InstruQuest, Inc.
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Versatile cell design for flow rates measurements through packed beds

PV-Pyc 200, Pressure/Vacuum Pycnometer Accessories

To enhance the analytical capabilities of the dual-technique gas pycnometer, PV-Pyc 200, a universal design of sample cell for flow measurements through packed beds of powdered materials (cement) is presented. Using the shown below hardware, the pycnometer resources, and additional devices, the user can carry out experiments that are not offered by other pycnometers and at a fraction of the cost if a dedicated analyzer needed to be acquired. Since different design features can be offered in the future, this specific hardware (and its quantities) is for illustration purposes only.

The photo below shows the main body of the cell (bottom, right corner), additional sleeves for packed bed diameter reduction, and plungers to form a flat bed. The sleeves have threaded holes at the top to facilitate insertion and removal by using appropriate adapter. The circular hole in this particular main body has diameter of 30 mm and the bed of up to 50 mm in height can be formed. Various constructions of the support for the bed can be materialized at the bottom of the main body. Usually a suitable paper filter or a SS metal cloth of very fine wire mesh are used as the first layer, which is supported by a more resilient metal cloth of coarser mesh. A metal circle with multiple holes is used to attach the filter setup to the main body of the cell. No part of the setup can fall out if cell is turned upside down and there is sufficient coverage of larger area then the bed area to prevent any powder escape. The filters selection and construction can be made and replaced as needed. An example of the filter setup with 8 micron filter paper is presented on the right hand side photo below.

The main body of the cell has threaded portions at the top and bottom to accept various adapters that can be used for different purposes. The bottom adapter is designed to form hermetic contact with cell bottom and the center port is used for connection to a flow measuring device or to a vacuum source. Likewise, the top adapter forms hermetic contact with upper cell surface and has a suitable port to install a fitting for connection to the pycnometer and accepting additional hardware. Another type of adapters can have a metal filter only to prevent powder escape when measuring the sample volume (density) inside the pycnometer chamber. And yes, the cell fits into the pycnometer chamber for regular pycnometric measurements as well as it can be used outside of the pycnometer sample chamber for flow measurements.
The photo below (on the left) shows the assembled main cell with top and bottom adapters attached and equipped with suitable fittings for particular type of measurements. In order to connect the cell to the

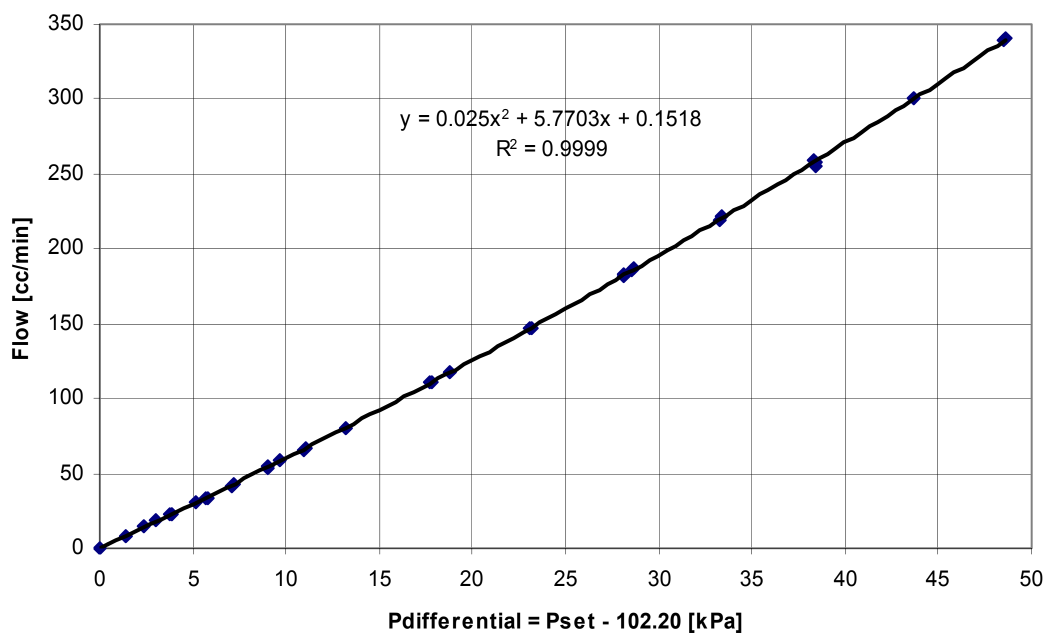
pycnometer, one of the possible ways is to use the volume reducing adapter presented on the right hand side photo. Such adapter is normally used to minimize the dead volume of the sample chamber when connecting external special sample chambers for measurements of unusual shapes.

After inserting the volume reducing adapter in the sample chamber and securing it with the locking arm with screw, the packed bed cell can be connected to the pycnometer via a tubular link. The photo below shows a particular setup for measurement of flow rates, where the selected gas is supplied to the top of the cell using the precision pressure regulator of the pycnometer to set appropriate pressure values and measure the resulting flow amount from the bottom of the cell.

Since the PV-Pyc 200 can be equipped with dual gas option, the user can carry out flow measurements using two different gases with the convenience of selecting one of them by using the front panel switch. Using the Manual Mode in the software, the pressure values set by the pressure regulator are measured by the pressure transducer of the pycnometer. Knowing these absolute pressure values, and previously determined value of the atmospheric pressure, the differential pressure values corresponding to each flow rate can be obtained. Therefore, the need of having a differential pressure transducer across the cell is eliminated, but one can be installed if desired. The flow rate measurements can be carried out very accurately using a bubble flow meter and a digital timer (stop-watch). To ensure large range of flow rates, either different range models of bubble flow meters can be used or multiple–range models of such flow meters can be employed. Alternatively, mass flow meters can be used but at much higher cost.

The resistance to gas flow through packed beds has been extensively studied for practical reasons and numerous examples of theoretical models were proposed to extract other useful quantities, like specific surface area of powders. From experimental point of view it is convenient to keep one side of the packed bed at the atmospheric pressure (or vacuum) as the reference and apply a certain flow or set pressure at the other side of the bed. In the presented example, the various pressure values were set at the top of the bed as an independent variable and the bottom of the cell was kept at atmospheric pressure. It is tacitly assumed, that gas source is infinite and for the rather small amount of gas needed, the pressure regulator is able to provide it. The pressure difference between the top and bottom of the packed bed is the driving force and the resulting flow of gas (air) is the response.

Air flow through cement bed vs. pressure



The chart above shows the results of flow rates measurements through a packed cement bed of 30mm diameter and 42.6 mm in height, where the bottom output was maintained at atmospheric pressure and connected to soap bubble meter of 50 cc range. The data were obtained at increasing and decreasing pressure differential, and the resulting flow values are both presented on the same graph, showing good repeatability. A fitted trend line exhibit good correlation with quadratic equation. It should be noticed, that this correlation refers to the amount of flow rate (y) versus pressure differential (x). Opposite, should various flow rates being used as an independent variable and the resulting pressure differentials be obtained, then the axes should be reversed.

Experimentally, the described setup, with some auxiliary hardware used, offers the following results:

1. **True volume (density)** as the sample can measured by the PV-Pyc 200 pycnometer
2. **Porosity of the bed**, as the physical (geometric) volume can be determined after forming the bed in the cell.
3. **Flow rates versus set pressure differentials** at isothermal conditions.

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