Dead Volume Correction for the Calibration of CFVNs -- Differential Calibration and Optimum Estimation --

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In the calibration facilities of CFVNs (critical flow Venturi nozzles) such as a constant volume tank system and a weighing tank system, the error caused by the trapped gas in the dead volume between the CFVN and the diverter valve that shuts down the tank will be the last correction since it is difficult to be estimated and also it can be made negligible by letting the mass of the charged gas in the tank large enough. In order to correct the error, the masses of the trapped gas in the dead volume at the moments of the starting and the finishing times of the charging period are required; the former one should be removed from and the latter one should be added to the mass of the gas charged in the tank. When the diverter valve is moving, the gas ejected from a CFVN is getting trapped in the dead volume that raises both the pressure and temperature rapidly, which makes the situation very complicated. Furthermore, there is an essential ambiguity in how large the dead volume is. The paper introduces the "differential calibration" that estimates the dead volume correction without ambiguity by keeping the initial exhaust condition constant. It is then replaced by a fitting method on the basis derived by the differential calibration to reduce the number of the measuring points required for the estimation. The paper also proposes the "optimum estimation" that allows any exhausting condition. It bases the fact that the discharge coefficient of a CFVN depends on the inverse of the square root of the Reynolds number in the laminar boundary layer regime, and then the fitting procedure produces the discharge coefficient equation automatically. These methods agree with each other very well that allows the PVTt facility in NMIJ to calibrate CFVNs with a charging time down to 10 s at a good accuracy. These demonstrations were performed by using two independent high-speed diverter valves of the similar structure but with different sizes.