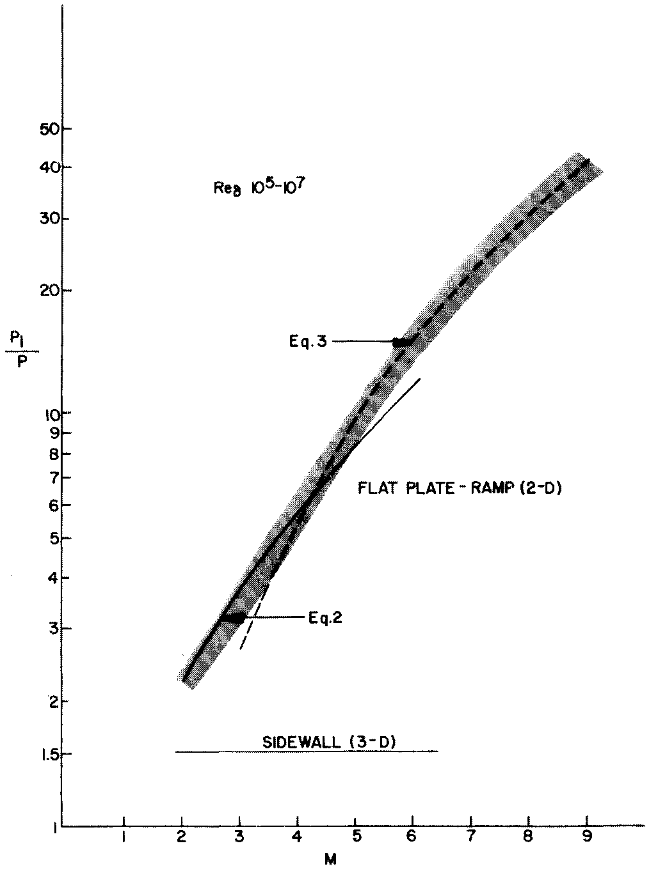


Fig. 3 Incipient separation pressure rise.

### Conclusions

Although two-dimensional data cover a wide band of incipient separation angles $\theta_i$, it is clear that the values are considerably higher than for skewed shock wave interactions, and the gap widens with increasing Mach number. Thus, it is the skewed shock wave interaction with the sidewall turbulent boundary layer in rectangular diffusers or inlets (see Fig. 1) that first leads to separation and possible flow breakdown for compression angles (or pressure rises) which may be well below the incipient values for the two-dimensional case.

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# Interferometric Technique for Measuring Mixing of a Buoyant Plume


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WHEN investigating the three-dimensional and unstable character of buoyant plumes, it is important to use a measurement technique which does not disturb the flowfield. Interferometry provides a simple means of making detailed concentration measurements under conditions which have a range of applicability. This Note concerns itself with a special case, namely, the isothermal, isobaric plume. A simple development follows which shows how interferometry can be used to measure buoyant plume mixing of a light gas into a heavy background gas, all at constant temperature and pressure. Finally, an example of the results is given in the form of reduced data of a vortex-like plume.

The standard equation for fringe shift is:

$$S = 1/\lambda \int_0^L (n - n_\infty)\, ds \tag{1}$$

where $S$ = fringe number, $\lambda$ = wave length of light in vacuum, $L$ = integration path length, $n$ = index of refraction, $s$ = path length along the light ray, and subscript $\infty$ refers to reference conditions.

An interferogram yields the fringe number $S$, and the solution of the integral equation provides the index field, $n$. An equation for $n$ can be developed in terms of the species mass fraction $C_i$ and Gladstone-Dale constants $K_i$ as


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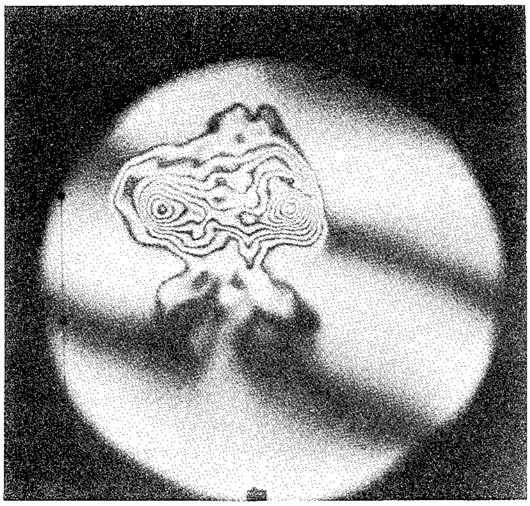

Fig. 1 Holographic interferogram of vortex formed buoyant rise of bursted helium-filled soap bubble in air (4 atm pressure).

$$\frac{n-n_H}{\rho_H K_H} = \frac{\rho}{\rho_H}\left[C_L\left(\frac{K_L}{K_H}-1\right)+1\right]-1 \qquad (2)$$

where

$$n = \Sigma K_i \rho_i + 1 = \rho \Sigma K_i C_i + 1$$
$$C_L + C_H = 1$$
$$n_\infty = n_H$$

were used. The subscripts $H$ and $L$ refer to heavy and light molecular weight gas conditions, respectively.

The density ratio:

$$\frac{\rho}{\rho_H} = \left[C_L\left(\frac{M_H}{M_L}-1\right)+1\right]^{-1} \qquad (3)$$

follows from the perfect gas law,

$$\rho/\rho_H = (p/p_H)(T_H/T)(M/M_H)$$

the assumptions of constant pressure and temperature, $p = p_H$ and $T = T_H$ and the definition of average molecular weight $M$,

$$1/M = C_L(1/M_L - 1/M_H) + 1/M_H$$

developed from $1/M = \Sigma C_i/M_i$.

By eliminating $\rho/\rho_H$ between Eqs. (2) and (3), one obtains the following expression for the light species mass fraction,

$$C_L = \frac{(n_H - n)/\rho_H K_H}{\{[(n-n_H)/\rho_H K_H]+1\}[(M_H/M_L)-1]-[(K_L/K_H)-1]} \qquad (4)$$

The solution of any problem commences with the solution of an integral equation, Eq. (1), for the quantity $n-n_H$. For the general three-dimensional index field, interferometric data must be available for various angular views of the phenomenon as formulated by Witte[1] and implemented in detail by Matulka.[2] This can be accomplished in principle by recording a holographic interferogram having 180° of angular viewing or by recording a series of interferograms by rotating the phenomenon about the test section of the interferometer. When the phenomenon is axisymmetric, the Abel inversion integral is used to solve for $n$ as a function of $S$.[3]

An example of the technique is provided by solving for the species mass fraction of a helium (or nitrogen) plume rising in air (or sulfur-hexafluoride). A typical interferogram is shown in Fig. 1. Initially, a spherical helium filled soap bubble is burst in air. A vortex-like plume forms after a rise of about 4 initial bubble diameters. The vortical motion quickly entrains air, especially into the region near the vertical axis of rise. Fringe data are read from the interferogram by counting fringes along slices of the plume taken perpendicular to the axis. The first dark fringe has an absolute value of $\frac{1}{2}$ and is negative relative to the air background because the optical path decreases as one proceeds into the helium plume. Because of statistical variations in these flow phenomena, a data-averaging scheme needs to be developed to arrive at the correct mean flowfield. Such an averaging scheme was developed and applied to these data by Mantrom and Haigh.[4] Data reduction provides the results in Fig. 2 for the isoconcentration profiles ($N_2$ mass fraction) for a turbulent vortex formed by bursting an $N_2$-filled bubble into a 10-atm $SF_6$ background. The initial bubble diameter was $\frac{1}{2}$ in. and the data were recorded at a height of ~10.4 initial bubble diameters. Mixing with the background gas is observed to be all but complete; however, the contours still show the vortex shape. Further details of these data as well as those for the helium vortex phenomena are given in Ref. 4.

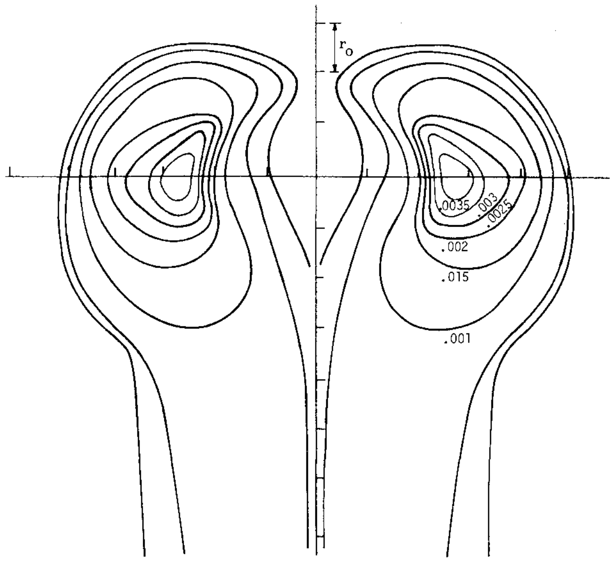


Fig. 2 ISO-concentration ($N_2$ mass fraction) profiles for a turbulent vortex rising in $SF_6$. Initial conditions: $N_2$ filled soap bubble, $SF_6$ background, $r_0 = \frac{1}{4}$ in. (initial bubble radius). Profile data = $h/2r_0 = 10.4$ (height of phenomena), 150 profiles denote $N_2$ mass fraction.

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# Two-Dimensional Supersonic Diffuser Experiments


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THE design of supersonic diffusers, as used in supersonic wind. tunnels is well understood. The flow mechanism primarily relied upon is that of the so-called "pseudo shock,"


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