Technical Note

PENDOTECH
Leading Process Analytics

Achieve Accurate Volume Measurement

In Flexible Bioprocess Containers

Accurate volume measurement in flexible bioprocess containers is critical in biopharmaceutical manufacturing. These single-use containers, commonly utilized for storing buffers, media, and other process fluids, require precise volume monitoring to ensure optimal process control. Precise volume data enables accurate dosing and mixing, preventing batch variability and ensuring consistent product quality. Real-time volume tracking facilitates automated process control and informed operational decisions. Additionally, non-invasive sensor integration preserves container integrity and maintains aseptic conditions, which is vital for cleanroom compliance.

METTLER TOLEDO

Introduction

The METTLER TOLEDO Pendotech Single-Use Pressure Sensor is designed to monitor pressure in flexible bioprocess containers for both gas and liquid applications, utilizing the same sensing technology as our in-line sensors but in a form factor that enables easy integration via a custom welded port plate and locking ring. It serves multiple purposes, including pressure monitoring in disposable bioreactors, integrity testing of single-use systems, and accurately measuring liquid height to calculate fluid volume - especially beneficial for buffer and media storage bags where traditional volume measurement methods are costly and complex. Since pressure directly correlates to liquid height due to constant gravity and fluid density, volume can be derived from the container's geometry. Accurate measurements depend on precise sensor placement at the container's bottom and high-resolution, low-pressure readings, which is why Pendotech recommends pairing the sensor with our High Resolution PressureMAT™ Sensor Monitors (PMAT2HR or PMAT-SHR), validated for reliable performance at low pressures.

Experimental Setup

An experiment was carried out using a custom 200 L flexible bioprocess container fitted with a Pendotech Port Plate welded at the bottom. This container was placed inside a modified 200 L tote, which had vertical slits cut along its sides to allow easy visual measurement of the liquid level inside the bag. Additionally, a 2-inch diameter hole was cut at the bottom of the tote to accommodate a Pendotech single-use pressure sensor, which was securely installed flush with the bottom of the bag using a locking ring. The sensor was connected to a high-resolution pressure monitor and calibrated to atmospheric pressure before the bag was filled with dyed water to improve visibility of the liquid meniscus through the slits. Liquid level measurements were taken at regular pressure intervals using a caliper through the tote's slits. These measurements were compared with theoretical liquid levels calculated from the pressure readings, using the formula to convert pressure to liquid height. The volume of liquid was then estimated using the cylindrical volume formula based on the measured liquid height. This process was repeated as the bag was filled to near capacity, demonstrating the application of pressure-based volume measurement in flexible bioprocess containers.

Results

Presented in Table 1 are the pressures exerted on the sensor located at the bottom of the bag, as recorded by the PMAT2HR. The actual liquid levels measured using a caliper, the calculated percentage errors between these measurements, and the computed volumes. The theoretical and actual liquid levels were very close, with an average difference of less than 1% across all data points. The highest error was observed at a pressure of 0.920 psi, where the actual liquid level was 0.39 inches higher than the theoretical value, resulting in a 1.53% error—still within the sensor's accuracy range of ±2%. The most precise measurement occurred at 0.620 psi, where the actual level exceeded the theoretical by only 0.01 inches, or 0.06%. As shown in Figure 1, the data demonstrated an almost perfect linear relationship, consistent with Pascal's Principle.

Bag Pressure Measured (psi)	Theoretical Liquid Level (in Aq)*	Measured Liquid Level (in Aq)*	Percent Error	Calculated Volume (L)
0.305	8.45	8.54	1.07%	53.2
0.451	12.5	12.56	0.48%	78.2
0.62	17.18	17.19	0.06%	107.1
0.769	21.31	21.27	0.19%	132.5
0.92	25.49	25.88	1.53%	161.2
1.13	31.31	31.54	0.73%	196.5

*in AQ refers to inches of water

Table 1: Theoretical vs Actual Liquid Level Measurements

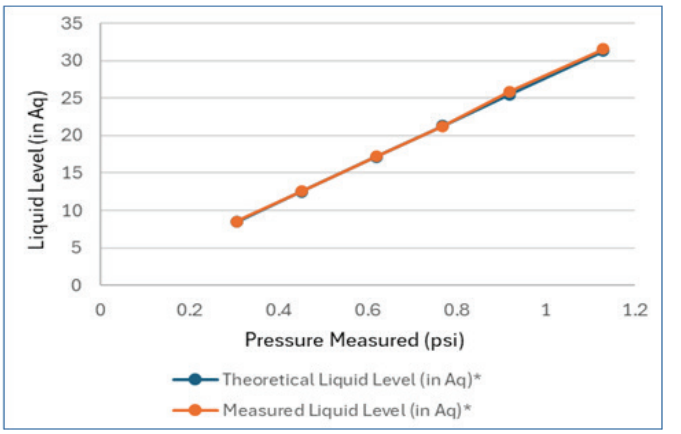

Figure 1: Theoretical vs Actual Liquid Level Measurements

An additional experiment was conducted to preliminarily evaluate the accuracy of volume measurements derived from pressure readings. In this test, the bag was filled up to the 160 L graduation mark on the tote. Although this mark is not a calibrated measurement, it provided a useful reference for qualitative comparison. At this point, the liquid level measured approximately 26 inches, corresponding to an estimated volume of about 166 L. The difference of under 4% between the volume e stimated from the pressure readings and the tote's reference volume is due to the qualitative aspects of the experiment. Despite being preliminary, the findings indicate that the calculated volume closely approximates the actual volume and will inform future efforts toward validating volume measurement accuracy.

Conclusion

The experimental validation demonstrates that Pendotech's Single Use Pressure Sensor, when paired with the High Resolution PressureMAT Sensor Monitor, can accurately and reliably measure liquid levels and calculate volumes in flexible bioprocess containers. The data collected consistently fell within the sensor's accuracy specification of ±2%, confirming its high precision in determining actual liquid levels and corresponding volumes. This technology presents a cost-effective and convenient alternative to traditional volume measurement methods. This case study highlights the significant potential of Pendotech's sensor system to enhance process monitoring and control in biopharmaceutical manufacturing environments, especially those utilizing single-use systems.

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