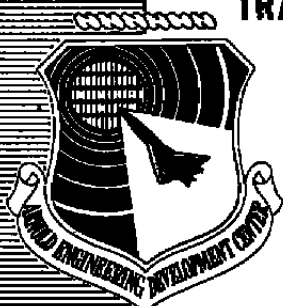


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**TRANSMISSION OF DOPPLER BROADENED RESONANCE RADIATION
THROUGH ABSORBING MEDIA WITH COMBINED
DOPPLER AND PRESSURE BROADENING
(NITRIC OXIDE γ -BANDS AS AN EXAMPLE)**



**ENGINE TEST FACILITY
ARNOLD ENGINEERING DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
ARNOLD AIR FORCE STATION, TENNESSEE 37389**

February 1976

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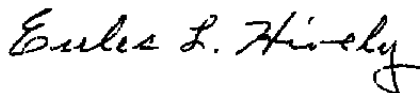
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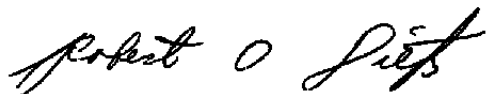
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20 ABSTRACT (Continue on reverse side if necessary and identify by block number) The combined Doppler and pressure broadening parameter has been determined for the 0,0 γ-band of nitric oxide (NO) by comparing measured spectral transmission data with the computed transmission using a radiative transfer model. The parameter (a', the ratio of collisional plus natural half-width to the Doppler half-width) was found to obey the relationship $a' = Cp/T$, where p is the pressure in atmospheres, T is the temperature in K, and C is a constant. The		

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20. ABSTRACT (Continued)

value of C was found to be 1270 ± 200 K/atm. This value of C leads to a value for the optical diameter of NO for broadening of 3.5 ± 0.3 Å. The determination of the broadening parameter permits the accurate calculation of the transmission of NO γ -band radiation through the high temperature, ambient pressure media corresponding to jet engine exhausts, in turn making possible the relating of transmission measurements to the concentration of NO. The application of the measurement and calculation procedure to the measurement problem is discussed.

PREFACE

The research reported herein was conducted by the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), under Program Element 65807F. The results were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of AEDC, AFSC, Arnold Air Force Station, Tennessee. The work was accomplished in the Engine Test Facility (ETF), under ARO Project Numbers R32P-54 and R32P-55A. The authors of this report were M. G. Davis, W. K. McGregor, J. D. Few, and H. N. Glassman, ARO, Inc. The manuscript (ARO Control No. ARO-ETF-TR-75-115) was submitted for publication on June 30, 1975.

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CONTENTS

	<u>Page</u>
1.0 INTRODUCTION.	7
2.0 THEORETICAL DEVELOPMENT	8
2.1 Development of Transmission Formulas for Cases Involving Absorption Lines Broadened by Foreign Gases	8
2.2 Relations between Absorption Coefficient and Absorbing Medium Properties	13
2.3 Examination of the Broadening Parameter (a').	14
3.0 DETERMINATION OF THE BROADENING PARAMETER (a) FOR THE NO MOLECULE IN THE PRESENCE OF N_2	15
3.1 Description of the Experimental Apparatus	15
3.2 Procedures and Results	22
4.0 DISCUSSION	30
REFERENCES	32

ILLUSTRATIONS

Figure

1. Illustration of Spectral Line Shape for Different Values of the Ratio of the Pressure Broadened Half-Width to the Doppler Half-Width.	11
2. Schematic of Experimental Apparatus for Resonance Line Absorption Measurements	16
3. Diagram of Heated Absorption Cell.	19
4. Schematic of Gas Handling System for Heated Absorption Cell	19
5. Diagram of Resonance Lamp Used to Produce Narrow-Line Radiation	20
6. (0, 0) Band of the NO γ -System Obtained from Discharge Tube Containing a Mixture of 12:3:1 (by volume) of A: N_2 : O_2 at 8 torr with 2800 v Applied by Use of 1-m Spectrometer in Second Order (Equivalent Slit Width, 0.03 Å)	20

<u>Figure</u>		<u>Page</u>
7.	Population Distribution of Excited Rotational States of the $A^2\Sigma$ Level of NO in a Water-Cooled Discharge Tube Operated at 8 torr with 2800 v Applied and Containing 12:3:1 Mixture (by volume) of A:N ₂ :O ₂	21
8.	Example of Transmission Measurements for NO (0,0) γ -Band, as Obtained with a 1-m Spectrometer having an Equivalent Slit Width of 0.03 Å	
	a. Optical Path Length for Absorption ($N_{O\ell} = 2$) . . .	23
	b. Optical Path Length for Absorption ($N_{O\ell} = 2.36 \times 10^{17}$ molecules/cm ²)	23
9.	Example Set of Transmission Measurements for NO (0,0) γ -Band, as Obtained with a 1/2-m Spectrometer Having an Equivalent Slit Width of 1.6 Å	24
10.	Example of Computed Transmission for NO (0,0) γ -Band for an Equivalent Spectral Slit Width of 0.03 Å and at Conditions Corresponding to Fig. 8	26
11.	Example Set of Computed Transmission for NO (0,0) γ -Band for an Equivalent Spectral Slit Width of 1.6 Å and at Conditions Corresponding to Fig. 9	27
12.	Calculated Transmissivity (t) of the Second Band Head of the (0,0) NO γ -Band as a Function of the Line Broadening Parameter (a')	28
13.	Values of the Spectral Broadening Parameter (a') as a Function of p/T for the (0,0) γ -Band of NO as Obtained by Comparing Experimental Data with Computed Data.. . . .	31

TABLES

1.	Determination of Broadening Parameter (a') from Resolved Lines of the (0,0) Band of the NO γ -System. .	28
2.	Determination of Broadening Parameter (a') from the Unresolved (0,0) Band of the NO γ -System.	29

APPENDIX

	<u>Page</u>
A. Computer Program for the Calculation and Simulation of the NO (0, 0) γ -Band Spectra Transmitted through an Absorbing Medium.	35
NOMENCLATURE	79

1.0 INTRODUCTION

The radiative transfer of Doppler broadened spectral lines, contained within electronic-vibrational-rotational bands, through Doppler broadened absorbing media has been treated in a previous report (Ref. 1). In the work reported herein, the radiative transfer of Doppler broadened source bands through media with Doppler and collision broadened lines is treated. In Ref. 1, the nitric oxide (NO) molecule was used to demonstrate the technique and to compare experimental data from low-pressure, Doppler broadened absorbing media with the calculated band profiles. In the work reported herein, NO will be used again but at pressures such that collisional broadening by a foreign gas (N_2) is present. Knowledge of the collisional broadening parameter for NO was found to be uncertain (Ref. 2) so that a major part of the present work was the determination of the broadening parameter to a higher degree of accuracy over a large range of pressure and temperature conditions.

The application of this work is found in the use of spectral line transmission through high temperature media to determine species concentration and temperature in situ. Previously, measurements using this spectral line resonance absorption technique (Refs. 3 and 4) have been made using empirical procedures to account for the finite width of the source lines. The work reported in Ref. 1 permitted the measured transmission to be related to species concentration and temperature in a rigorous fashion when pressure (e. g., collisional) broadening could be neglected. The development in the present report will permit measurements to be related to species concentration and temperature over pressure ranges where the pressure broadening is comparable to, or dominates, the Doppler broadening.

The broadening parameter (a') as used in most treatments of spectral line broadening (Refs. 5 and 6, for example) is proportional to the ratio of the sum of the natural half-width and the collisional half-width of the line to the Doppler half-width. The natural half-width can be neglected for electronic resonance transitions. Theoretical estimating procedures are generally inadequate to predict the collisional broadening and measurements cannot separate the Doppler from the collisional contributions so that the parameter (a') must be experimentally determined. Direct measurement of the broadening half-width to determine a' requires high resolution

spectral instruments. In the treatment used in the present study, a theoretical calculation procedure is used to predict transmission from experimental measurements, and thus by iteration of the calculations using a' as a parameter, the value of a' is indirectly determined by matching calculated and measured transmission. The required experimental data were obtained by measurement of the transmission of Doppler broadened lines in the (0, 0) γ -band of NO from a gas discharge lamp through a temperature-controlled (60 to 1,000°F) absorption cell containing known mixtures of NO and N₂ at pressures varying from about 0.1 to 2 atm.

The results of the theoretical development and the empirically determined value of a' are applicable directly to calculations of the transmission of the (0, 0) γ -band of NO emitted by a resonance radiation source through absorbing media of various NO concentrations, pressures, and temperatures. The temperatures and pressures accessible in the calibration laboratory is limited, so that direct calibration for all possible conditions is not possible. However, the determination of a' and the use of the theoretical relationships between the transmissivity and NO concentration permits extension to environments expected at the exhaust exit of combustion engines and other devices in which measurements of NO concentration might be desired.

2.0 THEORETICAL DEVELOPMENT

2.1 DEVELOPMENT OF TRANSMISSION FORMULAS FOR CASES INVOLVING ABSORPTION LINES BROADENED BY FOREIGN GASES

For a single, isolated j^{th} spectral line, the transmission ($\bar{T}_j$) of a source line having some frequency distribution ($I_{\nu_j}^0$) through uniform absorbing medium of length ℓ is given by (Ref. 5):

$$\bar{T}_j = \int_0^\infty I_{\nu_j}^0 \exp(-k_{\nu_j} \ell) d\nu \quad (1)$$

where ν is the frequency and k_{ν_j} is the absorption coefficient which has a frequency distribution independent of $I_{\nu_j}^0$. If the radiation source is maintained at low pressure, the frequency distribution for $I_{\nu_j}^0$ can be attributed to the Doppler effect, and is given by

$$I_{\nu_j}^o = I_{\nu_j^o}^o \exp \left\{ - \left[\frac{2(\nu - \nu_j^o)}{(\Delta_s \nu_j)_D} \sqrt{\ell_n 2} \right]^2 \right\} \quad (2)$$

where $I_{\nu_j^o}^o$ is the intensity of the source line at center frequency (ν_j^o) and $(\Delta_s \nu_j)_D$ is the Doppler width at half the intensity (half-width) of the emitted spectral line. The Doppler half-width of the source line is given by

$$(\Delta_s \nu_j)_D = 2 \nu_j^o \sqrt{\frac{2 \ell_n 2 \kappa T_s}{M_s c^2}} \quad (3)$$

In Eq. 3, κ is Boltzmann's constant, T_s is the absolute temperature of the source, M_s is the molecular weight of the emitting molecule, and c is the speed of light.

In general, the frequency distribution of the absorption coefficient (k_{ν_j}) is given by (Ref. 6):

$$k_{\nu_j} = k_{\nu_j^o} \frac{1}{\pi} \int_{-\infty}^{\infty} \frac{a' e^{-y^2}}{a'^2 + (\omega_j - y)^2} dy \quad (4)$$

where

$$a' = \frac{(\Delta_a \nu_j)_L}{(\Delta_a \nu_j)_D} \sqrt{\ell_n 2} \quad (5)$$

$$\omega_j = \frac{2(\nu_j - \nu_j^o)}{(\Delta_a \nu_j)_D} \sqrt{\ell_n 2} \quad (6)$$

and y is a dummy variable of integration. In Eq. 4, $k_{\nu_j^o}$ is the absorption coefficient at line center for Doppler conditions. In Eq. 5, $(\Delta_a \nu_j)_L$ is the Lorentz half-width (due to collision broadening) of the absorption line and is given by (Ref. 6):

$$(\Delta_a \nu_j)_L = \frac{Z_L}{\pi} \quad (7)$$

where Z_L is the frequency of collisions between the absorbing molecules and the surrounding molecules which leads to broadening of the energy states of the absorbing molecules. The factor $(\Delta_a \nu_j)_D$ is the Doppler half-width of the absorption line and is given by

$$(\Delta_a \nu_j)_D = 2 \nu_j^0 \sqrt{\frac{2 \ell_n 2 \kappa T_a}{M_a c^2}} \quad (8)$$

where T_a is the static temperature of the absorbing medium and M_a is the molecular weight of the absorbing molecules.

Equation 4 for k_{ν_j} can be shown to reduce to (Ref. 7):

$$k_{\nu_j} = k_{\nu_j^0} R \{ \exp [-(\omega_j + i a')^2] \operatorname{erfc} [-i \omega_j + a'] \} \quad (9)$$

where R denotes the real part and $i = \sqrt{-1}$. It should be noted that, for low pressures and high temperatures, a' is very small and Eq. (9) reduces to

$$k_{\nu_j} = k_{\nu_j^0} e^{-\omega^2} \quad (10)$$

This is the Doppler case examined in Ref. 1.

Close examination of Eq. (9) shows that the absorption line half-width increases and the absorption coefficient at line center decreases as a' increases, as illustrated graphically in Fig. 1.

Equations (1), (2), and (4) can be combined to give the transmission of a single line through a medium:

$$T_j = I_{\nu_j^0}^c \int_0^\infty \exp \left\{ - \left[\frac{2(\nu - \nu_j^0)}{(\Delta_a \nu_j)_D} \sqrt{\ell_n 2} \right]^2 \right\} \exp \left\{ - \ell k_{\nu_j^0} \frac{1}{\pi} \int_{-\infty}^\infty \frac{a' e^{-y^2} dy}{a'^2 + (\omega_j - y)^2} \right\} d\nu \quad (11)$$

If there are other absorption lines which might contribute to the measured transmission of the j th line, Eq. (4) must be replaced by

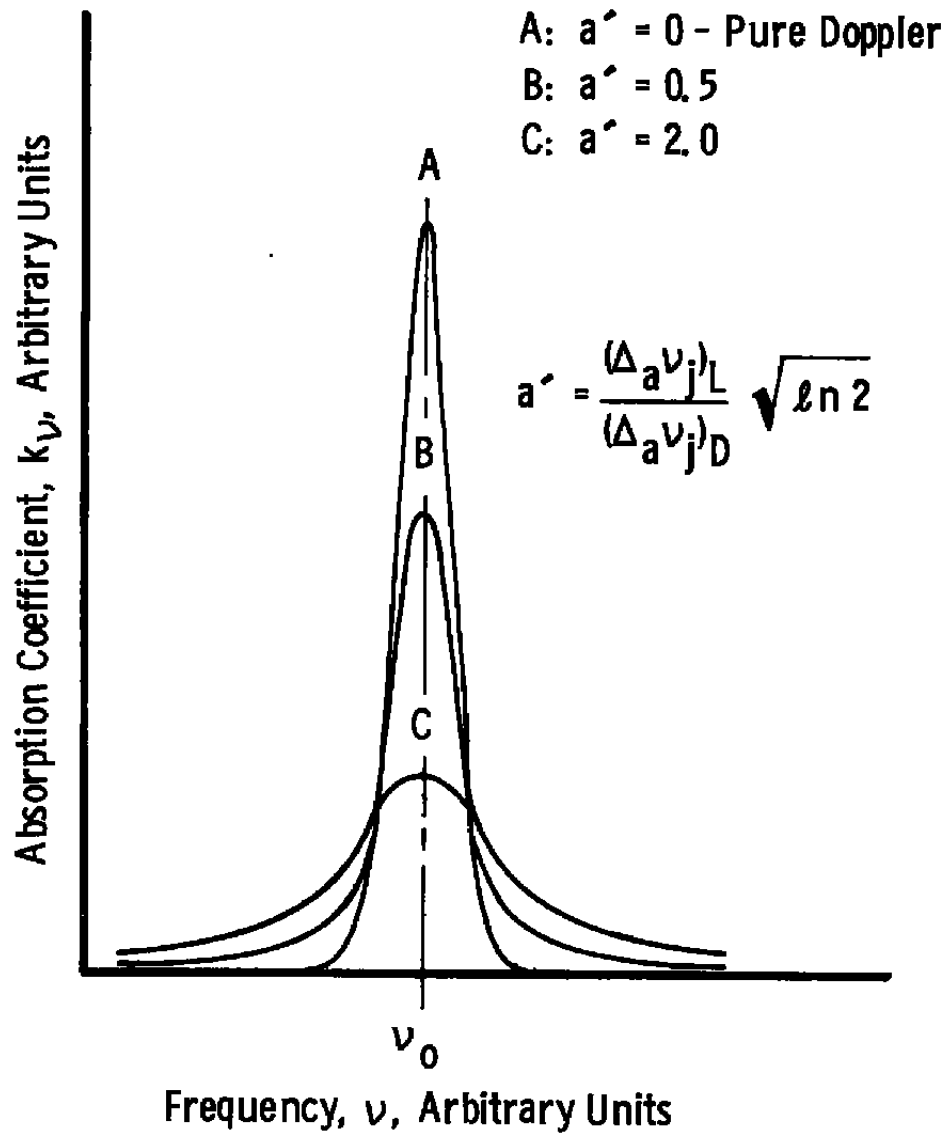


Figure 1. Illustration of spectral line shape for different values of the ratio of the pressure broadened half-width to the Doppler half-width.

$$k_{\nu} = \frac{1}{\pi} \sum_i k_{\nu_i^0} \int_{-\infty}^{\infty} \frac{a' e^{-y^2}}{a'^2 + (\omega_i - y)^2} dy \quad (12)$$

where the summation is over all absorption lines, including the j th line, which have a finite value of the absorption coefficient contributing to absorption of the j th emission line. The transmission of the radiation in the j th emission line due to absorption by many lines is given by

$$T_j = I_{\nu_j^0} \int_0^{\infty} \exp \left\{ - \left[\frac{2(\nu - \nu_j^0)}{(\Delta_s \nu_j)_D} \sqrt{\ell n 2} \right]^2 \right\} \exp \left\{ - \frac{\ell}{\pi} \sum_i k_{\nu_i^0} \int_{-\infty}^{\infty} \frac{a' e^{-y^2}}{a'^2 + (\omega_i - y)^2} dy \right\} d\nu \quad (13)$$

The total transmission ($\bar{T}$) in a particular frequency interval (e. g., bandpass of a spectrometer or interference filter) is given by summing over all the emission lines in that interval and results in the equation:

$$\bar{T}_{\Delta\nu} = \sum_j I_{\nu_j^0} \int_0^{\infty} \exp \left\{ - \left[\frac{2(\nu - \nu_j^0)}{(\Delta_s \nu_j)_D} \sqrt{\ell n 2} \right]^2 \right\} \exp \left\{ - \frac{\ell}{\pi} \sum_i k_{\nu_i^0} \int_{-\infty}^{\infty} \frac{a' e^{-y^2}}{a'^2 + (\omega_i - y)^2} dy \right\} d\nu \quad (14)$$

where the summation over j includes all emission lines which have components falling within the frequency interval of interest ($\Delta\nu$). The transmissivity (t) or fractional transmission in a particular frequency interval ($\Delta\nu$) is then given by

$$t_{\Delta\nu} = \frac{\sum_j I_{\nu_j^0} \int_0^{\infty} \exp \left\{ - \left[\frac{2(\nu - \nu_j^0)}{(\Delta_s \nu_j)_D} \sqrt{\ell n 2} \right]^2 \right\} \exp \left\{ - \frac{\ell}{\pi} \sum_i k_{\nu_i^0} \int_{-\infty}^{\infty} \frac{a' e^{-y^2}}{a'^2 + (\omega_i - y)^2} dy \right\} d\nu}{\sum_j I_{\nu_j^0} \int_0^{\infty} \exp \left\{ - \left[\frac{2(\nu - \nu_j^0)}{(\Delta_s \nu_j)_D} \sqrt{\ell n 2} \right]^2 \right\} d\nu} \quad (15)$$

In order to carry out the evaluation of $t_{\Delta\nu}$, values of $k_{\nu_i^0}$ and a' must be determined for a particular medium and path.

2.2 RELATIONS BETWEEN ABSORPTION COEFFICIENT AND ABSORBING MEDIUM PROPERTIES

The absorption coefficient of a diatomic molecule for Doppler conditions at line center frequency ($k_{\nu_i^o}$) is given by (Ref. 5):

$$k_{\nu_i^o} = \frac{2e^2\sqrt{\pi}\ell_n2}{mc^2} \frac{N_{J''} f_{J'J''}}{(\Delta\nu_i)_D} \quad (16)$$

where e is the charge on an electron, c is the velocity of light, m is the mass of an electron, $f_{J'J''}$ is the oscillator strength of the appropriate absorption line, $N_{J''}$ is the number density of molecules in the lower energy state of the molecule corresponding to the i th line, J'' is the rotational quantum number of the lower energy state, and J' is the rotational quantum number of the upper energy state.

The number density of the lower energy state ($N_{J''}$) under equilibrium conditions is given by

$$N_{J''} = \frac{hc B_0 (2J'' + 1) \exp \left[-\frac{hc}{\kappa T_a} F(J'') \right]}{2 \kappa T_a} N_0 \quad (17)$$

where N_0 is the number density of the molecule of interest, B_0 is the rotational constant for the ground state, h is Planck's constant, κ is Boltzmann's constant, and $F(J'')$ is the rotational energy term for the lower rotational energy state.

The value for the oscillator strength ($f_{J'J''}$) is given by (Ref. 8):

$$f_{J'J''} = f_{\nu'\nu''} \frac{\nu_{J'J''}}{\nu_{\nu'\nu''}} \frac{S_{J''J'}}{2(2J'' + 1)(2S + 1)} \quad (18)$$

where $f_{\nu'\nu''}$ is the band oscillator strength, $\nu_{J'J''}$ is the frequency of the line of interest, $\nu_{\nu'\nu''}$ is the frequency of the band head, $S_{J''J'}$ is the normalized Hönl-London factor for the line of interest, and S is the spin quantum number. Combining Eqs. (16), (17), and (18) gives

$$k_{\nu_i^o} = \frac{e^2\sqrt{\pi}\ell_n2}{2(2S + 1)mc^2} \frac{h B_0 \nu_{J'J''} f_{\nu'\nu''} S_{J''J'} N_0 \exp \left[-\frac{hc}{\kappa T_a} F(J'') \right]}{\kappa T_a \nu_{\nu'\nu''} (\Delta\nu_i)_D} \quad (19)$$

For a particular spectral line of a given molecular species for which the various molecular parameters in Eq. (19) are known, values of $k_{\nu_i}^o$ can be calculated as functions of N_o and T_a .

For the (0, 0) γ -band of NO, Eq. (19) reduces to (Ref. 1):

$$k_{\nu_i}^o = 1.603 \times 10^{-14} \frac{S_J J'' N_o}{T_a^{3/2}} \exp [-1.4383 F(J'')/T_a] \quad (20)$$

where the cgs system of units is used throughout

2.3 EXAMINATION OF THE BROADENING PARAMETER (a')

Equation (7) states that collisional broadening of a spectral absorption line depends on the collisional frequency of the absorbing molecules with the surrounding molecules. It can be shown from classical kinetic theory that the broadening collisional frequency (Z_L) for an absorbing molecule of molecular weight (M_a) is given by

$$Z_L = \sum_{\ell} Z_{\ell} = 2 \sum_{\ell} N_{\ell} \sigma_{\ell}^2 \sqrt{2\pi\kappa T_a \left(\frac{1}{M_{\ell}} + \frac{1}{M_a} \right)} \quad (21)$$

where M_{ℓ} is the mass of the ℓ th type of colliding molecule causing the broadening, N_{ℓ} is the concentration of the ℓ th type of molecule, and σ_{ℓ}^2 is the effective collisional cross section for the broadening process by the ℓ th type molecule.

Combining Eqs. (5), (7), (8), and (21) results in the equation,

$$a' = \frac{\lambda_j^o}{\sqrt{\pi}} \sum_{\ell} N_{\ell} \sigma_{\ell}^2 \sqrt{1 + \frac{M_a}{M_{\ell}}} \quad (22)$$

where λ_j^o is the wavelength of the absorption line at line center and results from the fact that

$$\lambda_j^o = \frac{c}{\nu_j^o} \quad (23)$$

By using the equation of state for a perfect gas, it can be shown that

$$N_{\ell} = 9.66 \times 10^{19} \frac{p_{\ell}}{T_a} \quad (24)$$

where p_{ℓ} is the partial pressure of the ℓ th type molecule in torr and T is in K. Combining Eqs. (22) and (24) results in

$$a' = \frac{5.45 \times 10^{19}}{T} \lambda_j^0 \sum_{\ell} p_{\ell} \sigma_{\ell}^2 \sqrt{1 + \frac{M_a}{M_{\ell}}} \quad (25)$$

For many cases, the foreign gas is composed of chiefly one constituent, and the concentration of the absorbing gas is relatively small. In such cases, self broadening is negligible, and Eq. (25) reduces to

$$a' = \left[5.45 \times 10^{19} \lambda_j \sigma^2 \sqrt{1 + \frac{M_a}{M_f}} \right] \frac{p_a}{T_a} \quad (26)$$

or

$$a' = C_j \frac{p_a}{T_a} \quad (27)$$

where σ^2 is the effective collisional cross section for the broadening process by the foreign gas, M_f is the mass of the foreign gas, and C_j is a constant for the j th line given by

$$C_j = 5.45 \times 10^{19} \lambda_j \sigma^2 \sqrt{1 + \frac{M_a}{M_f}} \quad (28)$$

It is this constant (C_j) that must be determined experimentally.

3.0 DETERMINATION OF THE BROADENING PARAMETER (a') FOR THE NO MOLECULE IN THE PRESENCE OF N_2

The value of a is functionally dependent on pressure and temperature as shown by Eq. (27). To completely define a' , the value of C_j must be determined experimentally. Although C_j depends on the wavelength of the spectral line of interest, for most spectral bands C_j may be considered a constant for all lines in the band and simply designated by C (i. e., λ_j changes by less than 0.1 percent throughout the (0, 0) γ -band of NO). In this section, the experimental determination of C_j for a few individual lines of the (0, 0) γ -band of NO and the determination of C for the entire, unresolved band will be described.

3.1 DESCRIPTION OF THE EXPERIMENTAL APPARATUS

The experimental apparatus consisted of a resonance gas discharge source lamp, a heated absorption cell, and two spectrometers. The arrangement of the apparatus is illustrated in Fig. 2.

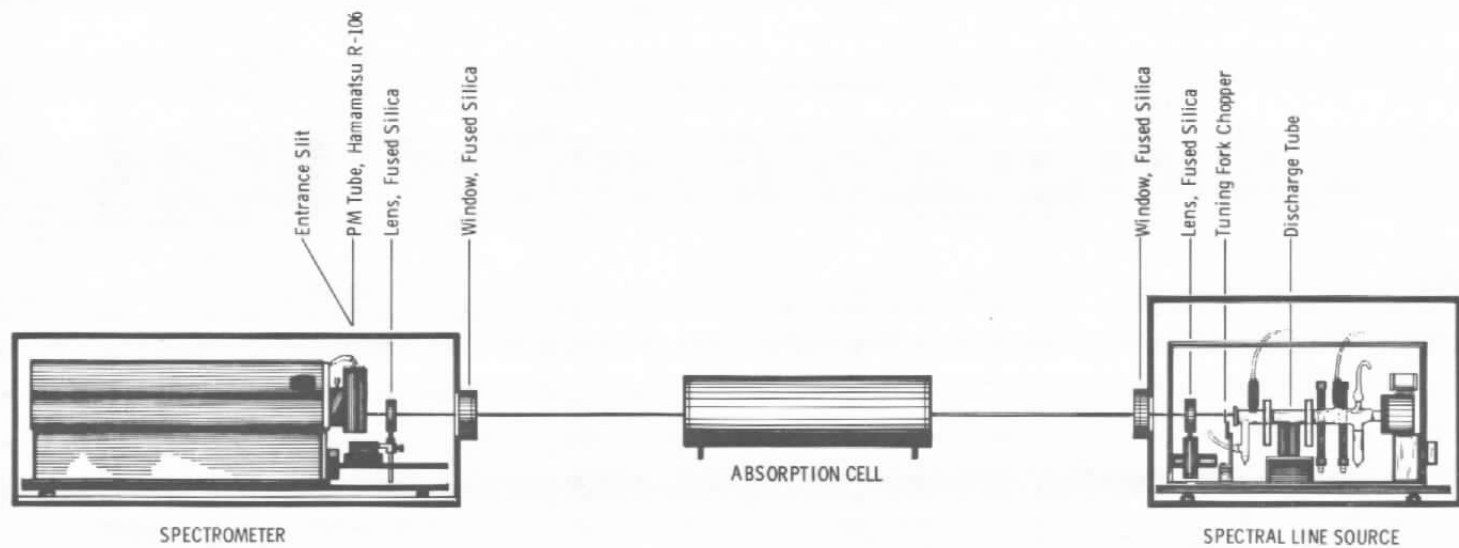


Figure 2. Schematic of experimental apparatus for resonance line absorption measurements.

3.1.1 Ultraviolet Spectrometers

A 1-m Jarrell-Ash grating spectrometer equipped with curved slits was used to obtain high resolution data. The grating has 1,180 lines/mm and was blazed for maximum reflection at 7,500 Å. All data taken with the 1-m spectrometer was in the second order of the spectrum. An RCA 1P28 photomultiplier tube with S-spectral response was used as the detector. The internal optics consisted of two fused silica lenses, each with an f-number of 4.4. The lenses were placed as shown in Fig. 2, so that parallel light was directed from the source through the absorbing gas and focused on the slit of the spectrometer. The 1-m spectrometer was operated with a physical slit width of 10 μ , resulting in an equivalent slit width of 0.03 Å, which gives sufficient resolution to separate several lines in the γ -bands of NO (Ref. 3).

A 1/2-m Jarrell-Ash grating spectrometer equipped with curved slits was used to obtain low resolution band spectra. The grating had 2,360 lines/mm and was blazed for maximum reflection at 3,000 Å. The external optics and detector were identical to those used on the 1-m spectrometer. The 1/2-m spectrometer was operated with a physical slit width of 200 μ , resulting in an equivalent slit width of 1.6 Å. No lines of NO γ -bands could be resolved using this slit width. The 1/2-m instrument, operated with the 200- μ slit width, has been used in lieu of the 1-m instrument for field measurements of the absorption of NO γ -band radiation (Ref. 4) because it is less susceptible to vibration and misalignment problems.

3.1.2 Absorption Cell

The absorption cell used in this research study was a specially designed 91.4-cm long by 10.2-cm-diam fused-silica tube with flat fused-silica end plates and 1/2-in. tubes for gas entry and exit (Fig. 3). The tube was enclosed in a copper sleeve which was wrapped with a Calrod[®] unit for heating purposes. A highly reflective aluminum sheet was wrapped around the heating unit, and the entire assembly was surrounded by three inches of insulation. The assembly was encased in a steel housing. Three-inch diameter holes were left in each end of the tube so that the light source could be directed through the cell and into the spectrometer.

The heating unit was connected to a temperature controller which controlled the temperature of the gas within the cell through the monitoring of strategically placed thermocouples. The temperature could

be varied between ambient and 1,000°F and controlled within an accuracy of ± 1 percent. The pressure of the gas in the cell was measured by means of pressure transducers over a range of from 50 to 1,500 torr, with an accuracy of ± 1 percent.

The gas system is shown schematically in Fig. 4. The absorber gases could be admitted to the cell and sealed off by valves or could be flowed continuously. In this experiment, the gases were admitted and sealed off. The gases used were mixtures of NO in N₂ which were supplied by Scott Research Corporation as calibration gases. Three mixtures were used: (1) 40 parts per million (ppm), (2) 100 ppm, or (3) 400 ppm of NO. The actual mixtures were determined to be 40, 99, and 395 ppm, using a gas chromatograph, with an accuracy of ± 5 percent.

3.1.3 Resonance Lamp Source Characteristics

A schematic of the resonance lamp used as a line source is presented in Fig. 5. The source was run using a 12:3:1 mixture (by volume) of (A:N₂:O₂) at approximately 5-torr pressure with an applied voltage of 2,800 v. Radiation emitted at the end of the water-cooled capillary tube was directed through the absorption cell and into the optics of the spectrometer (Fig. 2). The gas temperature in the capillary tube was maintained at approximately 320 K by the water-cooling jacket. It is assumed that the dominant broadening mechanism under these conditions is due to the Doppler effect. The Doppler line width (Eq. (3)) for the lines of the (0,0) γ -band of NO at 320 K is 0.0005 Å, so that the actual width of the lines is much smaller than the equivalent slit width of the spectrometer (0.03 Å). A spectrum of the (0,0) band from the lamp in which many of the lines are resolved is given in Fig. 6. In order to employ the computational technique developed in Section 2.0 and the spectrometer simulation described in Ref. 1, it is necessary to define the relative intensity of each line in the band. By using all the resolved lines in the spectra of Fig. 6, a plot of the radiation intensity divided by the relative line strength versus the upper state energy (F_J') was made (Fig. 7). The upper state energy parameter varies from the energy at $J' = 1/2$ to the energy at $J' = 81/2$. A more complete discussion of the energy levels of the upper state for the (0,0) γ -bands appears in Ref. 3.

In order to find the relative intensity of those lines that are not resolvable, it is necessary to use the curve in Fig. 7. For a particular line, the value of $I_{J'J''}/S_{J'J''}$ corresponding to its value of F_J' is found from Fig. 7 and is then multiplied by the appropriate value of $S_{J'J''}$ resulting in a value of the relative intensity ($I_{J'J''}$) for the $J'J''$

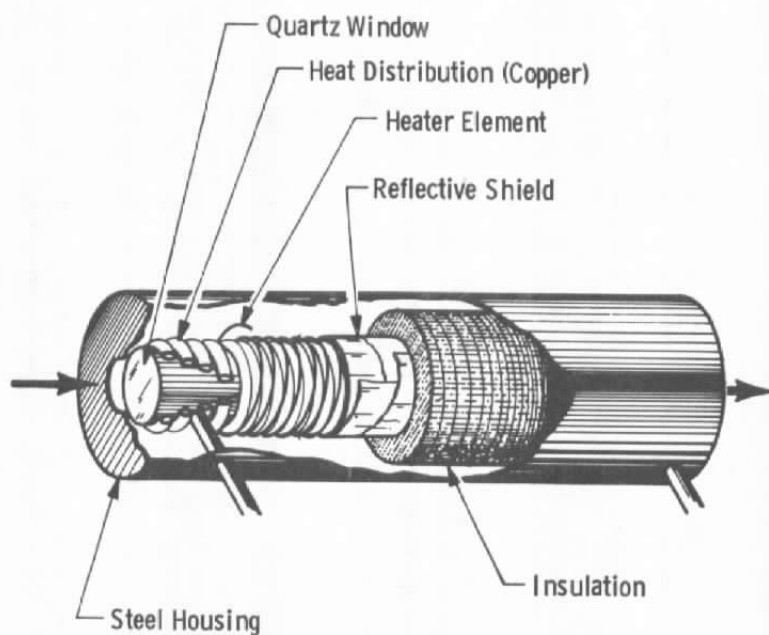


Figure 3. Diagram of heated absorption cell.

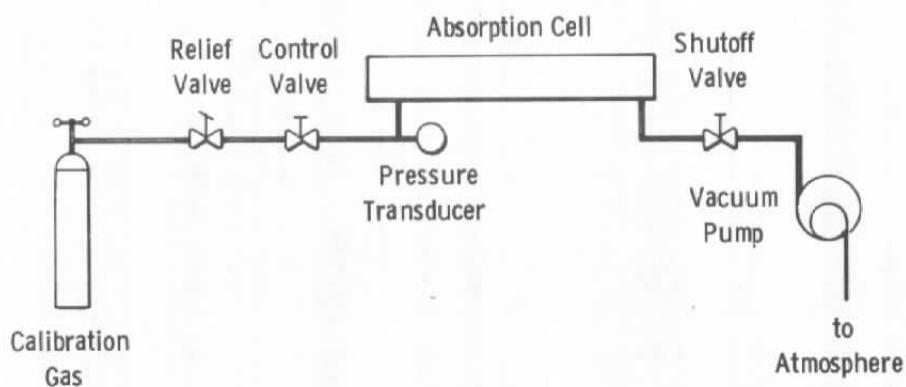


Figure 4. Schematic of gas handling system for heated absorption cell.

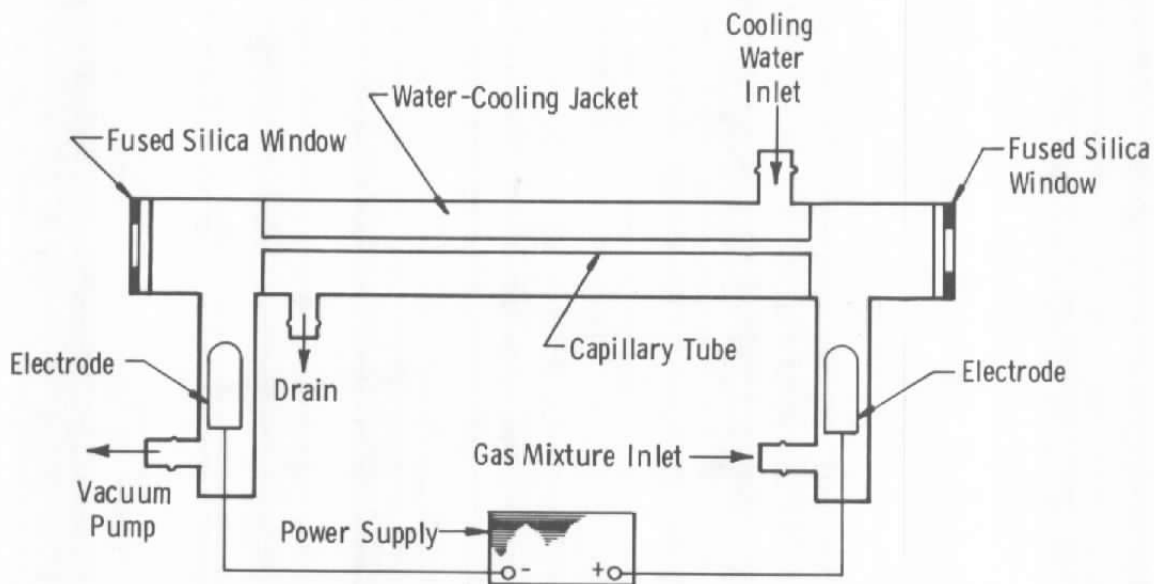


Figure 5. Diagram of resonance lamp used to produce narrow-line radiation.

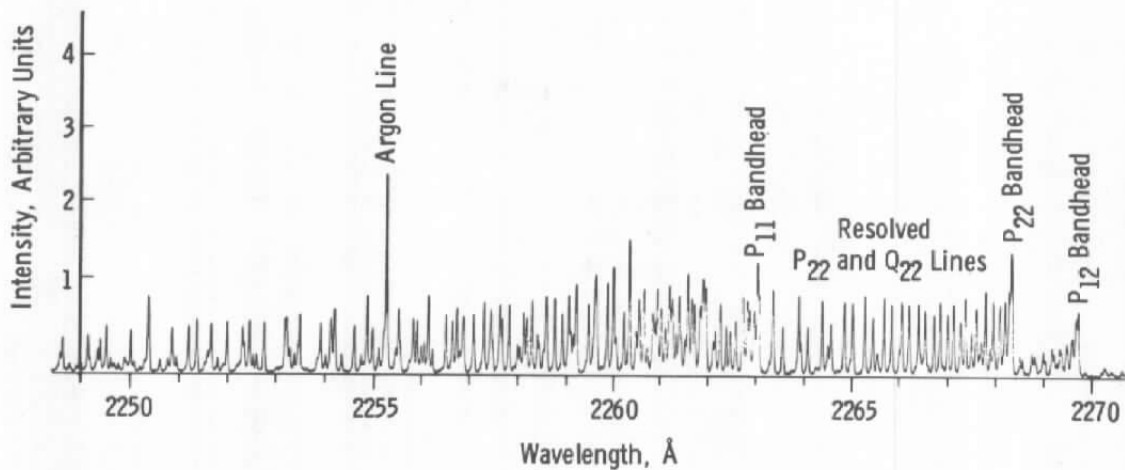


Figure 6. (0,0) band of the NO γ -system obtained from discharge tube containing a mixture of 12:3:1 (by volume) of A: N_2 : O_2 at 8 torr with 2,800 v applied by use of 1-m spectrometer in second order (equivalent slit width, 0.03 $\text{\AA}$).

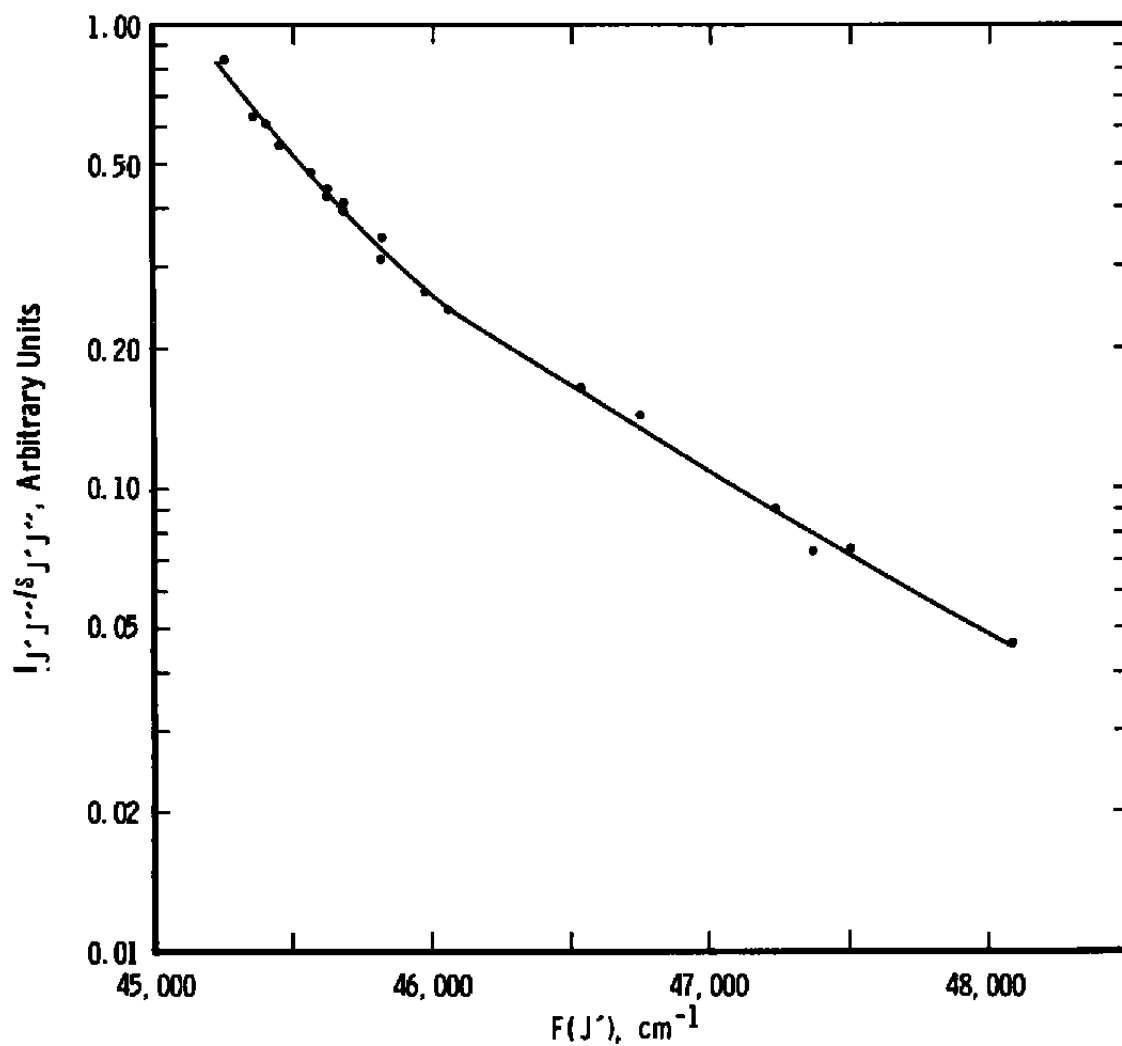


Figure 7. Population distribution of excited rotational states of the $A^2\Sigma$ level of NO in a water-cooled discharge tube operated at 8 torr with 2,800 v applied and containing 12:3:1 mixture (by volume) of A:N₂:O₂.

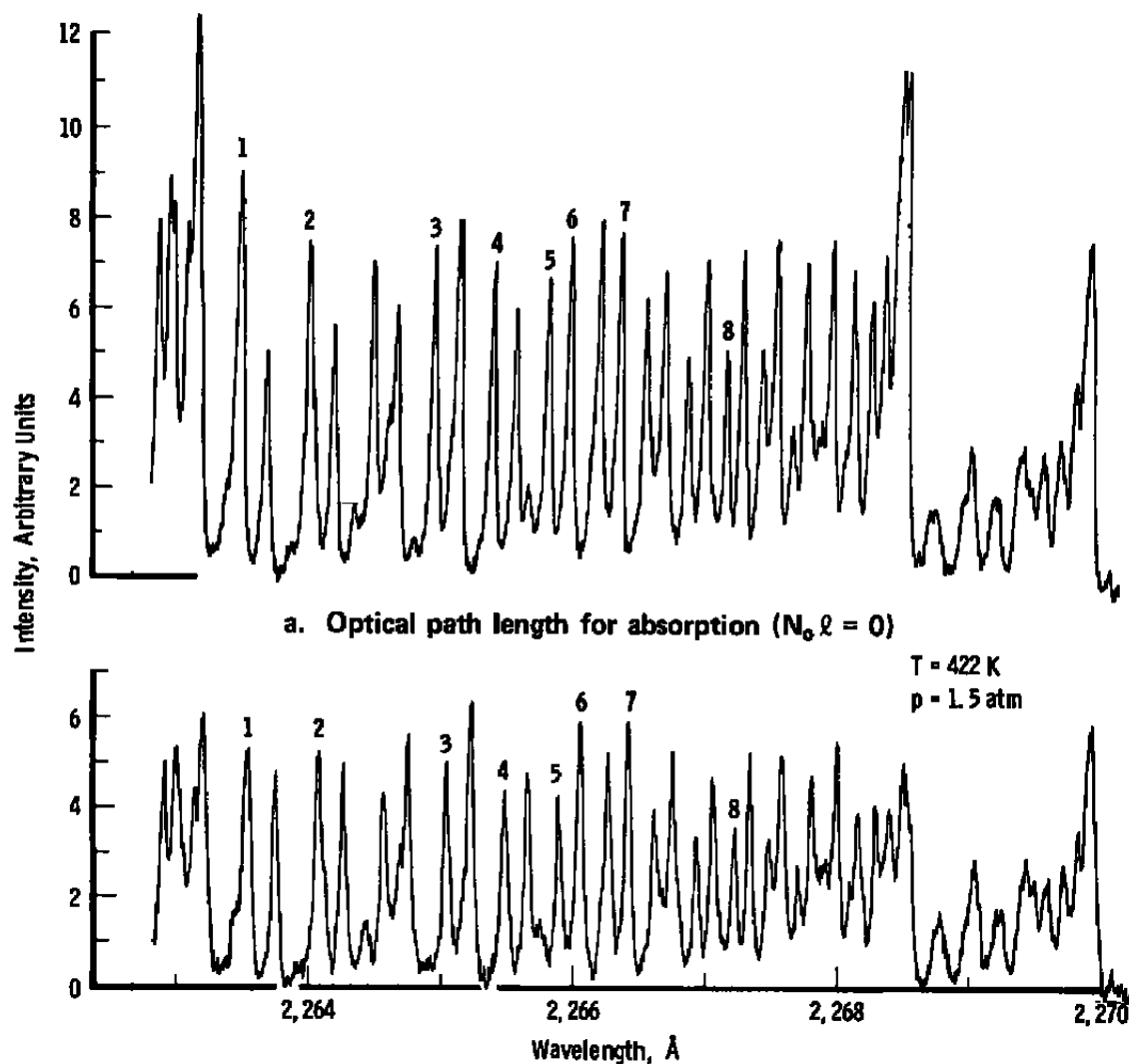
line. Values for $\delta_{J'J''}$ are obtained from the formulas developed by Earls (Ref. 9) as given in Ref. 3. Experimental values of ν_j , as given by Deeszi (Ref. 10) were used in these calculations. The experimental values of ν_j are more accurate than can be calculated using the Hill and Van Fleck formula as discussed in Ref. 1. Values for I_{ν_j} used in the transmission equations (Eqs. (13), (14), or (15)) are thus calculated from the values of $I_{J'J''}/\delta_{J'J''}$ in Fig. 7.

The distributions of line intensities were measured several times during these experiments using pressures in the resonance lamp ranging from 5 to 15 torr with corresponding changes in the applied voltage and current. No measurable changes in the relative distribution of line intensities shown in Fig. 7 have been found, although the level of intensity may change considerably with the lamp operating conditions.

3.2 PROCEDURES AND RESULTS

The procedure for determining the value of C for NO consisted of the following steps:

- (1) A series of laboratory spectral absorption measurements of the (0, 0) γ -band of NO were made for several partial pressures of NO and N₂ and for several gas temperatures. Several sets of high resolution data were taken using the 1-m spectrometer to measure the spectral transmission at the various conditions. A portion of the resolved spectrum for one of these tests is shown in Fig. 8 with no gas in the cell and with a mixture of NO and N₂ in the cell. For the case illustrated in Fig. 8, the number density of NO is 2.58×10^{15} molecules/cm³, the pressure is 1.5 atm, and the temperature is 422 K. Several lines used to obtain values of a' are identified in Fig. 8. The transmissivity (t_j) for each of the lines was determined. Data comparable to that shown in Fig. 8 were obtained for three conditions in the absorption cell. Low resolution measurements were also made with the 1/2-m spectrometer in order to determine the transmission of the unresolved band. Example data for the band transmission are shown in Fig. 9 with the operating conditions stated on the figure. The transmissivity at the second band-head was determined from the data in Fig. 9. Unresolved band transmission data for the second band-head were obtained at 27



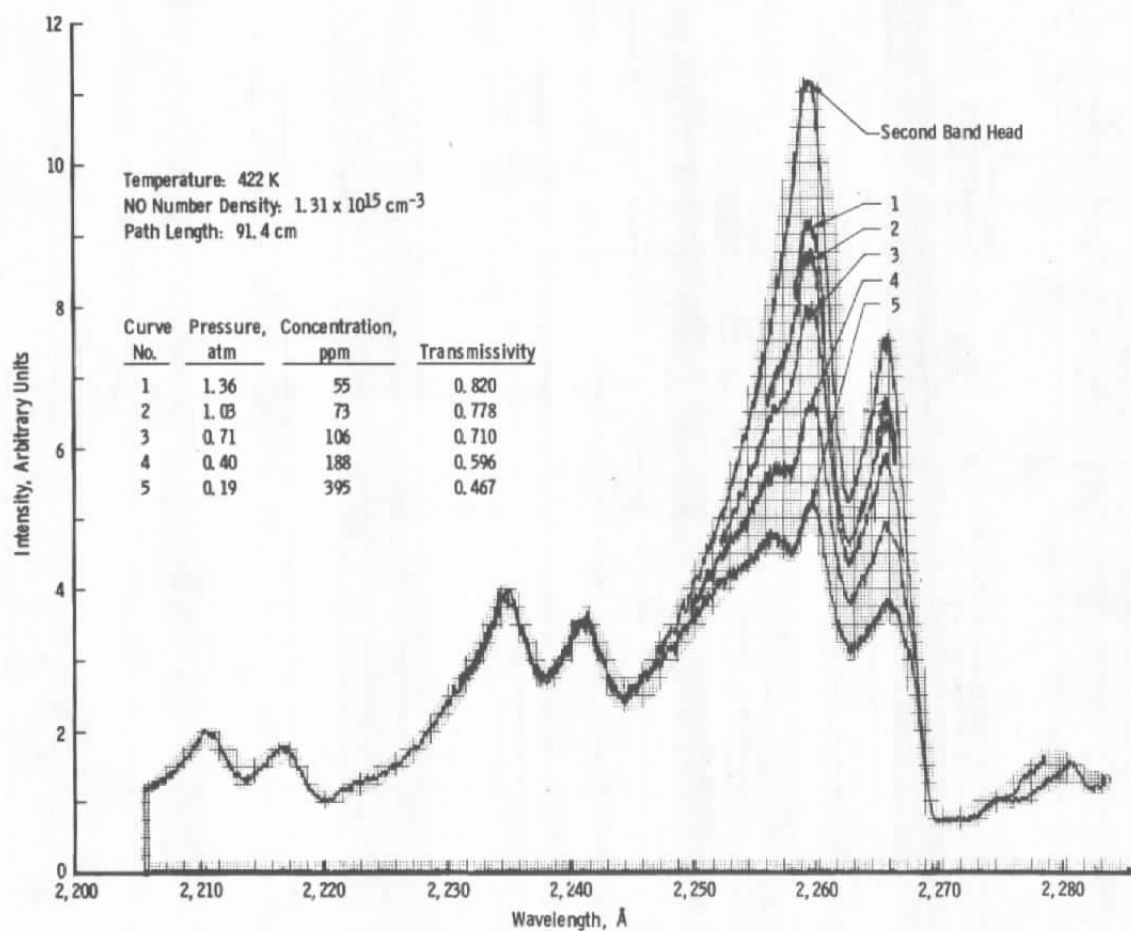


Figure 9. Example set of transmission measurements for NO (0,0) γ -band, as obtained with a 1/2-m spectrometer having an equivalent slit width of 1.6 Å .

conditions of pressure, temperature, and NO concentration in the cell.

- (2) By using the computer simulation of spectra described in Ref. 1 and utilizing Eq. (14), a series of calculated transmitted spectra for many values of a' was obtained for several values of NO concentration, temperature, and with the spectrometer slit width identical to that used in the laboratory experiments. An example synthetic spectrum for the high resolution simulation is shown in Fig. 10, and an example for the low resolution simulation is shown in Fig. 11. The computer program for spectral simulation is presented in Appendix A.
- (3) By comparing the laboratory spectra taken at a given set of pressure, temperature, and concentration conditions in the absorption cell with the computer simulated spectra, which was calculated for the same conditions and at various values of a' , the value of a' which best matches the experimental result was determined. The procedure is illustrated by comparing Fig. 8 with Fig. 10 and Fig. 9 with Fig. 11. The computed spectra led to values of transmission for varying values of a' , as illustrated in Fig. 12, which is taken from the second band-head transmission for various a' values in Fig. 11. The values of a' in Figs. 10 and 11 were the values which gave the best match between the measured and computed spectra. The values were chosen in this way so that the reader might make a direct comparison of the simulated and measured spectra. In practice, the a' values for a particular experimental condition were obtained from plots like Fig. 12, which were obtained from simulated spectra over a range of arbitrarily selected values of a' .

The results obtained from the high resolution spectral absorption measurements are summarized in Table 1, and the results from the low resolution data are summarized in Table 2. For the high resolution data, eight individual lines were selected for determining the values of C_j . These lines are numbered in Table 2 to correspond to Figs. 8 and 10. For the low resolution data, the transmission at the second band-head as marked in Figs. 9 and 11 was used for determining the values of a' .

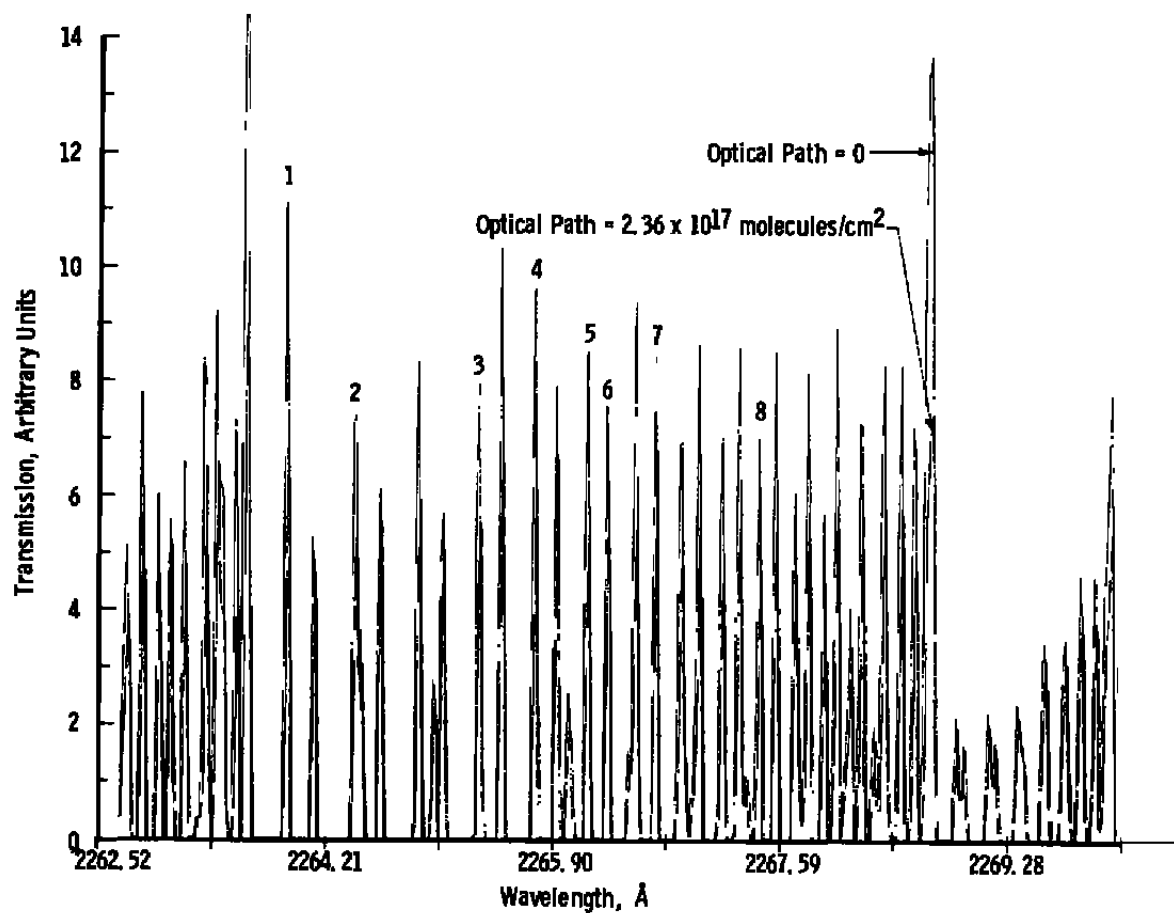


Figure 10. Example of computed transmission for NO (0,0) γ -band for an equivalent spectral slit width of 0.03 Å and at conditions corresponding to Fig. 8.

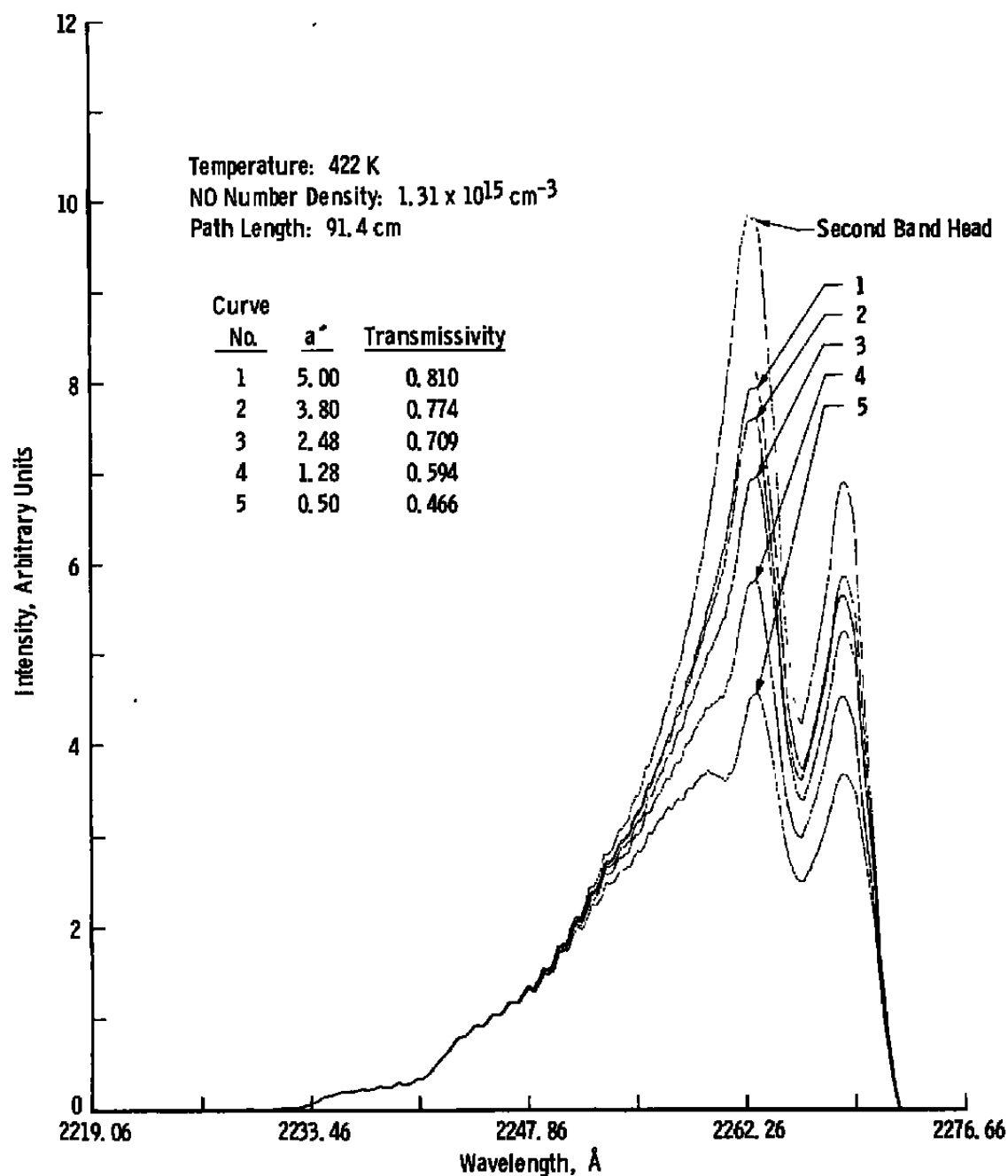


Figure 11. Example set of computed transmission for NO (0,0) γ -band for an equivalent spectral slit width of 1.6 Å and at conditions corresponding to Fig. 9.

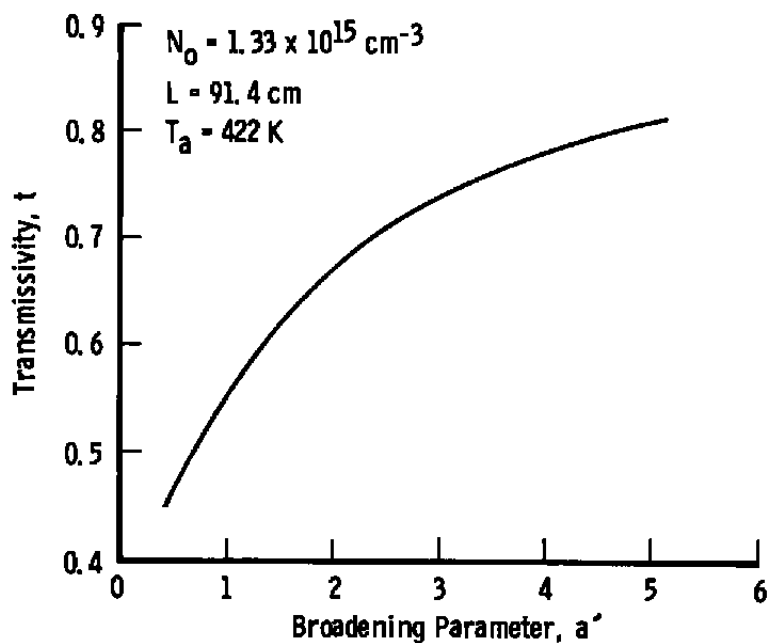


Figure 12. Calculated transmissivity (t) of the second band head of the (0,0) NO γ -band as a function of the line broadening parameter (a').

Table 1. Determination of Broadening Parameter (a') from Resolved Lines of the (0,0) Band of the NO γ -System

Line Number	Absorbing Medium Parameters			t	a'
	NO, Molecules/cm ³	Pressure, atm	Temperature, K		
1	2.58×10^{15}	1.500	422	0.84	4.4
2				0.73	4.6
3				0.70	4.5
4				0.67	4.4
5				0.66	4.4
6				0.65	4.6
7				0.82	4.5
8				0.76	4.6
1	10.32×10^{15}	1.500	422	0.19	4.5
2				0.28	4.6
3				0.25	4.6
4				0.21	4.0
5				0.21	4.3
6				0.51	4.9
7				0.45	4.8
8				0.27	4.1
1	1×10^{15}	0.102	296	0.65	0.8
2				0.66	0.7
3				0.54	0.7
4				0.52	0.5
5				0.51	0.9
6				0.84	0.5
7				0.78	0.6
8				0.59	0.7

Table 2. Determination of Broadening Parameter (a') from the Unresolved (0,0) Band of the NO γ -System

Absorbing Medium Parameters			T, Second Band Peak	a'
NO, Molecules/cm ³	Pressure, atm	Temperature, K		
1.33×10^{15}	0.190	422	0.465	0.50
	0.395	422	0.591	1.28
	0.707	422	0.710	2.48
	1.034	422	0.777	3.80
7.52×10^{13}	0.721	744	0.977	1.00
	1.362	744	0.988	2.65
1.36×10^{14}	0.190	411	0.900	0.30
	0.395	411	0.942	1.18
	0.707	411	0.965	2.54
3.314×10^{14}	0.190	422	0.792	0.34
	0.395	422	0.870	1.26
	0.721	422	0.920	2.63
	1.034	422	0.936	3.70
2.75×10^{15}	0.395	422	0.323	1.00
	0.707	422	0.436	1.84
	1.034	422	0.526	2.74
	1.361	422	0.586	3.55
1.61×10^{15}	0.408	744	0.498	0.34
	0.721	744	0.658	1.21
	1.034	744	0.752	2.22
3.91×10^{15}	0.395	296	0.270	1.95
	0.707	296	0.330	2.75
	1.020	296	0.402	3.77
	1.350	296	0.468	5.18
1.89×10^{15}	0.190	296	0.370	1.03
	0.395	296	0.450	1.65
	0.707	296	0.600	3.35

The tabulated values of a' are plotted as a function of the ratio p/T in Fig. 13, and a straight line given by a least mean square fit is drawn through the points. The value of C in Eq. (27) (shown as C_j) is equal to the slope of the line in Fig. 12. For the (0,0) γ -band of NO, C is found to be $1,270 \pm 200$ K/atm. From Eq. (28), the value of the optical cross section (σ^2) is found to be $(9.5 \pm 1.5) \times 10^{-16}$ cm². The optical diameter is 3.5 ± 0.3 Å approximated by Thorsen and Badger in Ref. 2 from the experimental work carried out by Weber and Penner (Ref. 11).

4.0 DISCUSSION

The major use for the work reported herein is to determine calibration curves for the transduction of transmission measurements of NO γ -band radiation through media containing NO to the number density of NO in the media. Such calculations are used to extend laboratory calibrations at limited pressures and temperatures to a wider range of values; thus accurate values of the broadening parameter becomes a necessity. An application of the use of the calculations to a measurement situation is described in Ref. 12, where calibration curves are generated for absorption through the exhaust of a turbine engine burner at temperatures well above those possible in a laboratory absorption cell.

The uncertainty in values of a' projects the uncertainty in the final values of concentration determined from the γ -band absorption measurements. The estimated uncertainty in the values of a' given in Fig. 13 is about ± 16 percent. When this value of uncertainty is used to determine the density of absorbers, the projected uncertainty in the density is about ± 10 percent and constitutes the principal uncertainty in the resonance absorption technique for concentration measurements through uniform media. A more accurate value of a' would correspondingly reduce the possible uncertainty in measuring the concentration of NO. However, experimental errors in measurements of this nature would probably limit the uncertainty to no better than ± 5 percent so that pursuit of a better value for the constant C is probably not warranted for purposes of measurement.

The experimental work from which the determination of a' was made utilized mixtures of NO in N₂. Thus, the foreign broadening gas is N₂. The question arises as to whether other gases which might

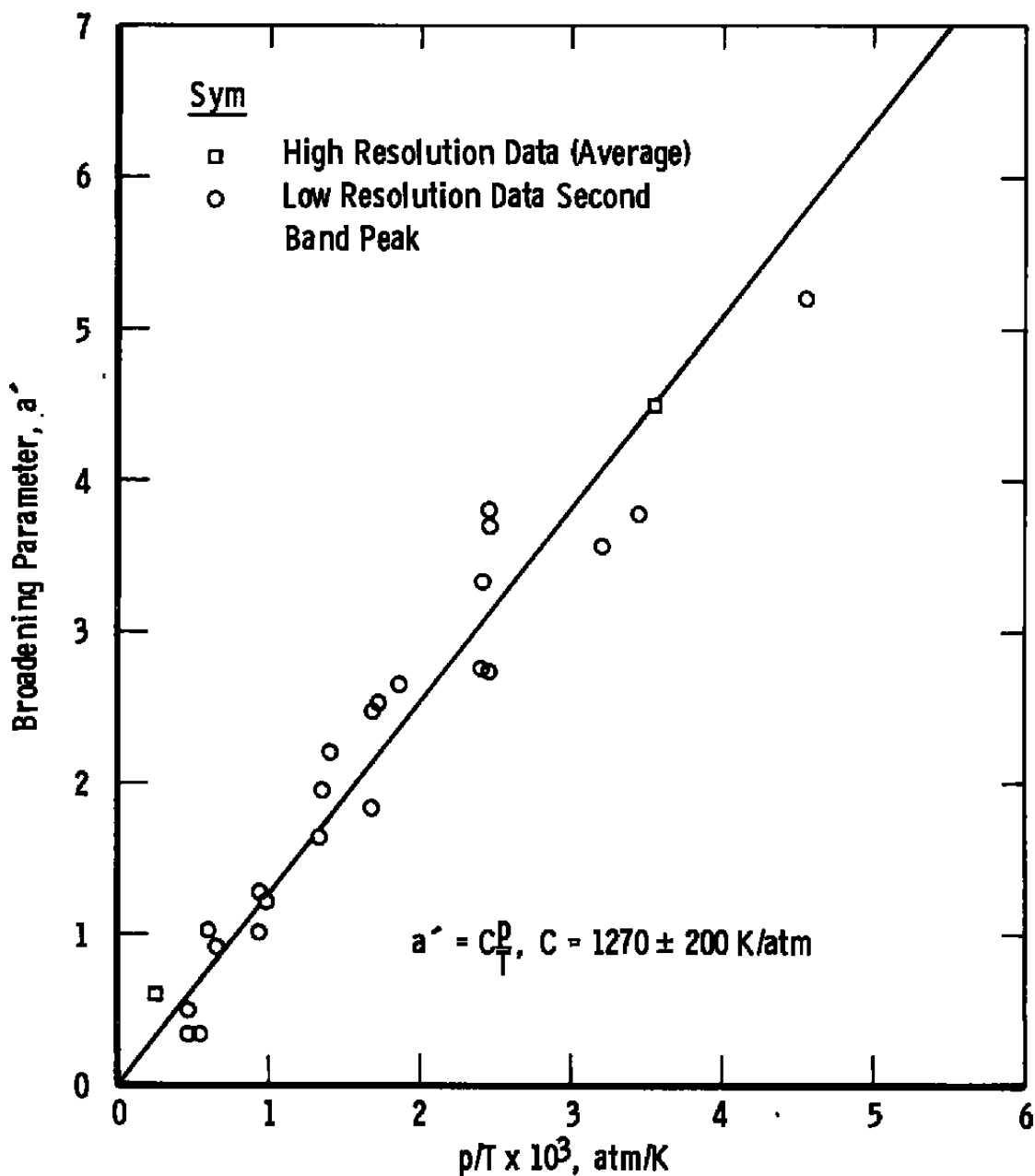


Figure 13. Values of the spectral broadening parameter (a') as a function of p/T for the (0,0) γ -band of NO as obtained by comparing experimental data with computed data.

be found in combustion gas streams, such as CO_2 , H_2O , CO , etc., might have significantly different broadening cross sections. Based on the results presented in Ref. 5 for CO , the broadening cross section for NO is not believed to be significantly different for other molecules than for N_2 . Experience with measurements in absorption cells located in sample lines in which measurements of NO concentration made by other means agreed well with the values obtained by the absorption technique (Ref. 12) also gives confidence to the universality of the broadening parameter with different molecules.

The indirect method of determining the broadening parameter used in this study is believed to be a valid alternative to the use of high resolution spectroscopy to measure line shapes and thus determine the parameter directly. However, the method requires the use of a good model for the radiation source and for the absorbing media, and a high speed digital computer to accomplish the complex numerical calculations.

Finally, a significant result of the work reported herein is the improved value of the effective cross section (or diameter) for collisional broadening of the ground state energy levels of NO . The value of the effective broadening collision diameter ($3.5 \pm 0.3 \text{ \AA}$) determined in this work offers considerable improvement in uncertainty over the best known previous estimate of Thorsen and Badger (Ref. 2) of $3.8 \pm 1 \text{ \AA}$.

REFERENCES

1. Davis, M. G., McGregor, W. K., and Few, J. D. "Spectral Simulation of Resonance Band Transmission Profiles for Species Concentration Measurements: NO γ -Bands as an Example." AEDC-TR-74-124 (ADA004105), January 1975.
2. Thorson, W. R. and Badger, R. M. "On the Pressure Broadening in the Gamma Bands of Nitric Oxide." The Journal of Chemical Physics, Vol. 27, No. 3, 1957, p. 609.
3. McGregor, W. K., Few, J. D., and Litton, C. D. "Resonance Line Absorption Method for Determination of Nitric Oxide Concentration." AEDC-TR-73-182 (AD771642), December 1973.

4. McGregor, W. K., Seiber, B. L., and Few, J. D. "Concentration of OH and NO in YJ93-GE-3 Engine Exhausts Measured in Situ by Narrow-Line UV Absorption." Proceedings of the Second Conference on the Climatic Impact Assessment Program, Cambridge, Massachusetts, November 1972, p. 124.
5. Mitchel, A. C. G. and Zemansky, M. W. Resonance Radiation and Excited Atoms, Cambridge University Press, Cambridge, Massachusetts, 1971.
6. Penner, S. S. Quantitative Molecular Spectroscopy and Gas Emissivities, Addison-Wesley Publishing Co., Reading, Massachusetts, 1959.
7. Jeffries, J. T. Spectral Line Formation. Blaisdell Publishing Company, 1968.
8. Tatum, J. B. "The Interpretation of Intensities in Diatomic Molecular Spectra." The Astrophysical Journal. Supplement No. 124, Vol. 16, 1967, p. 21.
9. Earls, L. T. "Rotational Strength Factors for ${}^2\Sigma \rightarrow {}^2\pi$ Transitions." Physical Review, Vol. 48, 1935, p. 423.
10. Deezsi, I. "A Recent Rotational Analysis of the γ -Bands of the NO Molecule." Acta Physica, Vol. 9, 1957, p. 125.
11. Weber, D. and Penner, S. S. "Intensity Measurements in the γ -Bands of NO." Journal Chemical Physics, Vol. 26, 1957, p. 860.
12. Few, J. D., Bryson, R. J., McGregor, W. K., and Davis, M. G. "Evaluation of Probe Sampling versus in Situ Optical Techniques for Nitric Oxide Concentration Measurement in Combustion Gas Streams." Paper presented at Third Joint Conference on Sensing of Environmental Pollutants, Las Vegas, November 1975.

APPENDIX A
COMPUTER PROGRAM FOR THE CALCULATION AND SIMULATION OF THE
NO (0,0) γ -BAND SPECTRA TRANSMITTED THROUGH
AN ABSORBING MEDIUM

The computer program included in this appendix was developed to calculate the transmission of a band of spectral lines from a particular molecule through an absorbing medium containing the same molecular species. The approach may be used for any molecule, but the line structure and angular momentum coupling are so different for each species that a separate program is usually needed for each molecular species. In this appendix, the computational procedure is described for the NO molecule.

DESCRIPTION

The program is separated into two steps. Step 1 records all input data and computes the transmission of the radiation due to each source line. Step 2 processes these data and generates the simulated spectrometer output signal. The program is currently being run on the IBM 370-165 computer; X-Y plotter data are presented on the CALCMP 765 plotter.

PROGRAM STEP 1

The first program step is divided into four parts:

Part 1 – Input Data

Part 1 contains the various COMMON and DIMENSION statements for the program. If more than 500 emission lines are to be considered, a modification of the program would be necessary. Values of $\Delta\lambda$, a' , T_a , T_s , and ℓ and various plot control parameters are input. Details of the input data and format are discussed in the following paragraph.

Part 2 – Spectral Line Calculation

Cards identifying each emission-line to be considered are read. For each line, the rotational energy of the upper electron state $F(J')$ is computed via SUBROUTINE FUPPER, and the rotational energy of

the lower rotation state $F(J'')$ is computed in SUBROUTINE FLOWER. The Hönl-London factor is then computed in SUBROUTINE HONNUM. The value of $I_{\nu_j}^o$ is found by interpolation from Fig. 7. The curve in Fig. 7 is an input to the program.

For the (0, 0) γ -Band of NO, the values of $k_{\nu_i}^o$ are given by Eq. (20) and are computed in Part 2.

Part 3 – Line-By-Line Transmission Calculation

In Part 3, the transmission (Eq. (13)) is evaluated for each line. Since k_{ν} is a function of ν , many time-consuming evaluations of k_{ν} are apparent. In fact, if there are n nodes used in the numerical integration, then nm^2 evaluations are required where m is the number of lines being considered. If the program variable ALLOW is set to zero, the program will sum over all the lines, i. e.,

$$\sum_i k_{\nu_i} = \sum_{i=1}^m k_{\nu_i} \quad (A-1)$$

To save time (although at the expense of some accuracy), another option is available. This option is selected by setting ALLOW > 0. By considering the j th spectral line, the sum $\sum_i k_{\nu_i}$ is written as:

$$\sum_i k_{\nu_i} \approx \sum_{i=j}^{j+j_u} k_{\nu_i} + \sum_{i=j-1}^{j-j_e} k_{\nu_i} \quad (A-2)$$

Note that the index in the second sum decreases. The indices j_u and j_e are chosen so that the contributions of the $(j + j_u)$ th and $(j - j_e)$ th lines are as small as desired. The exact criterion used is

$$\left| \frac{k_{\nu_{j+j_u}}}{\sum_{i=j}^{j-j_e} k_{\nu_i}} \right| < \text{ALLOW} \quad (A-3)$$

and

$$\left| \frac{k_{\nu_{j-j_e}}}{\sum_{i=j-1}^{j+j_u} k_{\nu_i}} \right| < \text{ALLOW} \quad (A-4)$$

In effect, only those lines in a chosen neighborhood of ν_j^o are considered.

If $a' = 0$, no collision broadening is considered and k_{ν_i} is calculated from Eq. (10). If $a' > 0$, then k_{ν_i} must be given by Eq. (A-4).

Subroutine WFUNC evaluates the function

$$R \exp [-(\omega_j + ia')^2] \operatorname{erfc} [-i\omega_j + a']$$

which is contained in Eq. (9) and leads to the determination of k_{ν_j} . The subsequent evaluation of the integral in Eq. (13) is done numerically using the trapezoidal rule.

Part 4 — Data Storage

This part writes program control data as well as wavenumber and source line transmission data onto a disc file for passage to Step 2.

PROGRAM STEP 2

Step 2 performs the plotting functions of the program. The mathematical and physical considerations are presented in detail in Ref. 1.

The program first reads in the various control parameters from Step 1. Then, the first set of values of ν_j and $\bar{T}_j$ are read in. These data correspond to the first value of N_0 supplied to Step 1. All following curves will be plotted according to the scale factor determined from the initial case. Generally, the case $N_0 = 0$ (no absorption) is calculated first, and all other plots are referenced to this case (Fig. 1).

If IPLOT1 = 1, then zero slit width plots are produced (Fig. 2).

If IPLOT2 = 1, a separate plot is produced for each value of N_0 as well as the final combined plot.

The conglomerate spectral profile is constructed as follows: A line with a height proportional to the spectral intensity is drawn at $\lambda_i + 1/2 \Delta\lambda_x$ for each spectral line and a triangular slit function of base width $2\Delta\lambda_x$ is constructed about that line. To arrive at the conglomerate profile, the contributions from each line at a given value of λ are simply added.

PROGRAM VARIABLE DESCRIPTION

The following variables are used in the program:

<u>Mathematical Symbol</u>	<u>Program Variable</u>	<u>Usage</u>
$\bar{T}_j$	TJ(J)	Transmission of spectral line, j
ν_j°	WO(J)	Center wavenumber of jth spectral line
$(\Delta_s \nu_j)_D$	DWJ	Doppler width at half maximum intensity of jth spectral line
$(\Delta_a \nu_j)_D$	DWL	Doppler width at half maximum absorption coefficient $k_{\nu_j}^\circ$ of the absorption line
$I_{\nu_j}^\circ$	E(J)	Intensity of source spectral line
$I_{\nu_j}^\circ$	EO(J)	Intensity of source spectral line at center wavenumber
k_{ν_i}	CAY(I)	Absorption coefficient for the ith line
ℓ	EL	Absorption path length
a'	AP	Collisional broadening parameter
T_s	TE	Source gas temperature, K
T_a	TA	Absorber gas temperature, K
$\Delta\lambda$	SLIT	Equivalent slit width
N_o	ENO	Total number density
V'	IVU	Upper vibrational state
V''	IVL	Lower vibrational state
J''	RJPP	Lower rotational state

<u>Mathematical Symbol</u>	<u>Program Variable</u>	<u>Usage</u>
	W(I)	Nodes for numerical integration (Eq. (1))
	NUP	Upper spin state
	NLO	Lower spin state
	BRANCH	Line branch designation
	IPLOT 1	For zero slit width plots, set IPLOT1 = 1 otherwise = 0
	IPLOT 2	For separate N_0 plots, set IPLOT2 = 1, otherwise = 0
	YHGT	Maximum height of spectral plots, in.
	DELPLT	Scale for abscissa of spectral plots, $A^\circ/\text{in.}$
$S_J''J'$	S(J)	Hönl-London factor for jth line
F(J')	FU	Rotational energy of the upper electron state
F(J'')	FL(J)	Rotational energy of the lower rotational state
	ALLOW	Relative error (see Eq. (10))
m	NLINES	Number of emission lines

DATA INPUT

All data is input to Step 1.

<u>CARDS 1</u>	FORMAT (2F10.0)
Column 1 F(J)	Column 11 ($I_{\nu_j^0}/\delta_{J''J'}$)

The first cards expected by the program are values of ($I_{\nu_j^0}/\delta_{J''J'}$) versus F_{uj} , one data pair per card. The cards should be arranged in order of increasing F_{uj} . A blank card must follow the final data card of this group. The data for the source lamp used in the measurements shown in this report are given in Table A-1.

<u>CARD 2</u>	TITLE CARD	FORMAT (20A4)
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This card should contain any title information the user wishes to use for plot identification.

<u>CARD 3</u>	DELPLT	FORMAT (F10.0)
<u>CARD 4</u>	SLIT	FORMAT (F10.0)
<u>CARD 5</u>	AP	FORMAT (F10.0)
<u>CARD 6</u>	TA	FORMAT (F10.0)
<u>CARD 7</u>	TE	FORMAT (F10.0)
<u>CARD 8</u>	EL	FORMAT (F10.0)
<u>CARD 9</u>	YHGT	FORMAT (F10.0)
<u>CARD 10</u>	IPLOT1	FORMAT((I1)
<u>CARD 11</u>	IPLOT2	FORMAT (I1)
<u>CARDS 12</u>	FORMAT (3X, A1, 2I1, 1X, F4.0, 1X, F11.0)	

These cards are those which describe the spectral lines to be considered.

COLUMN 4	BRANCH (P, Q, or R)	FORMAT A1
COLUMN 5	NUP	FORMAT I1
COLUMN 6	NUPP	FORMAT I1
COLUMN 8-11	RJPP	F4.0
COLUMN 13-23	WO	F11.0

These cards must be arranged in order of increasing wave-number WO. A blank card must follow the last line description card. The data for the NO (0, 0) γ -Band are given in Table A-2.

CARDS 13

FORMAT (F10.0)

These cards contain the values of ENO to be considered. All plots will be scaled to the plot representing the first value of ENO in this group.

SAMPLE CASE

The case to be considered here is the (0, 0) NO γ -band with collisional broadening considered. The following values will be used:

$$\begin{aligned}
 a' &= 1.5 \\
 T_a &= 420 \text{ K} \\
 T_e &= 320 \text{ K} \\
 \ell &= 91 \text{ cm} \\
 \Delta\lambda &= 1.6 \text{ \AA} \\
 N_o &= 0., 1 \times 10^{15}, 1 \times 10^{16} \text{ cm}^{-3} \\
 \text{YHGT} &= 10 \text{ in.} \\
 \text{DELPLT} &= 6 \text{ \AA/in.}
 \end{aligned}$$

The equations and constants used for computing the upper and lower energy states and the Hönl-London factors are discussed in Ref. 3 and are repeated here for completeness.

For the upper state (SUBROUTINE FUPPER),

$$F' = T_e' + G' + F_n' \quad n = 1, 2$$

where

$$T_e' = 43965.7 \text{ cm}^{-1}$$

$$G' = \omega_e'(v' + 1/2) - \omega_e x_e'(v' + 1/2)^2$$

where

$$\omega_e' = 2374.8 \text{ cm}^{-1}$$

$$\omega_e x_e' = 16.46 \text{ cm}^{-1}$$

$$F_1' = B_v'(J' + 1/2)(J' - 1/2) + D_v'(J' + 1/2)^2(J' - 1/2)^2$$

$$F_2' = B_v'(J' + 1/2)(J' + 3/2) + D_v'(J' + 1/2)^2(J' + 3/2)^2$$

$$B_v' = B_e' - \alpha_e'(v' + 1/2)$$

where

$$B_e' = 1.9977 \text{ cm}^{-1}$$

$$\alpha_e' = 0.0198 \text{ cm}^{-1}$$

$$D_v' = -6.2 \times 10^{-6} \text{ cm}^{-1}$$

For the lower state (SUBROUTINE FLOWER),

$$F'' = T_e'' + G'' + F_n'' \quad n = 1, 2$$

$$T_e'' = G'' = 0$$

$$F_1'' = B_v''[(J'' + 1/2)^2 - 1 - u] + D_v''J''^4$$

$$F_2'' = B_v''[(J'' + 1/2)^2 - 1 + u] + D_v''(J'' + 1)^4$$

where

$$u = \left[(J'' + 1/2)^2 - Y_v \left(1 - \frac{Y_v}{4} \right) \right]^{1/2}$$

$$Y_v = A/B_v''$$

and

$$A = 124.2 \text{ cm}^{-1}$$

$$B_v'' = B_e'' - \alpha_e''(v'' + 1/2)$$

$$B_e'' = 1.7046 \text{ cm}^{-1}$$

$$\alpha_e'' = 0.0178 \text{ cm}^{-1}$$

$$D_v'' = -4.8 \times 10^{-6} \text{ cm}^{-1}$$

The Hönl-London factors are given in Table A-3.

The emission lines being considered can be read from the data card listing which follows. The plots produced by this case are shown in Fig. A-1. Many other calculations as well as comparisons between actual and computed spectra are presented in Ref. 1.

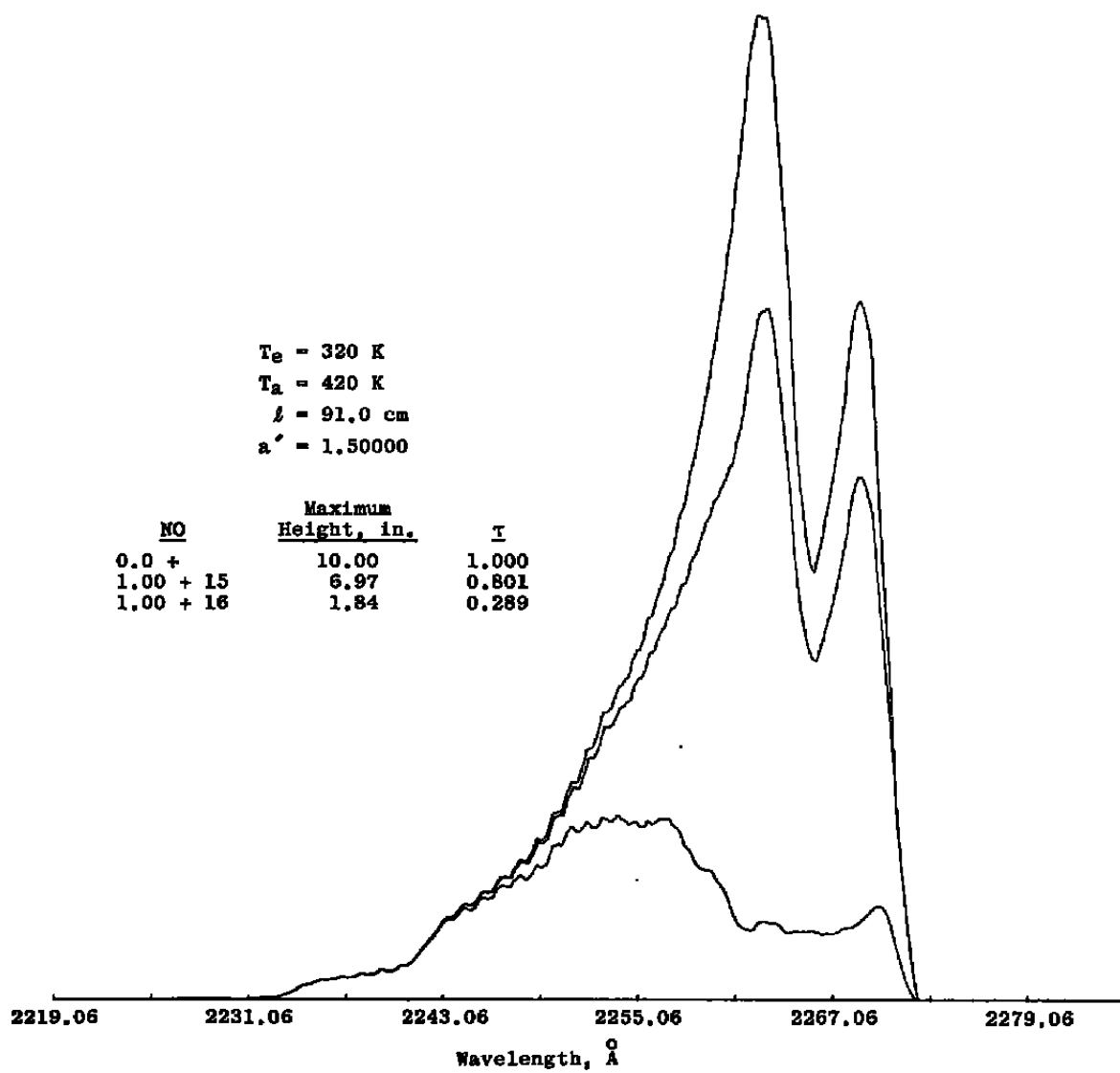


Figure A-1. Spectral test case.

Table A-1. Data Cards for Sample Case

Column 1			
		48600.	.0218
		48700.	.0198
		48800.	.018
		48900.	.0165
		49000.	.015
		49100.	.0138
		49200.	.0126
		49300.	.0115
		49400.	.0105
		49500.	.0097
		49600.	.0088
		49700.	.0081
		49800.	.0074
		49900.	.0068
		50000.	.0062
		50100.	.0056
		50200.	.0052
		50300.	.0047
		50400.	.0043
		50500.	.0039
		50600.	.0036
		50700.	.0033
		50800.	.003
45100.	1.25		
45200.	.92		
45300.	.68		
45400.	.54		
45500.	.45		
45600.	.39		
45700.	.33		
45800.	.28		
45900.	.255		
46000.	.23		
46100.	.208		
46200.	.19		
46300.	.175		
46400.	.158		
46500.	.145		
46600.	.1325		
46700.	.12		
46800.	.11		
46900.	.1		
47000.	.092		
47100.	.084		
47200.	.077		
47300.	.07		
47400.	.064		
47500.	.058		
47600.	.053		
47700.	.049		
47800.	.044		
47900.	.041		
48000.	.037		
48100.	.034		
48200.	.031		
48300.	.0285		
48400.	.026		
48500.	.0238		

Table A-2. Spectra Test Case

Blank Card		R12(1.5)	44086.15
SPECTRA TEST CASE		P22(9.5)	44087.98
6.		Q12(9.5)	44087.98
1.6		Q22(2.5)	44089.56
1.5		R12(2.5)	44089.56
420.		P12(22.5)	44090.28
320.		P22(10.5)	44091.56
91.└─ Branch (Column 4)		Q12(10.5)	44091.56
10.└─└─ NUP (Column 5)		Q22(3.5)	44093.39
0└─└─└─ NUPP (Column 6)		R12(3.5)	44093.39
0└─└─└─└─ RJPP (Column 8-11)		P22(11.5)	44095.70
P12(10.5)	44052.03	Q12(11.5)	44095.70
P12(11.5)	44052.03	R22(1.5)	44096.82
P12(9.5)	44052.03	P12(23.5)	44097.18
P12(12.5)	44052.78	Q22(4.5)	44097.68
P12(8.5)	44052.78	R12(4.5)	44097.68
P12(13.5)	44054.22	P22(12.5)	44100.45
P12(7.5)	44054.22	Q12(12.5)	44100.45
P12(14.5)	44056.16	Q22(5.5)	44102.72
P12(6.5)	44056.49	R12(5.5)	44102.72
P12(15.5)	44058.33	P12(24.5)	44104.59
P12(5.5)	44058.80	P22(13.5)	44105.72
P12(16.5)	44061.30	Q12(13.5)	44105.72
P12(4.5)	44061.77	R22(2.5)	44105.72
P12(17.5)	44064.66	Q22(6.5)	44108.17
P12(3.5)	44065.40	R12(6.5)	44108.17
P12(18.5)	44068.69	P22(14.5)	44111.50
P12(2.5)	44069.60	Q12(14.5)	44111.50
P12(19.5)	44073.21	P12(25.5)	44112.34
P12(1.5)	44074.26	R22(3.5)	44113.52
P22(3.5)	44077.58	Q22(7.5)	44114.15
P22(4.5)	44077.95	R12(7.5)	44114.15
P22(2.5)	44077.95	P22(15.5)	44117.84
Q12(4.5)	44077.95	Q12(15.5)	44117.84
Q12(2.5)	44077.95	P12(26.5)	44120.71
P12(20.5)	44078.59	Q22(8.5)	44120.71
P22(5.5)	44078.59	R12(8.5)	44120.71
P22(1.5)	44078.59	R22(4.5)	44121.52
Q12(5.5)	44078.59	P22(16.5)	44124.74
Q12(1.5)	44078.59	Q12(16.5)	44124.74
P22(6.5)	44080.32	Q22(9.5)	44127.68
Q12(6.5)	44080.32	R12(9.5)	44127.68
P22(7.5)	44082.33	P12(27.5)	44129.98
Q12(7.5)	44082.33	R22(5.5)	44130.42
P12(21.5)	44084.33	P22(17.5)	44132.16
P22(8.5)	44084.83	Q12(17.5)	44132.16
Q12(8.5)	44084.83	Q22(10.5)	44135.31
Q22(1.5)	44086.15	R12(10.5)	44135.31

Table A-2. Continued

P12(28.5)	44140.13	P11(1.5)	44194.29
P22(18.5)	44140.13	R22(11.5)	44194.93
Q12(18.5)	44140.13	P12(33.5)	44195.91
R22(6.5)	44140.13	Q11(2.5)	44197.98
Q22(11.5)	44143.44	P21(2.5)	44197.98
R12(11.5)	44143.44	Q11(3.5)	44197.98
P22(19.5)	44148.68	P21(3.5)	44197.98
Q12(19.5)	44148.68	Q11(1.5)	44197.98
P12(29.5)	44149.83	P21(1.5)	44197.98
R22(7.5)	44149.83	P22(24.5)	44199.21
Q22(12.5)	44152.17	Q12(24.5)	44199.21
R12(12.5)	44152.17	P11(17.5)	44199.21
P22(20.5)	44157.73	Q11(4.5)	44199.21
Q12(20.5)	44157.73	P21(4.5)	44199.21
P12(30.5)	44160.46	Q11(0.5)	44199.21
R22(8.5)	44160.46	P21(0.5)	44199.21
Q22(13.5)	44161.32	Q11(5.5)	44200.13
R12(13.5)	44161.32	P21(5.5)	44200.13
P22(21.5)	44167.31	Q11(6.5)	44202.36
Q12(21.5)	44167.31	P21(6.5)	44202.36
Q22(14.5)	44171.19	Q22(17.5)	44203.49
R12(14.5)	44171.19	R12(17.5)	44203.49
R22(9.5)	44171.19	R11(0.5)	44203.49
P11(9.5)	44176.85	Q21(0.5)	44203.49
P11(8.5)	44176.85	P11(18.5)	44204.96
P22(22.5)	44177.28	Q11(7.5)	44204.96
Q12(22.5)	44177.28	P21(7.5)	44204.96
P11(10.5)	44177.28	R11(1.5)	44206.03
P11(7.5)	44177.28	Q21(1.5)	44206.03
P11(11.5)	44178.53	R22(12.5)	44207.81
P11(6.5)	44178.53	Q11(8.5)	44208.38
P11(12.5)	44180.58	P21(8.5)	44208.38
P11(5.5)	44180.58	R11(2.5)	44209.69
Q22(15.5)	44181.38	Q21(2.5)	44209.69
R12(15.5)	44181.38	R21(0.5)	44210.69
R22(10.5)	44183.02	P22(25.5)	44211.21
P11(13.5)	44183.02	Q12(25.5)	44211.21
P11(4.5)	44183.02	P11(19.5)	44211.21
P12(32.5)	44184.08	Q11(9.5)	44212.25
P11(14.5)	44186.07	P21(9.5)	44212.25
P11(3.5)	44186.07	R11(3.5)	44213.81
P22(23.5)	44188.16	Q21(3.5)	44213.81
Q12(23.5)	44188.16	Q22(18.5)	44215.46
P11(15.5)	44189.80	R12(18.5)	44215.46
P11(2.5)	44189.80	Q11(10.5)	44217.00
Q22(16.5)	44192.18	P21(10.5)	44217.00
R12(16.5)	44192.18	R21(1.5)	44217.60
P11(16.5)	44194.29	P11(20.5)	44217.73

Table A-2. Continued

R11(4.5)	44218.55	R11(10.5)	44260.93
Q21(4.5)	44218.55	Q21(10.5)	44260.93
R22(13.5)	44220.78	R21(6.5)	44261.79
Q11(11.5)	44222.24	P22(29.5)	44264.24
P21(11.5)	44222.24	Q12(29.5)	44264.24
P22(26.5)	44223.95	R22(16.5)	44264.24
Q12(26.5)	44223.95	Q11(17.5)	44266.44
R11(5.5)	44223.95	P21(17.5)	44266.44
Q21(5.5)	44223.95	Q22(22.5)	44268.65
R21(2.5)	44225.14	R12(22.5)	44268.65
P11(21.5)	44225.26	R11(11.5)	44269.92
Q22(19.5)	44228.00	Q21(11.5)	44269.92
R12(19.5)	44228.00	P11(26.5)	44271.53
Q11(12.5)	44228.00	R21(7.5)	44272.49
P21(12.5)	44228.00	Q11(18.5)	44275.98
R11(6.5)	44230.23	P21(18.5)	44275.98
Q21(6.5)	44230.23	P22(30.5)	44278.96
P11(22.5)	44233.24	Q12(30.5)	44278.96
R21(3.5)	44233.31	R22(17.5)	44278.96
R22(14.5)	44234.47	R11(12.5)	44279.65
Q11(13.5)	44234.47	Q21(12.5)	44279.65
P21(13.5)	44234.47	P11(27.5)	44282.69
P22(27.5)	44236.86	Q22(23.5)	44283.28
Q12(27.5)	44236.86	R12(23.5)	44283.28
R11(7.5)	44236.86	R21(8.5)	44283.28
Q21(7.5)	44236.86	Q11(19.5)	44286.10
Q22(20.5)	44241.13	P21(19.5)	44286.10
R12(20.5)	44241.13	R11(13.5)	44290.12
P11(23.5)	44241.68	Q21(13.5)	44290.12
Q11(14.5)	44241.68	P22(31.5)	44294.38
P21(14.5)	44241.68	Q12(31.5)	44294.38
R21(4.5)	44242.11	R22(18.5)	44294.38
R11(8.5)	44244.30	P11(28.5)	44294.38
Q21(8.5)	44244.30	R21(9.5)	44295.79
R22(15.5)	44249.10	Q11(20.5)	44296.87
Q11(15.5)	44249.10	P21(20.5)	44296.87
P21(15.5)	44249.10	Q22(24.5)	44298.56
P22(28.5)	44250.17	R12(24.5)	44298.56
Q12(28.5)	44250.17	R11(14.5)	44301.17
P11(24.5)	44251.31	Q21(14.5)	44301.17
R11(9.5)	44252.05	P11(29.5)	44306.57
Q21(9.5)	44252.05	Q11(21.5)	44308.22
R21(5.5)	44252.05	P21(21.5)	44308.22
Q22(21.5)	44254.52	R21(10.5)	44308.22
R12(21.5)	44254.52	P22(32.5)	44309.89
Q11(16.5)	44257.54	Q12(32.5)	44309.89
P21(16.5)	44257.54	R22(19.5)	44311.13
P11(25.5)	44260.93	R11(15.5)	44312.82

Table A-2. Continued

Q21(15.5)	44312.82	Q21(20.5)	44380.21
Q22(25.5)	44314.35	R21(15.5)	44380.21
R12(25.5)	44314.35	R22(23.5)	44382.31
P11(30.5)	44319.69	Q22(29.5)	44382.93
Q11(22.5)	44320.28	R12(29.5)	44382.93
P21(22.5)	44320.28	Q11(27.5)	44389.23
R21(11.5)	44321.38	P21(27.5)	44389.23
R11(16.5)	44325.12	P11(35.5)	44393.03
Q21(16.5)	44325.12	R11(21.5)	44395.56
P22(33.5)	44326.20	Q21(21.5)	44395.56
Q12(33.5)	44326.20	R21(16.5)	44396.60
R22(20.5)	44328.22	P22(37.5)	44397.04
Q22(26.5)	44330.62	Q12(37.5)	44397.04
R12(26.5)	44330.62	Q22(24.5)	44401.45
P11(31.5)	44332.92	R12(24.5)	44401.45
Q11(23.5)	44332.92	R22(24.5)	44401.45
P21(23.5)	44332.92	Q11(28.5)	44404.77
R21(12.5)	44335.22	P21(28.5)	44404.77
R11(17.5)	44337.97	P11(36.5)	44409.50
Q21(17.5)	44337.97	R11(22.5)	44411.51
P22(34.5)	44343.01	Q21(22.5)	44411.51
Q12(34.5)	44343.01	R21(17.5)	44413.05
R22(21.5)	44345.86	P22(38.5)	44416.27
Q11(24.5)	44345.86	Q12(38.5)	44416.27
P21(24.5)	44345.86	Q22(31.5)	44420.73
Q22(27.5)	44347.45	R12(31.5)	44420.73
R12(27.5)	44347.45	R22(25.5)	44421.02
P11(32.5)	44347.45	Q11(29.5)	44421.02
R21(13.5)	44349.51	P21(29.5)	44421.02
R11(18.5)	44351.46	P11(37.5)	44426.61
Q21(18.5)	44351.46	R11(23.5)	44428.01
Q11(25.5)	44359.81	Q21(23.5)	44428.01
P21(25.5)	44359.81	R21(18.5)	44430.56
P22(35.5)	44360.38	P22(39.5)	44435.89
Q12(35.5)	44360.38	Q12(39.5)	44435.89
P11(33.5)	44361.81	Q11(30.5)	44437.77
R22(22.5)	44363.61	P21(30.5)	44437.77
Q22(28.5)	44365.00	Q22(32.5)	44440.23
R12(28.5)	44365.00	R12(32.5)	44440.23
R21(14.5)	44365.00	R22(26.5)	44441.26
R11(19.5)	44365.55	P11(38.5)	44444.40
Q21(19.5)	44365.55	R11(24.5)	44445.05
Q11(26.5)	44374.12	Q21(24.5)	44445.05
P21(26.5)	44374.12	R21(19.5)	44448.65
P11(34.5)	44377.09	Q11(31.5)	44455.09
P22(36.5)	44378.49	P21(31.5)	44455.09
Q12(36.5)	44378.49	Q22(33.5)	44460.45
R11(20.5)	44380.21	R12(33.5)	44460.45

Table A-2. Concluded

R22(27.5)	44462.07	Q21(31.5)	44581.73
P11(39.5)	44462.71	R21(26.5)	44591.53
R11(25.5)	44462.71	Q22(39.5)	44593.46
Q21(25.5)	44462.71	R12(39.5)	44593.46
R21(20.5)	44467.16	Q11(38.5)	44593.46
Q11(32.5)	44473.15	P21(38.5)	44593.46
P21(32.5)	44473.15	R22(33.5)	44598.17
Q22(34.5)	44481.26	R11(32.5)	44603.58
R12(34.5)	44481.26	Q21(32.5)	44603.58
R11(26.5)	44481.26	R21(27.5)	44614.41
Q21(26.5)	44481.26	Q11(39.5)	44615.72
R22(28.5)	44483.40	P21(39.5)	44615.72
R21(21.5)	44486.41	R22(34.5)	44622.97
Q11(33.5)	44491.75	R11(33.5)	44626.16
P21(33.5)	44491.75	Q21(33.5)	44626.16
R11(27.5)	44500.09	R21(28.5)	44637.85
Q21(27.5)	44500.09	R22(35.5)	44648.22
Q22(35.5)	44502.61	R11(34.5)	44649.12
R12(35.5)	44502.61	Q21(34.5)	44649.12
R22(29.5)	44505.24	R21(29.5)	44661.86
R21(22.5)	44506.13	R11(35.5)	44672.76
Q11(34.5)	44510.92	Q21(35.5)	44672.76
P21(34.5)	44510.92	R22(36.5)	44673.94
R11(28.5)	44519.47	R21(30.5)	44686.59
Q21(28.5)	44519.47	R11(36.5)	44697.12
Q22(36.5)	44524.55	Q21(36.5)	44697.12
R12(36.5)	44524.55	R22(37.5)	44700.02
R21(23.5)	44526.75	R21(31.5)	44711.69
R22(30.5)	44527.76	R11(37.5)	44722.14
Q11(35.5)	44530.67	Q21(37.5)	44722.14
P21(35.5)	44530.67	R22(38.5)	44727.04
R11(29.5)	44539.74	R21(32.5)	44737.46
Q21(29.5)	44539.74	R11(38.5)	44747.37
Q22(37.5)	44546.76	Q21(38.5)	44747.37
R12(37.5)	44546.76	R22(39.5)	44754.43
R21(24.5)	44547.80	R21(33.5)	44763.28
R22(31.5)	44550.89	R11(39.5)	44773.43
Q11(36.5)	44550.89	Q21(39.5)	44773.43
P21(36.5)	44550.89	R21(34.5)	44789.81
R11(30.5)	44560.38	R21(35.5)	44818.26
Q21(30.5)	44560.38	R21(37.5)	44874.81
Q22(38.5)	44569.86	R21(38.5)	44904.54
R12(38.5)	44569.86	R21(39.5)	44934.51
R21(25.5)	44569.86	Blank Card	
Q11(37.5)	44571.93		
P21(37.5)	44571.93		
R22(32.5)	44574.03		
R11(31.5)	44581.73		
		0.0	
		.000E15	
		.000E16	

TABLE A-3
HÖNL-LONDON FACTORS FOR $2\Sigma \rightarrow 2\pi$ TRANSITIONS
INTERMEDIATE BETWEEN HUND'S CASES (a) AND (b)

$$R_{22} = \frac{(2J''+1)^2 + (2J''+1)[Y(Y-4) + (2J''+1)^2]^{-1/2} (4J''^2 + 4J'' + 1 - 2Y)}{8(J''+1)}$$

$$Q_{22} = \frac{(2J''+1)[(4J''^2 + 4J'' - 1) + \{Y(Y-4) + (2J''+1)^2\}^{-1/2} (8J''^3 + 12J''^2 - 2J'' + 1 - 2Y)]}{8J''(J''+1)}$$

$$P_{22} = \frac{(2J''+1)^2 + (2J''+1)[Y(Y-4) + (2J''+1)^2]^{-1/2} (4J''^2 + 4J'' - 7 + 2Y)}{8J''}$$

$$R_{12} = \frac{(2J''+1)^2 - (2J''+1)[Y(Y-4) + (2J''+1)^2]^{-1/2} (4J''^2 + 4J'' - 7 + 2Y)}{8(J''+1)}$$

$$Q_{12} = \frac{(2J''+1)[(4J''^2 + 4J'' - 1) - \{Y(Y-4) + (2J''+1)^2\}^{-1/2} (8J''^3 + 12J''^2 - 2J'' - 7 + 2Y)]}{8J''(J''+1)}$$

$$P_{12} = \frac{(2J''+1)^2 - (2J''+1)[Y(Y-4) + (2J''+1)^2]^{-1/2} (4J''^2 + 4J'' + 1 - 2Y)}{8J''}$$

$$R_{11} = \frac{(2J''+1)^2 + (2J''+1)[Y(Y-4) + (2J''+1)^2]^{-1/2} (4J''^2 + 4J'' - 7 + 2Y)}{8(J''+1)}$$

$$Q_{11} = \frac{(2J''+1)[(4J''^2 + 4J'' - 1) + \{Y(Y-4) + (2J''+1)^2\}^{-1/2} (8J''^3 + 12J''^2 - 2J'' - 7 + 2Y)]}{8J''(J''+1)}$$

$$P_{11} = \frac{(2J''+1)^2 + (2J''+1)[Y(Y-4) + (2J''+1)^2]^{-1/2} (4J''^2 + 4J'' + 1 - 2Y)}{8J''}$$

$$R_{21} = \frac{(2J''+1)^2 - (2J''+1)[Y(Y-4) + (2J''+1)^2]^{-1/2} (4J''^2 + 4J'' + 1 - 2Y)}{8(J''+1)}$$

$$Q_{21} = \frac{(2J''+1)[(4J''^2 + 4J'' - 1) - \{Y(Y-4) + (2J''+1)^2\}^{-1/2} (8J''^3 + 12J''^2 - 2J'' + 1 - 2Y)]}{8J''(J''+1)}$$

$$P_{21} = \frac{(2J''+1)^2 - (2J''+1)[Y(Y-4) + (2J''+1)^2]^{-1/2} (4J''^2 + 4J'' - 7 + 2Y)}{8J''}$$

where $Y = A/B_v$

THE PROGRAM

IV 6 LEVEL 21

MAIN

DATE = 75178

09/06/45

```

C
C*****
C PART1  PART1  PART1  PART1  PART1  PART1  PART1  PART1
C*****
C
      REAL*4 KO
      INTEGER*4 P,G,R,ELANK
      INTEGER*4 BRANCH
      DIMENSION S(500),FL(500),NC(500),EO(500)
      DIMENSION HEADS(20)
      DIMENSION KO(500)
      DATA P/'P'/'Q'/'Q'/'R'/'R'/'
      DATA BLANK/' '
      COMMON/PAREM/CONST1,CONST2,CONST3,W0,EO,KO,NLINES
      DIMENSION W(500),E(500),CAY(500),OAT(500),EJ(500),TJ(500)
      CALL ERASET(208,256,-1,1)
      ALLOW=.001
      CALL FUNC(XDUM)
      LIR2=2
      IYU=0
      IYL=0
      READ(5,366)HEADS
366  FORMAT(20A4)
      READ(5,36)DELPLT
      READ(5,36)SLIT
      ULAM=SLIT
      READ(5,36)AP
      READ(5,36)TA
      READ(5,36)TE
      READ(5,36)EL
      READ(5,36)YNGT
      READ(5,700)IPL0T1
      READ(5,700)IPL0T2
700  FORMAT(2I1)
37  FORMAT(11,2F10.0)
      C1=.8015EO-14/TA**(.3-D0/2.D0)
      C1=C1*2.D0
      C2=-1.43836D0/TA
      CONST1=-2.D0*D0*DSORT(DLG6(2.D0))
      CONST2=1.367D-7* SORT(TE)
      CONST3=1.307D-7* SORT(TA)
      CONST4=3.E-7*SQRT(TE)
      WRITE(6,87)HEADS,AP
87  FORMAT(1H1,20X,20A4,10X,3HA*,F7.4)
C
C*****
C PART2  PART2  PART2  PART2  PART2  PART2  PART2  PART2
C*****
C
      J=1
749 READ(5,1)BRANCH,NUP,NLC,RJPP,NC(J)
      IF(BRANCH.EQ.BLANK)GO TO 2
      JPP=RJPP
      1  FORMAT(1X,A1,11,11,1X,F4.0,1X,F11.0)
      IF(BRANCH.EQ.P)GO TO 16
      IF(BRANCH.EQ.Q)GO TO 20

```

IV G LEVEL 21

MAIN

DATE = 75178

09/06/45

```

      CALL FUPPER(IVU,NUP,JPP+1,FU)
      CALL MONNUM(IVU,IVL,NUP,NLC,JPP+1,JPP+3,S(J))
      GO TO 100
30  FORMAT(4F10.0)
20  CALL FUPPER(IVU,NUP,JPP,FU)
      CALL MONNUM(IVU,IVL,NUP,NLC,JPP,JPP+2,S(J))
      GO TO 100
10  CALL FUPPER(IVU,NUP,JPP-1,FU)
      CALL MONNUM(IVU,IVL,NUP,NLC,JPP-1,JPP+1,S(J))
100 CALL FLOWER(IVL,NLC,JPP,FL(J))
      EQ(J)=S(J)*FUNC(FU)
      WRITE(6,101)J,BRANCH,NUP,NLC,JPP,FU,FL(J),NO(J),S(J),EQ(J)
101  FORMAT(2X,13,2X,A1,11,11,'( ',12,' )',*FU=*,D16.8,*FL=*,D16.8,
      *SX,*MU=*,D16.8,*EX,*SJ=*,D16.8,*SX,*EQJ=*,D16.8)
      J=J+1
      GO TO 749
2  CONTINUE
      NLINES=J-1
800 READ(5,30,END=800)ENG
      DO 69 I=1,NLINES
          B=C1*S(I)*EXP(C2*FL(I))
          KO(I)=B*ENU
69  CONTINUE

```

```

C
C*****
C PART3  PART3  PART3  PART3  PART3  PART3  PART3  PART3
C*****
C

```

```

      ISAVE=1
      NINT=40
      NP1=NINT+1
      TAU0P=0.00
      TAU0T=0.00
      DO 200 J=1,NLINES
          DWJ=CONST2*NO(J)
          DELTA=CONST4*NO(J)
          AZJ=NO(J)-DELTA
          BZJ=NO(J)+DELTA
          DIST=BZJ-AZJ
          DEL=DIST/NINT
          DO 700 I=1,NP1
              W(I)=AZJ+(I-1)*DEL
              E(I)=NO(J)*EXP(-(W(I)-NO(J))*CONST1/DWJ)**2)
              IF(ENG.EQ.0.)GO TO 67447
              JLEFT=0
              SUML=0.
              SUMR=0.
              II=J
1100 WNL=CONST3*NO(II)
              IF(AP.EQ.0.)GO TO 1100
              DELTA=-CONST1*(W(I)-W(II))/DEL
              CALL SFUNC(BETA,AP,TERM,DUMS)
              GO TO 1101
1100 TERM=EXP(-(W(I)-W(II))*CONST1/DWJ)**2)
1101 CONTINUE
              TNEW=KCL(II)*TERM

```

IV G LEVEL 21

MAIN

DATE = 75178

09/08/85

```

      IF(JLEFT.EQ.1)GO TO 1109
      SUMR=SUMR+TNEW
      IF(WO(1).GT.W(1).AND.TNEW.EQ.0.)GO TO 1107
      IF(11.EQ.NLINES)GO TO 1107
      IF(WO(1).LT.BZJ)GO TO 33550
      IF(ABS(TNEW/SUMR).LE.ALLOC)GO TO 1107
33550  CONTINUE
      I1=I1+1
      GO TO 1108
1107  JLEFT=1
      I1=J-1
      IF(J.EQ.1)GO TO 7013
      GO TO 1108
1109  CONTINUE
      SUML=SUML+TNEW
      IF(WO(1).LT.W(1).AND.TNEW.EQ.0.)GO TO 7013
      IF(11.EQ.1)GO TO 7013
      IF(WO(1).GT.AZJ)GO TO 33551
      IF(ABS(TNEW/SUML).LE.ALLOC)GO TO 7013
33551  CONTINUE
      I1=I1-1
      GO TO 1108
7013  CONTINUE
      GO TO 7000
87447  SUML=0.
      SUMR=0.
7000  CAY(1)=SUML+SUMR
      SUM1=0.00
      SUM2=0.00
      DCL2=DCL/2.00
      DO 9000 I=1,NP1
9000  DAT(1)=E(1)*EXP(-CAY(1)*EL)
      DO 9001 I=1,NINT
      SUM1=SUM1+DCL2*(DAT(I)+DAT(I+1))
9001  SUM2=SUM2+DCL2*(E(I)+E(I+1))
      EJ(J)=SUM2
      TJ(J)=SUM1
      TALTUP=TAUTOP+TJ(J)
      TAUBUT=TAUBUT+EJ(J)
200  CONTINUE
C
C*****
C PART4  PART4  PART4  PART4  PART4  PART4  PART4  PART4
C*****
C
      TAC=TAUTOP/TAUBUT
      ALPHA=1.00-TAU
      WRITE(L,846) TA,EL,ENL,EL,TAC,ALPHA
846  FORMAT(/,1A,1TA=,D10.8,5X,1E=,D10.8,5X,1AC=,D10.8,5X,1L=,
     +D10.8,5X,1SA,1TAU=,D10.8,5X,1ALPHA=,D10.8)
      WRITE(20)SLIT,PLTMIN,FLTHAX,DCLPLT,PLAN,YMGT,NLINES,END.
      *TA,TA,EL,IFLUT1,IPLLT2
      *.L INZ,AP
      *.TAC
      *.PLAUS
      DO 5431 I=1,NLINES

```

IV 6 LEVEL 21

MAIN

DATE = 75178

09/06/45

```
LKT=NLINES-1+1
9431 aW(TL(20)NO(LKT),TJ(LKT))
GO TO 200
200 ENDFILE 20
REWIND 20
STOP
END
```

IV G LEVEL 21

FUNC

DATE = 75176

09/06/45

```

FUNCTION FUNC(X).
  DIMENSION XDATA(100),YDATA(100)
  DATA IRST/0/
  IF (IRST.EQ.0)GO TO 1
  IF (X.LT.XDATA(1))GO TO 200
  DO 10 I=1,NP1
  IF (XDATA(I).LE.X.AND.XDATA(I+1).GE.X)GO TO 20
10 CONTINUE
  FUNC=(YDATA(NP)-YDATA(NP1))*(X-XDATA(NP1))/(XDATA(NP)-XDATA(NP1))+Y
  *DATA(NP)
  RETURN
20 FUNC=(YDATA(I+1)-YDATA(I))/(XDATA(I+1)-XDATA(I))*(X-XDATA(I))
  *YDATA(I)
  RETURN
200 FUNC=(YDATA(2)-YDATA(1))*(X-XDATA(1))/(XDATA(2)-XDATA(1))+YDATA(1)
  RETURN
1 GO 100 I=1,1000
HEAD(5,2)XDATA(1),YDATA(1)
2 FORMAT(8F10.0)
IF (XDATA(1).EQ.0.D0)GO TO 3
100 CONTINUE
3 CONTINUE
NP=I-1
NP1=NP+1
IRST=1
RETURN
END

```

IV G LEVEL 21

FUPPER

DATE = 75178

09/06/46

```

SUBROUTINE FUPPER(V,M,JINDEX,F)
C
C SUBROUTINE FUPPER CALCULATES THE ROTATIONAL ENERGY OF THE UPPER
C ELECTRON STATE FOR A GIVEN VIBRATIONAL STATE(V), A GIVEN SPIN
C STATE(M), AND A GIVEN ROTATIONAL STATE(J)
C
  INTEGER V
  REAL*4 J
  J=JINDEX+.5
  T=43965.7
  WE=2374.8
  WEXE=16.46
  BE=1.5977
  ALPHAE=.0158
  UV=-6.2E-6
  BV=BE-ALPHAE*(V+.5)
  GO TO(1,2),M
1 FN=BV*(J+.5)*(J-.5)+DV*(J+.5)**2*(J-.5)**2
  GU TO 3
2 FN=BV*(J+.5)*(J+1.5)+DV*(J+.5)**2*(J+1.5)**2
3 CONTINUE
  G=WE*(V+.5)-WEXE*(V+.5)**2
  F=T+G+FN
  RETURN
END

```

IV G LEVEL <1

FLOWER

DATE = 75174

09/06/85

```

      SUBROUTINE FLOWER(V,M,JINDEX,F)
C
C   SUBROUTINE FLOWER CALCULATES THE ROTATIONAL ENERGY OF A GIVEN
C   ROTATIONAL STATE(J), VIBRATIONAL STATE(V), AND SPIN STATE(M)
      INTEGER V
      REAL** J
      J=JINDEX*.5
      T=0.
      G=0.
      UV=-4.8E-6
      A=1.4E2
      BE=1.7046
      ALPHA=AL=.0176
      BV=BE-ALPHA*(V+.5)
      YV=A/BV
      U=SQRT((J+.5)**2-YV*(1.-YV/4.))
      GO TO(1,2),M
1     FN=UV*((J+.5)**2-1.-U)+DV*J**4
      GO TO 3
2     FN=BV*((J+.5)**2-1+U)+DV*((J+1.))**4
3     F=T+G+FN
      RETURN
      END

```

IV G LEVEL 21

HONNUM

DATE = 75178

09/06/45

```

SUBROUTINE HONNUM(NUP,NLPP,MEGAN,MEGAN,JF,JPP,IB,HONL)
C SUBROUTINE HONNUM CALCULATES THE HONL-LONDON FACTOR WHERE
C NUP=UPPER VIBRATIONAL STATE
C NLPP=LOWER VIBRATIONAL STATE
C MEGAN=UPPER SPIN STATE
C MEGAN=LOWER SPIN STATE
C J=J''
C IB=1 FOR P BRANCH, =2 FOR Q BRANCH, =3 FOR R BRANCH
C
REAL*4 J
J=JPP+.5
T1=2.*J+1.
T2=T1*T1
T3=1./SQRT(73.3+69.3+T2)
JB=IB+1
GO TO(2,2,3,4),JB
2 CONTINUE
GO TO(21,22),MEGAN
21 CONTINUE
GL TO(211,212),MEGAN
211 RNUM=T2+T1*T3*(4.*J+J+4.*J+1.-146.5)
DENOM=8.*J
GO TO 11111
212 RNUM=T2-T1*T3*(4.*J+J+4.*J+1.-146.5)
DENOM=8.*J
GO TO 11111
22 CONTINUE
GL TO(221,222),MEGAN
221 RNUM=T2-T1*T3*(4.*J+J+4.*J-7.+146.5)
DENOM=8.*J
GL TO 11111
222 RNUM=T2+T1*T3*(4.*J+J+4.*J-7.+146.5)
DENOM=8.*J
GO TO 11111-1
3 CONTINUE
GO TO(31,32),MEGAN
31 CONTINUE
GL TO(311,312),MEGAN
311 RNUM=T1*((4.*J+J-4.*J-1)+T3*(8.*J+J+12.*J+J-2.*J-7.+146.5))
DENOM=8.*J*(J+1.)
GO TO 11111
312 RNUM=T1*(4.*J+J+4.*J-1.-T3*(8.*J+J+12.*J+J-2.*J-7.+146.5))
DENOM=8.*J*(J+1.)
GO TO 11111
32 CONTINUE
GL TO(321,322),MEGAN
321 RNUM=T1*((4.*J+J+4.*J-1.)-T3*(8.*J+J+12.*J+J-2.*J+1.-146.5))
DENOM=8.*J*(J+1.)
GO TO 11111
322 RNUM=T1*((4.*J+J+4.*J-1.)+T3*(8.*J+J+12.*J+J-2.*J+1.-146.5))
DENOM=8.*J*(J+1.)
GO TO 11111
4 CONTINUE
GO TO(41,42),MEGAN
41 CONTINUE
GL TO(411,412),MEGAN

```

IV 6 LEVEL 21

HCONCLP

DATE = 75178

09/06/45

```

      411 RNUM=T2+T1*T3*(4.*J+J+4.*J-7.+146.5)
      DENOM=D.*(J+1.)
      GO TO 11111
      412 RNUM=T2-T1*T3*(4.*J+J+4.*J-7.+146.5)
      DENOM=D.*(J+1.)
      GO TO 11111
      42  CONTINUE
      GO TJ(4+1,4+2),NEGAM
      421 RNUM=T2-T1*T3*(4.*J+J+4.*J+1.-146.5)
      DENOM=D.*(J+1.)
      GO TO 11111
      422 RNUM=T2+T1*T3*(4.*J+J+4.*J+1.-146.5)
      DENOM=D.*(J+1.)
11111 CONTINUE
      IF(DENOM=EO.0)GO TO 541
      HML=RNUM/DENOM
      RETURN
541 HML=C.
      RETURN
      END

```

IV G CVCLL 21

WFUNC

DATE = 7-17-76

09/06/75

```

SUBROUTINE WFUNC(XF,YF,W1,W2)
C
C   XF,YF ARE THE REAL AND IMAGINARY PARTS OF THE ARGUMENT
C   W1,W2 ARE THE REAL AND IMAGINARY PARTS OF THE FUNCTION
C   W(Z)=EXP(-Z**2)ERFC(-IZ) (SEE NATIONAL BUREAU OF STANDARDS
C   HANDBOOK OF MATHEMATICAL FUNCTIONS, PAGE 297)
C
C   IMPLICIT REAL*8(A-H,L-Z)
C   COMPLEX*16 ZC,WC,J,ZS,T1,T2,T3
C   COMMON/TAUL/2(31,40,2),X(40),Y(31)
C   DIMENSION W(Z)
C   IFLAG=0
C   IF(XF.LT.0.)IFLAG=IFLAG+1
C   IF(YF.LT.0.)IFLAG=IFLAG+3
C   X1=DAWS(XF)
C   Y1=DAWS(YF)
C   IF(X1.GE.0.5000000R.Y1.GE.3.00)GO TO 1
C   I1=10*Y1+1
C   JJ=10*X1+1
C   I11=I1+1
C   JJ1=JJ+1
C   DO 16 K=1,2
C     Z1=(Z(11,JJ,K)-Z(11,JJ1,K))*(X1-X(JJ1))/(X(JJ)-X(JJ1))+Z(11,JJ1,K)
C     Z2=(Z(111,JJ,K)-Z(111,JJ1,K))*(X1-X(JJ1))/(X(JJ)-X(JJ1))
C     *+Z(111,JJ1,K)
C   10 W(K)=(Z1-Z2)*(Y1-Y(111))/(Y(11)-Y(111))+Z2
C     W1=W(1)
C     W2=W(2)
C     IF(IFLAG.EQ.0)RETURN
C     GU TO(100,300,300,400),IFLAG
C     RETURN
C   1 IF(X1.GT.0.5000000R.Y1.GT.0.5000000)GO TO 2
C     J=(0.0001,00)
C     ZC=DCMPLX(X1,Y1)
C     ZS=ZC*ZC
C     T1=.401514500/(ZS-.150163500)
C     T2=.00999921000/(ZS-1.784452700)
C     T3=.00268369400/(ZS-1.525343700)
C     WC=J*ZC*(T1+T2+T3)
C     W1=(WC+JCONJG(WC))*0.500
C     W2=(JCONJG(WC)-WC)*J*.500
C     IF(IFLAG.EQ.0)RETURN
C     GU TO(100,300,300,400),IFLAG
C   2 J=(0.0001,00)
C     ZC=DCMPLX(X1,Y1)
C     ZS=ZC*ZC
C     T1=.512424200/(ZS-.275255100)
C     T2=.0517853600/(ZS-2.72474500)
C     WC=J*ZC*(T1+T2)
C     W1=(WC+JCONJG(WC))*0.500
C     W2=(JCONJG(WC)-WC)*J*.500
C     IF(IFLAG.EQ.0)RETURN
C     GU TO(100,300,300,400),IFLAG
C   100 W1=W1-W2
C     RETURN
C   300 G=2.00*DEXP(Y1*Y1-X1*X1)

```

IV G LEVEL 41

BT LAL

DATE = 75178

04/06/45

```

GG=2+DG*AI*YI
AI=GG*CCS(GG)-MI
AZ=GG*CSIN(GG)+MZ
N=TURN
400 GG=2+GG*GL*AI*(YI+YI-AI*AI)
GG=2+DG*AI*YI
AI=GG*CCS(GG)-MI
AZ=GG*CSIN(GG)+MZ
N=TURN
END

```

W(Z)	51
w(Z)	52
W(Z)	53
w(Z)	54
W(Z)	55
w(Z)	56
W(Z)	57
w(Z)	58
W(Z)	59
w(Z)	60

IV G LEVEL 21

BLK DATA

DATE = 75178

09/06/45

```

BLOCK DATA
IMPLICIT REAL*8(A-H,O-Z)
COMMON/TAJLCL/
*Z 1(31), Z 2(31), Z 3(31), Z 4(31), Z 5(31), Z 6(31), Z 7(31), W(2) 61
*Z 8(31), Z 9(31), Z10(31), Z11(31), Z12(31), Z13(31), Z14(31), W(2) 62
*Z15(31), Z16(31), Z17(31), Z18(31), Z19(31), Z20(31), Z21(31), W(2) 63
*Z22(31), Z23(31), Z24(31), Z25(31), Z26(31), Z27(31), Z28(31), W(2) 64
*Z29(31), Z30(31), Z31(31), Z32(31), Z33(31), Z34(31), Z35(31), W(2) 65
*Z36(31), Z37(31), Z38(31), Z39(31), Z40(31), Z41(31), Z42(31), W(2) 66
*Z43(31), Z44(31), Z45(31), Z46(31), Z47(31), Z48(31), Z49(31), W(2) 67
*Z50(31), Z51(31), Z52(31), Z53(31), Z54(31), Z55(31), Z56(31), W(2) 68
*Z57(31), Z58(31), Z59(31), Z60(31), Z61(31), Z62(31), Z63(31), W(2) 69
*Z64(31), Z65(31), Z66(31), Z67(31), Z68(31), Z69(31), Z70(31), W(2) 70
*Z71(31), Z72(31), Z73(31), Z74(31), Z75(31), Z76(31), Z77(31), W(2) 71
*Z78(31), Z79(31), Z80(31), W(2) 72
*Z81(31), W(2) 73
*Z82(31), W(2) 74
*Z83(31), W(2) 75
*Z84(31), W(2) 76
*Z85(31), W(2) 77
*Z86(31), W(2) 78
*Z87(31), W(2) 79
*Z88(31), W(2) 80
*Z89(31), W(2) 81
*Z90(31), W(2) 82
*Z91(31), W(2) 83
*Z92(31), W(2) 84
*Z93(31), W(2) 85
*Z94(31), W(2) 86
*Z95(31), W(2) 87
*Z96(31), W(2) 88
*Z97(31), W(2) 89
*Z98(31), W(2) 90
*Z99(31), W(2) 91
*Z100(31), W(2) 92
*Z101(31), W(2) 93
*Z102(31), W(2) 94
*Z103(31), W(2) 95
*Z104(31), W(2) 96
*Z105(31), W(2) 97
*Z106(31), W(2) 98
*Z107(31), W(2) 99
*Z108(31), W(2) 100
*Z109(31), W(2) 101
*Z110(31), W(2) 102
*Z111(31), W(2) 103
*Z112(31), W(2) 104
*Z113(31), W(2) 105
*Z114(31), W(2) 106
*Z115(31), W(2) 107
*Z116(31), W(2) 108
*Z117(31), W(2) 109
*Z118(31), W(2) 110
*Z119(31), W(2) 111
*Z120(31), W(2) 112
*Z121(31), W(2) 113
*Z122(31), W(2) 114
*Z123(31), W(2) 115
*Z124(31), W(2) 116

```

IV G LEVEL	21	BLK DATA	DATE = 7517B	09/06/45	
* .85214400.	.77726700.	.71214600.	.65524400.	.60529500.	W(Z) 117
* .56125200.	.52224600.	.40755600.	.45657900.	.42880800.	W(Z) 118
* .40381800.	.38125600.	.36079900.	.34220600.	.32524600.	W(Z) 119
* .30473000.	.25550600.	.28241700.	.27034600.	.25918600.	W(Z) 120
* .24884400.	.23923900.	.23030000.	.22196300.	.21417200.	W(Z) 121
* .20687900.	.20003900.	.15361300.	.18756600.	.18186800.	W(Z) 122
* .17645100./					W(Z) 123
DATA Z 6/					W(Z) 124
* .77880100.	.71758800.	.66322300.	.61485200.	.57171700.	W(Z) 125
* .53315700.	.45851100.	.40752100.	.43951200.	.41419100.	W(Z) 126
* .39123400.	.37036300.	.35133500.	.33394200.	.31600100.	W(Z) 127
* .30315500.	.28966600.	.27741200.	.26589000.	.25520500.	W(Z) 128
* .24527600.	.23603100.	.22740700.	.21934700.	.21180000.	W(Z) 129
* .23472300.	.15607400.	.19181800.	.18592400.	.18036100.	W(Z) 130
* .17510800./					W(Z) 131
DATA Z 7/					W(Z) 132
* .64767600.	.65167600.	.60832200.	.56923800.	.53358100.	W(Z) 133
* .50107900.	.47145300.	.44443400.	.41976600.	.39721600.	W(Z) 134
* .37657100.	.35763700.	.34024100.	.32422900.	.30946300.	W(Z) 135
* .29502000.	.28315200.	.27147900.	.26059800.	.25046900.	W(Z) 136
* .24102500.	.23220400.	.22395200.	.21621900.	.20896100.	W(Z) 137
* .20213900.	.15571700.	.18966400.	.18395000.	.17854900.	W(Z) 138
* .17343700./					W(Z) 139
DATA Z 8/					W(Z) 140
* .01262600.	.58069600.	.54973900.	.52019200.	.49228900.	W(Z) 141
* .46012700.	.44171200.	.41899800.	.39790600.	.37834100.	W(Z) 142
* .36020000.	.34337500.	.32776600.	.31327300.	.29960400.	W(Z) 143
* .28727400.	.27500200.	.26471800.	.25455400.	.24505000.	W(Z) 144
* .23615200.	.22781000.	.21957800.	.21261600.	.20586800.	W(Z) 145
* .19915500.	.19245200.	.18717000.	.18166200.	.17644700.	W(Z) 146
* .17150200./					W(Z) 147
DATA Z 9/					W(Z) 148
* .52729200.	.50524400.	.48971000.	.46948000.	.44924400.	W(Z) 149
* .42941800.	.41026400.	.39143600.	.37451800.	.35804300.	W(Z) 150
* .34251100.	.32750000.	.31417600.	.30124400.	.28920800.	W(Z) 151
* .27786900.	.26722800.	.25723700.	.24785100.	.23902700.	W(Z) 152
* .23072400.	.22250500.	.21553500.	.20858100.	.20201300.	W(Z) 153
* .19580400.	.18952800.	.18436200.	.17908400.	.17407400.	W(Z) 154
* .16931500./					W(Z) 155
DATA Z 10/					W(Z) 156
* .44485800.	.43942100.	.43027100.	.41873600.	.40576300.	W(Z) 157
* .39202100.	.37757700.	.36395700.	.35018200.	.33679900.	W(Z) 158
* .32345500.	.31153700.	.29947400.	.28851900.	.27786500.	W(Z) 159
* .26776600.	.25820300.	.24915100.	.24058600.	.23248200.	W(Z) 160
* .22481300.	.21755200.	.21067600.	.20416000.	.19798200.	W(Z) 161
* .19212000.	.18655400.	.18126500.	.17623700.	.17145200.	W(Z) 162
* .16089500./					W(Z) 163
DATA Z 11/					W(Z) 164
* .36787900.	.37317100.	.37315300.	.36938600.	.36302000.	W(Z) 165
* .35450600.	.36564900.	.33572100.	.32544600.	.31506400.	W(Z) 166
* .30474400.	.29400600.	.28473100.	.27517400.	.26596700.	W(Z) 167
* .25712800.	.24866500.	.24057800.	.23286100.	.22550300.	W(Z) 168
* .21849300.	.21181600.	.20545700.	.19940200.	.19363400.	W(Z) 169
* .18613900.	.18250300.	.17791000.	.17314700.	.16860200.	W(Z) 170
* .16426100./					W(Z) 171
DATA Z 12/					W(Z) 172

IV G LEVEL 21

BLK DATA

DATE = 75178

09/06/45

* .29815700.	.31213600.	.31971700.	.32258600.	.32199300.	W(2) 173
* .31888400.	.31347800.	.30781600.	.30080700.	.29325900.	W(2) 174
* .28540200.	.27740700.	.26940100.	.26147600.	.25369700.	W(2) 175
* .24611200.	.23875200.	.23163500.	.22477500.	.21817600.	W(2) 176
* .21143900.	.20576000.	.19993500.	.19435600.	.18901400.	W(2) 177
* .18390100.	.17900800.	.17432400.	.16984000.	.16554600.	W(2) 178
* .16143400/					W(2) 179
DATA Z13/					W(2) 180
* .23652800.	.25737400.	.27092800.	.27919900.	.28344300.	W(2) 181
* .28461300.	.26354000.	.26074000.	.27669300.	.27175200.	W(2) 182
* .26612400.	.26021300.	.25368500.	.24762800.	.24123300.	W(2) 183
* .23487000.	.22859200.	.22243600.	.21642800.	.21058700.	W(2) 184
* .20492600.	.19949200.	.19416600.	.18907200.	.18416500.	W(2) 185
* .17944400.	.17456300.	.17053800.	.16634200.	.16231000.	W(2) 186
* .15843500/					W(2) 187
DATA Z14/					W(2) 188
* .18452000.	.26543100.	.22736200.	.23979300.	.24790800.	W(2) 189
* .25265400.	.25478400.	.25489500.	.25346100.	.25085800.	W(2) 190
* .24738100.	.24326600.	.23869500.	.23381300.	.22873300.	W(2) 191
* .22354200.	.21830900.	.21308600.	.20791200.	.20281800.	W(2) 192
* .19782700.	.19255300.	.18820800.	.18359900.	.17913100.	W(2) 193
* .17480500.	.17062300.	.16658200.	.16268100.	.15891600.	W(2) 194
* .15528500/					W(2) 195
DATA Z15/					W(2) 196
* .14085800.	.16840700.	.18924700.	.20466200.	.21571100.	W(2) 197
* .22326200.	.22842600.	.23057800.	.23138500.	.23082600.	W(2) 198
* .22420500.	.22676700.	.22371000.	.22019200.	.21634000.	W(2) 199
* .21225300.	.20801400.	.20368400.	.19931500.	.19494700.	W(2) 200
* .19060800.	.18632400.	.18211200.	.17798500.	.17395400.	W(2) 201
* .17002400.	.16620100.	.16248700.	.15888300.	.15536900.	W(2) 202
* .15200500/					W(2) 203
DATA Z16/					W(2) 204
* .10539900.	.13444900.	.15652100.	.17386500.	.18698400.	W(2) 205
* .19003600.	.20346100.	.20799000.	.21066400.	.21184600.	W(2) 206
* .21185700.	.21088100.	.20918200.	.20690200.	.20417700.	W(2) 207
* .20111500.	.19780600.	.19432000.	.19071700.	.18704300.	W(2) 208
* .18303500.	.17962300.	.17593000.	.17227600.	.16867400.	W(2) 209
* .16513600.	.16166500.	.15828100.	.15497500.	.15175300.	W(2) 210
* .14801500/					W(2) 211
DATA Z17/					W(2) 212
* .07730500.	.10584300.	.12889500.	.14727200.	.16170200.	W(2) 213
* .17262600.	.18117700.	.18725500.	.19142300.	.19404900.	W(2) 214
* .19540700.	.19573400.	.19522800.	.19405300.	.19234700.	W(2) 215
* .19022500.	.18777200.	.18507300.	.18218900.	.17917200.	W(2) 216
* .17806400.	.17560100.	.16971000.	.16651300.	.16333000.	W(2) 217
* .16617500.	.16370600.	.15399300.	.15098100.	.14803000.	W(2) 218
* .14814400/					W(2) 219
DATA Z18/					W(2) 220
* .05557000.	.08311200.	.10592900.	.12461200.	.13971700.	W(2) 221
* .15175100.	.16117100.	.16837900.	.17372500.	.17751300.	W(2) 222
* .18000200.	.18141400.	.18193800.	.18173300.	.18093300.	W(2) 223
* .17965100.	.17756300.	.17600800.	.17379200.	.17139000.	W(2) 224
* .16804900.	.16620600.	.16349300.	.16073700.	.15795800.	W(2) 225
* .15517500.	.15240200.	.14964900.	.14692700.	.14424300.	W(2) 226
* .14100200/					W(2) 227
DATA Z19/					W(2) 228

IV G LEVEL	Z1	BLK DATA	DATE = 75178	09/06/45	
*	.03916400.	.00509900.	.00709000.	.10552200.	.12079300. W(Z) 229
*	.11326600.	.14336900.	.15136600.	.15757800.	.16226800. W(Z) 230
*	.16566700.	.16757700.	.16937300.	.17000300.	.16949700. W(Z) 231
*	.16946600.	.16850000.	.16718300.	.16557900.	.16374600. W(Z) 232
*	.16171300.	.15956000.	.15752000.	.15498200.	.15259100. W(Z) 233
*	.15016600.	.14772200.	.14527400.	.14283400.	.14041100. W(Z) 234
*	.13601200/				W(Z) 235
DATA 220/					W(Z) 236
*	.02705200/	.00103800.	.07181100.	.08959200.	.10464100. W(Z) 237
*	.11723300.	.12764400.	.13013400.	.14294900.	.14831000. W(Z) 238
*	.15241800.	.15545200.	.15756900.	.15890600.	.15958500. W(Z) 239
*	.15970900.	.15536900.	.15864100.	.15759300.	.15628200. W(Z) 240
*	.15475700.	.15305900.	.15122400.	.14928100.	.14725600. W(Z) 241
*	.14517200.	.14304500.	.14089200.	.13872500.	.13655500. W(Z) 242
*	.13439100/				W(Z) 243
DATA 221/					W(Z) 244
*	.01831600.	.04020100.	.05953100.	.07639600.	.09094400. W(Z) 245
*	.10335700.	.11363600.	.12257400.	.12978800.	.13560000. W(Z) 246
*	.14024000.	.14364000.	.14654100.	.14846600.	.14972500. W(Z) 247
*	.15041500.	.15062200.	.15041800.	.14987000.	.14903200. W(Z) 248
*	.14755300.	.14667500.	.14523400.	.14366000.	.14198200. W(Z) 249
*	.14022000.	.13834500.	.13652300.	.13461900.	.13269300. W(Z) 250
*	.13075700/				W(Z) 251
DATA 222/					W(Z) 252
*	.01215500.	.03195000.	.04972000.	.06552100.	.07946500. W(Z) 253
*	.09142200.	.10176500.	.11055800.	.11794800.	.12408100. W(Z) 254
*	.12909700.	.13312500.	.13626000.	.13866900.	.14043200. W(Z) 255
*	.14160400.	.14228300.	.14254900.	.14243400.	.14202100. W(Z) 256
*	.14134900.	.14045300.	.13937500.	.13814500.	.13678900. W(Z) 257
*	.13533100.	.13379100.	.13218700.	.13053300.	.12884200. W(Z) 258
*	.12712500/				W(Z) 259
DATA 223/					W(Z) 260
*	.00790700.	.02567800.	.04192700.	.05656600.	.06965500. W(Z) 261
*	.08116200.	.09124500.	.09994300.	.10738300.	.11367900. W(Z) 262
*	.11694100.	.12327700.	.12678800.	.12957000.	.13170900. W(Z) 263
*	.14326400.	.14436700.	.13502100.	.13539500.	.13526900. W(Z) 264
*	.13455900.	.13441400.	.13366900.	.13275500.	.13169900. W(Z) 265
*	.13052400.	.12925200.	.12790000.	.12648300.	.12501600. W(Z) 266
*	.12351000/				W(Z) 267
DATA 224/					W(Z) 268
*	.00504200.	.02095000.	.03572300.	.04924800.	.06147300. W(Z) 269
*	.07246300.	.08205200.	.09088300.	.09796300.	.10430900. W(Z) 270
*	.10570900.	.11425100.	.11861900.	.12109200.	.12354800. W(Z) 271
*	.12544400.	.12687700.	.12787300.	.12849500.	.12879200. W(Z) 272
*	.12880500.	.12857400.	.12813000.	.12750600.	.12672600. W(Z) 273
*	.12581400.	.12475200.	.12367000.	.12248400.	.12122900. W(Z) 274
*	.11942200/				W(Z) 275
DATA 225/					W(Z) 276
*	.00315100.	.01735700.	.03079200.	.04321100.	.05458500. W(Z) 277
*	.06489000.	.07410200.	.08234500.	.08957000.	.09588400. W(Z) 278
*	.10133600.	.10599900.	.10994200.	.11323200.	.11593500. W(Z) 279
*	.11616900.	.11961200.	.12109600.	.12201000.	.12259700. W(Z) 280
*	.12285700.	.12294500.	.12277300.	.12241100.	.12188400. W(Z) 281
*	.12121500.	.12042400.	.11953300.	.11859800.	.11749200. W(Z) 282
*	.11037500/				W(Z) 283
DATA 226/					W(Z) 284

IV G LEVEL	Z1	BLK DATA	DATE = 75178	09/06/45	
*	.00163000.	.01465800.	.02684100.	.03822600.	.04877300. W(Z) 285
*	.05843700.	.06720000.	.07508800.	.08211200.	.08831700. W(Z) 286
*	.09375100.	.05840600.	.10251800.	.10596000.	.10884800. W(Z) 287
*	.11123300.	.11316500.	.11469000.	.11585100.	.11668900. W(Z) 288
*	.11723900.	.11753400.	.11760000.	.11748100.	.11718400. W(Z) 289
*	.11673700.	.11616000.	.11547100.	.11468500.	.11381000. W(Z) 290
*	.11267800/				W(Z) 291
DATA Z27/					W(Z) 292
*	.00115900.	.01263500.	.02365300.	.03408700.	.04384900. W(Z) 293
*	.05288500.	.06116700.	.06869100.	.07546700.	.08152100. W(Z) 294
*	.08086500.	.09159800.	.09570200.	.09924300.	.10226400. W(Z) 295
*	.10481100.	.10652500.	.10864700.	.11001600.	.11106700. W(Z) 296
*	.11183400.	.11234700.	.11263500.	.11272300.	.11263300. W(Z) 297
*	.11238900.	.11266800.	.11150800.	.11090400.	.11021000. W(Z) 298
*	.10943900/				W(Z) 299
DATA Z28/					W(Z) 300
*	.00068200.	.01103700.	.02105700.	.03062600.	.03965600. W(Z) 301
*	.04809000.	.05589000.	.06304300.	.06954800.	.07541600. W(Z) 302
*	.08067000.	.08533800.	.08945100.	.09304400.	.09615500. W(Z) 303
*	.09882000.	.10167600.	.10295700.	.10449800.	.10573000. W(Z) 304
*	.10668300.	.10738600.	.10786400.	.10814000.	.10823800. W(Z) 305
*	.10817700.	.10797500.	.10764800.	.10721300.	.10668200. W(Z) 306
*	.10606700/				W(Z) 307
DATA Z29/					W(Z) 308
*	.00035400.	.00977800.	.01891800.	.02770700.	.03606400. W(Z) 309
*	.04343000.	.05126400.	.05804600.	.06442600.	.06992700. W(Z) 310
*	.07504300.	.07963200.	.08371600.	.08732800.	.09049200. W(Z) 311
*	.09323900.	.09566100.	.09760800.	.09928800.	.10067100. W(Z) 312
*	.10178300.	.10264900.	.10329300.	.10373700.	.10400200. W(Z) 313
*	.10414500.	.10466600.	.10389800.	.10361700.	.10323600. W(Z) 314
*	.10276700/				W(Z) 315
DATA Z30/					W(Z) 316
*	.00022300.	.00876400.	.01713400.	.02522500.	.03296700. W(Z) 317
*	.04030400.	.04719400.	.05361100.	.05954300.	.06498600. W(Z) 318
*	.06954400.	.07443100.	.07846200.	.08205900.	.08524500. W(Z) 319
*	.08804400.	.09048200.	.09258400.	.09437600.	.09586200. W(Z) 320
*	.09712700.	.09813300.	.09892200.	.09951300.	.09992500. W(Z) 321
*	.10017700.	.10028400.	.10026100.	.10012200.	.09987900. W(Z) 322
*	.09954400/				W(Z) 323
DATA Z31/					W(Z) 324
*	.00012300.	.00754300.	.01562700.	.02309500.	.03027900. W(Z) 325
*	.03712600.	.04359800.	.04966500.	.05531100.	.06052900. W(Z) 326
*	.06531800.	.06968500.	.07364100.	.07720200.	.08038500. W(Z) 327
*	.08321000.	.08565700.	.08787000.	.08974900.	.09135500. W(Z) 328
*	.09271100.	.09385500.	.09474800.	.09546700.	.09601000. W(Z) 329
*	.09639300.	.09663200.	.09673900.	.09672900.	.09661300. W(Z) 330
*	.09640200/				W(Z) 331
DATA Z32/					W(Z) 332
*	.00000700.	.00725400.	.01433800.	.02125000.	.02792900. W(Z) 333
*	.03432600.	.04040700.	.04614100.	.05150900.	.05650100. W(Z) 334
*	.06111400.	.06535000.	.06921600.	.07272200.	.07588300. W(Z) 335
*	.07871200.	.08122900.	.08345000.	.08539400.	.08708000. W(Z) 336
*	.08852500.	.08974900.	.09076700.	.09159700.	.09225500. W(Z) 337
*	.09275400.	.09311000.	.09333600.	.09344200.	.09344200. W(Z) 338
*	.09334500/				W(Z) 339
DATA Z33/					W(Z) 340

IV C LEVEL	Z1	BLK DATA	DATE = 7517d	09/06/45		
*	.00003600.	.0C067000.	.01322500.	.01963500.	.02586200.	W(Z) 341
*	.03184900.	.03756500.	.04298300.	.04806300.	.05285400.	W(Z) 342
*	.05726900.	.06138700.	.06515100.	.06856900.	.07171100.	W(Z) 343
*	.07462900.	.07705500.	.07930600.	.08129700.	.08304400.	W(Z) 344
*	.08462200.	.08566700.	.08647400.	.08790000.	.08865700.	W(Z) 345
*	.08925900.	.08971900.	.09005000.	.09026300.	.09036600.	W(Z) 346
*	.09037500/					W(Z) 347
DATA Z34/						W(Z) 348
*	.00001900.	.00010700.	.01225200.	.01822200.	.02403200.	W(Z) 349
*	.02464300.	.03502200.	.04014400.	.04498900.	.04954400.	W(Z) 350
*	.05101000.	.05775700.	.06141300.	.06477300.	.06784400.	W(Z) 351
*	.07013600.	.07315600.	.07542300.	.07744500.	.07923600.	W(Z) 352
*	.08001100.	.08218200.	.08336400.	.08437000.	.08521300.	W(Z) 353
*	.08566500.	.08646600.	.08688300.	.08719000.	.08739100.	W(Z) 354
*	.08745300/					W(Z) 355
DATA Z35/						W(Z) 356
*	.00001000.	.00572000.	.01139400.	.01690600.	.02240300.	W(Z) 357
*	.02767000.	.03273800.	.03758200.	.04218500.	.04653200.	W(Z) 358
*	.05001500.	.05442600.	.05797100.	.06124600.	.06425800.	W(Z) 359
*	.06701200.	.06951600.	.07178500.	.07362300.	.07564600.	W(Z) 360
*	.07726300.	.07868700.	.07993000.	.08100400.	.08192100.	W(Z) 361
*	.08264900.	.08332400.	.08383200.	.08422500.	.08461100.	W(Z) 362
*	.08476000/					W(Z) 363
DATA Z36/						W(Z) 364
*	.00000300.	.00634000.	.01063300.	.01584600.	.02094400.	W(Z) 365
*	.02505700.	.03167700.	.03526300.	.03963700.	.04378500.	W(Z) 366
*	.04769200.	.05137600.	.05474800.	.05798400.	.06092800.	W(Z) 367
*	.06363700.	.06611600.	.06837400.	.07041900.	.07226000.	W(Z) 368
*	.07356800.	.07537300.	.07666600.	.07779600.	.07877400.	W(Z) 369
*	.07961100.	.08031600.	.08089800.	.08136600.	.08173000.	W(Z) 370
*	.08155600/					W(Z) 371
DATA Z37/						W(Z) 372
*	.00000200.	.00445500.	.00995200.	.01484100.	.01963200.	W(Z) 373
*	.0246700.	.02861200.	.03315800.	.03731600.	.04127400.	W(Z) 374
*	.04502300.	.04856800.	.05186900.	.05496200.	.05783500.	W(Z) 375
*	.06004100.	.06243600.	.06517600.	.06721700.	.06906800.	W(Z) 376
*	.07073600.	.07223200.	.07356300.	.07473900.	.07577000.	W(Z) 377
*	.07666400.	.07743600.	.07807600.	.07861200.	.07904400.	W(Z) 378
*	.07950100/					W(Z) 379
DATA Z38/						W(Z) 380
*	.00000100.	.00468500.	.00933900.	.01393500.	.01844600.	W(Z) 381
*	.02264700.	.02711800.	.03123900.	.03501900.	.03897400.	W(Z) 382
*	.04256500.	.04556200.	.04916100.	.05215900.	.05495800.	W(Z) 383
*	.05755700.	.05956200.	.06217700.	.06420600.	.06605800.	W(Z) 384
*	.06773800.	.06925400.	.07061500.	.07182900.	.07290200.	W(Z) 385
*	.07304500.	.07466300.	.07536600.	.07596100.	.07645500.	W(Z) 386
*	.07608500/					W(Z) 387
DATA Z39/						W(Z) 388
*	.00000100.	.00440600.	.00878600.	.01311500.	.01737000.	W(Z) 389
*	.02152900.	.02557400.	.02946600.	.03325300.	.03686100.	W(Z) 390
*	.04031300.	.04356700.	.04666300.	.04955800.	.05227900.	W(Z) 391
*	.05401900.	.05717400.	.05936200.	.06137400.	.06321900.	W(Z) 392
*	.06450300.	.06664300.	.06781500.	.06905800.	.07016600.	W(Z) 393
*	.07114500.	.07261300.	.07276400.	.07341100.	.07395900.	W(Z) 394
*	.07441800/					W(Z) 395
DATA Z40/						W(Z) 396

IV G LEVEL	21	BLK DATA	DATE = 7-178	09/06/45	
* .00000000	.00415300	.00028200	.01230800	.01638900	W(2) 397
* .00200000	.02410200	.02768000	.03140900	.03491600	W(2) 398
* .00400000	.04135200	.04432800	.04713900	.04978300	W(2) 399
* .00600000	.05457200	.05672000	.05870800	.06054000	W(2) 400
* .00800000	.06375900	.06515000	.06664200	.06755600	W(2) 401
* .01000000	.06947400	.07026700	.07095900	.07155500	W(2) 402
* .01200000					W(2) 403
DATA 241/					W(2) 404
* .00000000	.00000000	.00000000	.00000000	.00000000	W(2) 405
* .00000000	.00000000	.00000000	.00000000	.00000000	W(2) 406
* .00000000	.00000000	.00000000	.00000000	.00000000	W(2) 407
* .00000000	.00000000	.00000000	.00000000	.00000000	W(2) 408
* .00000000	.00000000	.00000000	.00000000	.00000000	W(2) 409
* .00000000	.00000000	.00000000	.00000000	.00000000	W(2) 410
* .00000000					W(2) 411
DATA 242/					W(2) 412
* .01200000	.05433200	.05002900	.05064100	.050889700	W(2) 413
* .02510400	.04452400	.043900400	.043440500	.043050600	W(2) 414
* .02700000	.03435200	.032153400	.031980500	.031795100	W(2) 415
* .01000000	.01490000	.01304800	.01253600	.01154700	W(2) 416
* .01000000	.01490000	.01490000	.01490000	.01490000	W(2) 417
* .00742700	.01055200	.00802000	.00612500	.00576400	W(2) 418
* .00542300					W(2) 419
DATA 243/					W(2) 420
* .01570000	.01052200	.010740300	.013473900	.011614700	W(2) 421
* .00700000	.00700000	.00700000	.00823500	.008056300	W(2) 422
* .00800000	.00800000	.00800000	.00800000	.00800000	W(2) 423
* .00340000	.00340000	.002715400	.002494800	.002298700	W(2) 424
* .00100000	.00100000	.00100000	.00100000	.00100000	W(2) 425
* .00400000	.00400000	.00400000	.00400000	.00400000	W(2) 426
* .00000000					W(2) 427
DATA 244/					W(2) 428
* .03000000	.02000000	.02000000	.01970000	.017020300	W(2) 429
* .04700000	.01000000	.011382100	.010004700	.008944400	W(2) 430
* .00900000	.00700000	.00600000	.00500000	.004293600	W(2) 431
* .00400000	.00400000	.00400000	.003711800	.003421700	W(2) 432
* .00100000	.00100000	.002721700	.002533000	.002303300	W(2) 433
* .02200000	.00200000	.001940900	.001824100	.001717200	W(2) 434
* .01000000					W(2) 435
DATA 245/					W(2) 436
* .00000000	.03400000	.02400000	.02000000	.01970000	W(2) 437
* .01000000	.01000000	.01000000	.01000000	.01000000	W(2) 438
* .00400000	.00400000	.00400000	.00400000	.00400000	W(2) 439
* .00000000	.00000000	.00000000	.00000000	.00000000	W(2) 440
* .00100000	.00100000	.00100000	.00100000	.00100000	W(2) 441
* .02000000	.00200000	.00200000	.00200000	.00200000	W(2) 442
* .00100000					W(2) 443
DATA 246/					W(2) 444
* .00000000	.00000000	.00000000	.00000000	.00000000	W(2) 445
* .02000000	.02000000	.02000000	.02000000	.02000000	W(2) 446
* .01200000	.01140000	.01033500	.009374400	.008524800	W(2) 447
* .00700000	.00710000	.00600000	.00500000	.00400000	W(2) 448
* .00100000	.00100000	.00100000	.00100000	.00100000	W(2) 449
* .00000000	.00000000	.00000000	.00000000	.00000000	W(2) 450
* .00000000					W(2) 451
DATA 247/					W(2) 452

IV G LEVEL 21	BLK DATA	DATE = 7517H	09/06/45		
* .53571300.	.45966500.	.39685200.	.34464500.	.30098900.	W(Z) 453
* .26426800.	.23320600.	.20676700.	.18420000.	.16479300.	W(Z) 454
* .14603600.	.13356100.	.12083800.	.10975900.	.10002600.	W(Z) 455
* .09144300.	.08384500.	.07709600.	.07108100.	.06570100.	W(Z) 456
* .06087600.	.05653400.	.05261700.	.04907300.	.04585900.	W(Z) 457
* .04253600.	.04027100.	.03783600.	.03560700.	.03356100.	W(Z) 458
* .03168000/					W(Z) 459
DATA 248/					W(Z) 460
* .57604200.	.45774400.	.43244200.	.37766800.	.33153500.	W(Z) 461
* .29243200.	.25413600.	.23064600.	.20615500.	.18500500.	W(Z) 462
* .16666000.	.15066100.	.13670600.	.12443500.	.11362000.	W(Z) 463
* .10405400.	.09556300.	.08800100.	.08124500.	.07519000.	W(Z) 464
* .06974800.	.06484200.	.06040900.	.05639100.	.05274100.	W(Z) 465
* .04941700.	.04636400.	.04360800.	.04106400.	.03872800.	W(Z) 466
* .03657700/					W(Z) 467
DATA 249/					W(Z) 468
* .60041200.	.52293200.	.45756900.	.40219400.	.35508200.	W(Z) 469
* .31482800.	.28029000.	.25053200.	.22476900.	.20242900.	W(Z) 470
* .18293200.	.16586800.	.15087700.	.13766100.	.12597100.	W(Z) 471
* .11565400.	.10635500.	.09810300.	.09071000.	.08406800.	W(Z) 472
* .07808500.	.07266000.	.06778500.	.06334200.	.05929800.	W(Z) 473
* .05561600.	.05223600.	.04915000.	.04631500.	.04370800.	W(Z) 474
* .04130600/					W(Z) 475
DATA 250/					W(Z) 476
* .61014200.	.53608700.	.47277300.	.41849100.	.37181300.	W(Z) 477
* .33154400.	.29665200.	.26642700.	.24005700.	.21700400.	W(Z) 478
* .19676300.	.17895000.	.16328100.	.14937000.	.13701200.	W(Z) 479
* .12600200.	.11616400.	.10734800.	.09942700.	.09229100.	W(Z) 480
* .08564500.	.08000500.	.07471200.	.06989400.	.06550000.	W(Z) 481
* .06148800.	.05781100.	.05443900.	.05133900.	.04848500.	W(Z) 482
* .04585100/					W(Z) 483
DATA 251/					W(Z) 484
* .60715400.	.53855600.	.47899100.	.42722500.	.38216600.	W(Z) 485
* .34287200.	.30853000.	.27844500.	.25202400.	.22875900.	W(Z) 486
* .20821900.	.19003600.	.17389600.	.15953100.	.14671200.	W(Z) 487
* .13524200.	.12495400.	.11570200.	.10736100.	.09982400.	W(Z) 488
* .09295800.	.08680100.	.08116200.	.07602100.	.07132400.	W(Z) 489
* .06702400.	.06308000.	.05945600.	.05611800.	.05304100.	W(Z) 490
* .05015700/					W(Z) 491
DATA 252/					W(Z) 492
* .59376100.	.53200900.	.47743900.	.42927500.	.38677700.	W(Z) 493
* .34926600.	.31612800.	.28681500.	.26084700.	.23780000.	W(Z) 494
* .21730600.	.19504600.	.18274200.	.16815100.	.15506600.	W(Z) 495
* .14330800.	.13271100.	.12314700.	.11449500.	.10665000.	W(Z) 496
* .09952300.	.09303500.	.08711600.	.08170600.	.07675300.	W(Z) 497
* .07220800.	.06863100.	.06418600.	.06063900.	.05736300.	W(Z) 498
* .05433100/					W(Z) 499
DATA 253/					W(Z) 500
* .57239700.	.51826300.	.46948800.	.42666700.	.38641200.	W(Z) 501
* .35125900.	.31541800.	.29185100.	.26675700.	.24429500.	W(Z) 502
* .22416800.	.20610600.	.18987800.	.17527100.	.16210000.	W(Z) 503
* .15020500.	.13944100.	.12908400.	.12082200.	.11276000.	W(Z) 504
* .10541100.	.09574600.	.08256200.	.08693600.	.08177300.	W(Z) 505
* .07702400.	.07265100.	.06861700.	.06489000.	.06144000.	W(Z) 506
* .05824300/					W(Z) 507
DATA 254/					W(Z) 508

IV G LEVEL	Z1	BLK DATA	DATE = 75178	09/06/45		
*	.249542000,	.459210000,	.456555000,	.417491000,	.381908000,	W(Z) 509
*	.249501100,	.420368000,	.293427000,	.270040000,	.248402000,	W(Z) 510
*	.228967000,	.211343000,	.195398000,	.180957000,	.167863000,	W(Z) 511
*	.155575000,	.145167000,	.135326000,	.126353000,	.116158000,	W(Z) 512
*	.110662000,	.103745000,	.097495000,	.091706000,	.086378000,	W(Z) 513
*	.081467000,	.076533000,	.072742000,	.068863000,	.065206000,	W(Z) 514
*	.061926000/					W(Z) 515
	DATA Z55/					W(Z) 516
*	.051511000,	.476535000,	.440005000,	.405623000,	.374110000,	W(Z) 517
*	.044864000,	.313022000,	.293453000,	.271015000,	.250549000,	W(Z) 518
*	.231857000,	.214902000,	.199416000,	.185299000,	.172423000,	W(Z) 519
*	.100660000,	.145527000,	.140103000,	.131106000,	.122858000,	W(Z) 520
*	.110286000,	.108325000,	.101419000,	.096015000,	.090567000,	W(Z) 521
*	.060522000,	.061673000,	.076557000,	.072553000,	.068834000,	W(Z) 522
*	.060375000/					W(Z) 523
	DATA Z56/					W(Z) 524
*	.403227000,	.451763000,	.421076000,	.391065000,	.363828000,	W(Z) 525
*	.337720000,	.313557000,	.290847000,	.270016000,	.250823000,	W(Z) 526
*	.233171000,	.216954000,	.202067000,	.186403000,	.175862000,	W(Z) 527
*	.104499000,	.153773000,	.144054000,	.135113000,	.126883000,	W(Z) 528
*	.119298000,	.112302000,	.105842000,	.099870000,	.094343000,	W(Z) 529
*	.089222000,	.084472000,	.0800061000,	.075960000,	.072142000,	W(Z) 530
*	.068555000/					W(Z) 531
	DATA Z57/					W(Z) 532
*	.345128400,	.426168000,	.400837000,	.375911000,	.351803000,	W(Z) 533
*	.328777000,	.306550000,	.286517000,	.267378000,	.249556000,	W(Z) 534
*	.233009000,	.217070000,	.203494000,	.190384000,	.178275000,	W(Z) 535
*	.167092000,	.156765000,	.147226000,	.138412000,	.130202000,	W(Z) 536
*	.122723000,	.115744000,	.109277000,	.103280000,	.097713000,	W(Z) 537
*	.092541000,	.087732000,	.083254000,	.079082000,	.075191000,	W(Z) 538
*	.071558000/					W(Z) 539
	DATA Z58/					W(Z) 540
*	.420388000,	.400743000,	.380161000,	.359313000,	.338676000,	W(Z) 541
*	.318584000,	.299261000,	.280846000,	.263418000,	.247012000,	W(Z) 542
*	.231630000,	.217253000,	.203847000,	.191366000,	.179762000,	W(Z) 543
*	.108980000,	.158969000,	.149674000,	.141045000,	.133033000,	W(Z) 544
*	.125590000,	.118674000,	.112243000,	.106260000,	.100689000,	W(Z) 545
*	.095499000,	.090666000,	.086163000,	.081925000,	.077982000,	W(Z) 546
*	.074243000/					W(Z) 547
	DATA Z59/					W(Z) 548
*	.391291000,	.376214000,	.359721000,	.342479000,	.324985000,	W(Z) 549
*	.307609000,	.290613000,	.274180000,	.258431000,	.243439000,	W(Z) 550
*	.229244000,	.215857000,	.203272000,	.191471000,	.180425000,	W(Z) 551
*	.170699000,	.160457000,	.151458000,	.143063000,	.135234000,	W(Z) 552
*	.127531000,	.121118000,	.114761000,	.108827000,	.103285000,	W(Z) 553
*	.098107000,	.093225000,	.0886735000,	.084493000,	.080519000,	W(Z) 554
*	.076754000/					W(Z) 555
	DATA Z60/					W(Z) 556
*	.364437000,	.353066000,	.340004000,	.325873000,	.311161000,	W(Z) 557
*	.296240000,	.281352000,	.268823000,	.252881000,	.239007000,	W(Z) 558
*	.226046000,	.213656000,	.201514000,	.190821000,	.180367000,	W(Z) 559
*	.170534000,	.161300000,	.152637000,	.144516000,	.136908000,	W(Z) 560
*	.125781000,	.123108000,	.116858000,	.111003000,	.105519000,	W(Z) 561
*	.100378000,	.095558000,	.091037000,	.0868794000,	.082809000,	W(Z) 562
*	.079065000/					W(Z) 563
	DATA Z61/					W(Z) 564

IV G LEVEL	21	BLK DATA	DATE = 75178	09/06/45	
* .34002600.	.33158300.	.32133200.	.30983100.	.29752900.	W(2) 565
* .28478600.	.27188100.	.25903100.	.24639600.	.23409600.	W(2) 566
* .22221300.	.21080500.	.19990400.	.18952900.	.17968700.	W(2) 567
* .17037100.	.16157200.	.15327400.	.14545700.	.13810000.	W(2) 568
* .13118000.	.12467400.	.11855800.	.11281000.	.10740800.	W(2) 569
* .10232900.	.09755400.	.09306200.	.08863700.	.08485900.	W(2) 570
* .08111300/					W(2) 571
DATA Z62/					W(2) 572
* .31807300.	.31188600.	.30389400.	.29457400.	.28432700.	W(2) 573
* .27346200.	.26230800.	.25101800.	.23977200.	.22870300.	W(2) 574
* .21790400.	.20744200.	.19730600.	.18770500.	.17847800.	W(2) 575
* .16969100.	.16134300.	.15342900.	.14593800.	.13885500.	W(2) 576
* .13216400.	.12584900.	.11989100.	.11427200.	.10897300.	W(2) 577
* .10367700.	.09926500.	.09482200.	.09063100.	.08667700.	W(2) 578
* .08254400/					W(2) 579
DATA Z63/					W(2) 580
* .29846800.	.29358200.	.28777100.	.28023200.	.27171000.	W(2) 581
* .26249900.	.25284400.	.24294700.	.23296800.	.22303700.	W(2) 582
* .21325300.	.20305200.	.19441000.	.18544600.	.17682700.	W(2) 583
* .16856900.	.16068000.	.15318100.	.14600900.	.13921700.	W(2) 584
* .13277300.	.12666700.	.12086500.	.11541300.	.11023600.	W(2) 585
* .10533900.	.10070900.	.09633000.	.09218900.	.08827300.	W(2) 586
* .08456800/					W(2) 587
DATA Z64/					W(2) 588
* .28102600.	.27775500.	.27296800.	.26686500.	.25977500.	W(2) 589
* .25145300.	.24461700.	.23445200.	.22611100.	.21721900.	W(2) 590
* .20837600.	.19960000.	.19113300.	.18284000.	.17481400.	W(2) 591
* .16707800.	.15964600.	.15252600.	.14572100.	.13922900.	W(2) 592
* .13304500.	.12716100.	.12156900.	.11625800.	.11121800.	W(2) 593
* .10643000.	.10196100.	.09760100.	.09352300.	.08965800.	W(2) 594
* .08555200/					W(2) 595
DATA Z65/					W(2) 596
* .26552200.	.26320100.	.25943500.	.25447800.	.24856600.	W(2) 597
* .24191400.	.23471400.	.22712900.	.21930200.	.21134900.	W(2) 598
* .20336800.	.19543800.	.18762000.	.17996500.	.17251000.	W(2) 599
* .16528100.	.15829500.	.15157600.	.14512000.	.13893300.	W(2) 600
* .13361500.	.12736300.	.12197200.	.11683400.	.11194200.	W(2) 601
* .10728600.	.10205800.	.09864800.	.09464600.	.09084200.	W(2) 602
* .08722700/					W(2) 603
DATA Z66/					W(2) 604
* .25172300.	.25005000.	.24709200.	.24304200.	.23809200.	W(2) 605
* .23242000.	.22615000.	.21954600.	.21261400.	.20550400.	W(2) 606
* .19830700.	.19109500.	.18394300.	.17688900.	.16997700.	W(2) 607
* .16323700.	.15669200.	.15036900.	.14424900.	.13836800.	W(2) 608
* .13274000.	.12730500.	.12212100.	.11716400.	.11242800.	W(2) 609
* .10790900.	.10356700.	.09948700.	.09557000.	.09183800.	W(2) 610
* .08828300/					W(2) 611
DATA Z67/					W(2) 612
* .23940300.	.23818700.	.23583800.	.23250400.	.22833700.	W(2) 613
* .22348200.	.21807700.	.21224700.	.20610300.	.19974400.	W(2) 614
* .19325500.	.18760700.	.18163000.	.17536700.	.16727000.	W(2) 615
* .16095600.	.15487200.	.14891800.	.14314700.	.13750900.	W(2) 616
* .13145100.	.12701500.	.12204200.	.11727100.	.11269900.	W(2) 617
* .10832200.	.10413600.	.10013300.	.09630900.	.09265700.	W(2) 618
* .08917000/					W(2) 619
DATA Z68/					W(2) 620

IV 6 LEVEL 21

BLK DATA

DATE = 75178

09/06/45

* .22835500.	.22745800.	.22558900.	.22280000.	.21926800.	W(2) 621
* .21509300.	.21438700.	.20525800.	.19980400.	.19411100.	W(2) 622
* .18825800.	.18231100.	.17632800.	.17035700.	.16443800.	W(2) 623
* .15860400.	.15288200.	.14729200.	.14185100.	.13657100.	W(2) 624
* .13145500.	.12652200.	.12176200.	.11718000.	.11277500.	W(2) 625
* .10854800.	.10446900.	.10060100.	.09687600.	.09331000.	W(2) 626
* .08985800/					W(2) 627
DATA 269/					W(2) 628
* .21835900.	.21772200.	.21618100.	.21385800.	.21084300.	W(2) 629
* .20723200.	.20311900.	.19859400.	.19374100.	.18863800.	W(2) 630
* .16835400.	.17795000.	.17248000.	.16699000.	.16151900.	W(2) 631
* .15605900.	.15075800.	.14551800.	.14039500.	.13540300.	W(2) 632
* .13055300.	.12585100.	.12130300.	.11691100.	.11267800.	W(2) 633
* .10859700.	.10467400.	.10090500.	.09728400.	.09381000.	W(2) 634
* .09047900/					W(2) 635
DATA 270/					W(2) 636
* .20937700.	.20885400.	.20757700.	.20560700.	.20301400.	W(2) 637
* .19487300.	.19226200.	.19225000.	.18792700.	.18334400.	W(2) 638
* .17854800.	.17385400.	.16865100.	.16360300.	.15854700.	W(2) 639
* .15351500.	.14853400.	.14362500.	.13880700.	.13409400.	W(2) 640
* .12949800.	.12502700.	.12068800.	.11648400.	.11241900.	W(2) 641
* .10845300.	.10470700.	.10105800.	.09754600.	.09416800.	W(2) 642
* .09092100/					W(2) 643
DATA 271/					W(2) 644
* .20115700.	.20074200.	.19966900.	.19798000.	.19573200.	W(2) 645
* .19258400.	.18979800.	.18623900.	.18238800.	.17824300.	W(2) 646
* .17391800.	.16944500.	.16488600.	.16022300.	.15555100.	W(2) 647
* .15088000.	.14623600.	.14164000.	.13711300.	.13266700.	W(2) 648
* .12831700.	.12407100.	.11993600.	.11591900.	.11202300.	W(2) 649
* .10824900.	.10460600.	.10107600.	.09767400.	.09449500.	W(2) 650
* .09123600/					W(2) 651
DATA 272/					W(2) 652
* .19363000.	.19325200.	.19237600.	.19091500.	.18895100.	W(2) 653
* .18653200.	.18371500.	.18053400.	.17706100.	.17334000.	W(2) 654
* .16941800.	.16533500.	.16114500.	.15687200.	.15255300.	W(2) 655
* .14821700.	.14388800.	.13958800.	.13533500.	.13114600.	W(2) 656
* .12703100.	.12306300.	.11906800.	.11523300.	.11150300.	W(2) 657
* .10788100.	.10437000.	.10066900.	.09768000.	.09450200.	W(2) 658
* .09143400/					W(2) 659
DATA 273/					W(2) 660
* .18070400.	.18042100.	.18063000.	.18435400.	.18262600.	W(2) 661
* .18048400.	.17797000.	.17512800.	.17200300.	.16863700.	W(2) 662
* .16507200.	.16134400.	.15750200.	.15356700.	.14957200.	W(2) 663
* .14554500.	.14151600.	.13748800.	.13349500.	.12954800.	W(2) 664
* .12566000.	.12184000.	.11809900.	.11444200.	.11087500.	W(2) 665
* .10740300.	.10402700.	.10075100.	.09757500.	.09449900.	W(2) 666
* .09152300/					W(2) 667
DATA 274/					W(2) 668
* .18030200.	.18006100.	.17936900.	.17824500.	.17671500.	W(2) 669
* .17480800.	.17258000.	.17000600.	.16718400.	.16413200.	W(2) 670
* .16088600.	.15746600.	.15394400.	.15032000.	.14662500.	W(2) 671
* .14288200.	.13912000.	.13535700.	.13160900.	.12789200.	W(2) 672
* .12421900.	.12000000.	.11704500.	.11396000.	.11015300.	W(2) 673
* .10482700.	.10358600.	.10043300.	.09736900.	.09439600.	W(2) 674
* .09151300/					W(2) 675
DATA 275/					W(2) 676

IV G LEVEL 21

BLK DATA

DATE = 75176

09/06/65

* .17436200.	.17416200.	.17354200.	.17254500.	.17118100.	M(Z) 677
* .16947500.	.16745500.	.16515100.	.16259600.	.15982100.	M(Z) 678
* .15685800.	.15373600.	.15049000.	.14714100.	.14371700.	M(Z) 679
* .14023900.	.13673100.	.13320900.	.12969100.	.12619200.	M(Z) 680
* .12272300.	.11925600.	.11591900.	.11260200.	.10934900.	M(Z) 681
* .10616600.	.10305700.	.10002600.	.09707300.	.09420200.	M(Z) 682
* .09141300/					M(Z) 683
DATA Z76/					M(Z) 684
* .16883000.	.16864500.	.16810200.	.16721200.	.16599000.	M(Z) 685
* .16449600.	.16263300.	.16054800.	.15822700.	.15569800.	M(Z) 686
* .15258800.	.15012400.	.14713200.	.14403800.	.14086200.	M(Z) 687
* .13762800.	.13435400.	.13105800.	.12775500.	.12446000.	M(Z) 688
* .12118500.	.11794000.	.11473500.	.11157800.	.10847400.	M(Z) 689
* .10543100.	.10245100.	.09953800.	.09669600.	.09392700.	M(Z) 690
* .09123000/					M(Z) 691
DATA Z77/					M(Z) 692
* .16366200.	.16349800.	.16301100.	.16221100.	.16111100.	M(Z) 693
* .15972600.	.15807500.	.15618100.	.15406600.	.15175600.	M(Z) 694
* .14927100.	.14663700.	.14387800.	.14101400.	.13806700.	M(Z) 695
* .13505600.	.13199900.	.12891300.	.12581200.	.12270900.	M(Z) 696
* .11961700.	.11654500.	.11350300.	.11050000.	.10754000.	M(Z) 697
* .10463100.	.10177700.	.09898100.	.09624700.	.09357700.	M(Z) 698
* .09067300/					M(Z) 699
DATA Z78/					M(Z) 700
* .15882100.	.15867300.	.15823500.	.15751300.	.15651600.	M(Z) 701
* .15526000.	.15376000.	.15203400.	.15010200.	.14798500.	M(Z) 702
* .14570300.	.14327700.	.14072700.	.13807400.	.13533600.	M(Z) 703
* .13253000.	.12967400.	.12678200.	.12386900.	.12094700.	M(Z) 704
* .11802700.	.11512000.	.11223400.	.10937700.	.10655600.	M(Z) 705
* .10377700.	.10104400.	.09836200.	.09573400.	.09316200.	M(Z) 706
* .09064900/					M(Z) 707
DATA Z79/					M(Z) 708
* .15427100.	.15414000.	.15374300.	.15308600.	.15218300.	M(Z) 709
* .15104600.	.14967200.	.14809400.	.14632400.	.14438000.	M(Z) 710
* .14227600.	.14003900.	.13768000.	.13521800.	.13267100.	M(Z) 711
* .13006400.	.12736400.	.12467300.	.12193500.	.11918200.	M(Z) 712
* .11642500.	.11367300.	.11093500.	.10821800.	.10553000.	M(Z) 713
* .10287800.	.10026000.	.09768800.	.09516300.	.09268800.	M(Z) 714
* .09026500/					M(Z) 715
DATA Z80/					M(Z) 716
* .14995200.	.14987100.	.14951000.	.14891300.	.14808800.	M(Z) 717
* .14704400.	.14575200.	.14434600.	.14272100.	.14093100.	M(Z) 718
* .13899300.	.13692200.	.13473500.	.13244800.	.13007600.	M(Z) 719
* .12763300.	.12513300.	.12259100.	.12001600.	.11742200.	M(Z) 720
* .11481700.	.11221200.	.10961400.	.10703100.	.10446900.	M(Z) 721
* .10153500.	.09943300.	.09696800.	.09454300.	.09216200.	M(Z) 722
* .08982600/					M(Z) 723
END					M(Z) 724

IV G LEVEL 21

MAIN

DATE = 75178

09/11/18

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      DIMENSION HEADS(20)
      DIMENSION HTSTOR(30),ENSTOR(30),IALSTH(30)
      DIMENSION ANG(2500),HT(2500),PLCTA(2500),PLCTY(2500),
      *XPLT(4),YPLT(4),BUFF(1000)
      NCASE=0
      ISTART=1
      JTMAX=-1000.
      WRITE(C,81527)
c1927 FORMAT(1H1///)
      CALL PLOTS(BUFF,4000,10)
      CALL PLUT(C,-12.,3)
      CALL PLUT(0.,-11.5 ,23)
c
c      READ IN CONTROL PARAMETERS
c
c8366 READ(20,END=4554)SLIT,PLTMIN,PLTMAX,DELPLT,DLAM,YHGT,NLINES,END,
      *TL,TA,CL,IPLOT1,IPLOT2
      *LIR2,APRIME
      *TAU
      *HEADS
      THAF=(-1)*LIR2
c
c      READ IN WAVENUMBER, TRANSMISSION PAIRS, CONVERT WAVENUMBERS
c      TO WAVELENGTH AND DETERMINE MAXIMUM TRANSMISSION
c
      DO 837 ICARD=1,NLINES
      READ(20)ANG(ICARD),HT(ICARD)
      IF(HT(ICARD).LT.0.)HT(ICARD)=0.
      STMAX=AMAX1(STMAX,HT(ICARD))
      ANG(ICARD)=(1.E+08)/ANG(ICARD)
c837 CONTINUE
      NCASE=NCASE+1
      II=NLINES
      PLTMIN=ANG(1)
      PLTMAX=ANG(II)
      WIDE=2.*DLAM
      PLTMIN=PLTMIN-2.*WIDE
      PLTMAX=PLTMAX+2.*WIDE
      DELTA=STMAX/5.
c35 CONTINUE
c
c      PRODUCE THE ZERO SLIT WIDTH PLOTS WHEN IPLOT1=1
c
      IF(IPLOT1.EQ.0)GO TO 66001
      TEST=(PLTMAX-PLTMIN)/DELPLT
      ILG=TEST
      ILG=ILG+2
      NLG=ILG
      XPLT(3)=PLTMIN
      XPLT(4)=DELPLT
      YPLT(3)=0.
      YPLT(4)=DELTA
      BUZZE=YPLT(4)*IC.
      CALL AXIS(4.,0.,*A*,-1,NLG,0.,XPLT(3),XPLT(4),10.)
      YPLT(1)=0.
      DO 50 I=1,II

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IV G LEVEL 21

MAIN

DATE = 75178

09/11/18

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      XLAM=ANG(I)
      IF(PLTMIN.GT.XLAM.OR.PLTHAX.LT.XLAM)GO TO 50
      YPLT(2)=ANIN1(HT(1),BCUZE)
      XPLT(1)=XLAM
      XPLT(2)=XPLT(1)
      CALL LINE(XPLT,YPLT,2,1,0,1)
50  CONTINUE
      CALL PLOT(RLG+2,0,-3)
06001 CONTINUE
C
C      PRODUCE THE ACTUAL SPECTRA PLOT
C
      ISAVE=1
      KKOUNT=1
      DELLAM=(PLTHAX-PLTMIN)/2499
      PP1=PLTMIN-DELLAM
991  LOOK=ISAVE-1
      IF(LOOK.LE.0)LOOK=1
C
C      CHOOSE A POINT ALONG THE PLOT AXIS AND SET AN INTERVAL OF WIDTH
C      EQUAL TO THE SLIT WIDTH ON EITHER SIDE
C
      P1=PP1+KKOUNT*DELLAM
      P2=P1+WIDL
      XLAM=(P1+P2)/2
      KOUNT=1
C
C      THIS LOOP DETERMINES WHICH LINES LIE IN THE CHOSEN INTERVAL
C
      DO 5565 I=LOOK,11
      IF(ANG(I).GT.P2)GO TO 992
      IF(ANG(I).LT.P1)GO TO 5569
      IF(KOUNT.EQ.1)ISAVE=1
      KOUNT=KOUNT+1
5565 CONTINUE
      552  NUPTS=KOUNT-1
C
C      THE FOLLOWING STATEMENTS SIMULATE THE TRIANGULAR SLIT FUNCTION
C      BY SUMMING THE CONTRIBUTIONS OF ALL THE LINES IN THE INTERVAL
C
      IF(NUPTS.EQ.0)GL TO 55741
      SUMMER=0.
      IPNT=ISAVE+NUPTS-1
      DO 55347 J=1,IPNT
      IX(J)=HT(J)*((DLAM-ABS(XLAM-ANG(J)))/DLAM
55347 SUMMER=SUMMER+AMAX1(C,THALD)
      PLUTX(KKOUNT)=XLAM
      PLUTY(KKOUNT)=SUMMER
      KKOUNT=KKOUNT+1
      IF(KKOUNT.EQ.2501)GO TO 77
      GO TO 551
55741 PLUTX(KKOUNT)=XLAM
      PLUTY(KKOUNT)=0.
      KKOUNT=KKOUNT+1
      IF(ANG(11).LT.P1)GO TO 77
      IF(KKOUNT.EQ.2501)GL TO 77

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IV G LEVEL 21

MAIN

DATE = 75178

09/11/18

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      GU TO 991
77  I1=KKOUNT-1
      N=11
      TTRAF=.5*TTRAF*DLAM
      DO 88 I=1,N
88  PLOTX(I)=PLQTX(I)+TTRAF
      TEST=(PLTMX-PLTM(N))/DELPLT
      ILG=TEST
      ILG=ILG+2
      RLG=ILG
C
C  DETERMINE THE MAXIMUM VALUE OF THE SPECTRAL CURVE AND IF THIS
C  IS THE FIRST CURVE COMPUTED, THE Y AXIS SCALE FACTOR IS CALCULATED
C
      SPMAX=-100.
      DO 800 I=1,N
      IF(PLQTY(I).LT.SPMAX)GO TO 800
      SPMAX=PLQTY(I)
800  CONTINUE
      IF(I1START.EQ.1)DELYP=SPMAX/YHGT
801  PLOTY(N+1)=0.
      PLOTX(N+2)=DELYP
      PLUTX(N+1)=PLTMIN
      PLQTX(N+2)=DELPLT
      VALMAX=10.*PLOTY(N+2)
      DO 65355 MONDAY=1,N
      IF(PLOTY(MONDAY).GT.VALMAX)PLCTY(MONDAY)=VALMAX
65355  CONTINUE
      NP2=N+2
      WRITE(40)NP2,(PLOTX(L),PLCTY(L),L=1,NP2)
C
C  PRODUCE A SEPARATE PLOT FOR EACH VALUE OF ENO IF I(PLOT2=1
C
      IF(I(PLOT2.EQ.0))GO TO 66002
      CALL AXIS(0.,0.,'A',-1,RLG,0.,PLOTX(N+1),PLOTX(N+2),10.)
      CALL SYMBOL(.5,5.0,.1,'NO',0.,3)
      CALL PLTFLT(-0.,-0.,-0.,ENC,6.,3)
      CALL LINE(PLOTX,PLQTY,N,1,0,1)
      CALL PLOT(RLG+2.,0,C,-J)
66002  CONTINUE
      ISTART=0
      TAUSTR(INCASE)=TAU
      HTSTOR(INCASE)=SPMAX/DELYP
      ENSTOR(INCASE)=ENO
      GO TO 66368
66368  CONTINUE
C
C  PRODUCE THE FINAL SPECTRA PLOT
C
      CALL AXIS(0.,0.,'WAVELENGTH',-10,RLG,0.,PLTMIN,DELPLT,10.)
      CALL SYMBOL(.5,5.9,.1,HEADS,0.,80)
      CALL SYMBOL(.5,5.5,.1,'TE',0.,3)
      CALL NUMBER(-0.,-0.,-0.,TE,0.,-1)
      CALL SYMBOL(.5,5.3,.1,'TA',0.,3)
      CALL NUMBER(-0.,-0.,-0.,TA,0.,-1)
      CALL SYMBOL(.5,5.1,.1,'L=',0.,3)

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IV G LEVEL 21

MAIN

DATE = 75176

09/11/18

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      CALL NUMBER(-0.,-0.,-0.,EL,0.,1)
      CALL SYMBOL(.5,6.9,.1,3HA*,0.,3)
      CALL NUMBER(-0.,-0.,-0.,APRIME,0.,5)
      CALL SYMBOL(-.285715,6.7,-1., NO MAX HT TAU*,0.,19)
      CALL SYMBOL(-.285715,8.55,-1., (IN)*,0.,13)
      DD 78 I=1,NLASE
      YB=8.6-.15*I
      CALL PLTFLY(-.385715,YB,.1,ENSTOR(I),0.,2)
      CALL NUMBER(.42914,YB,.1,HTSTCR(I),0.,2)
      CALL NUMBER(1.028578,YB,.1,TALSTR(I),0.,3)
76  CONTINUE
      ENDFILE 40
      REWIND 40
150  READ(40,END=4995)NP2,(PLOTX(L),PLOTY(L),L=1,NP2)
      N=NP2-2
      CALL LINE(PLOTX,PLOTY,N,1,0,1)
      GO TO 150
4995 CALL PLOT(RLG+2.,0.,-3)
4997 CALL PLOT(0.0,555)
      STOP
      END

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NOMENCLATURE

$\bar{T}_j$	Transmission of spectral line (designated j) through a medium, intensity units
ν_i, ν_j	Wavenumber of the ith or jth spectral line, cm^{-1}
I_{ν_j}	Intensity of source spectral line at wavenumber, ν_j , intensity units
k_{ν_j}, k_{ν_i}	Absorption coefficient for the spectral line at wavenumber, ν_j or ν_i , cm^{-1}
ℓ	Absorption path length, cm
ν	Wavenumber, cm^{-1}
$I_{\nu_j}^{\circ}$	Intensity of source spectral line at center wavenumber, ν_j° , intensity units
$\nu_i^{\circ}, \nu_j^{\circ}$	Center wavenumber of the ith or jth spectral line, cm^{-1}
$(\Delta_s \nu_i)_D$, $(\Delta_s \nu_j)_D$	Doppler width at half maximum intensity of the ith or jth source spectral line, cm^{-1}
κ	Boltzmann's constant, $0.6952 \text{ cm}^{-1} \text{ K}^{-1}$
T_s	Temperature of gas in light source, K
M_s, M_a	Mass of molecules in light source and absorber, respectively, gm
c	Velocity of light, $3 \times 10^{10} \text{ cm/sec}$
$k_{\nu_j}^{\circ}, k_{\nu_i}^{\circ}$	Absorption coefficient at center wavenumber, ν_j° or ν_i° , cm^{-1}
a'	Spectral line broadening parameter (ratio of collisional to Doppler line widths)
y	Dummy variable of integration
ω	Doppler frequency function, $\frac{2(\nu_j - \nu_j^{\circ})}{(\Delta_a \nu_j)_D} \sqrt{\ell n 2}$
$(\Delta_a \nu_j)_D$, $(\Delta_a \nu_i)_D$	Doppler width at half maximum absorption coefficient, $k_{\nu_j}^{\circ}$, of the ith or jth absorption line, cm^{-1}

$(\Delta a^{\nu_j})_L$	Lorentz width at half maximum intensity of the j th absorbing spectral line, cm^{-1}
Z_L	Effective collision frequency for spectral line broadening, sec^{-1}
T_a	Temperature of absorber gas, $^{\circ}\text{K}$
$\overline{T}_{\Delta\nu}$	Transmission over the frequency interval $\Delta\nu$ through a medium, intensity units
$t_{\Delta\nu}$	Transmissivity over the frequency interval $\Delta\nu$; ratio of incident to transmitted intensity
$\Delta\nu$	Wavenumber increment, cm^{-1}
e	Electronic charge, 4.80×10^{-10} esu
m	Electron mass, 9.11×10^{-28} gm
$N_{J''}$	Number density of molecules in the lower state, J'' , cm^{-3}
$f_{J'J''}$	Oscillator strength for the transition from the upper state J' to the lower state J''
h	Planck's constant, 6.625×10^{-27} erg sec
B_{v_0}	Rotational constant for the v th vibrational state (ground state, $v = 0$), cm^{-1}
J''	Rotational quantum number for the lower state
$F(J'')$	Rotational energy of the J'' th rotational state, cm^{-1}
N_0	Total number density of molecules, cm^{-3}
$f_{v'v''}$	Band oscillator strength for the $v' \leftrightarrow v''$ transition
$\nu_{J'J''}$	Wavenumber of the line corresponding to the transition $v'J' \rightarrow v''J''$, cm^{-1}
$\nu_{v'v''}$	Wavenumber at the bandhead of the (v', v'') band, cm^{-1}
$S_{J''J'}$	Rotational strength, or Hönl-London factor, for the $v'J' - v''J''$ vibrational - rotational transition
S	Total electron spin quantum number
N_ℓ	Number density of molecules ℓ other than the absorbing molecule in the absorbing medium, cm^{-3}

σ_{ℓ}^2	Effective collisional cross section for the broadening process by the ℓ th type molecule, cm^2
N/ℓ	Mass of the ℓ th type molecule, gm
λ_j°	Wavelength at line center of the j th spectral line, cm
P_{ℓ}	Partial pressure of the ℓ th type molecule, torr
M_f	Mass of the f th type molecule, gm
C_j	Line broadening constant for the j th spectral line, K/torr or K/atm
C	Average line broadening constant for all spectral lines in a given band, K/atm