

4613-91-T

Report of BAMIRAC

**STUDIES OF  
INFRARED RADIATIVE TRANSFER  
IN HOT GASES**

I: <sup>Spectral</sup> ~~Special~~ Absorptance Measurements  
in the 2.7- $\mu$  H<sub>2</sub>O Bands

F. S. SIMMONS  
C. B. ARNOLD  
D. H. SMITH

August 1965



INFRARED PHYSICS LABORATORY

*Willow Run Laboratories*  
THE INSTITUTE OF SCIENCE AND TECHNOLOGY

Prepared for the Advanced Research Projects Agency,  
Department of Defense, Washington, D. C., Contract SD-91

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THE UNIVERSITY OF MICHIGAN  
Ann Arbor, Michigan

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## NOTICES

Sponsorship. The work reported herein was conducted at the Willow Run Laboratories of the Institute of Science and Technology for the Advanced Research Projects Agency, Department of Defense, under Contract SD-91 (ARPA Order 236) as a part of Project DEFENDER (research on and defense against ballistic missiles). Contracts and grants to The University of Michigan for the support of sponsored research by the Institute of Science and Technology are administered through the Office of the Vice-President for Research.

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## PREFACE

BAMIRAC, the Ballistic Missile Radiation Analysis Center, is a facility of the Infrared Physics Laboratory of the Willow Run Laboratories, a unit of The University of Michigan's Institute of Science and Technology. Supported by ARPA, the Advanced Research Projects Agency, under Contract SD-91, this center for analysis of scientific and technical information is a part of ARPA's Project DEFENDER (research on ballistic missile defense). A variety of theoretical and experimental investigations on ballistic missile phenomenology are performed by BAMIRAC. This report describes one such investigation. The facility also aids ARPA by planning and conducting various technical conferences.

BAMIRAC, which is under the technical direction of the Infrared Physics Laboratory, draws also upon the capabilities of the Infrared and Optical Sensor Laboratory and the Computation Department of the Institute, and upon those of the Aircraft Propulsion Laboratory of the Department of Aeronautical and Astronautical Engineering and of other departments of The University of Michigan, particularly within the College of Engineering.



**ACKNOWLEDGMENT**

The efforts of Mr. Norman F. Kent in programming the data reduction are greatly appreciated.

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## STUDIES OF INFRARED RADIATIVE TRANSFER IN HOT GASES I: Spectral Absorptance Measurements in the 2.7- $\mu$ H<sub>2</sub>O Bands

### ABSTRACT

Measurements of spectral absorptances in the 2.7- $\mu$  water vapor bands were made at moderate resolution, for pressures from 50 mm to 1 atm, temperatures from 750<sup>o</sup> to 1300<sup>o</sup>K, and path lengths of 7.75 and 60.0 cm. Samples of pure water vapor were contained in quartz cells heated in a furnace which was built into a specially designed double-beam spectrometer. The resultant spectra are presented and correlated with those obtained by other investigators. Values of a strong-line parameter and a mean line strength for use in nonisothermal radiance calculations were determined.

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### 1

### INTRODUCTION

The infrared radiation in the vibration-rotation bands of hot water vapor is a salient spectral characteristic of the exhaust jets from most modern rocket engines. Quantitative calculations of the spectral and total radiant intensity of ballistic missiles during the launch phase would be of obvious value in their characterization as infrared targets. An exact approach would consist of a direct application of the equation of transfer using absorption coefficients derived from the contributions along the contours of all lines in the particular region of the spectrum; integration with respect to both wavelength and distance along the line of sight would then provide a precise detailed spectrum of the emission from the extended gaseous region in a particular direction. This approach was used in a recent study by Gates et al. [1] of the related but simpler problem of transmission through the atmosphere. Such computations for nonisothermal emission would require positions, strengths, shapes, and half-widths of the multitude of lines arising from the many possible initial energy states populated at higher temperatures in the three vibrational bands located in the 2.7  $\mu$  region. Therefore, such an approach is not considered reasonable for engineering purposes which require only a reliable estimate of the average spectral radiances in this region.

The alternative approach is an application of a suitable model [2] to represent the arrangement of spectral lines within the band. Calculations of average spectral radiances can then be made using experimental data on the spectral emissivities of water vapor at high temperatures. The experimental investigation reported here was undertaken with such a purpose in mind.

A number of previous investigators [3-5] have measured emissivities in the  $2.7 \mu$  bands of hot water vapor; unfortunately those measurements were made using geometrical path lengths of about 10 cm or less. Since it was shown in a recent analysis [6] that the determination of the proper nonisothermal calculations based on a particular band-model would require measurements over a wide range of optical depths, the present experimental study was partly directed toward extending the range of those data. Reported herein are the results of this study which was made using sample cells 7.75 and 60.0 cm long, containing pure water vapor in various amounts, heated in a furnace to temperatures from  $750^{\circ}$  to  $1300^{\circ}$ K.

Another report will cover the application of these data in nonisothermal band model representations and compare calculated and observed spectral radiances for water vapor heated in the 60-cm cell with various temperature gradients imposed [7].

## 2

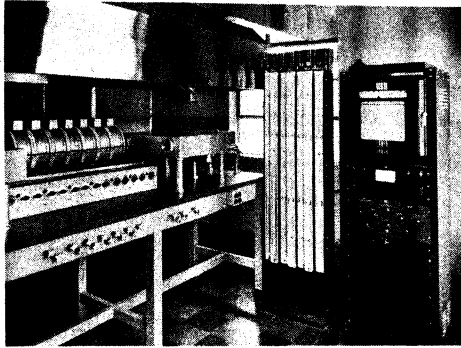
### EXPERIMENTAL DETAILS

The apparatus used for the experimental study of infrared absorption (and emission) in hot gases is shown in Fig. 1. In essence, it consists of a segmented combustion tube furnace built into one beam of a double-beam ratio-recording spectrometer which was designed and constructed specifically for this study. The arrangement of the choppers and the use of a blackbody as the reference source afford the direct measurement of either spectral absorptance or spectral radiance of a sample.

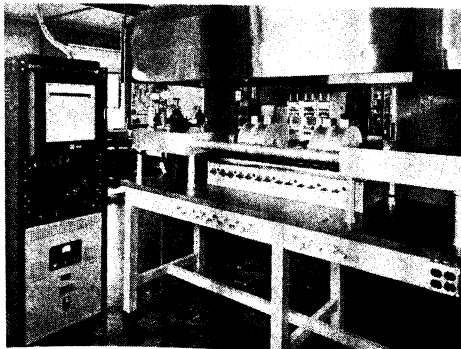
#### 2.1. OPTICS

Figure 2 is a schematic of the optical circuit. Light from a graphite-tube blackbody (1) is split into two beams by a pair of diagonals and redirected into a pair of spherical mirrors (3) (2 1/2-in. diameter and 36-in. radius). One beam passes through the sample cell (8) in the furnace; the two beams are collected by another pair of spherical mirrors which reimage the blackbody aperture onto the slit of the monochromator (7) (Perkin-Elmer Model 99G). Iris diaphragms (6) at each of the second pair of spheres serve to limit the angular field and to balance the beams.

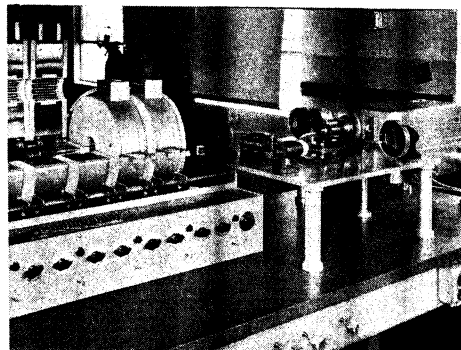
For absorption, the chopper (2) adjacent to the blackbody source is used; thus emission from the hot gas is not sensed. For emission, the chopper adjacent to the monochromator is actuated. In both cases, quadrature chopping is used; i.e., the beams are chopped  $90^{\circ}$  out of phase. The shutters (4) are manually operated; the zero level in absorption is obtained by closing



(a)



(b)



(c)

FIGURE 1. DOUBLE-BEAM SPECTROMETER. (a) Right end view. (b) Left end view. (c) Optical assembly.

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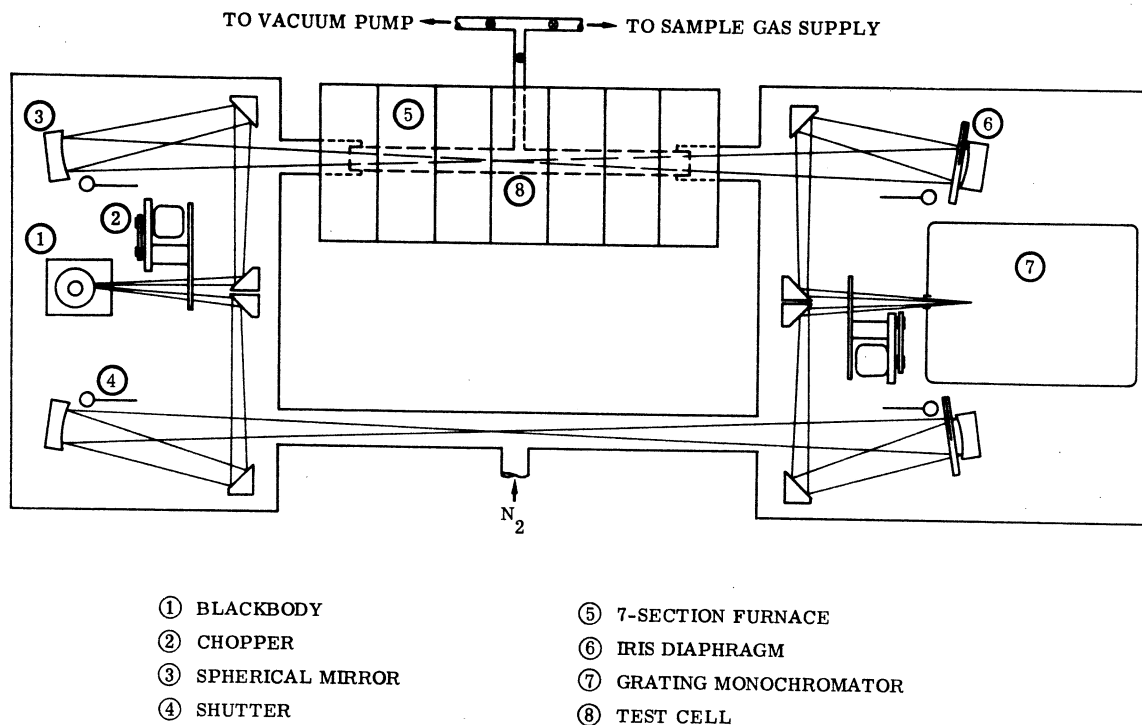


FIGURE 2. OPTICAL DIAGRAM

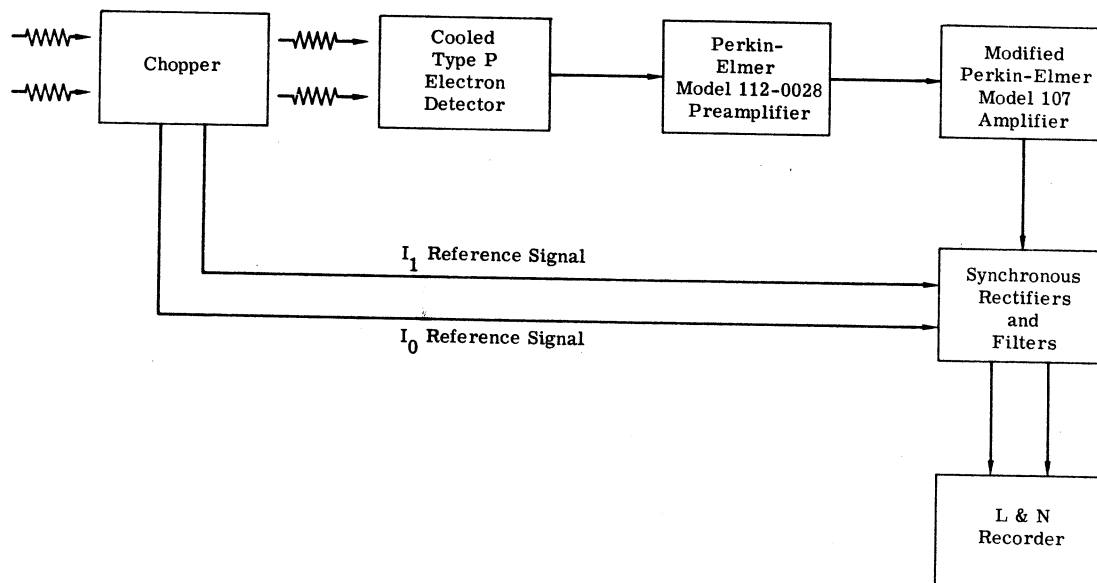


FIGURE 3. ELECTRONIC BLOCK DIAGRAM

the upstream shutter (closer to the source) in the sample beam; in emission this shutter remains closed after the beams are balanced, and the zero level is obtained by closing the downstream shutter.

For an emission measurement the blackbody can be calibrated by redirecting the reference beam into an optical pyrometer by means of a mirror mounted on the back of the downstream shutter. The blackbody current vs temperature is sufficiently stable that only intermittent recalibrations are necessary. The optical pyrometer itself is calibrated against an NBS-certified tungsten ribbon filament lamp.

The monochromator double-passes the radiation onto a grating with 300 lines/mm blazed for  $3 \mu$ . A germanium filter in front of the entrance slit cuts off the radiation below  $1.8 \mu$  to prevent mixing of second-order dispersed light in the wavelength region of detector operation. A cooled PbS detector is installed external to the monochromator with an elliptical mirror to collect the light from the exit slit. The detector is a  $0.25 \times 2.0$  mm Type P Kodak Ektron cell installed in a dewar and cooled with liquid nitrogen.

The entire optical path outside the sample cell is thoroughly flushed by dry nitrogen gas (generated by boiling liquid nitrogen) in order to eliminate absorption by  $H_2O$  and  $CO_2$  in the atmosphere. The resultant residual absorption is sufficiently low that individual lines can be assumed to be within their linear region of growth. Under these conditions, double-beam ratio measurements are reliable, especially for samples whose concentrations are such that the absorptance exhibits square-root growth.

## 2.2. ELECTRONICS

The electronic circuit is illustrated in block diagram form in Fig. 3. The signal from the detector is amplified and synchronously rectified by the demodulation circuit, which is driven by the signals of two photodiodes facing a pair of small lamps across the chopper. The quadrature chopping provides a zero reference level so that two dc signals proportional to the radiances in the two beams can be separated. The signal corresponding to the reference beam is then placed across the slide wire of a recording potentiometer, the sample beam signal across the slider. In this way, the ratio of the radiances in the sample and reference beams is indicated directly in spite of an order-of-magnitude variation in blackbody radiance and detector responsivity over the wavelength range of interest.

The completeness of beam-signal separation by the demodulation is quite sensitive to the phasing of the reference signal; a  $1^\circ$  error in phase would result in about a 1.5% contribution



of unwanted energy from the other channel. The fine adjustment of the phasing therefore is based on observations of the final display on the potentiometer. In single-beam operation, the phase adjustment is set to minimize the effect of interrupting the light in the other beam. The residual mixing of the beams in double-beam operation was thus determined to be about 1%.

### 2.3. SAMPLE CELL LOADING

The optical depth, i.e., the quantity of water vapor, in a given sample was determined by the pressure and temperature measured during the loading process, the equipment for which is schematized in Fig. 4. The sample cell was evacuated and maintained at a desired uniform temperature. Distilled water was heated in a flask to a temperature at which the vapor pressure equaled the desired sample pressure. The valve between the flask and the sample cell was then opened. Since the sample cell and the connecting tubing were maintained at a temperature above that of the flask, no condensation could occur during loading, and at equilibrium the optical depth of the sample corresponded to the cell temperature and flask pressure. The flask thermometer was calibrated against a more precise instrument from 0° to 100°C. Prior to loading, the entire system including the space above the liquid level in the flask was evacuated to remove the air. After loading, the petcock on the cell was closed; since the cell could hold a vacuum of 10  $\mu$  for more than 24 hours, it was assumed to be pressure tight during the measurement.

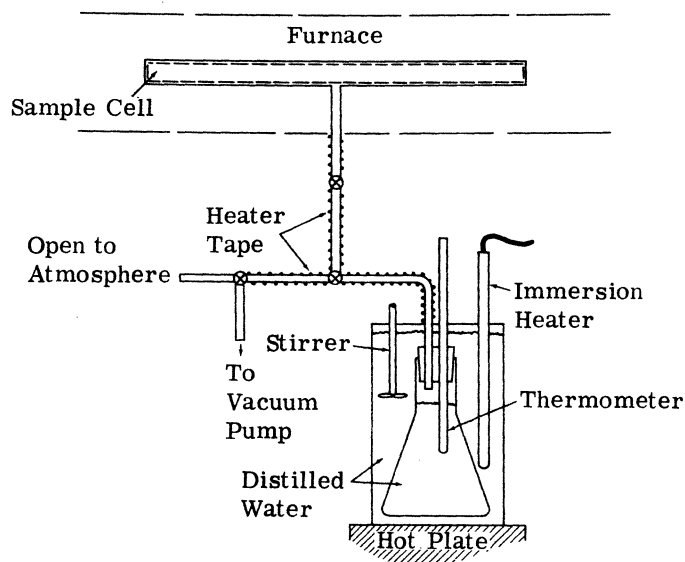


FIGURE 4. ARRANGEMENT FOR LOADING SAMPLE CELL

#### 2.4. DATA REDUCTION

Quartz cells 7.75 cm and 60.0 cm long were used. The cells were fabricated from fused quartz tubing and G. E. "waterfree" quartz flats for windows. Nonetheless, the characteristic absorption band due to water occluded in the quartz windows was evident during all measurements; the peak absorptance was approximately 20%. However, this caused no difficulty in the absorptance measurement since the ratio was determined from the differences in recorder deflection between the sample scan and the background scan immediately preceding or following. An automatic curve reader provided punched-card inputs for a simple computer program which yielded the reduced data in two forms: the primary output is a curve of absorptance vs. wavelength at the resolution of the measurement; in addition, a corresponding curve is produced in which the spectral detail is mostly eliminated by a simple averaging procedure. A typical spectrum at the higher resolution is shown in Fig. 5.

The data-reduction process for emission proceeds similarly to that for absorption except that a correction is necessary to account for emission from the cell windows. The resultant reduced spectra are obtained in terms of the fraction of the reference beam radiance; conversion to spectral radiance is made simply by multiplying by the value of the Planck function corresponding to the temperature of the blackbody.

#### 2.5. RESOLUTION

The principal objective of the experimental study was to provide data at a fairly low resolution, i.e., spectra in which the shape of the band is evident but individual rotational lines or clusters of lines are not resolved. The resolution at which Fig. 5 was obtained actually represented the minimum possible in the experimental arrangement shown in Fig. 2. (The slit opening that was used, 0.5 mm, was the widest that could be filled with an image of the blackbody aperture. This necessitated the smoothing in the data-reduction process.) Figure 5 indicates the effective slit width,  $0.003 \mu$ , which is typical for this study. A few spectra were obtained at higher resolution in order to examine relative line strengths throughout the band. Representative unreduced spectra are shown in Fig. 6 and 7; the distance between the short vertical lines indicated by arrows in each figure represents the same spectral interval. The apparent intensities of the spectral lines are considerably greater at the higher resolution; however, the apparent line widths are much greater than the actual widths which have been reported [8]. Hence, it follows that most of the prominent lines in these spectra must be strong.

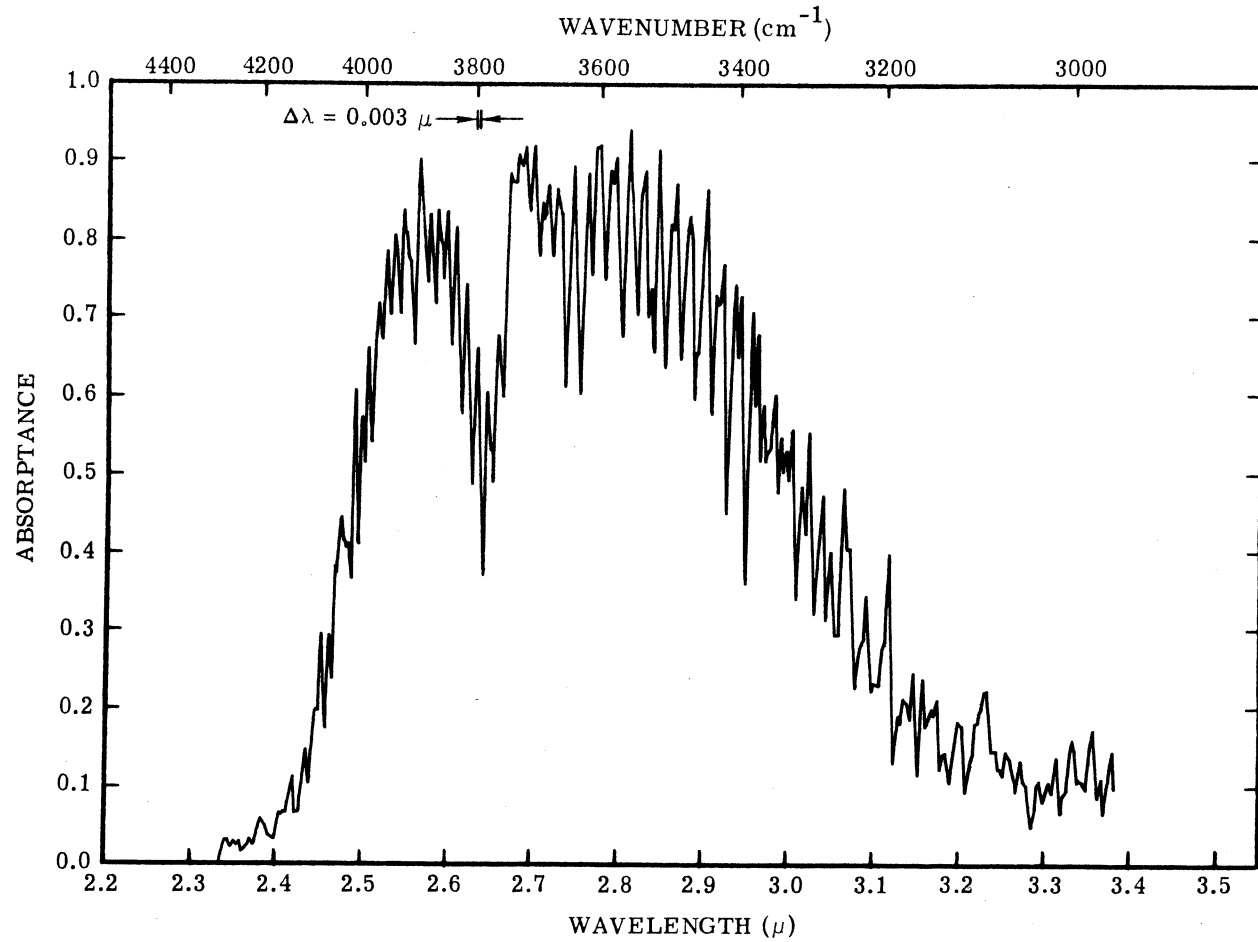


FIGURE 5. TYPICAL ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 744 mm, T = 941<sup>o</sup>K.

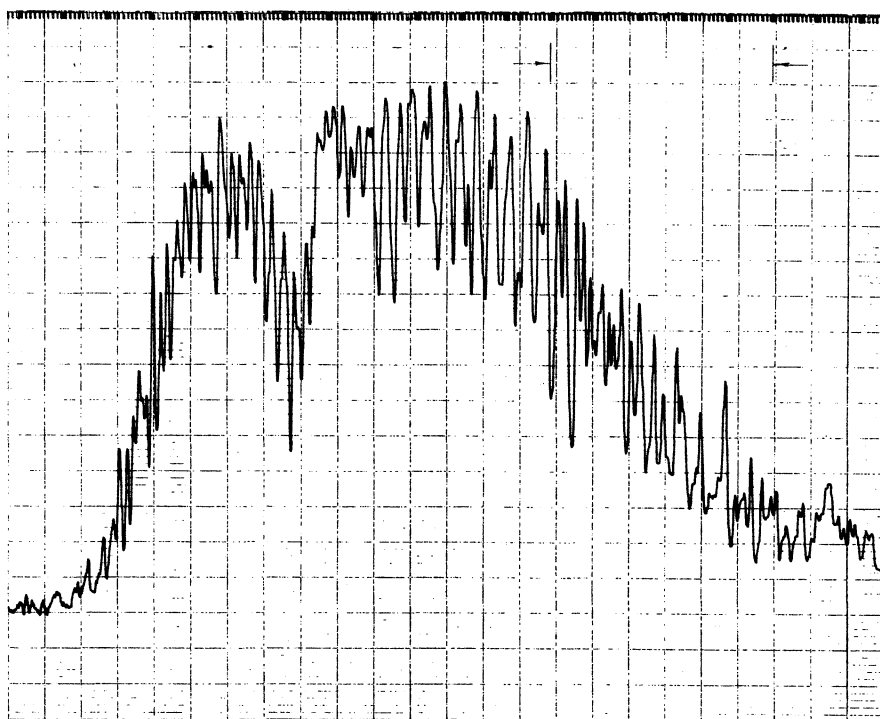


FIGURE 6. TYPICAL UNREDUCED SPECTRUM FOR SLIT OPENING OF  $500 \mu$

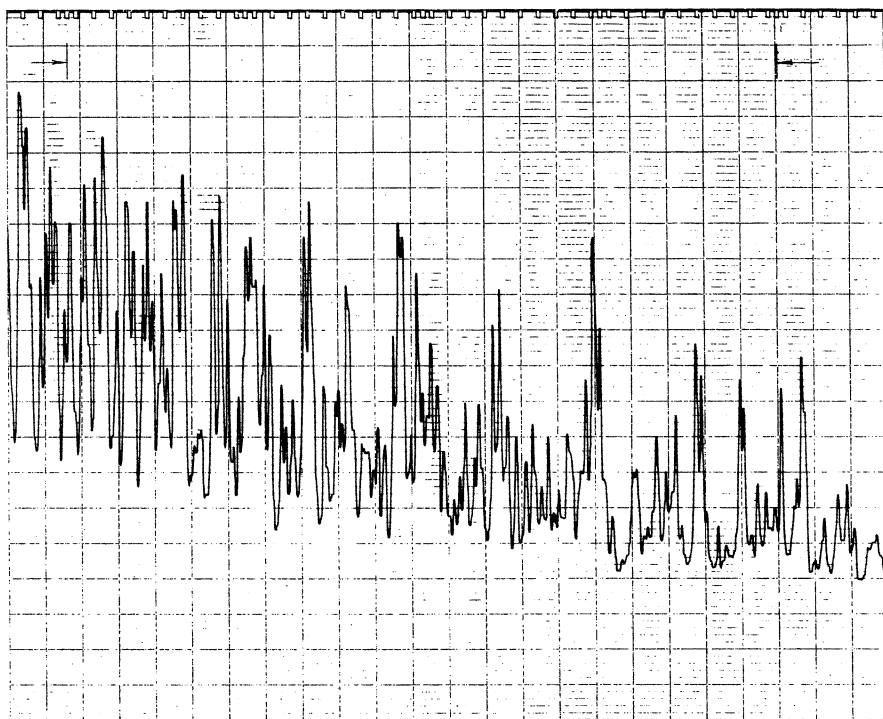


FIGURE 7. TYPICAL UNREDUCED SPECTRUM FOR SLIT OPENING OF  $55 \mu$

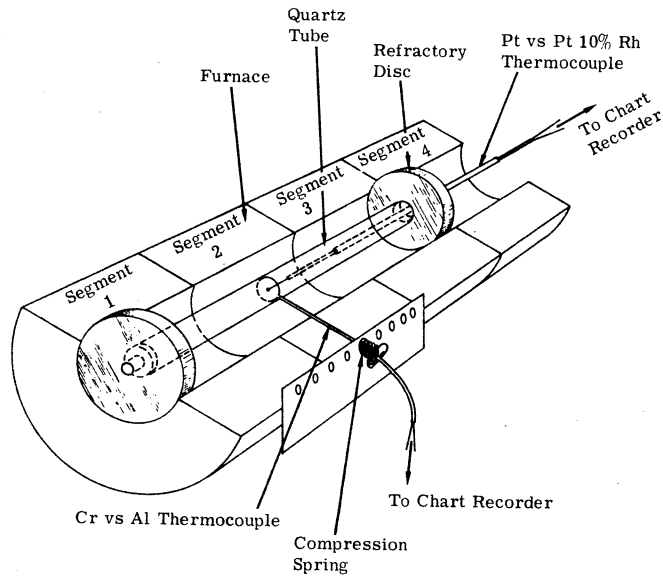
### 2.6. TEMPERATURE MEASUREMENTS

The temperatures along the length of 60-cm quartz cell are measured with chromel-alumel thermocouples looped around the tube at various locations. In order to ascertain whether the temperature gradient in the gas sample within the tube corresponds to the temperature gradient in the tube wall, a few preliminary tests were made. A quartz tube 12 in. long and 1 in. in diameter was mounted between two refractory discs, Fig. 8(a). The tube was scribed at 1-in. intervals along its length. The outside temperature of the tube was measured with loop thermocouples of chromel vs. alumel, (Fig. 8b); the air temperature within the tube was measured with a fine-wire thermocouple of platinum and platinum—10% rhodium (Fig. 8c).

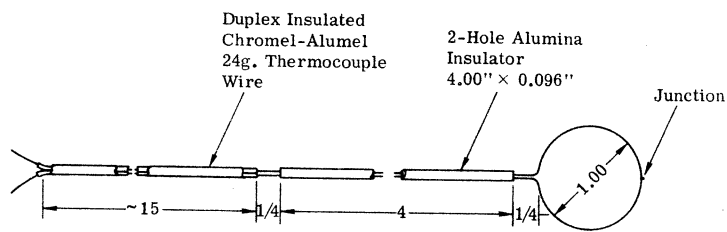
The tube was installed in the furnace, and a number of temperature profiles were imposed. The results are presented in Table I. For air at 1 atm, the differences between the indicated air temperature and tube wall temperature are seen to be quite small. By virtue of the lower molecular weight, the thermal conductivity of water vapor is greater than that of air; hence it was concluded that differences between the water vapor and cell-wall temperature profiles in the test cell would likewise be small for pressures of the order of an atmosphere.

TABLE I. COMPARISON OF SAMPLE CELL WALL AND GAS TEMPERATURE, °K

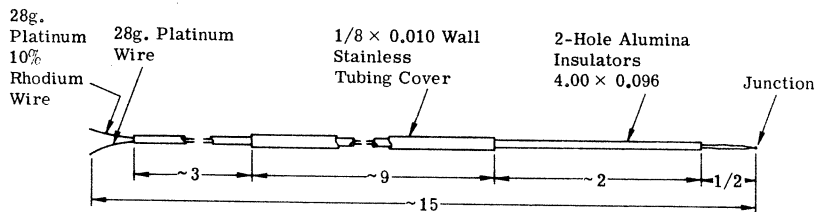
Station	T <sub>wall</sub>	T <sub>gas</sub>	T <sub>wall</sub>	T <sub>gas</sub>	T <sub>wall</sub>	T <sub>gas</sub>	T <sub>wall</sub>	T <sub>gas</sub>	T <sub>wall</sub>	T <sub>gas</sub>
1	414	394	478	500	278	305		900	942	939
2	449	452	557	563	350	330	937	946	972	978
3	510	517	632	634	384	375	947	954	985	997
4	639	629	747	736	445	433	960	962	1003	1008
5	749	752	846	842	506	499	996	1000	1037	1038
6	809		905	906	565	563	1019	1015	1057	1068



(a)



(b)



(c)

FIGURE 8. ARRANGEMENT FOR COMPARING TEMPERATURE GRADIENTS IN SAMPLE GAS AND CELL WALL

## CORRELATION OF ABSORPTION DATA

The complete set of 48 reduced absorption spectra for pure water vapor comprises the appendix. The set represents a range of temperatures (T) from 750° to 1300°K, and pressures (P) of 25 to 760 mm in cells of length (L) 7.75 and 60.0 cm. The corresponding smoothed spectra are presented in composite Fig. 9 through 15.

For nonisothermal radiative transfer calculations, two parameters are required: the strong-line parameter  $\langle [(b/d)(S/d)]^{1/2} \rangle$ , and the mean absorption coefficient  $\langle S/d \rangle$ , where S is the temperature-dependent line strength, b and d are the width and spacing of the lines, and  $\langle \rangle$  denotes an average value. In order to evaluate these parameters, the smoothed spectral absorptance ( $\bar{\alpha}$ ) obtained in the 60-cm cell (Fig. 9 through 12) were cross-plotted vs. either X, the standard optical depth, or vs. Y, the modified optical depth [6], for representative wavelengths (Fig. 16 through 23).

The strong-line parameter was obtained by fitting lines of slope 1/2 through the data of  $\bar{\alpha}$  vs. Y (Fig. 16-19), for  $Y < 1.0$ . (At larger values of Y, the decreasing slope is attributable to overlapping of lines, and gradually approaches zero for complete absorption.) The mean absorption coefficients were evaluated by fitting lower-limit asymptotes of slope 1 to the plots of  $\bar{\alpha}$  vs. X (Fig. 20-23). (Actually, the results so obtained are questionable in absolute value; the asymptotic value of unity slope for  $\bar{\alpha}$  vs. X, i.e., a linear growth of absorptance with optical depth, although necessary, is not sufficient for establishing the mean absorption coefficient [4]. However, if only the ratio of the absorption coefficient to that at a reference temperature is required in a calculation of net radiance from a nonisothermal region, error due to the uncertainty in the absolute values is probably small.) The resultant values of the strong-line parameter and the mean absorption coefficient so obtained are plotted vs. temperature in Fig. 24 and 25, respectively. The pairs of curves for  $\bar{\alpha}/2\sqrt{Y}$  and  $\bar{\alpha}/X$  vs. T at the specified wavelengths were fitted under the constraint, based on physical considerations, that they be similar and monotonic.

Figure 26 is a comparison of data obtained with the 60-cm cell and the 7.75-cm cell in plots of  $\bar{\alpha}$  vs. Y or X at the wavelengths indicated. Clearly, the use of the modified optical depth Y provides much better correlation than the standard optical depth X. The disagreement in the data of  $\bar{\alpha}$  vs. X can be attributed to the effects of pressure broadening; a given optical depth, i.e., a certain amount of gas, implies a much higher pressure in the short cell than in the long. Thus the broadening of the lines with some attendant overlapping can result in significantly larger values of absorptance. This effect is well known and must be taken into account in either isothermal or nonisothermal transfer calculations.



These results were obtained using pure water vapor. In practice, however, hot water as an emitter is usually found as one of several components of an exhaust gas. Since it is well known that foreign gases broaden spectral lines in varying degrees compared with self-broadening [9], extension of these results to gas mixtures must be done with care. A moderate amount of foreign-gas broadening can be taken into account by defining the modified optical depth as  $dY \equiv [P(\text{H}_2\text{O})/P_0][P(\text{total})/P_0][T_0/T]^{3/2} dL$ , i.e., by assuming equal broadening by foreign and emitting molecules. The validity of so doing is supported by the correlation of the absorptances for pure water vapor obtained here and in a previous study by Burch and Gryvnak [3], with absorptances in rocket exhaust gases consisting of  $\text{O}_2/\text{H}_2$  and  $\text{O}_2/\text{NH}_3$  combustion products [10,11]. The degree of this correlation is indicated in Fig. 27, which shows plots of average absorptances at the maxima of the "P, Q, and R branches" of the  $2.7\text{-}\mu$  band structure vs. the modified optical depth as defined above. The dotted lines have a slope of  $1/2$  and were fitted by inspection. The correlation is quite good in view of the differences in temperatures and spectral slit widths among the several experiments.

## 4

## CONCLUSION

The data presented herein are by no means complete. Especially needed are additional measurements at higher temperatures over the entire range of optical depths from the linear to the overlapping strong-line region, and measurements to more thoroughly account for the effects of foreign gas broadening and of the effective spectral slitwidths used in a particular experiment. However, the present results should provide a reasonable basis for nonisothermal radiance calculations from rocket exhaust jets in which temperatures do not greatly exceed  $1300^\circ\text{K}$  and in which the partial pressure of the water vapor is comparable to the sum of those for the other molecular constituents.

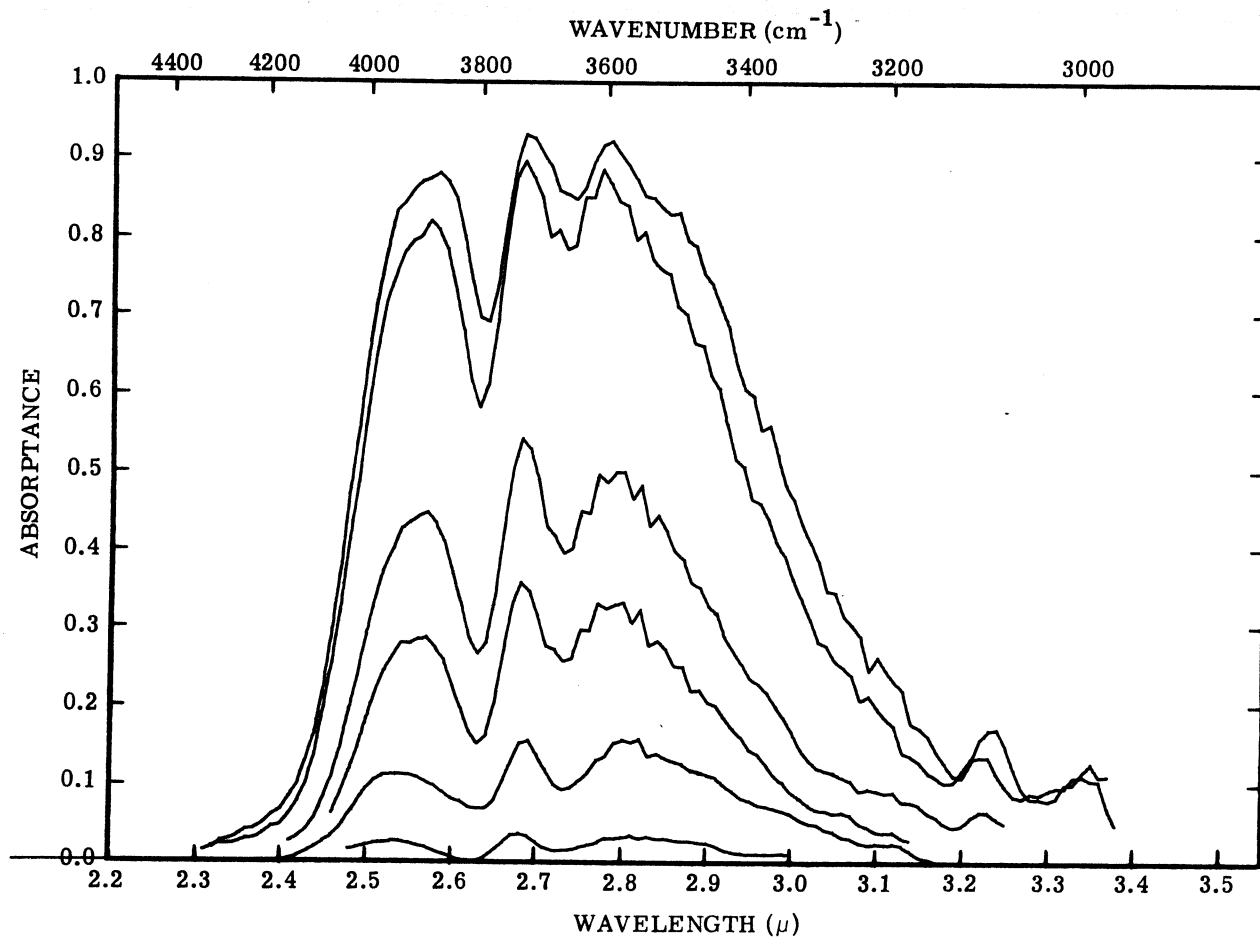


FIGURE 9. SMOOTHED ABSORPTION SPECTRA FOR H<sub>2</sub>O. L = 60 cm; T = 784 ± 18°K;  
 P = 24, 49, 100, 225, 495, 731 mm.

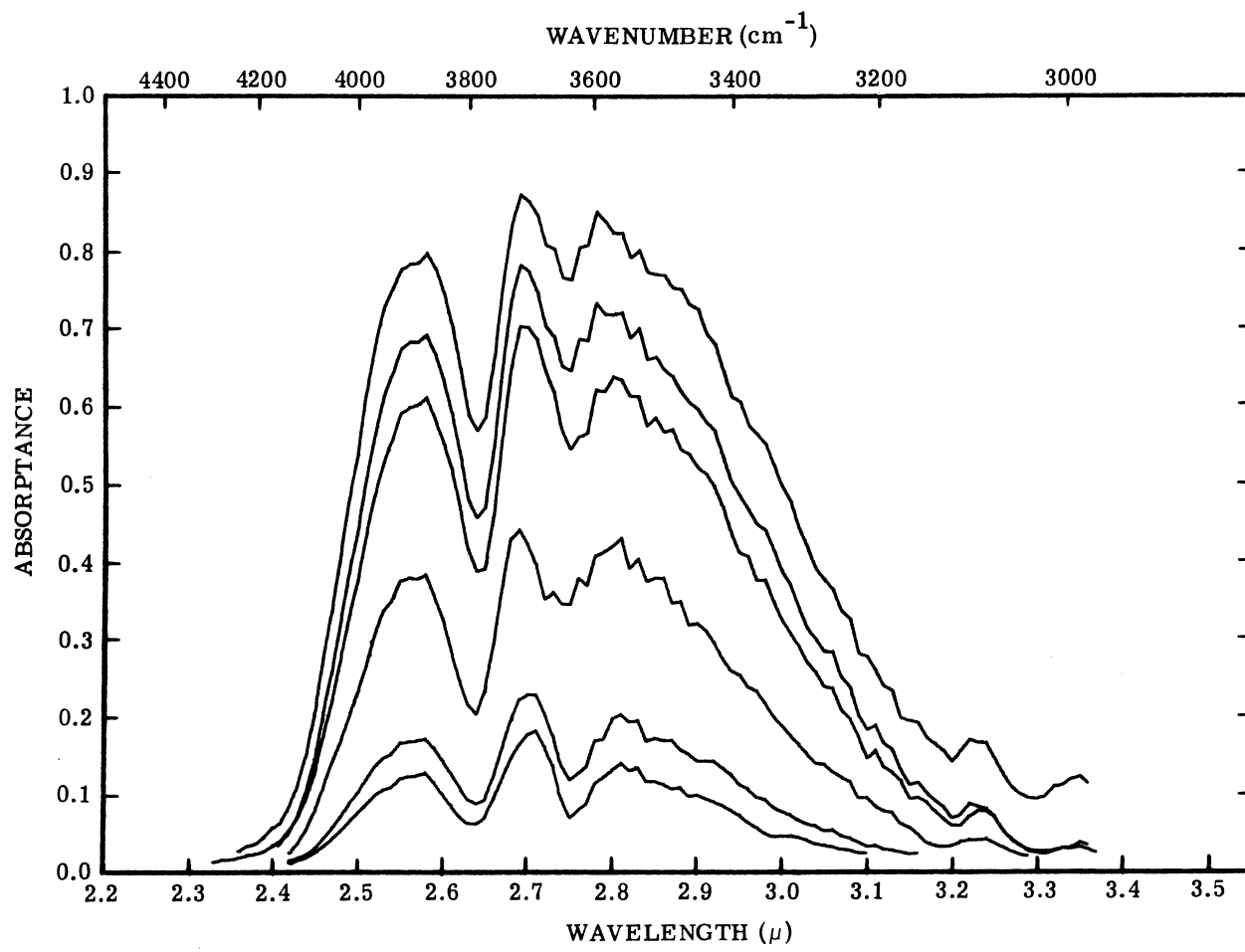


FIGURE 10. SMOOTHED ABSORPTION SPECTRA FOR H<sub>2</sub>O. L = 60 cm; T = 944 ± 7°K;  
P = 46, 78, 150, 373, 510, 744 mm.

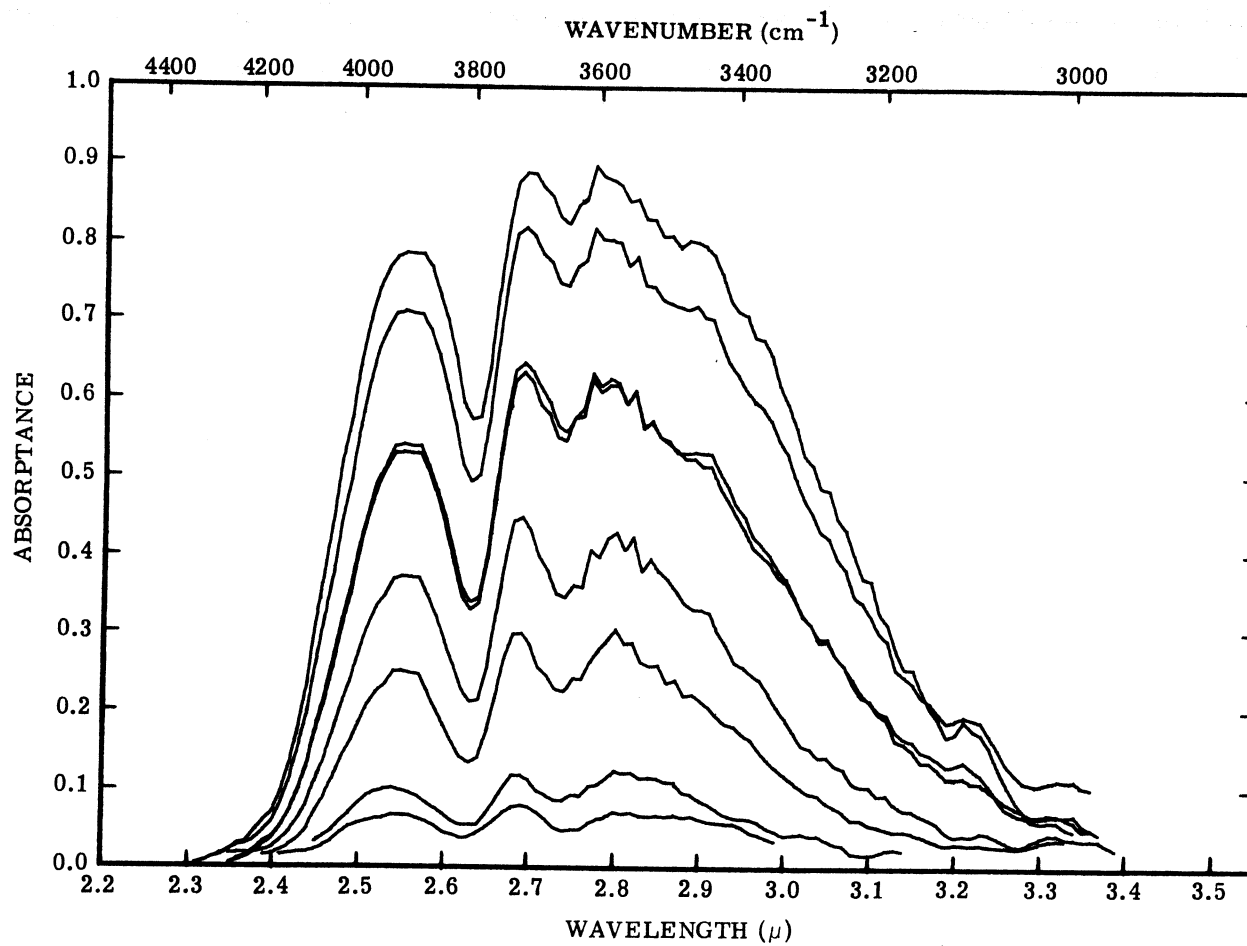


FIGURE 11. SMOOTHED ABSORPTION SPECTRA FOR H<sub>2</sub>O. L = 60 cm; T = 1020 ± 7°K;  
 P = 25, 50, 109, 201, 345, 349, 548, 712 mm.

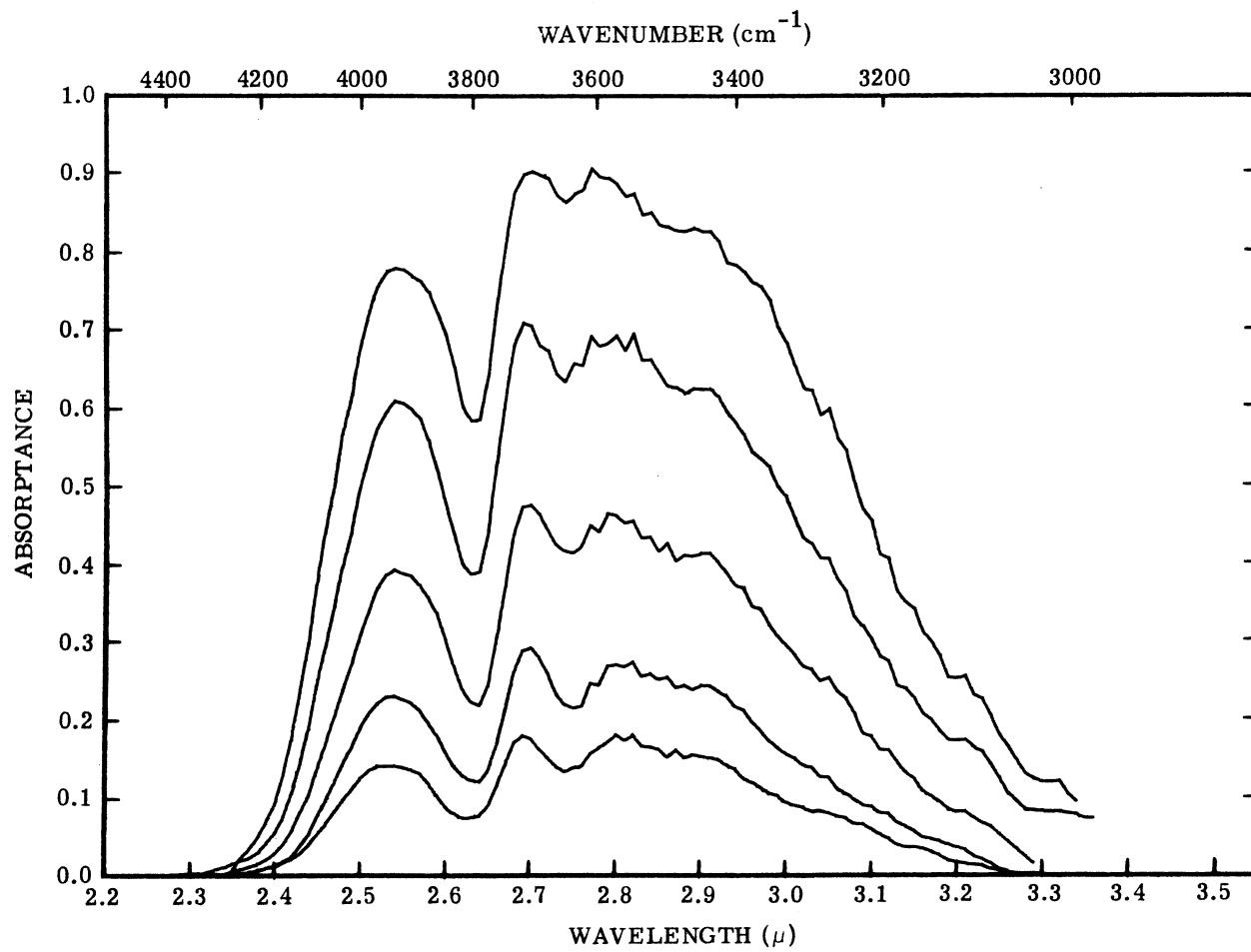


FIGURE 12. SMOOTHED ABSORPTION SPECTRA FOR H<sub>2</sub>O. L = 60 cm; T = 1177 ± 6°K;  
P = 77, 131, 243, 446, 808 mm.

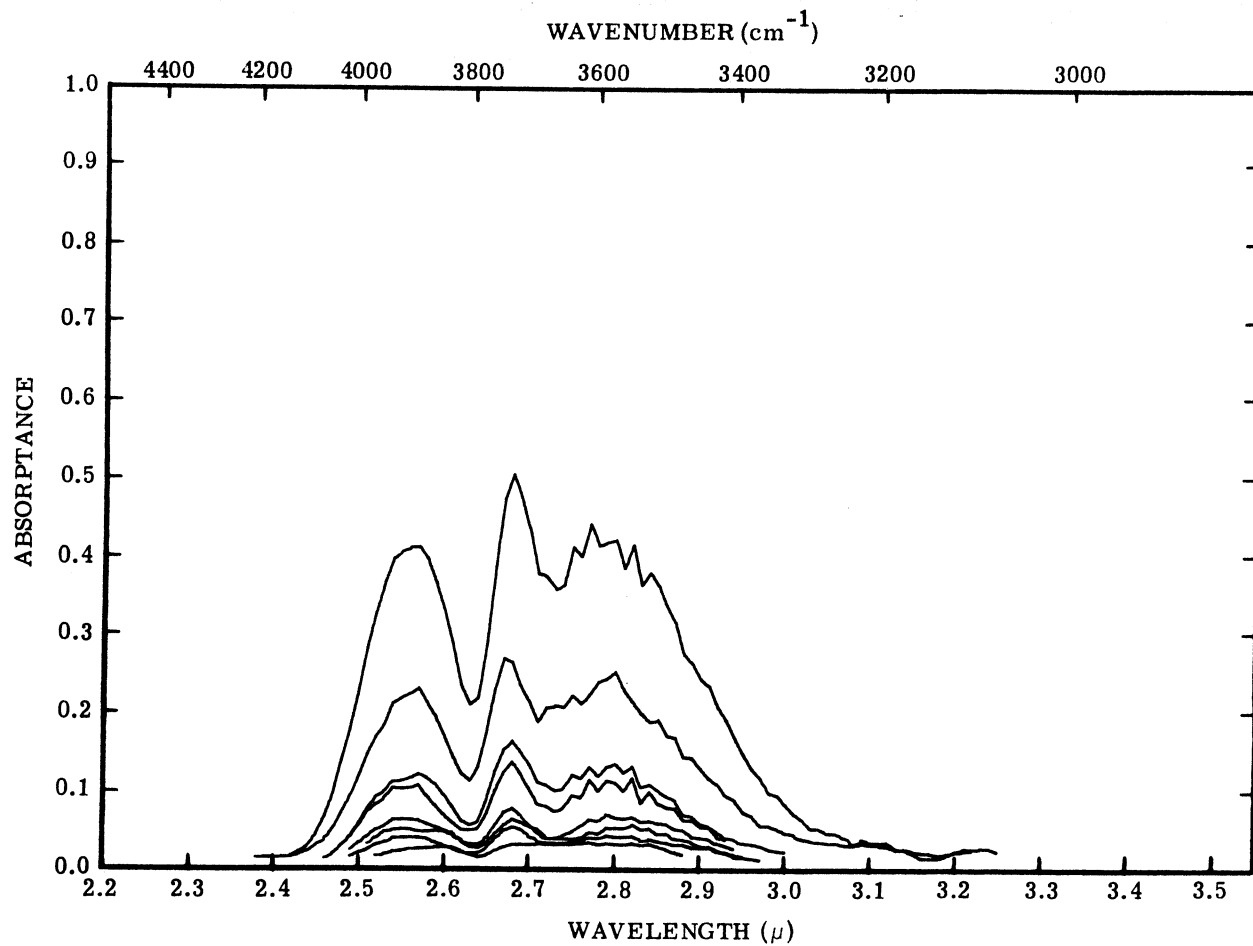


FIGURE 13. SMOOTHED ABSORPTION SPECTRA FOR  $H_2O$ .  $L = 7.75$  cm;  $T = 773 \pm 13^\circ K$ ;  
 $P = 26, 49, 52, 89, 143, 285, 625$  mm

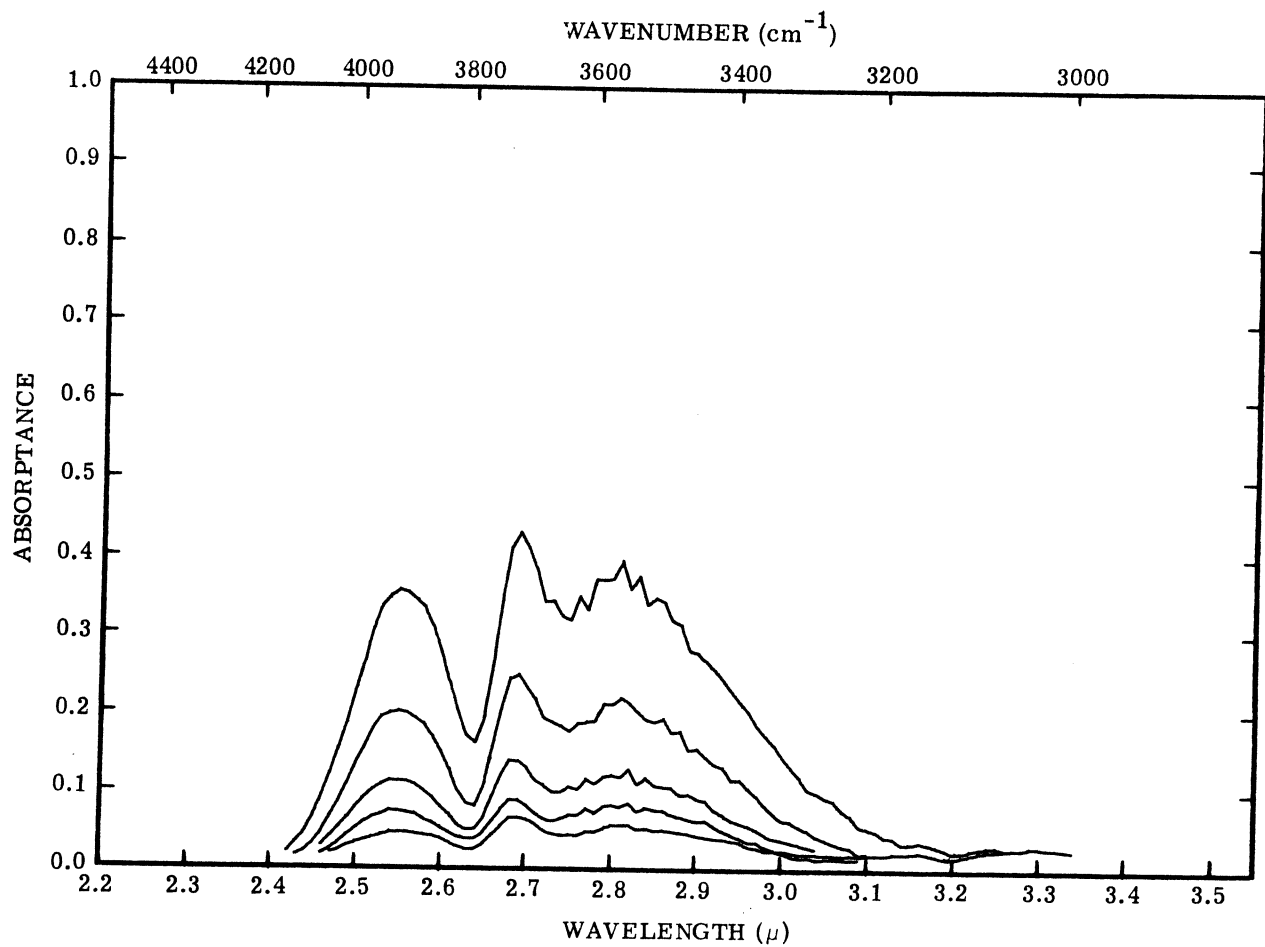


FIGURE 14. SMOOTHED ABSORPTION SPECTRA FOR H<sub>2</sub>O. L = 7.75 cm; T = 1046 ± 18°K;  
P = 57, 113, 181, 357, 707 mm.

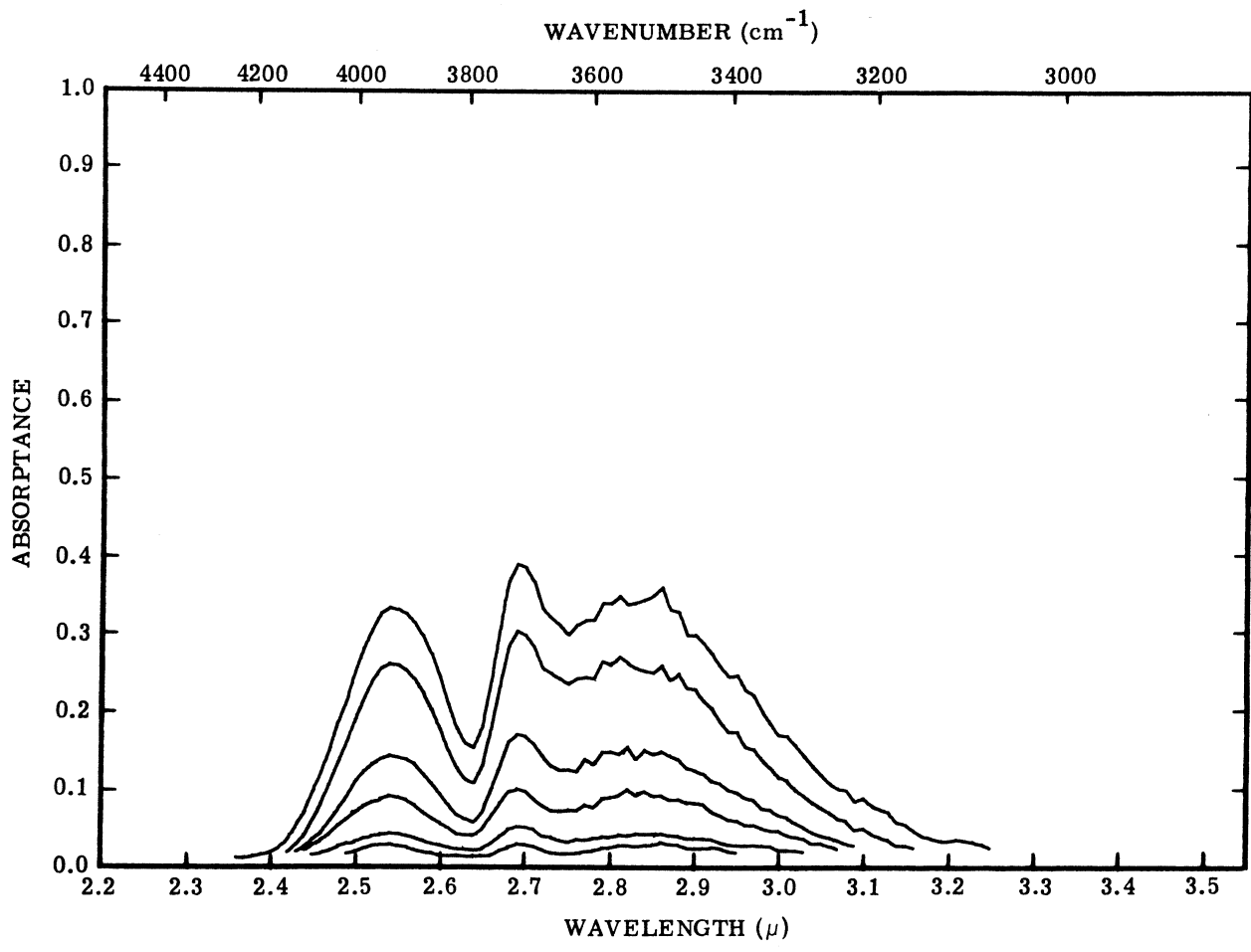


FIGURE 15. SMOOTHED ABSORPTION SPECTRA FOR  $\text{H}_2\text{O}$ .  $L = 7.75$  cm;  $T = 1263 \pm 17^\circ\text{K}$ ;  
 $P = 41, 75, 149, 275, 546$  mm.



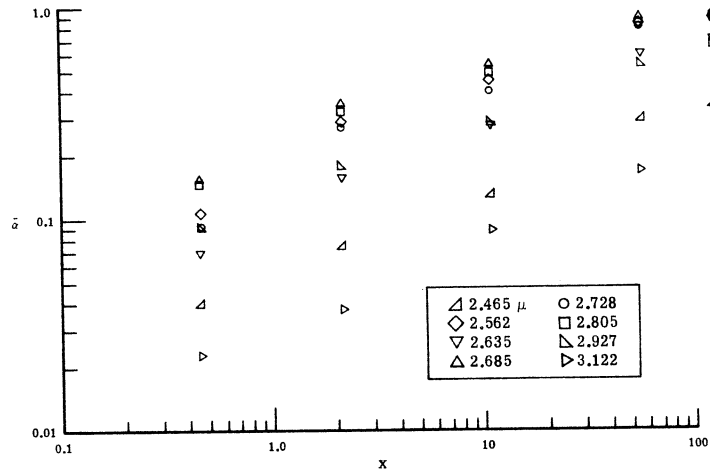


FIGURE 16. AVERAGE ABSORPTANCE VS. MODIFIED OPTICAL DEPTH.  
 $L = 60 \text{ cm}$ ,  $T = 784 \pm 18^\circ\text{K}$ .

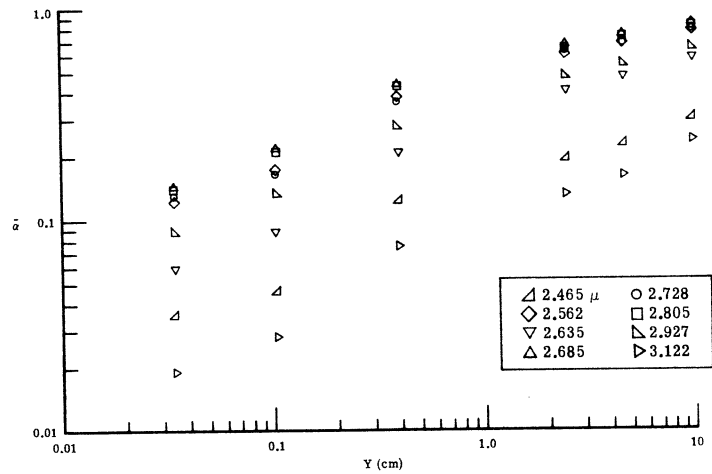


FIGURE 17. AVERAGE ABSORPTANCE VS. MODIFIED OPTICAL DEPTH.  
 $L = 60 \text{ cm}$ ,  $T = 944 \pm 7^\circ\text{K}$ .

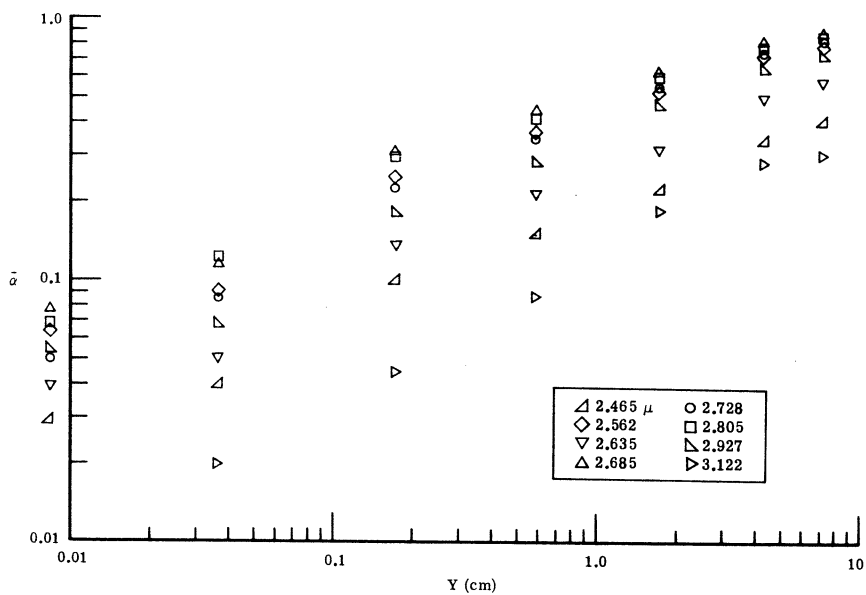


FIGURE 18. AVERAGE ABSORPTANCE VS. MODIFIED OPTICAL DEPTH.  $L = 60$  cm,  $T = 1020 \pm 7^{\circ}\text{K}$ .

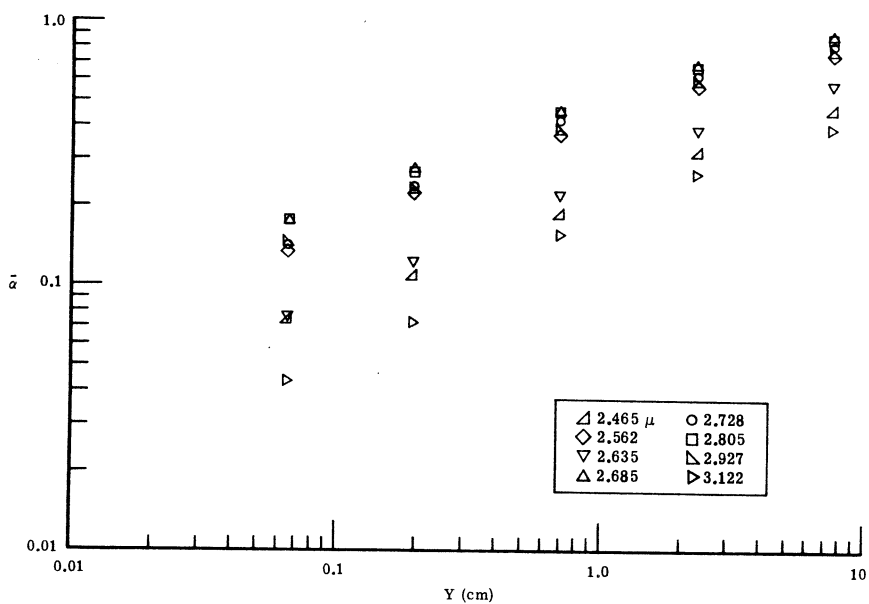


FIGURE 19. AVERAGE ABSORPTANCE VS. MODIFIED OPTICAL DEPTH.  $L = 60$  cm,  $T = 1177 \pm 6^{\circ}\text{K}$ .

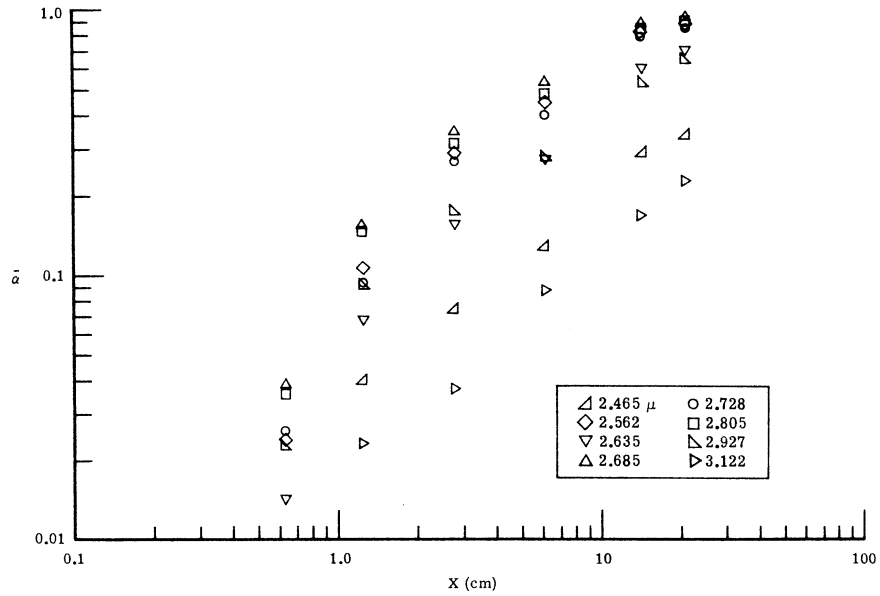


FIGURE 20. AVERAGE ABSORPTANCE VS. STANDARD OPTICAL DEPTH.  $L = 60$  cm,  $T = 784 \pm 18^\circ\text{K}$ .

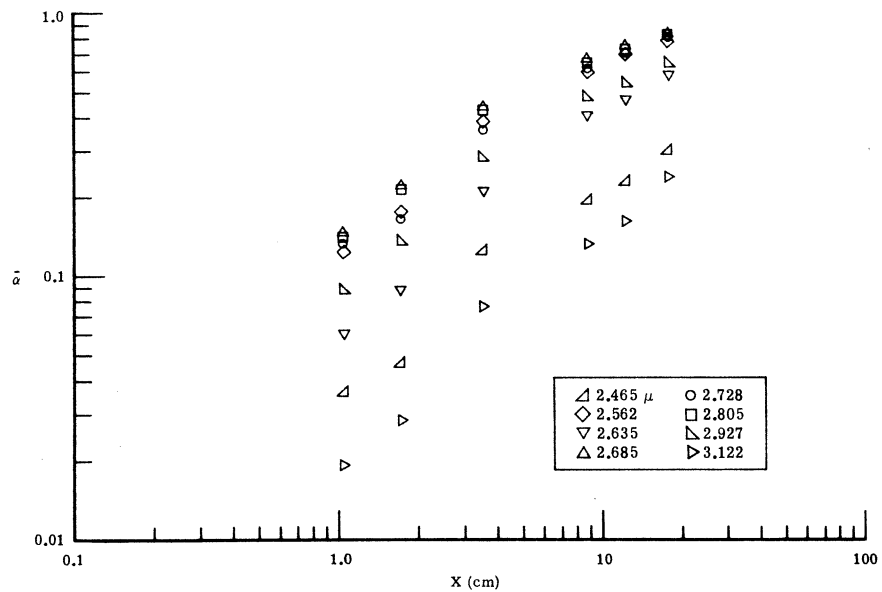


FIGURE 21. AVERAGE ABSORPTANCE VS. STANDARD OPTICAL DEPTH.  $L = 60$  cm,  $T = 944 \pm 7^\circ\text{K}$ .

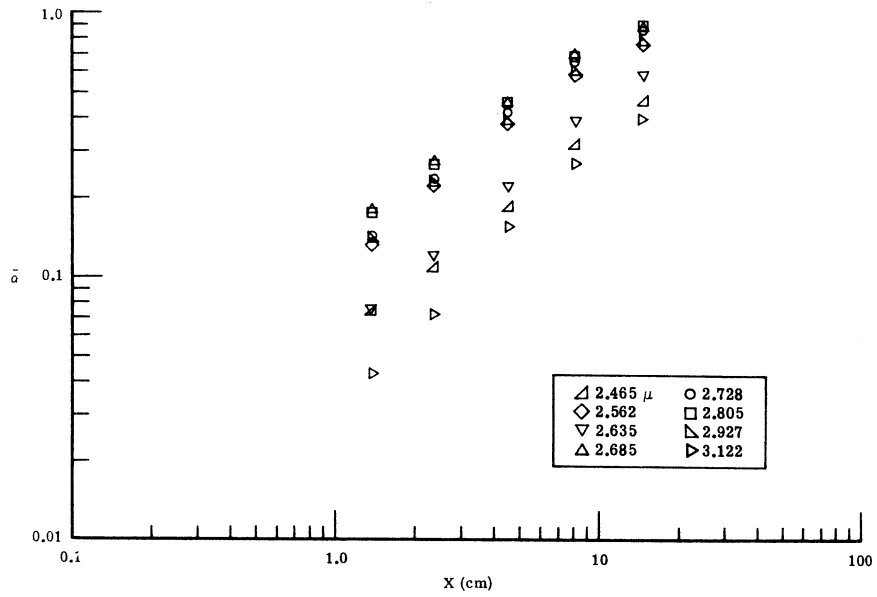


FIGURE 22. AVERAGE ABSORPTANCE VS. STANDARD OPTICAL DEPTH.  $L = 60$  cm,  $T = 1020 \pm 7^\circ\text{K}$ .

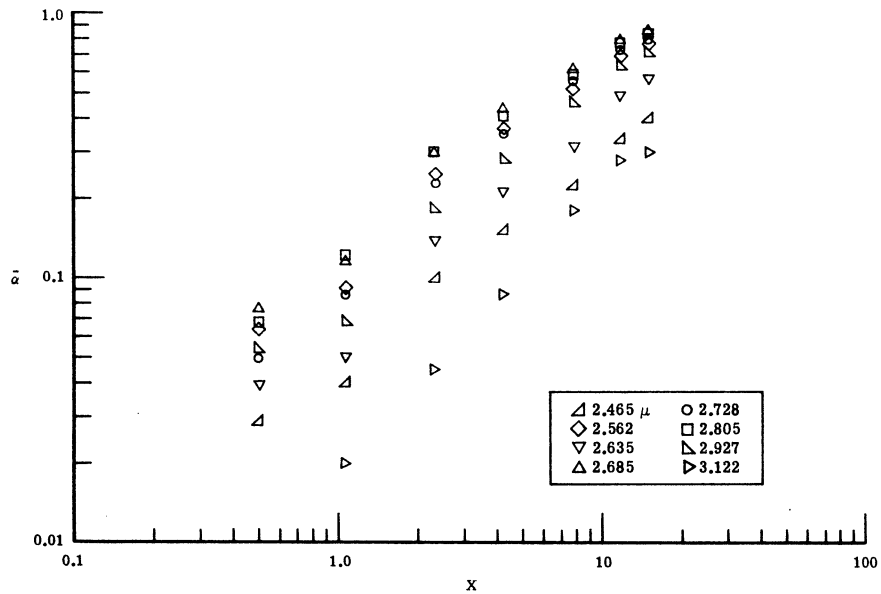


FIGURE 23. AVERAGE ABSORPTANCE VS. STANDARD OPTICAL DEPTH.  $L = 60$  cm,  $T = 1177 \pm 6^\circ\text{K}$ .

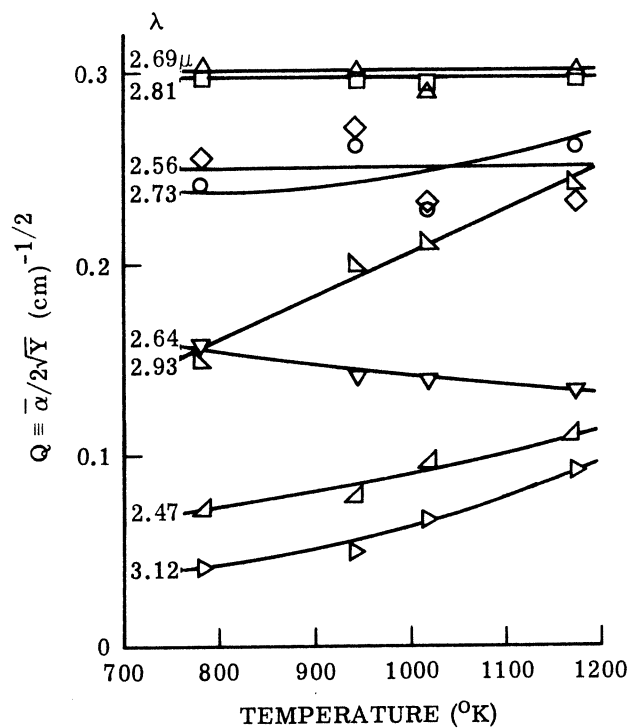


FIGURE 24. STRONG-LINE PARAMETER AS A FUNCTION OF TEMPERATURE

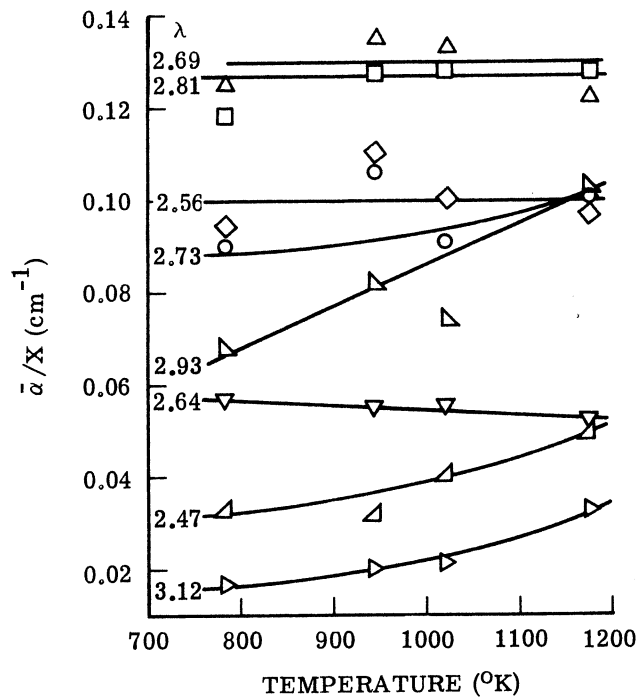
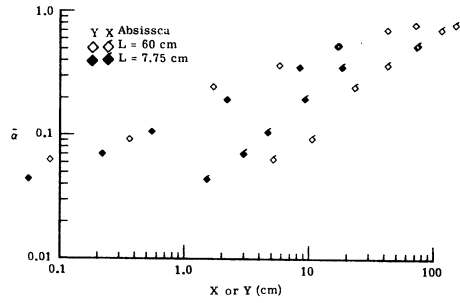
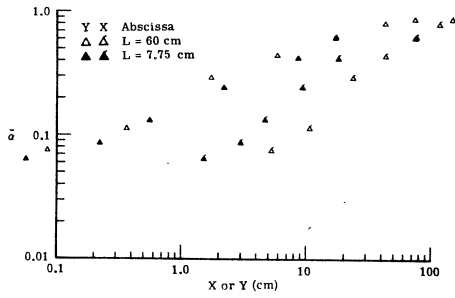


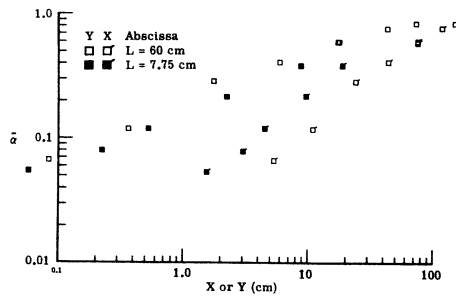
FIGURE 25. APPARENT LINE STRENGTH AS A FUNCTION OF TEMPERATURE



(a)  $T = 1031 \pm 17^{\circ}\text{K}$ ,  $\lambda = 2.562 \mu$ .



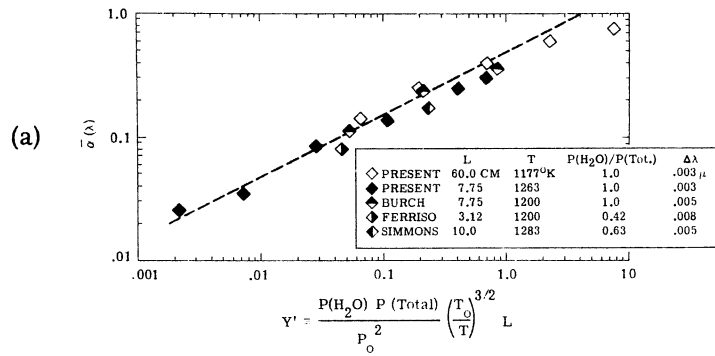
(b)  $T = 1031 \pm 17^{\circ}\text{K}$ ,  $\lambda = 2.685 \mu$ .



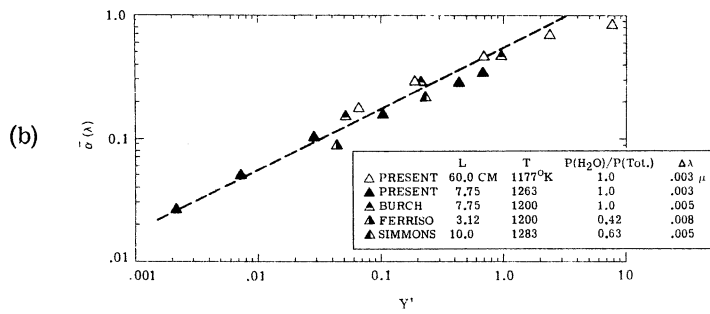
(c)  $T = 1031 \pm 17^{\circ}\text{K}$ ,  $\lambda = 2.805 \mu$ .

FIGURE 26. COMPARISON OF DATA OBTAINED IN 60-CM AND 7.75-CM CELLS.

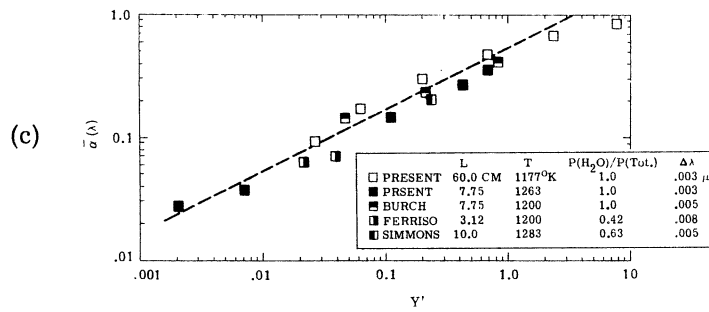
WILLOW RUN LABORATORIES



CORRELATION OF MEAN ABSORPTANCES NEAR THE MAXIMUM OF THE R-BRANCH



CORRELATION OF MEAN ABSORPTANCES NEAR THE MAXIMUM OF THE Q-BRANCH



CORRELATION OF MEAN ABSORPTANCES NEAR THE MAXIMUM OF THE P BRANCH

FIGURE 27. CORRELATION OF LABORATORY AND ROCKET EXHAUST DATA.

**Appendix**

**ABSORPTION SPECTRA OF PURE WATER VAPOR**



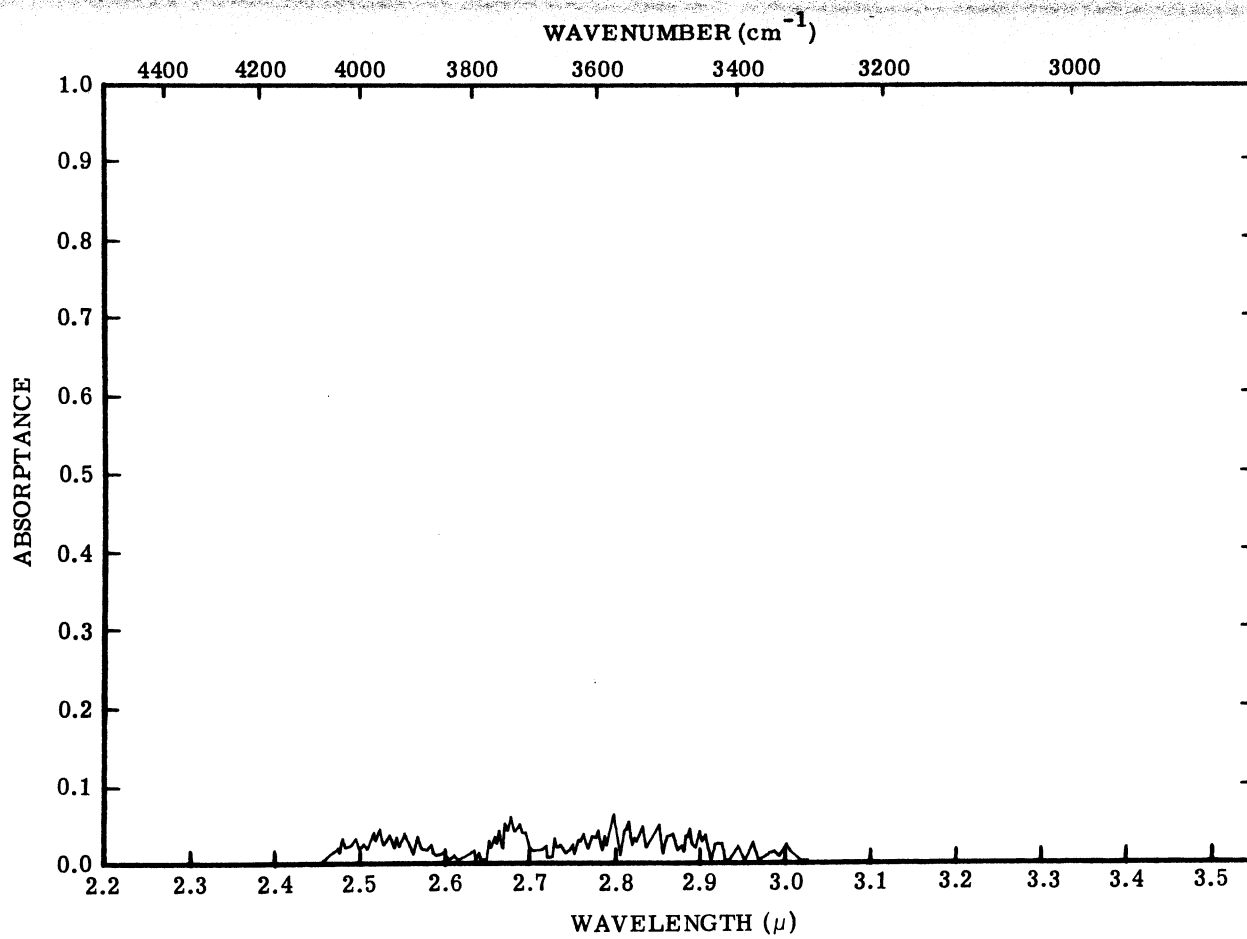


FIGURE 28. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 23.9 mm, T = 805°K.

WILLOW RUN LABORATORIES

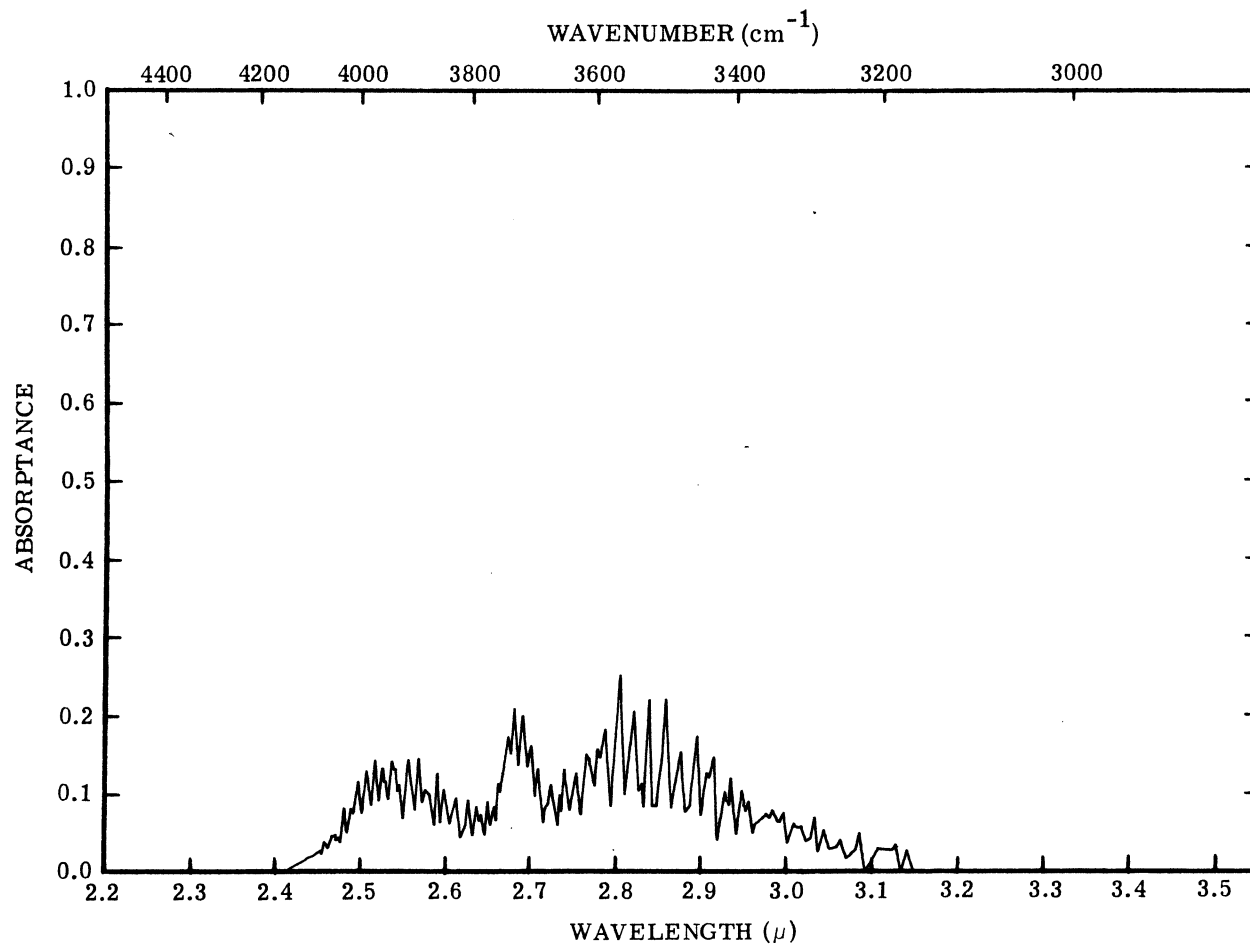


FIGURE 29. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 47.8 mm, T = 813°K.

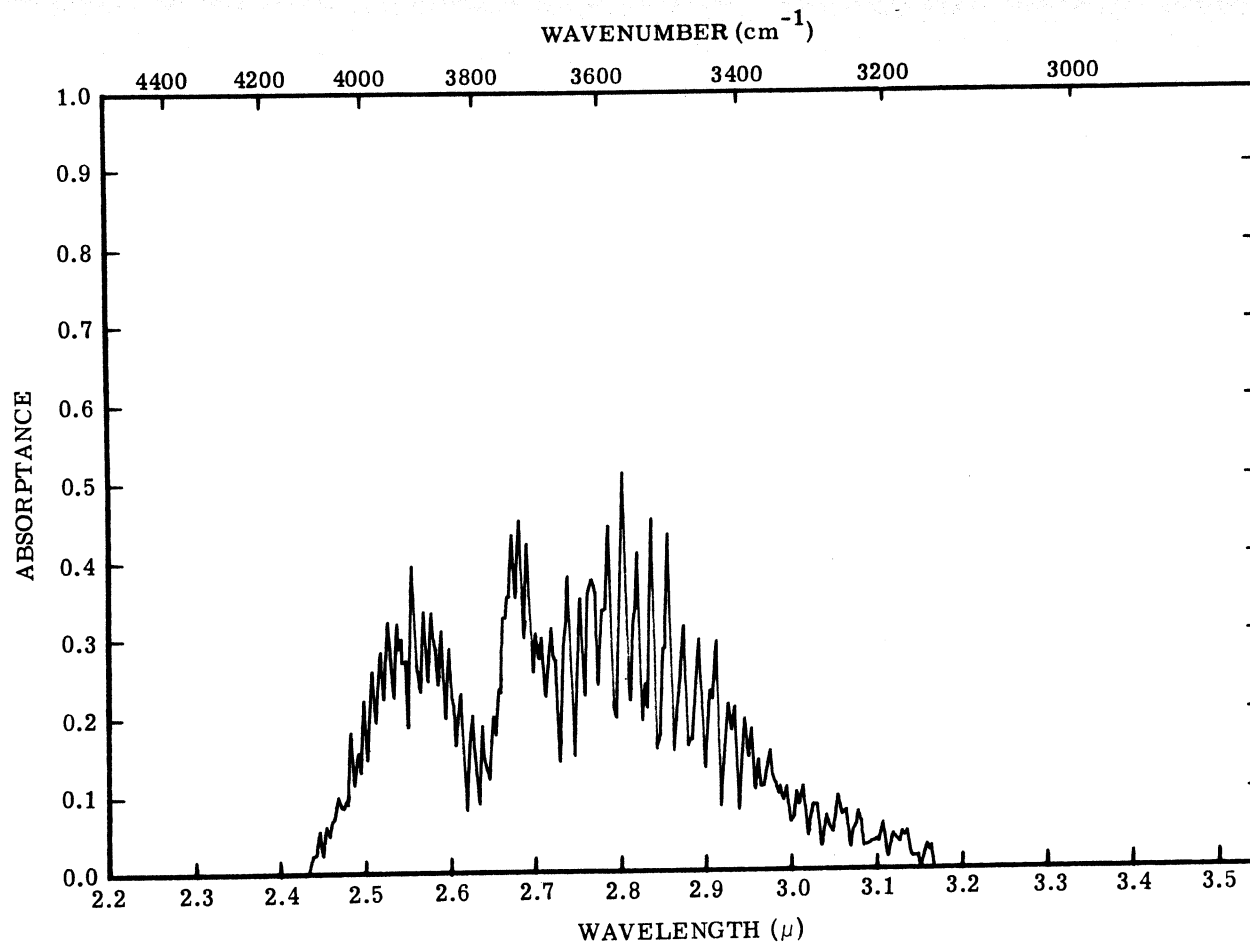


FIGURE 30. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 100.0 mm, T = 785°K.

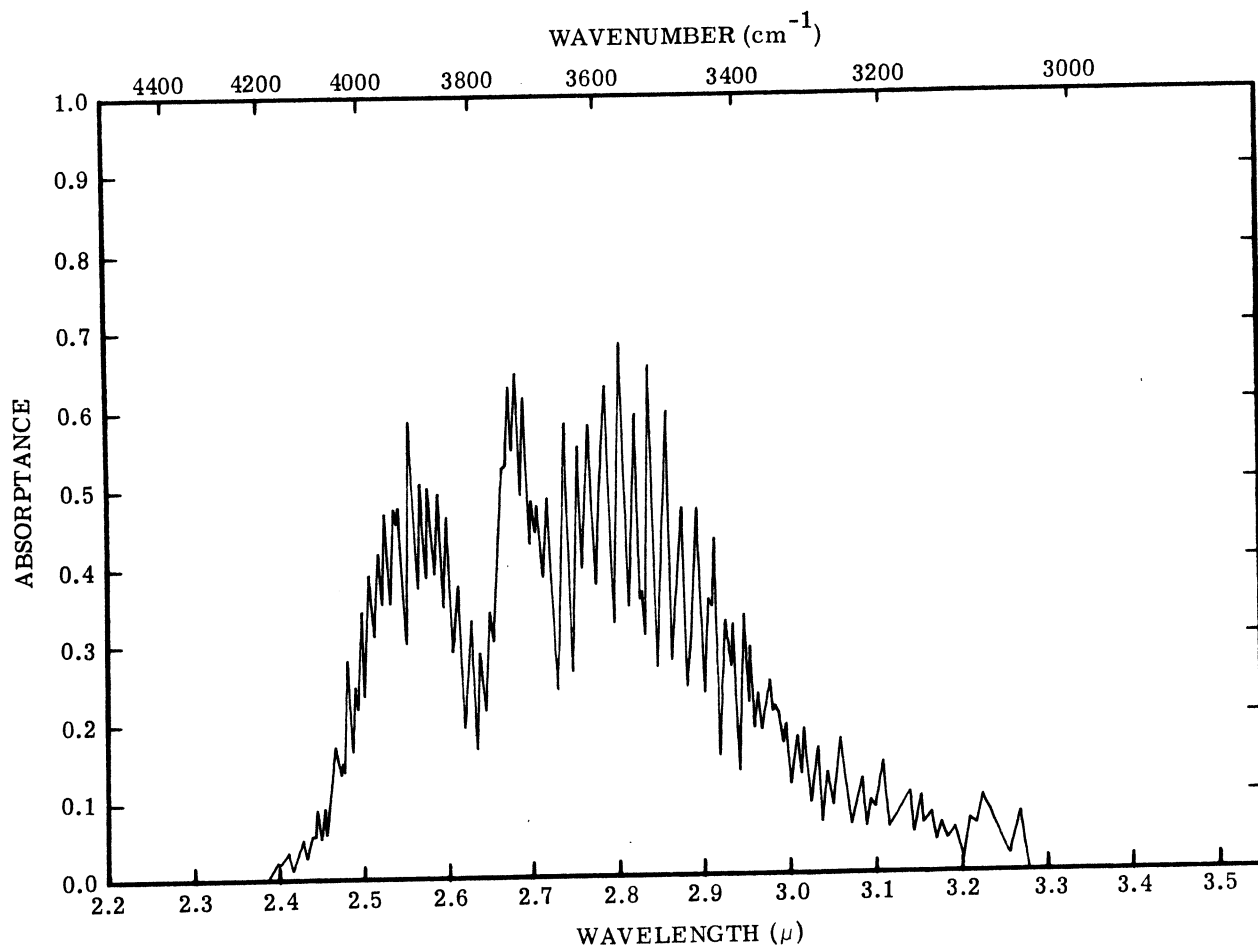


FIGURE 31. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 224.7 mm, T = 790°K.

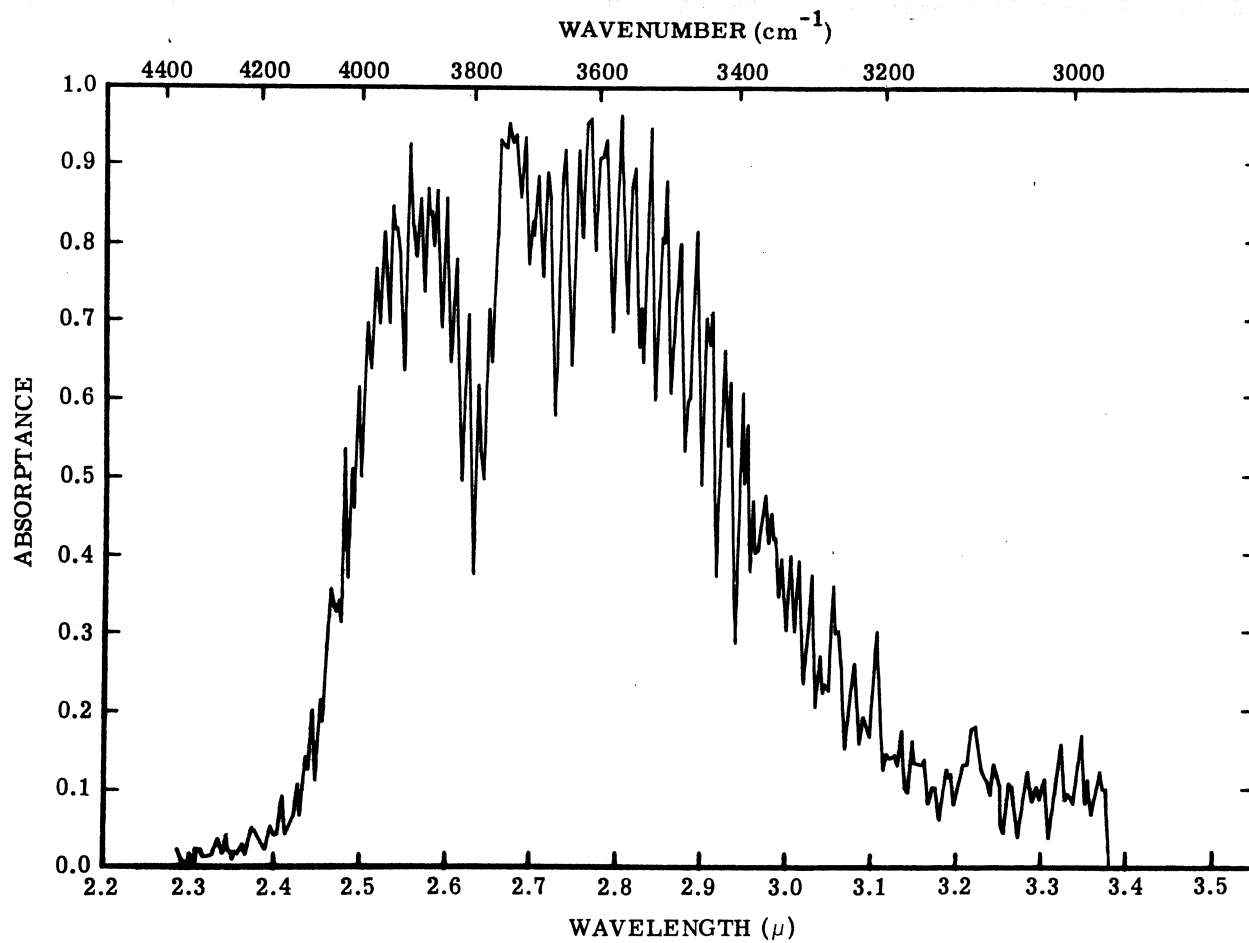


FIGURE 32. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 494.7 mm, T = 757°K.

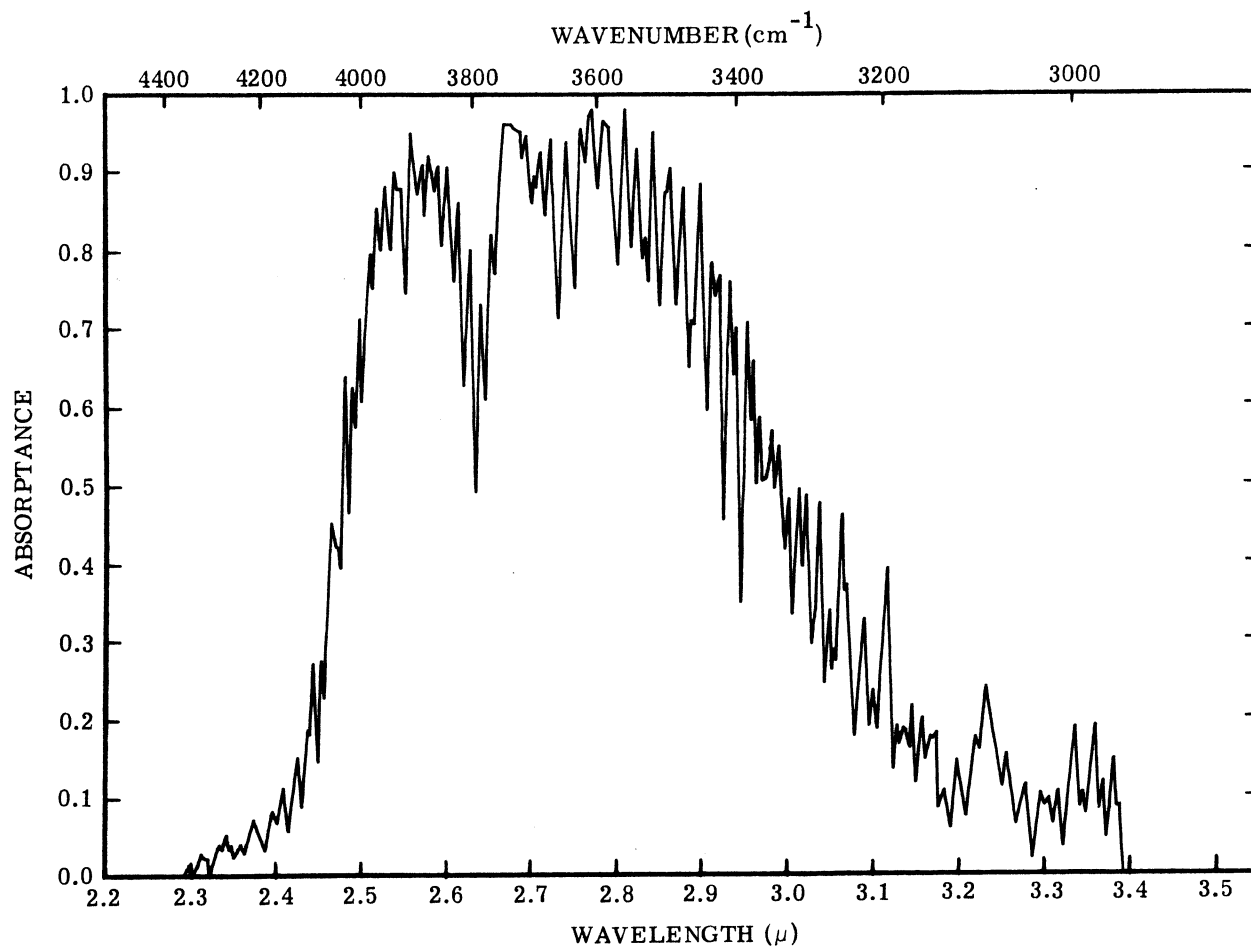


FIGURE 33. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 730.6 mm, T = 756°K.

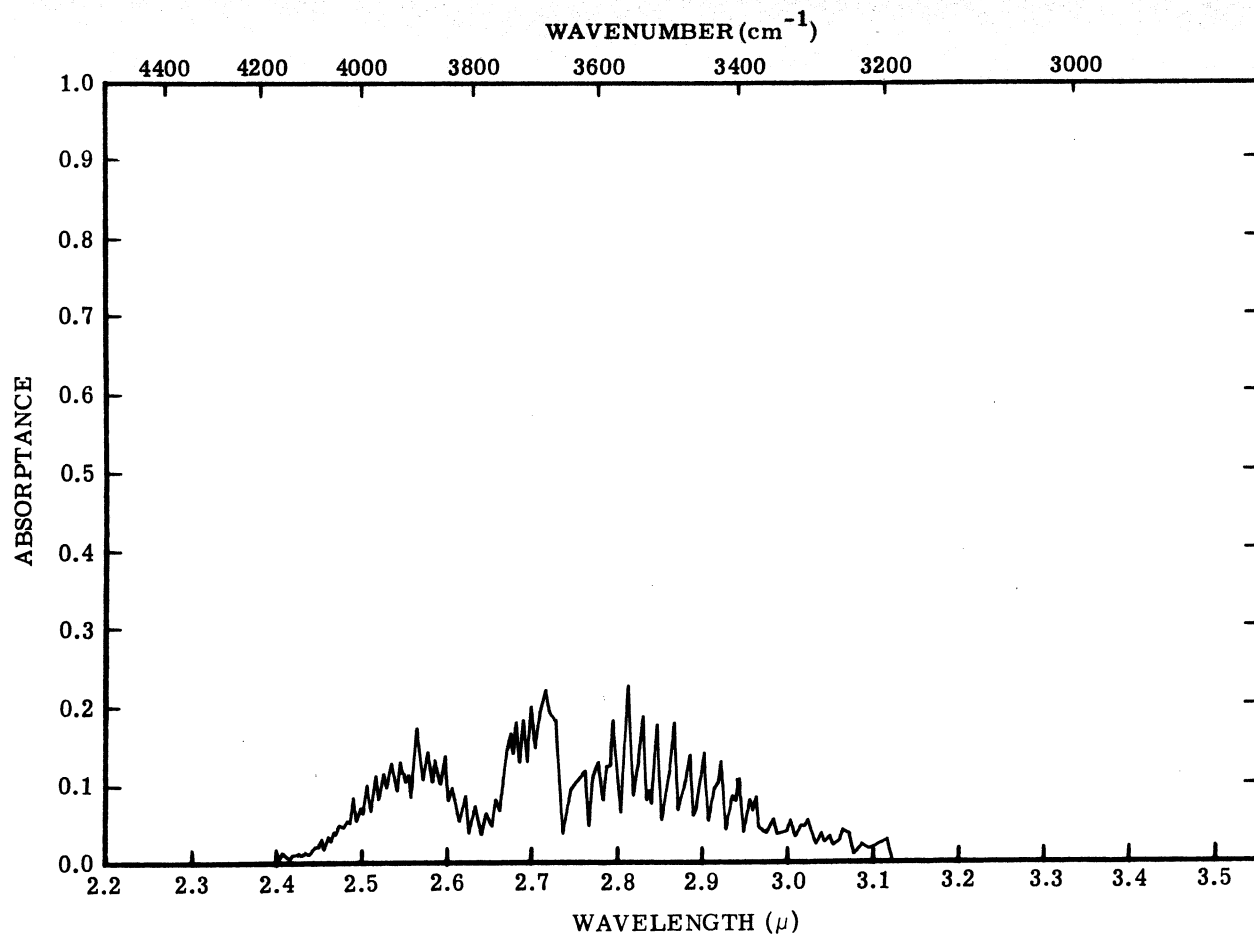


FIGURE 34. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 45.6 mm, T = 941<sup>o</sup>K.

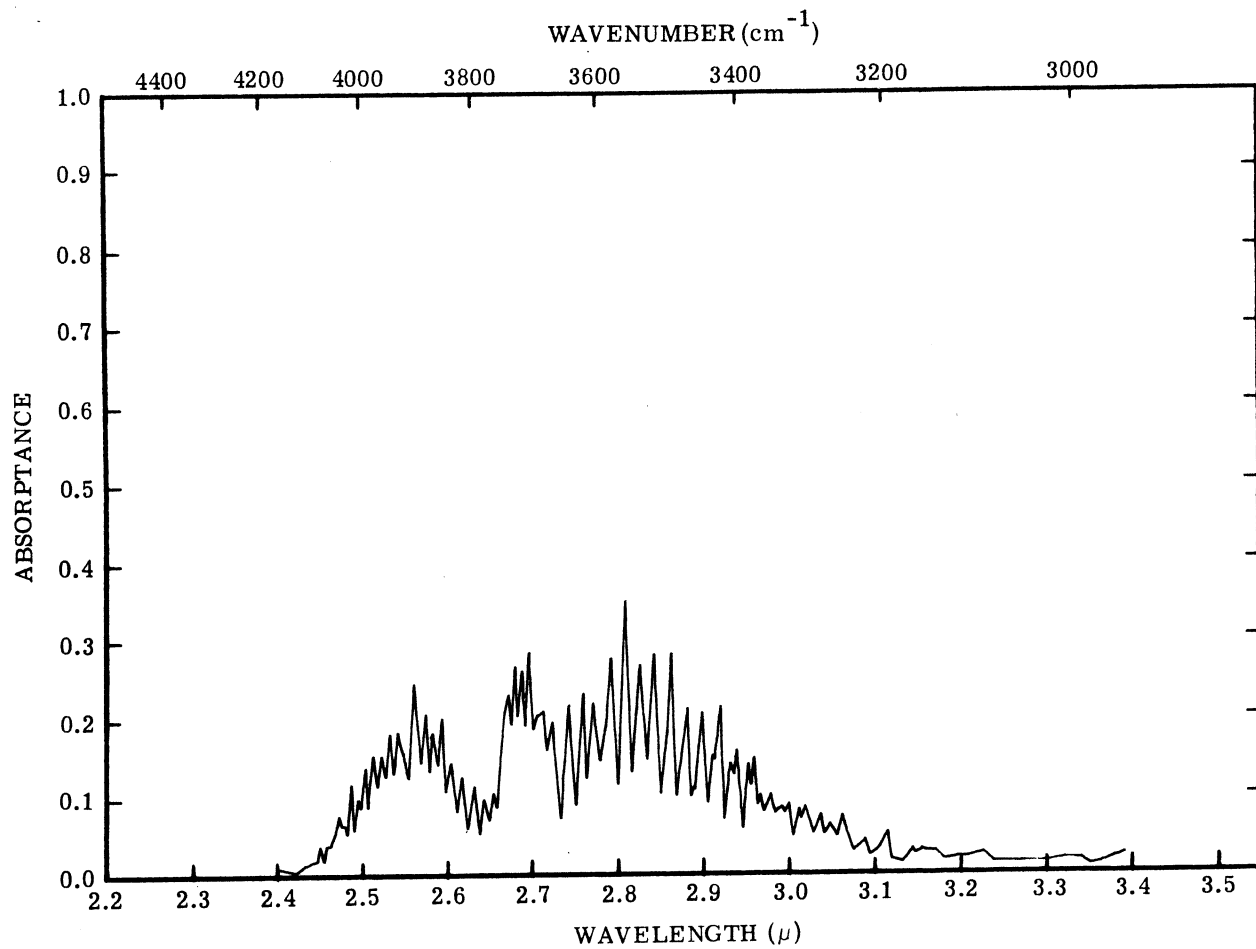


FIGURE 35. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 78.0 mm, T = 941°K.



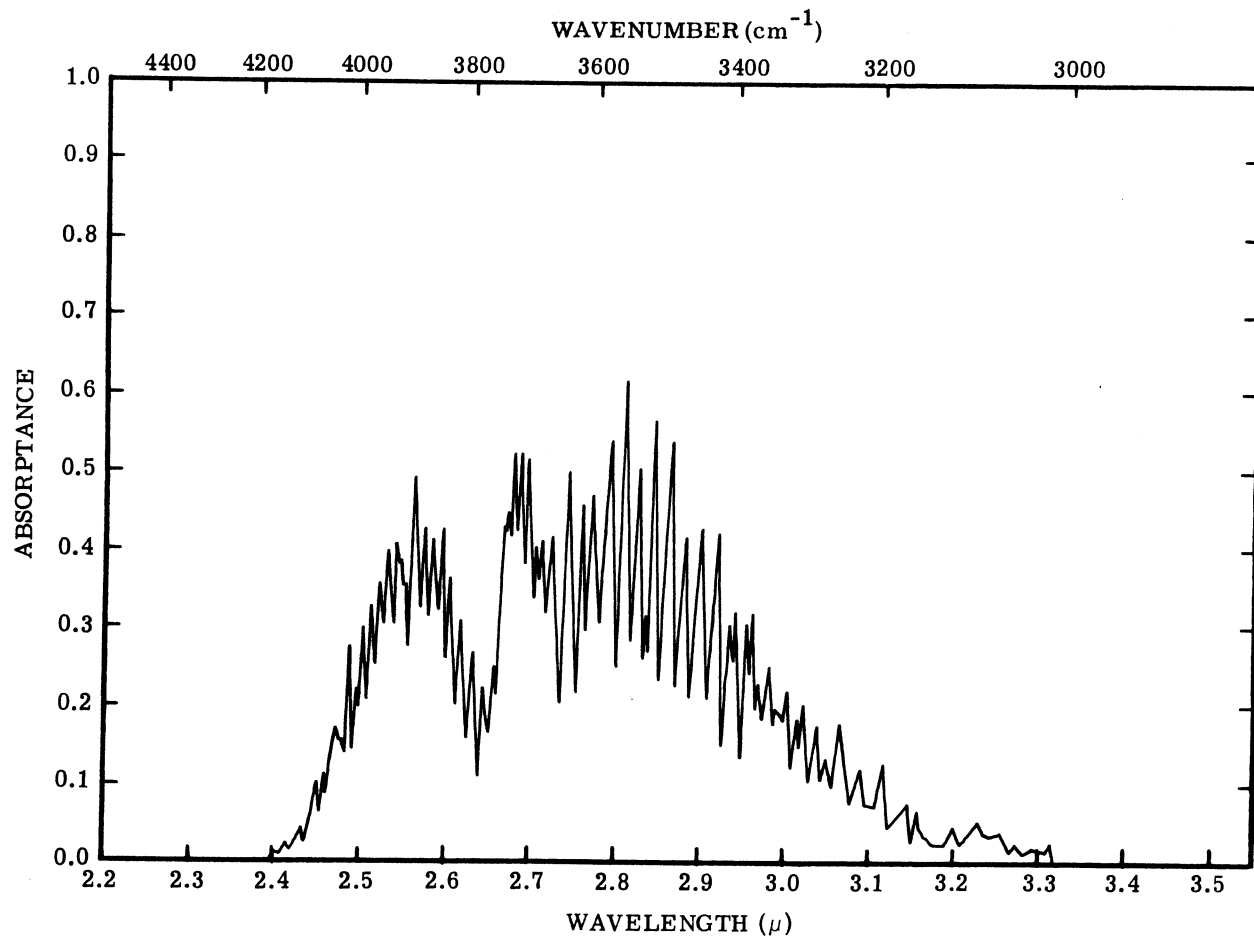


FIGURE 36. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 150.0 mm, T = 941°K.

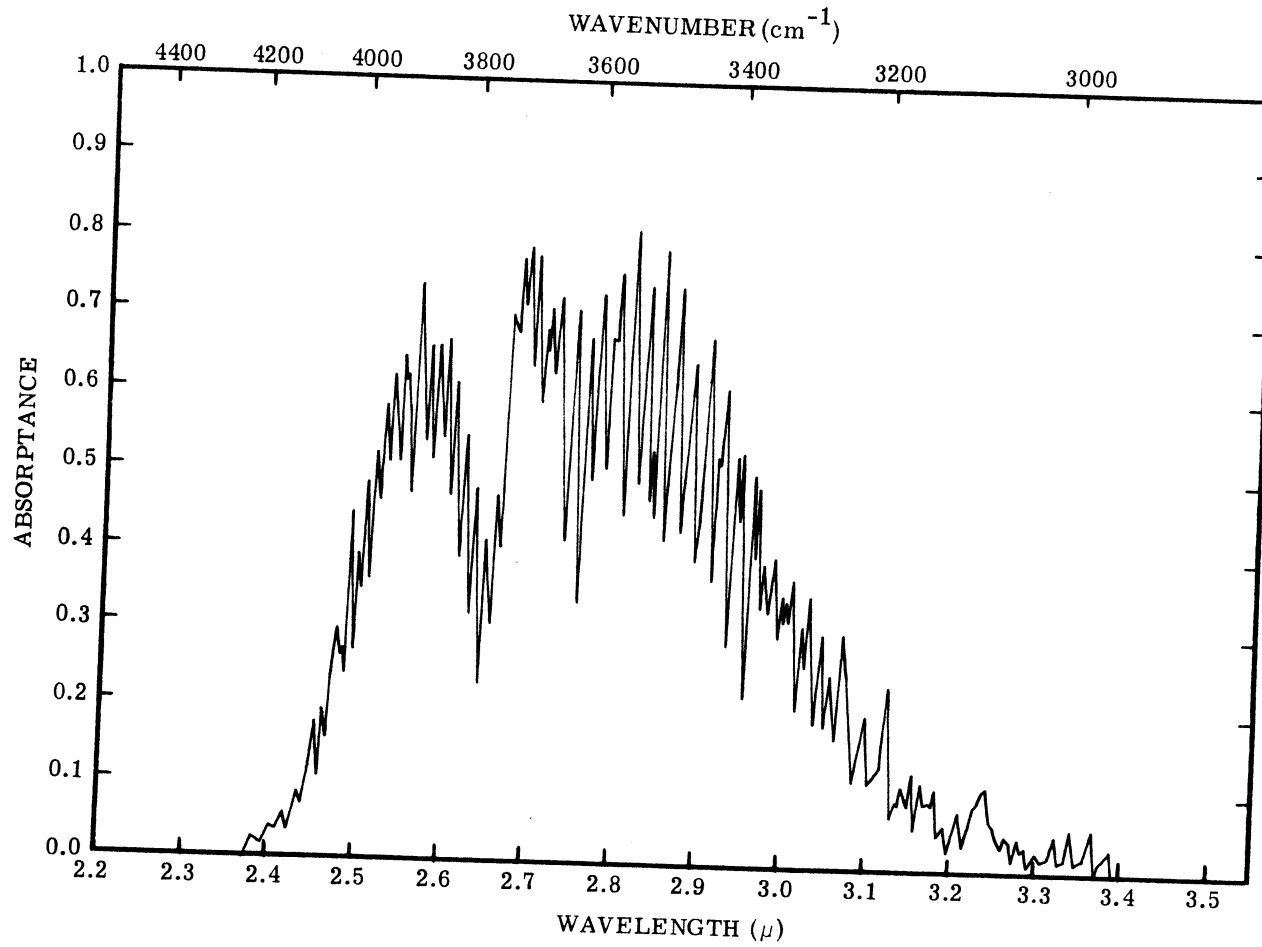


FIGURE 37. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 372.6 mm, T = 947°K.

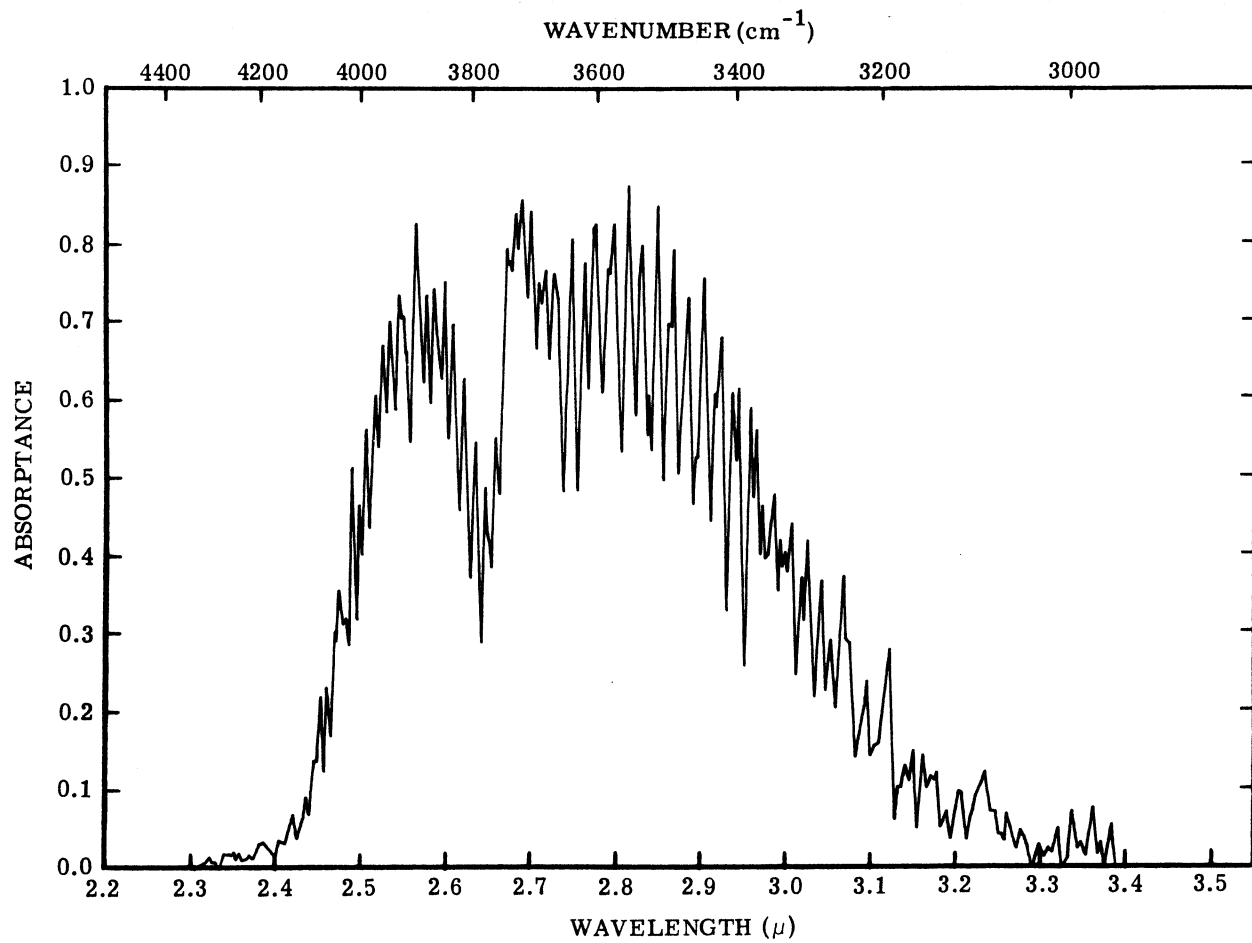


FIGURE 38. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 510.0 mm, T = 945°K.

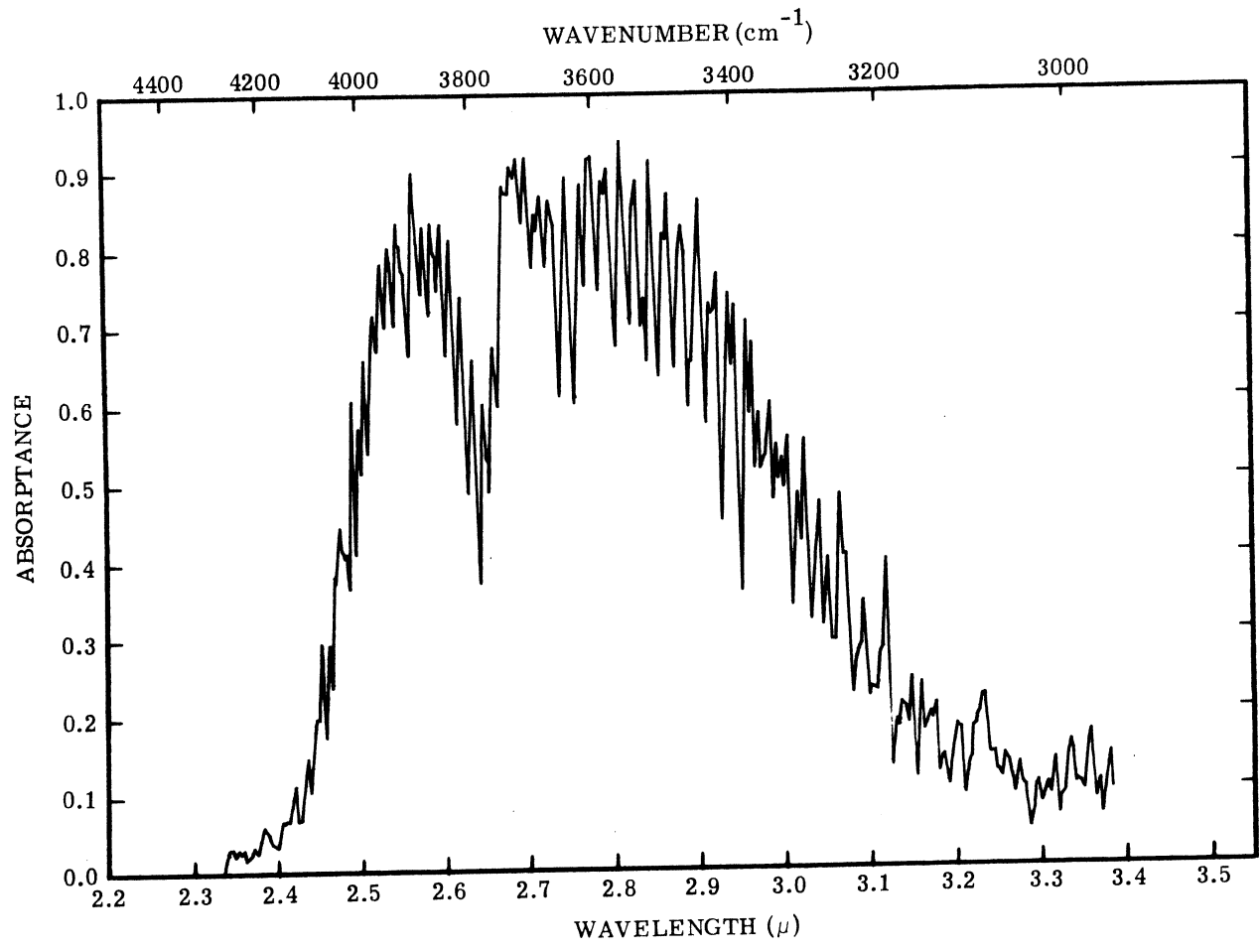


FIGURE 39. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 743.9 mm, T = 941°K.

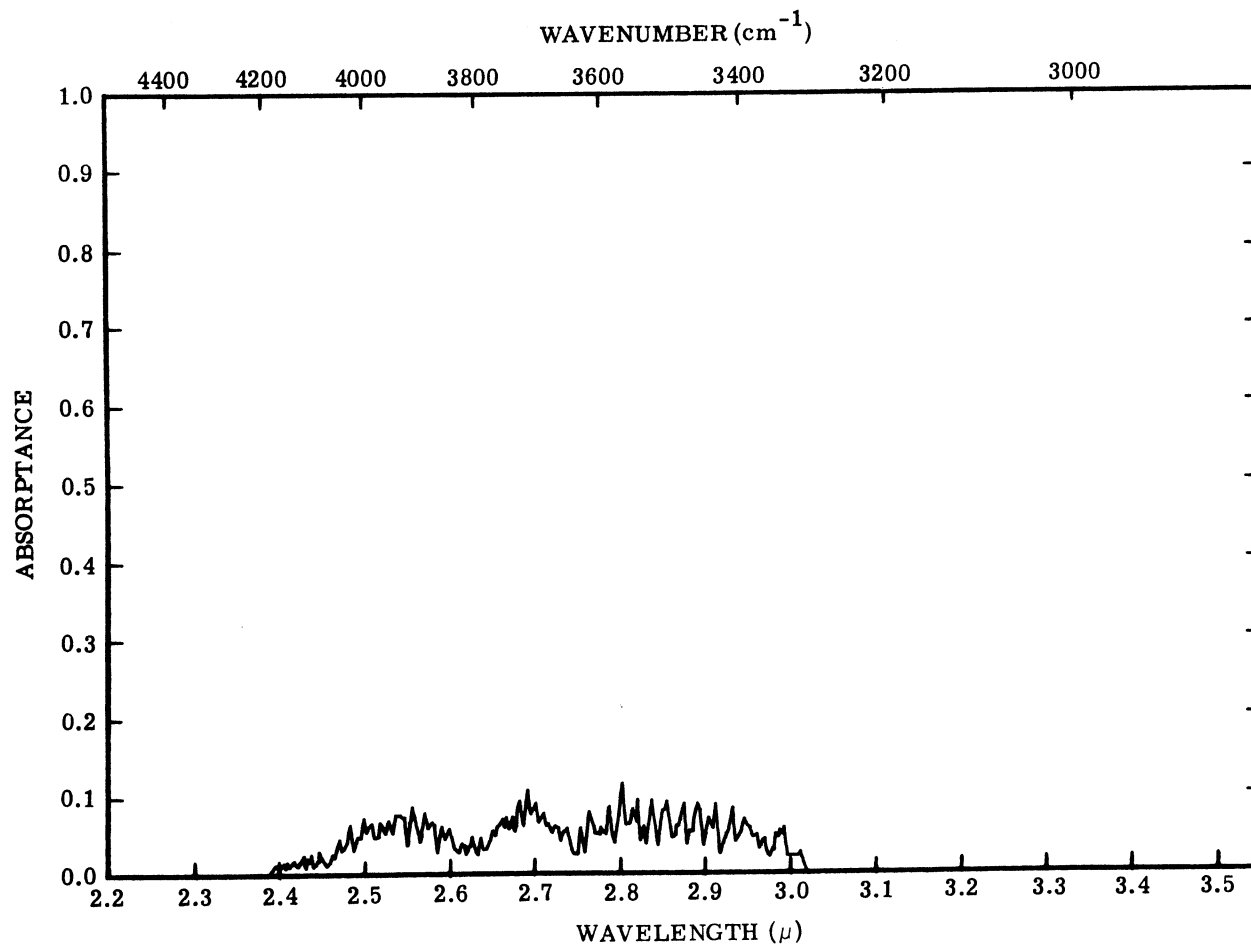


FIGURE 40. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 24.8 mm, T = 1020°K.

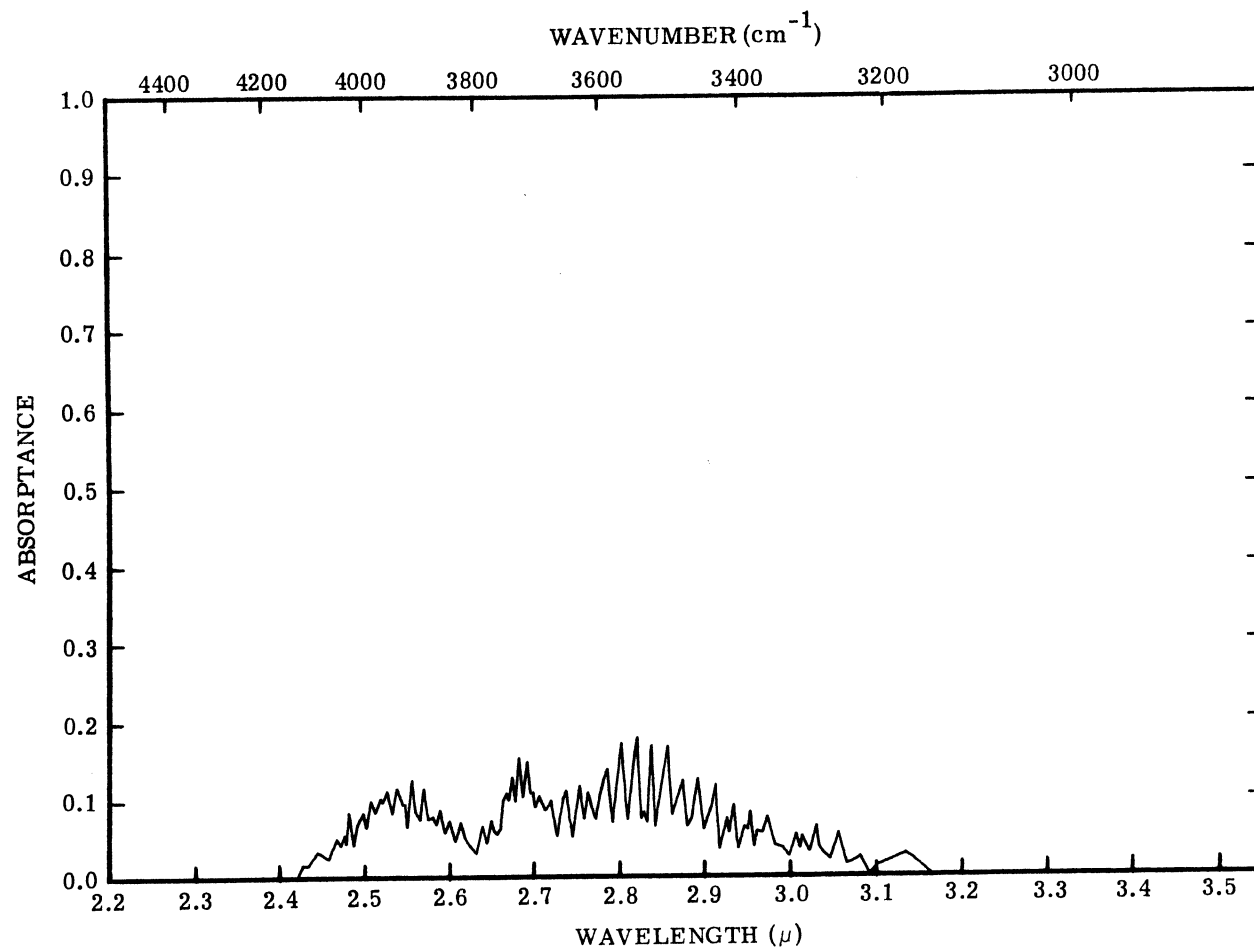


FIGURE 41. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 50.2 mm, T = 1005°K.

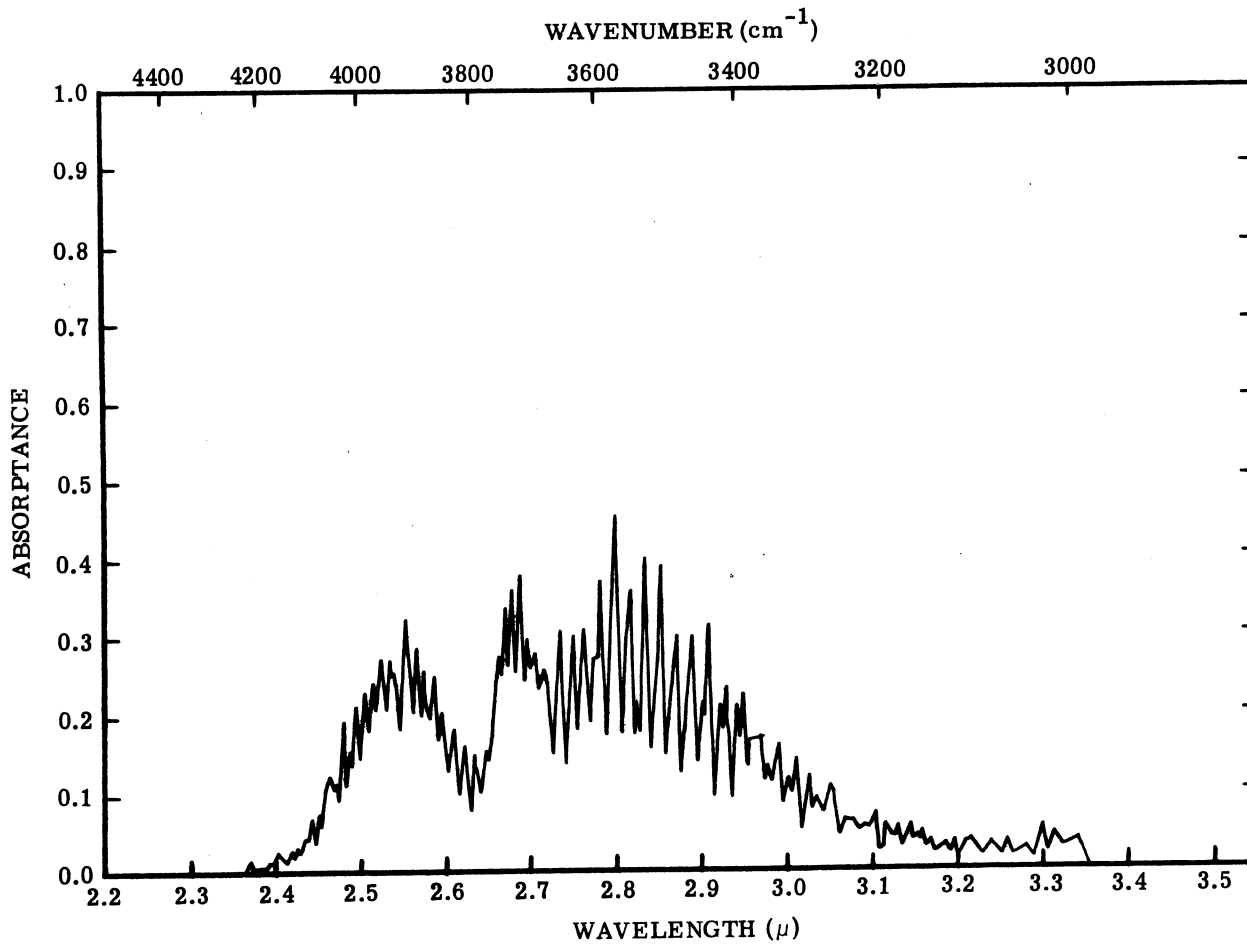


FIGURE 42. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 109.3 mm, T = 1011°K.

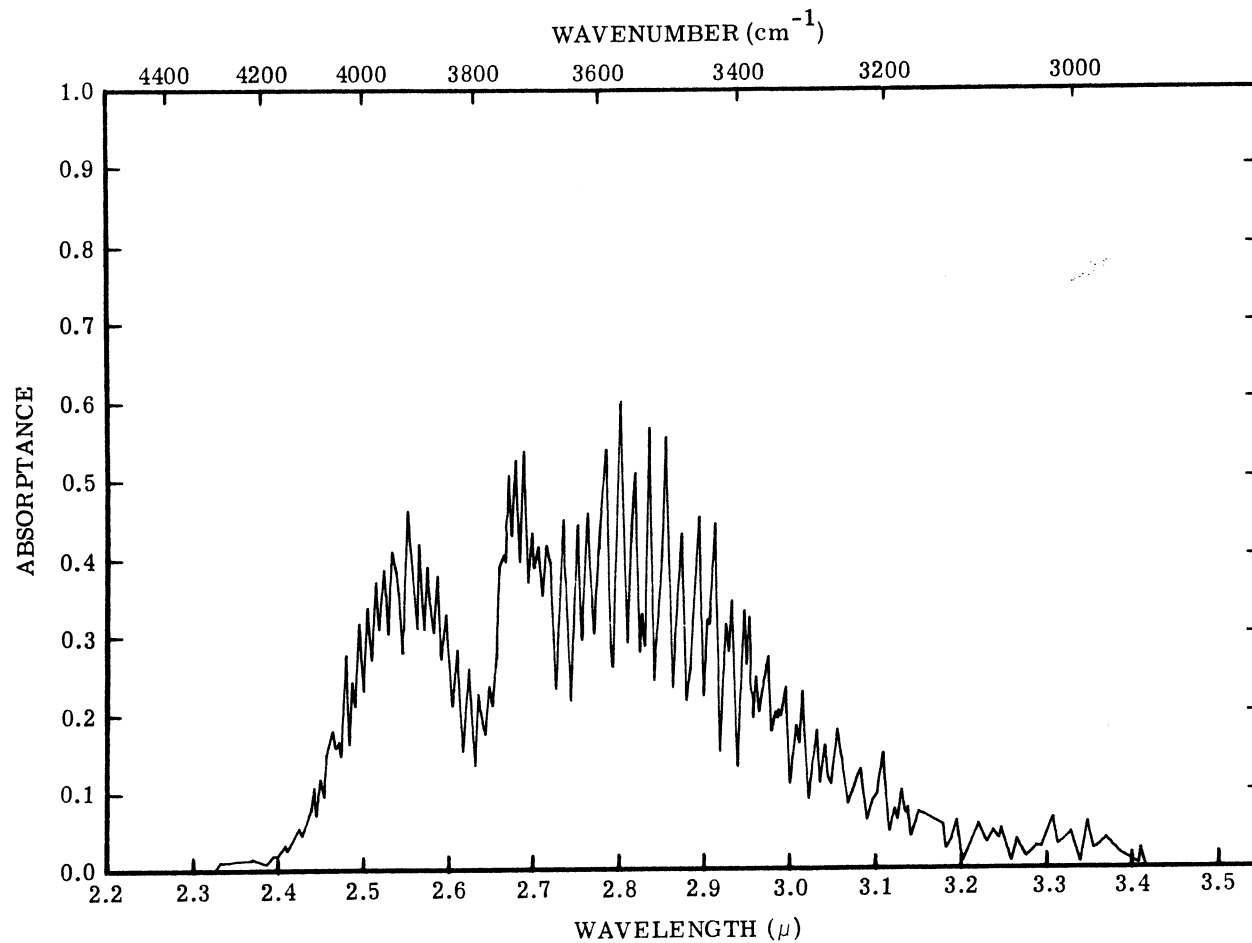


FIGURE 43. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 201.3 mm, T = 1016°K.



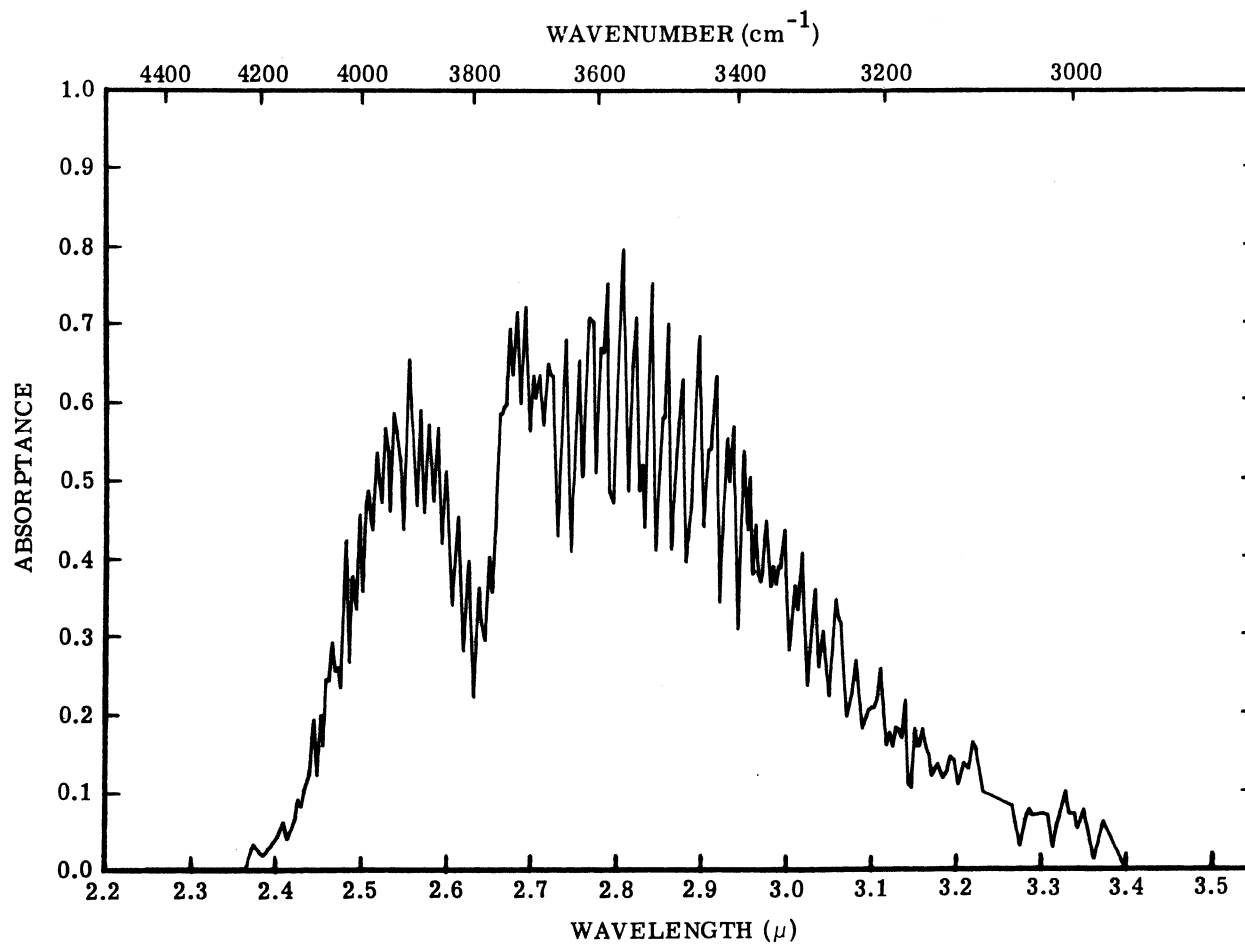


FIGURE 44. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 349.4 mm, T = 1019°K.

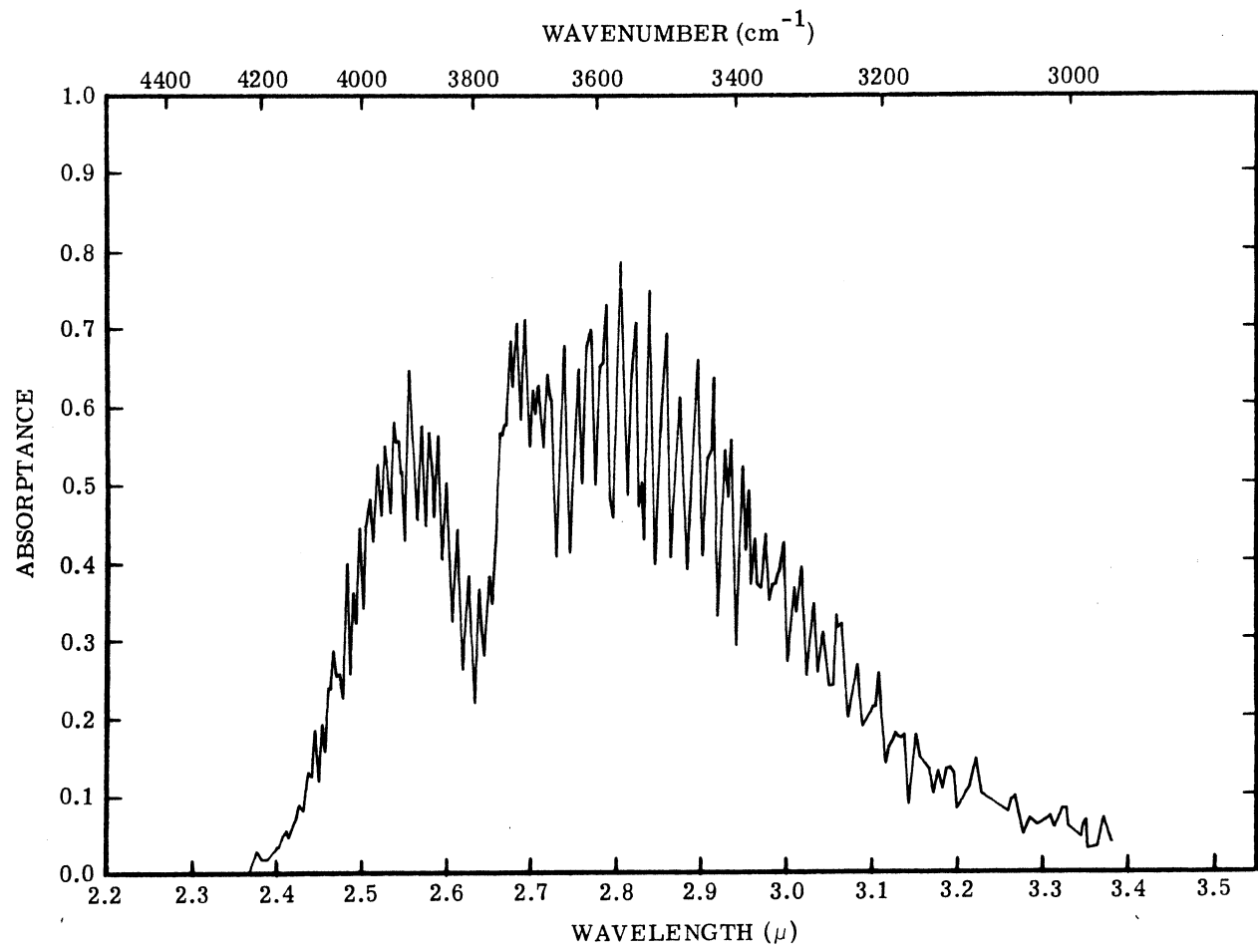


FIGURE 45. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 345.2 mm, T = 1024<sup>o</sup>K.

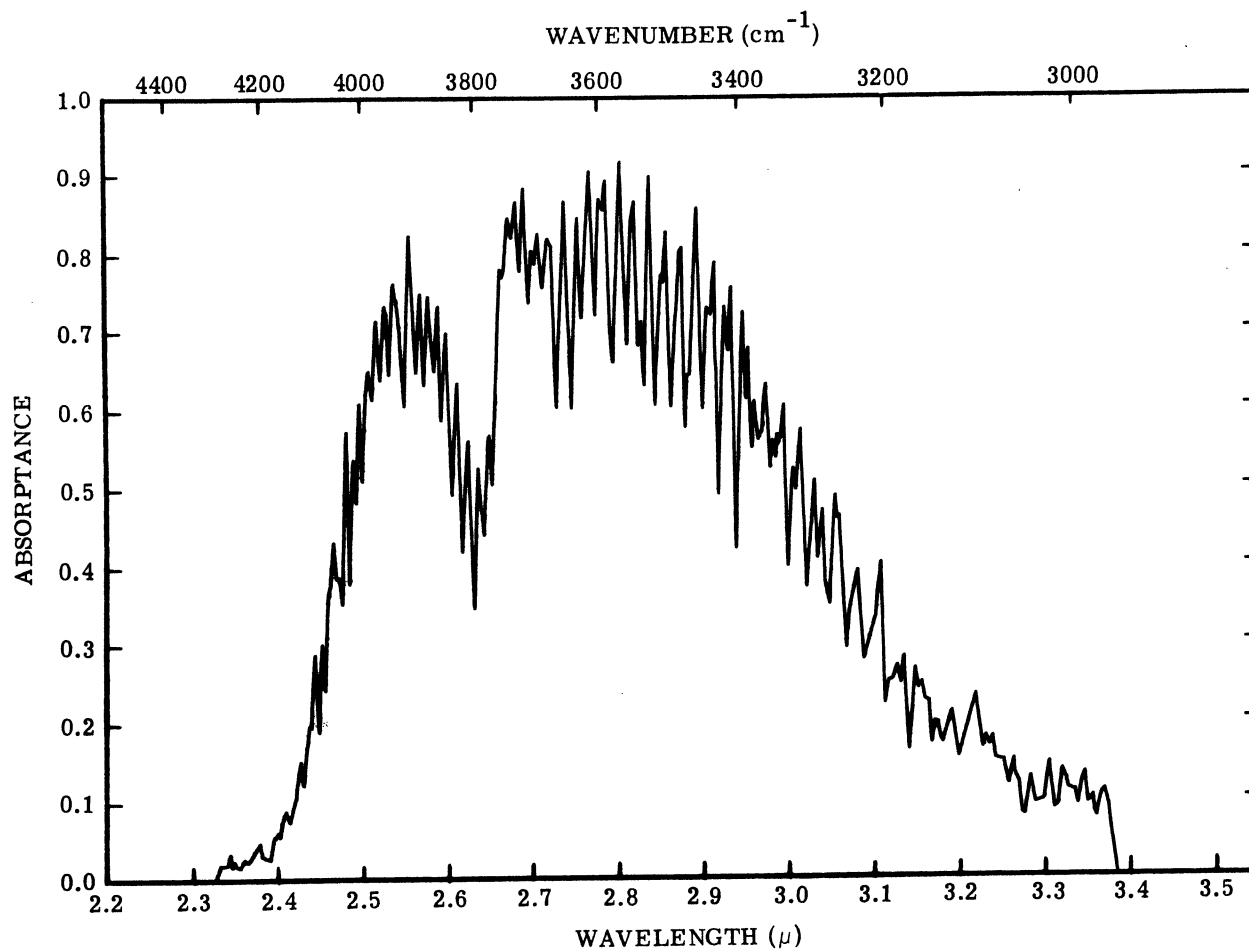


FIGURE 46. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 548.1 mm, T = 1037°K.

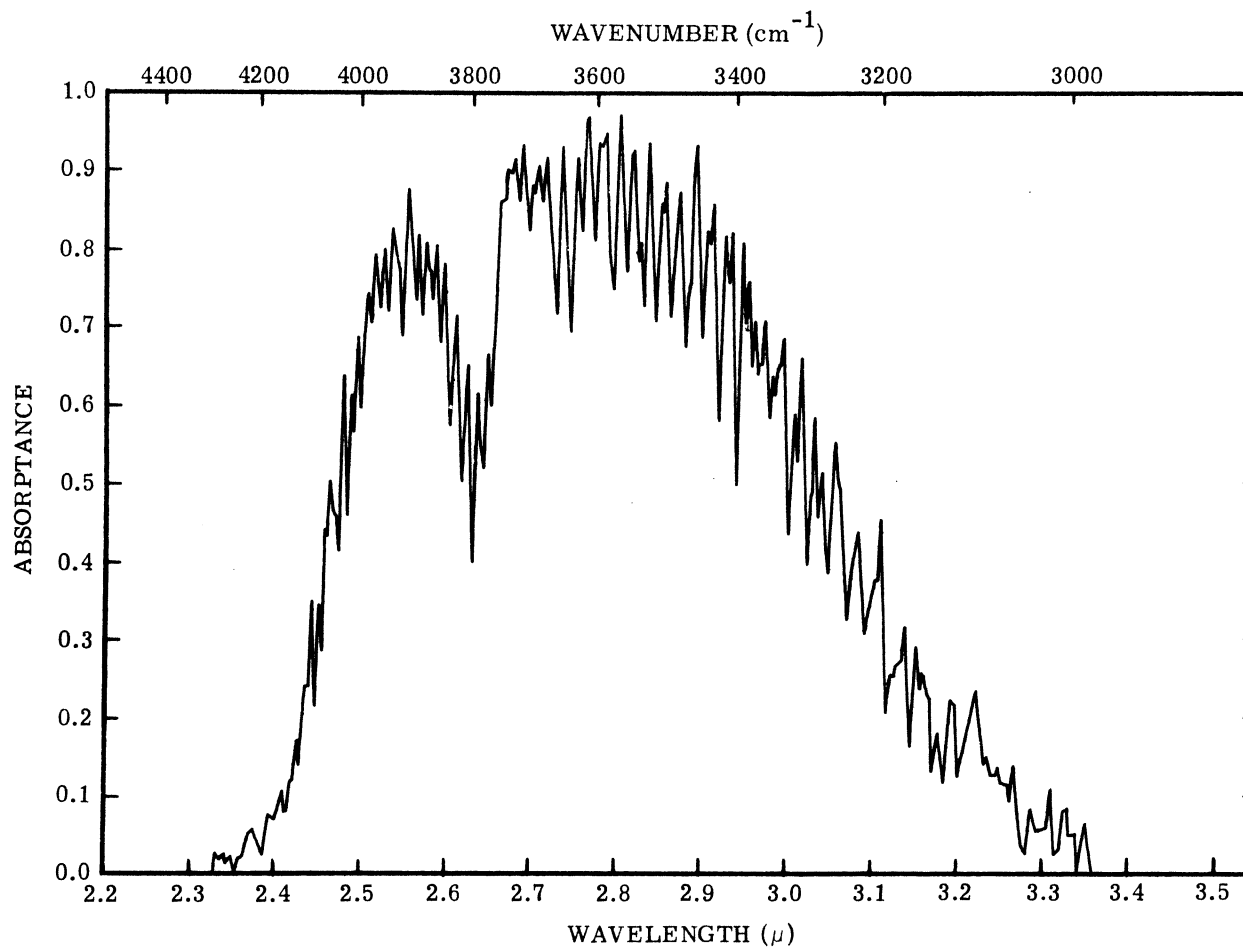


FIGURE 47. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 712.4 mm, T = 1040°K.

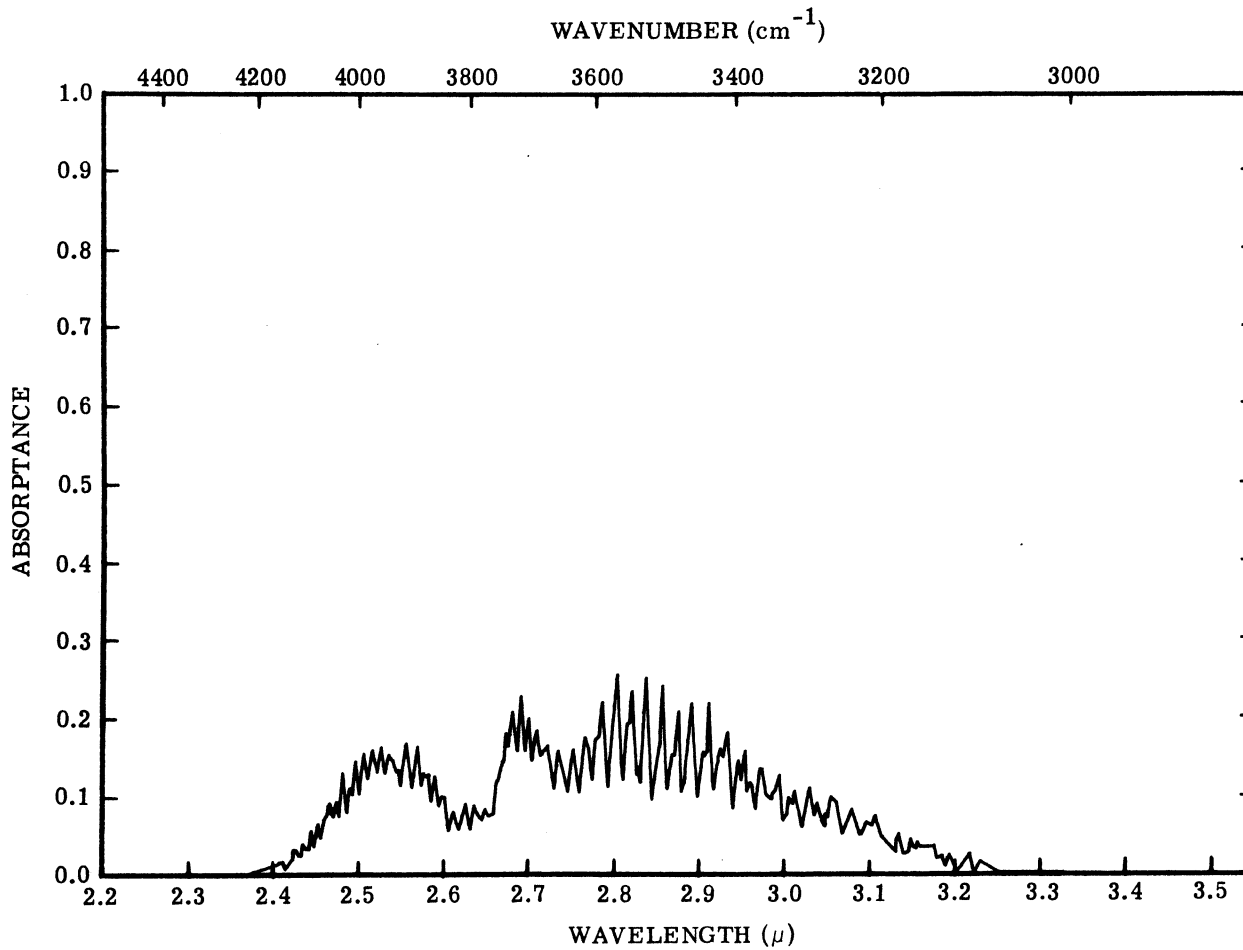


FIGURE 48. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 76.8 mm, T = 1186°K.

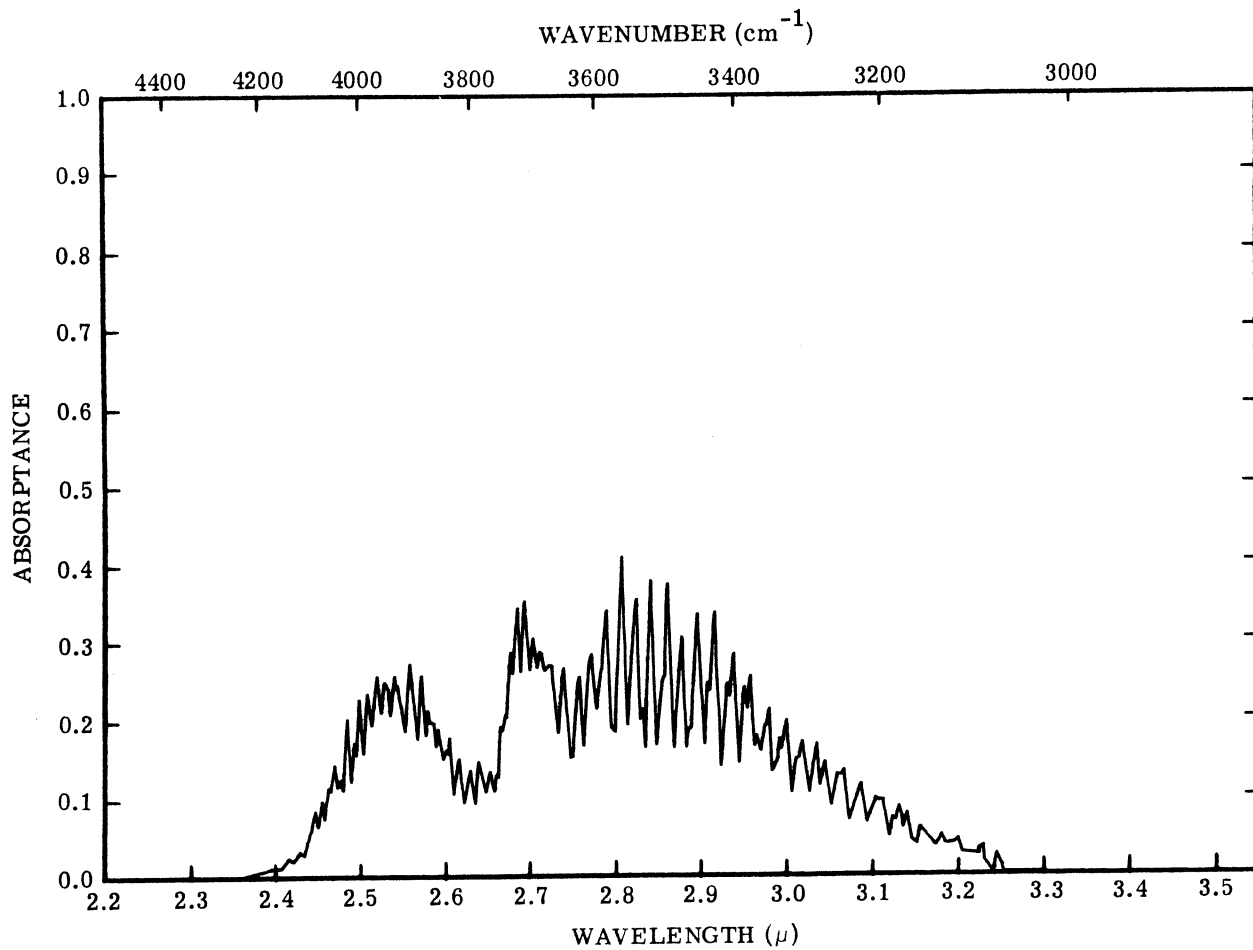


FIGURE 49. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 131.0 mm, T = 1179°K.

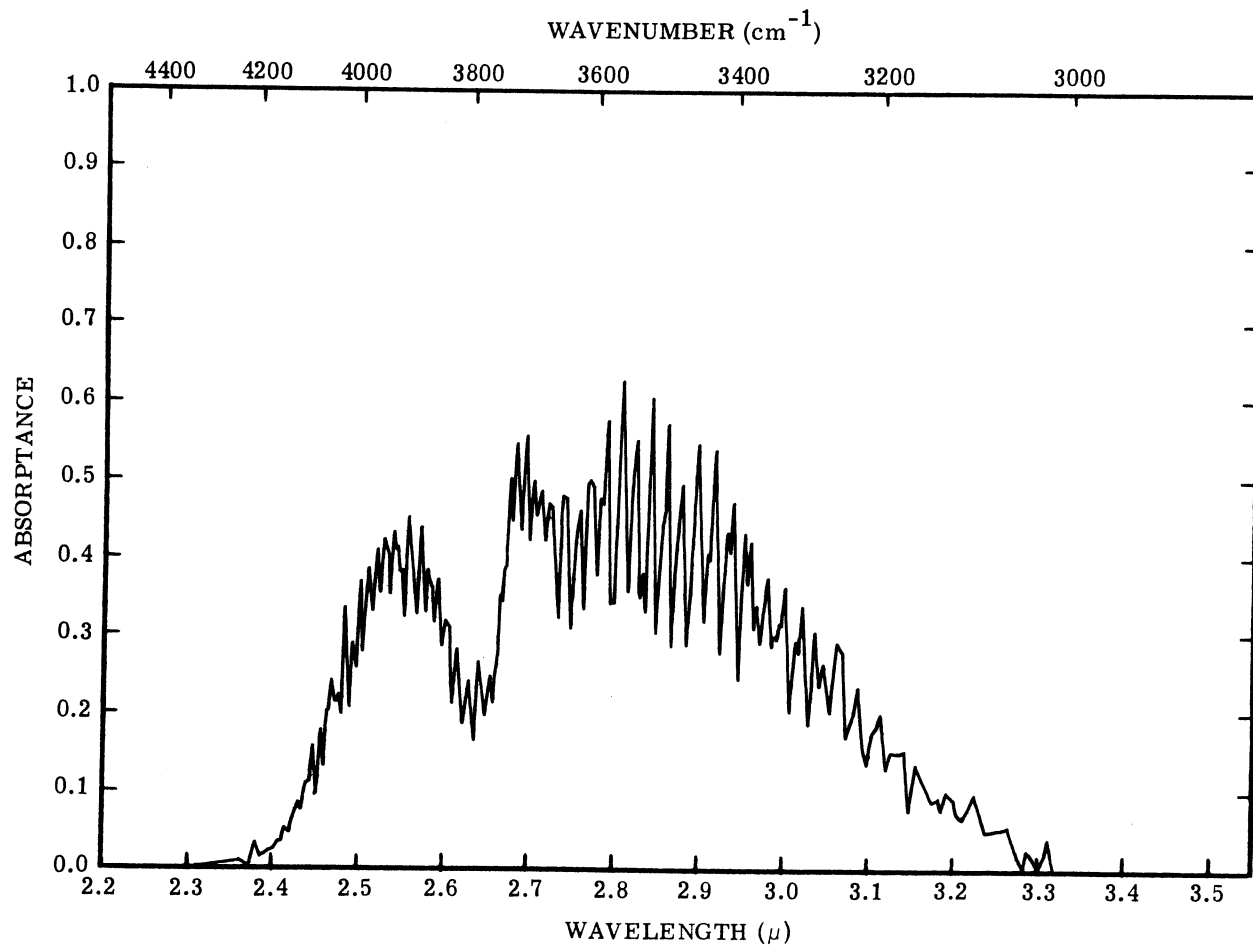


FIGURE 50. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 242.9 mm. T = 1160°K.

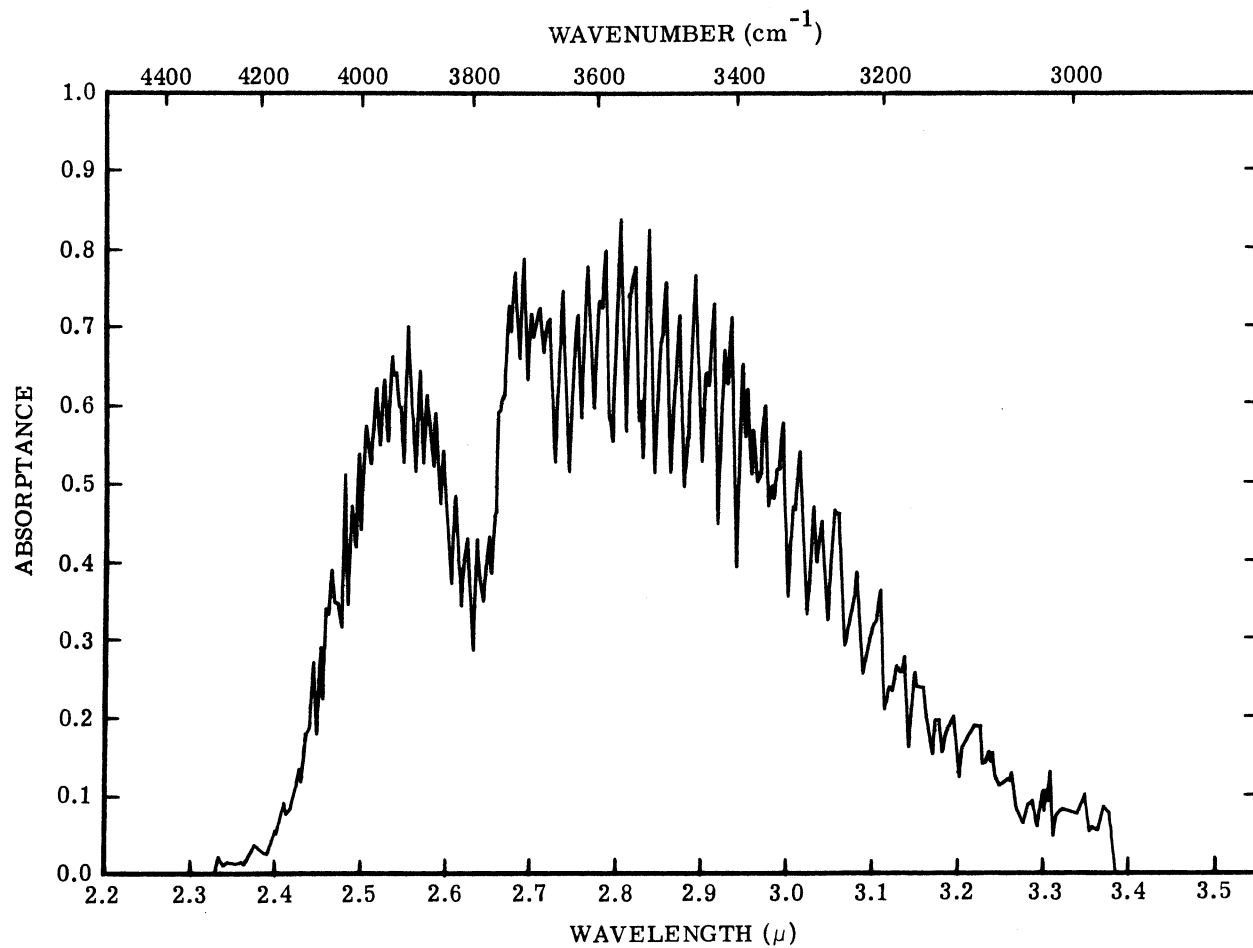


FIGURE 51. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 445.8 mm, T = 1178°K.



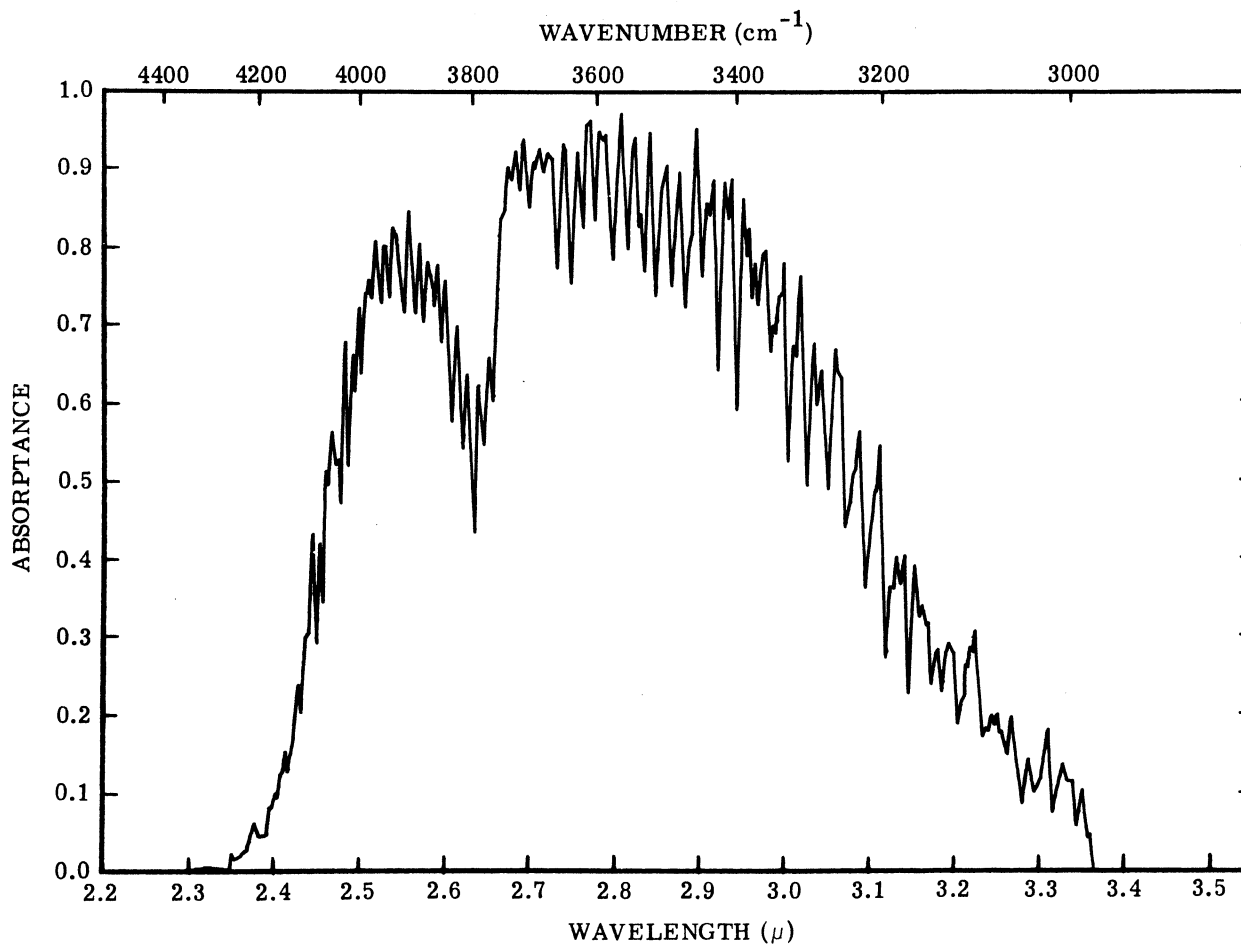


FIGURE 52. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 808.3 mm, T = 1180°K.

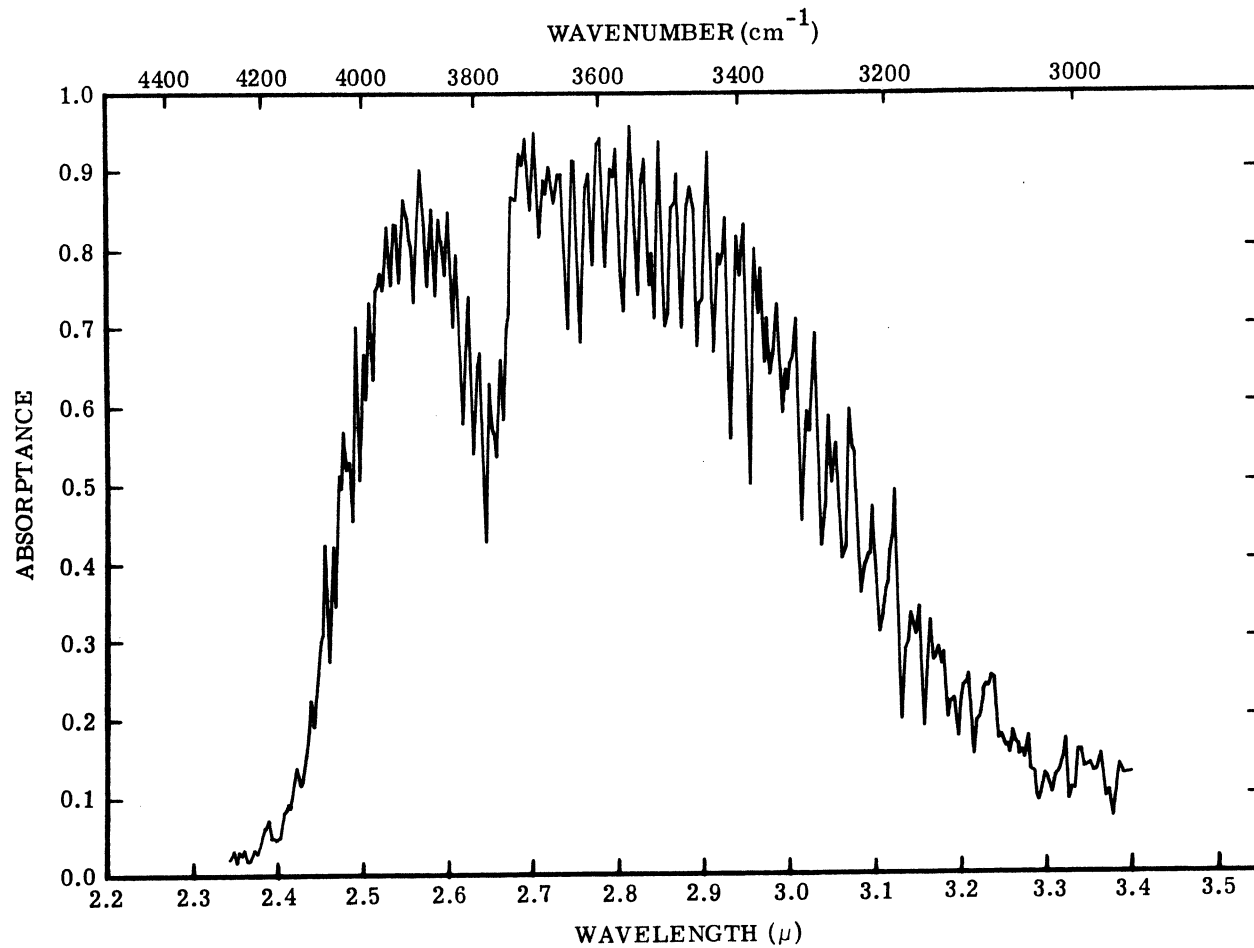


FIGURE 53. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 60 cm, P = 969.4 mm, T = 1173°K.

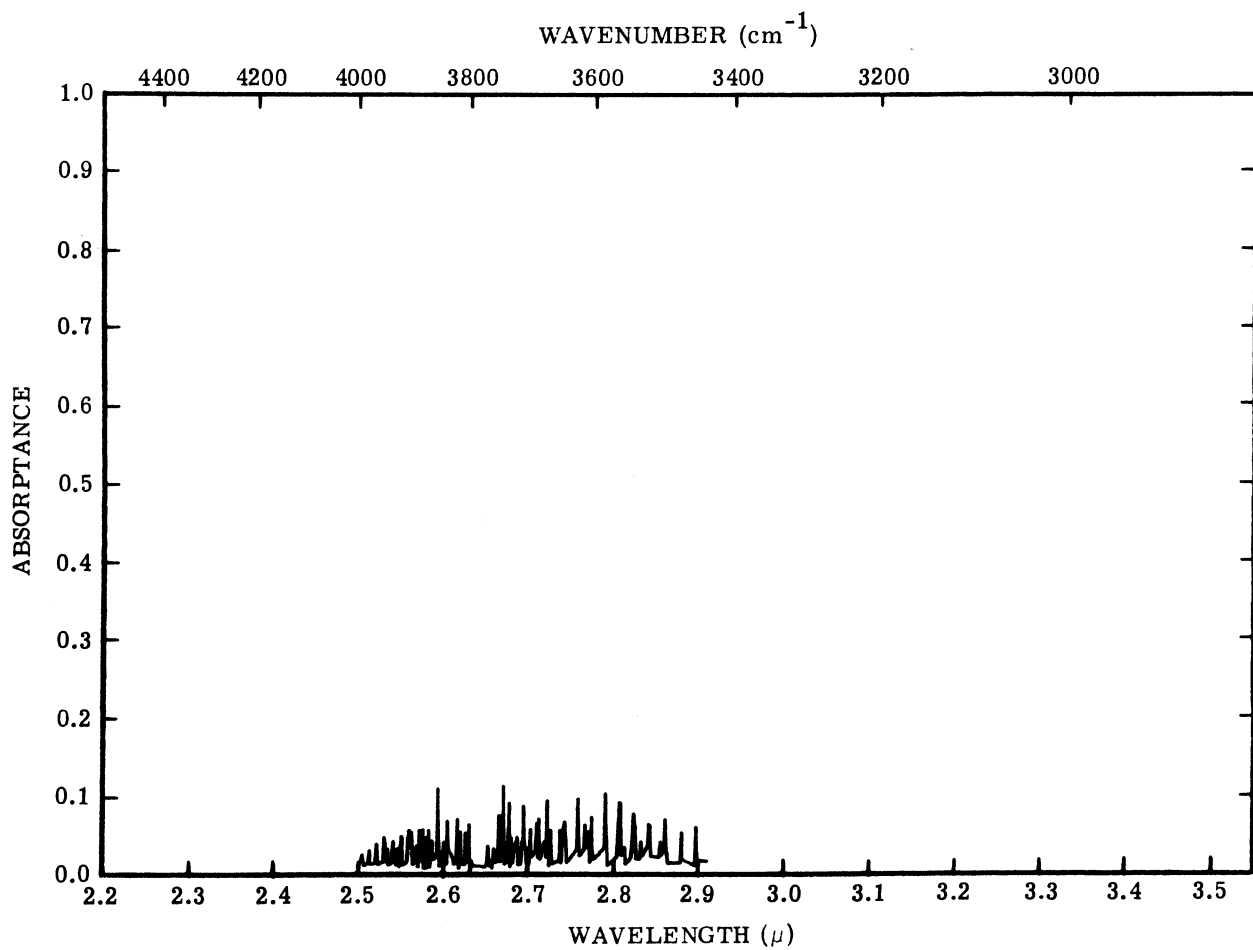


FIGURE 54. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 26.4 mm, T = 795°K.

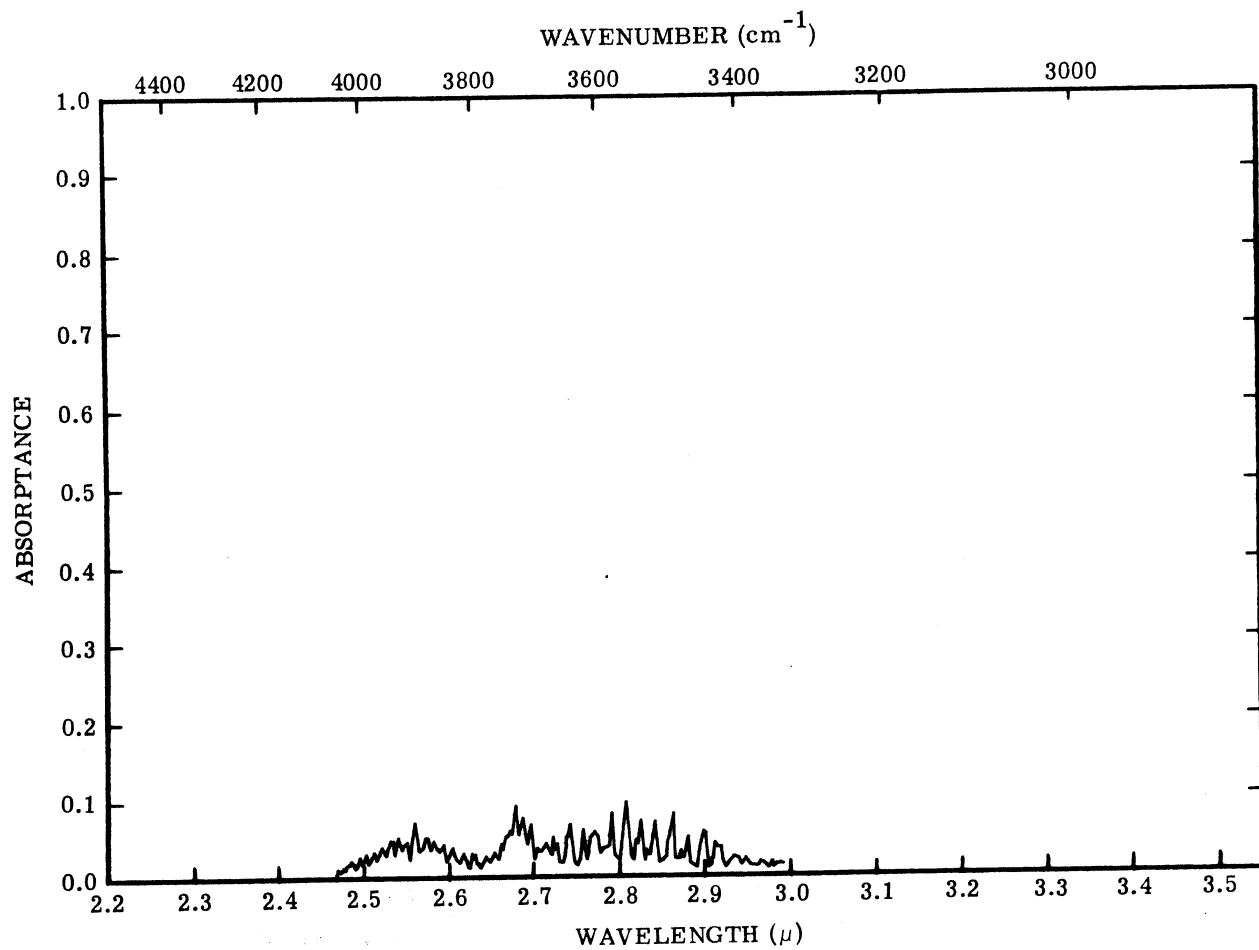


FIGURE 55. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 49.2 mm, T = 762°K.

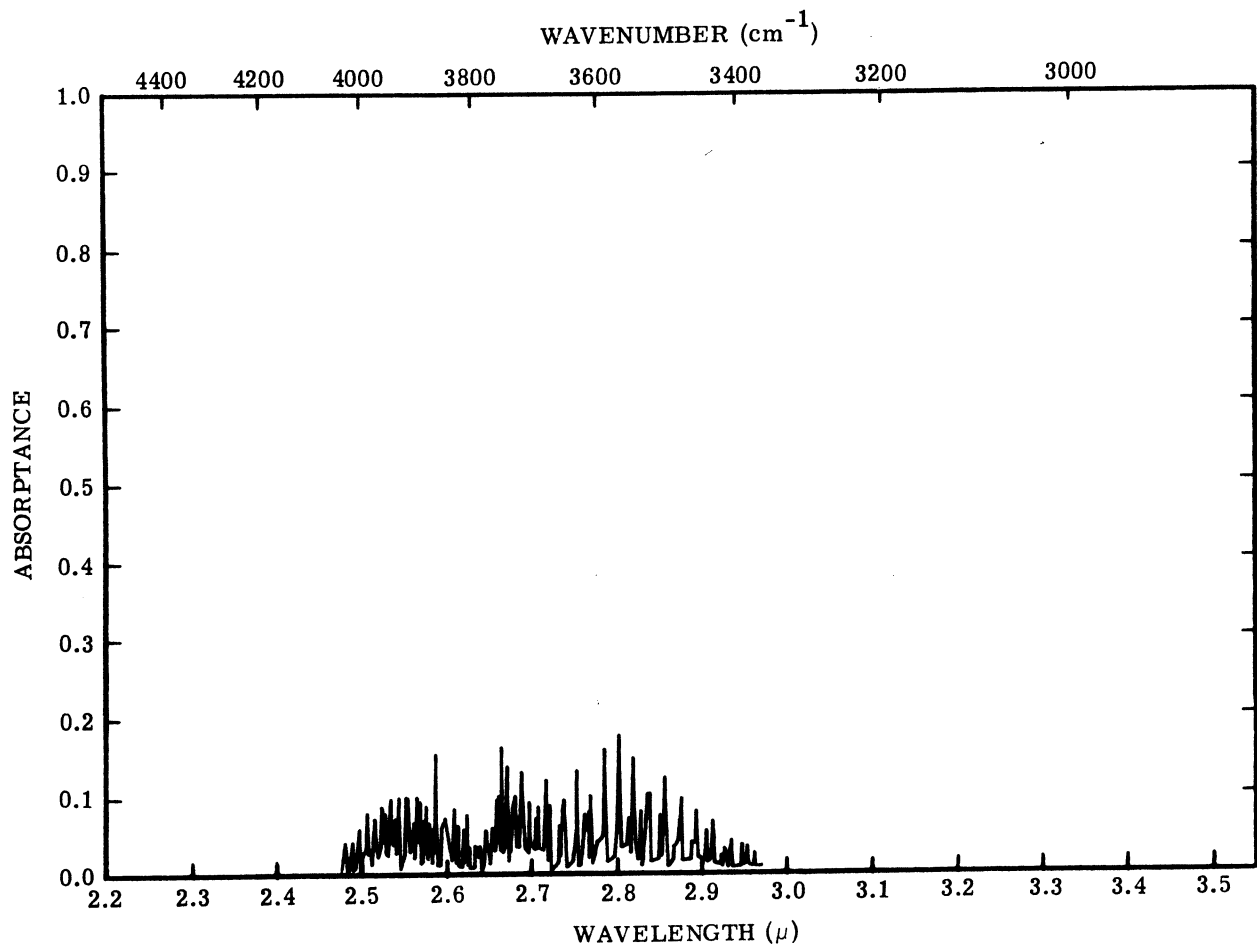


FIGURE 56. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 51.6 mm, T = 777°K.

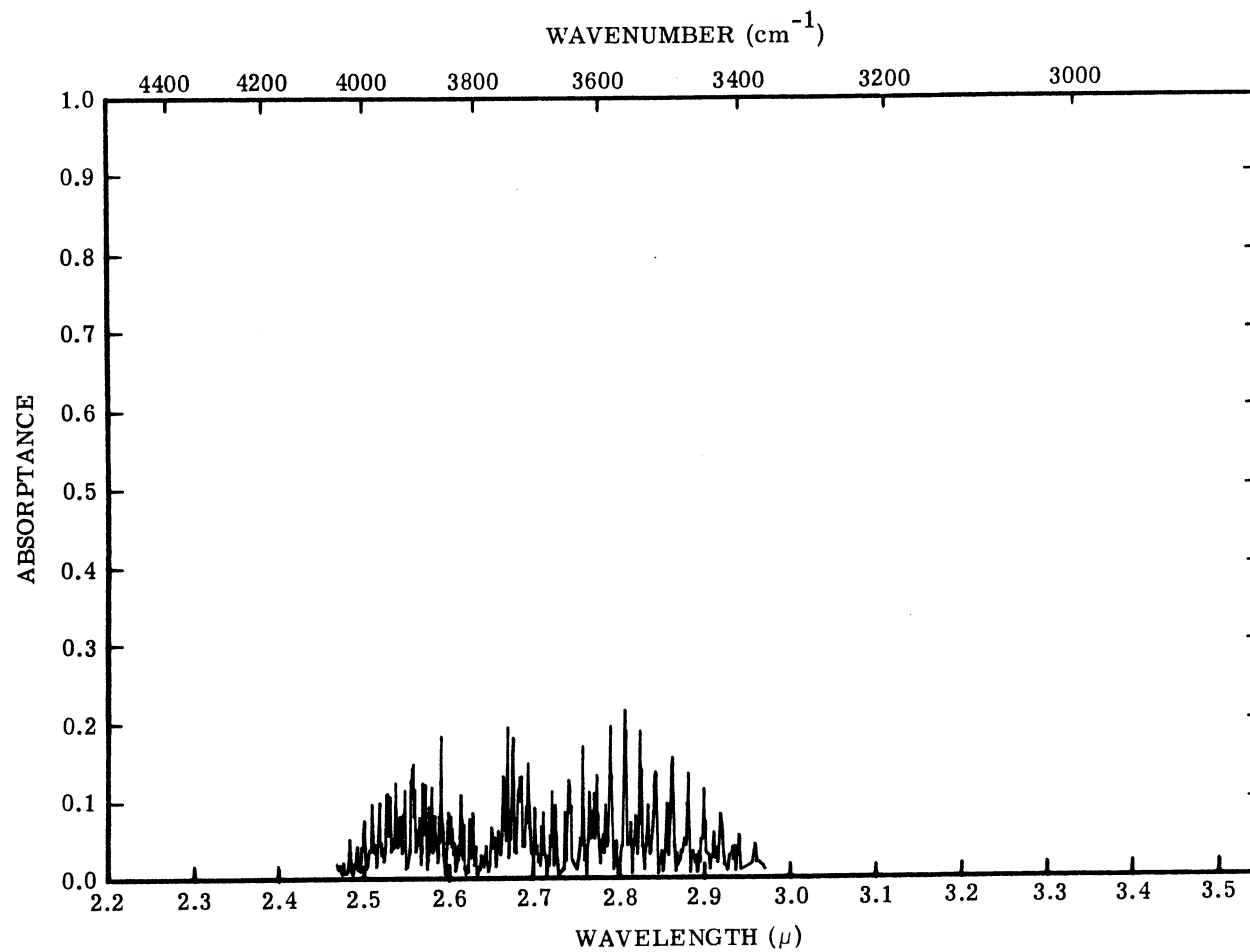


FIGURE 57. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 88.9 mm, T = 779°K.

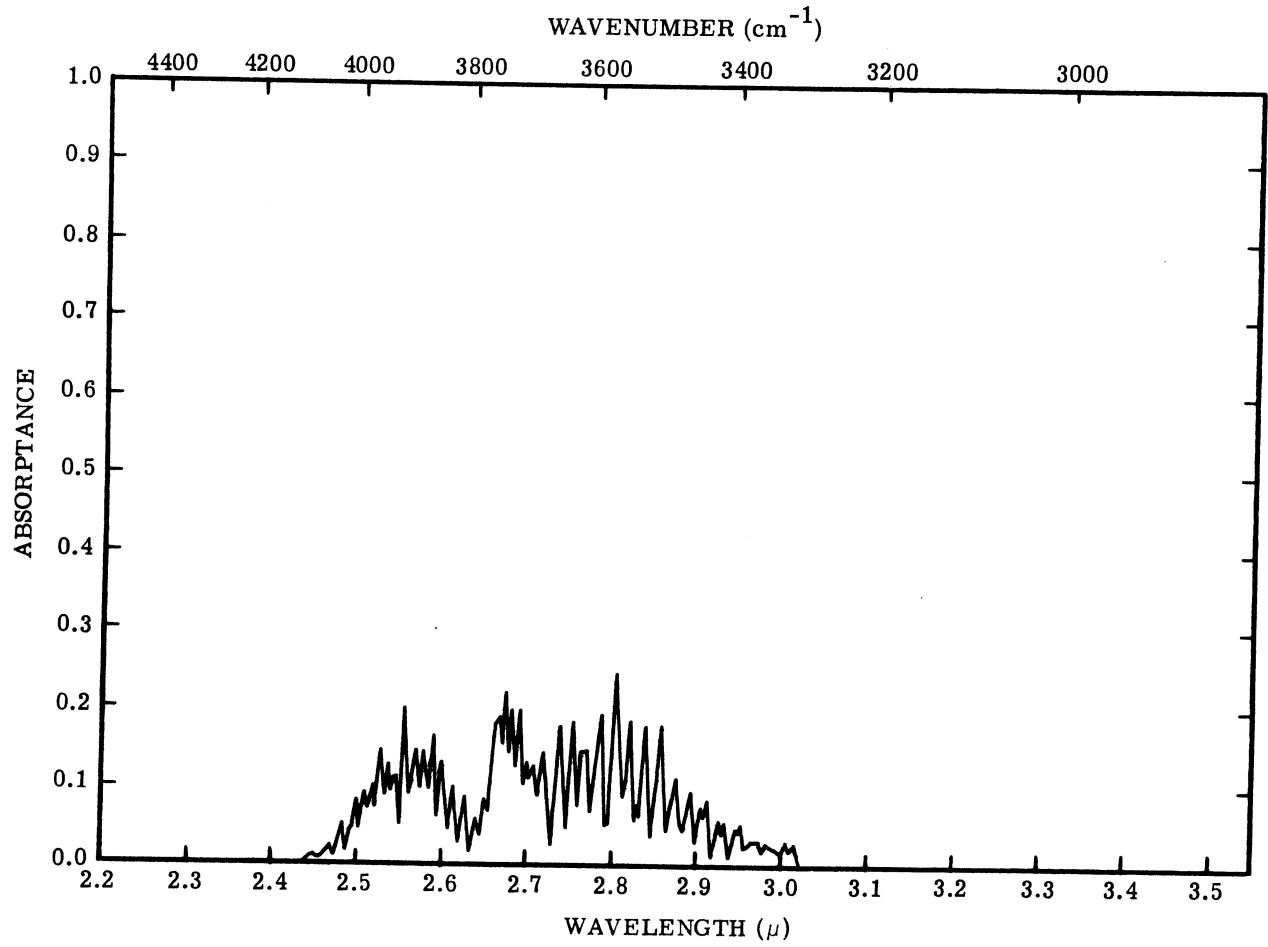


FIGURE 58. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 142.6 mm, T = 758°K.

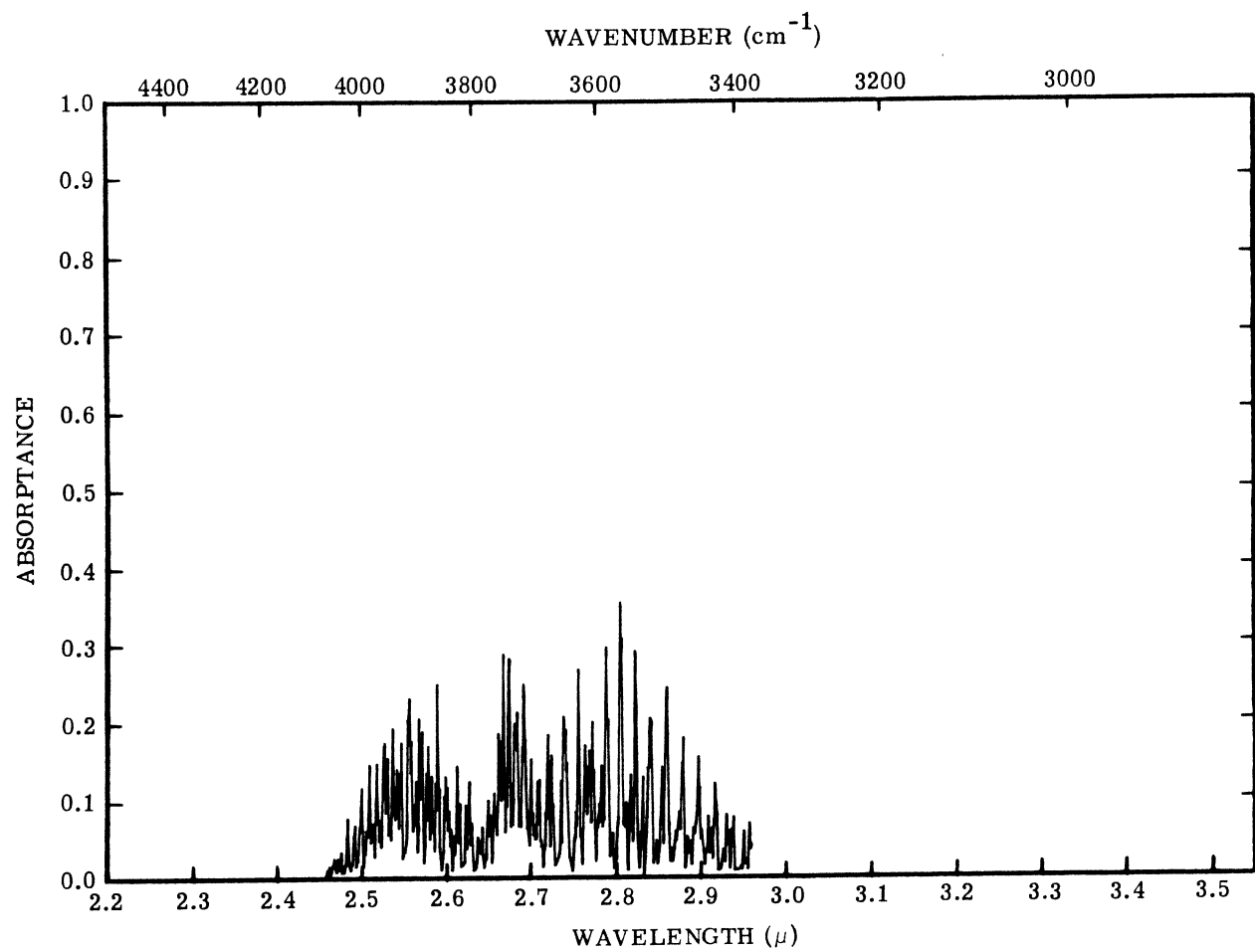


FIGURE 59. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 143.2 mm, T = 769°K.



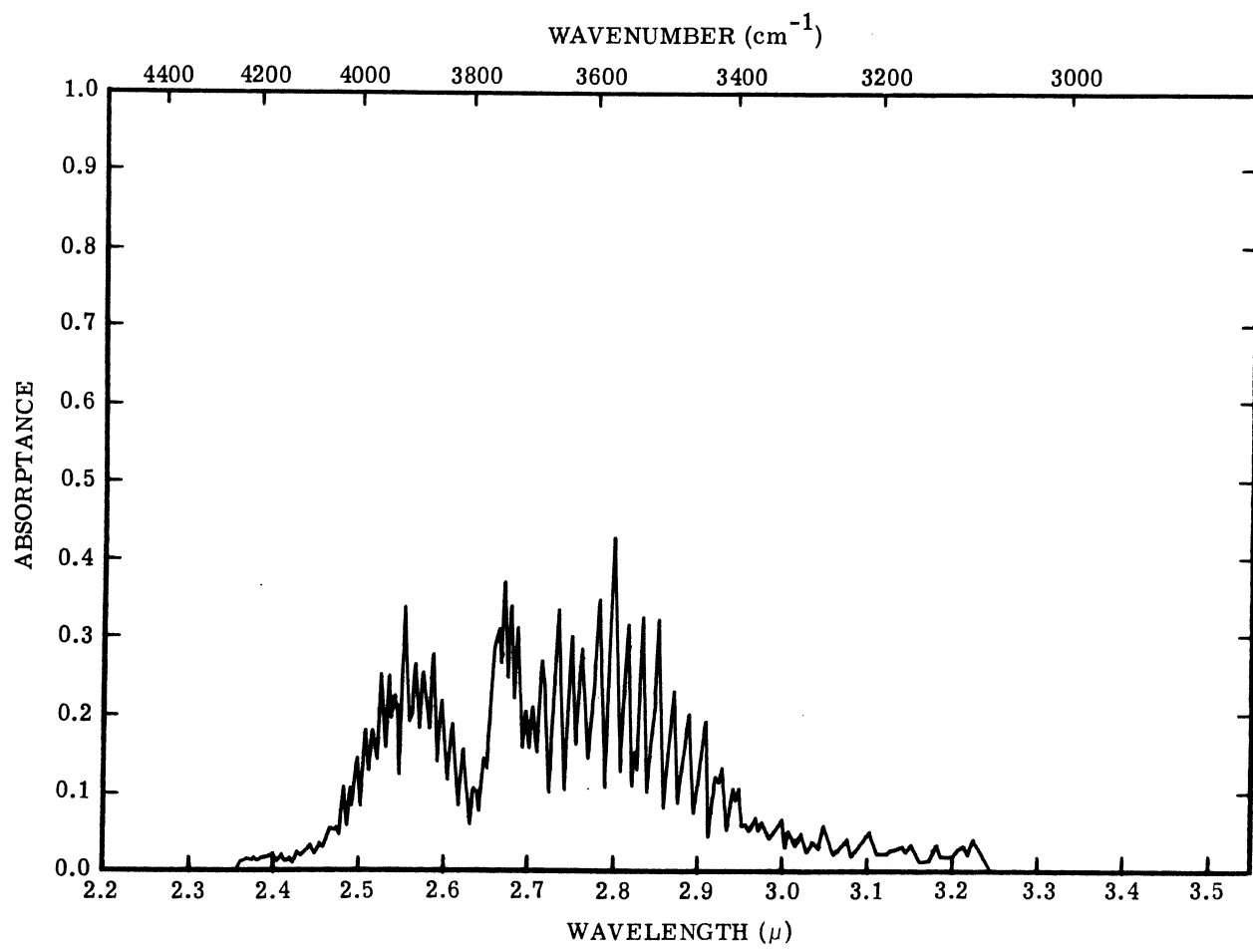


FIGURE 60. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 281.8 mm, T = 750°K.

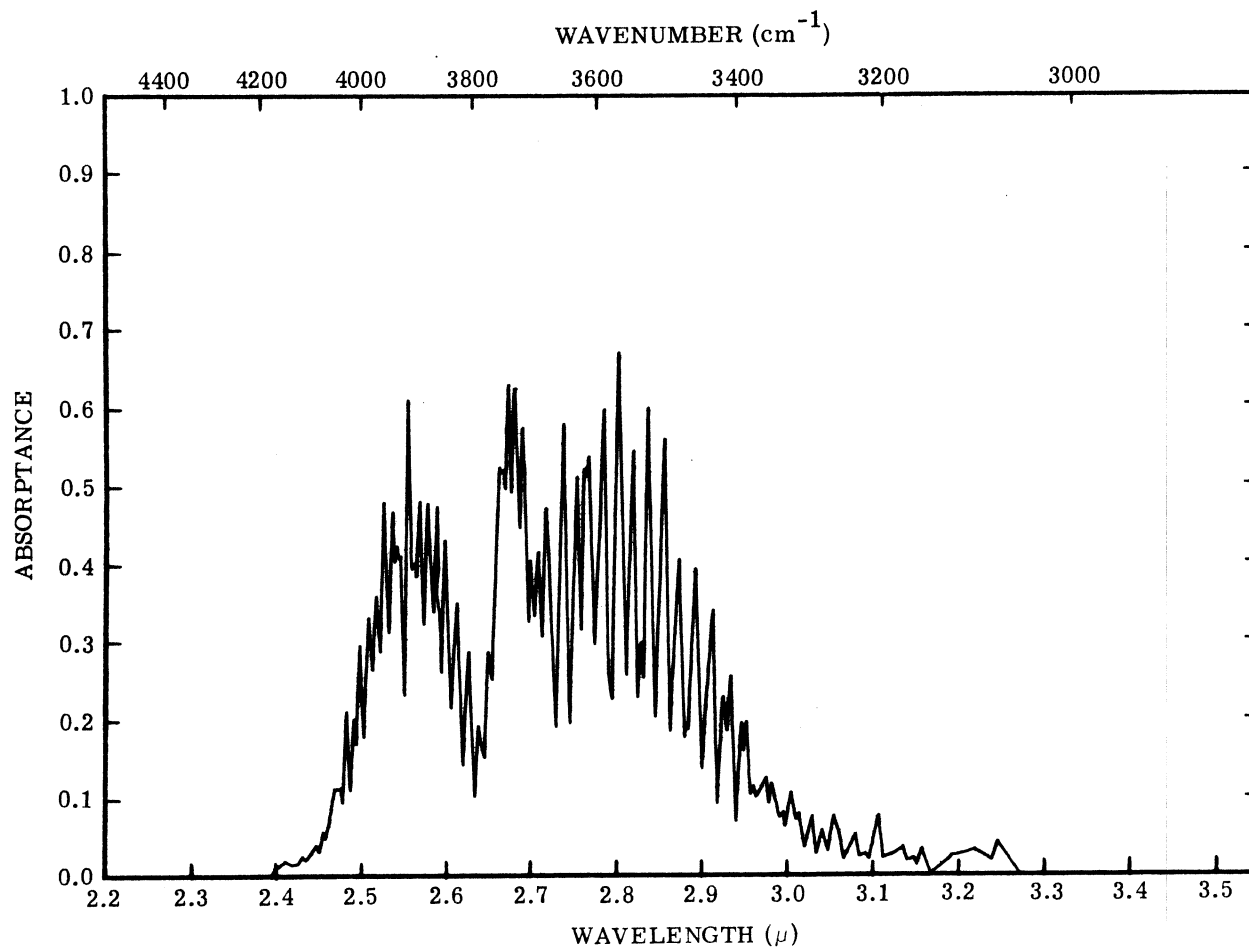


FIGURE 61. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 624.6 mm, T = 790°K.

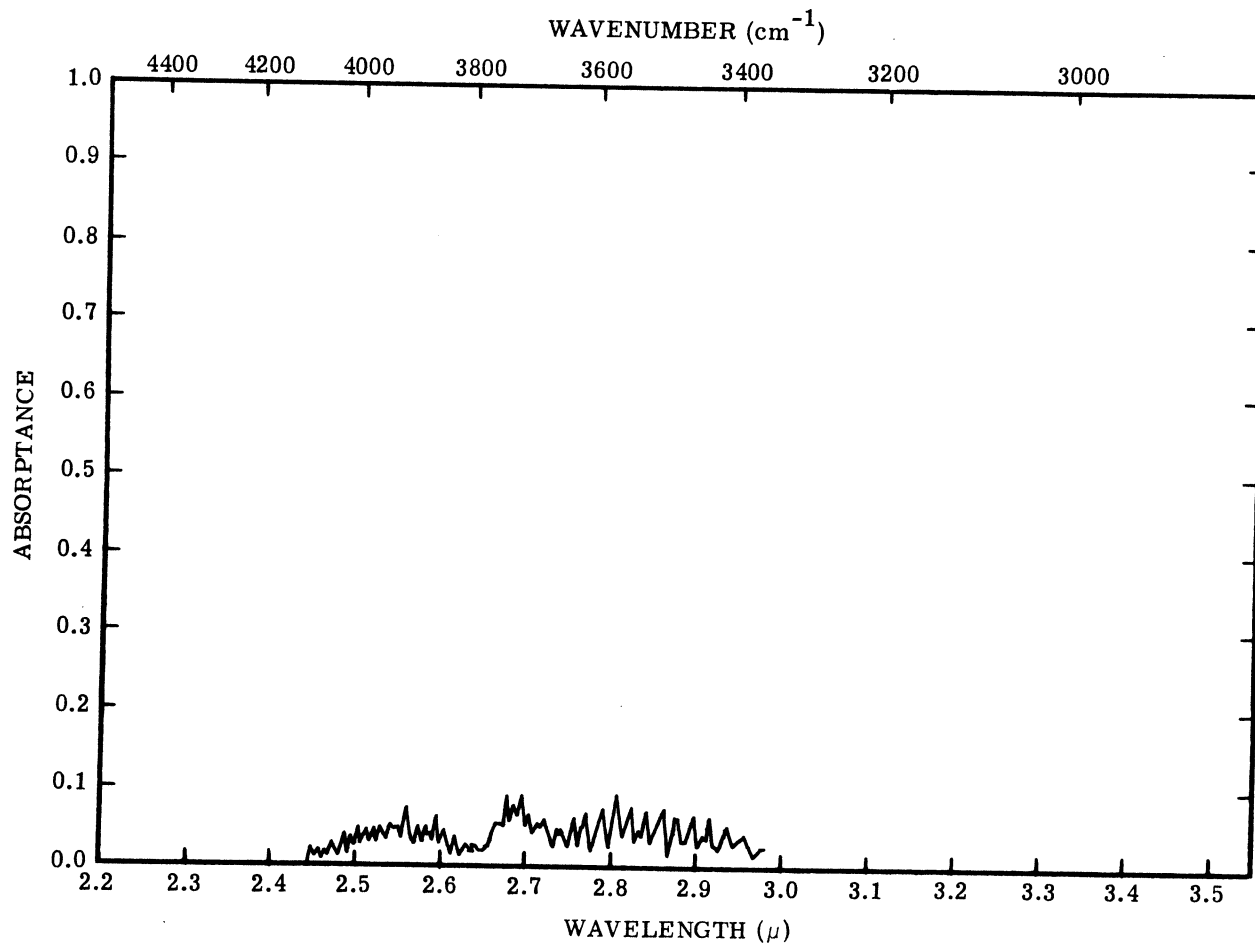


FIGURE 62. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 57.1 mm, T = 1027°K.

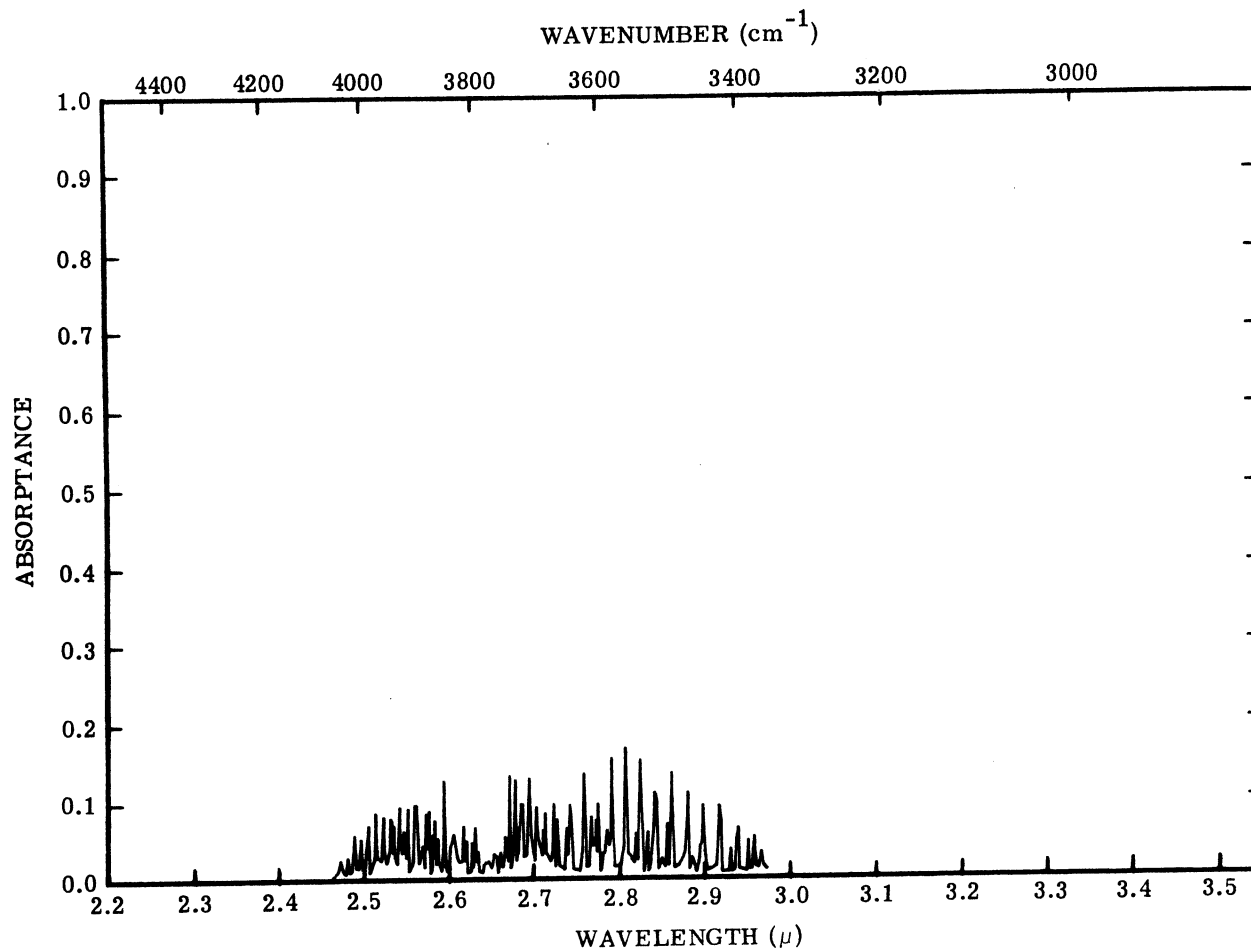


FIGURE 63. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 76.8 mm, T = 1013°K.

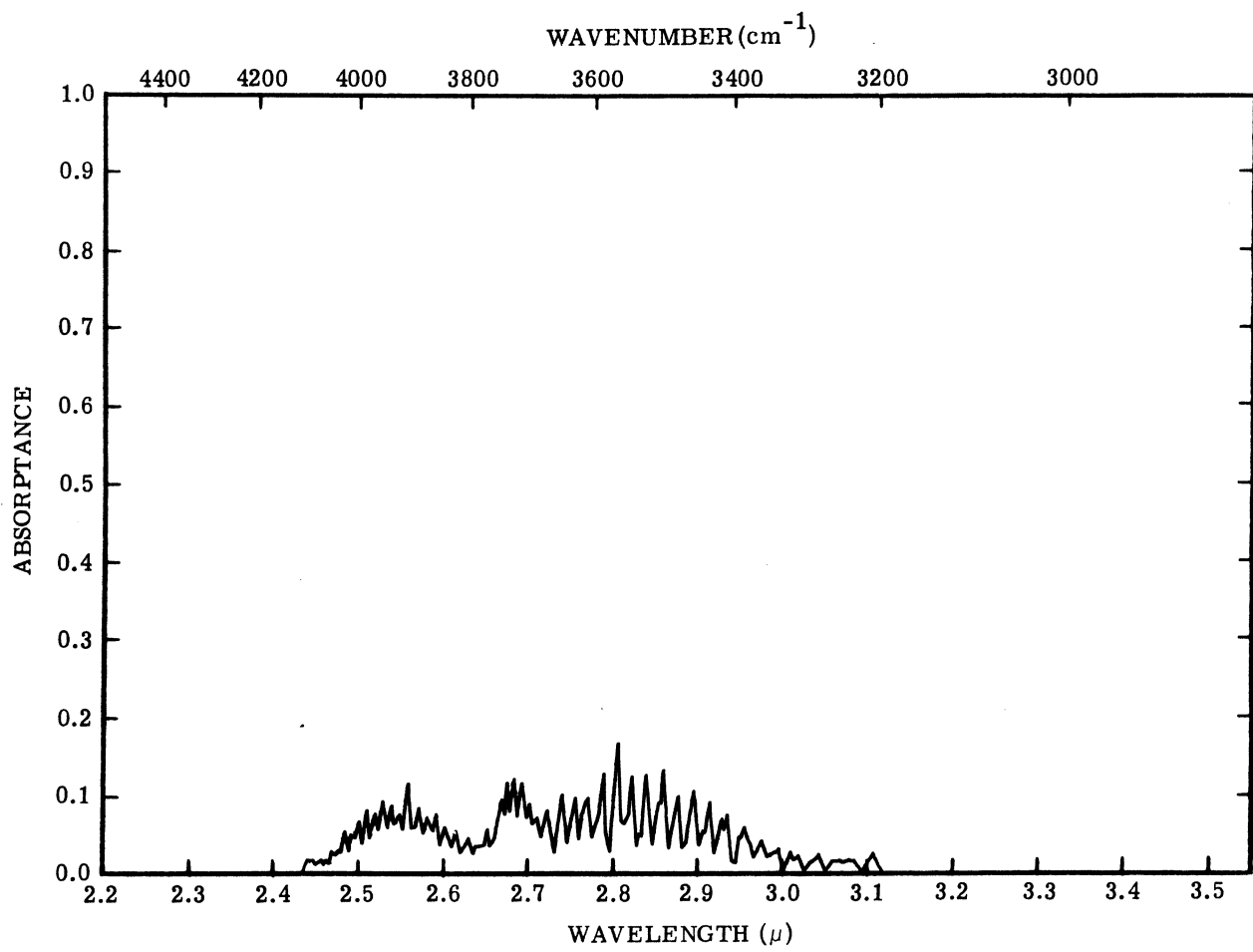


FIGURE 64. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 112.5 mm, T = 1045°K.

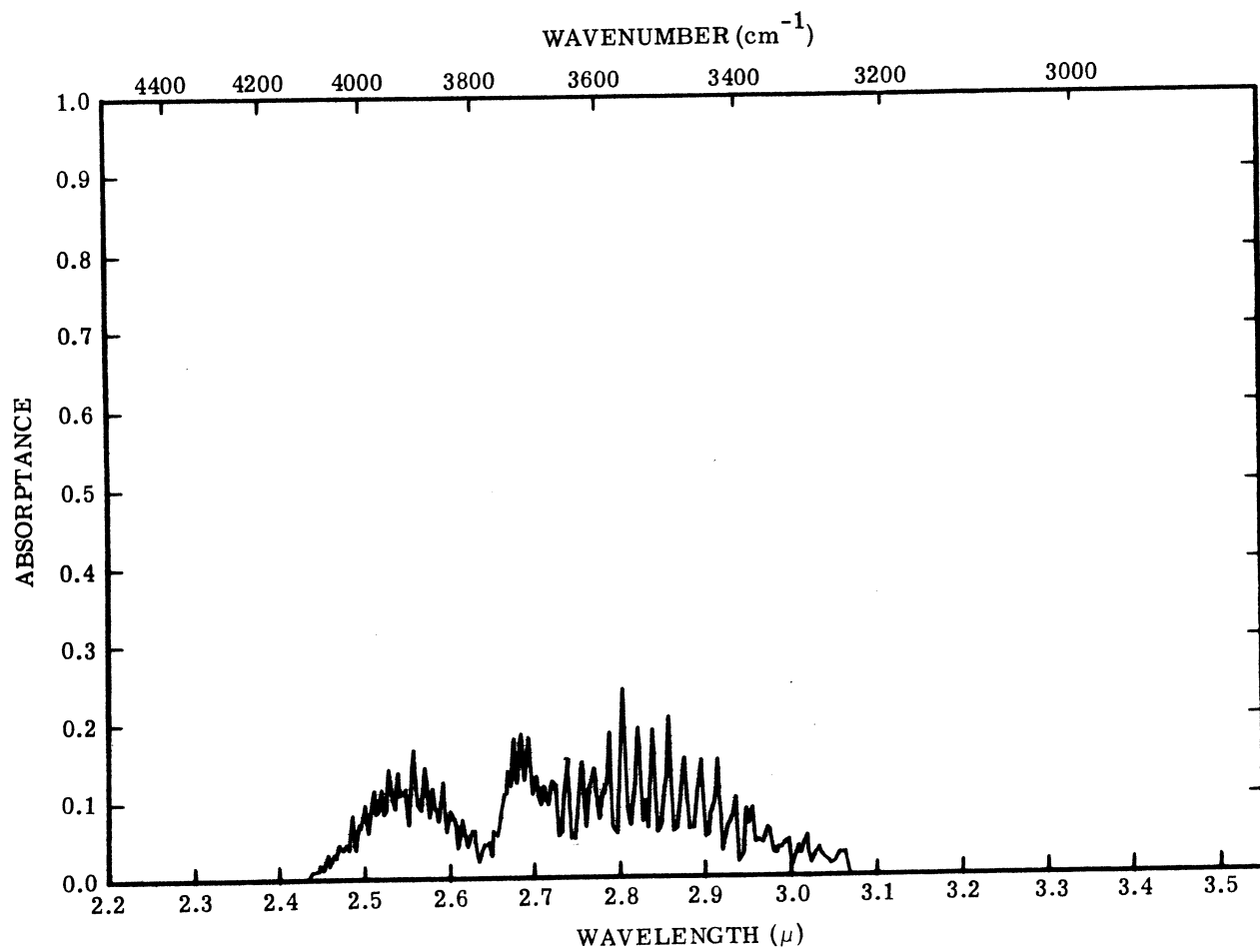


FIGURE 65. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 180.9 mm, T = 1057°K.

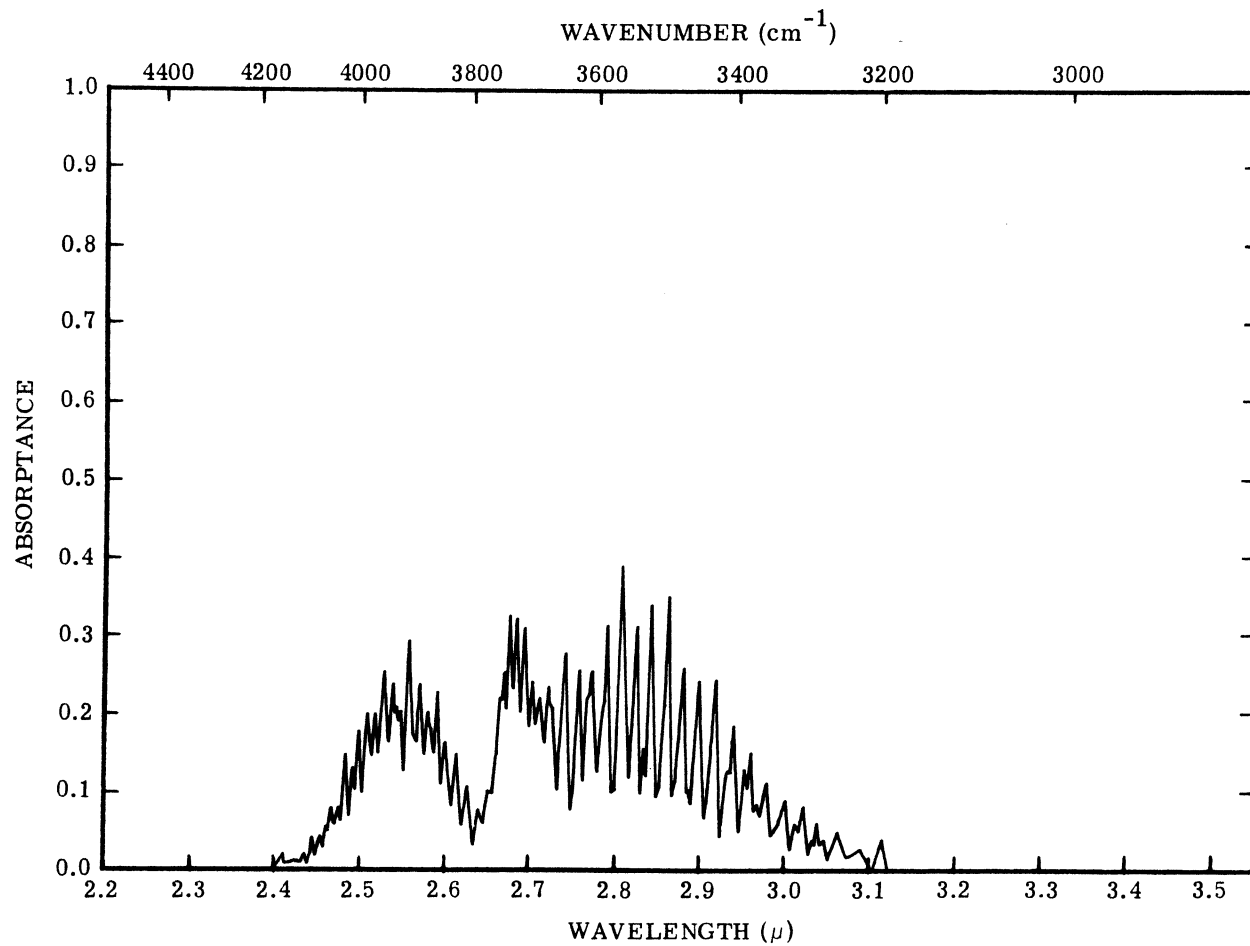


FIGURE 66. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 356.6 mm. T = 1063°K.

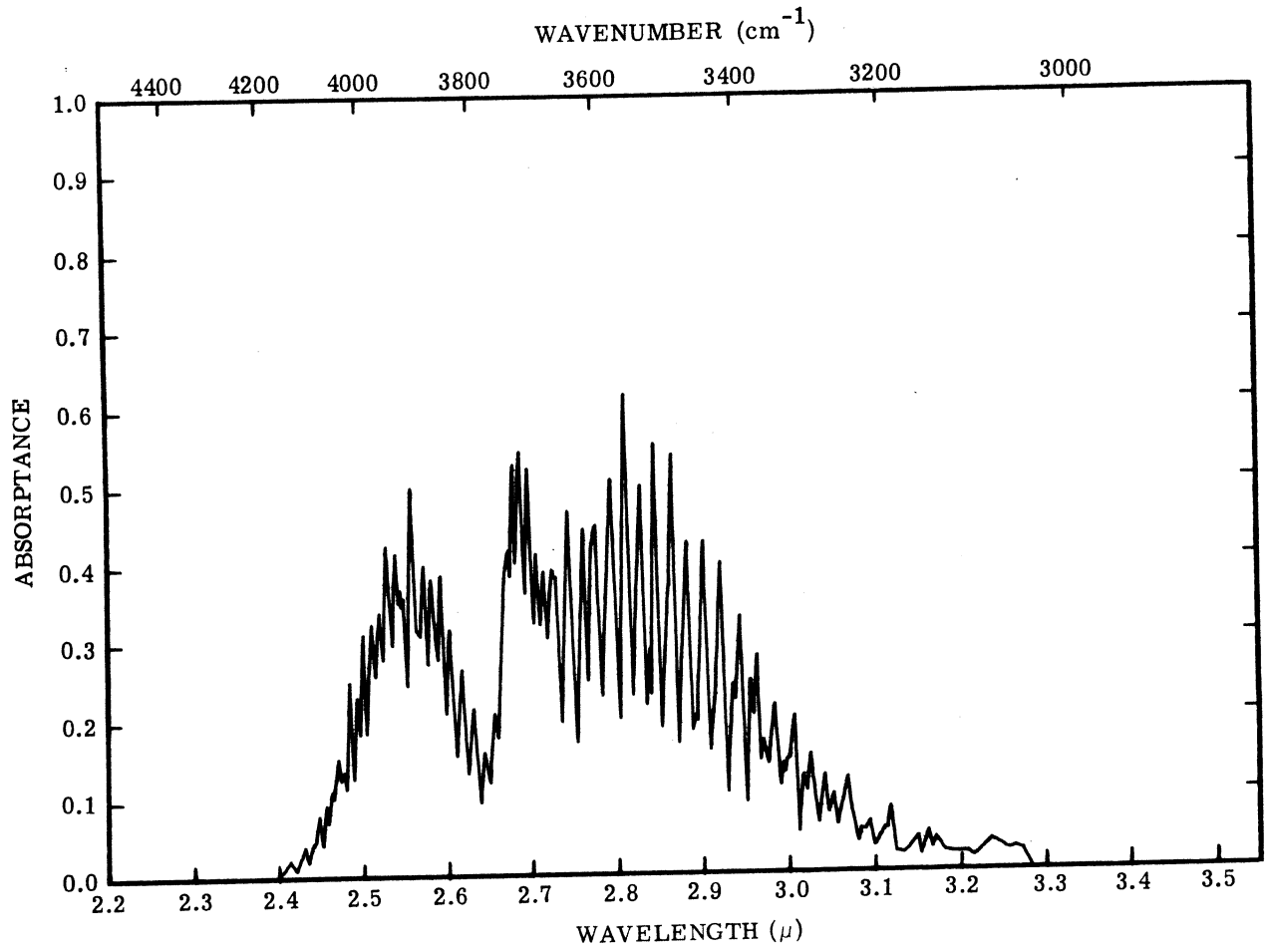


FIGURE 67. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 707.3 mm, T = 1073°K.



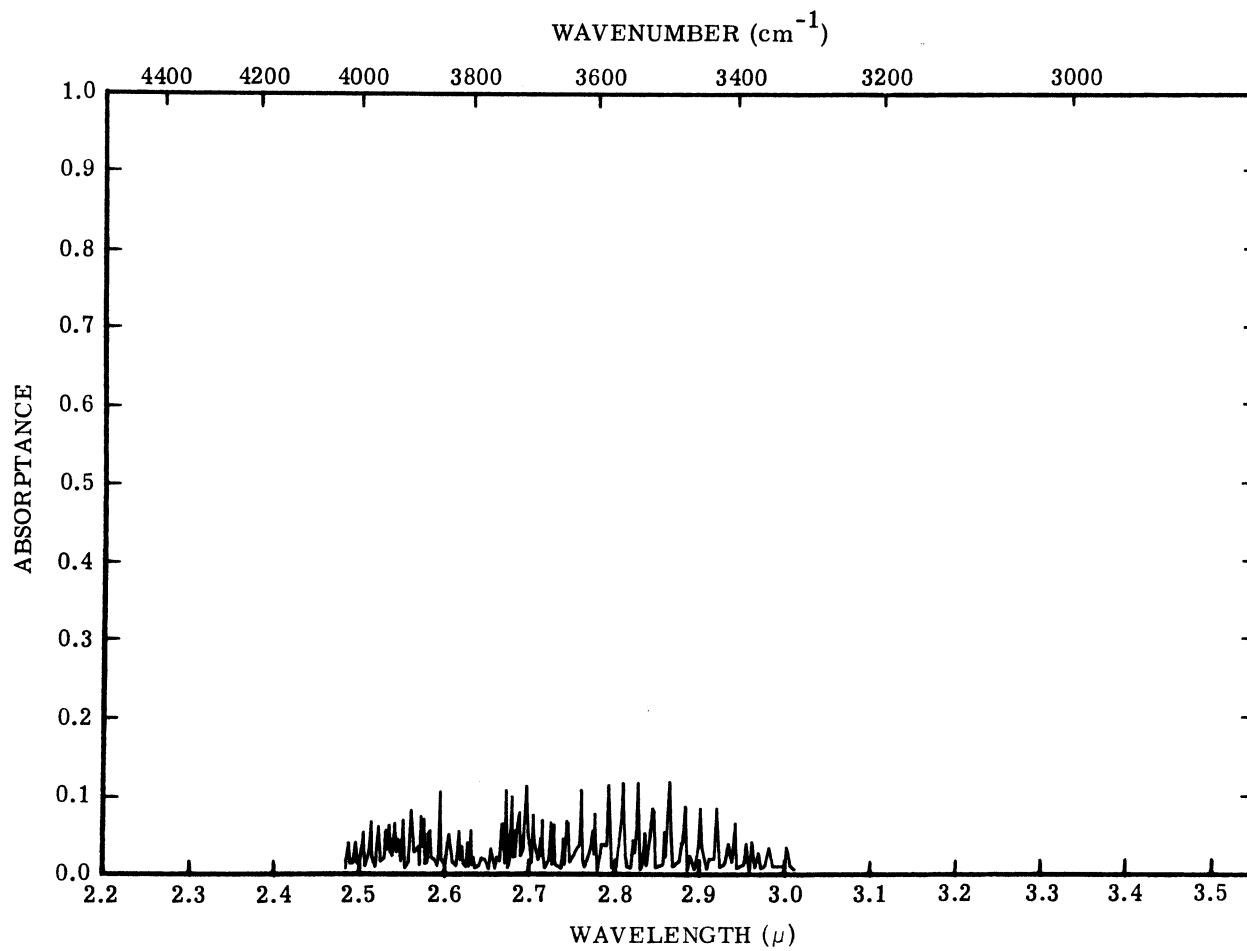


FIGURE 68. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 72.6 mm, T = 1155°K.

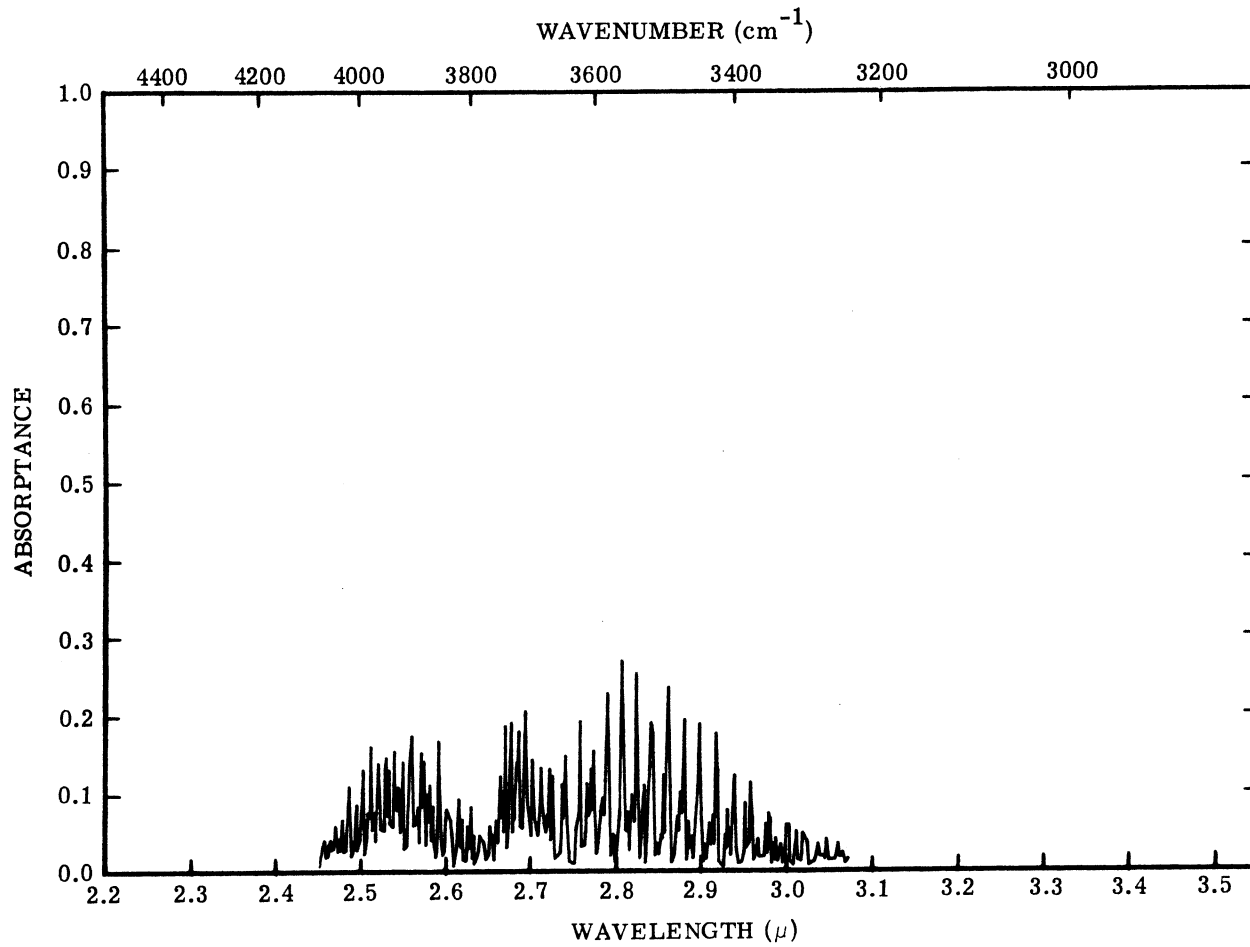


FIGURE 69. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 156.6 mm, T = 1165°K.

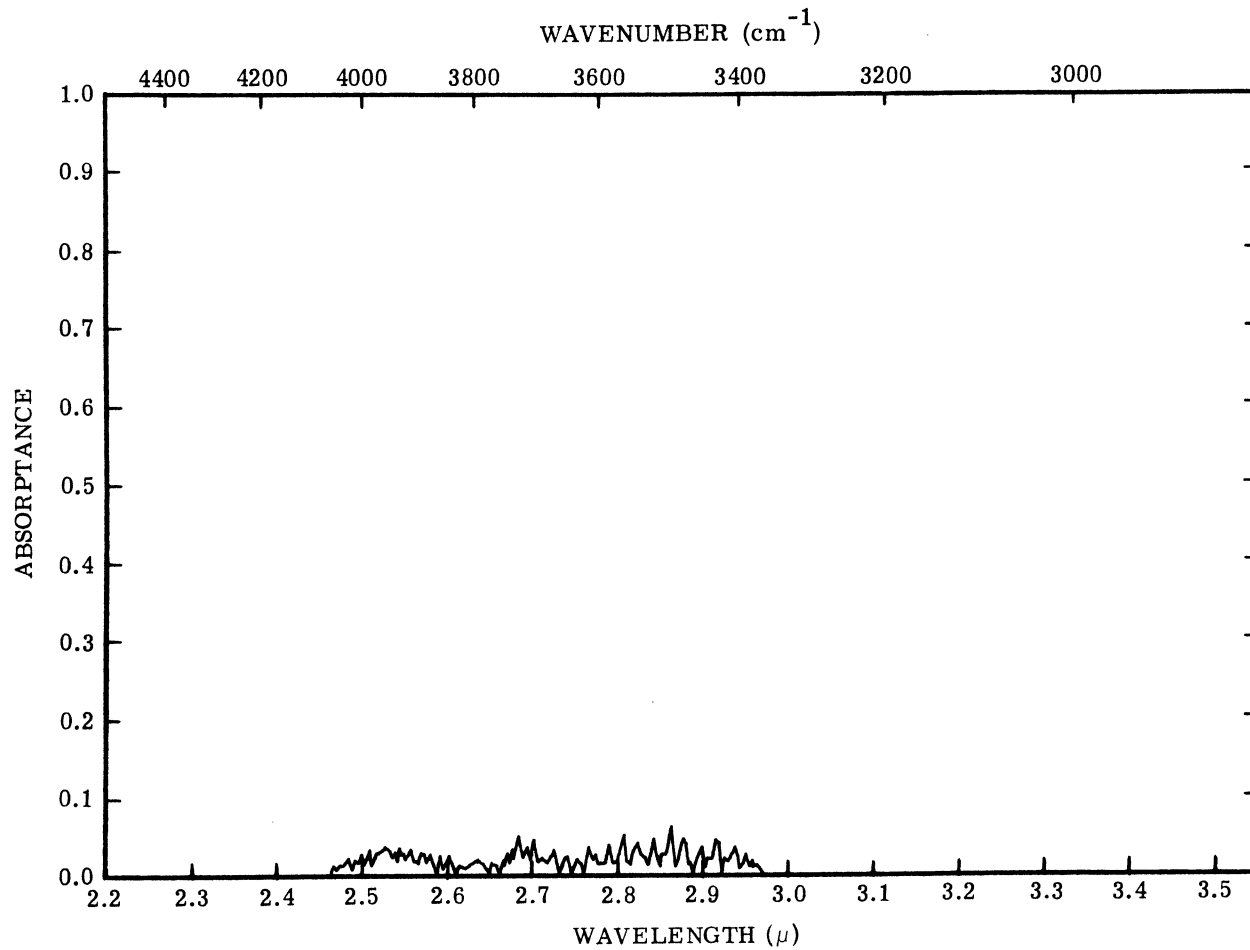


FIGURE 70. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 41.3 mm, T = 1275°K.

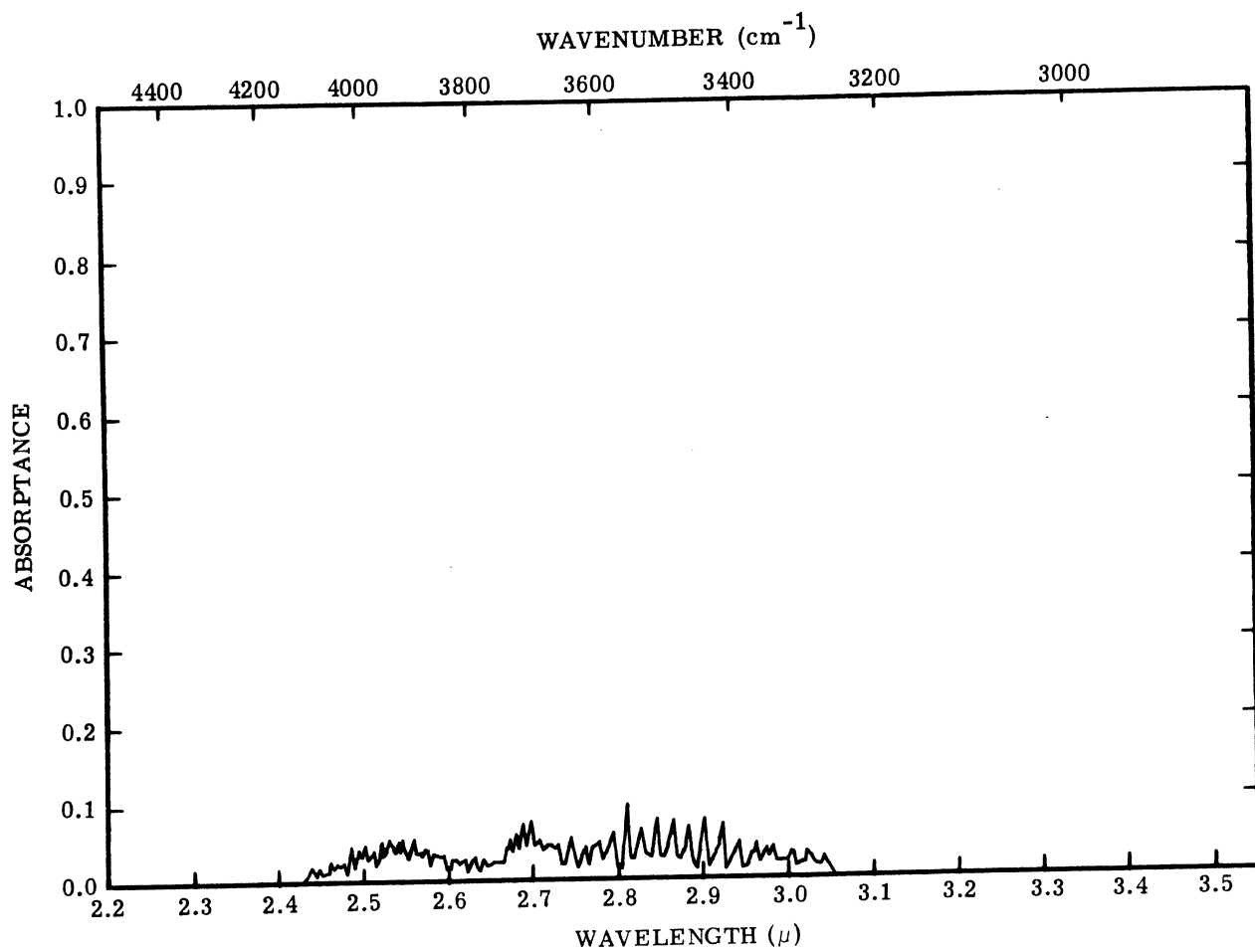


FIGURE 71. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 74.9 mm, T = 1287°K.

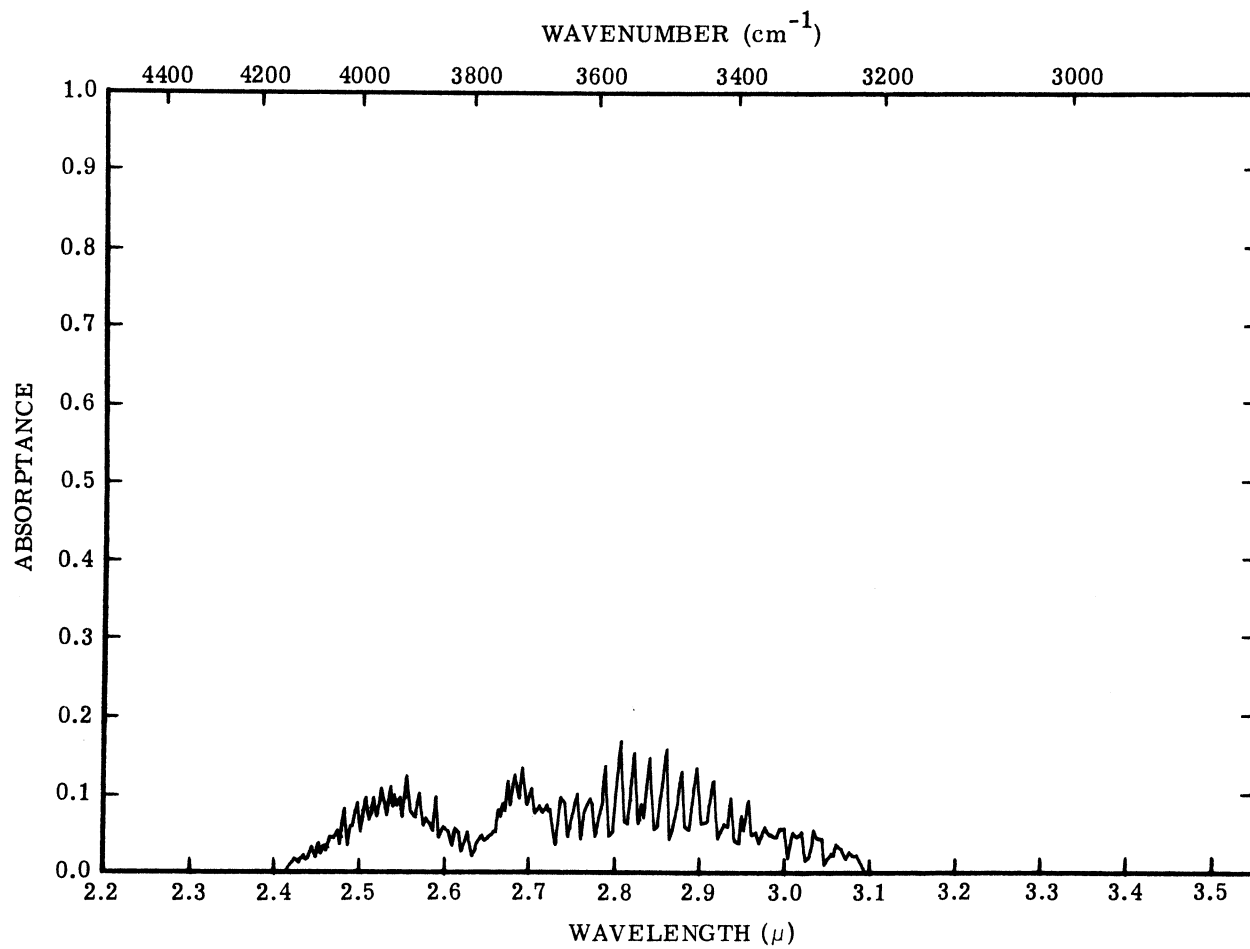


FIGURE 72. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 148.7 mm, T = 1297°K.

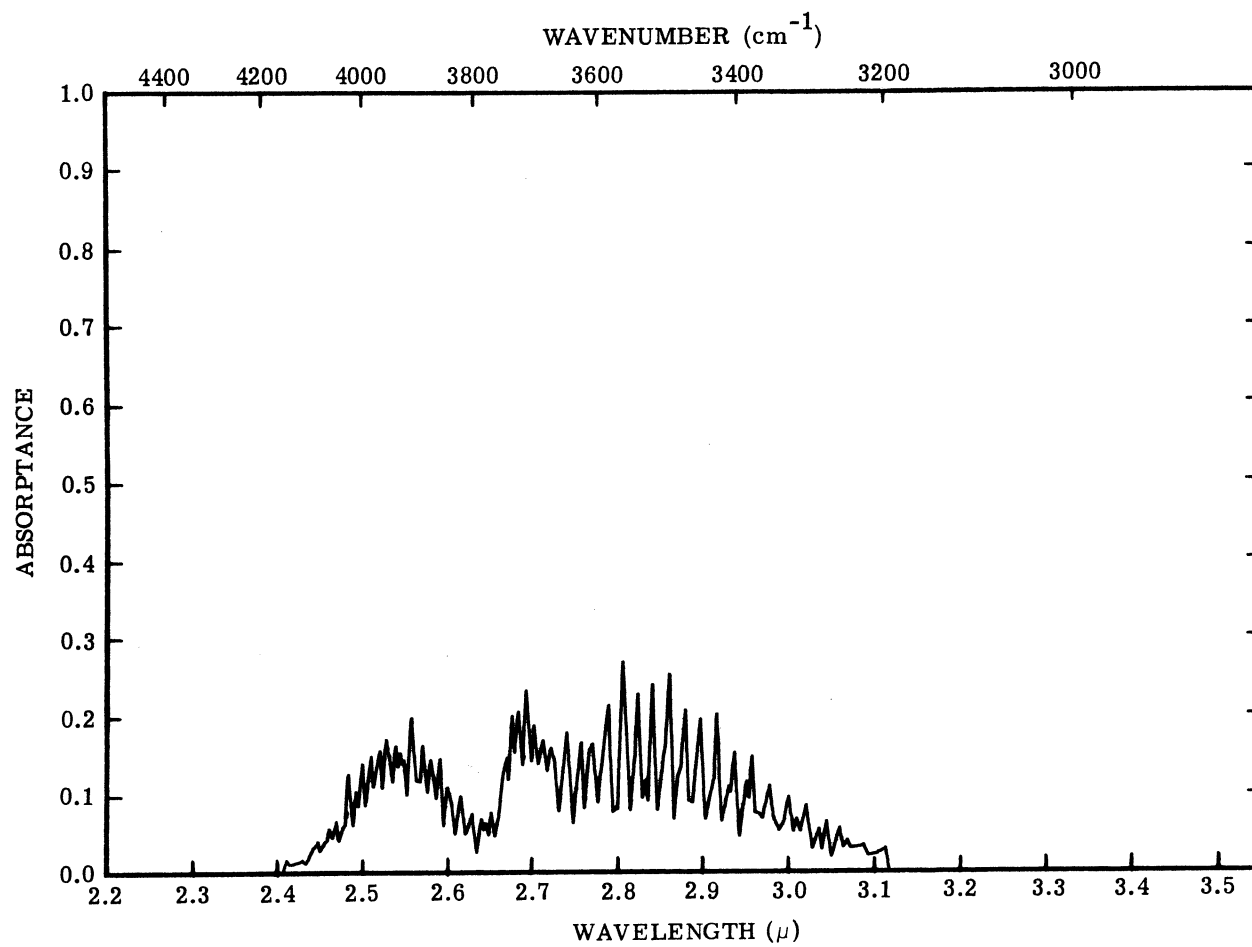


FIGURE 73. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 274.8 mm, T = 1267°K.

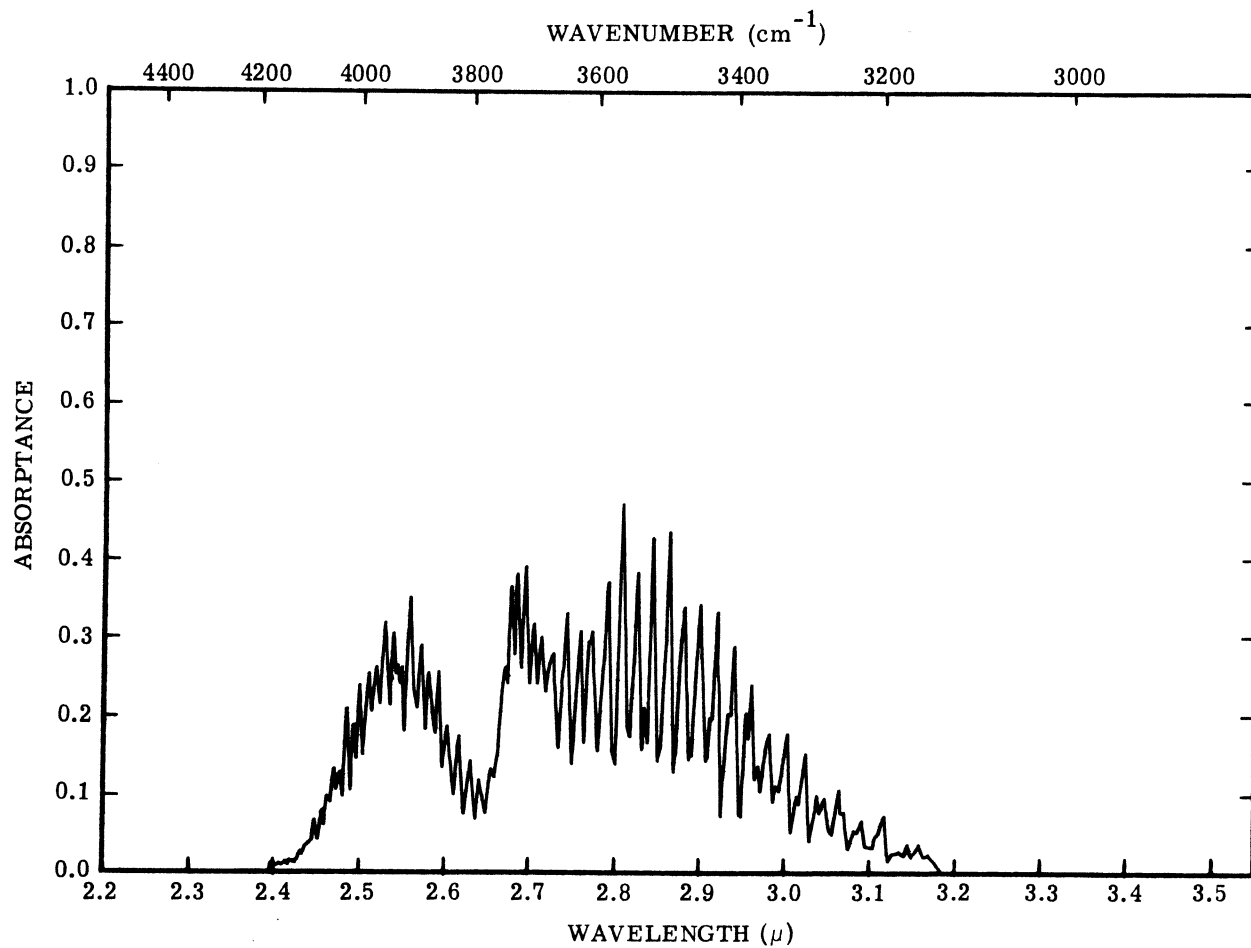


FIGURE 74. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 546.1 mm, T = 1266°K.

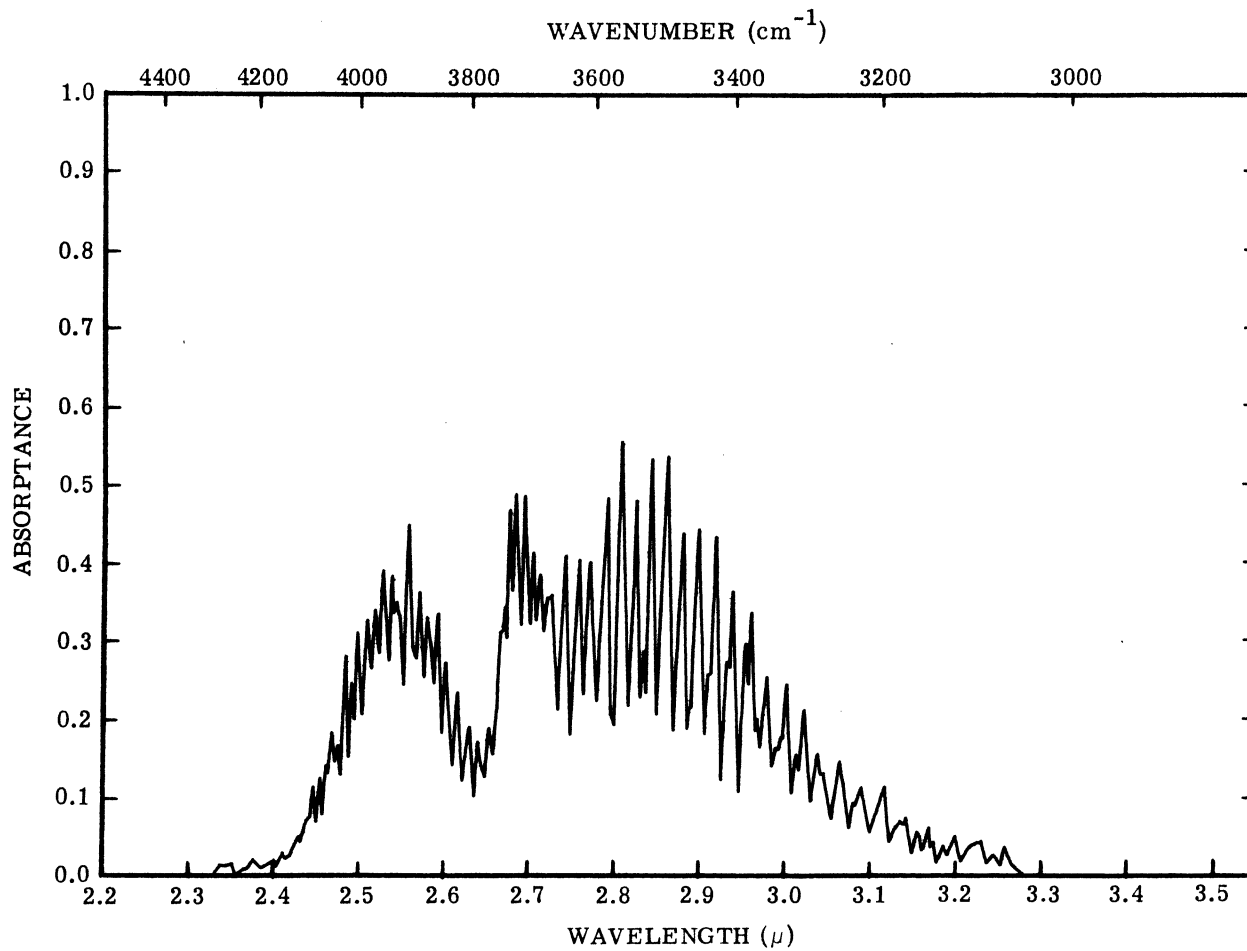


FIGURE 75. ABSORPTION SPECTRUM OF H<sub>2</sub>O. L = 7.75 cm, P = 728.0 mm, T = 1288<sup>o</sup>K.



REFERENCES

1. D. M. Gates, et al., "Line Positions, Strengths, and Half-Widths for Water Vapor Bands  $\nu_1$ ,  $2\nu_2$ , and  $\nu_3$  in the Interval 2857 to 444  $\text{cm}^{-1}$ ," NBS Monograph No. 71, National Bureau of Standards, Washington, D. C., 1965.
2. F. S. Simmons, Studies of Infrared Radiative Transfer in Hot Gases, II: Formulations of Band Models for Nonisothermal Optical Paths, Rept. 4613-92-T, Institute of Science and Technology, The University of Michigan, Ann Arbor, June 1965.
3. D. E. Burch and D. A. Gryvnak, Infrared Radiation Emitted by Hot Gases and Its Transmission Through Synthetic Atmospheres, Rept. U-1929, Aeronutronic Div., Ford Motor Co., Newport Beach, Calif., 1962.
4. U. P. Oppenheim and A. Goldman, "Spectral Emissivity of Water Vapor at 1200°K," Tenth Symposium on Combustion, p. 411, The Combustion Institute, 1965.
5. R. H. Tourin, "Spectral Emissivities of Hot  $\text{CO}_2$ - $\text{H}_2\text{O}$  Mixtures in the 2.7  $\mu$  Region," J. Opt. Soc. Am., 1961, Vol. 51, p. 799.
6. F. S. Simmons, "An Analytical and Experimental Study of Molecular Radiative Transfer in Nonisothermal Gases," Tenth Symposium on Combustion, p. 403, The Combustion Institute, 1965.
7. F. S. Simmons, C. B. Arnold, and N. F. Kent, Studies of Infrared Radiative Transfer in Hot Gases, III: Nonisothermal Radiance in the 2.7- $\mu$   $\text{H}_2\text{O}$  Bands, Rept. 4613-93-T, Institute of Science and Technology, The University of Michigan, Ann Arbor, in preparation.
8. W. S. Benedict and L. D. Kaplan, "Calculation of Line Widths in  $\text{H}_2\text{O}$ - $\text{H}_2\text{O}$  and  $\text{H}_2\text{O}$ - $\text{O}_2$  Collisions," J. Quant. Spectros. Rad. Trans., 1964, Vol. 4, p. 453.
9. D. E. Burch, E. B. Singleton, and D. Williams, "Absorption Line Broadening in the Infrared," Appl. Opt., 1962, Vol. 1, p. 359.
10. C. C. Ferriso and C. B. Ludwig, "Spectral Emissivities and Integrated Intensities of the 2.7  $\mu$   $\text{H}_2\text{O}$  Band Between 530° and 2200°K," J. Quant. Spectros. Rad. Trans., 1964, Vol. 4, p. 215.
11. F. S. Simmons, unpublished data obtained at Rocketdyne, Canoga Park, Calif., during 1961. (Experimental procedure and facility described in J. Quant. Spectros. Rad. Trans., 1964, Vol. 4, p. 95.)

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REIFMAN, ALFRED COPY NO. 149</p> <p>ATLANTIC RESEARCH CORPORATION 4056 EASY STREET EL MONTE, CALIFORNIA ATTN. LIBRARY NIEDERMAN, HAROLD COPY NO. 150</p> <p>ATLANTIC RESEARCH CORPORATION HENRY G. SHIRLEY MEMORIAL HIGHWAY ALEXANDRIA, VIRGINIA ATTN. LIBRARY COPY NO. 151</p> <p>AVCO-EVERETT RESEARCH LABORATORY 2385 REVERE BEACH PARKWAY EVERETT 49, MASSACHUSETTS ATTN. ABELL, GORDON R. COPY NO. 152</p> <p>AVCO-EVERETT RESEARCH LABORATORY 2385 REVERE BEACH PARKWAY EVERETT 49, MASSACHUSETTS ATTN. KANTROWITZ, ARTHUR R. COPY NO. 153</p> <p>AVCO-EVERETT RESEARCH LABORATORY 2385 REVERE BEACH PARKWAY EVERETT, MASSACHUSETTS ATTN. KIVEL, DR. BENNETT COPY NO. 154</p> <p>AVCO-EVERETT RESEARCH LABORATORY 2385 REVERE BEACH PARKWAY EVERETT, MASSACHUSETTS 02149 ATTN. NORLING, ROBERT A. COPY NO. 155</p> <p>AVCO-EVERETT RESEARCH LABORATORY 2385 REVERE BEACH PARKWAY EVERETT, MASSACHUSETTS 02149 ATTN. PETTY, CHARLES C. COPY NO. 156</p> <p>AVCO-EVERETT RESEARCH LABORATORY 2385 REVERE BEACH PARKWAY EVERETT 49, MASSACHUSETTS ATTN. SPENCE, BARBARA TECHNICAL LIBRARY COPY NO. 157</p> <p>AVCO-EVERETT RESEARCH LABORATORY 2385 REVERE BEACH PARKWAY EVERETT, MASSACHUSETTS 02149 ATTN. TAYLOR, DR. RAYMOND L. COPY NO. 158</p>	<p>AVCO CORPORATION ADV. RESEARCH + DEV. DIVISION 201 LOWELL STREET WILMINGTON, MASSACHUSETTS ATTN. DETRA, DR. RALPH W. COPY NO. 159</p> <p>AVCO CORPORATION RAD FLIGHT TECHNOLOGY DEPT. 201 LOWELL STREET WILMINGTON, MASSACHUSETTS ATTN. FLICKINGER, H. COPY NO. 160</p> <p>AVCO CORPORATION ADV. RESEARCH + DEV. DIVISION 201 LOWELL STREET WILMINGTON, MASS. 01887 ATTN. GEDRGIEV, STEVEN COPY NO. 161</p> <p>AVCO CORPORATION RAD FLIGHT TECHNOLOGY DEPT. 201 LOWELL STREET WILMINGTON, MASSACHUSETTS ATTN. GREENBERG, ED COPY NO. 162</p> <p>AVCO CORPORATION RESEARCH + ADV. DEV. DIVISION 201 LOWELL STREET WILMINGTON, MASS. 01887 ATTN. HUNTER, HERBERT E. VIA. DOCUMENT CONTROL COPY NO. 163</p> <p>AVCO CORPORATION ADV. RESEARCH + DEV. DIVISION 201 LOWELL STREET WILMINGTON, MASSACHUSETTS ATTN. DOCUMENT CONTROL COPY NO. 164</p> <p>AVCO CORPORATION RESEARCH + ADV. DEV. DIVISION 201 LOWELL STREET WILMINGTON, MASSACHUSETTS ATTN. RUPPRECHT, THEODORE A. CHIEF RES. LIBRARIAN COPY NO. 165</p> <p>AVCO CORPORATION PENETRATION PROGRAM OFFICE 201 LOWELL STREET WILMINGTON, MASSACHUSETTS ATTN. WALKER, DONALD R. VIA. DOCUMENT CONTROL COPY NO. 166</p> <p>AVCO CORPORATION ADV. RESEARCH + DEV. DIVISION 201 LOWELL STREET WILMINGTON, MASSACHUSETTS ATTN. WENTINK, DR. TUNIS JR. COPY NO. 167</p> <p>BAIRD-ATOMIC, INCORPORATED 33 UNIVERSITY ROAD CAMBRIDGE, MASS. 02138 ATTN. LANGTON, WILLIAM G. VIA. DOCUMENT CONTROL COPY NO. 168</p> <p>BAIRD-ATOMIC, INCORPORATED 33 UNIVERSITY ROAD CAMBRIDGE 38, MASSACHUSETTS ATTN. DOCUMENTS CONTROL CENTER COPY NO. 169</p> <p>BAIRD-ATOMIC, INCORPORATED 95 SECOND AVENUE WALTHAM, MASSACHUSETTS ATTN. BRENNAN, THOMAS W. COPY NO. 170</p> <p>LIBRARIAN BARNES ENGINEERING COMPANY DEVELOPMENT ENGINEERING 30 COMMERCE ROAD STAMFORD, CONNECTICUT ATTN. RACZKA, J. G. COPY NO. 171</p> <p>BARNES ENGINEERING COMPANY FIELD ENGINEERING DEPARTMENT 30 COMMERCE ROAD STAMFORD, CONNECTICUT ATTN. YATES, HAROLD W. COPY NO. 172</p> <p>BATTELLE MEMORIAL INSTITUTE 505 KING AVENUE COLUMBUS, OHIO 43200 ATTN. BADERTSCHER, ROBERT F. COPY NO. 173</p> <p>BATTELLE MEMORIAL INSTITUTE 505 KING AVENUE COLUMBUS, OHIO 43201 ATTN. GLOBE, SAMUEL COPY NO. 174</p>	<p>BATTELLE MEMORIAL INSTITUTE 505 KING AVENUE COLUMBUS 1, OHIO ATTN. BMI-DEFENDER JAMES OTT COPY NO. 175</p> <p>BATTELLE MEMORIAL INSTITUTE 505 KING AVENUE COLUMBUS, OHIO 43201 ATTN. UNGAR, EDWARD W. COPY NO. 176</p> <p>BELL TELEPHONE LABORATORIES WHIPPANY LABORATORIES WHIPPANY, NEW JERSEY 07981 ATTN. TECH. INFORMATION LIBRARY HAY, GEORGE W. COPY NO. 177</p> <p>BELL TELEPHONE LABORATORIES WHIPPANY ROAD WHIPPANY, NEW JERSEY ATTN. HURLBUT, HAROLD D. COPY NO. 178</p> <p>BELL TELEPHONE LABORATORIES WHIPPANY, NEW JERSEY ATTN. IRVINE, MERLE M. COPY NO. 179</p> <p>BELL TELEPHONE LABORATORIES WHIPPANY ROAD WHIPPANY, NEW JERSEY ATTN. SINCLAIR, ROBERT O., JR. RM. 3B-103 COPY NO. 180</p> <p>BENDIX CORPORATION MISHAWAKA DIVISION 400 S. BEIGER STREET MISHAWAKA, INDIANA ATTN. INGALLS, EGBERT C. COPY NO. 181</p> <p>BENDIX CORPORATION SYSTEMS DIVISION 3300 PLYMOUTH ROAD P. O. BOX 639 ANN ARBOR, MICHIGAN 48107 ATTN. BITONDO, DOMENIC COPY NO. 182</p> <p>BENDIX CORPORATION SYSTEMS DIVISION 3300 PLYMOUTH ROAD ANN ARBOR, MICHIGAN ATTN. KRESSE, ARTHUR D. COPY NO. 183</p> <p>BENDIX CORPORATION SYSTEMS DIVISION 3300 PLYMOUTH ROAD ANN ARBOR, MICHIGAN ATTN. LIBRARY COPY NO. 184</p> <p>BISSETT-BERMAN CORPORATION 2941 NEBRASKA AVENUE SANTA MONICA, CALIFORNIA ATTN. DOCUMENT CONTROL COPY NO. 185</p> <p>BLOCK ENGINEERING, INC. 19 BLACKSTONE STREET CAMBRIDGE, MASSACHUSETTS 02139 ATTN. BLOCK, MYRON J. VIA. MC GRADIE, CAROL SECURITY OFFICER COPY NO. 186</p> <p>BOEING COMPANY 3801 S. OLIVER WICHITA, KANSAS ATTN. GALLI, CHIEF JOSEPH R. COPY NO. 187</p> <p>BOEING COMPANY P. O. BOX 3707 SEATTLE, WASHINGTON ATTN. ADAM, WILLIAM B. COPY NO. 188</p> <p>BOEING COMPANY AERO-SPACE DIVISION P. O. BOX 3707 SEATTLE 24, WASHINGTON ATTN. BARBAR, R. R. COPY NO. 189</p> <p>BOEING COMPANY AERO-SPACE DIVISION POST OFFICE BOX 3707 SEATTLE 24, WASHINGTON ATTN. MC DONALD, RICHARD K. COPY NO. 190</p>	<p>BOEING AIRCRAFT COMPANY AERO-SPACE DIVISION P. O. BOX 3707 M/S 41-08 SEATTLE 24, WASHINGTON ATTN. SUTTON, JOHN W. COPY NO. 191</p> <p>BURROUGHS CORPORATION POST OFFICE BOX 892 PAOLI, PENNSYLVANIA ATTN. LOHSE, EDWARD COPY NO. 192</p> <p>CALIFORNIA INSTITUTE OF TECHNOLOGY JET PROPULSION LABORATORY 4800 OAK GROVE DRIVE PASADENA 3, CALIFORNIA ATTN. LIBRARY (TOS) DENSLOW, H. COPY NO. 193</p> <p>CALIFORNIA INSTITUTE OF TECHNOLOGY GRADUATE AERO. LABORATORY PASADENA, CALIFORNIA ATTN. LEES, LESTER COPY NO. 194</p> <p>CALIFORNIA, UNIVERSITY OF LAWRENCE RADIATION LABORATORY TECH. INFO. DIV., P. O. BOX 808 LIVERMORE, CALIFORNIA ATTN. CRAIG, CLOVIS G. COPY NO. 195</p> <p>CANOGA ELECTRONICS CORPORATION P. O. BOX 2086 CANOGA PARK, CALIFORNIA 91306 ATTN. FOOTIE, EUGENE W. COPY NO. 196</p> <p>CHRYSLER CORPORATION MISSILE DIVISION P. O. BOX 2628 DETROIT 31, MICHIGAN ATTN. ERICKSON, ROBERT P. COPY NO. 197</p> <p>CHRYSLER CORPORATION MISSILE DIVISION P. O. BOX 2628 DETROIT 31, MICHIGAN ATTN. SAHS, JOHN H. TECH. INFORMATION CENTER COPY NO. 198</p> <p>CHRYSLER CORPORATION MISSILE DIVISION P. O. BOX 2628 DETROIT 31, MICHIGAN ATTN. SEVICK, FRANK VIA. BRIDGES, F. L. MASTER LOG COPY NO. 199</p> <p>COLUMBIA UNIVERSITY ELECTRONICS RESEARCH LAB. 532 WEST 125TH STREET NEW YORK 27, NEW YORK ATTN. CRESSMAN, HELEN COPY NO. 200</p> <p>COLUMBIA UNIVERSITY ELECTRONICS RESEARCH LAB. 632 WEST 125TH STREET NEW YORK 27, NEW YORK ATTN. SECURITY OFFICER COPY NO. 201</p> <p>CONDUCTRON CORPORATION 343 S. MAIN STREET ANN ARBOR, MICHIGAN ATTN. RITT, ROBERT K. LIBRARY COPY NO. 202</p> <p>CORNELL AERONAUTICAL LAB., INC. 4455 GENESEE STREET P. O. BOX 235 BUFFALO, NEW YORK 14221 ATTN. CHAPMAN, SEVILLE VIA. LIBRARY COPY NO. 203</p> <p>LIBRARIAN CORNELL AERONAUTICAL LAB., INC. 4455 GENESEE STREET BUFFALO 21, NEW YORK ATTN. DESMOND, JOSEPH COPY NO. 204</p> <p>CORNELL AERONAUTICAL LAB., INC. 4455 GENESEE STREET, P.O. BOX 235 BUFFALO, NEW YORK 14221 ATTN. KAUSHAGEN, W. MAURICE VIA. LIBRARY COPY NO. 205</p>
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# WILLOW RUN LABORATORIES

<p>CORNELL AERONAUTICAL LAB., INC. P. O. BOX 235 BUFFALO, NEW YORK 14221 ATTN. KELL, ROBERT E. VIA. LIBRARY COPY NO. 206</p>	<p>FORD MOTOR COMPANY AERONAUTIC DIVISION FORD ROAD NEWPORT BEACH, CALIFORNIA ATTN. BLACK, F. M. ACQUISITION LIBRARIAN COPY NO. 223</p>	<p>GENERAL ELECTRIC COMPANY VALLEY FORGE TECHNOLOGY CENTER KING OF PRUSSIA, PENNSYLVANIA ATTN. RAYL, GEORGE J. COPY NO. 238</p>	<p>GENERAL MOTORS CORPORATION DEFENSE SYSTEMS DIVISION BOX T SANTA BARBARA, CALIFORNIA ATTN. BURT, ROBERT T. LIBRARIAN COPY NO. 252</p>
<p>CORNELL AERONAUTICAL LAB., INC. 4455 GENESEE STREET P. O. BOX 235 BUFFALO, NEW YORK 14221 ATTN. WURSTER, DR. WALTER H. VIA. SECURITY OFFICER COPY NO. 207</p>	<p>GENERAL APPLIED SCIENCE LAB., INC. MERRICK + STEWART AVENUES WESTBURY, NEW YORK 11591 ATTN. BYRNE, ROBERT W. VIA. MASTER CONTROL STATION COPY NO. 224</p>	<p>GENERAL ELECTRIC COMPANY RE-ENTRY SYSTEMS DEPT. 3198 CHESTNUT STREET PHILADELPHIA, PA. 19104 ATTN. BOEJE, JACOBUS M. COPY NO. 239</p>	<p>GENERAL MOTORS CORPORATION DEFENSE RESEARCH LABORATORIES BOX T SANTA BARBARA, CALIFORNIA ATTN. MAIDEN, COLIN J. COPY NO. 253</p>
<p>DEFENSE RESEARCH CORPORATION 6300 HOLLISTER AVENUE GOLETA, CALIFORNIA ATTN. ALEXANDER, BEN VIA. HERRING, J. E. SECURITY OFFICER COPY NO. 208</p>	<p>GENERAL DYNAMICS CORPORATION POMONA DIVISION P. O. BOX 1011 POMONA, CALIFORNIA ATTN. DIVISION LIBRARY COPY NO. 225</p>	<p>GENERAL ELECTRIC COMPANY MISSILE + SPACE DIVISION SPACE TECH. CTR. P. O. BOX 8555 PHILADELPHIA, PA. 19101 ATTN. DOCUMENT LIBRARY, ROOM L1343 CHASEN, LAWRENCE I. COPY NO. 240</p>	<p>GENERAL PRECISION, INCORPORATED LIBRASCOPY DIVISION 808 WESTERN AVENUE GLENDALE 1, CALIFORNIA ATTN. SANDS, NATHAN J. SUPERVISOR LIBRARY SERV. COPY NO. 254</p>
<p>DEFENSE RESEARCH CORPORATION 6300 HOLLISTER AVENUE GOLETA, CALIFORNIA ATTN. TECHNICAL INFORMATION OFFICE COPY NO. 209</p>	<p>GENERAL DYNAMICS CORPORATION THERMO-MECHANICS SECTION DEPT. 6, SECTION 332 MAIL ZONE 6-51 P.O. BOX 1011 POMONA, CALIFORNIA ATTN. POLICH, DR. W. F. VIA. ECC-INTRA-PLANT ZONE 6-11 COPY NO. 226</p>	<p>GENERAL ELECTRIC COMPANY MISSILE + SPACE DIVISION SPACE TECH. CENTER P.O. BOX 8555 PHILADELPHIA, PA. 19101 ATTN. FARBER, JOSEPH ROOM M9539 COPY NO. 241</p>	<p>GEOPHYSICS CORPORATION OF AMERICA BURLINGTON ROAD BEDFORD, MASSACHUSETTS ATTN. TECHNICAL LIBRARY NAZZARO, L. COPY NO. 255</p>
<p>DIKEWOOD CORPORATION 4605 MENAUL BOULEVARD, N. E. ALBUQUERQUE, NEW MEXICO ATTN. CARLSON, CARL R. COPY NO. 210</p>	<p>GENERAL DYNAMICS CORPORATION CONVAIR P. O. BOX 1128 - MAIL ZONE 596-00 SAN DIEGO, CALIFORNIA 92112 ATTN. FERRISO, DR. CARMINE C. COPY NO. 227</p>	<p>GENERAL ELECTRIC COMPANY MISSILE + SPACE DIVISION P. O. BOX 8555 PHILADELPHIA, PA. 19101 ATTN. FRIEL, PATRICK J. ROOM U7216 COPY NO. 242</p>	<p>GEOPHYSICS CORPORATION OF AMERICA PHYSICS RESEARCH DIVISION BURLINGTON ROAD BEDFORD, MASSACHUSETTS ATTN. PRESSMAN, JEROME COPY NO. 256</p>
<p>DOUGLAS AIRCRAFT COMPANY, INC. 3000 OCEAN PARK BLVD. SANTA MONICA, CALIFORNIA ATTN. ARNQUIST, DR. WARREN N., G-25 COPY NO. 211</p>	<p>GENERAL DYNAMICS CORPORATION ASTRONAUTICS DIVISION BOX 1128 SAN DIEGO 12, CALIFORNIA ATTN. ENGINEERING LIBRARY COPY NO. 228</p>	<p>GENERAL ELECTRIC COMPANY MISSILE + SPACE DIVISION SPACE TECH. CENTER P. O. BOX 8555 PHILADELPHIA, PA. 19101 ATTN. GUTTMAN, ANDREW COPY NO. 243</p>	<p>HELIODYNE CORPORATION 850/DMRS DATA CORRELATION FAC. NORTON AIR FORCE BASE CALIFORNIA 92409 ATTN. HARSHBARGER, DR. F. C. COPY NO. 257</p>
<p>DOUGLAS AIRCRAFT COMPANY, INC. 3000 OCEAN PARK BOULEVARD SANTA MONICA, CALIFORNIA ATTN. AVIONICS SECTION COPY NO. 212</p>	<p>GENERAL DYNAMICS CORPORATION ASTRONAUTICS DIVISION P. O. BOX 1128 MAIL ZONE 596-04-1 SAN DIEGO 12, CALIFORNIA ATTN. THOMSON, JAMES A. L. COPY NO. 229</p>	<p>GENERAL ELECTRIC COMPANY MISSILE + SPACE DIVISION SPACE TECH. CENTER P.O. BOX 8555 PHILADELPHIA 1, PENNSYLVANIA ATTN. LEW, HENRY G. RM. 9167-L COPY NO. 244</p>	<p>HUGHES AIRCRAFT COMPANY MAIL STATION B-108 FLORENCE AVENUE + TEALE STREET CULVER CITY, CALIFORNIA ATTN. CRAVEN, WILLIAM A., JR. COPY NO. 259</p>
<p>DOUGLAS AIRCRAFT COMPANY, INC. 3000 OCEAN PARK BOULEVARD SANTA MONICA, CALIFORNIA ATTN. TECHNICAL LIBRARY COPY NO. 213</p>	<p>GENERAL DYNAMICS CORPORATION GENERAL ATOMIC DIVISION P. O. BOX 1111 SAN DIEGO, CALIFORNIA 92112 ATTN. HAYS, STANLEY D. VIA. CHIEF, TECH. INFO. SERVICES COPY NO. 230</p>	<p>GENERAL ELECTRIC COMPANY RE-ENTRY SYSTEMS DEPARTMENT P. O. BOX 8555 PHILADELPHIA, PA. 19101 ATTN. TECH. INFO. CENTER COPY NO. 245</p>	<p>TECHNICAL DOCUMENTS CENTER HUGHES AIRCRAFT COMPANY SPACE SYSTEMS DIVISION FLORENCE AVENUE + TEALE STREET CULVER CITY, CALIFORNIA ATTN. DEVEREUX, N. E. COPY NO. 260</p>
<p>DYNAMICS RESEARCH CORPORATION 38 MONTVALE AVENUE STONEHAM, MASSACHUSETTS ATTN. TECHNICAL LIBRARY COPY NO. 214</p>	<p>GENERAL DYNAMICS CORPORATION GENERAL ATOMIC DIVISION P. O. BOX 748 FORT WORTH, TEXAS ATTN. DE FONNAICOUR, P. R. CHIEF, LIBRARIAN COPY NO. 231</p>	<p>GENERAL ELECTRIC COMPANY MISSILE + SPACE DIVISION SPACE TECH. CENTER P. O. BOX 8555 PHILADELPHIA, PA. 19101 ATTN. RIETHOF, THOMAS R. VIA. RE-ENTRY PHYSICS LIBRARY COPY NO. 246</p>	<p>TECHNICAL DOCUMENTS CENTER HUGHES AIRCRAFT COMPANY SPACE SYSTEMS DIVISION FLORENCE AVENUE + TEALE STREET CULVER CITY, CALIFORNIA ATTN. ROSENBERG, N. C. SUPERVISOR TECH. DOCUMENTS CENTER COPY NO. 261</p>
<p>EASTMAN KODAK COMPANY APPARATUS + OPTICAL DIVISION 400 PLYMOUTH AVENUE NORTH ROCHESTER 4, NEW YORK ATTN. GODZE, IRVING COPY NO. 215</p>	<p>GENERAL ELECTRIC COMPANY TEMPO DIVISION 735 STATE STREET SANTA BARBARA, CALIFORNIA ATTN. DOCUMENT CONTROL OFFICER COPY NO. 232</p>	<p>GENERAL ELECTRIC COMPANY MISSILE + SPACE DIVISION P. O. BOX 8555, SPC. RM. M9539 PHILADELPHIA, PA. 19101 ATTN. SCALA, SINGLATRE M. COPY NO. 247</p>	<p>HUGHES AIRCRAFT COMPANY GROUND SYSTEMS GROUP FULLERTON, CALIFORNIA ATTN. HAIRE, MARY LOU TECHNICAL LIBRARY COPY NO. 262</p>
<p>ELECTROMAGNETIC RESEARCH CORP. 5001 COLLEGE AVENUE COLLEGE PARK, MARYLAND ATTN. LIBRARIAN COPY NO. 216</p>	<p>GENERAL ELECTRIC COMPANY TEMPO DIVISION 735 STATE ST., P. O. DRAWER 00 SANTA BARBARA, CALIFORNIA ATTN. LIEBHOLD, KLAUS DIRECTOR, DASA DATA CEN. COPY NO. 233</p>	<p>GENERAL ELECTRIC COMPANY MISSILE + SPACE DIVISION SPACE TECH. CENTER P.O. BOX 8555 PHILADELPHIA 1, PENNSYLVANIA ATTN. DOCUMENTS LIBRARY, RM 1343L THORKELSON, WILLIAM L. COPY NO. 248</p>	<p>HUGHES AIRCRAFT COMPANY SPACE SYSTEMS DIVISION P. O. BOX 90919 LOS ANGELES, CALIFORNIA 90009 ATTN. STROUP, RICHARD E. COPY NO. 263</p>
<p>ELECTRO-OPTICAL SYSTEMS, INC. 300 N. HALSTEAD STREET PASADENA, CALIFORNIA ATTN. LIBRARIAN COPY NO. 217</p>	<p>GENERAL ELECTRIC COMPANY TEMPO DIVISION 735 STATE ST., P. O. DRAWER 00 SANTA BARBARA, CALIFORNIA ATTN. LIEBHOLD, KLAUS DIRECTOR, DASA DATA CEN. COPY NO. 233</p>	<p>GENERAL MOTORS CORPORATION DEFENSE RESEARCH LABORATORIES 6767 HOLLISTER AVENUE GOLETA, CALIFORNIA 93017 ATTN. PRIMICH, ROBIN I. VIA. CENTRAL DOCUMENT CONTROL COPY NO. 249</p>	<p>ARMOUR RESEARCH FOUNDATION PHYSICS DIVISION 10 WEST 35TH STREET CHICAGO 16, ILLINOIS ATTN. DOCUMENT LIBRARY COPY NO. 264</p>
<p>EMERSON ELECTRIC MANUFACTURING CO. STAR DIVISION 322 PALM AVENUE SANTA BARBARA, CALIFORNIA ATTN. COURTNEY, HOWARD COPY NO. 218</p>	<p>GENERAL ELECTRIC COMPANY TEMPO DIVISION 735 STATE ST., P. O. DRAWER 00 SANTA BARBARA, CALIFORNIA ATTN. LIEBHOLD, KLAUS DIRECTOR, DASA DATA CEN. COPY NO. 233</p>	<p>GENERAL ELECTRIC COMPANY MISSILE + SPACE DIVISION SPACE TECH. CENTER P.O. BOX 8555 PHILADELPHIA 1, PENNSYLVANIA ATTN. DOCUMENTS LIBRARY, RM 1343L THORKELSON, WILLIAM L. COPY NO. 248</p>	<p>INSTITUTE FOR DEFENSE ANALYSES 400 ARMY-NAVY DRIVE ARLINGTON, VIRGINIA 22202 ATTN. BIBERMAN, LUCIEN M. COPY NO. 265</p>
<p>FAIRCHILD STRATOS CORPORATION AIRCRAFT MISSILE DIVISION HAGERSTOWN, MARYLAND ATTN. ENGINEERING LIBRARY COPY NO. 219</p>	<p>GENERAL ELECTRIC COMPANY TEMPO DIVISION 735 STATE ST., P. O. DRAWER 00 SANTA BARBARA, CALIFORNIA ATTN. LIEBHOLD, KLAUS DIRECTOR, DASA DATA CEN. COPY NO. 233</p>	<p>GENERAL ELECTRIC COMPANY MISSILE + SPACE DIVISION SPACE TECH. CENTER P.O. BOX 8555 PHILADELPHIA 1, PENNSYLVANIA ATTN. DOCUMENTS LIBRARY, RM 1343L THORKELSON, WILLIAM L. COPY NO. 248</p>	<p>INSTITUTE FOR DEFENSE ANALYSES 400 ARMY-NAVY DRIVE ARLINGTON, VIRGINIA 22202 ATTN. CRISLER, DR. EARL H. VIA. DOCUMENT CONTROL CLERK COPY NO. 266</p>
<p>FAIRCHILD-STRATOS CORPORATION AIRCRAFT MISSILE DIVISION HAGERSTOWN 10, MARYLAND ATTN. ENGINEERING LIBRARY TABISH, BERNARD S. COPY NO. 220</p>	<p>GENERAL ELECTRIC COMPANY TEMPO DIVISION 735 STATE ST., P. O. DRAWER 00 SANTA BARBARA, CALIFORNIA ATTN. LIEBHOLD, KLAUS DIRECTOR, DASA DATA CEN. COPY NO. 233</p>	<p>GENERAL ELECTRIC COMPANY MISSILE + SPACE DIVISION SPACE TECH. CENTER P.O. BOX 8555 PHILADELPHIA, PA. 19101 ATTN. SCALA, SINGLATRE M. COPY NO. 247</p>	<p>INSTITUTE FOR DEFENSE ANALYSES 400 ARMY-NAVY DRIVE ARLINGTON, VIRGINIA 22202 ATTN. HOCHSTIM, ADOLF R. VIA. DOCUMENT CONTROL COPY NO. 267</p>
<p>FEDERAL SCIENTIFIC CORPORATION 615 WEST 131ST STREET NEW YORK, NEW YORK 10027 ATTN. LIBRARY COPY NO. 221</p>	<p>RE-ENTRY PHYSICS LIBRARY GENERAL ELECTRIC COMPANY MISSILE + SPACE VEHICLE DEPT. SPACE TECHNOLOGY LIBRARY RM. 1343L VALLEY FORGE, PENNSYLVANIA ATTN. LIBRARIAN COPY NO. 237</p>	<p>GENERAL ELECTRIC COMPANY MISSILE + SPACE DIVISION SPACE TECH. CENTER P.O. BOX 8555 PHILADELPHIA, PA. 19101 ATTN. STEINBERG, MARTIN VIA. CENTRAL DOCUMENT CONTROL COPY NO. 250</p>	<p>INSTITUTE FOR DEFENSE ANALYSES 400 ARMY-NAVY DRIVE ARLINGTON, VIRGINIA 22202 ATTN. HOCHSTIM, ADOLF R. VIA. DOCUMENT CONTROL COPY NO. 267</p>
<p>FLORIDA, UNIVERSITY OF DEPARTMENT OF PHYSICS GAINESVILLE, FLORIDA ATTN. BALLARD, DR. STANLEY COPY NO. 222</p>	<p>RE-ENTRY PHYSICS LIBRARY GENERAL ELECTRIC COMPANY MISSILE + SPACE VEHICLE DEPT. SPACE TECHNOLOGY LIBRARY RM. 1343L VALLEY FORGE, PENNSYLVANIA ATTN. LIBRARIAN COPY NO. 237</p>	<p>GENERAL ELECTRIC COMPANY MISSILE + SPACE DIVISION SPACE TECH. CENTER P.O. BOX 8555 PHILADELPHIA, PA. 19101 ATTN. STEINBERG, MARTIN VIA. CENTRAL DOCUMENT CONTROL COPY NO. 250</p>	<p>INSTITUTE FOR DEFENSE ANALYSES 400 ARMY-NAVY DRIVE ARLINGTON, VIRGINIA 22202 ATTN. HOCHSTIM, ADOLF R. VIA. DOCUMENT CONTROL COPY NO. 267</p>

# WILLOW RUN LABORATORIES

INSTITUTE FOR DEFENSE ANALYSES  
400 ARMY-NAVY DRIVE  
ARLINGTON, VIRGINIA 22202  
ATTN. TECH. INFORMATION OFFICE  
COPY NO. 268

INSTITUTE FOR DEFENSE ANALYSES  
400 ARMY-NAVY DRIVE  
ARLINGTON, VIRGINIA 22202  
ATTN. MENKES, JOSHUA  
VIA. DOCUMENT CONTROL  
COPY NO. 269

INSTITUTE FOR DEFENSE ANALYSES  
400 ARMY-NAVY DRIVE  
ARLINGTON, VIRGINIA 22202  
ATTN. WOLFHARD, HANS G.  
VIA. DOCUMENT CONTROL  
COPY NO. 270

INSTITUTE OF NAVAL STUDIES  
545 TECHNOLOGY SQUARE  
CAMBRIDGE 39, MASSACHUSETTS  
ATTN. LIBRARY  
COPY NO. 271

ITEK CORPORATION  
VIDYA DIVISION  
1450 PAGE MILL ROAD  
PALO ALTO, CALIFORNIA  
ATTN. DOCUMENT CONTROL  
COPY NO. 272

ITEK CORPORATION  
VIDYA DIVISION  
1450 PAGE MILL ROAD  
PALO ALTO, CALIFORNIA  
ATTN. DOCUMENT CONTROL  
RAGENT, BORIS  
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3 REPORT TITLE STUDIES OF INFRARED RADIATIVE TRANSFER IN HOT GASES I: SPECTRAL ABSORPTANCE MEASUREMENTS IN THE 2.7- $\mu$ H <sub>2</sub> O BANDS		
4 DESCRIPTIVE NOTES <i>(Type of report and inclusive dates)</i>		
5 AUTHOR(S) <i>(Last name, first name, initial)</i> Simmons, F. S., Arnold, C. B., Smith, D. H.		
6 REPORT DATE August 1965	7a. TOTAL NO. OF PAGES 86	7b. NO. OF REFS 11
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KEY WORDS

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