NEW PYCNOMETER DESIGN FOR THIN-SLICED METEORITES. Robert J. Macke SJ[1], Daniel T. Britt[2] and Guy J. Consolmagno SJ[3], [1]Boston College, 140 Commonwealth Ave, Chestnut Hill MA 02467, macke@alum.mit.edu, [2]University of Central Florida Department of Physics, P.O. Box 162385, Orlando FL 32816-2385, britt@physics.ucf.edu, [3]Vatican Observatory, V-00120 Vatican City State, gjc@specola.va.

Introduction: Ideal-gas pycnometry has become a standard technique for non-destructive and non-contaminating measurement of meteorite grain densities (cf. [1]). These measurements, together with bulk densities obtained through techniques such as the Archimedean glass bead method (cf. [2]), x-ray microtomography [3], or 3-D laser scanning [4], permit the calculation of meteorite porosity. Commercially available pycnometers provide high-precision measurements of meteorite volumes, but the sample chamber is limited in size. (For example, the Quantachrome Ultrapycnometer uses a cylindrical sample cell 7 cm deep with a diameter less than 5 cm, which limits the size of measurable samples to typically less than ~130 gms.)

Our research interests include the density and porosity of a wide variety of meteorites, including lunar and martian meteorites. Many of the martian and lunar samples held in private collections have been cut into thin slices (sometimes ~ 1 mm thick) to maximize the surface area per gram. These slices are often quite fragile, making their placement in a cylindrical sample cell problematic. They also can be large in two dimensions, not fitting the sample cell. In addition, there have been several instances in which access has been granted to measure large meteorites before they have been sliced, but which were far too large to fit the sample cell of our standard pycnometer.

We have designed a new pycnometer (Fig. 1) to accommodate these large samples and thin slices. It has a much larger sample cell than commercial pycnometers: 12.7 cm (5 inches) deep and 10.2 cm (4 inches) in diameter. We have also designed inserts to accommodate a range of sample sizes. One such insert is designed especially to accommodate thin-sliced samples, up to ¼ in (0.64 cm) thick. It allows the sample to lay flat and fully supported.

This device opens up a new range of meteorite sizes and geometries for grain density measurement through ideal-gas pycnometry. In addition, with promising new techniques for measuring bulk density through ideal-gas pycnometry [5], using this device we may be able to determine porosity for thin-sliced meteorites without risking damage of such fragile samples through contact with beads.

Pycnometer Design: The basic design follows that of other pycnometers, with cylindrical primary and secondary chambers. The primary chamber serves as the sample cell. Its interior dimensions are 10.2 cm in diameter by 12.7 cm deep deep, sporting a volume of approximately 1000 cm^3. The secondary chamber is subdivided into two parts, each approximately 500 cm^3, connected by a valve. This allows for the selection of a secondary chamber volume appropriate for sample volume and chanber inserts. This design also permits two separate expansion steps, allowing for two volume measurements per run.

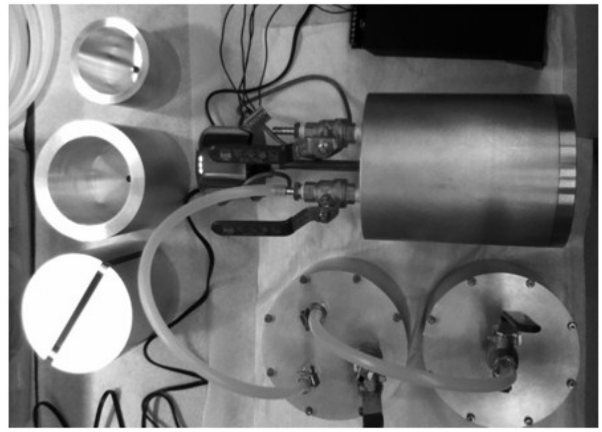

Fig. 1 *Top view of the pycnometer. The primary chamber is upper right. Secondary chambers are bottom right. At left are the inserts for the primary chamber.*

The primary and secondary chambers are machined out of solid aluminum cylinders. Chamber walls are 0.5 in (1.2 cm) thick, making them resistant to deformation. Valves and fittings are standard plumbing for natural-gas systems. All valves are controlled manually. Gas pressure is measured using a Setra 270 pressure transducer attached to the primary chamber.

Standard inserts. To accommodate meteorites of various sizes, a set of nested sleeves were manufactured from solid non-porous blocks. These sleeves fit snugly within the primary chamber (Fig. 2) and fill excess volume, allowing for more precise volumetric measurements of smaller samples. The large insert has a cell size of 3 in (7.6 cm) diameter by 3.5 in (8.9 cm) deep. The small insert, which fits snugly inside the large, has a cell size of 1.18 in (3.01 cm) diameter by 2.5 in (6.35 cm). This cell size was selected to accommodate 2.24-cm-diameter calibration spheres (approximately the size of standard billiard balls).

Thin-slice insert. The sleeve for thin-sliced meteorites was manufactured from a solid cylinder of aluminum, machined to fit snugly inside the primary chamber. The piece was sliced completely down the middle,

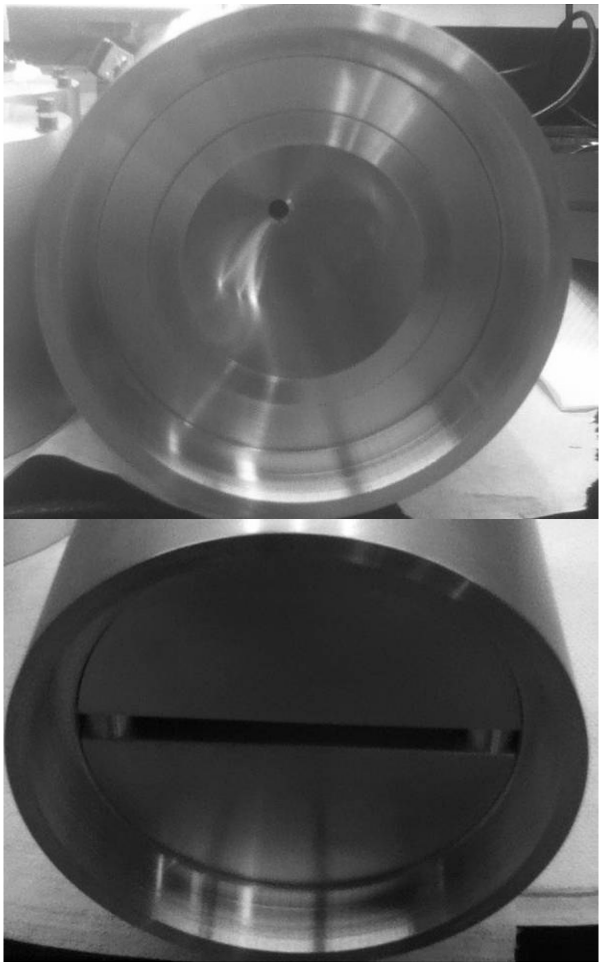

Fig. 2 *Inserts placed in the primary chamber, with lid removed. (Top) Nested sleeves. (Bottom) Thin-slice insert.*

leaving a gap of 0.7 cm (just over ¼ in.) between the two parts in which the sample can rest. The two halves are connected by four spacers (one at each corner) which rest in holes drilled into the faces. None of the parts are permanently affixed, allowing for the halves to be completely separated to assist in the placement and removal of samples (Fig. 3). When placed inside the primary chamber, the sample surface lies parallel to the ground (Fig. 2), with the sample fully supported. Calibration is performed using a stainless steel block machined to 9.53 cm x 9.53 cm x 0.64 cm (3.75 in. x 3.75 in. x 0.25 in.)

Discussion: Besides supporting fragile materials, these inserts also improve measurement precision. They increase the relative size of the sample to the cell, which in turn allows for a greater difference between initial and final pressures. This minimizes the uncertainty due to imprecision in pressure measurements. This is especially true for the thin-slice insert, since a sliced meteorite is dwarfed by any cylindrical chamber large enough to contain it.

Early test measurements performed with the thin-slice insert were conducted on two plastic credit-card-sized sheets, which together have a caliper-determined volume of 7.76 cm^3. The pycnometer-measured volume of the two sheets together was accurate to within 0.05 cm^3 (a difference of 0.6%). Measurements on rhodonite and unakite slabs exhibited very small variances (< 1% over ten measurements apiece) and were consistent with typical densities of these rocks.

Conclusion: The new pycnometer design, particularly with its adaptor for thin-sliced meteorites, presents the opportunity to measure meteorites of a range of sizes and shapes that do not fall neatly into existing pycnometer designs. When used in conjunction with the Quantachrome Ultrapyc for smaller samples, we can now measure grain density for meteorites ranging from about 1 cm^3 to over 400 cm^3.

With the thin-slice insert, we hope not only to use this device to measure grain densities of sliced samples, but bulk densities as well. Shijie et al. [5] have developed a method for measuring bulk densities via ideal-gas pycnometry by encasing samples in a thin-walled balloon. We believe that a modified version of this procedure can be applied with minimal risk to slices. This will eliminate the risk of breakage of the sample from immersion in glass beads when the glass-bead method is applied, a procedure which leaves much of the meteorite unsupported.

References: [1] Consolmagno G. J. et al. (2008) *Chemie der Erde–Geochem.* 68, 1-29. [2] Macke R. J. et al. (2010) *Planet. Space Sci.* 58, 421-426. [3] McCausland P. J. A. et al. (2010) *LPS XLI*, Abstract #1533. [4] McCausland P. J. A. et al. (2011) *Meteoritics & Planet. Sci.* 46, 1097-1109. [5] Shijie L. et al. (2012) *J. Geophys. Res.* 117, E10.

Fig. 3 *Thin-slice insert with the halves separated. A sample (in this case, terrestrial rhodonite) lies flat on the face of the bottom half. Separators are visible at each corner of the face.*