BEHAVIOR OF PERIODICALLY FORCED BUOYANT PLUMES

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This presentation reports on experiments concerning the behavior of periodically forced plumes of helium which naturally exhibit oscillations of the type observed in pool fires. Detailed characterization of non-reacting oscillating buoyant plumes has been recently reported[1,2]. The naturally occurring plume instability results from buoyant acceleration of the light plume gas in stagnant surroundings forming a toroidal vortex which exerts its influence on the unstable density stratification to lock the shedding frequency to a value described by the expression $S = fD/V = 0.8\ Ri^{0.38}$ for $Ri = (\rho_\infty - \rho_p)gD/\rho_\infty V^2 \leq 500$ and $S = 2.1\ Ri^{0.28}$ for $Ri > 500$. In this effort, we are exploring the receptivity of this natural instability to externally imposed periodic oscillations. Figure 1 shows the schematic of the experimental facility which consists of a 10 cm diameter nozzle attached to a loudspeaker, a wave form generator and an amplifier to provide the excitation, two pressure transducers, one in the cavity and another located at a height of one half burner diameter downstream along the centerline of the nozzle to detect the excitation and plume pulsation wave forms. The low frequency pressure transducer signals are first amplified and subsequently analyzed by a spectrum analyzer. For a helium plume originating from a 10 cm. diameter nozzle, the natural oscillation frequency is between 4.5 to 5.0 Hz. Our initial experiments involved excitation of this plume at single frequencies of 1 to 10 Hz . The excitation amplitude was kept to a low level providing a perturbation to the nozzle exit velocity. Later on, we conducted dual frequency excitation tests where a fundamental and a sub harmonic of the same amplitude were superimposed as the excitation wave form. Figure 2 shows a series of plume oscillation spectra with excitation frequencies in the range of 2 to 6 Hz. The natural oscillation frequency of this plume lies at 4.5 Hz. When excited at 2 Hz, the frequencies detected in the plume are those of the excitation and its harmonics. The highest amplitude occurs at 2 Hz. At 3 Hz, the amplitudes are all small and only the excitation frequency and its harmonics appear. Results at 4 Hz are similar to those at 2 Hz with similar pressure perturbation amplitudes. At 4.5 Hz excitation, the only identifiable frequency is at 4.5 Hz with no other significant peaks in the spectrum. The 5 Hz excitation also exhibits a single peak at the fundamental frequency. Finally at 6 Hz, spectrum is devoid of any significant peaks indicating that the coherence of the pulsations is destroyed to a large extent at this frequency. This result is also similar to that obtained at 3 Hz excitation. There also appear some frequency peaks which result from the interaction of the excitation frequency with the natural plume frequency. In general, these preliminary experiments show that the buoyant plume instability is highly receptive to the externally imposed frequencies and does not seem to have a preferential range of frequencies which undergo amplification. These results along with dual frequency excitation results and motion images of these plumes will be further analyzed and presented at this meeting.

References:

1. K. D. Kasper and B. M. Cetegen, Experiments on the Oscillatory Behavior of Buoyant Plumes of Helium and Helium-Air Mixtures, to appear in *Physics of Fluids*, 1996

2. A. Hamins, J. C. Yang and T. Kashiwagi, An Experimental Investigation of the Pulsation Frequencies of Flames, *Proceed. of the 24th Int'l Symp. on Comb.*, p. 1695 (1992)

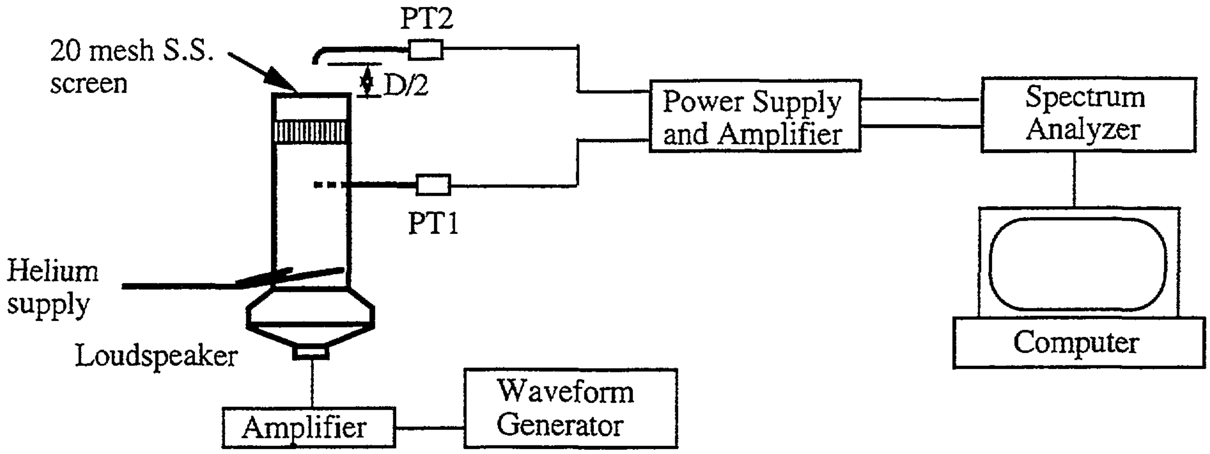

Figure 1. Experimental Set-up

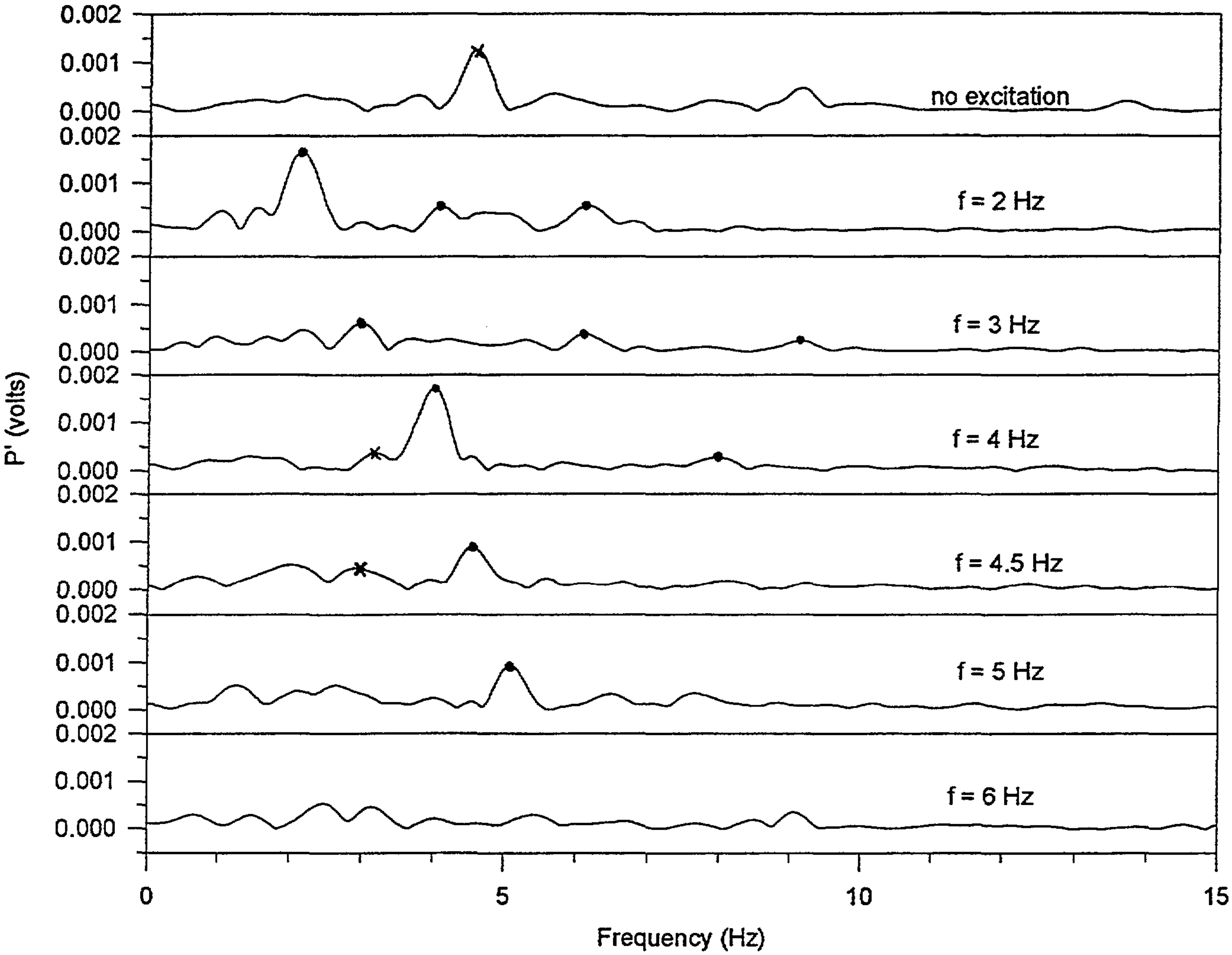

Figure 2. Frequency spectra of a helium plume at different excitation frequencies. Dots indicate excitation frequency and its harmonic peaks.