where the signal amplitude had fallen to $1/2^{1/2}$ of its maximum value

Combustion gases were obtained by burning 8 g of solid propellant in a Peters combustion bomb, which contained approximately 0 4 mg of air The gases were allowed to cool to room temperature in the bomb The resonance tube was pumped down to approximately 8 mm Hg absolute and then filled to slightly over 1 atm pressure with combustion gases from the bomb It was then re-evacuated and refilled with combustion gases to 1 atm pressure The apparatus was allowed to equilibrate to room temperature before the experiment was started

Results

Figure 1 shows the results obtained from tests on room air and compares them with values calculated from the expression[1, 3]

$$\sigma = \left[\frac{(\pi\mu)^{1/2}}{R}\right]\left[\left(\frac{1}{\gamma}\right)^{1/2} + \left(\frac{\lambda}{\mu C}\right)^{1/2}\left(\frac{\gamma - 1}{\gamma}\right)\right]\left[\frac{f}{P}\right]^{1/2} \quad (3)$$

The physical properties of dry air at 1 atm and 23°C were taken as[4, 5] μ = 1 86 × 10^{-4} poise, γ = 1 40, and $P = (C_p\mu/\lambda) = 0\ 73$

The calculated and experimental curves are in reasonable agreement at the lower frequencies with the experimental values somewhat in excess of the theoretical values, as has been noted by other investigators [1] The experimental results show an expected departure from a linear function of $f^{1/2}$ at the higher frequencies [1]

Figure 2 shows the results for combustion gases from a typical nonmetalized double-base propellant It must be remembered that these gases were expanded into the tube from a room temperature container at pressures from 18 to 2 atm Therefore, they were relatively dry, and their composition was not that of flame-temperature gases from the same propellant A comparison will show that the absorption coefficient from these gases is almost identical with that obtained for air

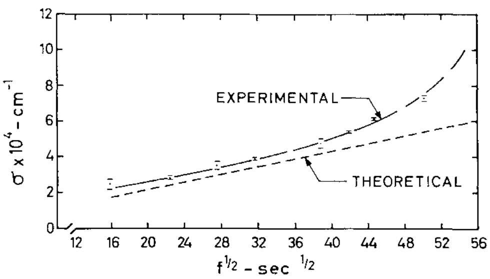

Fig 1 Acoustic damping constant for air as a function of $f^{1/2}$ Temperatuıe range is 22°–26 C Pressuıe is 1 atm The theoretical curve was calculated foı 23 C Horizontal lines above and below each average point mark the two values that were used to compute the average

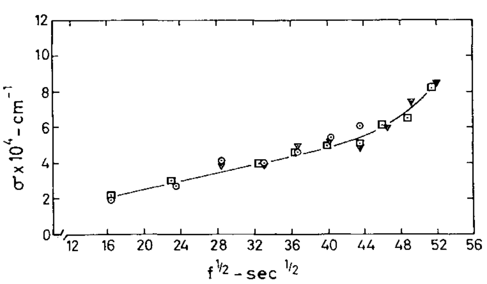

Fig 2 Acoustic damping constant for combustion gases from a typical double-base solid propellant as a function of $f^{1/2}$ Temperature range is 21°–23°C Pressure is 1 atm Ihe diffeıent point symbols represent three separate sets of data for a single type of propellant

By assuming $P \propto T^0$, $\mu \propto T^{1/2}$, and $\gamma \propto T^0$, one sees that $\sigma \propto T^{1/4}$, and these results may be roughly extrapolated to higher temperatures

Future Work

It is intended to extend this preliminary low-temperature work to the case where the test gas contains suspended particles of Al_2O_3 Also, apparatus that will directly determine σ for combustion gases at the flame temperature is presently being manufactured This apparatus will be used with both nonmetalized and metalized propellants

Finally, it is hoped in the future to arrange a method that will permit hot tests to be run in the 10–20 kc frequency range

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Tracer-Spark Technique for Velocity Mapping of Hypersonic Flow Fields

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In the experimental study of the aerodynamic structure of hypersonic wakes at Stanford University, a technique for measuring density was desired It appeared that the density could be deduced from measurements of Pitot pressure and flow velocity according to the relation

$$\rho = p_t/k(\rho, T, V)V^2 \quad (1)$$

where ρ is the stream density, p_t the Pitot pressure, T the stream temperature, and V the flow velocity It can be readily shown that $k(\rho, T, V)$ is essentially a constant over a wide range of flow conditions Although Pitot-pressure measurements could be made with "conventional" instrumentation techniques, this was not the case for velocity measurements Thus, it was necessary to develop a technique for the direct measurement of flow velocity

Bomelburg[1] was successful in using a series of electric sparks to measure velocity at lower speeds An extension of this method has therefore been attempted for the measurement of velocity in hypersonic wakes Ihe large differences between the freestream velocities and densities encountered in hypersonic wakes and those of Bomelburg's work made it necessary to use a different method of producing the sparks With the present system, a set of electrodes is positioned in the flow field to be studied The electrodes, which can be seen in Fig 1, are cylindrical rods about 6 in apart, aligned with the flow Two pairs of electrodes are used, a pair of initiator or tip electrodes and a pair of main

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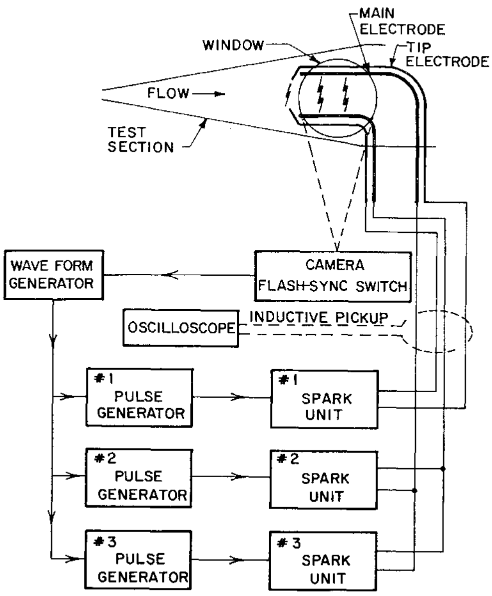

Fig 1 Schematic diagram of system for tracer-spark measurements

electrodes An initial spark is struck between the tip electrodes, leaving an ionized path through the stream The ionization persists for a short period of time, and the path travels with the stream at the local stream velocity After a prescribed time interval (typically 50 μsec or less), a spark is struck between the main electrodes, which are designed to permit the arc to strike anywhere along their 10-in length Because of the residual ionization from the previous spark, the second spark will strike through the same path In addition to producing light so that the position of the sparks can be recorded photographically, each spark also reionizes the path Thus, as long as the path remains between the main electrodes, as many sparks as desired can be struck through it A composite photograph of the sparks and a record of spark timing yields a series of velocity profiles corresponding to the average flow velocity between pairs of sparks Each spark arises from the discharge of a separate capacitor, and the time of discharge is controlled by a hydrogen thyratron A schematic diagram of the system is shown in Fig 1 The spark timing sequence begins with a pulse from the flash-synchronization switch on the camera shutter This pulse triggers the waveform generator, which generates a saw-tooth wave The pulse generators are set to trigger at voltage levels that correspond to uniform time intervals Upon triggering, each pulse generator produces a 50-v pulse that actuates the corresponding spark unit The spark unit consists of a pulse amplifier, a hydrogen thyratron, an energy-storage capacitor, and a damping resistor The elements of the spark unit (with the exception

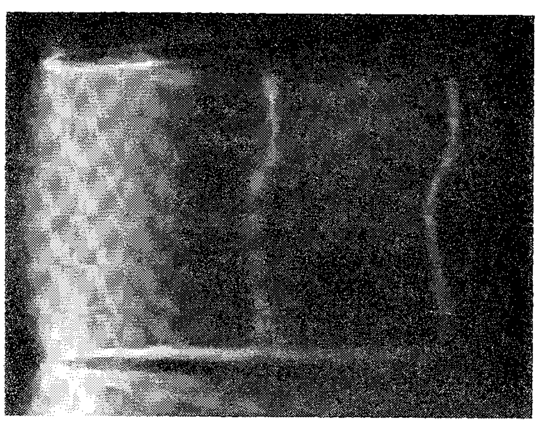

Fig 2 Tracer-spark photograph

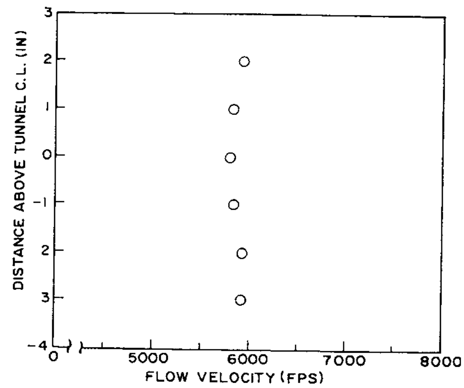

Fig 3 Flow velocity computed from tracer-spark photograph

of the pulse amplifier), the transmission cable, and the electrodes comprise the spark circuit Only the first spark circuit is connected to the tip electrodes; the remaining spark circuits are connected to the main electrodes By careful electrode design and proper selection of the damping resistor, a submicrosecond spark with close-to-critical damping has been achieved

A Polaroid model 110B camera is used to photograph the sparks The maximum shutter speed of $\frac{1}{300}$ sec allows all of the sparks to be superimposed on a single photograph while preventing excessive exposure from background luminosity Spark timing is measured by recording the output of an inductive pickup, located near the thyratron chassis, on a Tektronix 551 oscilloscope

Tracer-spark measurements of flow velocity have been obtained in the Stanford spark-heated hypersonic tunnel both in the empty test section and in the wake of a cylinder model mounted in the test section A typical photograph made during a test run with the test section empty is shown in Fig 2 Unfortunately, some detail has been lost in the reproduction process Although the initial spark is diffuse, the two subsequent sparks are sufficiently well defined on the original photograph to yield accurate displacement data for use in the flow-velocity computation The exact reasons for the diffuse nature of the first spark are not known, but experimentation with circuit and electrode design is being continued in an effort to eliminate this problem

Velocity data obtained from the second and third sparks in Fig 2 are shown in Fig 3 The spark paths were not straight, but the displacement of a given point in the third spark relative to the corresponding point in the second spark is essentially constant, thus resulting in the uniformity of velocity computed from the two sparks Even though the present state of refinement of the technique permits good measurements of velocity, it would be desirable to reduce the width of the first spark

Attempts to measure the velocity in the wake of the circular cylinder model at a Mach number of 17 have produced successful photographs of the sparks Owing to the excessive width of the photographed sparks, however, there is insufficient resolution for observing the large velocity gradients in the viscous wake It is anticipated that this can be improved somewhat by the experimentation previously mentioned

In conclusion, the technique appears capable at present of making measurements of the velocity in a uniform hypersonic stream The resolution must be improved considerably, however, to permit the mapping of complex flow fields

Reference

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