A Microwave Method of determining the Displacement and Velocity of a Piston in a Hypersonic Gun Tunnel

The 'hypersonic gun tunnel' is a development of the conventional shock tube, giving a comparatively long running time for aerodynamic testing purposes. Its mode of operation has been fully described[1].

A vessel containing gas at high pressure is initially separated from the main tube or gun barrel at a lower pressure by a metal diaphragm and a light piston. When the diaphragm is ruptured, the piston is driven down the barrel and a strong shock wave forms ahead of it. The shock wave is reflected several times between the end of the barrel and the piston before the latter is finally brought to rest, the slug of air ahead of it being heated and compressed in a non-isentropic manner. This region ahead of the piston can experience very high transient pressures and temperatures.

We particularly wished to study the effect of the mass and shape of the piston on the flow parameters.

The displacement and velocity of a nylon piston in the hypersonic gun tunnel at the University of Southampton has been determined by means of a microwave technique[2]. This method has been devised because it provides a large number of test stations (in this instance 120 over 10 ft.) at which displacement and velocity of the piston can be determined.

The technique regards the steel gun barrel as a resonant microwave cavity and the travelling piston as a tuning plunger moving in the cavity. A radially symmetric wave-guide mode (TM_{01}) is established in the 10-ft. long steel gun barrel of 1·25 in. internal diameter. Microwave power obtained from a reflector klystron operating in the 3-cm. commercial band is launched into the barrel by an axial probe through a wave-guide directional coupler, the latter permitting the simultaneous monitoring of the reflected or transmitted wave system with a single aerial. A crystal diode detects the reflected wave signal from the moving nylon piston. The reflexion-coefficient of the piston is increased by facing it with a shim metal disk. The time between successive standing wave minima indicates the time taken for the piston to move through a half guide wave-length. Displacements and velocities have been measured throughout the period of the piston motion.

The oscillogram (Fig. 1) shows variation of crystal diode voltage with time during a typical run; it was taken 4·0 m.sec. after the diaphragm was ruptured. Analysis indicates that the piston is increasing in velocity from 1,445 ft./sec. to 1,490 ft./sec. over a length of barrel of 3·02 in. during a time-interval of 170 μsec. This requires an acceleration of order 265,000 ft./sec.^{2}. The maximum piston velocity so far observed has been 1,700 ft./sec. If the measured signal is deliberately made asymmetric (by alteration of matching) then it is possible to observe a change of signal phase whenever the piston reverses its direction. This effect has been clearly seen during actual runs.

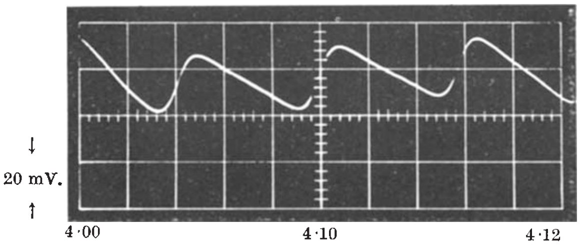

Fig. 1. Variation of crystal diode voltage with time

A raster type of cathode-ray oscillograph display is being developed which will enable the whole run to be recorded, yet have an individual line time-base sufficiently short in duration to enable accurate variations of piston velocity to be determined.

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[1] Cox, R. N., and Winter, D. F. T., Advisory Gp. Aero. Res. and Dev. Report No. 139.

[2] Bray, K. N. C., Pennelegion, L., and East, R. A., Aero. Res. Council, 20, 520.

A 'Solid-Image' Microscope

The disadvantage of the 'solid-image' microscope described by Gregory and Donaldson[1], as they point out, is that objects are seen through a relatively intense haze of background light, rather as if they were immersed in milk. There is a fairly straightforward way around this difficulty, though it entails a loss of some of the elegant simplicity of Gregory and Donaldson's instrument. During 1948–49 I devised and built at King's College a 3-dimensional scanning microscope on the same basic principle[2], which was described briefly in a report on university research in physics in 1949 [3] and exhibited at the College conversazione in that year. The slide carrier was vibrated in depth between 10 and 20 times a second with a saw-tooth motion, by means of a linear electromagnetic servo. The object, however, was scanned laterally by a flying spot on a cathode-ray tube, and the signal detected by a photomultiplier, exactly as in the 2-dimensional 'flying spot microscope' later (and apparently independently) described by Roberts and Young[4] of University College, London. The three deflecting voltages and the photomultiplier signal were supplied to a 3-dimensional projective cathode-ray tube display of the type devised for use in radar and electronic computing[5], so that a 'solid' representation of the object appeared on the screen and could be rotated at will by calibrated controls which enabled angles to be read directly.

The crucial advantage of the electronic display is that the signal can be electronically 'inverted' so as to present a negative picture showing objects in white on an otherwise dark background. In this way one could readily see single nuclear particle-tracks in emulsion (for the study of which the instrument was particularly intended) when in a 'positive' picture they were quite obscured by the bright background.

Work on the instrument was unavoidably interrupted in 1949, but my preliminary conclusion was that the astigmatism due to the inevitably poor depth-resolution must limit its usefulness to the study of fairly simple (preferably linear) structures (such as particle tracks, and perhaps nerve fibres). A severe compromise between signal-to-noise ratio, electronic resolving power, and rate of scanning is determined by the brightness of available flying-spot sources, since even ten pictures a second, with only twenty horizontal 'layers' each, require 200 frames to be scanned each second. At such rates, non-uniform scanning[6] was found to be essential to give acceptable resolution in the centre of the picture, and it seemed unlikely that for a tolerable signal-to-noise ratio, resolving power could equal that of