Physical Test Methods Sub-Group

Technical Report

Comparison of Ventilation Standard Calibration Methods

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1. PARTICIPATING LABORATORIES

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SODIM, Fleury-les-Aubrais, France

Zhengzhou Tobacco Research Institute Calibration Laboratory, Zhengzhou, China

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3. SUMMARY

The four laboratories undertaking to calibrate ventilation standards have small differences in calibration equipment and in methodology. Most of the differences are slight and are unlikely to have a significant influence on the overall laboratory to laboratory repeatability.

Noticeable differences are

- Small differences in sample preparation exist that could be standardised between laboratories simply
- ZTRI and SODIM use soap bubble volumeter to measure the ventilation flow. Air flowing through the ventilation path may be saturated in ZTRI and SODIM methods. The significance upon accuracy of measurement of this is unknown.
- Cerulean uses dry mass flow measurement device to measure the ventilation flow with compensation of the pressure drop this introduces. This adds complexity but the degree of improved accuracy of this method is not known.
- Borgwaldt-KC use dry mass flow measurement but do not compensate for pressure drop so introduced. The influence upon accuracy with respect to the overall method is not known.
- An alternative method is under evaluation by Borgwaldt-KC.

The methods and equipment are probably similar enough that a cross check would provide valuable information of the relative merits of the different methods and establish a baseline for improving the consistency of preparing and recalibrating ventilation transfer standards for the industry as a whole.

4. INTRODUCTION

Ventilation standards are produced by three suppliers of ventilation measurement equipment and the suppliers calibrate these standards as part of their manufacturing process and offer a recalibration service for these standards to the industry. In addition, the Calibration Laboratory of China Tobacco Standardisation Research Centre, ZTRI recalibrate existing standards as a service to the industry.

It is clear that to allow comparisons between instrumentation and laboratories close agreement in calibration is needed between transfer standards. For PD standards this has been established through a collaborative study and is maintained through regular cross checks between the calibrating laboratories. This currently does not occur for ventilation standards.

The PTM Sub-Group of CORESTA is considering the adopting a regular collaborative study to establish and maintain commonality in ventilation standard calibration. As a first step the PTM group required that a comparison of existing methods of the four main laboratories conducting such calibrations be compared to establish if there was sufficient commonality in method that a collaborative study would be useful for the industry.

4.1 Definition of terms

Total Ventilation is defined as the sum of the tip and envelope ventilation – figure 1A. Total ventilation is expressed as a percentage i.e.

$$\text{Tot V\%} = (\text{V vent} / \text{V out}) * 100$$

Tip ventilation is defined as the air entering the cigarette through the perforated tipping as a proportion of the total flow through the cigarette – Figure 1B. Tip ventilation is expressed as a percentage i.e.

$$\text{TV\%} = (\text{V tip} / \text{V out}) * 100$$

Envelope ventilation is defined as the air entering the cigarette through the porous wrapper covering the tobacco rod as a proportion of the total flow through the cigarette – Figure 1C. Envelope ventilation is expressed as a percentage i.e.

$$\text{EV\%} = (\text{V env} / \text{V out}) * 100$$

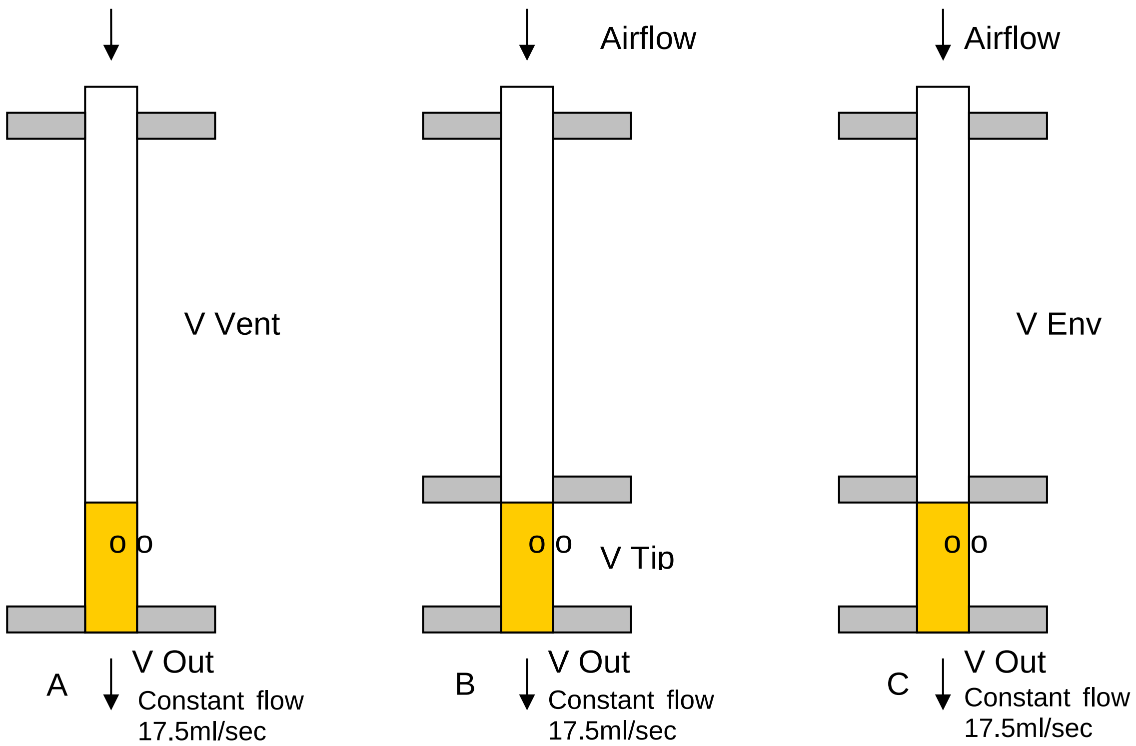


Figure1: Schematic of terms used to describe ventilation

5. EQUIPMENT AND METHODS

Detailed process specifications and equipment schematics were received from Cerulean, ZTRI, Borgwaldt-KC and SODIM. An additional alternative method under evaluation by Borgwaldt-KC was supplied and is detailed in appendix 1, the method currently being used for calibration being the basis for this comparison report.

6. STANDARDS

A schematic of a multicapillary glass standard is shown in figure 2[1]. Each manufacturer produces standards that are essentially the same and should be compatible with all the test equipment being considered. There is some difference in the position of the ventilation holes in standards produced by different suppliers ranging from 11mm from the end to 15mm from the end.

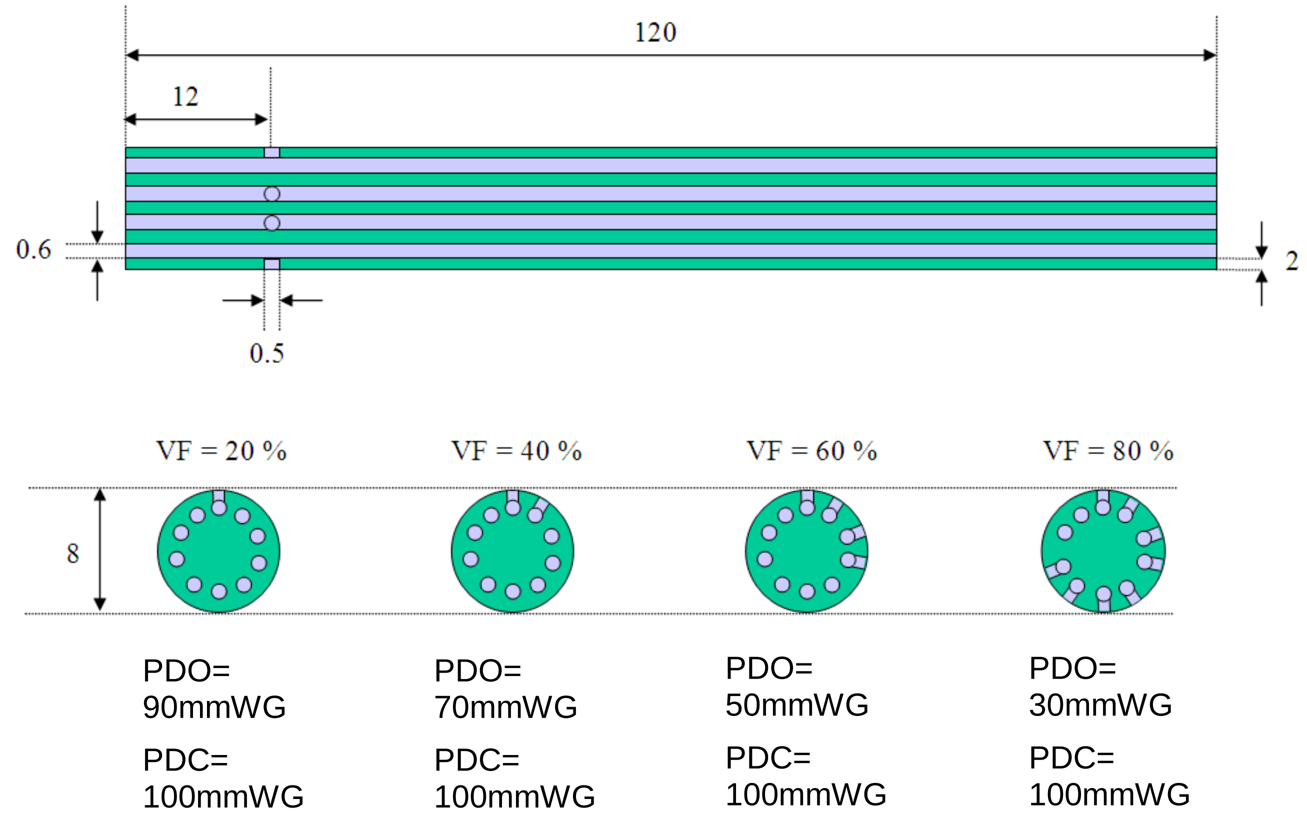


Figure 2: Schematic of typical ventilation standard

[1] Diagram supplied by SODIM

7. COMPARISON OF PROCESSES

Each method specified conditions under which measurements should be taken including conditioning time within the atmosphere for the standards and stabilisation periods for flow before measurement. A comparison is shown in table 1.

It can be seen that conditioning parameters are in each case the same, and detailed corrections are made for actual temperature of the atmosphere and pressure. The conditioning periods vary but could be easily harmonised with little practical inconvenience, for example Cerulean store un-calibrated standards for extended periods in the calibration atmosphere so in practice the conditioning period long exceeds the longest stated period from SODIM.

The time for flow to equilibrate through the standards varies and this may be a consequence of the differing equipment and methods used. This would be dependant upon experience and the nature of the equipment used.

	Conditioning temp	Conditioning Humidity	Conditioning time	Flow equilibrium through standard
CERULEAN	22°C±1°C	60% RH ±2%	1 hour	2 min
SODIM	22°C±2°C	60% RH ±5%	24 hours	10 min
BORGWALDT	22°C±2°C	60% RH ±5%	12 hours	5 min
ZTRI	22°C±2°C	60% RH ±5%	6 hours	None stated
Comment	Cerulean, ZTRI correct Brooks volumeter for actual temp and ambient pressure. SODIM and Borgwaldt-KC correct for atmospheric pressure		Harmonisation could be achieved with little practical inconvenience	

Table 1: comparison of conditioning and stabilisation parameters for methods supplied.

The processes differ between Cerulean, Borgwaldt-KC, ZTRI and SODIM. The four flow charts attached show the processes in schematic form (figures 3, 4, 5, 6). The boxes have been colour coded to show equivalence between the three processes. White shows all process have equivalent steps; Dark blue Cerulean specific, Pale blue Cerulean and SODIM equivalence; pink ZTRI specific; dark orange common to SODIM, Cerulean and Borgwaldt-KC; dark green common to Borgwaldt-KC and SODIM; and purple common to Cerulean and ZTRI.

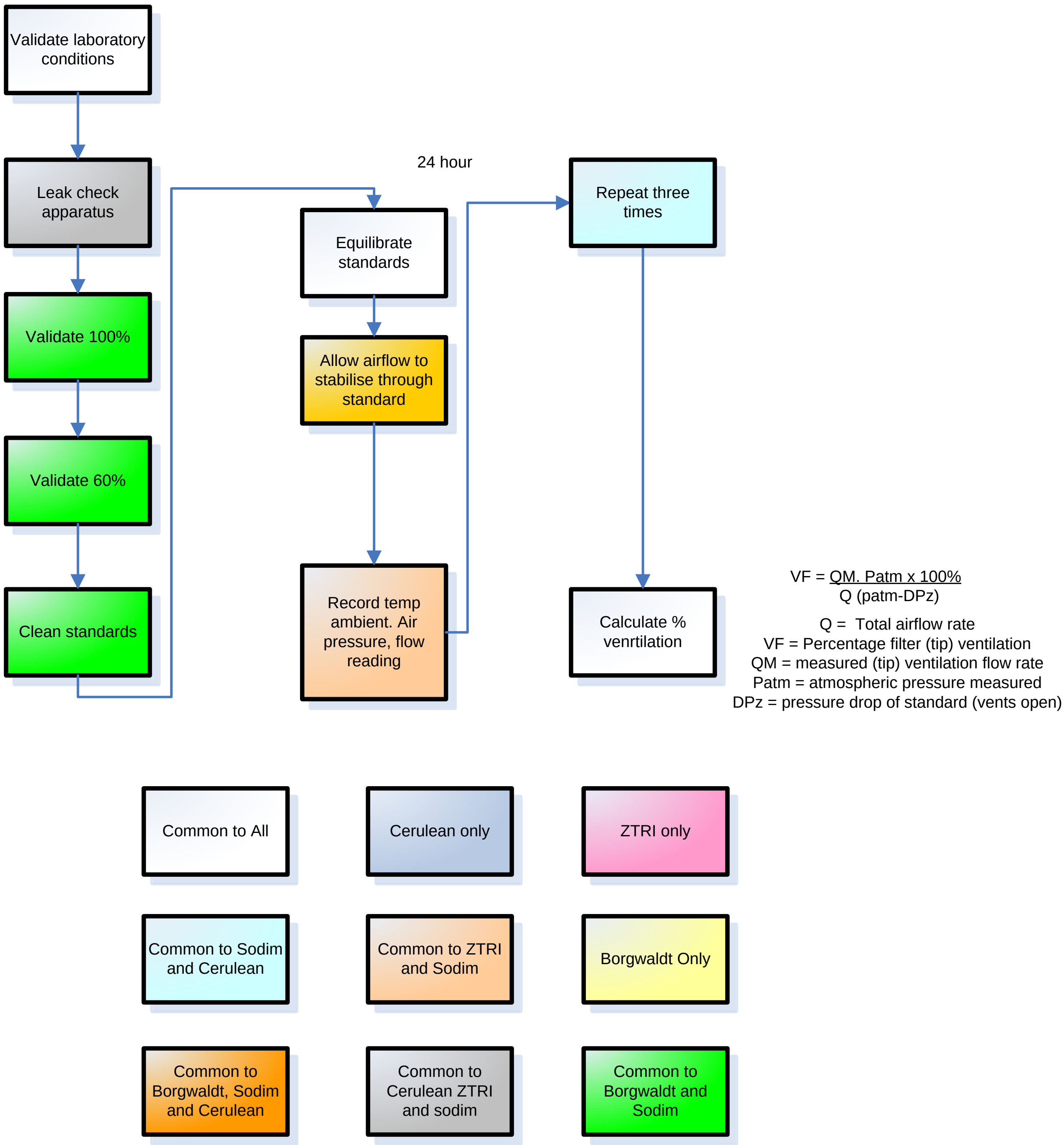
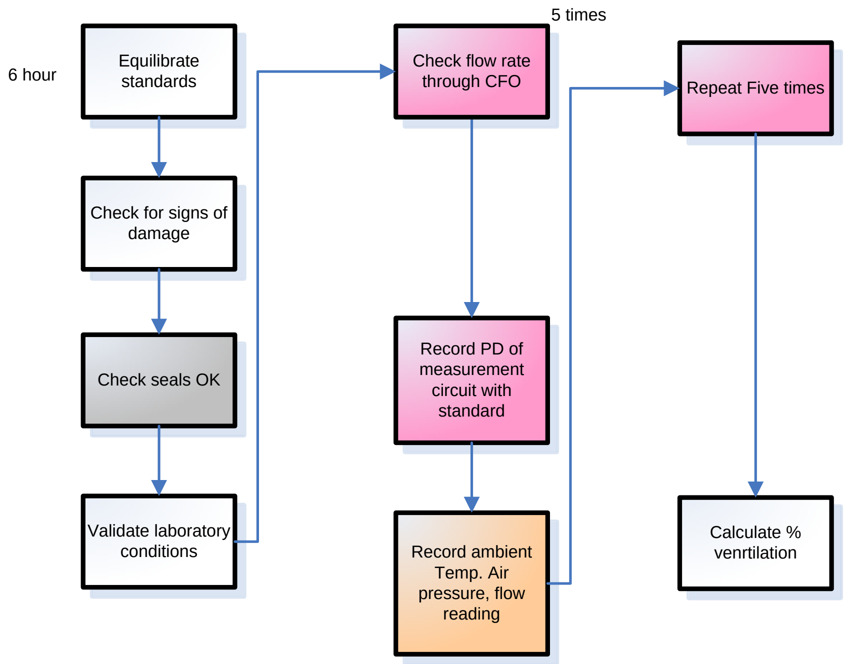


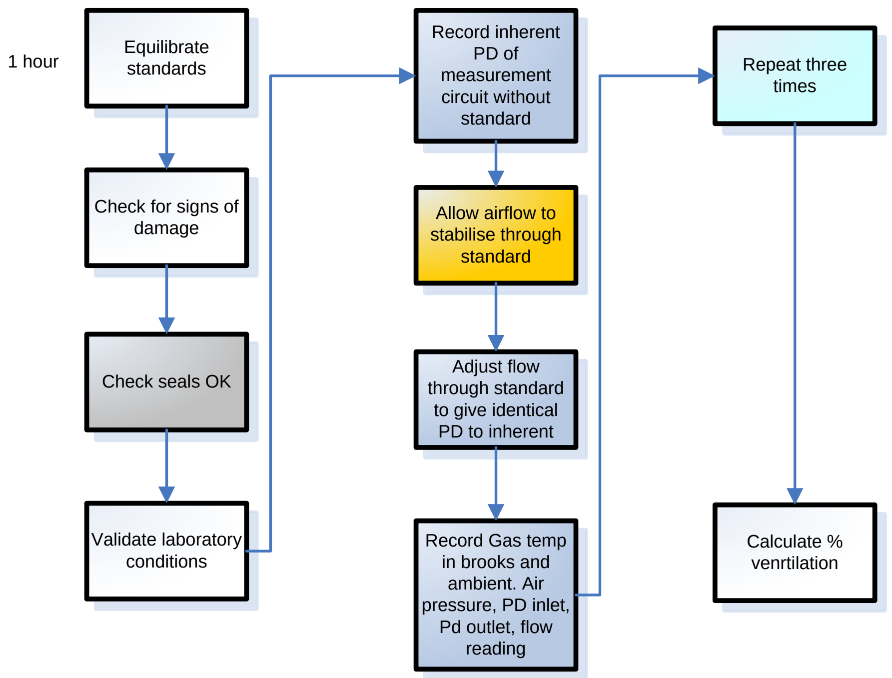
Figure 3: SODIM process schematic



$$VF = \frac{100\% \times QM.Patm(T+273.15)}{Q\ (Patm-Dpz)(22+273.15)}$$

QM= Measured filter tip ventilation flow rate
Q = Total airflow rate (CFO)
VF = Percentage filter (tip) ventilation
Patm = atmospheric pressure measured
DPz = pressure drop of standard (vents open)
T= Atmos temperature

Figure 4: ZTRI process



$$VF = \frac{QM.\ Patm \times 100\%}{Q\ (patm-DPz)}$$

Q = Total airflow rate
VF = Percentage filter (tip) ventilation
QM = measured (tip) ventilation flow rate
Patm = atmospheric pressure measured
DPz = pressure drop of standard (vents open)

Figure 5: Cerulean process

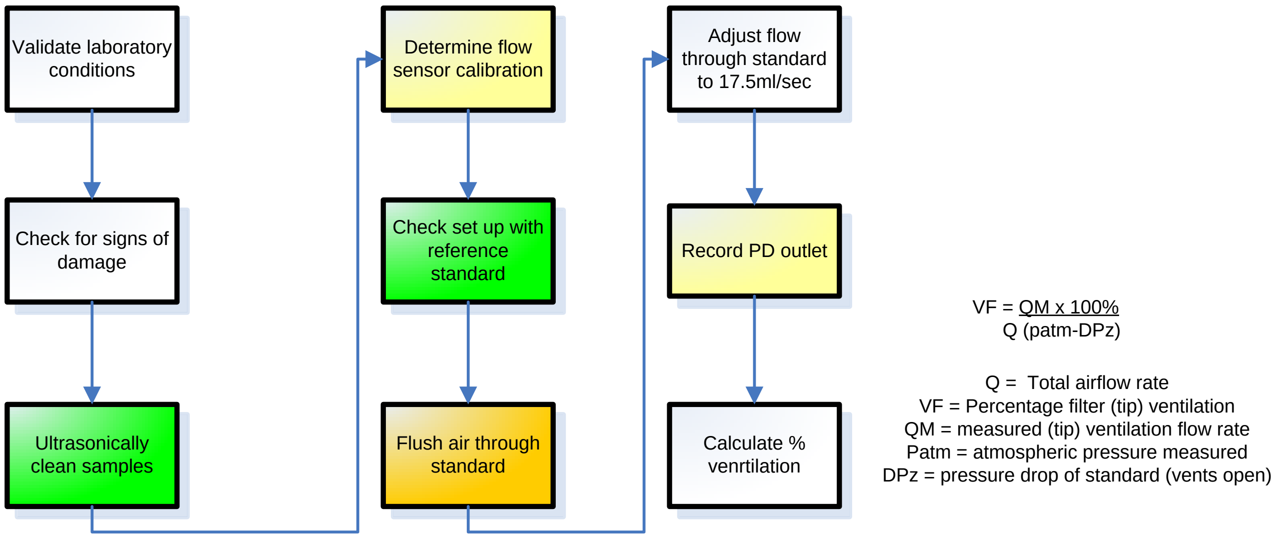


Figure 6: Borgwaldt-KC process

The SODIM process has a series of steps used to establish that the equipment is operating within process control limits. Within the Cerulean laboratory this is conducted on a regular but less frequent basis as part of SPC of calibration and is not part of the accredited process. It is assumed that other laboratories make regular proficiency checks as part of their own accreditation/SPC controls but do not document these steps as a part of the calibration process.

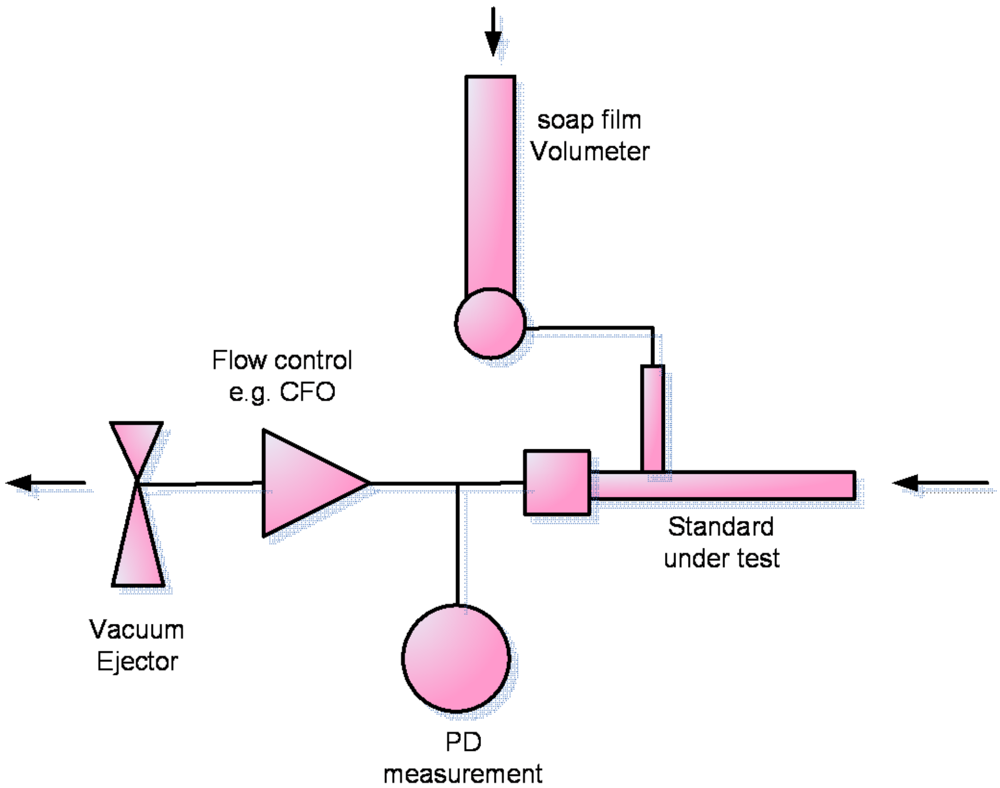


Figure 7: Schematic of equipment used by SODIM and ZTRI.

In the case of ZTRI, flow from the standard to the vacuum ejector is established by use of a CFO (constant flow orifice). In the case of the SODIM instrumentation a Brooks Volumeter and a flow controller is used.

In each case air flow is stabilised through the standard before measurements are taken and a number of repeats are made. The calculation of percentage ventilation is corrected in each case for ambient temperature and pressure and use essentially the same method of calculation - below.

$$VF = \frac{QM.\ Patm \times 100\%}{Q\ (patm-DPz)}$$ [2]

Where:

- Q = Total airflow rate
- VF = Percentage filter (tip) ventilation
- QM = measured (tip) ventilation flow rate
- Patm = atmospheric pressure measured
- DPz = pressure drop of standard (vents open)

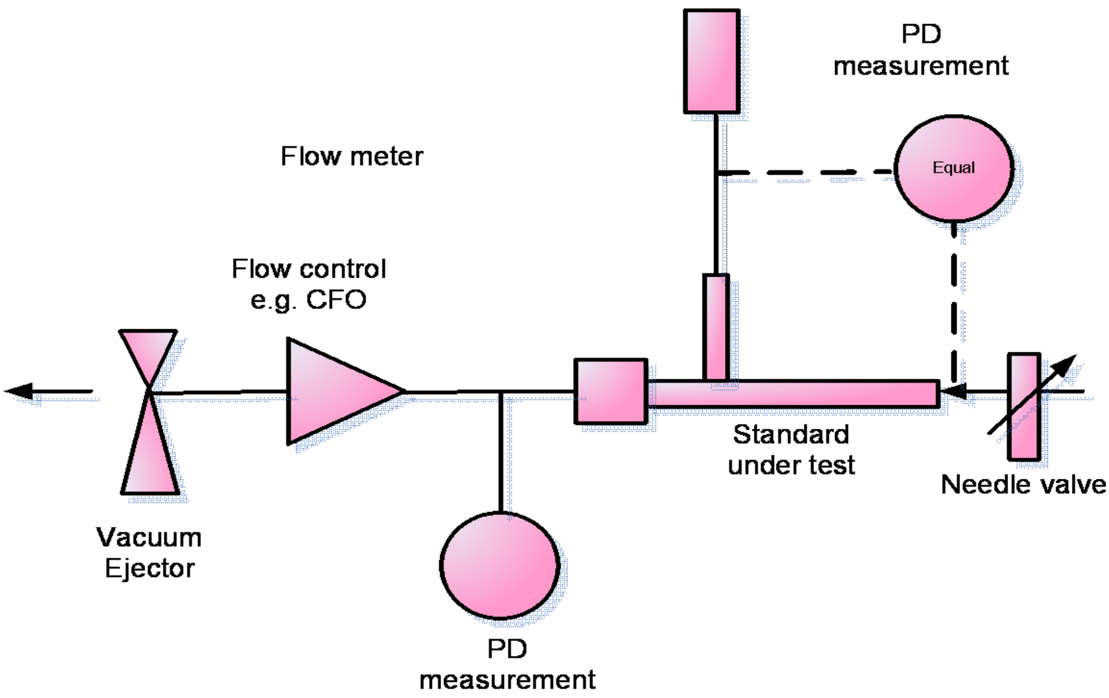


Figure 8: Cerulean equipment schematic

[2] The ZTRI calculation includes a term for temperature compensation, but in a controlled laboratory as specified in the process documents this term tends to 1.

$$VF = \frac{100\% \times QM.Patm(T+273.15)}{Q\ (Patm-Dpz)(22+273.15)}$$

The differences in the process flows are explained by the differing equipment used. SODIM and ZTRI use a Volumeter (soap film meter) to establish flow through the ventilation standard (figure 7). Here ZTRI use a calibrated constant flow orifice and vacuum generator to establish flow through the main body of the standard, measuring the pressure drop of the standard, whilst SODIM use a vacuum injector and Brooks flow meter and needle valve to control flow also measuring pressure drop in the circuit.

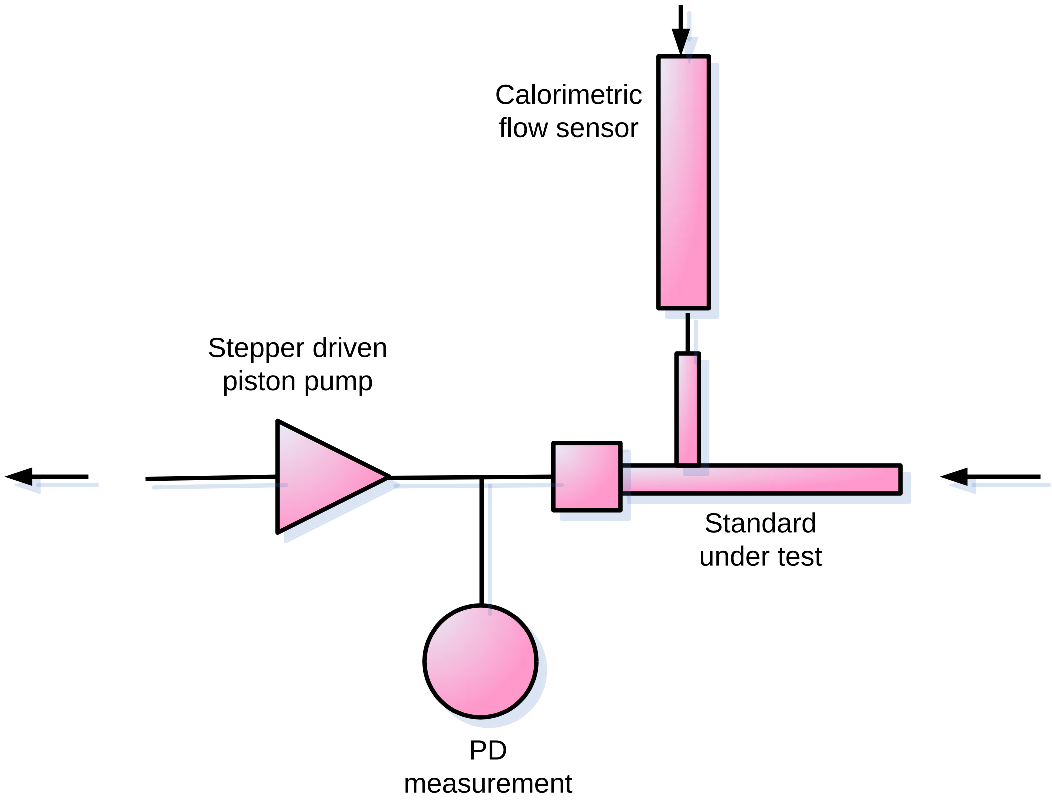


Figure 9: Schematic of Borgwaldt-KC apparatus

In contrast Cerulean and Borgwaldt-KC use calorimetric flow sensors with Cerulean compensating for the additional PD introduced by this device through using a leak valve and second PD measurement device (figures 8 and 9). The use of a “dry” device such as the flow sensor specified by Borgwaldt-KC and Cerulean means that the humidity of the air flowing through the ventilation path of the standard is known and controlled being that of the test room, the soap bubble film meter will saturate the air above the soap film reservoir. This could influence the apparent flow as the viscosity of the air flowing through the standard will be slightly changed. The disadvantage of the “dry” methods is that an additional PD is introduced from the meter. Cerulean have tried to take this into account by balancing the inlet PD to the primary and ventilation flow paths. The significance of the errors introduced by the additional but small pressure drop from the “dry” method or the error introduced by “wet” air is not understood within the context of the overall uncertainty of the method and can only probably be established by experiment.

8. ANALYSIS AND DISCUSSION

To a first approximation the methods appear equivalent and would form a platform from which a collaborative study could be made to establish the reproducibility of the calibration methods used and also the errors introduced by the slight differences in calibration equipment with respect to the overall method precision/repeatability. In summary

- Some small differences in sample preparation exist
- There are some small differences in equipment validation of function before test commences
- ZTRI and SODIM use soap bubble volumeter. Air flowing through standard may be saturated in ZTRI and SODIM methods. The significance upon accuracy of measurement of this is unknown.
- Cerulean uses dry mass flow measurement device with compensation of the pressure drop this introduces. This adds complexity but the degree of improved accuracy of this method is not known.
- Borgwaldt-KC use dry mass flow measurement but do not compensate for pressure drop so introduced. The influence upon accuracy with respect to the overall method is not known.

It would be simple for the laboratories calibrating standards to agree to standardise on conditioning times and stabilisation times which could introduce some variation in laboratory to laboratory results.

APPENDIX 1 – BORGWALDT-KC ALTERNATE METHOD

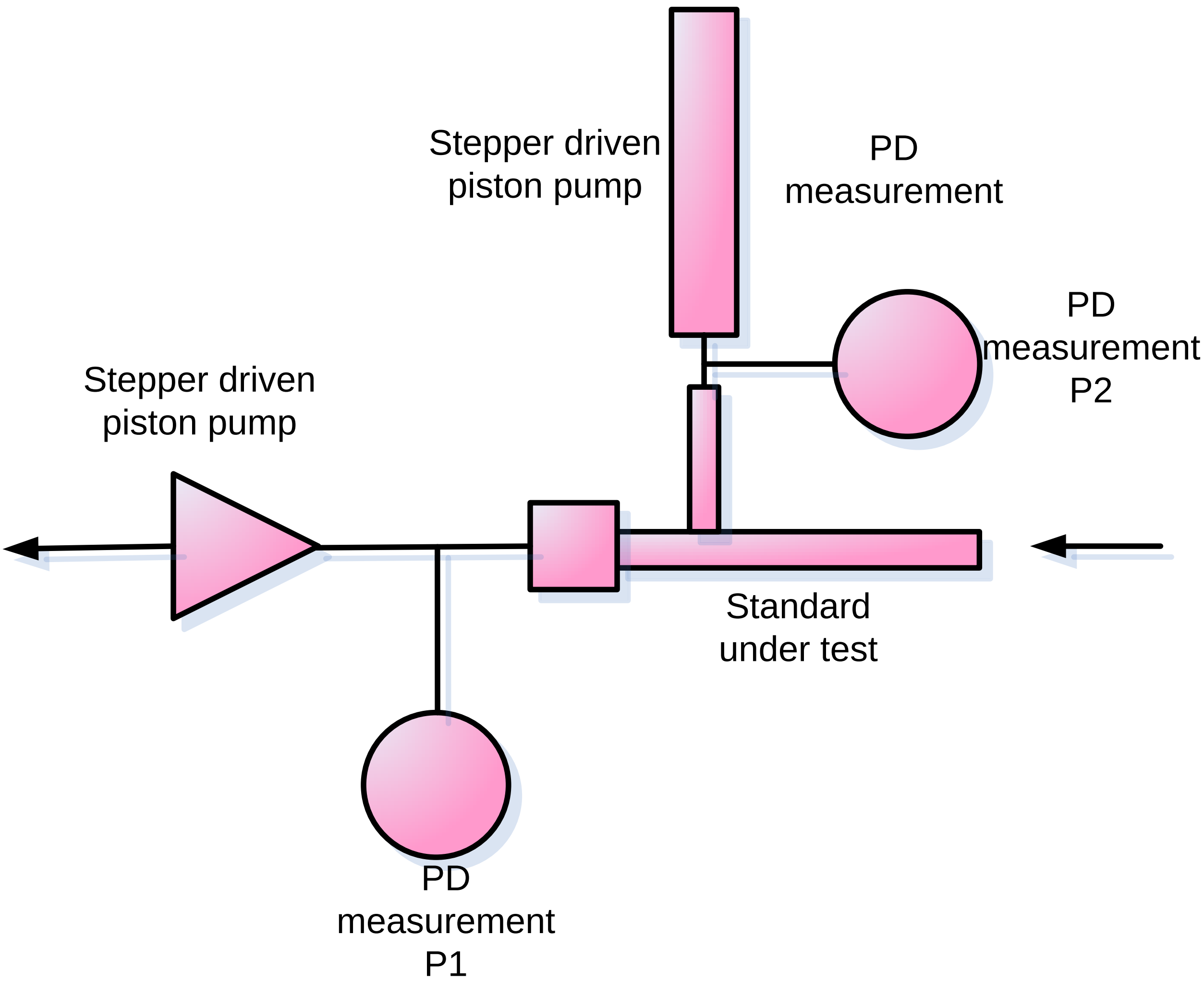


Figure 10: Schematic of Borgwaldt-KC alternate apparatus

In this scheme the measurement is conducted by setting the draw through the standard by means of the stepper driven piston pump to 17.5ml/min. The second stepper driven piston pump is connected to the ventilation path and adjusted so that P2 is 0Pa. BY characterising the control frequency/syringe dimensions the ventilation flow can be calculated. Taking P1 into account the ventilation can be determined.