Technical Notes

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Effects of Skimmer and Endwall Temperature of Condensed Molecular Beams

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It has generally been accepted that attenuation of beam intensity results from a scattering of the jet molecules in front of or within the skimmer. It is concluded that, despite an understanding of the skimmer interference phenomena, there seems to be little that can be done to avoid skimmer interference except to keep jet densities low at the skimmer entrance. It is suggested[1] that cryogenically cooling the skimmer would trap the molecules striking its surfaces and thus avoid the problem of skimmer interference.

It is the purpose of this Note to present some measurements of beam intensity and velocity obtained in a wholly cryogenically cooled molecular beam chamber. The measurements discussed herein are a direct outcome of some earlier studies of the condensation phenomenon in freejet expansions.[2,3]

The wholly cryopumped molecular beam chamber used in the present study is fully described in Ref. 3. An 8-kw gaseous helium refrigerator operating at temperatures of 14-20 K enables a wide range of gases to be pumped at comparatively high flow rates.

At a fixed source temperature, as the source pressure is increased, condensation can occur in a freejet expansion. The stages of condensation are: 1) formation of molecular clusters, dimers, trimers, etc.; 2) appearance of liquid droplets; and/or 3) formation of crystals. As a result of an electron diffraction analysis of an argon freejet expansion Audit[4] has been able to identify the source pressures at which the above events occur. It has been found[3] that the presence of liquid droplets in the expansion is accompanied by an increase in the measured velocity of the monomers in the expansion. This increase in velocity results from the addition of the heat of condensation to the flow.[5] In the present analysis it has been assumed that this increase of velocity is indicative of significant condensation in the freejet expansion.

Total beam intensity measurements obtained with an argon beam with four skimmer configurations are shown in Fig. 1. Prior to condensation (i.e., $p_0 \leq 600$ torr) it can be seen from a comparison of configurations A and B (Fig. 1) that beam attenuation resulting from a conical skimmer is relatively small. For similar source conditions configuration D shows a significant beam attenuation. Configuration B has a cryogenically cooled endwall (pumping), whereas configuration D has a 295 K (nonpumping) endwall. This suggests that scattering from the endwall is the dominant factor in incident beam intensity attenuation. To illustrate the importance of endwall effects further, a 295 K ring having inner and outer diameters of 14.5 and 23 cm, respectively, was mounted concentric with the 20 K skimmer (configuration C, Fig. 1). This configuration produced a degree of beam attenuation almost identical to that observed for configuration D, which has a 295 K skimmer and endwall.

With condensation (i.e., $p_0 > 600$ torr), the total beam intensity decreases to a minimum value and then increases rapidly with increasing source pressure for configurations B, C, and D. Leckenby et al.[6] have suggested that when large molecular clusters impact upon a warm surface they are destroyed and a cloud of single molecules is reflected from the surface. When a large cluster strikes a 295 K endwall or skimmer, regions of locally high monomer intensity are formed, which scatter the light species (monomers, dimers, etc.) in the incident beam. As the source pressure increases a larger percentage of the gas is condensed and the clusters increase in size. The large clusters traveling down the centerline are not scattered by the monomers reflected from the warm surface. (A similar effect has been observed in gas mixtures composed of heavy and light molecules, where heavy molecules are affected less than the light molecules by skimmer interference.) Furthermore, since these large clusters now form a large percentage of the incident flow, the total beam intensity now in-

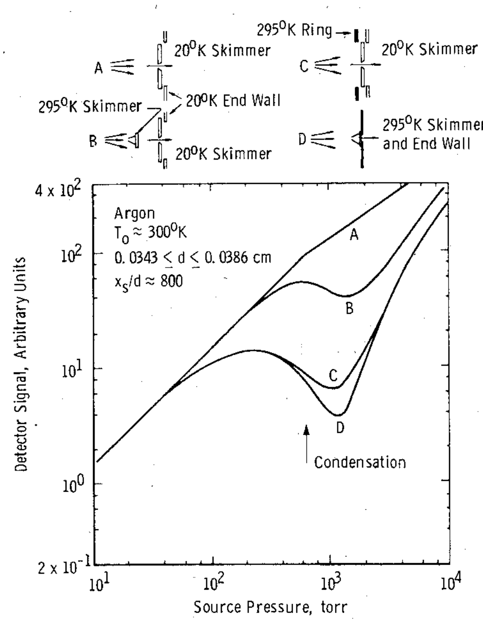

Fig. 1 Effect of skimmer and endwall temperature on beam intensity.

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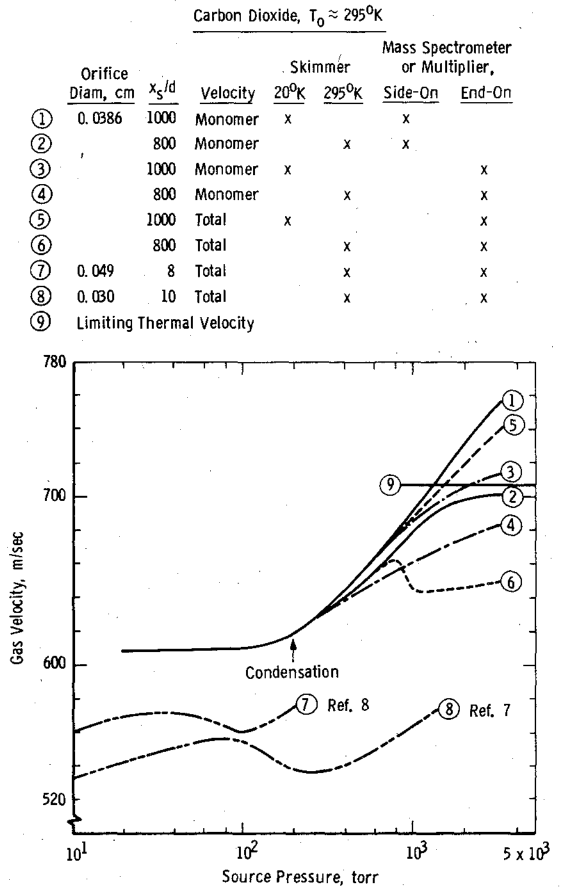

Fig. 2 Effect of skimmer interaction on measured beam velocity.

creases with increasing source pressure. It can be seen from Fig. 1 that the total beam intensity for configurations B, C, and D approaches to within 40% of configuration A at the highest source pressure.

A series of velocity measurements has been made in a carbon dioxide molecular beam for a number of skimmer and velocity detector configurations (Fig. 2). Using the criterion discussed earlier, we assumed that there are clusters in the flow for source pressures greater than 150 torr. In noncondensed flow the present results indicate that, for large source skimmer separations, i.e., $x_s/d > 800$ the measured velocity is independent of the skimmer configuration. Velocity measurements[7,8] at $8 < x_s/d < 10$ are lower than the present data and presumably reflect a skimmer and/or endwall interference effect upon beam velocity.

In condensed flows the measured velocity is dependent upon the skimmer configuration used to form the molecular beam (e.g., Fig. 2). There is experimental evidence[9] to suggest that at these source-flow conditions, condensation occurs within a few nozzle diameters of the source. These large clusters are formed before the noncondensed gas has attained the limiting thermal velocity. Abuaf et al.[10] have shown that, in the expansion of gas mixtures composed of heavy and light molecules for a range of source conditions, the velocity of the heavy molecule can be less than that of the light molecule. On the basis of these measurements, it is assumed the large clusters formed in the carbon dioxide expansion are traveling slower than the noncondensed gas. Fragmentation of molecular clusters can occur in the ionizing region of a mass spectrometer. Therefore, the monomer intensity is comprised of freestream monomers and fragmentation monomers. From an earlier consideration of skimmer effects it can be concluded that freestream monomers are dependent upon the skimmer configuration, whereas those monomers resulting from the fragmentation of large clusters are not. This results in an increase in the ratio of slow to fast monomers in a molecular beam formed with a 295 K skimmer over that formed by a 20 K skimmer. This in turn results in a lower average velocity for the 295 K skimmer (e.g., Fig. 2). Note that with the improved technique of cryogenic skimming it is possible to observe the expected increase in beam velocity over the limiting thermal velocity, due to the release of the heat of condensation.

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Buckling of Cylinders of Variable Thickness under Lateral Pressure

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Introduction

SITUATIONS arise where it is necessary to join two shells of unequal thickness or radius of curvature. Significant bending stresses and local variations of membrane stresses are known to exist at the junction of these shells. It is customary to strengthen the structure in this region by gradually increasing the thickness. Not much attention has been given to the analysis of shells of variable thickness, particularly in the stability domain. The purpose of this Note is, therefore, to bridge the gap and compare the efficiency of these shells with shells of constant thickness from buckling considerations.

Federhofer[1] and Wagner[2] treated axisymmetric buckling of cylinders of linearly varying thickness. Asymmetric buckling of a stepped cylinder under external pressure was analyzed by

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