TABLE 2. Atmospheric Properties

Constituent	Density* ρ/ρ_o	Viscosity* μ/μ_o	Sound Speed c/c_o	Ratio of Specific Heats
Air	1.00	1.00	1.000	1.4
Helium	0.138	1.06† (0.75)	2.915	1.66
Nitrogen	0.969	0.97	1.009	1.4
Argon	1.38	1.21	0.964	1.66
Carbon dioxide	1.52	0.80	0.782	1.2

* With respect to air: $\rho_o = 1.29 \times 10^{-3}$ g/cm^3, $\mu_o = 183$ µp; $c_o = 331$ m/s.

† One series of experiments (871209-871212) used evaporated liquid helium in order to examine possible effect of viscosity for a given gas. Value in parentheses were applied for this series.

TABLE 3. Projectile Properties

Type	Density, g/cm^3	Diameters Used, cm	Shape
Aluminum	2.78	0.159, 0.318, 0.635	spheres
Cadmium	8.9	0.318	cylinder
Steel	7.9	0.318	spheres
Polyethylene	0.9	0.318	spheres

contrast, targets composed of 100 µm low density (0.7 g/cm^3) ceramic microspheres ("Z-Light Spheres" trade-name) resulted in a target with very low bulk density (0.5 g/cm^3) and low internal angle of friction (20°) with sizes comparable to the no. 140-200 sand or pumice. Hence this target should maximize the effects of aerodynamic drag. While aluminum spheres were principally used for sand and pumice targets, polyetheline spheres were used for the microsphere targets in order to maintain the same projectile/target density contrast.

Last, a limited number of experiments were performed with mixtures of different targets. A mix of 8% by weight of pumice and no. 24 sand yielded a target with relatively low internal friction but a fine-grained component. The uncertain effects of the angular pumice shards, on internal friction, however, prompted further use of a mixture of the microspheres (5% by weight) with sand.

The AVGR uses a large chamber (~2.5 m x 2.5 m) that can be evacuated to 0.5 mbar. A variety of ambient gases were introduced following gradual evacuation of the chamber (>30 min.); these included helium, nitrogen, argon, and carbon dioxide (Table 2). Powder and two-stage light gas guns permitted launch velocities for 0.0159 to 0.635-cm spheres (Table 3) ranging from 0.5 to 6.5 km/s as determined electronically and photographically prior to entering the impact chamber. The impact chamber was isolated from the launch tubes by a thin mylar diaphragm and actual impact velocities were estimated from standard drag formulae from this point of entry into the atmosphere. Use of ductile projectiles (principally aluminum and polyetheline) minimized the effect of this thin diaphragm on the projectle integrity and velocity. High-speed photography (35,000 frames per second) with short exposure (0.5 µs) permitted confirmation of the calculated impact velocities, while aluminum witness plates demonstrated the integrity of the projectile.

Because granular targets have relatively high porosities (~40%), it is useful to examine any possible evidence and effects of target-trapped gases on the derived scaling relations. Nominal procedure involved evacuation of the impact chamber followed by reintroduction of the desired atmosphere. Evacuation was controlled in order to avoid explosive release of target-trapped gas. Impacts into neither pumice nor sand evacuated at 0.6 torr exhibited any significant evidence of a trapped atmosphere in high frame rate photographs (nonballistic modification of the ejecta, ionized gas release); blast effects on low-density styrafoam tracers (yet observed in volatile-rich targets); and pressure changes in the chamber. No difference was observed in the results for impacts in air whether the chamber was evacuated directly to the desired pressure or evacuated then refilled. Consequently, it is believed that the evacuation rate and diffusion rate of gas through the target were reasonably matched. Refilling the chamber most likely reintroduced the ambient atmosphere into target pore spaces since the infill rate generally was comparable to the evacuation rate. If gases entrapped in the pore spaces play a role, then they should play a comparable role for all gases. Such a role could appear in the form of an effective viscosity of the gas-particle mixture in the cratering flow field.

EXPERIMENTAL RESULTS

The effect of varying atmospheric conditions (pressure, composition, and density) and target grain size (sand, compacted pumice) can be graphically demonstrated through