Are Your Glass Volumetric Instruments Accurate?

Dr Christian Schurz, BRAND GMBH + CO KG, Christian.Schurz@brand.de

Analyses of chemical and pharmaceutical products are only reliable if measuring equipment is accurate. Glass volumetric instruments represent an important part of measuring equipment in nearly every laboratory. Therefore these instruments (bulb and graduated pipettes, volumetric flasks, graduated cylinders, and burets) have to be considered for regular monitoring.

Highest volume accuracy, dimensional stability, and excellent chemical resistance against nearly all common substances are the main reasons why laboratories often use volumetric instruments made of glass. Only hydrofluoric acid (HF) attacks glass significantly because HF dissolves SiO2. Concentrated phosphoric acid and high concentrated alkaline solutions do attack glass significantly but only at elevated temperatures above 70°C. Although glass is virtually resistant to all other common chemicals, e.g. organic solvents, water and acids, glass will be slightly degraded with a very small depth of erosion over a relatively long time *(Figure 1)*. Subject to this effect, glass volumetric instruments have to be monitored regularly in order to get reliable results.

Evaluating Glass Erosion

The use and, especially, cleaning of the volumetric instruments lead to increasing volumes after a certain time. Usually, volumetric instruments are cleaned in dish washing machines along with alkaline detergents including complex agents. The depth of erosion depends on temperature, duration and detergent (pH value). The concentration of the detergent and the temperature has a high influence on erosion: Higher concentration causes higher depth of erosion *(Figure 1, left)*. If temperature is increased from 70°C to 100°C tenfold higher depth of erosion can be observed *(Figure 1, right)*. Other aggressive cleaning methods like ultra sonic baths increase the glass erosion, but cannot be avoided in some cases.

In general, due to wear and tear of the inner surface, the measured volume exceeds admissible limits after repeated cycles of use/cleaning. Furthermore, the legibility of graduation(s) may diminish because the outer surface suffers from alkaline detergents too. It is also possible that the volume might exceed admissible limits although graduation marks may still be legible and meniscus may be set easily. This degradation or erosion of glass volumetric instruments takes more or less from 2 to 5 years, but depends strongly on application and cleaning methods and may take shorter or longer in some cases.

Relevant Standards

Laboratories working in accordance to Good-Laboratory-Practice(GLP)- and Good-Manufacturing-Practice(GMP)-Standards, laboratories accredited in accordance with DIN EN ISO/IEC 17025, or laboratories certified in accordance with DIN EN ISO 9001 are obliged to monitor their measuring equipment regularly. In general, every laboratory is advised to monitor its equipment in order to get reliable results for analyses.

With reference to DIN EN ISO 4787, calibration (monitoring) of volumetric instruments with nominal volumes between 0.1 and 10,000 ml should be carried out gravimetrically. For calibration use of distilled water of quality class 3 (DIN ISO 3696), determination of humidity (between 35 – 85%) via hygrometer with a tolerance of maximum 5%, and measuring air pressure with barometer with a tolerance of maximum 1 kPa to consider buoyancy is recommended. Other requirements described in DIN EN ISO 4787 are summarised in *Table 1*.

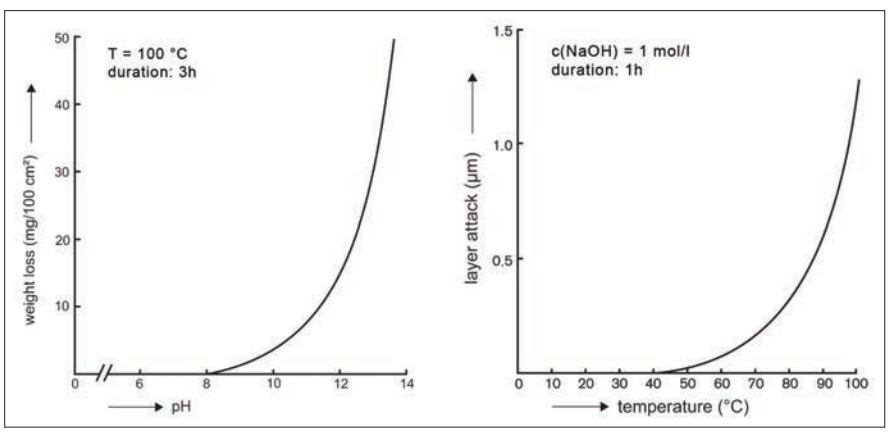

Figure 1. Typical curve of alkali attack on borosilicate glass 3.3 dependent on temperature (left) and pH value (right).

Table 1. Some requirements for calibration procedure described in DIN EN ISO 4787.

Volume [ml]	Recommended balance			Maximum error limit for thermometer to measure calibration liquid [°C]
	Resolution [mg]	Repeatability [mg]	Linearity [mg]	
0.1 < V ≤ 10	0.1	0.2	0.2	0.2
10 < V < 1000	1	1	2	0.2
1,000 ≤ V ≤ 2,000	10	10	20	0.1
V > 2,000	100	100	200	0.1

Procedure

Monitoring including documentation proceeds within four steps *(Figure 2)*:

Initially the instruments have to be identified and visually inspected to discard damaged equipment. Typical damage for volumetric instruments include deep scratches, broken tips, and faded, illegible graduations.

After cleaning, the instruments volume shall be measured one time for volumetric instruments calibrated to contain (TC; In) and three times for volumetric instruments calibrated to deliver (TD; Ex).

For (TC; In) volumetric instruments, weigh empty instrument (I_E) before filling with calibration liquid slightly above the graduation mark. Then the meniscus must be set correctly and the instrument weighed again (I_L).

For (TD; Ex) volumetric instruments, they should be filled slightly above the graduation mark then set the meniscus to the required mark (read at eye level). Afterwards the calibration liquid has to be delivered in a glass vessel to weigh the delivered liquid (I_L–I_E). The waiting times for pipets (5 seconds) and burets (30 seconds) have to be taken into account, because liquid flows down the walls during the waiting time. Without considering this continuous flow, the measured volume will be likely too low.

The simplified equation $V_{20} = (I_L – I_E) \times Z$ along with common correction factors (Z) listed in the standard DIN EN ISO 4787 is sufficient for evaluation. Other Z factors can be calculated with the following equation:

$$Z = \left(\frac{1}{\rho_W - \rho_A}\right)\left(1 - \frac{\rho_A}{\rho_B}\right)[1 - \gamma(t - 20\,°C)]$$

ρ_B … density of the balance weight used for calibration of balance,

ρ_A … density of air (dependent on air pressure, temperature and humidity),

ρ_W … density of water (dependent on temperature),

γ … coefficient of cubical thermal expansion of the material,

t … temperature of the calibration liquid used in testing (distilled water).

An entry into a database or a protocol documents the calibration result including evaluation and conditions of the measurement. The decision if the calibrated volumetric instrument is sufficient for another period of time has to be made by comparing measured volume with wear limits, which must be defined by each testing lab.

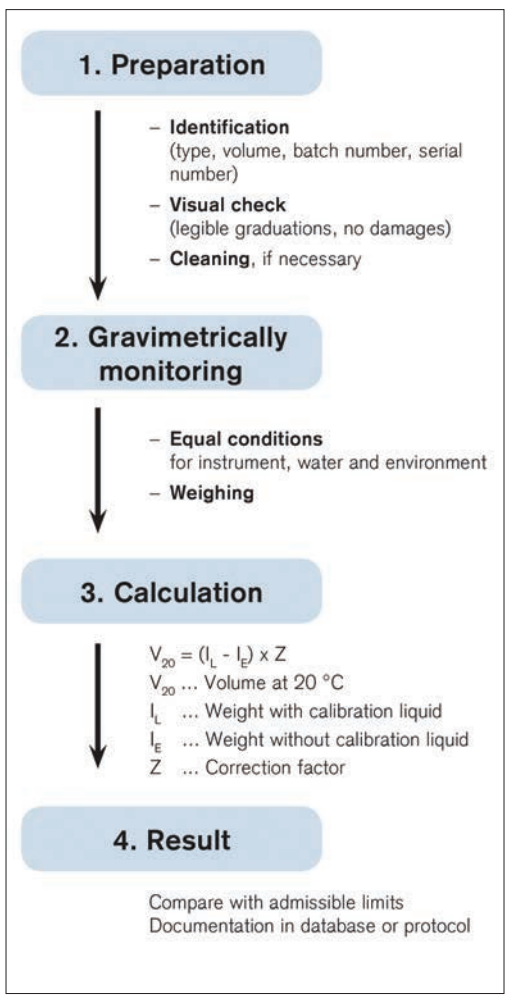

Figure 2. Procedure of monitoring volumetric instruments.

Starting Values and Limits

The values provided by a certificate from the manufacturer can be used as starting values. It is important to note that the certificate of individual certified instruments whether in accordance to ISO (International Organization for Standardization) or USP (United States Pharmacopeia) displays the values only for each specific volumetric instrument. Therefore these instruments have to be monitored separately. Volumetric instruments delivered with a batch certificate allow monitoring of random samples of the corresponding batch if all volumetric instruments of this batch are used in the same way.

Companies and laboratories must define their processes for products to analyse and, thus, also define admissible limits for volumetric instruments. *Figure 3* shows an example with a wear limit that is one and a half times the error limit of the volumetric instrument. If a volumetric instrument exceeds the wear limit, statements made since the last monitoring have to be considered as not reliable. Occasionally that leads to time-consuming and cost-intensive actions if appropriate. Therefore, it is worthwhile to monitor volumetric instruments within defined periods of time.

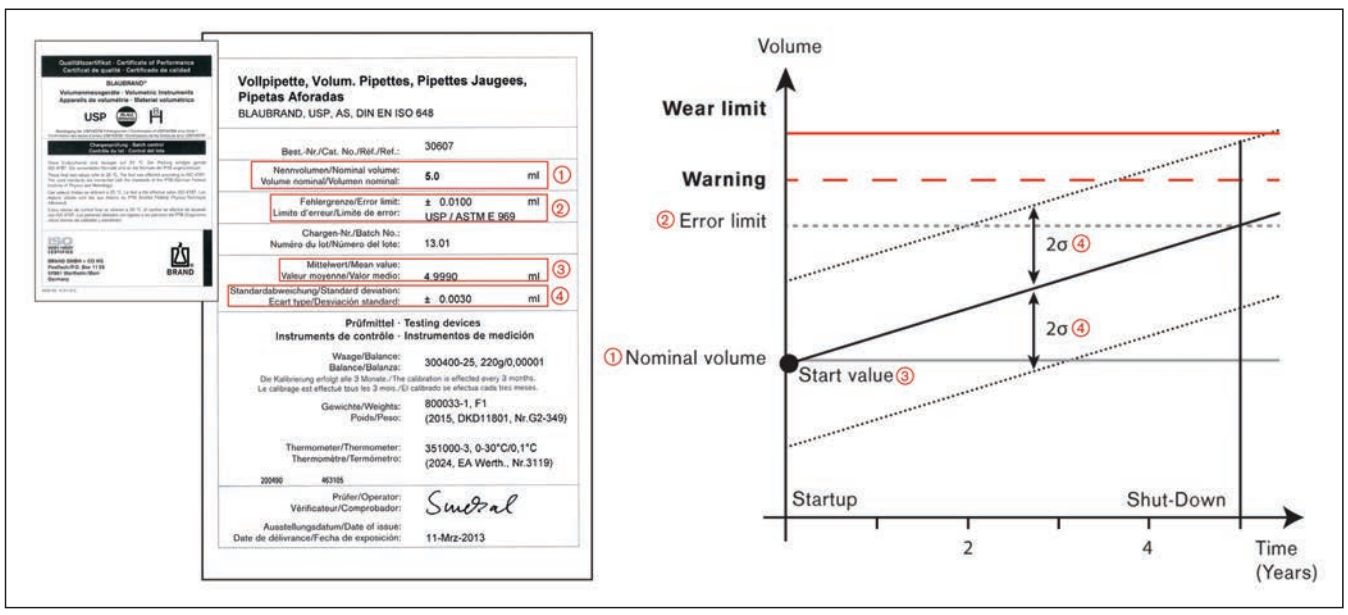

Figure 3. Batch certificate with highlighted values (left) as example for using a 5-ml-USP-bulb pipette within 2 to 5 years under consideration of the twofold standard deviation of manufacturing process, the wear limit (one-and-a-half time of error limit), and warning limit at 80% of wear limit (right).

Adjusting intervals

New installed processes or methods require close monitoring. Time slots for monitoring may be extended, while gaining experience and knowledge about the new process. In accordance to DIN EN ISO 4787, glass volumetric instruments should be monitored every 1 to 3 years. For volumetric instruments made of plastics and liquid-handling devices, a time period of 3 to 12 months is recommended.

Specifying a warning limit, e.g. at 80% of wear limit (0.08 ml in comparison to 0.1 ml), might help to decide if a volumetric instrument is sufficient for another period of use. Exceeding this limit (not wear limit) issues a warning, so that the volumetric instrument should be replaced without further use. Exceeding the warning limit (not wear limit) also means that all results obtained during the use of the volumetric instrument are reliable. Therefore wear and warning limits support a highly effective and cost-efficient monitoring.

Article First Published In International Labmate - October/November 2014