP))
      ATOT(2)=1.01*TO/TEMP*(1.-EXP(-C2*COM2/TEMP))/(1.-EXP(-C2*OM1/TEMP)
1)/(1.-EXP(-C2*OM2/TEMP))**2/(1.-EXP(-C2*OM3/TEMP))
      ATOT(1)=0.272*TO/TEMP*(1.-EXP(-C2*COM1/TEMP))/(1.-EXP(-C2*OM2/TEMP)
1) )**4/(1.-EXP(-C2*OM3/TEMP))
      SDWEAK=0.0
      DO 510 K=1,3
      SDWEAK=SDWEAK+ATOT(K)*C2/(4.*BE*TEMP)*ABS(OMEGA-BCNT(K))
1*EXP(-C2/(4.*BE*TEMP)*(OMEGA-BCNT(K))**2)
510  CONTINUE
      DINV=1./(4.*BE)
      GDINV=GC1*DINV
      GDDINV=GD*DINV
C***EXPRESS S/D AT STP, AS IS IN NASA SP-3080
      SDWEAK=SDWEAK*TEMP/273.
      RETURN
100  CONTINUE
      B=.391635
      A=.0030875

```



```

X13=-19.37
X23=-12.53
X33=-12.63
OM1=1354.91
OM2=673.
OM3=2396.49
T0=300.
C2=1.4388
XBAR=.5*(.5*X13+X23)
OM12=.5*(.5*OM1+OM2)
SDWEAK=0.
SDSTRG=0.
IF(OMEGA.LE.2395.)GO TO 200
CALCULATE ABSORPTION COEF. AND LINE SPACING PARAMETER FOR 2.7 MICRON BAND
L=1
CONTRIBUTION TO 2.7 MICRON BAND FROM (000)-(021) AND (010)-(031) TRANS.
ALPHA=28.5
OMPRIM=2.*OM2+OM3
120 AA=ALPHA*B*C2/(A*(1.-EXP(-OM3*C2/T0))*(1.-EXP(-OM12*C2/T0)))**3
1*(1.+EXP(-OM12*C2/T0))*(1.-EXP(-OMPRIM*C2/T0))
BB=(1.-EXP(-C2*OMEGA/TEMP))*(1.-EXP(-C2*OM3/TEMP))*
1(1.-EXP(-OM12*C2/TEMP))**3*(1.+EXP(-OM12*C2/TEMP))
2*(1.-EXP(-C2*OMPRIM/TEMP))
CC=AA*BB*OMEGA/TEMP*T0/TEMP
DO 102 J=1,20
V=FLOAT(J-1)
IF(J/2*2.EQ.J)G=(V+1.)*(V+3.)/4.
IF(J/2*2.NE.J)G=(V+2.)*(V+2.)/4.
VBAR1=-1.+(V+3.)*(V+4.)/(V+2.)/6.
IF(J/2*2.EQ.J)VBAR1=-1.+(V+5.)/6.
DO 101 K=1,10
V3=FLOAT(K-1)
DD=(V3+1)*G*EXP(-(V3*OM3+V*OM12)*C2/TEMP)*(VBAR1+1.)
GAM=B-A*(V3+1.)
IF(L.EQ.2)GO TO 125
OMVV3=3598.-18.*V-47.*V3
IF(V.EQ.0.)OMVV3=3613.-47.*V3
GO TO 130
125 OMVV3=3728.-5.*V-47.*V3
IF(V.EQ.0.)OMVV3=3715.-47.*V3
130 DELTA=A*(OMEGA-OMVV3)
IF(GAM*GAM.LE.DELTA)GO TO 102
D=2.*(GAM*GAM-DELTA)**.5
OMVBAR=OMVV3*(1.-EXP(-OMVV3*C2/TEMP))
F1=GAM-D/2
F2=GAM+D/2.
EE=C2*GAM/(A*A*TEMP)
UNFLO1=EE*DELTA*(1.+5*A/GAM)
IF(UNFLO1.LE.-78.)GO TO 102
UNFLO2=EE*2.*GAM*F1
IF(UNFLO2.GE.78.)GO TO 102
FF=DEXP(EE*DELTA*(1.+5*A/GAM))
SMINUS=CC*DD/OMVBAR*ABS(F1)*FF*DEXP(-EE*2.*GAM*F1)
UNFLO3=EE*2.*GAM*F2
IF(UNFLO3.GE.78.)GO TO 160
SPLUS=CC*DD/OMVBAR*ABS(F2)*FF*DEXP(-EE*2.*GAM*F2)
GO TO 170
160 SPLUS=0.
170 GG=SDWEAK
SDWEAK=(SMINUS+SPLUS)/D+SDWEAK
TEST=(SDWEAK-GG)/SDWEAK
IF(TEST.LT..0001)GO TO 102
SDSTRG=(.5*G)**.5*(SMINUS**.5+SPLUS**.5)/D+SDSTRG
101 CONTINUE
102 CONTINUE
IF(L.EQ.2)GO TO 250
CONTRIBUTION TO 2.7 MICRON BAND FROM (000)-(101) AND (010)-(111) TRANS.

```

```

ALPHA =42.3
OMPRIM=OM1 +OM3
L=2
GO TO 120
CALCULATE ABSORPTION COEF AND LINE SPACING PARAMETER FOR 4.3 MICRON BAND
200 ALPHA =2700.
OMPRIM=OM3
AA =ALPHA *B*C2/(A*(1.-EXP(-OM3*C2/T0))*(1.-EXP(-OM12*C2/T0)))**3
1*(1.+EXP(-OM12*C2/T0))*(1.-EXP(-OMPRIM*C2/T0))
BB=(1.-EXP(-C2*OMEGA/TEMP))*(1.-EXP(-C2*OM3/TEMP))*
1(1.-EXP(-OM12*C2/TEMP))**3*(1.+EXP(-OM12*C2/TEMP))
2 *(1.-EXP(-C2*OMPRIM/TEMP))
CC =AA *BB*OMEGA/TEMP*T0/TEMP
DO 202 J=1,20
V=FLOAT(J-1)
IF(J/2*2.EQ.J)G=(V+1.)*(V+3.)/4.
IF(J/2*2.NE.J)G=(V+2.)*(V+2.)/4.
DO 201 K=1,10
V3=FLOAT(K-1)
DD=(V3+1.)*G*EXP(-(V3*OM3+V*OM12)*C2/TEMP)
GAM=B-A*(V3+1.)
OMVV3=OM3+.5*X13+X23+2.*X33+XBAR*V+2.*X33*V3
DELTA=A*(OMEGA-OMVV3)
IF(GAM*GAM.LE.DELTA)GO TO 202
D=2.*(GAM*GAM-DELTA)**.5
OMVBAR=OMVV3*(1.-EXP(-OMVV3*C2/TEMP))
F1=GAM-D/2
F2=GAM+D/2.
EE=C2*GAM/(A*A*TEMP)
UNFLO1=EE*DELTA*(1.+5*A/GAM)
IF(UNFLO1.LE.-78.)GO TO 202
UNFLO2=EE*2.*GAM*F1
IF(UNFLO2.GE.78.)GO TO 202
FF=DEXP(EE*DELTA*(1.+5*A/GAM))
SMINUS=CC*DD/OMVBAR*ABS(F1)*FF*DEXP(-EE*2.*GAM*F1)
UNFLO3=EE*2.*GAM*F2
IF(UNFLO3.GE.78.)GO TO 246
SPLUS=CC*DD/OMVBAR*ABS(F2)*FF*DEXP(-EE*2.*GAM*F2)
GO TO 247
246 SPLUS=0.
247 GG=SDWEAK
SDWEAK=(SMINUS+SPLUS)/D+SDWEAK
TEST=(SDWEAK-GG)/SDWEAK
IF(TEST.LT..0001)GO TO 202
SDSTRG=(.5*G)**.5*(SMINUS**.5+SPLUS**.5)/D+SDSTRG
201 CONTINUE
202 CONTINUE
250 CONTINUE
IF(SDWEAK.EQ.0.)GO TO 300
DINV=SDSTRG*SDSTRG/SDWEAK
GDINV=GC1*DINV
GDDINV=GD*DINV
C***EXPRESS S/D AT STP, AS IS K IN NASA SP-3080
SDWEAK=SDWEAK*TEMP/273.
RETURN
CONTRIBUTION TO 10.0 MICRON BAND FROM (100)-(001) AND (020)-(001) TRANS.
600 OM1=1354.91
OM2=673.
OM3=2396.49
C2=1.4388
BCNT(1)=960.8
BCNT(2)=1063.6
OMA=OM3
OMB=(OM1+2.*OM2)/2.
TO=300.
ATOT(1)=0.0219
ATOT(2)=0.0532

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```

BE=0.391635
DO 610 K=1,2
ATOT(K)=TO/TEMP*ATOT(K)*EXP(C2*OMB*(1./TO-1./TEMP))
1*(1.-EXP(-C2*(OMA-OMB)/TEMP))/(1.-EXP(-C2*OMA/TEMP))
2/(1.-EXP(-OMB*C2/TEMP))
610 CONTINUE
SDWEAK=0.
DO 620 I=1,2
SDWEAK=SDWEAK+ATOT(I)*C2/(4.*BE*TEMP)*ABS(OMEGA-BCNT(I))
1*EXP(-C2/(4.*BE*TEMP)*(OMEGA-BCNT(I))**2)
620 CONTINUE
DINV=1./4./BE
GDINV=GC1*DINV
GDDINV=GD*DINV
C***EXPRESS S/D AT STP, AS IS IN NASA SP-3080
SDWEAK=SDWEAK*TEMP/273.
RETURN
CONTRIBUTION TO 15.0 MICRON BAND FROM (000)-(010) TRANS.
400 TTEMP=TEMP
J=(OMEGA-495.)/5.
W1=495.+5.*FLOAT(J)
WW=(OMEGA-W1)/5
IF(TEMP.GT.2400.)TEMP=2399.99
IF(TEMP.LT.300.)TEMP=300.
I=TEMP/300.
IF((I.GT.2).AND.(TEMP.LT.1200.))GO TO 410
IF((I.GT.5).AND.(TEMP.LT.2400.))GO TO 420
T1=FLOAT(I)*300.
TT=(TEMP-T1)/300.
IF(I.GT.4)I=I-1
GO TO 430
410 I=2
TT=(TEMP-600.)/600.
GO TO 430
420 I=5
TT=(TEMP-1800.)/600.
430 TW=TT*WW
SDWEAK=SD15(I,J)*(1.-TT-WW+TW)+SD15(I+1,J)*(TT-TW)
1+SD15(I,J+1)*(WW-TW)+SD15(I+1,J+1)*TW
IF(SDWEAK.EQ.0.)GO TO 300
CALCULATE LINE SPACING PARAMETER FOR 15.0 MICRON BAND
DINV1=1.2
DINV2=8.0
DINV3=30.0
TEMP1=300.0
TEMP2=550.0
TEMP3=830.0
DINV=DINV1*(TEMP-TEMP2)*(TEMP-TEMP3)/(TEMP1-TEMP2)/
1(TEMP1-TEMP3)+DINV2*(TEMP-TEMP1)*(TEMP-TEMP3)/(TEMP2-TEMP1)
2/(TEMP2-TEMP3)+DINV3*(TEMP-TEMP1)*(TEMP-TEMP2)/(TEMP3-TEMP1)
3/(TEMP3-TEMP2)
GDINV=GC1*DINV
GDDINV=GD*DINV
RETURN
300 SDWEAK=0.
GDINV=1.
GDDINV=1.
RETURN
END
C
C*****
C
SUBROUTINE H2O(OMEGA,TEMP,GC2,SDWEAK,GDINV,GDDINV)
DOUBLE PRECISION SDWEAK,GDINV,GDDINV
COMMON/CH2O/SD(6,376)
IF (OMEGA.GE.9300..OR.OMEGA.LT.50.)GOTO 200
WM=18.

```

```

GD=5.94E-6*OMEGA*(TEMP/(273.*WM))**.5
J=(OMEGA-25.)/25.
TTEMP=TEMP
IF(TEMP.GE.2500.) TEMP=2499.99
IF(TEMP.LT.300.) TEMP=300.
I=TEMP/500. +1
IF(I.EQ.2.AND.TEMP.LT.600.) I=1
W1=25. +25.*FLOAT(J)
WW=(OMEGA-W1)/25.
IF(I.GT.2) GO TO 75
IF(I.EQ.1) TT=(TEMP-300.)/300.
IF(I.EQ.2) TT=(TEMP-600.)/400.
GO TO 100
75  T1=FLOAT(I-1)*500.
    TT=(TEMP-T1)/500.
100  TW=TT*WW
    SDWEAK=SD(I,J)*(1.-TT-WW+TW)+SD(I+1,J)*(TT-TW)+SD(I,J+1)*(WW-TW)
    I +SD(I+1,J+1)*TW
    D=-2.294+.3004E-02*TEMP-.366E-06*TEMP**2
    B=SIN(.0036*OMEGA-8.043)
    DINV=EXP(.7941*B+D)
C   DINV=EXP(0.00106*TEMP-1.21)
    GDINV=GC2*DINV
    GDDINV=GD*DINV
    TEMP=TTEMP
    RETURN
200 CONTINUE
    SDWEAK=0.
    GDINV=1.
    GDDINV=1.
    RETURN
    END
C
C*****
C
SUBROUTINE CO(OMEGA,TEMP,GC4,SDWEAK,GDINV,GDDINV)
DOUBLE PRECISION AA,BB,CC,DD,EE,FF,GG,SMINUS,SPLUS,SDWEAK,SDSTRG
2,GDINV,GDDINV
IF(OMEGA.LT.1600.OR.OMEGA.GT.2400.)GO TO 300
B=1.93139
ALPHA=260.
A=.017485
OME=2170.21
WX=13.461
WY=.0308
OMPRIM=OME-2.*WX+3.25*WY
T0=300.
C2=1.4388
WM=28.
GD=5.94E-6*OMEGA*(TEMP/(273.*WM))**.5
SDWEAK=1.D-99
SDSTRG=1.D-99
AA=ALPHA*B*C2/(A*(1.-EXP(-OMPRIM*C2/T0))**2)
BB=(1.-EXP(-OMEGA*C2/TEMP))*(1.-EXP(-OMPRIM*C2/TEMP))**2
CC=AA*BB*OMEGA/TEMP*T0/TEMP
DO 101 J=1,20
V=FLOAT(J-1)
DD=(V+1.)*EXP(-V*OME*C2/TEMP)
GAM=B-A*(V+1.)
OMV=OME-2.*(V+1.)*WX+(3.*(V+1.)*(V+1.)+.25)*WY
DELTA=A*(OMEGA-OMV)
IF(GAM*GAM.LE.DELTA)GO TO 102
D=2.*(GAM*GAM-DELTA)**.5
OMVBAR=OMV*(1.-EXP(-OMV*C2/TEMP))
F1=GAM-D/2.
F2=GAM+D/2.
EE=C2*GAM/(A*A*TEMP)

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```

FF=DEXP(EE*DELTA*(I.+.5*A/GAM))
SMINUS=CC*DD/OMVBAR*ABS(F1)*FF*DEXP(-EE*2.*GAM*F1)
SPLUS=CC*DD/OMVBAR*ABS(F2)*FF*DEXP(-EE*2.*GAM*F2)
GG=SDWEAK
SDWEAK=(SMINUS+SPLUS)/D+SDWEAK
TEST=(SDWEAK-GG)/SDWEAK
IF(TEST.LT..0001) GO TO 102
SDSTRG=(SMINUS**5+SPLUS**5)/D+SDSTRG
101 CONTINUE
102 DINV=SDSTRG*SDSTRG/SDWEAK
GDINV=GC4*DINV
GDDINV=GD*DINV
C***EXPRESS S/D AT STP, AS IS K IN NASA SP-3080
SDWEAK=SDWEAK*TEMP/273.
RETURN
300 SDWEAK=0.
GDINV=1.
GDDINV=1.
RETURN
END
C
C*****
C
SUBROUTINE POD(OMEGA)
C***POD CALCULATES PARTICLE OPTICAL DEPTH, XPART, OF THE VOLUME
C FRACTION OF SOOT PARTICLES IN GAS CLOUD. RIN AND RIK ARE
C THE REAL AND IMAGINARY PARTS OF THE INDEX OF REFRACTION. THE
C PARTICLES ARE ASSUMED TO BE IN THE RAYLEIGH LIMIT.
C
COMMON/CPART/W(50),XPART(50),T(50),DD(50),NPT
AMBDA=10000./OMEGA
RIN=1.6
RIK=.5
C FF=36.*3.1416*RIN*RIK/AMBDA/((RIN*RIN-RIK*RIK+2.)**2+(2.*RIN*RIK)
C 2**2)
C
C ABSORPTION COEF. IS BASED UPON MEASUREMENTS OF DALZELL AND
C SAROFIM.
FF=7./AMBDA
DO 300 J=1,NPT
ABCO=FF*W(J)*1.E06
IF(J.EQ.1)GO TO 290
XPART(J)=XPART(J-1)+ABCO*DD(J)
GO TO 300
290 XPART(1)=ABCO*DD(1)
300 CONTINUE
RETURN
END
C
C*****
C
SUBROUTINE FUEL(OMEGA,TEMP,PCH4,PTOT,GC3,SDWEAK,GDINV,GDDINV)
COMMON/CCH4/SD7(3,16),SD3(3,32)
DOUBLE PRECISION SDWEAK,GDINV,GDDINV
DIMENSION BCNT(4),ATOT(4)
IF(OMEGA.GT.5000..OR.OMEGA.LT.1125.)GOTO 100
P1=3.14159
BE=5.2412
C2=1.4388
WM=16.
GD=5.94E-6*OMEGA*(TEMP/(273.*WM))**.5
IF(OMEGA.GT.3400.)GO TO 50
PE=PTOT+.3*PCH4
IF(OMEGA.GE.2625.)GO TO 200
IF(OMEGA.GT.1450.)GO TO 100
GO TO 300
C

```


C CONTRIBUTION TO 2.4 MICRON BAND FROM (0000)-(0110), (0000)-(0011),
 C (0000)-(1001), AND (0000)-(0102) TRANS. THE INTEGRATED BAND INTENSITIES
 C OF VINCENT-GEISSE (ANNALES DE PHYSIQUE SER.12, V. 10, 1955) HAVE
 C BEEN MULTIPLIED BY A FACTOR OF 4 AND THE LINE SPACING IS THAT
 C OF $\sqrt{4}$ FROM GRAY AND PENNER (JQSRT V. 5, 1965).

```

C
50  OM1=2914.2
    OM2=1526.0
    OM3=3020.3
    OM4=1306.2
    BCNT(1)=4123.0
    BCNT(2)=4216.3
    BCNT(3)=4313.2
    BCNT(4)=4546.0
    COM1=OM2+2.*OM4
    COM2=OM1+OM4
    COM3=OM3+OM4
    COM4=OM2+OM3
    ATOT(1)=.64*273./TEMP**(1.-EXP(-C2*COM1/TEMP))/
    2(1.-EXP(-C2*OM2/TEMP))/(1.-EXP(-C2*OM4/TEMP))**2
    ATOT(2)=17.6*273./TEMP*(1.-EXP(-C2*COM2/TEMP))/
    2(1.-EXP(-C2*OM1/TEMP))/(1.-EXP(-C2*OM4/TEMP))
    ATOT(3)=14.8*273./TEMP*(1.-EXP(-C2*COM3/TEMP))/
    2(1.-EXP(-C2*OM3/TEMP))/(1.-EXP(-C2*OM4/TEMP))
    ATOT(4)=5.04*273./TEMP*(1.-EXP(-C2*COM4/TEMP))/
    2(1.-EXP(-C2*OM2/TEMP))/(1.-EXP(-C2*OM3/TEMP))
    DINV=1./5.74
    GDINV=GC3*DINV
    GDDINV=GD*DINV
    SDWEAK=0.0
    DO 51 1=1,4
    SDWEAK=SDWEAK+2.*(OMEGA-BCNT(I))**2*(C2*BE/TEMP)**1.5*ATOT(I)
    2/PI**0.5*DINV**3*EXP(-C2*BE*DINV**2/TEMP*(OMEGA-BCNT(I))**2)
51  CONTINUE
    SDWEAK=SDWEAK*(TEMP/273.)
    RETURN
  
```

C
 CONTRIBUTION TO 3.3 MICRON BAND FROM (0000)-(0010) TRANS.
 C REFER TO BROSNER AND TIEN, JQSRT V. 33, P. 521

```

200 CONTINUE
    GDINV=.00734*PE*(273./TEMP)**.5*EXP(1.02*(TEMP-273.)/273.)
    GDDINV=GD/9.4
    J=(OMEGA-2600.)/25.
    W1=2600.+25.*FLOAT(J)
    SDB=SD3(2,J)+(OMEGA-W1)/25.*(SD3(2,J+1)-SD3(2,J))
    IF(TEMP.GT.600.)GO TO 260
    SDA=SD3(1,J)+(OMEGA-W1)/25.*(SD3(1,J+1)-SD3(1,J))
    SDWEAK=SDA+(TEMP-290.)/310.*(SDB-SDA)
    IF(SDWEAK.LT.0.)SDWEAK=0.
    RETURN
260 SDC=SD3(3,J)+(OMEGA-W1)/25.*(SD3(3,J+1)-SD3(3,J))
    SDWEAK=SDB+(TEMP-600.)/250.*(SDC-SDB)
    IF(SDWEAK.LT.0.)SDWEAK=0.
    RETURN
  
```

C
 CONTRIBUTION TO 7.7 MICRON BAND FROM (0000)-(0001) TRANS.
 C REFER TO BROSNER AND TIEN, JQSRT V. 33, P. 521.

```

300 CONTINUE
    GDINV=.0243*PE*(TEMP/273.))**.8
    GDDINV=GD/5.1
    J=(OMEGA-1100.)/25.
    W1=1100.+25.*FLOAT(J)
    SDB=SD7(2,J)+(OMEGA-W1)/25.*(SD7(2,J+1)-SD7(2,J))
    IF(TEMP.GT.600.)GO TO 360
    SDA=SD7(1,J)+(OMEGA-W1)/25.*(SD7(1,J+1)-SD7(1,J))
    SDWEAK=SDA+(TEMP-290.)/310.*(SDB-SDA)
    IF(SDWEAK.LT.0.)SDWEAK=0.
  
```

```

RETURN
360 SDC=SD7(3,J)+(OMEGA-W1)/25.*(SD7(3,J+1)-SD7(3,J))
SDWEAK=SDB+(TEMP-600.)/250.*(SDC-SDB)
IF(SDWEAK.LT.0.)SDWEAK=0.
RETURN
100 SDWEAK=0.0
GDINV=1.
GDDINV=1.
RETURN
END

C
C*****
C
FUNCTION PLANCK(A,B)
C COMPUTES BLACKBODY FUNCTION IN UNITS OF W/M-2/MICRON/SR
C1=.59544E08
C2=14388.
IF(A.EQ.0.)GO TO 100
OVRFLO=C2/A/B
IF(OVRFLO.GT.38.)GO TO 100
PLANCK=2.*C1*(B**(-5))/(EXP(C2/A/B)-1.)
GO TO 101
100 PLANCK=0.
101 CONTINUE
RETURN
END

```

RCPART2.FOR

```

BLOCK DATA BD1
COMMON/CH2O/SD(6,376)
DIMENSION A1(6,8),A2(6,8),A3(6,8),A4(6,8),A5(6,8),A6(6,8),A7(6,8),
2A8(6,8),A9(6,8),A10(6,8),A11(6,8),A12(6,8),A13(6,8),A14(6,8),
3A15(6,8),A16(6,8),A17(6,8),A18(6,8),A19(6,8),A20(6,8),A21(6,8)
EQUIVALENCE(A1(1,1),SD(1,1)),(A2(1,1),SD(1,9)),(A3(1,1),SD(1,17))
1,(A4(1,1),SD(1,25)),(A5(1,1),SD(1,33)),(A6(1,1),SD(1,41))
2,(A7(1,1),SD(1,49)),(A8(1,1),SD(1,57)),(A9(1,1),SD(1,65))
3,(A10(1,1),SD(1,73)),(A11(1,1),SD(1,81)),(A12(1,1),SD(1,89))
4,(A13(1,1),SD(1,97)),(A14(1,1),SD(1,105)),(A15(1,1),SD(1,113))
5,(A16(1,1),SD(1,121)),(A17(1,1),SD(1,129)),(A18(1,1),SD(1,137))
6,(A19(1,1),SD(1,145)),(A20(1,1),SD(1,153)),(A21(1,1),SD(1,161))
C TEMP,K= 300 600 1000 1500 2000 2500 WAVE NO.
DATA A1/
1 .950E+00, .103E+00, .420E-01, .114E-01, .450E-02, .300E-02, 50
1 .208E+01, .365E+00, .113E+00, .375E-01, .195E-01, .134E-01, 75
1 .368E+01, .990E+00, .300E+00, .104E+00, .577E-01, .365E-01, 100
1 .650E+01, .201E+01, .650E+00, .214E+00, .128E+00, .845E-01, 125
1 .825E+01, .325E+01, .121E+01, .415E+00, .260E+00, .168E+00, 150
1 .870E+01, .452E+01, .189E+01, .765E+00, .450E+00, .289E+00, 175
1 .810E+01, .540E+01, .261E+01, .126E+01, .695E+00, .460E+00, 200
1 .682E+01, .600E+01, .337E+01, .179E+01, .101E+01, .679E+00/ 225
DATA A2/
1 .493E+01, .622E+01, .407E+01, .230E+01, .135E+01, .935E+00, 250
1 .316E+01, .592E+01, .456E+01, .281E+01, .172E+01, .122E+01, 275
1 .199E+01, .528E+01, .479E+01, .328E+01, .213E+01, .149E+01, 300
1 .113E+01, .450E+01, .484E+01, .361E+01, .249E+01, .179E+01, 325
1 .585E+00, .370E+01, .471E+01, .383E+01, .284E+01, .208E+01, 350
1 .293E+00, .289E+01, .443E+01, .394E+01, .312E+01, .237E+01, 375
1 .138E+00, .205E+01, .400E+01, .396E+01, .330E+01, .260E+01, 400
1 .620E-01, .143E+01, .347E+01, .388E+01, .341E+01, .280E+01/ 425
DATA A3/
1 .255E-01, .950E+00, .292E+01, .370E+01, .345E+01, .295E+01, 450
1 .940E-02, .610E+00, .236E+01, .343E+01, .342E+01, .304E+01, 475
1 .340E-02, .386E+00, .188E+01, .310E+01, .334E+01, .309E+01, 500
1 .105E-02, .236E+00, .145E+01, .274E+01, .319E+01, .307E+01, 525
1 .350E-03, .144E+00, .110E+01, .238E+01, .300E+01, .301E+01, 550

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1 .126E-03, .820E-01, .818E+00, .204E+01, .276E+01, .289E+01,	575
1 .430E-04, .445E-01, .598E+00, .174E+01, .248E+01, .275E+01,	600
1 .150E-04, .242E-01, .427E+00, .145E+01, .222E+01, .260E+01/ DATA A4/	625
1 .510E-05, .127E-01, .294E+00, .118E+01, .195E+01, .241E+01,	650
1 .170E-05, .630E-02, .200E+00, .950E+00, .169E+01, .221E+01,	675
1 .570E-06, .300E-02, .134E+00, .748E+00, .146E+01, .200E+01,	700
1 .195E-06, .140E-02, .902E-01, .580E+00, .124E+01, .178E+01,	725
1 .680E-07, .620E-03, .590E-01, .443E+00, .103E+01, .156E+01,	750
1 .385E-07, .275E-03, .450E-01, .330E+00, .845E+00, .136E+01,	775
1 .670E-07, .113E-03, .355E-01, .242E+00, .695E+00, .117E+01,	800
1 .113E-06, .500E-04, .289E-01, .174E+00, .560E+00, .100E+01/ DATA A5/	825
1 .195E-06, .230E-04, .245E-01, .123E+00, .450E+00, .855E+00,	850
1 .328E-06, .103E-04, .214E-01, .100E+00, .357E+00, .718E+00,	875
1 .560E-06, .460E-05, .189E-01, .830E-01, .278E+00, .595E+00,	900
1 .950E-06, .205E-05, .174E-01, .730E-01, .239E+00, .492E+00,	925
1 .160E-05, .140E-05, .166E-01, .665E-01, .211E+00, .405E+00,	950
1 .275E-05, .350E-05, .165E-01, .630E-01, .195E+00, .352E+00,	975
1 .470E-05, .850E-05, .167E-01, .620E-01, .190E+00, .312E+00,	1000
1 .810E-05, .215E-04, .175E-01, .630E-01, .191E+00, .289E+00/ DATA A6/	1025
1 .136E-04, .570E-04, .188E-01, .675E-01, .194E+00, .281E+00,	1050
1 .235E-04, .150E-03, .208E-01, .745E-01, .202E+00, .283E+00,	1075
1 .400E-04, .380E-03, .233E-01, .865E-01, .223E+00, .314E+00,	1100
1 .680E-04, .950E-03, .268E-01, .122E+00, .260E+00, .380E+00,	1125
1 .120E-03, .245E-02, .343E-01, .176E+00, .328E+00, .461E+00,	1150
1 .200E-03, .620E-02, .638E-01, .251E+00, .411E+00, .511E+00,	1175
1 .365E-03, .140E-01, .107E+00, .330E+00, .458E+00, .542E+00,	1200
1 .680E-03, .330E-01, .166E+00, .405E+00, .487E+00, .571E+00/ DATA A7/	1225
1 .130E-02, .635E-01, .244E+00, .459E+00, .535E+00, .557E+00,	1250
1 .250E-02, .123E+00, .341E+00, .477E+00, .502E+00, .562E+00,	1275
1 .500E-02, .212E+00, .407E+00, .547E+00, .531E+00, .514E+00,	1300
1 .103E-01, .285E+00, .489E+00, .592E+00, .497E+00, .486E+00,	1325
1 .219E-01, .328E+00, .491E+00, .558E+00, .489E+00, .485E+00,	1350
1 .485E-01, .345E+00, .505E+00, .521E+00, .477E+00, .484E+00,	1375
1 .114E+00, .361E+00, .538E+00, .563E+00, .503E+00, .502E+00,	1400
1 .249E+00, .460E+00, .621E+00, .624E+00, .538E+00, .538E+00/ DATA A8/	1425
1 .397E+00, .569E+00, .749E+00, .768E+00, .581E+00, .565E+00,	1450
1 .418E+00, .627E+00, .824E+00, .849E+00, .640E+00, .594E+00,	1475
1 .108E+01, .125E+01, .113E+01, .940E+00, .807E+00, .663E+00,	1500
1 .165E+01, .155E+01, .118E+01, .670E+00, .562E+00, .483E+00,	1525
1 .142E+01, .675E+00, .557E+00, .349E+00, .276E+00, .263E+00,	1550
1 .451E+00, .202E+00, .132E+00, .118E+00, .134E+00, .156E+00,	1575
1 .603E-01, .538E-01, .863E-01, .112E+00, .120E+00, .125E+00,	1600
1 .501E+00, .252E+00, .118E+00, .112E+00, .131E+00, .140E+00/ DATA A9/	1625
1 .730E+00, .430E+00, .237E+00, .191E+00, .171E+00, .170E+00,	1650
1 .149E+01, .506E+00, .294E+00, .238E+00, .210E+00, .201E+00,	1675
1 .100E+01, .553E+00, .434E+00, .340E+00, .260E+00, .220E+00,	1700
1 .802E+00, .658E+00, .528E+00, .411E+00, .300E+00, .240E+00,	1725
1 .580E+00, .527E+00, .460E+00, .378E+00, .322E+00, .283E+00,	1750
1 .330E+00, .403E+00, .430E+00, .356E+00, .318E+00, .270E+00,	1775
1 .250E+00, .393E+00, .405E+00, .342E+00, .301E+00, .275E+00,	1800
1 .147E+00, .249E+00, .313E+00, .318E+00, .291E+00, .268E+00/ DATA A10/	1825
1 .910E-01, .252E+00, .298E+00, .295E+00, .269E+00, .253E+00,	1850
1 .580E-01, .158E+00, .214E+00, .244E+00, .244E+00, .245E+00,	1875
1 .370E-01, .113E+00, .184E+00, .218E+00, .214E+00, .218E+00,	1900
1 .244E-01, .118E+00, .156E+00, .188E+00, .195E+00, .200E+00,	1925
1 .162E-01, .606E-01, .976E-01, .141E+00, .166E+00, .179E+00,	1950
1 .112E-01, .425E-01, .903E-01, .133E+00, .148E+00, .156E+00,	1975
1 .780E-02, .400E-01, .765E-01, .112E+00, .129E+00, .137E+00,	2000
1 .540E-02, .352E-01, .647E-01, .876E-01, .110E+00, .118E+00/ DATA A11/	2025

1 .380E-02, .252E-01, .507E-01, .705E-01, .888E-01, .100E+00,	2050
1 .260E-02, .179E-01, .377E-01, .546E-01, .724E-01, .828E-01,	2075
1 .180E-02, .123E-01, .294E-01, .443E-01, .608E-01, .686E-01,	2100
1 .127E-02, .850E-02, .212E-01, .378E-01, .579E-01, .640E-01,	2125
1 .880E-03, .680E-02, .152E-01, .275E-01, .449E-01, .521E-01,	2150
1 .620E-02, .400E-02, .107E-01, .214E-01, .374E-01, .453E-01,	2175
1 .480E-03, .298E-02, .931E-02, .189E-01, .329E-01, .403E-01,	2200
1 .405E-03, .175E-02, .696E-02, .152E-01, .295E-01, .365E-01/ DATA A12/	2225
1 .321E-03, .120E-02, .452E-02, .101E-01, .252E-01, .331E-01,	2250
1 .229E-03, .721E-03, .364E-02, .930E-02, .225E-01, .305E-01,	2275
1 .195E-03, .544E-03, .318E-02, .750E-02, .202E-01, .284E-01,	2300
1 .154E-03, .375E-03, .185E-02, .603E-02, .175E-01, .269E-01,	2325
1 .101E-03, .263E-03, .119E-02, .480E-02, .156E-01, .253E-01,	2350
1 .852E-04, .185E-03, .909E-03, .360E-02, .133E-01, .241E-01,	2375
1 .763E-04, .137E-03, .711E-03, .316E-02, .122E-01, .237E-01,	2400
1 .615E-04, .126E-03, .610E-03, .257E-02, .101E-01, .218E-01/ DATA A13/	2425
1 .480E-04, .113E-03, .518E-03, .201E-02, .920E-02, .200E-01,	2450
1 .372E-04, .106E-03, .435E-03, .168E-02, .785E-02, .183E-01,	2475
1 .355E-04, .101E-03, .376E-03, .168E-02, .669E-02, .166E-01,	2500
1 .358E-04, .990E-04, .366E-03, .167E-02, .651E-02, .156E-01,	2525
1 .389E-04, .102E-03, .376E-03, .167E-02, .641E-02, .152E-01,	2550
1 .422E-04, .106E-03, .373E-03, .168E-02, .656E-02, .150E-01,	2575
1 .521E-04, .111E-03, .371E-03, .170E-02, .673E-02, .152E-01,	2600
1 .646E-04, .121E-03, .384E-03, .179E-02, .798E-02, .179E-01/ DATA A14/	2625
1 .742E-04, .129E-03, .479E-03, .201E-02, .788E-02, .175E-01,	2650
1 .953E-04, .165E-03, .544E-03, .249E-02, .945E-02, .204E-01,	2675
1 .101E-03, .190E-03, .761E-03, .324E-02, .106E-01, .231E-01,	2700
1 .147E-03, .272E-03, .892E-03, .441E-02, .125E-01, .257E-01,	2725
1 .195E-03, .326E-03, .100E-02, .499E-02, .147E-01, .295E-01,	2750
1 .261E-03, .421E-03, .145E-02, .568E-02, .161E-01, .306E-01,	2775
1 .305E-03, .515E-03, .195E-02, .754E-02, .185E-01, .363E-01,	2800
1 .362E-03, .645E-03, .237E-02, .830E-02, .205E-01, .373E-01/ DATA A15/	2825
1 .507E-03, .850E-03, .274E-02, .888E-02, .234E-01, .431E-01,	2850
1 .799E-03, .118E-02, .322E-02, .110E-01, .262E-01, .451E-01,	2875
1 .935E-03, .160E-02, .386E-02, .126E-01, .292E-01, .530E-01,	2900
1 .108E-02, .231E-02, .451E-02, .140E-01, .306E-01, .536E-01,	2925
1 .192E-02, .271E-02, .563E-02, .159E-01, .357E-01, .629E-01,	2950
1 .263E-02, .300E-02, .625E-02, .179E-01, .385E-01, .666E-01,	2975
1 .295E-02, .330E-02, .701E-02, .203E-01, .460E-01, .782E-01,	3000
1 .310E-02, .370E-02, .846E-02, .220E-01, .519E-01, .889E-01/ DATA A16/	3025
1 .340E-02, .400E-02, .969E-02, .279E-01, .662E-01, .109E+00,	3050
1 .730E-02, .450E-02, .111E-01, .272E-01, .676E-01, .109E+00,	3075
1 .900E-02, .480E-02, .137E-01, .372E-01, .864E-01, .133E+00,	3100
1 .100E-02, .510E-02, .162E-01, .471E-01, .100E+00, .142E+00,	3125
1 .640E-03, .550E-02, .205E-01, .530E-01, .122E+00, .168E+00,	3150
1 .160E-02, .600E-02, .247E-01, .633E-01, .135E+00, .177E+00,	3175
1 .330E-02, .700E-02, .283E-01, .770E-01, .153E+00, .185E+00,	3200
1 .410E-02, .860E-02, .376E-01, .914E-01, .166E+00, .206E+00/ DATA A17/	3225
1 .410E-02, .103E-01, .514E-01, .117E+00, .194E+00, .228E+00,	3250
1 .290E-02, .129E-01, .664E-01, .147E+00, .220E+00, .254E+00,	3275
1 .220E-02, .161E-01, .834E-01, .171E+00, .237E+00, .263E+00,	3300
1 .220E-02, .212E-01, .103E+00, .201E+00, .268E+00, .283E+00,	3325
1 .250E-02, .285E-01, .135E+00, .240E+00, .295E+00, .295E+00,	3350
1 .310E-02, .385E-01, .169E+00, .272E+00, .312E+00, .301E+00,	3375
1 .420E-02, .540E-01, .214E+00, .309E+00, .329E+00, .307E+00,	3400
1 .600E-02, .770E-01, .267E+00, .343E+00, .332E+00, .314E+00/ DATA A18/	3425
1 .940E-02, .117E+00, .333E+00, .372E+00, .344E+00, .303E+00,	3450
1 .165E-01, .173E+00, .365E+00, .385E+00, .353E+00, .300E+00,	3475
1 .360E-01, .258E+00, .438E+00, .393E+00, .315E+00, .288E+00,	3500
1 .720E-01, .375E+00, .510E+00, .409E+00, .294E+00, .271E+00,	3525

1 .133E+00, .401E+00, .499E+00, .390E+00, .281E+00, .257E+00,	3550
1 .215E+00, .500E+00, .443E+00, .341E+00, .254E+00, .230E+00,	3575
1 .318E+00, .450E+00, .346E+00, .286E+00, .245E+00, .219E+00,	3600
1 .442E+00, .400E+00, .354E+00, .279E+00, .233E+00, .216E+00/	3625
DATA A19/	
1 .473E+00, .405E+00, .347E+00, .281E+00, .238E+00, .219E+00,	3650
1 .568E+00, .501E+00, .423E+00, .315E+00, .243E+00, .218E+00,	3675
1 .690E+00, .708E+00, .673E+00, .432E+00, .268E+00, .189E+00,	3700
1 .617E+00, .831E+00, .566E+00, .320E+00, .194E+00, .123E+00,	3725
1 .181E+01, .520E+00, .200E+00, .131E+00, .124E+00, .107E+00,	3750
1 .136E+00, .124E+00, .120E+00, .119E+00, .115E+00, .115E+00,	3775
1 .455E+00, .298E+00, .167E+00, .129E+00, .123E+00, .112E+00,	3800
1 .760E+00, .503E+00, .242E+00, .154E+00, .129E+00, .127E+00/	3825
DATA A20/	
1 .836E+00, .584E+00, .277E+00, .184E+00, .161E+00, .145E+00,	3850
1 .840E+00, .728E+00, .422E+00, .236E+00, .197E+00, .167E+00,	3875
1 .505E+00, .500E+00, .379E+00, .276E+00, .227E+00, .192E+00,	3900
1 .117E+00, .400E+00, .423E+00, .315E+00, .243E+00, .202E+00,	3925
1 .460E-01, .300E+00, .358E+00, .290E+00, .230E+00, .202E+00,	3950
1 .183E-01, .205E+00, .269E+00, .235E+00, .195E+00, .192E+00,	3975
1 .730E-02, .135E+00, .186E+00, .179E+00, .159E+00, .168E+00,	4000
1 .557E-02, .790E-01, .113E+00, .124E+00, .124E+00, .134E+00/	4025
DATA A21/	
1 .283E-02, .415E-01, .662E-01, .886E-01, .103E+00, .106E+00,	4050
1 .226E-02, .197E-01, .367E-01, .594E-01, .801E-01, .879E-01,	4075
1 .155E-02, .860E-02, .211E-01, .395E-01, .503E-01, .610E-01,	4100
1 .103E-02, .521E-02, .119E-01, .246E-01, .354E-01, .480E-01,	4125
1 .821E-03, .365E-02, .759E-02, .166E-01, .258E-01, .370E-01,	4150
1 .752E-03, .183E-02, .445E-02, .100E-01, .179E-01, .268E-01,	4175
1 .429E-03, .141E-02, .354E-02, .821E-02, .142E-01, .212E-01,	4200
1 .327E-03, .902E-03, .209E-02, .588E-02, .112E-01, .172E-01/	4225
END	

RCPART3.FOR

BLOCK DATA BD2

COMMON/CH2O/SD(6,376)

DIMENSION A22(6,8),A23(6,8),A24(6,8),A25(6,8),A26(6,8),A27(6,8),
4A28(6,8),

5A29(6,8),A30(6,8),A31(6,8),A32(6,8),A33(6,8),A34(6,8),A35(6,8),
6A36(6,8),A37(6,8),A38(6,8),A39(6,8),A40(6,8),A41(6,8),A42(6,8),
7A43(6,8),A44(6,8),A45(6,8),A46(6,8),A47(6,8)

EQUIVALENCE(A22(1,1),SD(1,169)),(A23(1,1),SD(1,177)),(A24(1,1)
1,SD(1,185)),(A25(1,1),SD(1,193)),(A26(1,1),SD(1,201)),(A27(1,1)
2,SD(1,209)),(A28(1,1),SD(1,217)),(A29(1,1),SD(1,225)),(A30(1,1)
3,SD(1,233)),(A31(1,1),SD(1,241)),(A32(1,1),SD(1,249)),(A33(1,1)
4,SD(1,257)),(A34(1,1),SD(1,265)),(A35(1,1),SD(1,273)),(A36(1,1)
5,SD(1,281)),(A37(1,1),SD(1,289)),(A38(1,1),SD(1,297))

EQUIVALENCE(A39(1,1),SD(1,305)),(A40(1,1),SD(1,313)),(A41(1,1)
1,SD(1,321)),(A42(1,1),SD(1,329)),(A43(1,1),SD(1,337)),(A44(1,1)
2,SD(1,345)),(A45(1,1),SD(1,353)),(A46(1,1),SD(1,361)),(A47(1,1)
3,SD(1,369))

C TEMP,K= 300 600 1000 1500 2000 2500 WAVE NO.

DATA A22/

1 .225E-03, .685E-03, .189E-02, .512E-02, .101E-01, .164E-01,	4250
1 .186E-03, .551E-03, .156E-02, .366E-02, .812E-02, .136E-01,	4275
1 .173E-03, .472E-03, .139E-02, .306E-02, .661E-02, .115E-01,	4300
1 .138E-03, .395E-03, .110E-02, .272E-02, .587E-02, .104E-01,	4325
1 .900E-04, .270E-03, .968E-03, .222E-02, .497E-02, .921E-02,	4350
1 .752E-04, .233E-03, .744E-03, .208E-02, .466E-02, .876E-02,	4375
1 .618E-04, .175E-03, .638E-03, .185E-02, .465E-02, .914E-02,	4400
1 .504E-04, .134E-03, .499E-03, .174E-02, .455E-02, .935E-02/	4425

DATA A23/

1 .375E-04, .123E-03, .485E-03, .182E-02, .456E-02, .971E-02,	4450
1 .305E-04, .892E-04, .338E-03, .134E-02, .460E-02, .104E-01,	4475
1 .257E-04, .790E-04, .329E-03, .154E-02, .477E-02, .112E-01,	4500

1 .242E-04, .740E-04, .308E-03, .135E-02, .497E-02, .122E-01,	4525
1 .215E-04, .653E-04, .282E-03, .131E-02, .521E-02, .133E-01,	4550
1 .218E-04, .660E-04, .272E-03, .152E-02, .573E-02, .148E-01,	4575
1 .215E-04, .671E-04, .268E-03, .134E-02, .607E-02, .159E-01,	4600
1 .217E-04, .695E-04, .285E-03, .161E-02, .677E-02, .173E-01/ DATA A24/	4625
1 .219E-04, .722E-04, .297E-03, .169E-02, .783E-02, .197E-01,	4650
1 .226E-04, .771E-04, .341E-03, .236E-02, .925E-02, .226E-01,	4675
1 .250E-04, .815E-04, .387E-03, .286E-02, .106E-01, .250E-01,	4700
1 .280E-04, .845E-04, .420E-03, .357E-02, .124E-01, .276E-01,	4725
1 .351E-04, .192E-03, .470E-03, .467E-02, .166E-01, .313E-01,	4750
1 .435E-04, .200E-03, .105E-02, .566E-02, .185E-01, .341E-01,	4775
1 .522E-04, .233E-03, .129E-02, .736E-02, .229E-01, .378E-01,	4800
1 .673E-04, .306E-03, .183E-02, .982E-02, .258E-01, .404E-01/ DATA A25/	4825
1 .886E-04, .399E-03, .246E-02, .128E-01, .302E-01, .430E-01,	4850
1 .113E-03, .618E-03, .346E-02, .161E-01, .358E-01, .459E-01,	4875
1 .174E-03, .825E-03, .441E-02, .200E-01, .417E-01, .493E-01,	4900
1 .265E-03, .163E-02, .777E-02, .245E-01, .450E-01, .507E-01,	4925
1 .355E-03, .200E-02, .978E-02, .317E-01, .492E-01, .527E-01,	4950
1 .538E-03, .271E-02, .167E-01, .401E-01, .503E-01, .523E-01,	4975
1 .651E-03, .301E-02, .264E-01, .467E-01, .520E-01, .526E-01,	5000
1 .987E-03, .530E-02, .321E-01, .499E-01, .523E-01, .510E-01/ DATA A26/	5025
1 .135E-02, .860E-02, .389E-01, .528E-01, .513E-01, .492E-01,	5050
1 .226E-02, .130E-01, .472E-01, .559E-01, .500E-01, .469E-01,	5075
1 .431E-02, .198E-01, .526E-01, .557E-01, .480E-01, .452E-01,	5100
1 .628E-02, .282E-01, .488E-01, .495E-01, .451E-01, .430E-01,	5125
1 .900E-02, .390E-01, .471E-01, .449E-01, .430E-01, .423E-01,	5150
1 .180E-01, .462E-01, .412E-01, .391E-01, .403E-01, .415E-01,	5175
1 .348E-01, .710E-01, .402E-01, .360E-01, .384E-01, .414E-01,	5200
1 .718E-01, .590E-01, .399E-01, .360E-01, .376E-01, .420E-01/ DATA A27/	5225
1 .111E+00, .368E-01, .340E-01, .369E-01, .409E-01, .454E-01,	5250
1 .329E-01, .285E-01, .365E-01, .423E-01, .461E-01, .482E-01,	5275
1 .281E-01, .270E-01, .432E-01, .505E-01, .529E-01, .511E-01,	5300
1 .121E+00, .422E-01, .589E-01, .598E-01, .572E-01, .544E-01,	5325
1 .139E+00, .105E+00, .844E-01, .687E-01, .593E-01, .560E-01,	5350
1 .774E-01, .710E-01, .683E-01, .618E-01, .556E-01, .534E-01,	5375
1 .858E-01, .483E-01, .579E-01, .547E-01, .503E-01, .495E-01,	5400
1 .985E-01, .575E-01, .589E-01, .510E-01, .451E-01, .449E-01/ DATA A28/	5425
1 .996E-01, .682E-01, .539E-01, .489E-01, .454E-01, .446E-01,	5450
1 .680E-01, .680E-01, .548E-01, .495E-01, .460E-01, .458E-01,	5475
1 .325E-01, .520E-01, .515E-01, .483E-01, .449E-01, .454E-01,	5500
1 .150E-01, .350E-01, .451E-01, .464E-01, .452E-01, .449E-01,	5525
1 .620E-02, .238E-01, .369E-01, .408E-01, .414E-01, .417E-01,	5550
1 .270E-02, .158E-01, .282E-01, .339E-01, .366E-01, .384E-01,	5575
1 .113E-02, .101E-01, .203E-01, .263E-01, .303E-01, .333E-01,	5600
1 .829E-03, .590E-02, .148E-01, .206E-01, .247E-01, .295E-01/ DATA A29/	5625
1 .365E-03, .310E-02, .969E-02, .154E-01, .203E-01, .258E-01,	5650
1 .240E-03, .130E-02, .589E-02, .112E-01, .164E-01, .222E-01,	5675
1 .158E-03, .400E-03, .417E-02, .850E-02, .134E-01, .190E-01,	5700
1 .103E-03, .262E-03, .208E-02, .594E-02, .109E-01, .162E-01,	5725
1 .741E-04, .181E-03, .142E-02, .455E-02, .907E-02, .141E-01,	5750
1 .625E-04, .135E-03, .816E-03, .316E-02, .698E-02, .121E-01,	5775
1 .499E-04, .111E-03, .624E-03, .230E-02, .551E-02, .102E-01,	5800
1 .325E-04, .677E-04, .425E-03, .124E-02, .385E-02, .818E-02/ DATA A30/	5825
1 .231E-04, .563E-04, .278E-03, .986E-03, .290E-02, .672E-02,	5850
1 .165E-04, .481E-04, .247E-03, .944E-03, .253E-02, .612E-02,	5875
1 .126E-04, .432E-04, .241E-03, .886E-03, .220E-02, .582E-02,	5900
1 .118E-04, .420E-04, .235E-03, .847E-03, .209E-02, .571E-02,	5925
1 .110E-04, .408E-04, .226E-03, .812E-03, .221E-02, .604E-02,	5950
1 .101E-04, .400E-04, .213E-03, .805E-03, .239E-02, .641E-02,	5975
1 .983E-05, .395E-04, .186E-03, .801E-03, .247E-02, .691E-02,	6000

1 .979E-05, .401E-04, .193E-03, .805E-03, .260E-02, .732E-02/ 6025
DATA A31/
1 .976E-05, .410E-04, .201E-03, .814E-03, .285E-02, .776E-02, 6050
1 .988E-05, .420E-04, .210E-03, .832E-03, .317E-02, .842E-02, 6075
1 .991E-05, .425E-04, .219E-03, .877E-03, .340E-02, .888E-02, 6100
1 .102E-04, .435E-04, .231E-03, .937E-03, .361E-02, .929E-02, 6125
1 .110E-04, .486E-04, .244E-03, .971E-03, .402E-02, .994E-02, 6150
1 .127E-04, .579E-04, .257E-03, .111E-02, .437E-02, .104E-01, 6175
1 .131E-04, .612E-04, .277E-03, .113E-02, .465E-02, .110E-01, 6200
1 .150E-04, .783E-04, .353E-03, .116E-02, .510E-02, .116E-01/ 6225
DATA A32/
1 .178E-04, .922E-04, .394E-03, .157E-02, .555E-02, .123E-01, 6250
1 .203E-04, .115E-03, .481E-03, .188E-02, .601E-02, .131E-01, 6275
1 .230E-04, .145E-03, .617E-03, .183E-02, .644E-02, .139E-01, 6300
1 .280E-04, .187E-03, .723E-03, .202E-02, .686E-02, .146E-01, 6325
1 .305E-04, .209E-03, .811E-03, .243E-02, .779E-02, .157E-01, 6350
1 .455E-04, .244E-03, .935E-03, .243E-02, .844E-02, .166E-01, 6375
1 .661E-04, .320E-03, .989E-03, .288E-02, .902E-02, .173E-01, 6400
1 .723E-04, .397E-03, .122E-02, .359E-02, .100E-01, .184E-01/ 6425
DATA A33/
1 .847E-04, .481E-03, .143E-02, .429E-02, .108E-01, .192E-01, 6450
1 .103E-03, .591E-03, .174E-02, .488E-02, .116E-01, .200E-01, 6475
1 .131E-03, .703E-03, .247E-02, .549E-02, .124E-01, .205E-01, 6500
1 .165E-03, .872E-03, .265E-02, .641E-02, .131E-01, .211E-01, 6525
1 .205E-03, .110E-02, .298E-02, .749E-02, .140E-01, .218E-01, 6550
1 .253E-03, .130E-02, .346E-02, .811E-02, .150E-01, .230E-01, 6575
1 .338E-03, .150E-02, .445E-02, .890E-02, .159E-01, .237E-01, 6600
1 .437E-03, .170E-02, .491E-02, .107E-01, .170E-01, .245E-01/ 6625
DATA A34/
1 .581E-03, .190E-02, .537E-02, .116E-01, .179E-01, .254E-01, 6650
1 .685E-03, .220E-02, .578E-02, .128E-01, .189E-01, .263E-01, 6675
1 .900E-03, .250E-02, .649E-02, .134E-01, .195E-01, .275E-01, 6700
1 .121E-02, .280E-02, .722E-02, .142E-01, .202E-01, .281E-01, 6725
1 .152E-02, .330E-02, .813E-02, .161E-01, .212E-01, .288E-01, 6750
1 .185E-02, .370E-02, .907E-02, .168E-01, .222E-01, .292E-01, 6775
1 .220E-02, .430E-02, .929E-02, .183E-01, .233E-01, .294E-01, 6800
1 .255E-02, .500E-02, .114E-01, .195E-01, .245E-01, .289E-01/ 6825
DATA A35/
1 .290E-02, .580E-02, .167E-01, .215E-01, .260E-01, .291E-01, 6850
1 .320E-02, .670E-02, .208E-01, .237E-01, .274E-01, .293E-01, 6875
1 .360E-02, .880E-02, .220E-01, .253E-01, .282E-01, .300E-01, 6900
1 .400E-02, .920E-02, .238E-01, .273E-01, .290E-01, .304E-01, 6925
1 .460E-02, .108E-01, .272E-01, .279E-01, .298E-01, .310E-01, 6950
1 .530E-02, .128E-01, .304E-01, .292E-01, .297E-01, .312E-01, 6975
1 .620E-02, .152E-01, .344E-01, .303E-01, .293E-01, .310E-01, 7000
1 .760E-02, .182E-01, .341E-01, .297E-01, .290E-01, .300E-01/ 7025
DATA A36/
1 .980E-02, .222E-01, .398E-01, .318E-01, .291E-01, .294E-01, 7050
1 .132E-01, .271E-01, .402E-01, .294E-01, .274E-01, .282E-01, 7075
1 .190E-01, .335E-01, .421E-01, .286E-01, .262E-01, .269E-01, 7100
1 .240E-01, .432E-01, .431E-01, .276E-01, .245E-01, .257E-01, 7125
1 .288E-01, .570E-01, .458E-01, .270E-01, .228E-01, .243E-01, 7150
1 .323E-01, .740E-01, .449E-01, .261E-01, .214E-01, .221E-01, 7175
1 .570E-01, .890E-01, .435E-01, .225E-01, .199E-01, .196E-01, 7200
1 .216E-01, .680E-01, .378E-01, .239E-01, .195E-01, .192E-01/ 7225
DATA A37/
1 .126E-01, .475E-01, .364E-01, .238E-01, .197E-01, .192E-01, 7250
1 .117E-01, .369E-01, .385E-01, .249E-01, .212E-01, .204E-01, 7275
1 .140E-01, .370E-01, .419E-01, .272E-01, .228E-01, .213E-01, 7300
1 .425E-01, .418E-01, .440E-01, .280E-01, .248E-01, .229E-01, 7325
1 .640E-01, .460E-01, .427E-01, .290E-01, .263E-01, .238E-01, 7350
1 .385E-01, .385E-01, .374E-01, .259E-01, .235E-01, .224E-01, 7375
1 .182E-01, .179E-01, .282E-01, .231E-01, .211E-01, .214E-01, 7400
1 .170E-01, .810E-02, .191E-01, .175E-01, .181E-01, .194E-01/ 7425
DATA A38/
1 .161E-01, .370E-02, .105E-01, .127E-01, .152E-01, .171E-01, 7450
1 .145E-01, .170E-02, .554E-02, .855E-02, .113E-01, .131E-01, 7475

1 .175E-02, .140E-02, .385E-02, .595E-02, .803E-02, .945E-02,	7500
1 .772E-03, .751E-03, .384E-02, .575E-02, .537E-02, .594E-02,	7525
1 .491E-03, .600E-03, .301E-02, .453E-02, .380E-02, .434E-02,	7550
1 .275E-03, .410E-03, .193E-02, .366E-02, .319E-02, .332E-02,	7575
1 .185E-01, .280E-03, .131E-02, .232E-02, .247E-02, .256E-02,	7600
1 .101E-03, .160E-03, .915E-03, .150E-02, .186E-02, .197E-02/ DATA A39/	7625
1 .691E-04, .110E-03, .565E-03, .114E-02, .205E-02, .192E-02,	7650
1 .476E-04, .750E-04, .114E-02, .124E-02, .175E-02, .187E-02,	7675
1 .305E-04, .590E-04, .529E-03, .114E-02, .160E-02, .185E-02,	7700
1 .240E-04, .480E-04, .293E-03, .842E-03, .141E-02, .184E-02,	7725
1 .170E-04, .360E-04, .122E-03, .435E-03, .124E-02, .182E-02,	7750
1 .120E-04, .240E-04, .121E-03, .435E-03, .118E-02, .187E-02,	7775
1 .810E-05, .170E-04, .103E-03, .439E-03, .126E-02, .192E-02,	7800
1 .550E-05, .120E-04, .866E-04, .367E-03, .119E-02, .193E-02/ DATA A40/	7825
1 .390E-05, .900E-05, .716E-04, .351E-03, .116E-02, .194E-02,	7850
1 .295E-05, .830E-05, .373E-04, .254E-03, .114E-02, .196E-02,	7875
1 .230E-05, .800E-05, .465E-04, .298E-03, .117E-02, .201E-02,	7900
1 .225E-05, .820E-05, .367E-04, .252E-03, .116E-02, .205E-02,	7925
1 .220E-05, .840E-05, .371E-04, .268E-03, .127E-02, .211E-02,	7950
1 .223E-05, .920E-05, .396E-04, .273E-03, .128E-02, .216E-02,	7975
1 .235E-05, .103E-04, .415E-04, .263E-03, .121E-02, .221E-02,	8000
1 .280E-05, .125E-04, .633E-04, .363E-03, .136E-02, .231E-02/ DATA A41/	8025
1 .310E-05, .150E-04, .979E-04, .492E-03, .150E-02, .241E-02,	8050
1 .370E-05, .180E-04, .120E-03, .580E-03, .167E-02, .251E-02,	8075
1 .420E-05, .200E-04, .987E-04, .509E-03, .171E-02, .257E-02,	8100
1 .510E-05, .240E-04, .134E-03, .547E-03, .173E-02, .267E-02,	8125
1 .600E-05, .270E-04, .121E-03, .534E-03, .172E-02, .274E-02,	8150
1 .720E-05, .300E-04, .204E-03, .684E-03, .184E-02, .285E-02,	8175
1 .820E-05, .330E-04, .276E-03, .819E-03, .199E-02, .297E-02,	8200
1 .100E-04, .380E-04, .317E-03, .859E-03, .214E-02, .308E-02/ DATA A42/	8225
1 .125E-04, .420E-04, .240E-03, .818E-03, .220E-02, .317E-02,	8250
1 .145E-04, .500E-04, .452E-03, .109E-02, .238E-02, .293E-02,	8275
1 .175E-04, .560E-04, .301E-03, .941E-03, .243E-02, .342E-02,	8300
1 .198E-04, .630E-04, .280E-03, .107E-02, .260E-02, .353E-02,	8325
1 .230E-04, .710E-04, .276E-03, .109E-02, .272E-02, .365E-02,	8350
1 .280E-04, .830E-04, .369E-03, .127E-02, .295E-02, .377E-02,	8375
1 .330E-04, .890E-04, .430E-03, .139E-02, .306E-02, .385E-02,	8400
1 .360E-04, .950E-04, .371E-03, .135E-02, .306E-02, .384E-02/ DATA A43/	8425
1 .390E-04, .980E-04, .434E-03, .147E-02, .316E-02, .385E-02,	8450
1 .400E-04, .990E-04, .397E-03, .143E-02, .318E-02, .384E-02,	8475
1 .400E-04, .980E-04, .364E-03, .141E-02, .317E-02, .381E-02,	8500
1 .390E-04, .940E-04, .390E-03, .142E-02, .314E-02, .376E-02,	8525
1 .380E-04, .900E-04, .380E-03, .145E-02, .318E-02, .375E-02,	8550
1 .380E-04, .900E-04, .380E-03, .145E-02, .318E-02, .375E-02,	8575
1 .330E-04, .750E-04, .358E-03, .138E-02, .310E-02, .372E-02,	8600
1 .270E-04, .580E-04, .382E-03, .143E-02, .315E-02, .369E-02/ DATA A44/	8625
1 .240E-04, .500E-04, .343E-03, .136E-02, .306E-02, .363E-02,	8650
1 .200E-04, .450E-04, .309E-03, .134E-02, .306E-02, .359E-02,	8675
1 .180E-04, .400E-04, .281E-03, .127E-02, .294E-02, .341E-02,	8700
1 .170E-04, .360E-04, .276E-03, .124E-02, .290E-02, .336E-02,	8725
1 .160E-04, .310E-04, .272E-03, .122E-02, .283E-02, .323E-02,	8750
1 .140E-04, .280E-04, .241E-03, .117E-02, .273E-02, .309E-02,	8775
1 .120E-04, .250E-04, .237E-03, .115E-02, .269E-02, .297E-02,	8800
1 .100E-04, .220E-04, .218E-03, .111E-02, .259E-02, .284E-02/ DATA A45/	8825
1 .920E-05, .198E-04, .206E-03, .105E-02, .246E-02, .269E-02,	8850
1 .810E-05, .170E-04, .205E-03, .100E-02, .235E-02, .257E-02,	8875
1 .720E-05, .160E-04, .177E-03, .921E-03, .220E-02, .245E-02,	8900
1 .650E-05, .150E-04, .172E-03, .834E-03, .205E-02, .232E-02,	8925
1 .590E-05, .130E-04, .147E-03, .735E-03, .194E-02, .218E-02,	8950
1 .510E-05, .110E-04, .120E-03, .629E-03, .177E-02, .203E-02,	8975


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1 .460E-05, .950E-05, .960E-04, .513E-03, .154E-02, .180E-02, 9000
1 .420E-05, .800E-05, .578E-04, .314E-03, .123E-02, .154E-02/ 9025
DATA A46/
1 .380E-05, .720E-05, .529E-04, .292E-03, .114E-02, .137E-02, 9050
1 .330E-05, .660E-05, .485E-04, .269E-03, .102E-02, .122E-02, 9075
1 .290E-05, .580E-05, .430E-04, .239E-03, .896E-03, .107E-02, 9100
1 .270E-05, .520E-05, .259E-04, .193E-03, .748E-03, .944E-03, 9125
1 .240E-05, .450E-05, .316E-04, .207E-03, .671E-02, .848E-03, 9150
1 .220E-05, .400E-05, .444E-05, .602E-04, .516E-03, .750E-03, 9175
1 .190E-05, .360E-05, .324E-05, .460E-04, .439E-03, .688E-03, 9200
1 .170E-05, .320E-05, .180E-05, .321E-04, .384E-03, .653E-03/ 9225
DATA A47/
1 .140E-05, .280E-05, .171E-05, .344E-04, .340E-03, .616E-03, 9250
1 .130E-05, .250E-05, .299E-05, .600E-04, .343E-03, .619E-03, 9275
1 .120E-05, .220E-05, .299E-05, .600E-04, .343E-03, .619E-03, 9300
1 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1.,
1 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1./
END

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RCPART4.FOR

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BLOCK DATA BD3
COMMON/CCO2/SD15(6,80)
COMMON/CCH4/SD7(3,16),SD3(3,32)
COMMON/CPARAM/GAMMA(4,7)
DIMENSION B1(6,8),B2(6,8),B3(6,8),B4(6,8),B5(6,8),
1B6(6,8),B7(6,8),B8(6,8),B9(6,8),B10(6,8)
DIMENSION C1(3,8),C2(3,8),C3(3,8),C4(3,8),C5(3,8),C6(3,8)
EQUIVALENCE(B1(1,1),SD15(1,1)),(B2(1,1),SD15(1,9)),(B3(1,1),
1SD15(1,17)),(B4(1,1),SD15(1,25)),(B5(1,1),SD15(1,33)),
2(B6(1,1),SD15(1,41)),(B7(1,1),SD15(1,49)),(B8(1,1),SD15(1,57))
3,(B9(1,1),SD15(1,65)),(B10(1,1),SD15(1,73))
EQUIVALENCE(C1(1,1),SD7(1,1)),(C2(1,1),SD7(1,9)),
1(C3(1,1),SD3(1,1)),(C4(1,1),SD3(1,9)),(C5(1,1),SD3(1,17)),
2(C6(1,1),SD3(1,25))
DATA GAMMA/
C LINE BROADENING PARAMETERS,GAMMA(1,J),
C J=CO2,H2O,CH4,CO,O2,N2,SELFRESONANT.
C I=      CO2 H2O CH4 CO
C J
1 .09 , .12, .0 , .07,
2 .07 , .09, .0 , .06,
3 .0 , .0 , .16, .0 ,
4 .06 , .10, .0 , .06,
5 .055, .04, .0 , .05,
6 .07 , .09, .0 , .06,
7 .01 , .44, .0 , .0 /
C THE FOLLOWING ARE DATA FOR THE 15.0 MICRON BAND OF CO2
C TEMP, K=300      600      1200      1500      1800      2400      WAVE NO.
DATA B1/
1 .000E+00, .000E+00, .000E+00, .105E-01, .300E-01, .880E-01, 500
1 .000E+00, .000E+00, .000E+00, .180E-01, .490E-01, .880E-01, 505
1 .000E+00, .000E+00, .000E+00, .300E-01, .540E-01, .740E-01, 510
1 .000E+00, .000E+00, .000E+00, .300E-01, .560E-01, .890E-01, 515
1 .000E+00, .000E+00, .000E+00, .330E-01, .690E-01, .990E-01, 520
1 .000E+00, .000E+00, .880E-02, .380E-01, .720E-01, .970E-01, 525
1 .000E+00, .000E+00, .110E-01, .530E-01, .950E-01, .124E+00, 530
1 .000E+00, .000E+00, .285E-01, .630E-01, .990E-01, .140E+00/ 535
DATA B2/
1 .000E+00, .000E+00, .330E-01, .680E-01, .103E+00, .134E+00, 540
1 .000E+00, .000E+00, .450E-01, .920E-01, .138E+00, .176E+00, 545
1 .000E+00, .000E+00, .490E-01, .970E-01, .148E+00, .191E+00, 550
1 .000E+00, .000E+00, .490E-01, .120E-01, .188E+00, .247E+00, 555
1 .000E+00, .000E+00, .480E-01, .126E+00, .201E+00, .241E+00, 560
1 .000E+00, .000E+00, .820E-01, .198E+00, .270E+00, .265E+00, 565
1 .000E+00, .750E-02, .690E-01, .140E+00, .225E+00, .340E+00, 570

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1 .000E+00, .205E-01, .820E-01, .145E+00, .236E+00, .530E+00/ DATA B3/	575
1 .000E+00, .355E-01, .117E+00, .193E+00, .295E+00, .550E+00,	580
1 .157E-01, .520E-01, .170E+00, .235E+00, .305E+00, .410E+00,	585
1 .150E-01, .880E-01, .270E+00, .330E+00, .440E+00, .520E+00,	590
1 .510E-01, .130E+00, .400E+00, .530E+00, .560E+00, .540E+00,	595
1 .120E+00, .165E+00, .275E+00, .320E+00, .420E+00, .560E+00,	600
1 .880E-01, .190E+00, .430E+00, .540E+00, .620E+00, .680E+00,	605
1 .110E+00, .350E+00, .710E+00, .760E+00, .760E+00, .690E+00,	610
1 .180E+00, .470E+00, .920E+00, .970E+00, .910E+00, .670E+00/ DATA B4/	615
1 .970E-01, .265E+00, .610E+00, .720E+00, .780E+00, .730E+00,	620
1 .175E+00, .380E+00, .720E+00, .790E+00, .830E+00, .840E+00,	625
1 .370E+00, .640E+00, .920E+00, .960E+00, .980E+00, .940E+00,	630
1 .590E+00, .840E+00, .107E+01, .110E+01, .111E+01, .106E+01,	635
1 .940E+00, .103E+01, .115E+01, .115E+01, .115E+01, .118E+01,	640
1 .196E+01, .177E+01, .146E+01, .136E+01, .132E+01, .139E+01,	645
1 .345E+01, .282E+01, .198E+01, .172E+01, .156E+01, .148E+01,	650
1 .282E+01, .248E+01, .200E+01, .190E+01, .186E+01, .205E+01/ DATA B5/	655
1 .254E+01, .234E+01, .184E+01, .176E+01, .174E+01, .203E+01,	660
1 .142E+02, .860E+01, .370E+01, .260E+01, .196E+01, .142E+01,	665
1 .450E+01, .570E+01, .580E+01, .520E+01, .350E+01, .420E+01,	670
1 .360E+01, .310E+01, .330E+01, .290E+01, .205E+01, .200E+01,	675
1 .310E+01, .260E+01, .200E+01, .196E+01, .180E+01, .210E+01,	680
1 .240E+01, .250E+01, .230E+01, .220E+01, .170E+01, .194E+01,	685
1 .182E+01, .200E+01, .218E+01, .205E+01, .184E+01, .130E+01,	690
1 .104E+01, .135E+01, .172E+01, .172E+01, .165E+01, .130E+01/ DATA B6/	695
1 .550E+00, .120E+01, .143E+01, .147E+01, .148E+01, .125E+01,	700
1 .136E+01, .128E+01, .128E+01, .135E+01, .138E+01, .134E+01,	705
1 .210E+00, .780E+00, .127E+01, .133E+01, .137E+01, .132E+01,	710
1 .190E+00, .780E+00, .140E+01, .146E+01, .147E+01, .142E+01,	715
1 .900E+00, .106E+01, .140E+01, .150E+01, .155E+01, .134E+01,	720
1 .720E-01, .300E+00, .800E+00, .100E+01, .115E+01, .126E+01,	725
1 .640E-01, .210E+00, .560E+00, .720E+00, .860E+00, .102E+01,	730
1 .680E-01, .210E+00, .530E+00, .670E+00, .790E+00, .101E+01/ DATA B7/	735
1 .690E-01, .210E+00, .540E+00, .690E+00, .820E+00, .910E+00,	740
1 .330E-01, .140E+00, .390E+00, .530E+00, .690E+00, .770E+00,	745
1 .230E-01, .780E-01, .270E+00, .410E+00, .560E+00, .890E+00,	750
1 .300E-01, .860E-01, .280E+00, .400E+00, .520E+00, .710E+00,	755
1 .175E-01, .620E-01, .225E+00, .335E+00, .450E+00, .660E+00,	760
1 .105E-01, .450E-01, .180E+00, .280E+00, .380E+00, .600E+00,	765
1 .450E-02, .300E-01, .148E+00, .240E+00, .345E+00, .570E+00,	770
1 .000E+00, .140E-01, .124E+00, .205E+00, .285E+00, .430E+00/ DATA B8/	775
1 .000E+00, .115E-01, .110E+00, .185E+00, .260E+00, .375E+00,	780
1 .000E+00, .135E-01, .840E-01, .140E+00, .205E+00, .335E+00,	785
1 .000E+00, .430E-02, .650E-01, .120E+00, .185E+00, .325E+00,	790
1 .000E+00, .000E+00, .540E-01, .115E+00, .180E+00, .315E+00,	795
1 .000E+00, .000E+00, .440E-01, .950E-01, .150E+00, .270E+00,	800
1 .000E+00, .000E+00, .360E-01, .790E-01, .125E+00, .205E+00,	805
1 .000E+00, .000E+00, .250E-01, .650E-01, .110E+00, .178E+00,	810
1 .000E+00, .000E+00, .180E-01, .620E-01, .103E+00, .153E+00/ DATA B9/	815
1 .000E+00, .000E+00, .320E-01, .580E-01, .860E-01, .147E+00,	820
1 .000E+00, .000E+00, .800E-02, .510E-01, .870E-01, .134E+00,	825
1 .000E+00, .000E+00, .600E-02, .480E-01, .830E-01, .133E+00,	830
1 .000E+00, .000E+00, .000E+00, .430E-01, .780E-01, .118E+00,	835
1 .000E+00, .000E+00, .000E+00, .420E-01, .700E-01, .108E+00,	840
1 .000E+00, .000E+00, .000E+00, .360E-01, .640E-01, .980E-01,	845
1 .000E+00, .000E+00, .000E+00, .350E-01, .610E-01, .870E-01,	850
1 .000E+00, .000E+00, .000E+00, .320E-01, .580E-01, .860E-01/ DATA B10/	855
1 .000E+00, .000E+00, .000E+00, .330E-01, .560E-01, .750E-01,	860
1 .000E+00, .000E+00, .000E+00, .300E-01, .530E-01, .750E-01,	865

1 .000E+00, .000E+00, .000E+00, .290E-01, .530E-01, .850E-01,	870
1 .000E+00, .000E+00, .000E+00, .240E-01, .470E-01, .900E-01,	875
1 .000E+00, .000E+00, .000E+00, .220E-01, .450E-01, .860E-01,	880
1 .000E+00, .000E+00, .000E+00, .000E+00, .000E+00, .000E+00,	
1 .000E+00, .000E+00, .000E+00, .000E+00, .000E+00, .000E+00,	
1 .000E+00, .000E+00, .000E+00, .000E+00, .000E+00, .000E+00/	

C THE FOLLOWING DATA ARE FOR THE 7.7 MICRON BAND OF CH4
 C TEMP,K= 290 600 850

WAVE NO.

DATA C1/
 1 0., 0., 0.,
 1 0., 0., 0.03,
 1 0., 0., 0.22,
 1 0.16, 0.20, 0.47,
 1 0.34, 0.34, 0.62,
 1 0.69, 0.53, 0.65,
 1 1.27, 0.88, 1.09,
 1 1.68, 1.38, 0.87/

DATA C2/
 1 0.55, 0.28, 0.40,
 1 1.25, 0.86, 0.93,
 1 0.34, 0.59, 0.75,
 1 0., 0.13, 0.25,
 1 0., 0., 0.06,
 1 0., 0., 0.,
 1 0., 0., 0.,
 1 0., 0., 0./

C THE FOLLOWING DATA ARE FOR THE 3.3 MICRON BAND OF CH4
 C TEMP, K= 290 600 850

DATA C3/
 1 0., 0., 0.03,
 1 0., 0., 0.03,
 1 0., 0., 0.03,
 1 0., 0., 0.06,
 1 0.03, 0.03, 0.09,
 1 0.07, 0.07, 0.12,
 1 0.09, 0.09, 0.12,
 1 0.14, 0.15, 0.22/

DATA C4/
 1 0.18, 0.22, 0.28,
 1 0.24, 0.31, 0.37,
 1 0.33, 0.44, 0.47,
 1 0.45, 0.50, 0.53,
 1 0.59, 0.62, 0.62,
 1 0.74, 0.70, 0.68,
 1 0.91, 0.77, 0.72,
 1 1.00, 0.81, 0.75/

DATA C5/
 1 1.03, 0.84, 0.78,
 1 1.03, 0.84, 0.78,
 1 1.00, 0.81, 0.75,
 1 0.94, 0.77, 0.72,
 1 0.72, 0.68, 0.68,
 1 0.52, 0.63, 0.63,
 1 0.33, 0.50, 0.56,
 1 0.25, 0.42, 0.50/

DATA C6/
 1 0.17, 0.26, 0.37,
 1 0.08, 0.18, 0.31,
 1 0.04, 0.11, 0.22,
 1 0., 0.06, 0.16,
 1 0., 0.02, 0.12,
 1 0., 0., 0.06,
 1 0., 0., 0.03,
 1 0., 0., 0./

END

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