was a report of the isolation of primary auditory neurons, and the investigation of small changes in intensity and in frequency response, by means of a new x-ray stereotaxic technique.

Architectural acoustics was represented by more than a score of papers, including reports on an automatic decay-rate meter for measuring reverberation times, the array effects of chairs in auditoria, as well as the widespread use of modeling in acoustical design. These sessions were capped by a visit to the Dorothy Chandler Pavilion of the Los Angeles Music Center, the new concert hall for Los Angeles and the home of the Los Angeles Philharmonic Orchestra.

Underwater acoustics. The main underwater theme was the transmission of sound in the deep sound channel. Significant effort, both experimental and theoretical, has been devoted to studying sound propagation along this minimum sound velocity axis. Continuing studies devoted to developing analytical models that would suitably describe ray convergence, travel time and pulse distortion for acoustic signals traveling in this unique channel were reviewed.

Also of underwater interest were the severe effects that the ocean has on sonar-system operation because of its nonideal nature as a medium for sound propagation. The frequency characteristics of deep-ocean reverberation, signal distortion caused by signals reflecting from the ocean bottom, and the acoustic backscattering from the ocean surface received considerable attention. A special evening session was held for a firsthand report from representatives of three Navy laboratories on the impact that the manned deep-research vehicle was having on the conduction of acoustical research studies in the deep ocean.

Physical acoustics. Although the role of physics can be traced in each of the previously mentioned studies, the field of physical acoustics is perhaps of most interest to the average physicist. This field was represented by a set of invited papers on cavitation phenomena and some twenty or more invited and contributed papers in other areas.

The cavitation material presented studies on cavitation in liquid helium, with special interest on the distinction between the conditions for onset of cavitation as measured by noise detection and by visual observation. Some correlation was suspected between cavitation and the local motion of the medium, and interpretation was presented on the basis of the Feynman theory of superfluidity. Other papers described the particular effect of radiation sources on lowering the onset of the cavitation phenomenon.

Measurements of the sound velocity in liquid helium close to the lambda point were presented—made within microdegrees of that value of the temperature. Other papers reported on different applications of lasers to the study of sound transmission in solids and liquids. Several papers were given on the study of ultrasonic absorption and dispersion in mixtures of gases, an old field, but one that has recently awakened widespread interest. Finally, two papers of particular interest to me were theoretical studies on the effect of sound absorption on the transient of an acoustic signal in an acoustic waveguide or delay line, which is of importance in accurate sound-velocity measurements, and an elegant "generalization of Bessel's Fourier analysis of Kepler's equation, based on the parametric statement of the Poisson-Earnshaw solution of finite-amplitude dissipationless plane-wave propagation." **Robert T. Beyer**
Brown University

Turbulence and Collision-Free Shock Waves in Plasmas

Widespread interest in plasma turbulence has developed in the past few years because of two primary considerations. First, it has been found both theoretically and experimentally that turbulence provides a mechanism by which particles with a high drift velocity can be rapidly thermalized. (In essence, one might say that the effective collision frequency for charged particles in a turbulent plasma is much higher than in a quiescent one.) Hence there is great interest in the phenomenon as a means of heating plasmas electrically to thermonuclear temperatures. (This is called "turbulent heating" by the fusion physicists.) At the conference on Turbulence and Collision–Free Shock Waves in Plasmas (Case Institute of Technology, 31 Oct.–1 Nov. 1966) Ihor Vitkovitsky reported on the experimental work at the Naval Research Laboratory using high-power discharges for turbulent heating and Sydney M. Hamberger reported on some preliminary turbulent-heating experiments that have been performed on a torus at the Culham Laboratory in England. However, the conferees were unable to hear a report on the extensive turbulent heating experiments in the Soviet Union (where temperatures of the order of 10^8 °K for both electrons and ions have been obtained for short times) due to the last minute decision of their delegation not to attend.

A second major area where plasma turbulence is believed to play an important role is in the shock-like structure observed in interplanetary plasmas. A prime example of this is the bow shock observed by several satellites at about 14 earth radii where the solar wind interacts with the earth's magnetic field. The mean free path in this interplanetary plasma is on the order of 10^8 km, while the shock wave is found to have a thickness many orders of magnitude smaller (perhaps 10^3 km or less); hence this phenomenon is referred to as a collisionless magnetohydrodynamic shock wave.

The most recent satellite data on this shock wave were presented by Frederick L. Scarf (TRW Systems), while laboratory experiments on collisionless shocks were described by Roy G. Bickerton (Culham), Edward Hintz (Julich, Germany) and George C. Goldenbaum (University of Maryland). (There was also a report on shock wave experiments at the Frascati Laboratories in Rome by Sergio Segre and Folker Englemann but they are able to explain their present data quite adequately on the basis of ordinary collision theory provided the shock is assumed to travel at a small oblique angle relative to the magnetic field lines.) While the attempts to fit the collisionless shock data to any quantitative theoretical results have generally met with little success, Charles Kennel reported on the work he had done with R. Z. Sagdeev at Trieste in explaining many qualitative aspects of the satellite data.

Readers familiar with ordinary hydrodynamic turbulence theory, which is based upon the nonlinear, macroscopic, Navier-Stokes equation, might expect current theories of plasma turbulence to be constructed, in a similar fashion, from the nonlinear fluid equations for a plasma together with Maxwell's equations to take account of the electromagnetic fields. That approach is used by a few workers, and the results of such a study were reported in a short paper by Chan M. Tchen (NBS). The majority of the current theoretical work on plasma turbulence, however, is based on a microscopic approach known as *quasi-linear* theory that was introduced in 1962 by William E. Drummond and David Pines in this country and by A. A. Vedenov, E. P. Velikov, R. Z. Sagdeev and others in the USSR.

To understand quasi-linear theory one must recall first that plane wave solutions to the linearized, Boltzmann-Vlasov (or collisionless Boltzmann) equation for a homogeneous plasma generally either decay or grow exponentially. The decay of such a wave is called Landau damping, while any wave that grows is called a microinstability. For a few cases, such as when the unperturbed plasma has a Maxwellian velocity distribution, all possible waves are damped and the plasma is stable. However, most non-Maxwellian velocity distributions are unstable in some range of frequencies and/or wave numbers, and, if the growth rate per cycle of these instabilities is *small*, then the quasi-linear theory (which includes one term beyond those kept in a linear analysis) can be used to study the nonlinear behavior of these growing waves. Typically, one finds from such an analysis that the unstable waves grow to a limited amplitude and then (because of the nonlinear terms) spread their energy over a broad band of frequencies and/or wave numbers to create a stable, turbulent medium.

At the conference Drummond (University of Texas) surveyed the current status of the quasi-linear or weak-turbulence theory. He emphasized that most experiments involved instabilities (like the two-stream instability when an energetic plasma beam passes through a background plasma) that are too strong to satisfy the assumptions in quasi-linear theory. Hence the theory at present can only be used to "interpret" most experiments rather than analyze them quantitatively. He noted, however, there was some hope that the quasi-linear theory may be successfully modified (perhaps by the method suggested recently by Thomas H. Dupree) to take account of the dominant nonlinear effects in cases with strong instabilities.

In other invited theoretical papers, Norman Rostoker (General Atomic) described a new formulation of weak-turbulence theory based upon an expansion procedure for solving the full set of BBGKY equations, and T. Kenneth Fowler (General Atomic) gave several examples of his methods of using simple energy considerations to establish bounds on the size to which plasma fluctuations may grow. Peter Sturrock (Stanford) looked at a somewhat different aspect of the turbulence problem and discussed the acceleration of particles in a turbulent plasma. In his work, which might be termed an extension of the Fermi mechanism for generating high-energy cosmic rays, the characteristic spectrum of the turbulence is assumed to be known, and the quantity calculated is the average energy gain of the charged particles trapped in these turbulent fields. (A related calculation was also reported in a short paper by Evry Schatzman of the Institut d' Astrophysique in Paris.)

Since the quasi-linear theory applies rigorously only to weakly unstable plasmas John H. Malmberg described the efforts that he and Charles B. Wharton have been making to produce and study such a plasma at General Atomic. Their initial experiments on propagation and attenuation of plasma oscillations are in remarkable quantitative agreement with the linear theory of Landau, and their current experiments on the growth of unstable waves are all consistent with the quasi-linear theory. Perhaps of all of the papers at the conference these experiments provide the most heartening illustration of the narrowing of the gulf between the theoretical and experimental aspects of plasma physics that has been gradually occurring as plasma physics becomes a more mature field.

Proceedings are to be published in a special issue of *Nuclear Energy*, Part C.

B. Samuel Tanenbaum
Case Institute of Technology