

# Testing Method for True Density of Ceramic Fracturing Proppants

## 1. Background

Fracturing proppants, also known as ceramic particles or ceramic sand, are sintered from high-quality bauxite and other raw materials. These proppants are widely used in deep-well and high-pressure oil/gas reservoir fracturing operations.

During deep oil and gas well extraction, hydraulic fracturing is applied to low-permeability reservoirs under high closure pressure. This process fractures the hydrocarbon-bearing rock layers, creating channels for oil and gas flow. Proppants are injected with high-pressure fluid into fractures to prevent closure under stress, maintaining high conductivity and enhancing production. Field data demonstrates that ceramic proppants can increase well productivity and extend operational lifespan.<sup>(1)</sup>

**True density** is defined as powder mass divided by the **true volume** of the powder, which is the powder volume excluding any internal pores, cracks, or voids. If the material is porous, like ceramic particles, the true density can differ significantly from the bulk density (pore volumes not subtracted). The true density of ceramic particles is directly related to proppant effectiveness. The particles sintered from bauxite tend to have high true densities, which allow them to resist crushing and breakage. However, some applications require lightweight proppants which resist particle settling and are typically less costly.<sup>(1)</sup> Therefore, accurate true density measurements are necessary to improve these technologies.

## 2. Experiment

The **Densi 100** True Density Analyzer from **AMI** measures true density by employing the gas displacement method. As demonstrated in the scientific literature, helium is recommended as the displacement gas for true density measurements due to its small molecular radius, high diffusivity, and chemical inertness.<sup>(2)</sup> These properties allow helium to penetrate fine pores and cracks of powder materials.

By measuring pressure changes in a calibrated chamber, the **true volume** and **true density** of the sample are determined. The procedure is as follows:

### Step 1: Empty Sample Cup Calibration

- ✓ Record the initial pressure ( $P_0$ , empty) of the empty reference chamber and then pressurize the sample chamber to the dosing pressure ( $P_d$ , empty) using He. Open the reference chamber to the sample chamber and record the equilibrium pressure ( $P_{cd}$ , empty) is recorded. Calculate the calibration parameter ( $M_P$ , empty) using Equation 1:

$$M_P(\text{empty}) = \frac{P_{cd}(\text{empty}) - P_0(\text{empty})}{P_d(\text{empty}) - P_{cd}(\text{empty})} \quad (1)$$

Definitions:

- ✓ Initial pressure ( $P_0$ ) – pressure inside reference chamber before He is introduced
- ✓ Dosing pressure ( $P_d$ ) – pressure of helium in sample chamber before opening to the reference chamber
- ✓ Equilibrium pressure ( $P_{cd}$ ) – total pressure measured after sample chamber is opened to reference chamber

**Step 2: Sample Measurement**

- ✓ Load the sample and record  $P_0$ ,  $P_d$ , and  $P_{cd}$ . Calculate  $M_P$  using Equation (2):

$$M_P = \frac{P_{cd} - P_0}{P_d - P_{cd}} \quad (2)$$

**Step 3: True Volume Calculation**

- ✓ Determine the true volume ( $V_T$ ) using Equation (3), where  $V_d$  is the chamber volume:

$$V_T = V_d \times [M_P(empty) - M_P] \quad (3)$$

**Step 4: True Density Calculation**

- ✓ Compute true density ( $D_T$ ) via Equation (4).

$$D_T = \frac{\text{Mass of sample}}{V_T} \quad (4)$$

The schematic of the **Densi100** is shown in Figure 1, which shows the sample chamber, reference chamber, pressure values, and connecting pipelines.

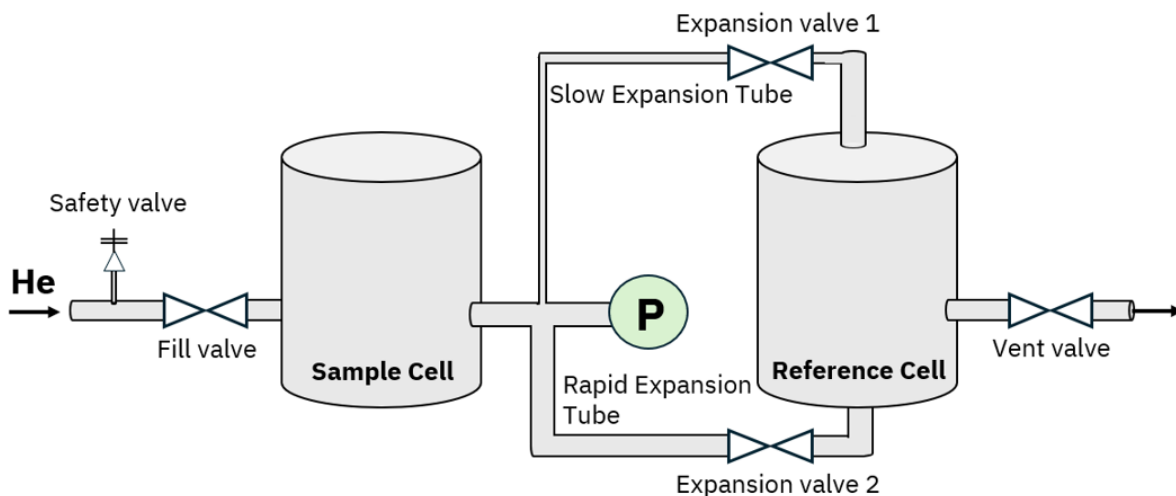


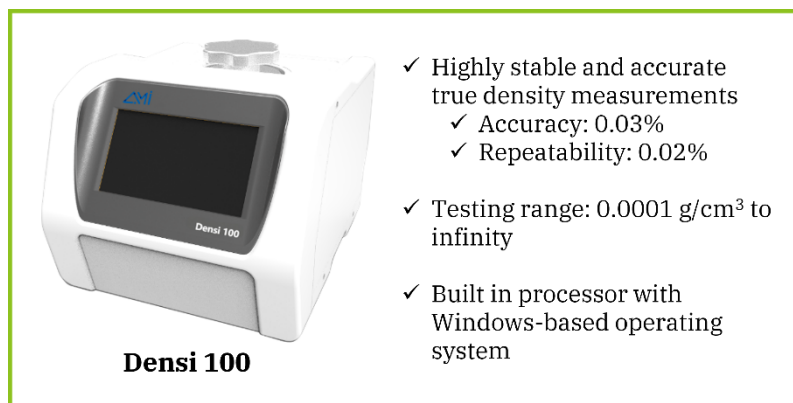
Figure 1: Instrument schematic of **Densi100** True Density Analyzer from **AMI**

### 3. Results

Sample	True Density (g/cm <sup>3</sup> )	Relative Error (%)	Bulk Density (g/cm <sup>3</sup> )	Difference between True Density and Bulk Density
1	2.8605	0.08	2.77	0.0905
2	2.8493	0.05	2.79	0.0593
3	3.0875	0.04	3.03	0.0575
4	3.0657	0.1	3.05	0.0157

Table 1: True density test results of fracturing proppants

The **Densi100** produced reliable, precise true density measurements of ceramic proppants with low relative error values, shown in Table 1. These results were significantly higher compared to the bulk density measurement, which illustrates the difference between the two parameters.



### 4. Conclusions

The **Densi 100** True Density Analyzer delivers high precision ( $\pm 0.03\%$ ) and reproducibility ( $\pm 0.02\%$ ), fulfilling the rigorous requirements for absolute density testing of ceramic proppants. This method ensures reliable quality control in hydraulic fracturing applications.

Figure 2: Highlighted features of the **Densi100** from AMI

### 5. References

- (1) Liang, F.; Sayed, M.; Al-Muntasheri, G. A.; Chang, F. F.; Li, L. A comprehensive review on proppant technologies. *Petroleum*, **2016**, *2*, 26-39.
- (2) Nguyen, H. G. T.; Horn, J. C.; Bleakney, M.; Siderius, D. W.; Espinal, L. Understanding material characteristics through signature traits from helium pycnometry. *Langmuir*, **2019**, *35*, 2115-2122.