NASA TECH BRIEF
Lewis Research Center

NASA Tech Briefs announce new technology derived from the U.S. space program. They are issued to encourage commercial application. Tech Briefs are available on a subscription basis from the National Technical Information Service, Springfield, Virginia 22151. Requests for individual copies or questions relating to the Tech Brief program may be directed to the Technology Utilization Office, NASA, Code KT, Washington, D.C. 20546.

Measurement of Temperature Profiles in Hot Gases and Flames

Temperature profiles in nonuniform hot gases and flames have been determined by means of infrared emission-absorption spectroscopy.

Experimental measurements of hot gases were made using a double-beam ratio-recording spectrometer which could accommodate long sample cells heated in a segmented furnace so that various temperature profiles could be maintained in the gas sample. Spectral radiances and absorptances in the 2-3 μm region were obtained for various pressures and temperature profiles in water vapor, carbon dioxide, hydrogen-fluoride, and a mixture of carbon dioxide, water vapor, and nitrogen. The spectral data were reduced to apparent temperatures as a function of frequency throughout the various vibration-rotation bands. Apparent temperatures are defined as those temperatures the Planck functions of which are the observed ratios of spectral radiance to absorptance.

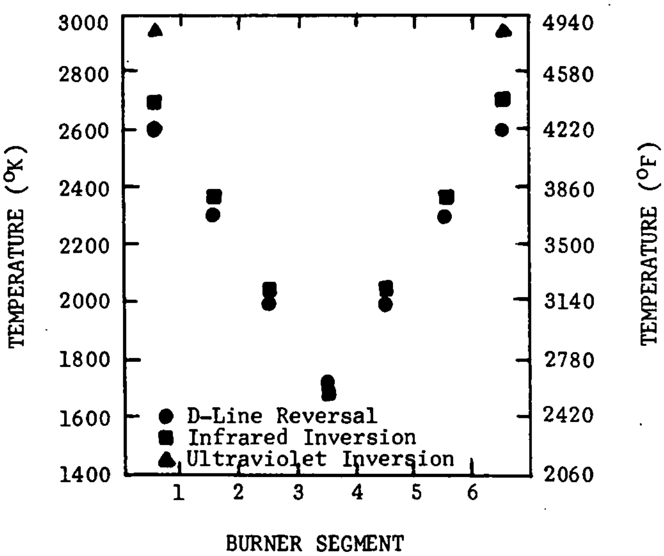
A computer program was written for the calculation of molecular radiative transfer from hot gases. For the case of polyatomic molecules, the calculation was based on a band model consisting of a random array of lines of nearly equal intensity. For diatomic molecules exhibiting non-overlapping lines, the calculation was based on expressions for the total radiances and equivalent widths of Lorentz lines for nonisothermal paths. Calculations based on the temperature profile in the cell measured by thermocouples were shown to agree well with the observed spectra.

The general shape of the temperature profile in the sample was assumed to be known, and was approximated in terms of simple geometric forms so that the profile could be characterized in terms of a few parameters. These parameters were then adjusted in calculations using the appropriate radiative-transfer expression until a best fit was obtained with the observed spectra. It was found to be most convenient and reliable to fit the band-model calculations to plots of apparent temperature versus absorptance, and the isolated-line calculations to plots of apparent temperature versus a generalized rotational operation number. The resultant temperature profiles so deduced showed satisfactory agreement with the thermocouple measurements in all cases where an appropriate profile shape was assumed.

Further experiments with temperature measurements by emission-absorption spectroscopy were conducted with a hydrogen-oxygen flame and results were shown to agree well with temperature measurements as determined by line-reversal measurements. However, measurements with OH radiation in the 0.3 μm ultraviolet band showed substantial error.

The experimental measurements with flames were made using a rectangular multiple-diffusion burner. The burner had seven independent in-line sections to establish a temperature profile along the sections by varying the fuel-oxidizer ratio. Sodium vapor was introduced into the central portion of each burner section for direct determination of the temperature profile by line-reversal measurements.

The molecular band model used for calculation of gas transmittance with heated gases was modified to handle more accurately the flame profiles that can exhibit large gradients in temperature.



The figure shows typical results for the three types of measurement with a temperature profile in a hydrogen-oxygen flame. Temperatures are plotted corresponding to

(continued overleaf)

the seven different burner segments described. These and the results with profiles of other shapes showed that temperature profiles determined from infrared measurements are valid with flames as well as with hot gases.

Notes:

1. Further information is available in the following reports:

   NASA CR-72491 (N69-32557), Measurement of Temperature Profiles in Hot Gases by Emission-Absorption Spectroscopy

   NASA CR-120894 (N72-19957), Measurement of Temperature Profiles in Flames by Emission-Absorption Spectroscopy

   Copies may be obtained at cost from:

   Aerospace Research Applications Center
   Indiana University
   400 East Seventh Street
   Bloomington, Indiana 47401
   Telephone: 812-337-7833
   Reference: B74-10060

2. Specific technical questions may be directed to:

   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B74-10060

Patent Status:

NASA has decided not to apply for a patent.

Source: R.S. Simmons, H.Y. Yamada,
G.H. Lindquist, and C.B. Arnold
The University of Michigan
under contract to
Lewis Research Center
(LEW-12055)