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Flow Cartridge Storage Life

Introduction

The ADM Flowmeter flow cartridge (G6692A) contains all the flow measurement components that are subject to periodic calibration. This unique feature allows the flowmeter to be recalibrated remotely by replacing this low-cost component. Testing has shown that the flow cartridge will hold its calibration, within the published tolerances, for a period greater than one year under heavy use. However, the time between manufacturing date and the date that the cartridge is first used cannot be predicted. This document demonstrates that the flow cartridge can hold a valid calibration for a period greater than three years when stored under the expected conditions.

The flow cartridge is electromechanical in design. Increasing the temperature increases the stress on the electrical and mechanical components, leading to premature failure compared to normal temperature conditions. We tested the performance of the flow cartridge stored for a prolonged period at a temperature higher than normal. The resulting data were used to calculate the minimum expected storage lifetime for the flow cartridge when stored within the expected storage temperature of less than 30 °C.

Test plan

Three new, calibrated flow cartridges were stored in a temperature chamber heated to 40 °C. Periodically, the flow cartridges were removed and cooled to room temperature. Then, they were tested on a production flow calibration system to measure their accuracy expressed as a percentage of the flow rate from the flow source. After testing, these flow cartridges were returned to the temperature chamber.

Data

Accuracy data were collected on nine different occasions over a period of 43 weeks. Figure 1 summarizes these data for flow rates less than 10 mL/min, and Figure 2 summarizes flow rates equal to and lower than 500 mL/min but greater than 10 mL/min, and Figure 3 summarizes flow rates above 500 mL/min. Accuracy specifications were as follws:

Low range: 0–10 mL/min: ±0.2 mL/min

Mid range: 10–500 mL/min: ±2 %

High range: 500–750 mL/min: ±3 %

Accuracy data were collected at each of the nine calibration points. The percent deviation was calculated using Equation 1. The deviation spread is reported for each cartridge.

$$\% \text{ Deviation} = \frac{\text{Flow rate}_{\text{Measured}}}{\text{Flow rate}_{\text{Standard}}} \times 100$$

Equation 1.

Accelerated life test calculation

We used the Arrhenius life-stress model to calculate the expected shelf storage life of the flow cartridge. Equation 2, which provides the expected lifetime of a device as a function of temperature, presents the Arrhenius model:

$$L(T) = Ce^{\frac{E_a}{kT}}$$

Equation 2.

Where:

L(T) is the life at a temperature of T (hours)

C is a scaling constant (hours)

E_a is the activation energy (eV)

k is Boltzmann's constant (8.617×10^{-5} eV/K)

T is the temperature (K)

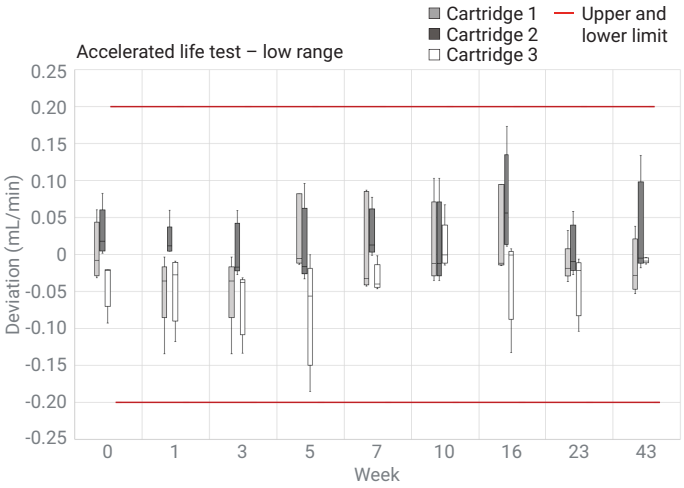

Figure 1. Cartridge accuracy over time for low flow rates.

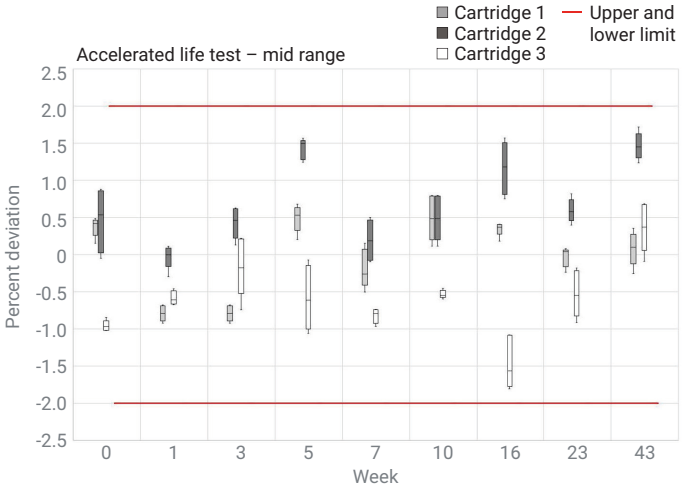

Figure 2. Cartridge accuracy over time for mid flow rates.

Figure 3. Cartridge accuracy over time for high flow rates.

Equation 3 shows that two Arrhenius models expressing lifetime at two different temperatures: storage (T_S), and accelerated (T_A), can be expressed as a ratio to calculate the acceleration factor (AF). The acceleration factor is useful here as it predicts the expected lifetime of the flow cartridge at the estimated storage temperature (T_S = 30 °C) based on the proven lifetime at the accelerated storage temperature (T_A = 40 °C).

$$AF = \frac{L(T_S)}{L(T_A)} = e^{\frac{E_a}{k}\left(\frac{1}{T_S} - \frac{1}{T_A}\right)}$$

Equation 3.

The cartridge was stored at 40 °C for 10 months, and has been shown to maintain its calibration within the factory specifications. Using the Arrhenius model ratio to calculate the acceleration factor assuming the stress/accelerated temperature is 40 °C and the use/storage temperature is 30 °C, we calculate an acceleration factor of 3.7. Applying this factor, at the use temperature, we estimate that the lifetime of the flow cartridge is at least 36.9 months, or greater than three years.

Cartridge lifetime

Based on an accelerated life test, the flow cartridge has maintained a valid calibration when stored at 30 °C for at least three years. For practical purposes, the flowmeter firmware will enforce a limit on the service age of the flow cartridge. Figure 4 shows three use scenarios starting with the date that cartridge is manufactured.

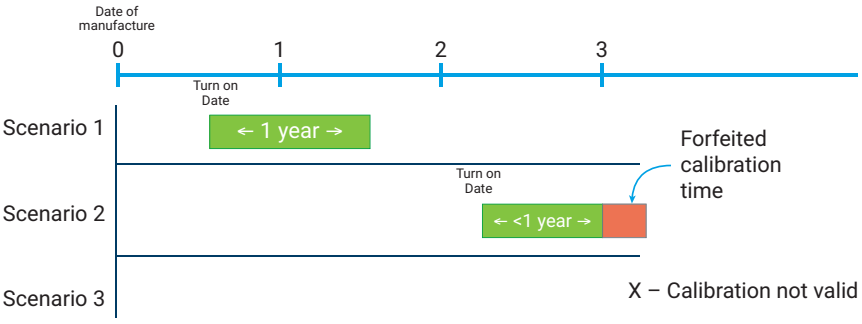

Figure 4. Cartridge lifetime scenarios.

- **Scenario 1:** The flow cartridge is turned on for the first time within two years of the manufacturing date. The cartridge's calibration is valid for one year of use and reported expired after this one-year period. This is the most common scenario.
- **Scenario 2:** The flow cartridge is turned on for the first time between two and three years after the date of manufacturing. Since the storage life of the flow cartridge cannot be guaranteed beyond a period of three years, the valid calibration ends three years after the manufacturing date, regardless of the time remaining after the turn on date.
- **Scenario 3:** The flow cartridge is turned on three years or more after the manufacturing date. This cartridge will not have a valid calibration.

Note that the flowmeter will still function and report flow readings outside the valid calibration period. A warning will be shown on the screen at start up, but the meter will function normally, just without the accuracy guarantee of valid calibration.

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