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Quantitative Spectroscopy

A TWO-DAY symposium on quantitative spectroscopy with selected military applications was held at the California Institute of Technology on March 28 and 29, 1960. The plans for the meeting were laid in Washington during December 1959 as the result of discussions between S. S. Penner of Caltech and J. W. Bond of the Advanced Research Projects Agency (ARPA). A review of studies connected with long-range missile detection and the physics of missile re-entry suggested that the enormous scientific and technical effort in this field could be planned more effectively and could be executed more efficiently through better utilization of people, facilities, and funds. The basic difficulty appeared to be associated with the tendency to collect essentially uninterpretable data: the measurements were often qualitative and were obtained in such a way that they were not useful either for predicting observable data on missiles under new test conditions or for understanding quantitatively the nature of the physical processes under study. What appeared to be needed was a more deliberate effort to reduce all missile radiation data to quantitative terms, an objective that could perhaps be furthered by a very special type of conference, namely, a symposium on *quantitative spectroscopy* at which the *military applications* represented nothing more than a special use of fundamental information.

Discussions with sponsors of military and basic spectroscopic research in various government agencies showed enthusiastic support for this special type of meeting and the final program enjoyed active support from Caltech (S. S. Penner), ARPA (J. W. Bond), the Office of Naval Research (S. Silverman and A. R. Laufer), the Air Force Office of Scientific Research (W. J. Otting), and the Air Force Cambridge Research Center (J. N. Howard). A. R. Laufer of the Pasadena Office of Naval Research did most of the work of arranging the conference; the technical program was planned by S. S. Penner with assistance from the other members of the organizing committee.

Lee A. DuBridge, president of the California Institute of Technology, opened the two-day symposium, expressing his pleasure at noting the participation of former colleagues at a meeting on classical physics that cut clearly across the borders of conventional academic disciplines.

The first session, under the chairmanship of S. S. Penner, was dominated by molecular spectroscopists.

W. S. Benedict of Johns Hopkins University discussed absolute intensity and line-width measurements of individual spectral lines in the infrared region; his beautiful experimental data dispelled at once the notion that the widths and contours of spectral lines in vibration-rotation bands could be represented by a single "effective" shape parameter or that the temperature dependence of line widths could be correlated by a simple collision theory. B. L. Crawford, Jr., of the University of Minnesota discussed techniques for the determination of absolute intensity measurements for entire vibration-rotation bands by the method which he chose to denote, "with total disregard for the valencies of tungsten", as the "W_3P method" (Wilson-Wells-Penner-Weber method). In this method, the test gas is pressurized with sufficient inert gas to smear out the rotational line structure, and the resulting integrated intensity data are then extrapolated to zero optical depth. The pitfalls involved in data reduction and precautions required in good experimental procedure were clearly defined. Absolute intensity measurements using the same procedure in the visible and ultraviolet regions of the spectrum for NO were considered by G. W. Bethke of the General Electric Company. D. H. Rank of the University of Pennsylvania told of the significant progress made in his laboratory in attaining extremely high-resolution spectra in the infrared. His methods of scanning spectra with etalons and diffraction gratings were covered. The first morning session was concluded by C. E. Treanor of the Cornell Aeronautical Laboratory with a discussion of experimental results of absolute intensity measurements on O_2 obtained in shock-tube studies performed in collaboration with W. H. Wurster.

The second session, chaired by A. R. Laufer, opened with a stimulating survey of the theories of line broadening by H. Margenau of Yale University: in 45 minutes the theories of natural, Doppler, pressure, and statistical line broadening were reviewed with admirable clarity and enthusiasm. Illustrative examples of astrophysical applications of quantitative spectroscopy were described by J. L. Greenstein of Caltech who noted a number of unusual features of astronomical spectra. The use of an atomic beam apparatus for the determination of absolute intensities of metallic spectral lines was considered by R. B. King of Caltech who reviewed the results of representative measurements made in his laboratory. In the concluding paper, D. H. Menzel presented an outline of a very successful screening theory developed with D. A. Layzer for application to the calculation of energy levels and transition probabilities of complex atoms.

The early evening was devoted to relaxation, including an industry-sponsored cocktail hour followed by a banquet at the Huntington-Sheraton Hotel. Nobel Laureate George W. Beadle, acting dean of the faculty at Caltech, concluded the educational activities of the first day with an after-dinner talk on "The Nature of Genetic Information". One cannot help but wonder if this choice of topic was designed to put additional

pressure on the participants concerned with early detection of missiles by spectroscopic techniques. Dr. Beadle presented a sober evaluation of genetic degeneration in informal additions to his lecture.

W. J. Otting served as chairman of the third session at which the discussion was opened by J. A. L. Thomson of Convair with a presentation of theoretical considerations on the radiation from rocket exhausts. A statistical treatment for the calculation of infrared emissivities was described. The results of numerical computations of emission from heated solid particles were summarized next by G. N. Plass of Aeronutronic. These data, which required information regarding particle-size distribution and refractive index of the pure solid material, were obtained through application of the Mie theory. Experimental studies on rocket exhaust radiation were outlined by C. C. Ferriso of Convair Astronautics, who conducted double-path experiments for the determination of spectral emissivities and temperatures in the exhausts of small rocket motors. The existence of nonequilibrium vibrational population distributions for CO_2 appeared to be indicated. D. B. Olfe of Caltech outlined the calculation of emissivities of hydrogen at temperatures up to 10 000°K and pressures up to 100 atmospheres. A. Skumanich noted measurements of gamma-ray-induced air luminescence conducted at the Los Alamos Scientific Laboratory during atomic bomb testing. Experiments by N. Solimene and M. Newstein of TRG, Incorporated, relating to the gas discharge properties of importance in connection with the operation of a LASER (Light Amplification by Stimulated Emission) device were reported by Solimene.

J. N. Howard presided over the final session of the symposium which bore the fetching designation "Hot Air". R. E. Meyerott of Lockheed Missile Systems Division presented an authoritative review of the radiative properties of heated air between 1000 and 200 000°K. Experimental data on the emission of radiation from heated air in shock tubes, based on the pioneering work performed by Kantrowitz's AVCO group, were presented by J. Keck. The meeting concluded with an open discussion on basic problems connected with military applications of quantitative spectroscopy that was both entertaining and informative because of John Howard's ability to make the best of a difficult assignment.

Judging from the comments made by participants at the Caltech Symposium, the technical meeting served as a productive opportunity for an exchange of views. Probably no one will object to the following conclusion: our practical difficulties in military applications of quantitative spectroscopy stem from a lack of knowledge of quantitative data of the type that were collected, in another age, by university professors who never thought of missiles. In quantitative spectroscopy, as in many other fields of science, our technology has simply outpaced our store of basic data. If the Caltech Symposium served no other purpose than to emphasize the overwhelming importance of this fact, and thereby leads to increased effort and support on the accumulation of basic data, then it will have been a worthwhile undertaking.

T. A. Jacobs, M. Lapp, and A. Guttman
Daniel and Florence Guggenheim Jet Propulsion Center, California Institute of Technology