New Pycnometer Design for Thin-Sliced Meteorites

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We have designed a new ideal-gas pycnometer capable of accommodating larger meteoritic samples and thin slices. This device opens up a new range of meteorite sizes and geometries for grain density measurement using this technique. It has a much larger sample cell than commercial pycnometers, with inserts to accommodate a range of sample sizes. One such insert is designed especially for thin-sliced samples, such as many of the lunar meteorites available for study. It allows the sample to lay flat and remain supported through the measurement process.

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 to only a few cm across.

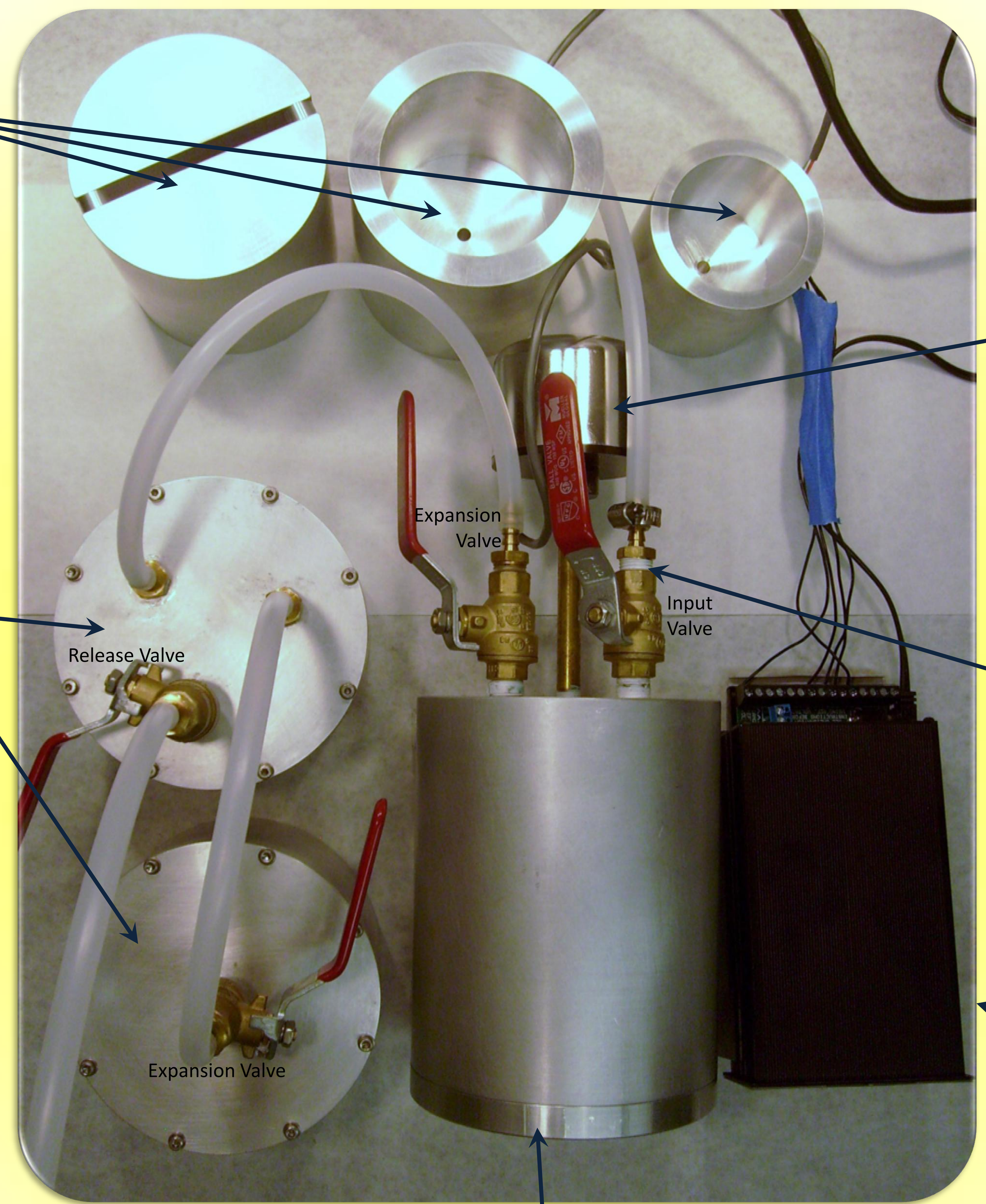
Our research interests also include lunar and martian meteorites. Many such samples held in private collections have been cut into thin slices (sometimes ~ 1 mm thick) to maximize the surface area per gram. These slices are often quite fragile, making their placement in a cylindrical sample cell problematic. 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.

These needs prompted the design and manufacture of a new, larger pycnometer that can accommodate and accurately measure these types of sample.

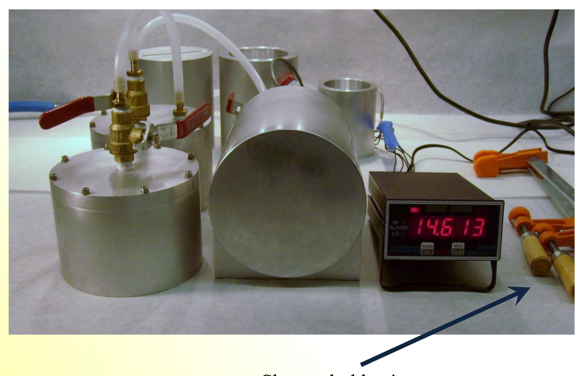
Pycnometer Design

The basic design follows that of other pycnometers, with cylindrical primary and secondary chambers.



Chamber Inserts
Fill excess volume for smaller samples.
The leftmost one is the thin-slice insert.

Secondary Chambers
Two secondary chambers, each ~500 cm^3.
This allows for the selection of a secondary volume appropriate for sample volume and chamber inserts.
This design also permits two separate expansion steps, allowing for two volume measurements per run.



Clamps hold primary chamber lid closed when pressurized.

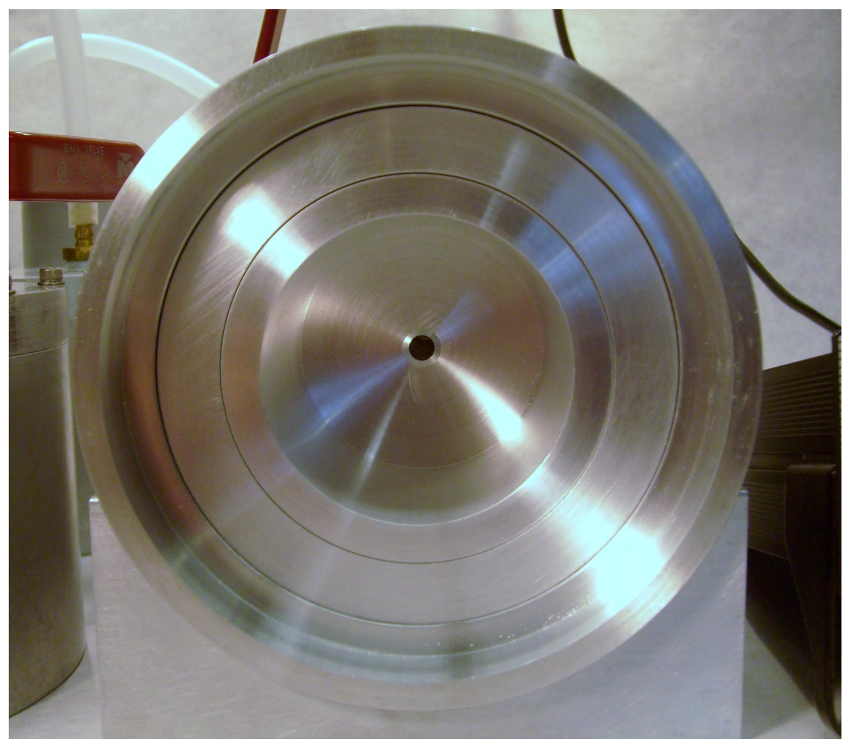
Pressure Transducer
Gas pressure measured by a Setra 270 pressure transducer attached to the primary chamber.

Valves and fittings:
Standard plumbing for natural-gas systems. All valves are controlled manually.

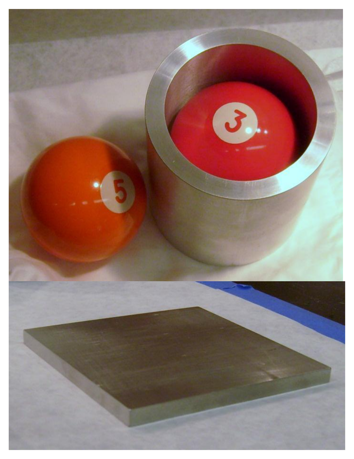
Pressure Readout
Digital display reads out pressure to within 0.007 psi.

Primary Chamber
Serves as the sample cell.
Interior:10.2 cm dia. x 12.7 cm deep
(Vol. ~1000 cm^3.)

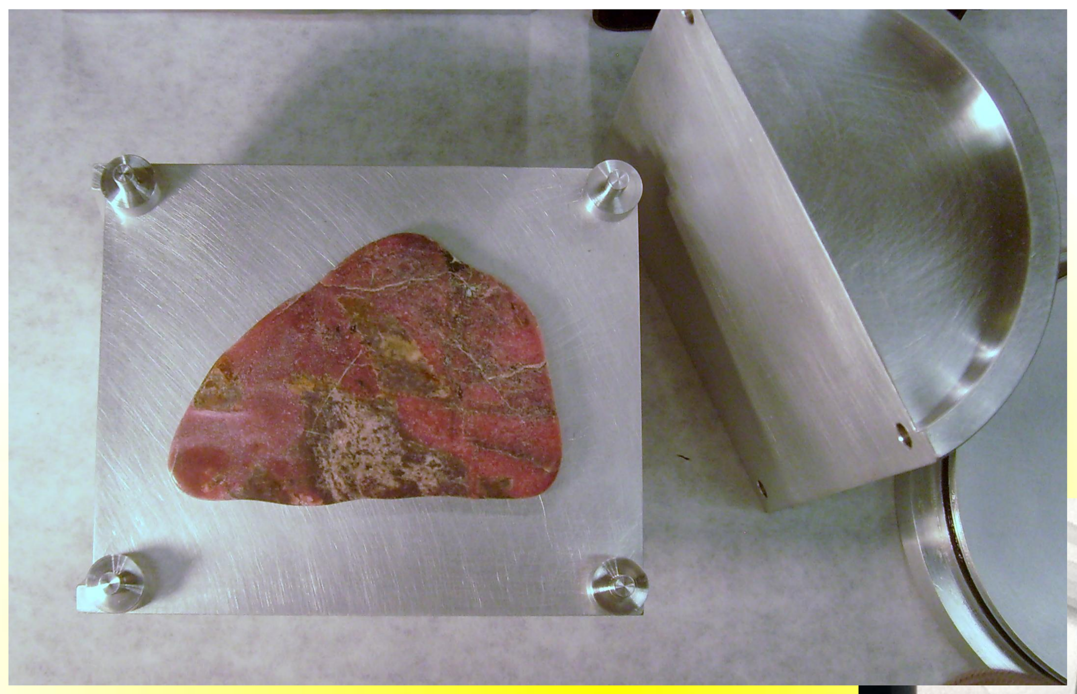
Manufacture
Chambers and inserts were milled out of solid aluminum cylinders, with no welds. The thin-slice insert was milled as one piece, then cut in two.
All valves and fittings are commercially-available equipment for natural gas plumbing.

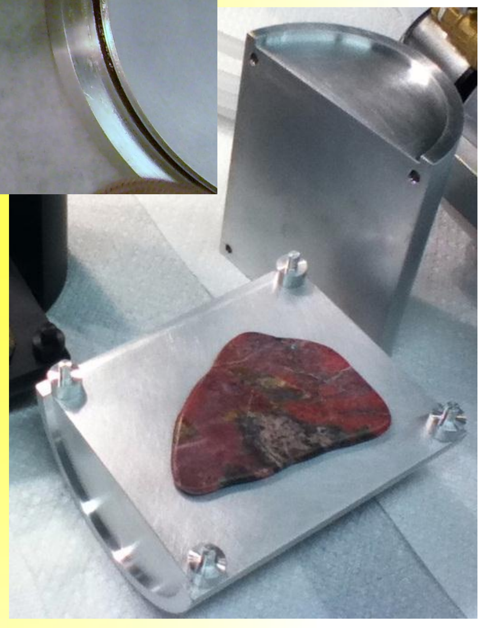


Standard inserts
These sleeves fit snugly within the primary chamber and fill excess volume, allowing for more precise volumetric measurements of smaller samples.
Large insert: 3 in (7.6 cm) dia. x 3.5 in (8.9 cm) deep.
Small insert (nested inside the large): 2.32 in (6.02 cm) dia. x 2.5 in (6.35 cm).



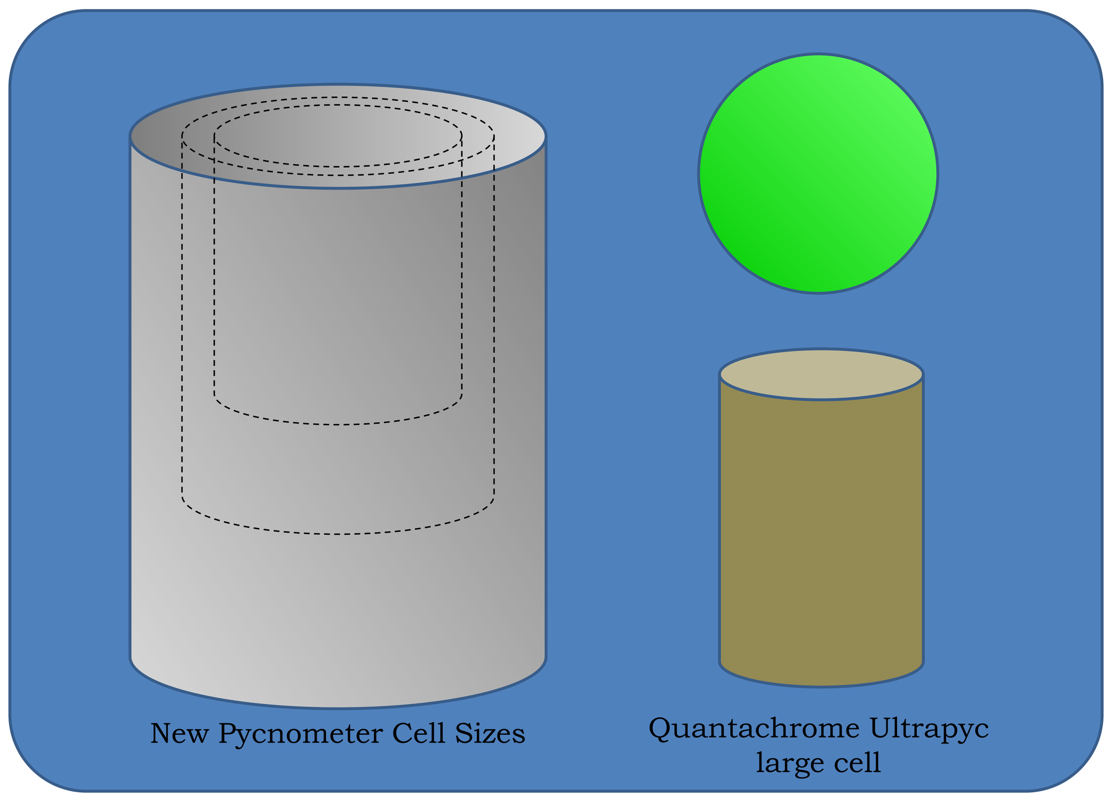
Calibration Volumes
For the cylindrical chambers, we use 5.69-cm-dia. resin spheres (shown inside the small sleeve insert).
For the thin-slice insert, we use a stainless steel block, machined to high tolerances, measuring 9.53 cm x 9.53 cm x 0.64 cm (3.75 in. x 3.75 in. x 0.25 in.).
Calibration volumes are used for determining chamber volumes (including contributions from plumbing, etc.), which are necessary for establishing sample volumes.





Thin-Slice Insert
Machined to fit snugly inside the primary chamber.
Sample rests in a gap of 0.7 cm (just over ¼ in.) between the two halves.
None of the parts are permanently affixed, allowing for the halves to be completely separated to assist in the placement and removal of samples.

When placed inside the primary chamber, the sample surface lies parallel to the ground with the sample fully supported.



Pycnometer cell sizes (shown approx. actual size). The grey cylinder on the left is the largest cell size for the new design (4 in. dia. x 5 in. deep). The two embedded dashed-line cylinders depict the cavity sizes for the two inserts. For comparison, on the right in brown is the largest cell of the Quantachrome pycnometer that we have been using until now. The green circle represents the size of the calibration sphere used with the new pycnometer. (Note that it would not fit into the Quantachrome cell.)

Discussion and Conclusion

This device, used in conjunction with the Quantachrome Ultrapyc for smaller samples, enables us to measure grain density for meteorites ranging from about 1 cm^3 to over 400 cm^3.

By increasing the relative size of the sample to the cell using inserts, 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 on two plastic credit-card-sized sheets, which together have a caliper-determined volume of 7.76 cm^3, were 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.

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 with pycnometers by encasing samples in a thin-walled balloon. A modified version of this procedure may be applied with minimal risk to slices. Ongoing work includes further testing of this possibility.

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