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NO.

APPROXIMATE RADIATION PROPERTIES OF
AIR BETWEEN 2000 AND 8000° K

F. R. Gilmore

PREPARED FOR:

ADVANCED RESEARCH PROJECTS AGENCY

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MEMORANDUM

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PREFACE

Tables of the radiation properties of high-temperature air are required in order to analyse possible optical schemes of discrimination between missiles and decoys. Even though considerable experimental and theoretical work on air radiation has been carried out by a number of organizations, there exist no comprehensive tables based on the latest information available as to the intensities of the individual radiative transitions. The tables calculated and presented here should partially satisfy this demand, although it is clear that further work is required to obtain the more accurate and detailed results needed for some applications.

This work is part of a continuing theoretical study of reentry physics and decoy discrimination supported by the Advanced Research Projects Agency of the Department of Defense.

ABSTRACT

The spectral absorption coefficient for equilibrium air at five temperatures between 2000 and 8000°K and six densities between 10 and 10^{-4} times the standard density has been calculated by correcting the 1959 tables of Meyerott, Sokolov, and Nicholls for revised values of the f-numbers of the molecular band systems, and adding the contributions of several band systems and continua not included by those investigators. The analysis indicates that band systems of NO₂ make an important contribution to the absorption coefficient of air below 6000°K, and the uncertainty in this contribution is probably the biggest source of uncertainty in the air results.

Tables of the spectral absorption coefficient, the Planck mean absorption coefficient, the spectral emission coefficient, the total emission rate, and the visible emission rate are included.

I. INTRODUCTION

The radiation properties of high-temperature air are of importance in problems concerned with hypersonic missiles and nuclear fireballs. In the temperature region up to about 8000°K , where molecular radiation is generally dominant, a number of calculations for air were made several years ago by workers at Avco⁽¹⁾ and at Lockheed.⁽²⁾ However, this early work suffered from a lack of knowledge of the f-numbers (intensity factors) of some of the important molecular band systems, and from approximations made to reduce the computational work.

In the last three or four years, most of the important f-numbers have been measured in the laboratory, often by more than one investigator (for a critical summary, see Keck, Allen, and Taylor⁽³⁾). Important experimental work has also been done on the "free-free" radiation due to electron-molecule collisions, which contributes significantly at temperatures above about 5000°K .⁽³⁾⁽⁴⁾ Moreover, many different groups are developing computing-machine codes to handle the complicated band structure of molecular radiation. In the next year or two, as the experimental and theoretical results are combined with machine calculations, results of good accuracy and great spectral detail should become available. In the meantime, however, workers on missile and fireball radiation have an immediate need for air radiation tables, even if of lesser accuracy or detail.

Recently, Breene and coworkers at General Electric MSVD have attempted to supply this need by issuing curves showing, in considerable spectral detail, the emission from air and its constituents at various temperatures.⁽⁵⁾⁽⁶⁾ Unfortunately, however, this work contains several errors.⁽³⁾ Also, it omits the free-free radiation due to $e + \text{N}_2$ collisions,⁽⁴⁾ the near-infrared bands probably due to NO ,⁽⁷⁾ and the emission due to NO_2 (or $\text{NO} + \text{O}$).⁽⁸⁾⁽⁹⁾

In the present study, approximate numerical results for the absorption and emission coefficients of air (including the spectral distribution) have been obtained simply by correcting the detailed tables of Meyerott, Sokoloff, and Nicholls⁽²⁾ for the revised f-values, and adding the contributions of bands systems and continua not considered by them.

II. CALCULATION OF THE ABSORPTION COEFFICIENT

The data now available on the electronic transition probabilities for six important band systems, and their variation with wavelength, have recently been summarized by Keck, Allen, and Taylor.⁽³⁾ For each band system, they give an average or "most likely" transition-probability curve. Table 1 shows the results of reading each curve at two wavelengths which bound the spectral region over which that system makes a large contribution to the air absorption coefficient. (For the N₂ first positive system beyond 0.85μ an extra factor of 4 has been included, following their suggestion, to allow for the additional near-infrared bands observed in air, probably due to NO, but which can be calculated as if they were due to N₂.) From these values the corresponding f-numbers have been calculated, using the formula

$$f = (R/ea_0)^2 / (3R_\infty \lambda) ,$$

where $(R/ea_0)^2$ is the dimensionless electronic transition probability, R_∞ is Rydberg's constant ($10.97 \mu^{-1}$) and λ is the wavelength. Table 1 shows that, except for the oxygen Schumann-Runge system, the variation of the f-numbers with wavelength is much less than the variation of the electronic transition probabilities. Since the basic data are not accurate to better than 20 or 30 percent, it is usually reasonable to neglect the f-number variation and use a mean value of each system. However, for the Schumann-Runge system, a linear fit to $f(\lambda)$ seems preferable, as indicated in the table.

The ratios of these new f-numbers to the f-numbers used by Meyerott, Sokoloff, and Nicholls⁽²⁾ then provide correction factors for the corresponding columns in their tables. These correction factors are listed in the last column of Table 1.

The values of Meyerott et al.⁽²⁾ for free-free absorption by electrons also need correction because their work included only the absorption in the field of the positive ions. Recently, Taylor⁽³⁾⁽⁴⁾ has shown that

Table 1

CORRECTION FACTORS FOR THE f-VALUES OF MEYEROTT, SOKOLOFF AND NICHOLLS

Band System	Recommended Values ⁽³⁾			Mean f	f-Number of MSN ⁽²⁾	Correction Factor
	$\lambda (\mu)$	$(R/ea_o)^2$	f			
N ₂ 1st Pos.	0.52	.017	.0017	.0028	.02	0.14
	0.76	.10	.0040			
	0.90	.5*	.017*	.018*	.02	0.9*
	1.10	.7*	.019*			
N ₂ 2nd Pos.	0.30	.41	.041	.043	.07	0.62
	0.47	.70	.045			
N ₂ ⁺ 1st Neg.	0.34	.46	.041	.047	.20	0.24
	0.52	.90	.052			
NO Beta	0.21	.038	.0055	.0053	.008	0.67
	0.52	.09	.0052			
NO Gamma	0.19	.014	.0022	.0025	.0025	1.0
	0.28	(.026)	.0028			
O ₂ S-R	0.19	.67	.107	(.17 - .34 λ)	.259	(0.66 - 1.3 λ)
	0.43	.35	.025			

*Includes factor of 4 to allow for extra near-infrared bands beyond 0.85 microns, probably due to NO, but calculable in air as if they were due to N₂.⁽³⁾

N_2 molecules are about 2.0 percent, and N atoms about 0.8 percent as effective as singly-charged ions in this regard* (assuming a mean Gaunt factor of 1.1 for the ions⁽²⁾). The effectiveness of O atoms is small enough to be negligible, while the concentrations of O_2 and NO molecules are negligible when electron densities are high enough to make free-free absorption important.

The corresponding correction factors to the free-free absorption coefficients of Meyerott et al. can be readily calculated using tables of the equilibrium composition of air. The results are summarized in Table 2; they are independent of wavelength, in the present approximation.

Table 2

CORRECTION FACTORS FOR THE FREE-FREE ABSORPTION COEFFICIENTS OF MEYEROTT, SOKOLOFF AND NICHOLLS⁽²⁾

Air Temperature ($^{\circ}K$)	Air Density Rate, ρ/ρ					
	10	1	10^{-1}	10^{-2}	10^{-3}	10^{-4}
6000	31	13	7.6	4.6	2.9	1.8
8000	3.9	2.4	1.6	1.2	1.1	1.0

Although most previous investigators of air radiation have included the O_2 Schumann-Runge bands, apparently none have included the Schumann-Runge continuum, which at low temperatures covers the spectral region below 0.19μ , but at higher temperatures extends to somewhat longer wavelengths. The recent theoretical and experimental work by Evans and Schexnayder⁽¹⁰⁾ permits easy inclusion of this

* However, as pointed out by R. Hundley (private communication), these results may be rather inaccurate. Since Taylor did not vary the N/N_2 ratio and the temperature independently, he had to assume that the temperature dependence was the same in the fields of neutral particles as in the fields of ions, which may be a poor assumption.

continuum in the air calculations. In the present work, their curves for pure O_2 were read at temperatures and wavelengths of interest, and multiplied by the corresponding equilibrium concentration of O_2 in air. The accuracy of these values is probably within 20 percent, except in the $0.18 - 0.20 \mu$ region where their curves are irregular and their methods less accurate.

It should be noted that in this vacuum-ultraviolet region the Delta and Epsilon bands of NO (around 0.2μ) and the Birge-Hopfield and Worley bands of N_2 (around 0.1μ) probably make significant contributions. These band systems have not been included in the present calculations, nor in any previous calculations known to the writer. However, their contribution should not increase the total air emission rate by more than a factor of 2 for any of the temperatures and densities considered here.

Probably the greatest uncertainty in calculating the radiation properties of air below $6000^\circ K$ lies in the treatment of NO_2 radiation in the visible and near infrared. In past studies this radiation has often been neglected, but the present work indicates that it is important up to about $6000^\circ K$ for air at sea-level density, and up to about $4000^\circ K$ for air at one-hundredth of sea-level density. In contrast to the other band systems, the NO_2 emission generally peaks in the visible and photographic spectral region.

Mueller⁽⁹⁾ has recently summarized the data available on the absorption coefficient of NO_2 and its variation with temperature. Unfortunately, the experimental absorption data extend only to $2000^\circ K$, and for wavelengths longer than 0.55μ only to $1000^\circ K$. Mueller also shows that the emission measurements of Levitt⁽¹¹⁾ on shock-heated NO_2 between 1500 and $2000^\circ K$ are inconsistent with the (partially extrapolated) absorption measurements, being up to an order of magnitude higher in the $0.5 - 0.6 \mu$ region. He attributes this discrepancy to a lack of equilibrium in Levitt's NO_2 . However, nonequilibrium effects may also be important in the high-temperature absorption measurements. Moreover, the simple extrapolation of the NO_2 absorption coefficient to higher temperatures and longer wavelengths, which might be reasonable when dealing with a single band

system, is less justified because three separate band systems probably contribute in the visible spectral region.⁽¹²⁾

In flames containing nitrogen and oxygen, Kaskan⁽¹³⁾ has observed an apparent continuum, probably due to $\text{NO} + \text{O}$, extending from 0.38 to at least 0.7 μ , and also a band system, probably due to excited NO_2 , extending from 0.55 to at least 0.7 μ . In shock-heated air at 3000 to 4000°K, Wurster and Marrone⁽⁸⁾ have observed radiation extending from about 0.4 to at least 1.2 μ , and proportional to the product of the (calculated) NO and O equilibrium concentrations. They attribute this radiation to the same $\text{NO} + \text{O}$ "continuum" observed in room-temperature afterglows, since the spectral distribution seems similar. However, Broida, Schiff, and Sugden⁽¹⁴⁾ present fairly convincing evidence that the room-temperature afterglow emission consists of diffuse bands emitted by excited NO_2 molecules (formed by atom-molecule recombination). Thus, the emission observed by Wurster and Marrone⁽⁸⁾ is probably also attributable to NO_2^* (whose equilibrium concentration, at a fixed temperature, is proportional to the product of the NO and O equilibrium concentrations), and is not simply related to the $\text{NO} + \text{O}$ radiative recombination rate. Therefore, their attempt to determine the temperature dependence of the emission by combining their data at 3750°K with the room-temperature afterglow data is not justified.

The air emission rate measured by Wurster and Marrone⁽⁸⁾ at 3750°K corresponds to an NO_2 absorption coefficient with a broad maximum at about 0.6 μ , falling off only by a factor of three at 0.42 and 1.2 μ , in contrast to Mueller's extrapolated curve⁽⁹⁾, which peaks at 0.4 μ and decreases rapidly toward longer wavelengths. The two curves cross at about 0.57 μ , so their averages over the visible spectral region are not much different. The Wurster and Marrone values lie about a factor of 1.5 to 2 below an extrapolation of Levitt's data⁽¹¹⁾ to 3750°K, and have a similar wavelength dependence, though Levitt's measurements cover a much narrower spectral region and have an absolute accuracy of only a factor of 2. (The agreement in wavelength dependence constitutes additional evidence that Wurster and Marrone are observing NO_2^* emission.)

In the present work, Mueller's extrapolation was used for wavelengths less than 0.6μ , where it can be argued that non-equilibrium effects are less likely to be important in absorption than in emission experiments. At longer wavelengths his values were increased by amounts which increase with the wavelength and temperature, to give better agreement with the emission data. Finally, at 6000 and 8000°K, constant values of 2.0 and $1.5 \times 10^3 \text{ cm}^2/\text{g NO}_2$, respectively, independent of wavelength, were used.

Table 3 (p. 13) shows the total absorption coefficient obtained by correcting the values of Meyerott et al.⁽²⁾ for the new f-numbers and for the NO-near-infrared, NO₂, and neutral-free-free absorption as described above, while leaving the ion-free-free and O⁻ photo-detachment values unchanged.* Values at air density ratios of 10^{-5} and 10^{-6} are omitted because of the unlikelihood that calculations assuming local thermodynamic equilibrium are applicable at such densities. At $\rho/\rho_0 = 10^{-5}$ and temperatures of a few thousand degrees, an air molecule experiences an elastic collision about every three microseconds, which is long compared to typical radiation times of a fraction of a microsecond. Since inelastic "exciting" collisions are probably less frequent than elastic collisions, the radiation is almost certainly nonequilibrium and "collision limited" at this air density.

It should be pointed out that, in addition to the uncertainties in intensities or f-numbers discussed above, the approximation of averaging (or smearing out) the individual lines and bands over each photon energy interval of 0.25 eV, following Meyerott et al., can also introduce errors. In calculations of air emission rates when self-absorption can be neglected (see Section III), this error is generally small. However, in calculations of radiation absorption, the amount absorbed may be considerably overestimated because of neglect of the more-transparent "gaps" between the lines or bands in the absorption spectrum.⁽¹⁵⁾⁽¹⁶⁾ On the other hand, the self-

* A number of typographical errors in their tables, mostly in the powers of ten, also had to be corrected.

absorption of the radiation emitted by a hotter region of the same gas may be underestimated, due to neglect of the correspondence between the strongly emitted and the strongly absorbed wavelengths.

III. OTHER RADIATION PROPERTIES OF AIR

As already mentioned, the radiation emitted by a medium in local thermodynamic equilibrium is closely related to its absorption coefficient. In situations where all important radiation mean free paths (i.e., reciprocals of the absorption coefficient) are much greater than the dimensions of the radiating region, so that both self-absorption and induced emission can be neglected, the total radiation emitted can be calculated by considering each volume element independently and summing over all the elements. In such cases, it is convenient to define a "spectral emission coefficient," ϵ_λ , which is the emission rate per unit volume and per unit wavelength interval. This coefficient is given by

$$\epsilon_\lambda = \frac{8\pi hc^2}{\lambda^5} e^{-hc/\lambda kT} \mu_\lambda,$$

where h is Planck's constant, c is the velocity of light, λ is the wavelength, k is Boltzmann's constant, T is the absolute temperature, and μ_λ is the absorption coefficient (listed in Table 3). Often an equivalent expression for the emission rate per unit photon frequency interval is given; it may be obtained from the above equation by use of the relations $\lambda = c/\nu$ and $\epsilon_\nu = (c/\nu^2)\epsilon_\lambda$, where ν is the photon frequency.

Table 4 presents values of the spectral emission coefficient, calculated from the absorption coefficients of Table 3. The total emission rate, which is simply the integral of the emission coefficient over all wavelengths, is given in Table 5. However, at air temperatures below about 4000°K these values may be considerably too small because of omission of the vibration-rotation bands of NO (fundamental at 5.3 μ , first harmonic at 2.7 μ), NO₂ (fundamentals at 6.2, 7.6 (weak) and 13 μ) and CO₂ (infrared-active fundamentals at 4.3 and 15 μ). If the emission rate per unit solid angle is desired, the values in Table 4 or 5 may simply be divided by 4π .

The Planck mean absorption coefficient (average of the absorption coefficient weighted by the black-body spectrum) is also of interest. It may be obtained by dividing the total emission rate by $4\sigma T^4$, where σ is the Stefan-Boltzmann constant. (The factor of 4 enters because of the difference between surface flux and volume emission; compare the well-known equation $\sigma = ac/4$, where a is the equilibrium radiation energy density divided by T^4 .) Values of the Planck mean absorption coefficient are presented in Table 6. It might be noted that the "emissivity per unit thickness" used by Avco workers⁽¹⁾ (which they denote by ϵ/L) is twice the Planck mean absorption coefficient.

Another useful parameter is the emission rate over the visible or photographic spectral region. Values of this parameter, for the nominal visible region of 0.40 to 0.65 μ , are listed in Table 7.

In applying these tables to practical problems, the reader should be warned that actual radiation rates may sometimes be considerably larger than the values listed here if the air is contaminated with metallic vapors or plastic decomposition products. This occurs because the molecules CH , OH , CN , C_2 and many of the metallic monoxides are probably much better emitters than any of the atmospheric molecules at temperatures below 4000 or 5000°K, while at higher temperatures the metals furnish more electrons for free-free emission (in addition to producing some metallic line emission). Rocketdyne workers⁽¹⁷⁾ have recently computed absorption coefficients per unit f-number for AlO , MgO , SiO , SrO and VO up to 6000°K. Unfortunately, no data appear to be available on the f-numbers of any of the metallic oxides.

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TABLE 3

ABSORPTION COEFFICIENT OF HIGH-TEMPERATURE AIR

UNITS: CM^{-1} . TEMPERATURE: 2000° K

PHOTON ENERGY (eV)	WAVE- LENGTH (μ)	DENSITY RATIO					
		10	1	10^{-1}	10^{-2}	10^{-3}	10^{-4}
0.625	1.9836	0.	0.	0.	0.	0.	0.
0.875	1.4169	0.	0.	0.	0.	0.	0.
1.125	1.1020	0.	0.	0.	0.	0.	0.
1.375	0.9017	7.0E-05	2.2E-06	7.0E-08	2.2E-09	6.9E-11	2.2E-12
1.625	0.7629	9.6E-04	3.1E-05	9.6E-07	3.0E-08	9.5E-10	3.0E-11
1.875	0.6612	3.6E-03	1.1E-04	3.6E-06	1.1E-07	3.6E-09	1.1E-10
2.125	0.5834	5.3E-03	1.7E-04	5.3E-06	1.7E-07	5.2E-09	1.6E-10
2.375	0.5220	7.9E-03	2.5E-04	7.9E-06	2.5E-07	7.5E-09	2.4E-10
2.625	0.4723	9.6E-03	3.1E-04	9.6E-06	3.0E-07	9.5E-09	3.0E-10
2.875	0.4312	1.1E-02	3.4E-04	1.1E-05	3.4E-07	1.1E-08	3.3E-10
3.125	0.3967	1.2E-02	3.7E-04	1.2E-05	3.7E-07	1.2E-08	3.6E-10
3.375	0.3673	1.1E-02	3.4E-04	1.1E-05	3.6E-07	1.3E-08	4.9E-10
3.625	0.3420	1.0E-02	3.4E-04	1.2E-05	4.8E-07	2.6E-08	1.9E-09
3.875	0.3179	9.4E-03	3.4E-04	1.5E-05	8.8E-07	6.9E-08	6.1E-09
4.125	0.3006	1.1E-02	5.0E-04	3.2E-05	2.7E-06	2.5E-07	2.4E-08
4.375	0.2834	1.6E-02	1.3E-03	9.0E-05	8.4E-06	8.3E-07	8.0E-08
4.625	0.2681	2.8E-02	2.3E-03	2.2E-04	2.1E-05	2.1E-06	2.1E-07
4.875	0.2543	9.1E-02	8.7E-03	8.5E-04	8.5E-05	8.4E-06	8.2E-07
5.125	0.2419	2.8E-01	2.8E-02	2.8E-03	2.8E-04	2.8E-05	2.7E-06
5.375	0.2307	3.9E-01	3.9E-02	3.9E-03	3.9E-04	3.9E-05	3.9E-06
5.625	0.2204	2.5E 00	2.5E-01	2.5E-02	2.5E-03	2.5E-04	2.6E-05
5.875	0.2110	4.9E 00	4.9E-01	4.9E-02	4.9E-03	4.9E-04	4.8E-05
6.125	0.2024	6.4E-01	6.4E-02	6.4E-03	6.4E-04	6.4E-05	6.3E-06
6.375	0.1945	1.2E 00	1.2E-01	1.2E-02	1.2E-03	1.1E-04	1.1E-05
6.625	0.1871	1.6E 01	1.6E 00	1.6E-01	1.6E-02	1.6E-03	1.6E-04
6.875	0.1803	7.4E 01	7.4E 00	7.4E-01	7.4E-02	7.3E-03	7.2E-04
7.125	0.1740	1.0E 02	1.0E 01	1.0E 00	1.0E-01	1.0E-02	1.0E-03
7.375	0.1681	1.6E 02	1.6E 01	1.6E 00	1.6E-01	1.5E-02	1.5E-03
7.625	0.1626	2.5E 02	2.5E 01	2.5E 00	2.5E-01	2.4E-02	2.4E-03
7.875	0.1574	3.4E 02	3.4E 01	3.4E 00	3.4E-01	3.3E-02	3.3E-03
8.125	0.1526	4.4E 02	4.4E 01	4.4E 00	4.4E-01	4.3E-02	4.3E-03
8.375	0.1480	5.2E 02	5.2E 01	5.2E 00	5.2E-01	5.2E-02	5.1E-03
8.625	0.1437	6.2E 02	6.2E 01	6.2E 00	6.2E-01	6.2E-02	6.1E-03
8.875	0.1397	6.7E 02	6.7E 01	6.7E 00	6.7E-01	6.7E-02	6.6E-03
9.125	0.1359	4.2E 02	4.2E 01	4.2E 00	4.2E-01	4.1E-02	4.1E-03
9.375	0.1322	8.2E 01	8.2E 00	8.2E-01	8.2E-02	8.1E-03	8.0E-04

TABLE 3 - - CONTINUED
UNITS: CM⁻¹. TEMPERATURE: 3000°K

PHOTON ENERGY (EV)	WAVE- LENGTH (μ)	DENSITY RATIO					
		10	1	10 ⁻¹	10 ⁻²	10 ⁻³	10 ⁻⁴
0.625	1.9836	0.	0.	0.	0.	0.	0.
0.875	1.4169	0.	0.	0.	0.	0.	0.
1.125	1.1020	5.8E-05	1.8E-06	5.3E-08	1.4E-09	2.7E-11	8.6E-13
1.375	0.9017	6.8E-04	2.3E-05	6.6E-07	1.6E-08	2.6E-10	2.7E-12
1.625	0.7629	3.2E-03	9.7E-05	2.8E-06	7.0E-08	1.1E-09	7.1E-12
1.875	0.6612	7.9E-03	2.4E-04	7.1E-06	1.8E-07	2.7E-09	1.7E-11
2.125	0.5834	1.2E-02	3.7E-04	1.1E-05	2.7E-07	4.1E-09	2.7E-11
2.375	0.5220	1.5E-02	4.6E-04	1.3E-05	3.3E-07	5.1E-09	3.3E-11
2.625	0.4723	1.6E-02	4.9E-04	1.4E-05	3.6E-07	5.8E-09	3.7E-11
2.875	0.4312	1.7E-02	5.5E-04	1.8E-05	6.3E-07	2.0E-08	4.8E-10
3.125	0.3967	1.9E-02	7.0E-04	3.1E-05	1.5E-06	6.6E-08	1.5E-09
3.375	0.3673	2.0E-02	8.3E-04	4.3E-05	2.6E-06	1.3E-07	3.7E-09
3.625	0.3420	3.3E-02	2.0E-03	1.5E-04	1.1E-05	5.6E-07	1.4E-08
3.875	0.3199	4.7E-02	3.5E-03	2.9E-04	2.3E-05	1.1E-06	2.8E-08
4.125	0.3006	1.0E-01	8.9E-03	7.9E-04	6.1E-05	3.1E-06	8.0E-08
4.375	0.2834	2.0E-01	1.9E-02	1.7E-03	1.4E-04	6.9E-06	2.0E-07
4.625	0.2681	3.6E-01	3.5E-02	3.2E-03	2.5E-04	1.3E-05	3.8E-07
4.875	0.2543	9.2E-01	8.8E-02	8.1E-03	6.6E-04	3.6E-05	1.1E-06
5.125	0.2419	2.1E 00	2.1E-01	2.0E-02	1.7E-03	1.1E-04	4.6E-06
5.375	0.2307	1.9E 00	1.9E-01	1.8E-02	1.6E-03	1.1E-04	4.5E-06
5.625	0.2204	8.9E 00	8.7E-01	8.0E-02	6.3E-03	3.2E-04	7.3E-06
5.875	0.2110	1.4E 01	1.4E 00	1.3E-01	1.0E-02	5.6E-04	1.6E-05
6.125	0.2024	2.7E 00	2.7E-01	2.6E-02	2.2E-03	1.5E-04	6.7E-06
6.375	0.1945	2.0E 00	2.0E-01	1.9E-02	1.6E-03	9.7E-05	3.6E-06
6.625	0.1871	2.2E 01	2.2E 00	2.0E-01	1.6E-02	7.6E-04	1.5E-05
6.875	0.1803	8.7E 01	8.5E 00	7.8E-01	6.1E-02	3.0E-03	6.0E-05
7.125	0.1740	1.5E 02	1.5E 01	1.3E 00	1.0E-01	5.0E-03	1.0E-04
7.375	0.1681	1.5E 02	1.5E 01	1.4E 00	1.1E-01	5.2E-03	1.1E-04
7.625	0.1626	2.1E 02	2.0E 01	1.9E 00	1.5E-01	7.3E-03	1.5E-04
7.875	0.1574	2.7E 02	2.6E 01	2.5E 00	1.9E-01	9.3E-03	1.9E-04
8.125	0.1526	3.3E 02	3.2E 01	3.0E 00	2.3E-01	1.1E-02	2.3E-04
8.375	0.1480	3.9E 02	3.8E 01	3.5E 00	2.7E-01	1.3E-02	2.7E-04
8.625	0.1437	4.6E 02	4.5E 01	4.2E 00	3.3E-01	1.6E-02	3.2E-04
8.875	0.1397	5.0E 02	4.9E 01	4.5E 00	3.5E-01	1.7E-02	3.5E-04
9.125	0.1359	3.0E 02	2.9E 01	2.7E 00	2.1E-01	1.0E-02	2.1E-04
9.375	0.1322	1.5E 02	1.5E 01	1.4E 00	1.1E-01	5.2E-03	1.1E-04

TABLE 3 - - CONTINUED
UNITS: CM⁻¹. TEMPERATURE: 4000°K

PHOTON ENERGY (EV)	WAVE- LENGTH (μ)	DENSITY RATIO					
		10	1	10 ⁻¹	10 ⁻²	10 ⁻³	10 ⁻⁴
0.625	1.9836	0.	0.	0.	0.	0.	0.
0.875	1.4169	1.8E-04	4.4E-06	6.3E-08	4.0E-10	1.5E-12	4.9E-15
1.125	1.1020	1.0E-03	2.8E-05	6.2E-07	2.9E-08	2.7E-09	2.6E-10
1.375	0.9017	3.2E-03	8.0E-05	1.5E-06	4.6E-08	4.0E-09	3.9E-10
1.625	0.7629	6.5E-03	1.6E-04	2.4E-06	2.0E-08	6.0E-10	5.4E-11
1.875	0.6612	1.1E-02	2.6E-04	3.8E-06	2.7E-08	4.2E-10	3.3E-11
2.125	0.5834	1.5E-02	3.6E-04	5.2E-06	3.4E-08	2.4E-10	1.2E-11
2.375	0.5220	1.6E-02	4.0E-04	6.0E-06	5.4E-08	8.0E-10	2.3E-11
2.625	0.4723	1.9E-02	5.1E-04	9.2E-06	1.5E-07	3.9E-09	1.2E-10
2.875	0.4312	2.7E-02	9.9E-04	3.5E-05	1.0E-06	3.0E-08	8.9E-10
3.125	0.3967	4.0E-02	2.0E-03	8.1E-05	2.1E-06	4.5E-08	1.2E-09
3.375	0.3673	5.2E-02	3.0E-03	1.5E-04	4.6E-06	1.4E-07	3.9E-09
3.625	0.3420	1.3E-01	9.4E-03	4.6E-04	1.2E-05	2.7E-07	7.2E-09
3.875	0.3199	1.9E-01	1.4E-02	6.9E-04	1.9E-05	4.7E-07	1.2E-08
4.125	0.3006	4.1E-01	3.2E-02	1.6E-03	4.5E-05	1.0E-06	2.9E-08
4.375	0.2834	7.2E-01	5.5E-02	2.8E-03	7.6E-05	1.8E-06	4.8E-08
4.625	0.2681	1.1E 00	8.9E-02	4.7E-03	1.5E-04	3.8E-06	1.1E-07
4.875	0.2543	2.4E 00	1.9E-01	1.1E-02	3.5E-04	9.6E-06	2.8E-07
5.125	0.2419	4.8E 00	4.1E-01	2.6E-02	1.1E-03	3.6E-05	1.1E-06
5.375	0.2307	3.6E 00	3.1E-01	2.0E-02	8.6E-04	2.9E-05	9.2E-07
5.625	0.2204	1.2E 01	1.0E 00	4.8E-02	1.2E-03	2.3E-05	5.5E-07
5.875	0.2110	1.9E 01	1.5E 00	8.1E-02	2.5E-03	6.5E-05	1.9E-06
6.125	0.2024	4.8E 00	4.1E-01	2.8E-02	1.2E-03	4.3E-05	1.4E-06
6.375	0.1945	1.4E 01	1.1E 00	5.2E-02	1.3E-03	2.7E-05	6.7E-07
6.625	0.1871	2.8E 01	2.1E 00	9.7E-02	1.9E-03	2.2E-05	2.3E-07
6.875	0.1803	7.0E 01	5.4E 00	2.4E-01	4.7E-03	5.7E-05	5.9E-07
7.125	0.1740	1.0E 02	7.8E 00	3.6E-01	7.0E-03	8.4E-05	8.2E-07
7.375	0.1681	1.1E 02	8.4E 00	3.8E-01	7.6E-03	9.0E-05	9.3E-07
7.625	0.1626	1.5E 02	1.1E 01	5.2E-01	1.0E-02	1.2E-04	1.3E-06
7.875	0.1574	1.8E 02	1.3E 01	6.1E-01	1.2E-02	1.4E-04	1.5E-06
8.125	0.1526	2.1E 02	1.6E 01	7.3E-01	1.4E-02	1.7E-04	1.8E-06
8.375	0.1480	2.4E 02	1.8E 01	8.2E-01	1.6E-02	1.9E-04	2.0E-06
8.625	0.1437	2.7E 02	2.1E 01	9.4E-01	1.9E-02	2.2E-04	2.3E-06
8.875	0.1397	3.0E 02	2.3E 01	1.0E 00	2.0E-02	2.4E-04	2.5E-06
9.125	0.1359	1.8E 02	1.4E 01	6.3E-01	1.2E-02	1.5E-04	1.5E-06
9.375	0.1322	1.2E 02	9.3E 00	4.2E-01	8.3E-03	9.9E-05	1.0E-06

TABLE 3 - - CONTINUED
UNITS: CM⁻¹. TEMPERATURE: 6000° K

PHOTON ENERGY (EV)	WAVE- LENGTH (μ)	DENSITY RATIO					
		10	1	10 ⁻¹	10 ⁻²	10 ⁻³	10 ⁻⁴
0.625	1.9836	1.3E-02	2.5E-04	4.7E-06	8.9E-08	1.8E-09	5.6E-11
0.875	1.4169	7.8E-03	1.1E-04	1.8E-06	3.3E-08	6.6E-10	2.1E-11
1.125	1.1020	1.2E-02	7.1E-04	6.3E-05	5.1E-06	2.9E-07	6.8E-09
1.375	0.9017	1.5E-02	1.1E-03	1.0E-04	8.3E-06	4.6E-07	1.1E-08
1.625	0.7629	2.6E-02	9.2E-04	3.3E-05	1.7E-06	7.8E-08	1.9E-09
1.875	0.6612	3.0E-02	1.0E-03	3.2E-05	1.4E-06	6.4E-08	1.5E-09
2.125	0.5834	3.1E-02	1.0E-03	2.8E-05	9.9E-07	4.1E-08	1.0E-09
2.375	0.5220	3.4E-02	1.1E-03	2.7E-05	6.3E-07	3.0E-08	1.9E-09
2.625	0.4723	4.2E-02	1.4E-03	3.8E-05	1.3E-06	1.5E-07	1.4E-08
2.875	0.4312	8.5E-02	3.2E-03	9.7E-05	4.2E-06	5.9E-07	5.3E-08
3.125	0.3967	1.2E-01	3.8E-03	1.1E-04	7.8E-06	1.6E-06	1.5E-07
3.375	0.3673	1.8E-01	6.8E-03	2.3E-04	1.1E-05	1.4E-06	1.4E-07
3.625	0.3420	3.6E-01	1.2E-02	3.4E-04	1.2E-05	6.2E-07	3.9E-08
3.875	0.3199	4.5E-01	1.6E-02	4.6E-04	1.6E-05	4.9E-07	9.7E-09
4.125	0.3006	7.8E-01	2.6E-02	7.4E-04	2.1E-05	5.6E-07	9.6E-09
4.375	0.2834	1.0E 00	3.5E-02	9.5E-04	2.5E-05	5.9E-07	9.4E-09
4.625	0.2681	1.5E 00	5.6E-02	1.6E-03	4.5E-05	1.0E-06	1.6E-08
4.875	0.2543	2.8E 00	1.1E-01	3.4E-03	9.5E-05	2.2E-06	3.4E-08
5.125	0.2419	5.4E 00	2.4E-01	8.1E-03	2.4E-04	5.6E-06	8.7E-08
5.375	0.2307	3.4E 00	1.5E-01	5.3E-03	1.6E-04	3.7E-06	5.8E-08
5.625	0.2204	6.6E 00	1.9E-01	4.5E-03	1.1E-04	2.5E-06	3.8E-08
5.875	0.2110	1.1E 01	3.7E-01	1.1E-02	3.0E-04	7.0E-06	1.1E-07
6.125	0.2024	4.3E 00	2.0E-01	7.0E-03	2.1E-04	4.9E-06	7.7E-08
6.375	0.1945	4.6E 00	1.4E-01	3.5E-03	9.0E-05	2.0E-06	3.1E-08
6.625	0.1871	9.5E 00	2.0E-01	2.7E-03	2.9E-05	3.1E-07	3.3E-09
6.875	0.1803	1.5E 01	3.3E-01	4.1E-03	4.5E-05	4.7E-07	5.0E-09
7.125	0.1740	2.1E 01	4.4E-01	5.6E-03	6.1E-05	6.3E-07	6.6E-09
7.375	0.1681	2.3E 01	4.9E-01	6.3E-03	6.8E-05	7.0E-07	7.4E-09
7.625	0.1626	2.7E 01	5.7E-01	7.4E-03	8.0E-05	8.2E-07	8.6E-09
7.875	0.1574	3.2E 01	6.9E-01	8.9E-03	9.7E-05	9.8E-07	1.0E-08
8.125	0.1526	3.7E 01	8.1E-01	1.0E-02	1.1E-04	1.1E-06	1.2E-08
8.375	0.1480	4.0E 01	8.6E-01	1.1E-02	1.2E-04	1.2E-06	1.3E-08
8.625	0.1437	4.4E 01	9.5E-01	1.2E-02	1.3E-04	1.3E-06	1.4E-08
8.875	0.1397	5.0E 01	1.1E 00	1.4E-02	1.5E-04	1.5E-06	1.6E-08
9.125	0.1359	3.2E 01	6.9E-01	8.9E-03	9.6E-05	9.9E-07	9.8E-09
9.375	0.1322	2.3E 01	4.9E-01	6.3E-03	6.8E-05	7.1E-07	7.0E-09
9.625	0.1288	1.0E 00	3.6E-03	7.8E-05	1.4E-06	2.6E-08	5.8E-10
9.875	0.1255	1.0E 00	3.6E-03	7.9E-05	1.4E-06	2.6E-08	5.9E-10
10.125	0.1224	1.1E 00	3.7E-03	8.0E-05	1.5E-06	2.6E-08	6.0E-10
10.375	0.1195	1.1E 00	3.7E-03	8.1E-05	1.5E-06	2.7E-08	6.0E-10
10.625	0.1167	1.1E 00	3.8E-03	8.1E-05	1.5E-06	2.7E-08	6.1E-10

TABLE 3 - - CONTINUED
UNITS: CM⁻¹. TEMPERATURE: 8000°K

PHOTON ENERGY (EV)	WAVE- LENGTH (μ)	DENSITY RATIO					
		10	1	10 ⁻¹	10 ⁻²	10 ⁻³	10 ⁻⁴
0.625	1.9836	1.0E-01	2.6E-03	7.9E-05	4.4E-06	3.9E-07	3.4E-08
0.875	1.4169	3.7E-02	9.6E-04	2.9E-05	1.6E-06	1.4E-07	1.3E-08
1.125	1.1020	4.7E-02	2.8E-03	1.4E-04	3.7E-06	1.0E-07	6.2E-09
1.375	0.9017	5.7E-02	4.3E-03	2.2E-04	5.3E-06	9.3E-08	3.8E-09
1.625	0.7629	1.0E-01	2.9E-03	8.8E-05	2.4E-06	7.2E-08	3.3E-09
1.875	0.6612	1.2E-01	3.2E-03	8.7E-05	2.4E-06	7.0E-08	2.8E-09
2.125	0.5834	1.2E-01	3.1E-03	8.0E-05	2.2E-06	6.9E-08	2.6E-09
2.375	0.5220	1.3E-01	3.4E-03	9.0E-05	3.4E-06	1.2E-07	4.0E-09
2.625	0.4723	1.5E-01	4.6E-03	2.3E-04	1.2E-05	4.6E-07	1.4E-08
2.875	0.4312	2.3E-01	8.5E-03	6.2E-04	4.9E-05	1.5E-06	4.5E-08
3.125	0.3967	2.7E-01	1.3E-02	1.3E-03	8.9E-05	3.2E-06	9.9E-08
3.375	0.3673	4.8E-01	2.0E-02	1.5E-03	8.6E-05	2.9E-06	8.8E-08
3.625	0.3420	5.7E-01	2.1E-02	9.4E-04	1.7E-05	9.6E-07	2.6E-08
3.875	0.3199	7.1E-01	2.8E-02	1.0E-03	2.2E-05	3.3E-07	5.5E-09
4.125	0.3006	8.6E-01	2.8E-02	8.8E-04	1.8E-05	3.4E-07	5.3E-09
4.375	0.2834	9.0E-01	2.5E-02	5.9E-04	1.1E-05	2.1E-07	4.7E-09
4.625	0.2681	1.2E 00	3.4E-02	7.6E-04	1.4E-05	2.3E-07	5.0E-09
4.875	0.2543	2.0E 00	5.9E-02	1.4E-03	2.3E-05	3.3E-07	6.1E-09
5.125	0.2419	3.3E 00	1.1E-01	2.6E-03	4.1E-05	5.3E-07	8.1E-09
5.375	0.2307	2.1E 00	6.8E-02	1.6E-03	2.7E-05	3.8E-07	6.7E-09
5.625	0.2204	2.5E 00	6.1E-02	1.3E-03	2.1E-05	3.2E-07	6.2E-09
5.875	0.2110	4.4E 00	1.3E-01	3.0E-03	4.5E-05	5.9E-07	9.0E-09
6.125	0.2024	2.5E 00	8.2E-02	2.0E-03	3.2E-05	4.6E-07	7.9E-09
6.375	0.1945	1.7E 00	4.3E-02	9.3E-04	1.6E-05	2.8E-07	6.3E-09
6.625	0.1871	2.4E 00	3.7E-02	5.0E-04	8.6E-06	2.0E-07	5.6E-09
6.875	0.1803	3.0E 00	4.4E-02	5.9E-04	9.6E-06	2.1E-07	5.7E-09
7.125	0.1740	3.6E 00	5.3E-02	6.9E-04	1.1E-05	2.2E-07	5.9E-09
7.375	0.1681	3.9E 00	5.7E-02	7.4E-04	1.1E-05	2.3E-07	6.0E-09
7.625	0.1626	4.4E 00	6.5E-02	8.1E-04	1.2E-05	2.4E-07	6.2E-09
7.875	0.1574	4.9E 00	7.2E-02	9.0E-04	1.3E-05	2.5E-07	6.4E-09
8.125	0.1526	5.5E 00	7.9E-02	9.8E-04	1.4E-05	2.7E-07	6.5E-09
8.375	0.1480	5.7E 00	8.2E-02	1.0E-03	1.4E-05	2.7E-07	6.7E-09
8.625	0.1437	5.2E 00	8.9E-02	1.1E-03	1.5E-05	2.8E-07	6.8E-09
8.875	0.1397	7.2E 00	1.0E-01	1.2E-03	1.6E-05	3.0E-07	7.0E-09
9.125	0.1359	6.7E 00	9.7E-02	1.2E-03	1.6E-05	3.0E-07	7.1E-09
9.375	0.1322	3.4E 00	5.2E-02	6.9E-04	1.1E-05	2.5E-07	6.6E-09
9.625	0.1288	4.5E-01	1.1E-02	2.4E-04	6.6E-06	2.1E-07	6.3E-09
9.875	0.1255	4.5E-01	1.1E-02	2.4E-04	6.7E-06	2.1E-07	6.4E-09
10.125	0.1224	4.6E-01	1.1E-02	2.5E-04	6.8E-06	2.1E-07	6.5E-09
10.375	0.1195	4.6E-01	1.1E-02	2.5E-04	6.9E-06	2.1E-07	6.5E-09
10.625	0.1167	4.7E-01	1.1E-02	2.5E-04	7.0E-06	2.2E-07	6.6E-09

TABLE 4

EMISSION COEFFICIENT OF HIGH-TEMPERATURE AIR

UNITS: WATTS/CM³·MICRON. TEMPERATURE: 2000°K

PHOTON ENERGY (EV)	WAVE- LENGTH (μ)	DENSITY RATIO					
		10	1	10 ⁻¹	10 ⁻²	10 ⁻³	10 ⁻⁴
0.625	1.9836	0.	0.	0.	0.	0.	0.
0.875	1.4169	0.	0.	0.	0.	0.	0.
1.125	1.1020	0.	0.	0.	0.	0.	0.
1.375	0.9017	6.0E-03	1.9E-04	6.0E-06	1.9E-07	6.0E-09	1.9E-10
1.625	0.7629	4.5E-02	1.4E-03	4.5E-05	1.4E-06	4.4E-08	1.4E-09
1.875	0.6612	8.0E-02	2.5E-03	8.0E-05	2.5E-06	8.0E-08	2.5E-09
2.125	0.5834	5.2E-02	1.7E-03	5.2E-05	1.7E-06	5.1E-08	1.6E-09
2.375	0.5220	3.2E-02	1.0E-03	3.2E-05	1.0E-06	3.0E-08	2.6E-10
2.625	0.4723	1.5E-02	4.8E-04	1.5E-05	4.6E-07	1.5E-08	4.6E-10
2.875	0.4312	6.3E-03	1.9E-04	6.3E-06	1.9E-07	6.3E-09	1.9E-10
3.125	0.3967	2.4E-03	7.5E-05	2.4E-06	7.5E-08	2.4E-09	7.3E-11
3.375	0.3673	7.7E-04	2.4E-05	7.7E-07	2.5E-08	9.1E-10	3.4E-11
3.625	0.3420	2.3E-04	8.0E-06	2.8E-07	1.1E-08	6.1E-10	4.5E-11
3.875	0.3199	7.2E-05	2.6E-06	1.2E-07	6.8E-09	5.3E-10	4.7E-11
4.125	0.3006	2.7E-05	1.2E-06	7.9E-08	6.6E-09	6.2E-10	5.9E-11
4.375	0.2834	1.2E-05	1.0E-06	7.0E-08	6.5E-09	6.4E-10	6.2E-11
4.625	0.2681	6.7E-06	5.5E-07	5.3E-08	5.0E-09	5.0E-10	5.0E-11
4.875	0.2543	6.7E-06	6.4E-07	6.2E-08	6.2E-09	6.1E-10	6.0E-11
5.125	0.2419	6.2E-06	6.2E-07	6.2E-08	6.2E-09	6.2E-10	5.9E-11
5.375	0.2307	2.6E-06	2.6E-07	2.6E-08	2.6E-09	2.6E-10	2.6E-11
5.625	0.2204	4.8E-06	4.8E-07	4.8E-08	4.8E-09	4.8E-10	5.0E-11
5.875	0.2110	2.7E-06	2.7E-07	2.7E-08	2.7E-09	2.7E-10	2.7E-11
6.125	0.2024	1.0E-07	1.0E-08	1.0E-09	1.0E-10	1.0E-11	1.0E-12
6.375	0.1945	5.6E-08	5.6E-09	5.6E-10	5.6E-11	5.1E-12	5.1E-13
6.625	0.1871	2.1E-07	2.1E-08	2.1E-09	2.1E-10	2.1E-11	2.1E-12
6.875	0.1803	2.8E-07	2.8E-08	2.8E-09	2.8E-10	2.7E-11	2.7E-12
7.125	0.1740	1.0E-07	1.0E-08	1.0E-09	1.0E-10	1.0E-11	1.0E-12
7.375	0.1681	4.6E-08	4.6E-09	4.6E-10	4.6E-11	4.4E-12	4.4E-13
7.625	0.1626	2.0E-08	2.0E-09	2.0E-10	2.0E-11	1.9E-12	1.9E-13
7.875	0.1574	7.5E-09	7.5E-10	7.5E-11	7.5E-12	7.3E-13	7.3E-14
8.125	0.1526	2.7E-09	2.7E-10	2.7E-11	2.7E-12	2.6E-13	2.6E-14
8.375	0.1480	8.6E-10	8.6E-11	8.6E-12	8.6E-13	8.6E-14	8.4E-15
8.625	0.1437	2.8E-10	2.8E-11	2.8E-12	2.8E-13	2.8E-14	2.7E-15
8.875	0.1397	8.1E-11	8.1E-12	8.1E-13	8.1E-14	8.1E-15	8.0E-16
9.125	0.1359	1.4E-11	1.4E-12	1.4E-13	1.4E-14	1.3E-15	1.3E-16
9.375	0.1322	7.2E-13	7.2E-14	7.2E-15	7.2E-16	7.1E-17	7.0E-18

TABLE 4 - - CONTINUED

UNITS: WATTS/CM³·MICRON. TEMPERATURE: 3000° K

PHOTON ENERGY (EV)	WAVE- LENGTH (μ)	DENSITY RATIO					
		10	1	10 ⁻¹	10 ⁻²	10 ⁻³	10 ⁻⁴
0.625	1.9836	0.	0.	0.	0.	0.	0.
0.875	1.4169	0.	0.	0.	0.	0.	0.
1.125	1.1020	6.9E-02	2.1E-03	6.3E-05	1.7E-06	3.2E-08	1.0E-09
1.375	0.9017	8.4E-01	2.8E-02	8.1E-04	2.0E-05	3.2E-07	3.3E-09
1.625	0.7629	3.5E 00	1.0E-01	3.0E-03	7.6E-05	1.2E-06	7.7E-09
1.875	0.6612	6.6E 00	2.0E-01	6.0E-03	1.5E-04	2.3E-06	1.4E-08
2.125	0.5834	7.2E 00	2.2E-01	6.6E-03	1.6E-04	2.4E-06	1.6E-08
2.375	0.5220	5.9E 00	1.8E-01	5.1E-03	1.3E-04	2.0E-06	1.3E-08
2.625	0.4723	4.0E 00	1.2E-01	3.5E-03	8.9E-05	1.4E-06	9.2E-09
2.875	0.4312	2.5E 00	8.2E-02	2.7E-03	9.4E-05	3.0E-06	7.1E-08
3.125	0.3967	1.6E 00	6.0E-02	2.7E-03	1.3E-04	5.7E-06	1.3E-07
3.375	0.3673	9.6E-01	4.0E-02	2.1E-03	1.2E-04	6.2E-06	1.8E-07
3.625	0.3420	8.6E-01	5.2E-02	3.9E-03	2.9E-04	1.5E-05	3.6E-07
3.875	0.3199	6.5E-01	4.8E-02	4.0E-03	3.2E-04	1.5E-05	3.9E-07
4.125	0.3006	7.2E-01	6.4E-02	5.7E-03	4.4E-04	2.2E-05	5.7E-07
4.375	0.2834	7.3E-01	7.0E-02	6.2E-03	5.1E-04	2.5E-05	7.3E-07
4.625	0.2681	6.6E-01	6.4E-02	5.9E-03	4.6E-04	2.4E-05	7.0E-07
4.875	0.2543	8.4E-01	8.0E-02	7.4E-03	6.0E-04	3.3E-05	1.0E-06
5.125	0.2419	9.3E-01	9.3E-02	8.9E-03	7.6E-04	4.9E-05	2.0E-06
5.375	0.2307	4.1E-01	4.1E-02	3.9E-03	3.4E-04	2.4E-05	9.6E-07
5.625	0.2204	9.1E-01	8.9E-02	8.2E-03	6.4E-04	3.3E-05	7.5E-07
5.875	0.2110	6.8E-01	6.8E-02	6.3E-03	4.8E-04	2.7E-05	7.7E-07
6.125	0.2024	6.1E-02	6.1E-03	5.9E-04	5.0E-05	3.4E-06	1.5E-07
6.375	0.1945	2.1E-02	2.1E-03	2.0E-04	1.7E-05	1.0E-06	3.8E-08
6.625	0.1871	1.1E-01	1.1E-02	9.7E-04	7.7E-05	3.7E-06	7.3E-08
6.875	0.1803	1.7E-01	1.9E-02	1.7E-03	1.4E-04	6.6E-06	1.3E-07
7.125	0.1740	1.5E-01	1.5E-02	1.3E-03	1.0E-04	5.0E-06	1.0E-07
7.375	0.1691	6.3E-02	6.3E-03	6.4E-04	5.0E-05	2.4E-06	5.0E-08
7.625	0.1626	4.3E-02	4.1E-03	3.9E-04	3.1E-05	1.5E-06	3.1E-08
7.875	0.1574	2.5E-02	2.4E-03	2.3E-04	1.7E-05	8.5E-07	1.7E-08
8.125	0.1526	1.3E-02	1.3E-03	1.2E-04	9.3E-06	4.5E-07	9.3E-09
8.375	0.1480	7.0E-03	6.8E-04	6.3E-05	4.8E-06	2.3E-07	4.8E-09
8.625	0.1437	3.6E-03	3.6E-04	3.3E-05	2.6E-06	1.3E-07	2.5E-09
8.875	0.1397	1.7E-03	1.7E-04	1.6E-05	1.2E-06	5.9E-08	1.2E-09
9.125	0.1359	4.5E-04	4.4E-05	4.1E-06	3.2E-07	1.5E-08	3.2E-10
9.375	0.1322	9.9E-05	9.9E-06	9.2E-07	7.2E-08	3.4E-09	7.2E-11

TABLE 4 - - CONTINUED

UNITS: WATTS/CM³. MICRON. TEMPERATURE: 4000° K

PHOTON ENERGY (eV)	WAVE- LENGTH (μ)	DENSITY RATIO					
		10	1	10 ⁻¹	10 ⁻²	10 ⁻³	10 ⁻⁴
0.625	1.9836	0.	0.	0.	0.	0.	0.
0.875	1.4169	3.7E-01	9.1E-03	1.3E-04	8.3E-07	3.1E-09	1.0E-11
1.125	1.1020	3.5E 00	9.9E-02	2.2E-03	1.0E-04	9.5E-06	7.2E-07
1.375	0.9017	1.5E 01	3.7E-01	7.0E-03	2.1E-04	1.9E-05	1.8E-06
1.625	0.7629	3.4E 01	8.3E-01	1.2E-02	1.0E-04	3.1E-06	2.8E-07
1.875	0.6612	5.7E 01	1.3E 00	2.0E-02	1.4E-04	2.2E-06	1.7E-07
2.125	0.5834	7.0E 01	1.7E 00	2.4E-02	1.6E-04	1.1E-06	5.6E-08
2.375	0.5220	6.3E 01	1.6E 00	2.4E-02	2.1E-04	3.1E-06	9.1E-08
2.625	0.4723	6.0E 01	1.6E 00	2.9E-02	4.7E-04	1.2E-05	3.3E-07
2.875	0.4312	6.5E 01	2.4E 00	8.4E-02	2.4E-03	7.2E-05	2.1E-06
3.125	0.3967	7.0E 01	3.5E 00	1.4E-01	3.7E-03	7.9E-05	2.1E-06
3.375	0.3673	6.5E 01	3.8E 00	1.9E-01	5.8E-03	1.8E-04	4.9E-06
3.625	0.3420	1.1E 02	8.2E 00	4.0E-01	1.0E-02	2.3E-04	6.2E-06
3.875	0.3199	1.1E 02	8.2E 00	4.0E-01	1.1E-02	2.8E-04	7.0E-06
4.125	0.3006	1.6E 02	1.2E 01	6.2E-01	1.7E-02	3.9E-04	1.1E-05
4.375	0.2834	1.8E 02	1.4E 01	7.1E-01	1.9E-02	4.5E-04	1.2E-05
4.625	0.2681	1.8E 02	1.4E 01	7.6E-01	2.4E-02	6.1E-04	1.8E-05
4.875	0.2543	2.4E 02	1.9E 01	1.1E 00	3.6E-02	9.7E-04	2.8E-05
5.125	0.2419	3.0E 02	2.6E 01	1.6E 00	6.9E-02	2.3E-03	6.9E-05
5.375	0.2307	1.4E 02	1.2E 01	7.9E-01	3.3E-02	1.1E-03	3.6E-05
5.625	0.2204	2.8E 02	2.4E 01	1.1E 00	2.8E-02	5.4E-04	1.3E-05
5.875	0.2110	2.7E 02	2.1E 01	1.1E 00	3.5E-02	9.2E-04	2.7E-05
6.125	0.2024	4.1E 01	3.5E 00	2.4E-01	1.0E-02	3.6E-04	1.2E-05
6.375	0.1945	7.0E 01	5.5E 00	2.6E-01	6.5E-03	1.4E-04	3.4E-06
6.625	0.1871	8.2E 01	6.2E 00	2.8E-01	5.6E-03	6.5E-05	6.7E-07
6.875	0.1803	1.2E 02	9.2E 00	4.1E-01	8.0E-03	9.7E-05	1.0E-06
7.125	0.1740	9.9E 01	7.7E 00	3.6E-01	6.7E-03	8.3E-05	8.1E-07
7.375	0.1681	6.3E 01	4.8E 00	2.2E-01	4.3E-03	5.1E-05	5.3E-07
7.625	0.1626	4.9E 01	3.6E 00	1.7E-01	3.3E-03	3.9E-05	4.2E-07
7.875	0.1574	3.3E 01	2.4E 00	1.1E-01	2.2E-03	2.6E-05	2.8E-07
8.125	0.1526	2.2E 01	1.7E 00	7.7E-02	1.5E-03	1.8E-05	1.9E-07
8.375	0.1480	1.4E 01	1.1E 00	4.8E-02	9.5E-04	1.1E-05	1.2E-07
8.625	0.1437	8.9E 00	7.0E-01	3.1E-02	6.3E-04	7.3E-06	7.6E-08
8.875	0.1397	5.6E 00	4.3E-01	1.9E-02	3.7E-04	4.4E-06	4.6E-08
9.125	0.1359	1.9E 00	1.4E-01	6.5E-03	1.2E-04	1.5E-06	1.5E-08
9.375	0.1322	6.8E-01	5.3E-02	2.4E-03	4.7E-05	5.6E-07	5.7E-09

TABLE 4 - - CONTINUED

UNITS: WATTS/CM³. MICRON. TEMPERATURE: 6000° K

PHOTON ENERGY (EV)	WAVE- LENGTH (μ)	DENSITY RATIO					
		10	1	10 ⁻¹	10 ⁻²	10 ⁻³	10 ⁻⁴
0.625	1.9836	1.9E 01	3.6E-01	6.9E-03	1.3E-04	2.6E-06	8.2E-08
0.875	1.4169	3.8E 01	5.3E-01	8.7E-03	1.6E-04	3.2E-06	1.0E-07
1.125	1.1020	1.3E 02	7.4E 00	6.6E-01	5.3E-02	3.0E-03	7.1E-05
1.375	0.9017	2.6E 02	1.9E 01	1.8E 00	1.5E-01	8.1E-03	1.9E-04
1.625	0.7629	6.5E 02	2.3E 01	8.3E-01	4.3E-02	2.0E-03	4.8E-05
1.875	0.6612	9.5E 02	3.2E 01	1.0E 00	4.4E-02	2.0E-03	4.7E-05
2.125	0.5834	1.1E 03	3.6E 01	1.0E 00	3.6E-02	1.5E-03	3.6E-05
2.375	0.5220	1.3E 03	4.3E 01	1.1E 00	2.5E-02	1.2E-03	7.4E-05
2.625	0.4723	1.7E 03	5.6E 01	1.5E 00	5.2E-02	6.0E-03	5.6E-04
2.875	0.4312	3.3E 03	1.2E 02	3.8E 00	1.6E-01	2.3E-02	2.1E-03
3.125	0.3967	4.3E 03	1.4E 02	4.0E 00	2.8E-01	5.8E-02	5.4E-03
3.375	0.3673	5.9E 03	2.2E 02	7.5E 00	3.6E-01	4.6E-02	4.6E-03
3.625	0.3420	1.0E 04	3.5E 02	9.8E 00	3.5E-01	1.8E-02	1.1E-03
3.875	0.3199	1.1E 04	4.0E 02	1.1E 01	4.0E-01	1.2E-02	2.4E-04
4.125	0.3006	1.6E 04	5.4E 02	1.6E 01	4.4E-01	1.2E-02	2.0E-04
4.375	0.2834	1.7E 04	6.1E 02	1.6E 01	4.3E-01	1.0E-02	1.6E-04
4.625	0.2681	2.1E 04	7.9E 02	2.3E 01	6.4E-01	1.4E-02	2.3E-04
4.875	0.2543	3.2E 04	1.2E 03	3.9E 01	1.1E 00	2.5E-02	3.9E-04
5.125	0.2419	4.8E 04	2.2E 03	7.3E 01	2.2E 00	5.0E-02	7.8E-04
5.375	0.2307	2.4E 04	1.1E 03	3.7E 01	1.1E 00	2.6E-02	4.1E-04
5.625	0.2204	3.6E 04	1.0E 03	2.4E 01	6.0E-01	1.4E-02	2.1E-04
5.875	0.2110	4.6E 04	1.5E 03	4.6E 01	1.2E 00	2.9E-02	4.6E-04
6.125	0.2024	1.4E 04	6.3E 02	2.2E 01	6.6E-01	1.5E-02	2.4E-04
6.375	0.1945	1.1E 04	3.3E 02	8.3E 00	2.1E-01	4.8E-03	7.4E-05
6.625	0.1871	1.7E 04	3.6E 02	4.8E 00	5.2E-02	5.5E-04	5.9E-06
6.875	0.1803	2.0E 04	4.4E 02	5.4E 00	5.9E-02	6.2E-04	6.6E-06
7.125	0.1740	2.0E 04	4.3E 02	5.4E 00	5.9E-02	6.1E-04	6.4E-06
7.375	0.1681	1.6E 04	3.5E 02	4.5E 00	4.8E-02	5.0E-04	5.3E-06
7.625	0.1626	1.4E 04	3.0E 02	3.8E 00	4.2E-02	4.3E-04	4.5E-06
7.875	0.1574	1.2E 04	2.6E 02	3.3E 00	3.6E-02	3.7E-04	3.8E-06
8.125	0.1526	1.0E 04	2.2E 02	2.7E 00	3.0E-02	3.0E-04	3.3E-06
8.375	0.1480	7.8E 03	1.7E 02	2.1E 00	2.3E-02	2.3E-04	2.5E-06
8.625	0.1437	6.1E 03	1.3E 02	1.7E 00	1.3E-02	1.8E-04	1.9E-06
8.875	0.1397	4.9E 03	1.1E 02	1.4E 00	1.5E-02	1.5E-04	1.6E-06
9.125	0.1359	2.2E 03	4.8E 01	6.2E-01	6.7E-03	6.9E-05	6.9E-07
9.375	0.1322	1.1E 03	2.4E 01	3.1E-01	3.4E-03	3.5E-05	3.5E-07
9.625	0.1298	3.5E 01	1.3E-01	2.7E-03	4.9E-05	9.0E-07	2.0E-09
9.875	0.1255	2.4E 01	8.8E-02	1.9E-03	3.4E-05	6.3E-07	1.4E-08
10.125	0.1224	1.9E 01	6.3E-02	1.4E-03	2.6E-05	4.4E-07	1.0E-08
10.375	0.1195	1.3E 01	4.4E-02	9.6E-04	1.8E-05	3.2E-07	7.1E-09
10.625	0.1167	9.1E 00	3.1E-02	6.7E-04	1.2E-05	2.2E-07	5.0E-09

TABLE 4 - - CONTINUED

UNITS: WATTS/CM³·MICRON. TEMPERATURE: 8000°K

PHOTON ENERGY (eV)	WAVE- LENGTH (μ)	DENSITY RATIO					
		10	1	10 ⁻¹	10 ⁻²	10 ⁻³	10 ⁻⁴
0.625	1.9836	2.0E 02	5.1E 00	1.6E-01	3.7E-03	7.7E-04	6.7E-05
0.875	1.4169	2.7E 02	7.1E 00	2.1E-01	1.2E-02	1.0E-03	9.6E-05
1.125	1.1020	8.5E 02	5.1E 01	2.5E 00	6.7E-02	1.8E-03	1.1E-04
1.375	0.9017	2.0E 03	1.5E 02	7.5E 00	1.8E-01	3.2E-03	1.3E-04
1.625	0.7629	5.5E 03	1.6E 02	4.8E 00	1.3E-01	4.0E-03	1.8E-04
1.875	0.6612	9.4E 03	2.5E 02	6.8E 00	1.9E-01	5.5E-03	2.2E-04
2.125	0.5834	1.2E 04	3.2E 02	8.1E 00	2.2E-01	7.0E-03	2.6E-04
2.375	0.5220	1.6E 04	4.2E 02	1.1E 01	4.2E-01	1.5E-02	4.9E-04
2.625	0.4723	2.1E 04	6.5E 02	3.3E 01	1.7E 00	6.5E-02	2.0E-03
2.875	0.4312	3.6E 04	1.3E 03	9.6E 01	7.6E 00	2.3E-01	7.0E-03
3.125	0.3967	4.4E 04	2.1E 03	2.1E 02	1.5E 01	5.2E-01	1.6E-02
3.375	0.3673	8.0E 04	3.4E 03	2.5E 02	1.4E 01	4.9E-01	1.5E-02
3.625	0.3420	9.5E 04	3.5E 03	1.6E 02	2.8E 00	1.6E-01	4.3E-03
3.875	0.3199	1.1E 05	4.5E 03	1.6E 02	3.6E 00	5.3E-02	8.9E-04
4.125	0.3006	1.3E 05	4.3E 03	1.4E 02	2.8E 00	5.2E-02	8.2E-04
4.375	0.2834	1.3E 05	3.6E 03	8.5E 01	1.6E 00	3.0E-02	6.8E-04
4.625	0.2681	1.6E 05	4.5E 03	1.0E 02	1.9E 00	3.0E-02	6.6E-04
4.875	0.2543	2.4E 05	7.1E 03	1.7E 02	2.9E 00	3.9E-02	7.3E-04
5.125	0.2419	3.5E 05	1.2E 04	2.8E 02	4.4E 00	5.7E-02	8.7E-04
5.375	0.2307	2.0E 05	6.4E 03	1.5E 02	2.5E 00	3.6E-02	6.3E-04
5.625	0.2204	2.1E 05	5.0E 03	1.1E 02	1.7E 00	2.6E-02	5.1E-04
5.875	0.2110	3.1E 05	9.3E 03	2.1E 02	3.2E 00	4.2E-02	6.4E-04
6.125	0.2024	1.5E 05	5.0E 03	1.2E 02	2.0E 00	2.8E-02	4.8E-04
6.375	0.1945	8.8E 04	2.2E 03	4.8E 01	3.3E-01	1.5E-02	3.3E-04
6.625	0.1871	1.1E 05	1.6E 03	2.2E 01	3.9E-01	8.9E-03	2.5E-04
6.875	0.1803	1.1E 05	1.6E 03	2.2E 01	3.5E-01	7.7E-03	2.1E-04
7.125	0.1740	1.1E 05	1.6E 03	2.1E 01	3.4E-01	6.7E-03	1.8E-04
7.375	0.1681	9.8E 04	1.4E 03	1.9E 01	2.8E-01	5.8E-03	1.5E-04
7.625	0.1626	9.1E 04	1.3E 03	1.7E 01	2.5E-01	5.0E-03	1.3E-04
7.875	0.1574	8.3E 04	1.2E 03	1.5E 01	2.2E-01	4.2E-03	1.1E-04
8.125	0.1526	7.6E 04	1.1E 03	1.4E 01	1.9E-01	3.7E-03	9.0E-05
8.375	0.1480	6.4E 04	9.2E 02	1.1E 01	1.6E-01	3.0E-03	7.5E-05
8.625	0.1437	5.6E 04	8.0E 02	9.9E 00	1.4E-01	2.5E-03	6.1E-05
8.875	0.1397	5.2E 04	7.2E 02	8.7E 00	1.2E-01	2.2E-03	5.1E-05
9.125	0.1359	3.9E 04	5.6E 02	6.9E 00	9.2E-02	1.7E-03	4.1E-05
9.375	0.1322	1.6E 04	2.4E 02	3.2E 00	5.1E-02	1.2E-03	3.0E-05
9.625	0.1288	1.6E 03	4.0E 01	8.8E-01	2.4E-02	7.7E-04	2.3E-05
9.875	0.1255	1.3E 03	3.2E 01	6.9E-01	1.9E-02	6.1E-04	1.8E-05
10.125	0.1224	1.0E 03	2.5E 01	5.7E-01	1.5E-02	4.8E-04	1.5E-05
10.375	0.1195	8.2E 02	2.0E 01	4.5E-01	1.2E-02	3.8E-04	1.2E-05
10.625	0.1167	6.6E 02	1.5E 01	3.5E-01	9.8E-03	3.1E-04	9.3E-06

TABLE 5

TOTAL EMISSION RATE OF HIGH TEMPERATURE AIR NEGLECTING
SELF-ABSORPTION, INDUCED EMISSION, AND
INFRARED EMISSION BEYOND 2.5 MICRONS

UNITS: WATTS/CM³ - 3.0E-10

TEMPERATURE (°K)	DENSITY RATIO					
	10	1	10 ⁻¹	10 ⁻²	10 ⁻³	10 ⁻⁴
2000	2.0E-02	6.1E-04	2.0E-05	6.1E-07	1.9E-08	6.1E-10
3000	2.4E 00	8.1E-02	3.0E-03	1.3E-04	5.0E-06	1.3E-07
4000	6.0E 01	3.3E 00	1.5E-01	4.5E-03	1.2E-04	3.9E-06
6000	5.2E 03	1.8E 02	5.5E 00	1.9E-01	9.8E-03	5.3E-04
8000	4.2E 04	1.3E 03	4.7E 01	1.8E 00	5.5E-02	1.7E-03

TABLE 6

PLANCK MEAN ABSORPTION COEFFICIENT
FOR HIGH-TEMPERATURE AIR

UNITS: CM⁻¹

TEMPERATURE (°K)	DENSITY RATIO					
	10	1	10 ⁻¹	10 ⁻²	10 ⁻³	10 ⁻⁴
2000	5.4E-05	1.7E-06	5.4E-08	1.7E-09	5.3E-11	1.7E-12
3000	1.3E-03	4.4E-05	1.6E-06	7.0E-08	2.7E-09	7.1E-11
4000	1.0E-02	5.7E-04	2.6E-05	7.7E-07	2.1E-08	6.7E-10
6000	1.8E-01	6.1E-03	1.9E-04	6.6E-06	3.3E-07	1.8E-08
8000	4.5E-01	1.4E-02	5.1E-04	1.9E-05	5.9E-07	1.8E-08

TABLE 7
EMISSION RATE OF HIGH-TEMPERATURE AIR
IN THE VISIBLE (0.40-0.65 MICRONS)
NEGLECTING SELF-ABSORPTION AND
INDUCED EMISSION

UNITS: WATTS/CM³

TEMPERATURE (°K)	DENSITY RATIO					
	10	1	10 ⁻¹	10 ⁻²	10 ⁻³	10 ⁻⁴
2000	8.8E-03	2.8E-04	8.8E-06	2.8E-07	8.6E-09	2.7E-10
3000	1.3E 00	4.1E-02	1.2E-03	3.2E-05	6.0E-07	7.0E-09
4000	1.6E 01	4.5E-01	9.8E-03	1.8E-04	4.5E-06	1.4E-07
6000	4.3E 02	1.5E 01	4.2E-01	1.7E-02	2.1E-03	1.8E-04
8000	4.8E 03	1.6E 02	9.1E 00	5.9E-01	2.0E-02	6.0E-04