eppendorf

Standard Operating Procedure

Standard operating procedure for manual dispensing systems

ASOP P39 020-10/042016

Table of contents

1 Operating instructions
1.1 Glossary

A

Accuracy
Accuracy between the actual value and the set value.

Additional volume
The total of the remaining stroke and the reverse stroke.

Adjustment
Mechanical modification of the piston stroke so that the error of measurement from the set value is low and corresponds to device specifications.

Air cushion principle
Design feature of piston-stroke pipettes. An air cushion separates the liquid in the plastic tip from the piston on the inside of the pipette. The air cushion is moved by the piston and acts as an elastic spring.

Autoclaving
Thermal procedure to kill microorganisms and inactivate viruses and enzymes. DNA is not completely destroyed. The objects to be autoclaved are stored in water vapor in a pressure vessel at 121 °C, 1000 hPa (1 bar) positive pressure for 20 min.

B

Blow out
The piston moves to the lowest position in order to blow out the residual liquid from the pipette tip. During pipetting operations, the liquid from the blow-out is part of the dispensing volume. During reverse pipetting operations, the liquid is **not** part of the dispensing volume.

Bottle-top buret
Piston burets are used for dispensing liquids until external criteria (such as, pH, conductivity) have been met. Dispenser for dispensing large amounts of fluids. The maximum dispensing volume corresponds to the volume of the bottle. The Top Buret M and the Top Buret H belong to this group.

Bottle-top dispenser
Dispenser that can dispense liquid once per liquid aspiration. The Varispenser and the Varispenser plus belong to this group.

C

Calibration
Measurement process for reliable and reproducible determination and documentation of a dispenser's error of measurement.

Combitip advanced
Dispensing tip for all Eppendorf Multipettes and Repeaters.Combitips advanced are consumables intended for single use. Combitips advanced consist of a piston and a cylinder and function according to the positive displacement principle.

Cycle
Together, the upward piston movement (liquid aspiration) and downward piston movement (liquid dispensing) form a cycle.

D

Dispenser
A dispenser is a dispensing device which functions according to the positive displacement principle. There are multi-dispensers and single stroke dispensers.

Dispensing step
Liquid dispensing of the set selected volume with positive-displacement devices and electronic pipettes.

Dispensing system
The dispenser and the corresponding dispensing tip form the dispensing system.

Dispensing volume
Volume per dispensing step.

E

epT.I.P.S.
Trade name of Eppendorf AG for pipette tips without filter.

F

Fixed-volume pipette
The volume that can be dispensed is fixed and cannot be adjusted.

Free jet dispensing
Dispensing of liquid without the dispensing tip (pipette tip, dispenser tip) touching the tube inner wall.

G

Gravimetric volume check
Mass determination of a dispensed volume under storage conditions. The weight of the liquid and the density value at the measurement temperature are used to calculate the dispensed volume.

I

Increment
Step size or resolution. The smallest possible change by which a value can be increased.

ISO 8655
The standard defines limit values for the systematic error, the random error and the test methods for dispensers.

L

Leak tightness
Impermeability to air or liquid. Dispensers must ensure that the area between the liquid and the piston is leak tight.

M

Maximum permissible errors
Specifications for the highest or lowest permissible deviation of the dispensed volume from the nominal volume or the useful volume range. For the maximum permissible errors the systematic and the random errors are specified. The maximum permissible errors are specified in accordance with ISO 8655 and in accordance with manufacturer limits of Eppendorf.

Maximum volume
The maximum volume that can be used for dispensing.

Multi-dispenser
Dispensers capable of multiple liquid dispensing per filling volume. The multi-dispensers include all Multipettes/Repeaters. Multi-dispensers are also called manual dispensers.

N

Nominal volume
The maximum dispensing volume of a dispensing system specified by the manufacturer.

P

Piston-stroke pipette
The piston in the pipette moves up or down depending on the task. The liquid is aspirated into a pipette tip.

Positive displacement principle
Design feature of piston-stroke dispensers. The liquid is in direct contact with the piston of the dispensing tip (Combitip) during aspiration and dispensing operations.

Precision
The scattering range of the measured values around the set value. A small scattering range represents a high level of precision. A large scattering range represents a low level of precision.

R

Rack
Mount for tubes or pipette tips.

Random error
Precision, standard deviation. A measure for the scattering of the measured values around the average value.

Remaining stroke
Liquid reserve. The liquid which remains after all dispensing steps have been completed.

Residual stroke lock
When the operating lever is operated, the residual stroke lock prevents the incorrect volume from being dispensed if the liquid required for the dispensing volume is no longer available.

Reverse stroke
After liquid aspiration, the piston is moved to a defined initial position. Liquid is dispensed during the piston movement. The reverse stroke is not a dispensing step.

S

Single stroke dispenser
Dispensers that function according to the positive displacement principle. Single stroke dispensers are also known as bottle-top dispensers. The total aspirated volume is dispensed during one dispensing step.

Stroke
The stroke is the distance traveled by the piston.

Systematic error
Inaccuracy. Deviation of the average value of the dispensed volumes from the selected volume.

V

Vapor pressure
This term refers to the pressure exerted by the vapor of a material (solid or liquid) in an enclosed container. The vapor is in equilibrium with the solid or liquid phase of the material. The vapor pressure increases when the temperature increases. Each pure liquid has a vapor pressure of 1013 hPa (mbar) at boiling point. Volume errors caused by high vapor pressure can be reduced by prewetting the tip.

Vessel
A micro test tube or a single well in a plate.

Viscosity
Viscosity describes the viscidity of liquids and suspensions. The dynamic or absolute viscosity is indicated in Pa·s or in mPa·s. In older literature, the unit P or cP is used (1 mPa·s corresponds to 1 cP). At ambient temperature, a 50 % glycerol solution has a viscosity of approx. 6 mPa·s. As the glycerol concentration increases, viscosity increases considerably. Absolutely anhydrous glycerol has a viscosity of approx. 1480 mPa s at ambient temperature.

W

Wall dispensing

Dispensing liquid against the tube wall. The pipette tip or the dispensing tip is held against the tube inner wall and the liquid is dispensed.

Z

Z factor

Also referred to as correction factor Z. The Z factor is used to convert a mass at a certain temperature and atmospheric pressure into a volume.

1.2 Preface

This "Standard operating procedure for manual dispensing systems (SOP)" is a complete review of the former "SOP - Standard operating procedure for pipettes" of Eppendorf AG.

The standard operating procedure summarizes the test location requirements, the necessary preparations, the execution of series of tests and the evaluation of the measuring results, which have to be performed when calibrating a manual dispenser (mechanical/electronic).

In the first step it is necessary to service the dispenser (e. g., cleaning). To keep the document easy to read, reference to the applicable operating manuals is made for product-specific information. The leakage test informs about whether the dispensing system is leak-tight or not. However, this does not provide information about the actual performance of the pipette and therefore does not replace a general check by means of calibration.

In the next step, the instrument is tested, i.e., the calibration is performed. This is based on the specifications of ISO 8655-6 regarding gravimetric testing. The next step is the evaluation of the measuring results and their assessment. Correspondingly, this SOP provides instructions regarding the calculation of the systematic and random error and the maximum permissible errors according to Eppendorf AG and ISO 8655.

For pipettes, another step may follow: If during a calibration it is determined that the pipette does not operate within the specified maximum permissible errors, the device can be adjusted. An adjustment may only be performed if errors due to handling, system or test equipment have been ruled out.

1.3 Version overview

Version number	Issue date	Change
10	2016-04	• Chapter structure and contents completely revised and updated • Gravimetric test of positive-displacement devices with 30 measured values added • Product-specific information regarding cleaning, service, autoclaving and adjustment deleted. Reference to applicable operating manual. • Calculation error corrected • Formulas adjusted • Flow charts on calibration process added • Multipette E3/E3x - Repeater E3/E3x added • Leakage test adapted for current pipettes • Glossary expanded • Title and title photo changed
09	2014-01	• Document number updated
08	2013-05	• Pipette Reference 2 added
07	2013-04	• Design change

1.4 Supported dispensers

The standard operating procedure can be used for the following dispensers.

1.4.1 Mechanical piston-stroke pipettes – Air cushion principle

- Reference
- Reference 2
- Research
- Research plus

1.4.2 Electronic piston-stroke pipettes – Air cushion principle

- Research pro
- Xplorer
- Xplorer plus

1.4.3 Mechanical piston-stroke pipettes – Hybrid system

- Varipette + Varitip S-System – Air cushion principle
- Maxipettor + Maxitip S-System – Air cushion principle
- Varipette + Varitip P – Positive displacement principle
- Maxipettor + Maxitip P – Positive displacement principle

1.4.4 Mechanical piston-stroke pipettes – Positive displacement principle

- Biomaster

1.4.5 Mechanical multi-dispensers – Positive displacement principle

- Multipette M4/Repeater M4
- Multipette/Repeater
- Multipette plus/Repeater plus

1.4.6 Electronic multi-dispensers – Positive displacement principle

- Multipette E3/E3x – Repeater E3/E3x
- Multipette stream/Repeater stream
- Multipette Xstream/Repeater Xstream

1.4.7 Mechanical single stroke dispensers – Positive displacement principle

- Varispenser
- Varispenser plus

1.4.8 Mechanical bottle-top buret – Positive displacement principle

- Top Buret M
- Top Buret H

2 Cleaning and service information

Regular cleaning and service of the dispensers ensures that the specified errors of measurement are complied with. How often a dispenser has to be cleaned and serviced depends on the utilization intensity and the dispensed chemicals. In the case of intensive use or if aggressive chemicals are dispensed, shorter cleaning intervals are feasible.

Eppendorf recommends keeping a service log for the dispensers or recording service details in the calibration protocol.

Information on cleaning, upkeep, maintenance, sterilization and disinfection can be found in the operating manual of the respective dispensers. The specifications in the "Maintenance" chapter of the operating manual of the respective dispenser must be complied with.

The operating manuals are available from the website www.eppendorf.com/manuals.

Cleaning/service must be performed prior to a calibration.

Exception: If the current state of the dispenser is to be recorded to draw conclusions about analysis results, a calibration prior to service may be feasible. In this case, a second calibration is performed after cleaning/service.

2.1 Cleaning and servicing piston-stroke pipettes – Air cushion principle

1. Clean the outside of the housing.
2. Remove, clean and dry the lower part.
3. Autoclave the pipette if required.
4. Check the piston seal for damage.
5. Exchange defective piston seal.
6. Lubricate the piston or cylinder if required.
7. Assemble the lower part.
8. Exchange the o-rings in the case of multi-channel pipettes.
9. Check leak tightness.

Only the special grease for pipettes by Eppendorf AG must be used. The grease is autoclavable and ensures optimum lubrication of the piston. As long as the grease is not contaminated, it does not have to be replaced. The grease can be ordered as an accessory.

2.2 Cleaning piston-stroke pipettes – Positive displacement principle

In the case of piston-stroke pipettes with positive displacement system, the piston is integrated in the pipette tip. This design feature protects the internal assemblies of the pipette against contamination.

- Clean the outside of the pipette.

2.3 Cleaning the multi-dispenser – Positive displacement principle

In the case of multi-dispensers, the piston is integrated in the dispensing tip. This design feature protects the internal assemblies of the multi-dispenser against contamination.

- Clean the outside of the dispenser.

2.4 Cleaning the single stroke dispenser

Single stroke dispensers are cleaned on the outside and the inside.

1. Clean the outside of the housing.
2. Flush the tube and piston system multiple times with a neutral cleaning solution.
3. Flush the tube and piston system multiple times with demineralized water.

2.5 Cleaning bottle-top burets

In the case of bottle-top burets, the piston comes into direct contact with the liquid to be dispensed. The dispenser must therefore be cleaned on the outside and the inside. The Top Buret is not autoclavable.

1. Clean the outside of the housing.
2. Flush the tube and piston system multiple times with a neutral cleaning solution.
3. Flush the tube and piston system multiple times with demineralized water.
4. Check leak tightness.

2.6 Decontamination before shipment

CAUTION! Use of a contaminated device may result in personal injuries and damage to the device.

- Clean and decontaminate the device in accordance with the cleaning instructions before shipping or storage.

Hazardous substances are:

- solutions presenting a hazard to health
- potentially infectious agents
- organic solvents and reagents
- radioactive substances
- proteins presenting a hazard to health
- DNA

1. Please note the information in the document "Decontamination certificate for product returns".
   You can find it as a PDF file on our webpage www.eppendorf.com.
2. Enter the serial number of the device in the decontamination certificate.
3. Enclose the completed decontamination certificate for returned goods with the device.
4. Send the device to Eppendorf AG or an authorized service center.

3 Error causes and solutions

Problem	Cause	Solution
Pipette is dripping	• Pipette tip is loose.	▶ Attach pipette tip again.
	• Incorrect pipette tip used.	▶ Use original Eppendorf pipette tip.
	• Piston is damaged.	▶ Exchange piston and piston seal.
	• Seal is damaged.	▶ Replace seal.
	• Liquid with slightly increased vapor pressure used.	▶ Pre-wet pipette tip several times.
	• Liquid with high vapor pressure used.	▶ Use positive-displacement device.
Wrong dispensing volume of multi-dispensers	• Dispensing tip is not leak-tight.	▶ Use new dispensing tip.
	• Dispensing tip is too warm.	▶ Ensure even temperature.
Control button is stiff	• Piston is contaminated.	▶ Clean and grease piston.
	• Seal is contaminated.	▶ Clean seal.
	• Seal is damaged.	▶ Exchange seal.
	• Piston is damaged.	▶ Replace piston.
	• Solvent vapors entered the pipette.	▶ Remove and disassemble lower part. ▶ Clean and grease piston.

4 Test intervals

The change of the systematic and random error is a gradual process. It is especially accelerated by aggressive chemicals. There is no general rule or basis of calculation for determining sensible time intervals.

Calibration results documented over a longer period can be used to draw conclusions as to an individual calibration frequency.

Test intervals can be specified by laboratory regulations. ISO 8655 requires annual calibration.

Shorter time intervals regarding maintenance, service and calibration depend on the factors:

- Frequency of use
- Accuracy required from the dispenser
- Handling
- Chemicals
- Laboratory regulations

5 Types of tests

There are different methods for testing a dispensing system. The easiest and most frequently performed check is a visual inspection for damage to and contamination of the dispenser. The individual test methods are described in the following chapters.

A calibration can be performed with the following processes:

- Titrimetric
- Photometric
- Gravimetric (reference process ISO 8655)

5.1 Visual inspection for all dispensers

- Inspect tip cone for scratches or cracks.
- Inspect dispenser for broken parts.
- Inspect dispenser for external contamination.
- Check free movement of the piston. An uneven piston movement can indicate a swollen seal.

5.2 Visual inspection of single stroke dispensers and bottle-top burets

- Exchange liquid in case of crystallization.
- Clean the dispenser.
- Vent the system if air bubbles form.

5.3 Checking leak tightness of dispensers with air cushion principle

Prerequisites
- Ambient temperature is constant
- Ambient temperature is between 20 °C – 25 °C
- Relative humidity > 50 %
- epT.I.P.S. test tip
- Test liquid: demineralized water
- Dispenser, test tip and test liquid are at ambient temperature

1. Set pipette to nominal volume.
2. Attach the pipette tip.
3. Fill and empty the pipette tip 5 times.
   This saturates the vapor phase in the air cushion and no more test liquid evaporates.
4. Aspirate nominal volume.
5. Hang the pipette into a holder in vertical position.

   The pipette can be held vertically with two fingers. The hand temperature must not be transferred to the pipette.

5.3.1 Dispensing system is leak-tight

The dispensing system is leak-tight if **no** liquid drop forms at the pipette tip within 15 seconds.

5.3.2 Dispensing system is not leak-tight

The dispensing system is not leak-tight if a liquid drop forms at the pipette tip within 15 seconds.

1. Check the assembly of the pipette.
2. Check the piston seal for damage.
   Exchange defective piston seal.
3. Repeat tightness test.

5.4 Checking leak tightness of dispensers with positive displacement principle

For positive displacement systems, only the dispensing tip determines the leak tightness. All dispensing tips are single-use items and can become leaky after extensive use.

In the case of single stroke dispensers and bottle-top burets, air in the tube system indicates a leakage in the piston/cylinder system. Crystallization or defective seals can be the cause of the leakage.

- Remove crystallizations in the device.
- If the cleaned device is still not leak-tight, send the instrument to an authorized service.

5.5 Intermediate testing – Quick-Check

The Quick-Check is a shortened calibration with 4 measurements per volume. With 4 measured values, statistical certainty is **not** provided. The Quick-Check does therefore not replace a complete calibration with 10 measurements per volume.

If the measuring results are outside the specified tolerances, the dispenser must be calibrated.

5.6 Conformity test

A complete calibration corresponds to a conformity test. A conformity test with a positive result confirms that the errors of measurement of a dispenser are within the required tolerances.

The conformity test tests if a dispensing system is within the specified measuring tolerances. For this purpose, a calibration with 10 measured values per volume is performed. The user can freely determine the thresholds within the ISO thresholds. In calibration laboratories tests are typically performed according to the manufacturer thresholds and conformity with these thresholds is assessed.

6 Prerequisites for gravimetric testing

To avoid a distortion of the measuring results, errors caused by test equipment and test method must be minimized.

6.1 Measuring station set-up

A completely equipped measuring station comprises:

- Analytical balance
- Evaporation protection (e.g., evaporation trap)
- Thermometer
- Hygrometer
- Barometer
- Reservoir for test liquid
- Test liquid (demineralized water)
- Test tips

6.1.1 Analytical balance and weighing vessel

Leading balance manufacturers offer special weighing vessels and evaporation protection (e.g., evaporation trap) for gravimetric testing of pipettes. Using such equipment results in stable weight values. Measurement errors caused by evaporation are significantly reduced especially for small volumes.

The analytical balance must meet the following requirements:

- The balance operates within the required weighing tolerances
- The weighing result is displayed in a fast and stable manner
- The balance resolution matches the testing volume

Nominal volume of dispenser	Resolution of the balance
1 µL – 10 µL	0.001 mg
1 µL – 100 µL	0.01 mg
100 µL – 1000 µL	0.1 mg
1 mL – 10 mL	0.1 mg
1 mL – 200 mL	1 mg

The weighing vessel should meet the following requirements:

- Sealable
- Size matches testing volume
- Height/width ratio of at least 3:1

6.1.2 Measuring station

The measuring station should meet the following requirements:

- No draft
- Vibration-free work station
- Relative humidity > 50 %
- Ambient temperature 15 °C – 30 °C, ±0.5 °C
- No direct thermal radiation

6.2 Test liquid

Distilled or demineralized water is used as test liquid. The reservoir for the test liquid should be sealable with a lid. This protects the test liquid from a drop in temperature due to evaporative cooling and dust particles do not contaminate the test liquid.

The test liquid must meet the following requirements (ISO 3696):

- Conductivity: ≤ 0.5 mS/m at 25 °C
- Water temperature corresponds to ambient temperature
- Degassed or at equilibrium with air

6.3 Test tips

All Eppendorf pipettes and dispensers must be tested with original Eppendorf pipette tips or dispensing tips.

- Piston-stroke pipettes – epT.I.P.S.
- Multipettes and Repeaters – Combitip advanced
- Biomaster – Mastertip P
- Maxipettor – Maxitip P or Maxitip S system
- Varipette – Varitip P or Varitip S system

6.4 Data transfer and data evaluation

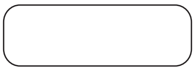
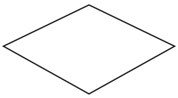
A calibration software is a useful means to automatically record the measured values obtained with gravimetric methods, convert measured values into corrected volumes and calculate the errors of measurement from these values.

6.5 Other test conditions

The duration of the test cycle (time required for weighing a dispensed volume) must be as short as possible. ISO 8655 specifies a maximum time of 60 seconds. For all listed dispensers, the inspection is performed by determining the dispensing volume in the weighing vessel (ex).

7 Performing the calibration

Calibration consists of different work steps that are described in this SOP. The following graphic provides a complete overview of the individual work steps.

Symbol	Meaning
	Start or end of the process.
	An individual action or a sequence of actions.
	A branch and decision in the sequence.

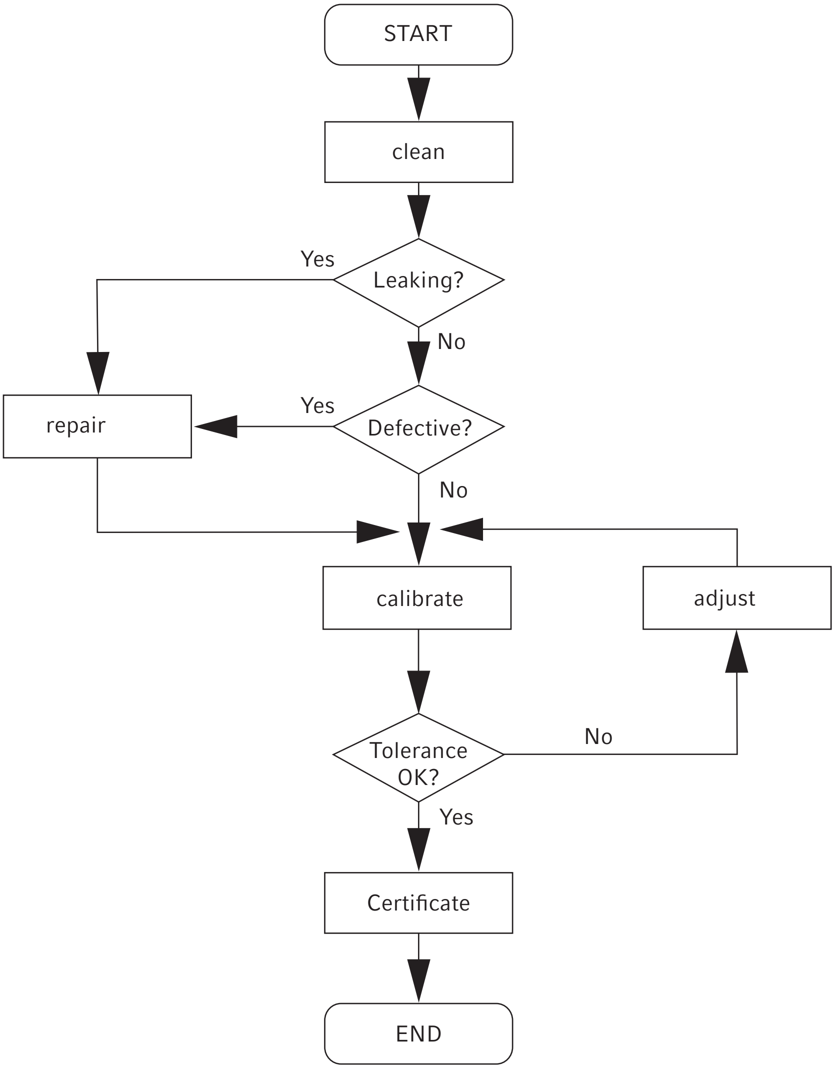


Fig. 7-1: Complete calibration process

7.1 Preparing the measuring station for calibration

7.1.1 Preparing the dispenser, test liquid and analytical balance

Prerequisites

- Dispenser has been cleaned.
- Defective parts of the dispenser have been exchanged.
- Dispenser has been decontaminated if required.

- ▶ Prepare the measuring station.
- ▶ Fill the test liquid.
- ▶ Position the dispenser and pipette tips near at measuring station.
- ▶ Allow the dispenser, pipette tips and test liquid to acclimatize in the testing room for at least 2 h.

7.1.2 Preparing documentation

- ▶ Print checklist (see p. 26).
- ▶ Print test protocol or prepare Excel list.
- ▶ Start calibration software.

7.2 Checklists for preparing the calibration

The following checklists can be used during the preparation process to ensure that all required work equipment is available at the time of calibration. For this reason, the tables feature fields for checking (Yes, No, Not applicable).

The checklist is divided into the following sections:

- A – Test conditions
- B – Test liquid
- C – Dispenser
- D – Analytical balance
- E – Calibration software

7.2.1 A – Test conditions

Number	Description	Yes	No
A01	Vibration-free weighing table is available.		
A02	Dispenser, pipette tips, test liquid, etc. are at ambient temperature.		
A03	No draft at measuring station.		
A04	The ambient temperature is between 15 °C – 30 °C, ±0.5 °C		
A05	The relative humidity is > 50 %		
A06	Document temperature, humidity and atmospheric pressure.		
A07	Tester is competent in operating the dispenser.		
A08	Document test data (name of tester, date, etc.).		
A09	Indicate test method (manufacturer information, ISO, laboratory standard, etc.).		
A10	Liquid dispensing into the weighing vessel (ex)		

7.2.2 B – Test liquid

Number	Description	Yes	No	Not applicable
B01	Test liquid is available (according to ISO 3696).			
B02	Test liquid has ambient temperature.			
B03	Larger vessels were filled at least 2 h prior to calibration.			
B04	Evaporation trap was filled with test liquid at least 2 h prior to calibration.			
B05	Pre-fill weighing vessel with test liquid (approx. 3 mm).			
B06	Bottle-top buret: Test liquid was filled at least 2 hours prior to calibration.			
B07	Bottle-top dispenser: Test liquid is filled at least 2 hours prior to calibration.			

7.2.3 C – Dispenser

Number	Description	Yes	No	Not applicable
C01	Dispenser was cleaned.			
C02	Defective assemblies were exchanged.			
C03	Mechanical piston-stroke pipette: Adjustment seal is available and not damaged.			
C04	Electronic dispenser: Rechargeable battery is charged.			
C05	Electronic multi-dispenser: "Dispensing" mode is set.			
C06	Electronic pipette: "Pipetting" mode is set.			
C07	Mechanical dispenser: Nominal volume was determined.			
C08	Variable volume dispensing system: Testing volume is set.			
C09	Piston-stroke pipette: Pipette tip is attached correctly.			
C10	Multi-dispenser: Dispensing tip is inserted correctly.			

7.2.4 D – Analytical balance

Number	Description	Yes	No
D01	Balance is aligned horizontally.		
D02	Balance is calibrated or valid calibration certificate is available.		
D03	Sensitivity is set according to the testing volume.		
D04	Volume of the weighing vessel is sufficient for 10 liquid dispensing operations of the nominal volume.		
D05	Balance was switched on at least 2 h prior to calibration.		

7.2.5 E – Calibration software

Number	Description	Yes	No	Not applicable
E01	Computer is switched on and connected with the analytical balance.			
E02	Calibration software can record the measured values.			
E03	Calibration software and analytical balance are available for communication.			

7.3 Performing a series of measurements

The measured values of a series of measurements should be determined consecutively. This reduces the risk of errors or deviations between the measured values.

7.3.1 Nominal volume

The nominal volume of a piston-stroke pipette is printed on and defines the largest selectable volume.

In the case of mechanical dispensers, the nominal volume is calculated from:

- Largest selection dial setting
- Volume of the dispensing tip
- Dispensing volume

In the case of electronic dispensers, the nominal volume results from the volume of the inserted dispensing tip.

7.3.2 Number of measured values

Variable volume single-channel pipettes:

- 10 measured values per testing volume

Multi-channel pipettes:

- 10 measured values per channel for every testing volume
  This means:
  - 8 channels = 240 measured values
  - 12 channels = 360 measured values

All channels must be equipped with a pipette tip and filled with test liquid, even if only one channel can be measured gravimetrically.

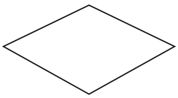
7.3.3 Testing volume

For variable volume pipettes, the following volumes are tested:

- 10 % of the nominal volume or the smallest selectable volume (select the larger of the two volumes)
- 50 % of the nominal volume
- 100 % of the nominal volume or
- Optional: freely selectable testing volume (e.g., requirement from laboratory regulation)

7.3.4 Overview of the calibration processes

The calibration process varies for the different device groups. The following overview illustrates this.

Symbol	Meaning
	Start or end of the process.
	A single action or a sequence of actions.
	A branch and decision in the sequence.

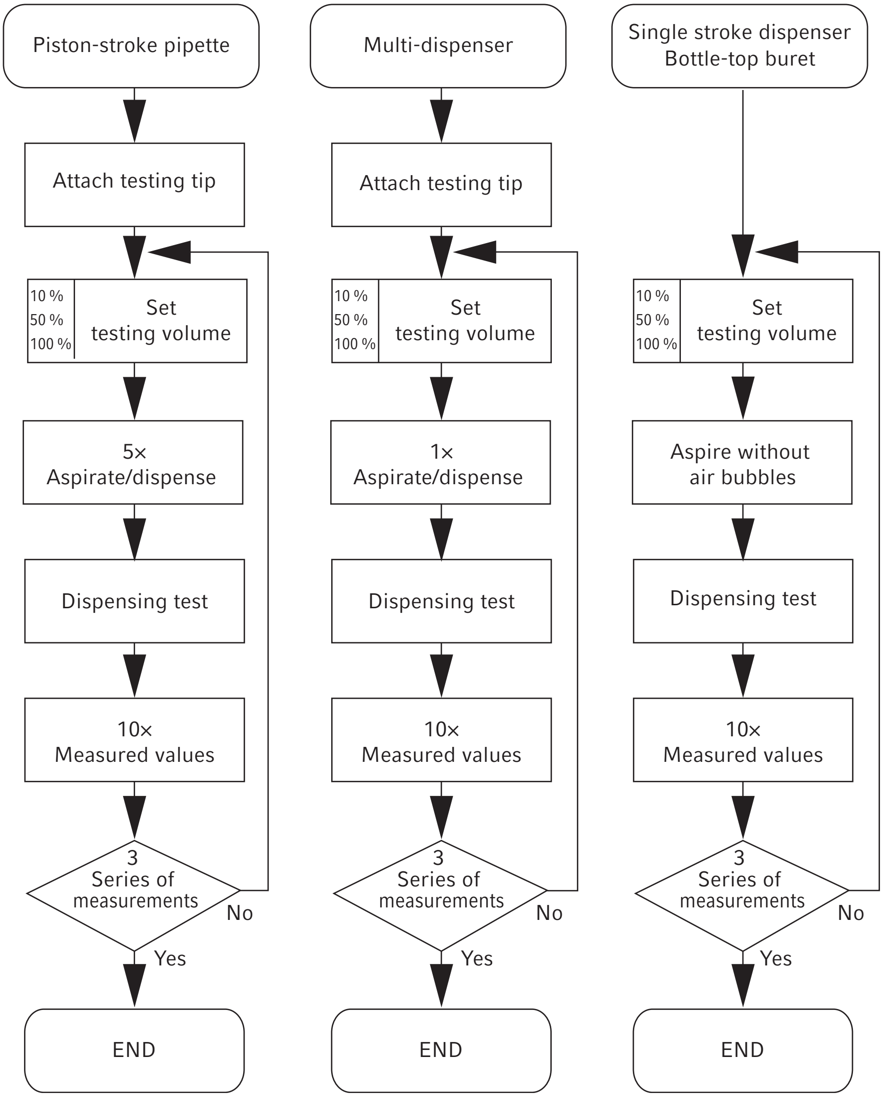


Fig. 7-2: Calibration process of the device groups

7.3.5 Determining measured values – Mechanical single-channel pipettes

Prerequisites

- Test tip is attached.

The test tip can be used for the entire calibration.

1. Set the testing volume.
2. Aspirate and dispense test liquid 5 times.
3. Immerse test tip vertically a few millimeters into the test liquid.
4. Maintain the immersion depth and aspirate the test liquid slowly and evenly.
5. Wait until the liquid aspiration is completed (several seconds).
6. Remove the test tip from the liquid.
7. Place the test tip on the tube inner wall of the weighing vessel at a steep angle.
8. Perform test dispensing.
9. Determine measured values for every testing volume.

7.3.6 Determining measured values – Mechanical multi-channel pipettes

Prerequisites

- Test tips are attached to all channels.

The test tips can be used for the entire calibration.

Every channel must be checked individually. For this purpose, either an analytical balance with one load cell per channel is used or a fixture with drain to discard of the liquid in the other channels.

1. Set the testing volume.
2. Aspirate and dispense test liquid 5 times.
3. Immerse test tips vertically a few millimeters into the test liquid.
4. Maintain the immersion depth and aspirate the test liquid slowly and evenly.
5. Wait until the liquid aspiration is completed (several seconds).
6. Remove the test tips from the liquid.
7. Place the test tip of the channel to be tested on the tube inner wall of the weighing vessel at a steep angle.
8. Dispense the test liquid quickly and evenly against the tube inner wall.
9. Discard of the test liquid in the other channels.
10. Perform test dispensing.
11. Determine measured values for every channel and every testing volume.

7.3.7 Determining measured values – Electronic single-channel pipettes

The electronic pipettes are only tested in one operating mode. Errors of measurement occur in all operating modes. A correction has the same effect for all modes.

The test tips can be used for the entire calibration.

1. Set the aspiration speed and dispensing speed (see *Test conditions on p. 45)*.
2. Set the operating mode (see *Test conditions on p. 45)*.
3. Attach the test tip.
4. Set the testing volume.
5. Aspirate and dispense test liquid 5 times.
6. Immerse test tip vertically a few millimeters into the test liquid.
7. Maintain the immersion depth and aspirate test liquid.
8. Wait until the liquid aspiration is completed (several seconds).
9. Remove the test tip from the liquid.
10. Place the test tip on the tube inner wall of the weighing vessel at a steep angle.
11. Dispense test liquid against the tube inner wall.

7.3.8 Determining measured values – Electronic multi-channel pipettes

The electronic pipettes are only tested in one operating mode. Errors of measurement occur in all operating modes. A correction has the same effect for all modes.

The test tips can be used for the entire calibration.

1. Set the aspiration speed and dispensing speed (see *Test conditions on p. 45)*.
2. Set the operating mode (see *Test conditions on p. 45)*.
3. Attach a test tip to every channel.
4. Set the testing volume.
5. Aspirate and dispense test liquid 5 times.
6. Immerse test tips vertically a few millimeters into the test liquid.
7. Maintain the immersion depth and aspirate test liquid.
8. Wait until the liquid aspiration is completed (several seconds).
9. Slowly remove the test tips from the liquid.
10. Place the test tip of the channel to be tested on the tube inner wall of the weighing vessel at a steep angle.
11. Perform test dispensing.
    Dispense test liquid against the tube inner wall.
12. Determine measured values for every testing volume.

7.3.9 Determining measured values – Hybrid systems

Depending on the inserted test tip, a hybrid system (Varipette/Maxipettor) works according to the air cushion principle or the positive displacement principle. Correspondingly, the measured values have to be determined according to the process for mechanical single-channel pipettes or the process for mechanical multi-dispensers.

As the test tip, use the same dispensing tip that is typically used in your laboratory.

1. Insert the test tip.
2. Set the testing volume.
3. Perform calibration according to the inserted test tip.
4. Perform test dispensing.
5. Determine measured values for every testing volume.

7.3.10 Determining measured values – Mechanical multi-dispensers

Eppendorf recommends using the 5 mL Combitip advanced, as the results of the quality check of a new multi-dispenser are determined by means of this Combitip. However, any other Combitip advanced can also be used for calibration. Eppendorf specifies maximum permissible errors for every Combitip advanced.

- Selection dial setting 1 corresponds to 10 % of the nominal volume
- Selection dial setting 5 corresponds to 50 % of the nominal volume
- Selection dial setting 10 corresponds to 100 % of the nominal volume

1. Insert the test tip.
2. Set the testing volume.
3. Set the speed.
4. Aspirate and dispense the test liquid once.
5. Perform test dispensing.
6. Determine measured values.

7.3.11 Determining measured values – Electronic multi-dispensers

Eppendorf recommends using the 5 mL Combitip advanced, as the results of the quality check of a new multi-dispenser are determined by means of this Combitip. However, any other Combitip advanced can also be used for calibration. Eppendorf specifies maximum permissible errors for every Combitip advanced.

1. Set the operating mode **Dis**.
2. Insert the test tip.
3. Set the testing volume.
4. Aspirate and dispense the test liquid once.
5. Perform test dispensing.
6. Determine measured values for every testing volume.

7.3.12 Determining measured values – Mechanical single stroke dispensers

Varispenser/Varispenser plus

1. Place the beaker on the analytical balance.
2. Set the testing volume.
3. Aspirate the test liquid without air bubbles.
4. Perform test dispensing.
5. Determine measured values for every testing volume.

7.3.13 Determining measured values – Mechanical bottle-top burets

1. Place the beaker on the analytical balance.
2. Remove air bubbles from the dispensing system.
3. Perform test dispensing.
4. Determine measured values for the testing volume.

8 Evaluating the calibration

To determine the performance of dispensers, the systematic and random error are identified. A conclusion can only be drawn from the combination of both errors of measurement.

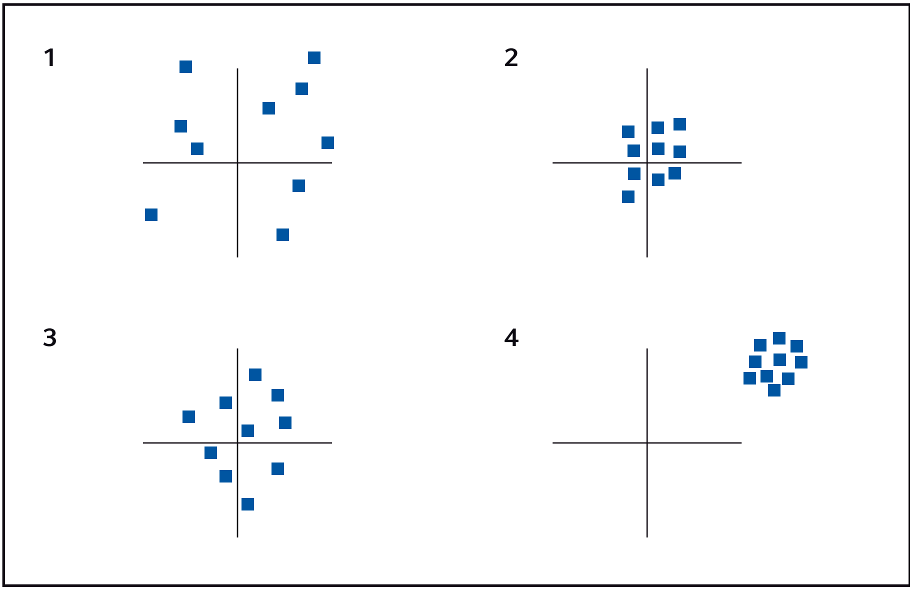


Fig. 8-1: Distribution of measured values

1 Poor precision and accuracy

2 Good precision and accuracy

3 Poor precision, good accuracy

4 Good precision, poor accuracy

The systematic and random error are calculated in the following steps:

- Convert mass value into volume
- Calculate the average value of the measured volume values
- Calculate the systematic and random error

8.1 Converting gravimetric measured values into volume

The measured values determined with gravimetric methods must be converted into volume values. The correction factor *Z* takes the density of water depending on temperature and atmospheric pressure into account.

$$V_i = m_i \cdot Z$$

- Multiply the gravimetric measured value by the correction factor *Z*.
  The result is the measured volume value.

Symbol	Meaning
Z	Correction factor
m_i	Gravimetric measured value
V_i	Volume value

8.2 Correction factor *Z*

Tabular overview of the correction values for distilled water depending on temperature and atmospheric pressure.

Temperature in °C	Correction factor *Z* in µL/mg						
	800 hPa	**850 hPa**	**900 hPa**	**950 hPa**	**1000 hPa**	**1013 hPa**	**1050 hPa**
15	1.0017	1.0018	1.0019	1.0019	1.0020	1.0020	1.0020
15.5	1.0018	1.0019	1.0019	1.0020	1.0020	1.0020	1.0021
16	1.0019	1.0020	1.0020	1.0021	1.0021	1.0021	1.0022
16.5	1.0020	1.0020	1.0021	1.0021	1.0022	1.0022	1.0022
17	1.0021	1.0021	1.0022	1.0022	1.0023	1.0023	1.0023
17.5	1.0022	1.0022	1.0023	1.0023	1.0024	1.0024	1.0024
18	1.0022	1.0023	1.0023	1.0024	1.0025	1.0025	1.0025
18.5	1.0023	1.0024	1.0024	1.0025	1.0025	1.0026	1.0026
19	1.0024	1.0025	1.0025	1.0026	1.0026	1.0027	1.0027
19.5	1.0025	1.0026	1.0026	1.0027	1.0027	1.0028	1.0028
20	1.0026	1.0027	1.0027	1.0028	1.0028	1.0029	1.0029
20.5	1.0027	1.0028	1.0028	1.0029	1.0029	1.0030	1.0030
21	1.0028	1.0029	1.0029	1.0030	1.0031	1.0031	1.0031
21.5	1.0030	1.0030	1.0031	1.0031	1.0032	1.0032	1.0032
22	1.0031	1.0031	1.0032	1.0032	1.0033	1.0033	1.0033
22.5	1.0032	1.0032	1.0033	1.0033	1.0034	1.0034	1.0034
23	1.0033	1.0033	1.0034	1.0034	1.0035	1.0035	1.0036
23.5	1.0034	1.0035	1.0035	1.0036	1.0036	1.0036	1.0037
24	1.0035	1.0036	1.0036	1.0037	1.0037	1.0038	1.0038
24.5	1.0037	1.0037	1.0038	1.0038	1.0039	1.0039	1.0039
25	1.0038	1.0038	1.0039	1.0039	1.0040	1.0040	1.0040
25.5	1.0039	1.0040	1.0040	1.0041	1.0041	1.0041	1.0042
26	1.0040	1.0041	1.0041	1.0042	1.0042	1.0043	1.0043
26.5	1.0042	1.0042	1.0043	1.0043	1.0044	1.0044	1.0044
27	1.0043	1.0044	1.0044	1.0045	1.0045	1.0045	1.0046
27.5	1.0045	1.0045	1.0046	1.0046	1.0047	1.0047	1.0047
28	1.0046	1.0046	1.0047	1.0047	1.0048	1.0048	1.0048
28.5	1.0047	1.0048	1.0048	1.0049	1.0049	1.0050	1.0050
29	1.0049	1.0049	1.0050	1.0050	1.0051	1.0051	1.0051
29.5	1.0050	1.0051	1.0051	1.0052	1.0052	1.0052	1.0053
30	1.0052	1.0052	1.0053	1.0053	1.0054	1.0054	1.0054

8.3 Calculating the arithmetic average value of the volume

Calculate the average value from the volume values.

$$\bar{V} = \frac{\sum_{i=1}^{n} V_i}{n}$$

- Divide the sum of the volume values by the number of measurements.
  Result: arithmetic average of the volume values.

Symbol	Meaning
$\bar{V}$	Average volume
V_i	Volume value
n	Number of measurements

8.4 Calculating the systematic error

The systematic error is the measure for the deviation of the average volume from the set value of the dispensed volume.

8.4.1 Absolute systematic error

$$e_s = \overline{V} - V_s$$

- Subtract the set testing volume from the average volume.
  Result: absolute error of measurement in volume.

8.4.2 Relative systematic error

$$e_s = \frac{(\overline{V} - V_s) \cdot 100\ \%}{V_s}$$

- Multiply absolute error of measurement by 100 and divide by the testing volume.
  Result: relative error of measurement in percent.

Symbol	Meaning
e_s	Systematic error
$\overline{V}$	Average volume
V_s	Testing volume

8.5 Calculating the random error

The standard deviation is a measure for the scattering of individual values around the average volume of the dispensed volume.

8.5.1 Absolute random error

$$s_r = \sqrt{\frac{\sum_{i=1}^{n} (V_i - \bar{V})^2}{n - 1}}$$

- Calculate the standard deviation of the volume value.
  Result: absolute random error.

8.5.2 Relative random error

$$CV = \frac{100\ \% \cdot s_r}{\bar{V}}$$

- Multiply absolute error of measurement by 100 and divide by the average volume.
  Result: percentage error of measurement.

Symbol	Meaning
s_r	Repeatability standard deviation
n	Number of measurements
V_i	Testing volume
$\bar{V}$	Average volume
CV	Coefficient of variation

8.6 Test protocol

The calibration results and all influencing factors must be documented. The following chapters indicate the contents of a test protocol.

8.6.1 Tester

Name	
First name	
Department	
Calibration date	

8.6.2 Dispenser

Manufacturer	
Type	
Model number	
Nominal volume	
Serial number	

8.6.3 Test tip

Manufacturer	
Designation	
Volume	
Lot number	

8.6.4 Analytical balance

Manufacturer	
Model	
Serial number	
Last calibration	

8.6.5 Adjustment

Basis of the adjustment (ex)	
Adjustment performed by	

8.6.6 Test conditions

Air temperature °C	
Atmospheric pressure hPa	
Relative humidity %	
Temperature of test liquid °C	

8.6.7 Testing process

ISO 8655	
Laboratory regulation	
Manufacturer information	
Other	

8.6.8 Series of measurements

Series of measurements 1										
Measured values										

	Actual value	**Set value**	**Rating**
Average value $\bar{V}$			
Systematic error e_s			
Random error CV			
Comment			

Series of measurements 2										
Measured values										

	Actual value	**Set value**	**Rating**
Average value $\bar{V}$			
Systematic error e_s			
Random error CV			
Comment			

Series of measurements 3										
Measured values										

	Actual value	Set value	Rating
Average value $\bar{V}$			
Systematic error e_s			
Random error CV			
Comment			

8.6.9 Cleaning

Name	
First name	
Department	
Date	
Comment	

8.6.10 Service

Name	
First name	
Department	
Date	
Exchanged parts	
Comment	

9 Permissible errors of measurement

The tables with the errors of measurement are sorted alphabetically by product name in this chapter.

9.1 Test conditions

Test conditions and test analysis in accordance with the standard ISO 8655, Part 6. The inspections are performed with a calibrated analytical balance with evaporation protection.

- Number of determinations per volume: 10
- Water according to ISO 3696
- Inspection at 20 °C – 27°C ±0.5 °C
- Dispensing onto the tube inner wall

9.1.1 Multipette E3/E3x

- Inspection with fully charged Combitip advanced
- Speed level: 5

9.1.2 Multipette stream/Xstream

- Operating mode: **Dis**
- Speed level: 7

9.1.3 Xplorer/Xplorer plus

- Operating mode: **Pip**
- Speed level: 5

9.2 Biomaster – Error of measurement

Model	Testing tip Mastertip	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± µL	± %	± µL
1 µL – 20 µL	20 µL light gray 52 mm	2 µL	6.0	0.12	4.0	0.08
		3 µL	5.0	0.15	3.0	0.09
		5 µL	4.0	0.2	2.0	0.1
		10 µL	3.0	0.3	1.5	0.15
		20 µL	2.0	0.4	0.8	0.16

9.3 Multipette/Repeater E3/E3x – Error of measurement

Testing tip Combitip advanced	Volume range	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± µL	± %	± µL
0.1 mL white	1 µL – 100 µL	10 µL	1.6	0.16	2.5	0.25
		50 µL	1.0	0.5	1.5	0.75
		100 µL	1.0	1.0	0.5	0.5
0.2 mL light blue	2 µL – 200 µL	20 µL	1.3	0.26	1.5	0.3
		100 µL	1.0	1.0	1.0	1.0
		200 µL	1.0	2.0	0.5	1.0
0.5 mL violet	5 µL – 500 µL	50 µL	0.9	0.45	0.8	0.4
		250 µL	0.9	2.25	0.5	1.25
		500 µL	0.9	4.5	0.3	1.5
1 mL yellow	10 µL – 1000 µL	100 µL	0.9	0.9	0.55	0.55
		500 µL	0.6	3.0	0.3	1.5
		1000 µL	0.6	6.0	0.2	2.00
2.5 mL green	25 µL – 2500 µL	250 µL	0.8	2.0	0.45	1.125
		1250 µL	0.5	6.25	0.3	3.75
		2500 µL	0.5	12.5	0.15	3.75
5 mL blue	50 µL – 5000 µL	500 µL	0.8	4.0	0.35	1.75
		2500 µL	0.5	12.5	0.25	6.25
		5000 µL	0.5	25	0.15	7.50
10 mL orange	0.1 mL – 10 mL	1 mL	0.5	5	0.25	2.5
		5 mL	0.4	20	0.25	12.5
		10 mL	0.4	40	0.15	15
25 mL red	0.25 mL – 25 mL	2.5 mL	0.3	7.5	0.35	8.8
		12.5 mL	0.3	37.5	0.25	31.3
		25 mL	0.3	75	0.15	37.5
50 mL light gray	0.5 mL – 50 mL	5 mL	0.3	15	0.5	25
		25 mL	0.3	75	0.20	50
		50 mL	0.3	150	0.15	75

9.4 Multipette/Repeater M4 – Error or measurement

Testing tip Combitip advanced	Volume range	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± µL	± %	± µL
0.1 mL white	0.1 µL – 20 µL	2 µL	1.6	0.032	3.0	0.06
		10 µL	1.2	0.12	2.4	0.24
		20 µL	1.0	0.2	2.0	0.4
0.2 mL light blue	2 µL – 40 µL	4 µL	1.3	0.052	2.0	0.08
		20 µL	0.8	0.16	1.5	0.3
		40 µL	0.8	0.32	1.5	0.6
0.5 mL violet	5 µL – 100 µL	10 µL	0.9	0.09	1.5	0.15
		50 µL	0.8	0.4	0.8	0.4
		100 µL	0.8	0.8	0.6	0.6
1 mL yellow	10 µL – 200 µL	20 µL	0.9	0.18	0.9	0.18
		100 µL	0.6	0.6	0.6	0.6
		200 µL	0.6	1.2	0.4	0.8
2.5 mL green	25 µL – 500 µL	50 µL	0.8	0.4	0.8	0.4
		250 µL	0.6	1.5	0.6	1.5
		500 µL	0.5	2.5	0.3	1.5
5 mL blue	50 µL – 1000 µL	100 µL	0.6	0.6	0.6	0.6
		500 µL	0.5	2.5	0.5	2.5
		1000 µL	0.5	5.0	0.25	2.5
10 mL orange	0.1 mL – 2 mL	0.2 mL	0.5	1.0	0.6	1.2
		1 mL	0.5	5	0.4	4
		2 mL	0.5	10	0.25	5.0
25 mL red	0.25 mL – 5 mL	0.5 mL	0.4	2.0	0.6	3.0
		2.5 mL	0.3	2.5	0.5	12.5
		5 mL	0.3	15	0.25	12.5
50 mL light gray	0.5 mL – 10mL	1 mL	0.3	3.0	0.5	5.0
		5 mL	0.3	15	0.5	25
		10 mL	0.3	30	0.3	30

9.5 Multipette/Repeater plus – Error of measurement

Testing tip Combitip advanced	Volume range	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± µL	± %	± µL
0.1 mL white	1 µL – 20 µL	2 µL	1.6	0.032	3.0	0.06
		10 µL	1.2	0.12	2.4	0.24
		20 µL	1.0	0.2	2.0	0.4
0.2 mL light blue	2 µL – 40 µL	4 µL	1.3	0.052	2.0	0.08
		20 µL	0.8	0.16	1.5	0.3
		40 µL	0.8	0.32	1.5	0.6
0.5 mL violet	5 µL – 50 µL	10 µL	0.9	0.09	1.5	0.15
		50 µL	0.8	0.4	0.8	0.4
		100 µL	0.8	0.8	0.6	0.6
1 mL yellow	10 µL – 200 µL	20 µL	0.9	0.18	0.9	0.18
		100 µL	0.6	0.6	0.6	0.6
		200 µL	0.6	1.2	0.4	0.8
2.5 mL green	25 µL – 500 µL	50 µL	0.8	0.4	0.8	0.4
		250 µL	0.6	1.5	0.6	1.5
		500 µL	0.5	2.5	0.3	1.5
5 mL blue	50 µL – 1000 µL	100 µL	0.6	0.6	0.6	0.6
		500 µL	0.5	2.5	0.5	2.5
		1000 µL	0.5	5.0	0.25	2.5
10 mL orange	0.1 mL – 2 mL	0,2 mL	0.5	1.0	0.6	1.2
		1 mL	0.5	5	0.4	4
		2 mL	0.5	10	0.25	5.0
25 mL red	0.25 mL – 5 mL	0,5 mL	0.4	2.0	0.6	3.0
		2.5 mL	0.3	2.5	0.5	12.5
		5 mL	0.3	15	0.25	12.5
50 mL light gray	0.5 mL – 10 mL	1 mL	0.3	3.0	0.5	5.0
		5 mL	0.3	15	0.5	25
		10 mL	0.3	30	0.3	30

9.6 Multipette/Repeater stream/Xstream – Error of measurement

Testing tip Combitip advanced	Volume range	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± µL	± %	± µL
0.1 mL white	1 µL – 100 µL	10 µL	1.6	0.16	2.5	0.25
		50 µL	1.0	0.5	1.5	0.75
		100 µL	1.0	1.0	0.5	0.5
0.2 mL light blue	2 µL – 200 µL	20 µL	1.3	0.26	1.5	0.3
		100 µL	1.0	1.0	1.0	1.0
		200 µL	1.0	2.0	0.5	1.0
0.5 mL violet	5 µL – 500 µL	50 µL	0.9	0.45	0.8	0.4
		250 µL	0.9	2.25	0.5	1.25
		500 µL	0.9	4.5	0.3	1.5
1 mL yellow	10 µL – 1000 µL	100 µL	0.9	0.9	0.55	0.55
		500 µL	0.6	3.0	0.3	1.5
		1000 µL	0.6	6.0	0.2	2.00
2.5 mL green	25 µL – 2500 µL	250 µL	0.8	2.0	0.45	1.125
		1250 µL	0.5	6.25	0.3	3.75
		2500 µL	0.5	12.5	0.15	3.75
5 mL blue	50 µLd – 5000 µL	500 µL	0.8	4.0	0.35	1.75
		2500 µL	0.5	12.5	0.25	6.25
		5000 µL	0.5	25	0.15	7.50
10 mL orange	0.1 mL – 10 mL	1 mL	0.5	5	0.25	2.5
		5 mL	0.4	20	0.25	12.5
		10 mL	0.4	40	0.15	15
25 mL red	0.25 mL – 25 mL	2.5 mL	0.3	7.5	0.35	8.8
		12.5 mL	0.3	37.5	0.25	31.3
		25 mL	0.3	75	0.15	37.5
50 mL light gray	0.5 mL – 50 mL	5 mL	0.3	15	0.5	25
		25 mL	0.3	75	0.20	50
		50 mL	0.3	150	0.15	75

9.7 Reference – Error of measurement

9.7.1 Reference – Fixed volume single-channel pipette

Model	Testing tip epT.I.P.S.	Error of measurement			
		Systematic error		Random error	
		± %	± µL	± %	± µL
1 µL	0.5 µL – 20 µL L light gray 46 mm	2.5	0.025	1.8	0.018
2 µL		2.0	0.04	1.2	0.024
5 µL		1.5	0.075	0.8	0.04
10 µL		1.0	0.1	0.5	0.05
10 µL	2 µL – 200 µL yellow 53 mm	1.0	0.1	0.5	0.05
20 µL		0.8	0.16	0.3	0.06
25 µL		0.8	0.2	0.3	0.075
50 µL		0.7	0.35	0.3	0.15
100 µL		0.6	0.6	0.2	0.2
200 µL	50 µL – 1000 µL blue 71 mm	0.6	1.2	0.2	0.4
250 µL		0.6	1.5	0.2	0.5
500 µL		0.6	3.0	0.2	1.0
1000 µL		0.6	6.0	0.2	2.0
1500 µL	500 µL – 2500 µL red 115 mm	0.6	9.0	0.2	3.0
2000 µL		0.6	12	0.2	4.0
2500 µL		0.6	15	0.2	5.0

9.7.2 Reference – Variable volume single-channel pipette

Model	Testing tip epT.I.P.S.	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± µL	± %	± µL
0.1 µL – 2.5 µL	0.1 µL – 10 µL dark gray 34 mm	0.25 µL	12.0	0.03	6.0	0.015
		1.25 µL	2.5	0.031	1.5	0.019
		2.5 µL	1.4	0.035	0.7	0.018
0.5 µL – 10 µL	0.5 µL – 20 µL light gray 46 mm	1 µL	2.5	0.025	1.8	0.018
		5 µL	1.5	0.075	0.8	0.04
		10 µL	1.0	0.1	0.4	0.04
2 µL – 20 µL	0.5 µL – 20 µL light gray 46 mm	2 µL	3.0	0.06	2.0	0.04
		10 µL	1.0	0.1	0.5	0.05
		20 µL	0.8	0.16	0.3	0.06
2 µL – 20 µL	2 µL – 200 µL yellow 53 mm	2 µL	5.0	0.1	1.5	0.03
		10 µL	1.2	0.12	0.6	0.06
		20 µL	1.0	0.2	0.3	0.06
10 µL– 100 µL	2 µL – 200 µL yellow 53 mm	10 µL	3.0	0.3	0.7	0.07
		50 µL	1.0	0.5	0.3	0.15
		100 µL	0.8	0.8	0.15	0.15
50 µL – 200 µL	2 µL – 200 µL yellow 53 mm	50 µL	1.0	0.5	0.3	0.15
		100 µL	0.9	0.9	0.3	0.3
		200 µL	0.6	1.2	0.2	0.4
50 µL – 250 µL	50 µL – 1000 µL blue 71 mm	50 µL	1.4	0.7	0.3	0.15
		100 µL	1.1	1.1	0.3	0.3
		250 µL	0.6	1.5	0.2	0.5
100 µL – 1000 µL	50 µL – 1000 µL blue 71 mm	100 µL	3.0	3.0	0.3	0.3
		500 µL	1.0	5.0	0.2	1.0
		1000 µL	0.6	6.0	0.2	2.0
500 µL – 2500 µL	500 µL – 2500 µL red 115 mm	0.5 mL	1.5	7.5	0.3	1.5
		1.25 mL	0.8	10	0.2	2.5
		2.5 mL	0.6	15	0.2	5.0

9.8 Reference 2 – Error of measurement

9.8.1 Reference 2 – Fixed volume single-channel pipette

Model	Testing tip epT.I.P.S.	Error of measurement			
		Systematic error		Random error	
		± %	± µL	± %	± µL
1 µL	0.1 µL – 10 µL dark gray 34 mm	2.5	0.025	1.8	0.018
2 µL		2.0	0.04	1.2	0.024
5 µL	0.1 µL – 20 µL medium gray 40 mm	1.2	0.06	0.6	0.03
10 µL		1.0	0.1	0.5	0.05
20 µL	0.5 µL – 20 µL L light gray 46 mm	0.8	0.16	0.3	0.06
10 µL	2 µL – 200 µL yellow 53 mm	1.2	0.12	0.6	0.06
20 µL		1.0	0.2	0.3	0.06
25 µL		1.0	0.25	0.3	0.075
50 µL		0.7	0.35	0.3	0.15
100 µL		0.6	0.6	0.2	0.2
200 µL		0.6	1.2	0.2	0.4
200 µL	50 µL – 1000 µL blue 71 mm	0.6	1.2	0.2	0.4
250 µL		0.6	1.5	0.2	0.5
500 µL		0.6	3.0	0.2	1.0
1000 µL		0.6	6.0	0.2	2.0
2.0 mL	0.5 mL – 2.5 mL red 115 mm	0.6	12	0.2	4
2.5 mL		0.6	15	0.2	5

9.8.2 Reference 2 – Variable volume single-channel pipette

Model	Testing tip epT.I.P.S.	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± µL	± %	± µL
0.1 µL – 2.5 µL	0.1 µL – 10 µL dark gray 34 mm	0.1 µL	48.0	0.048	12.0	0.012
		0.25 µL	12.0	0.03	6.0	0.015
		1.25 µL	2.5	0.031	1.5	0.019
		2.5 µL	1.4	0.035	0.7	0.018
0.5 µL – 10 µL	0.1 µL – 20 µL medium gray 40 mm	0.5 µL	8.0	0.04	5.0	0.025
		1 µL	2.5	0.025	1.8	0.018
		5 µL	1.5	0.075	0.8	0.04
		10 µL	1.0	0.10	0.4	0.04
2 µL – 20 µL	0.5 µL – 20 µL L light gray 46 mm	2 µL	3.0	0.06	1.5	0.03
		10 µL	1.0	0.10	0.6	0.06
		20 µL	0.8	0.16	0.3	0.06
2 µL – 20 µL	2 µL – 200 µL yellow 53 mm	2 µL	5.0	0.10	1.5	0.03
		10 µL	1.2	0.12	0.6	0.06
		20 µL	1.0	0.2	0.3	0.06
10 µL – 100 µL	2 µL – 200 µL yellow 53 mm	10 µL	3.0	0.3	0.7	0.07
		50 µL	1.0	0.5	0.3	0.15
		100 µL	0.8	0.8	0.2	0.2
20 µL – 200 µL	2 µL – 200 µL yellow 53 mm	20 µL	2.5	0.5	0.7	0.14
		100 µL	1.0	1.0	0.3	0.3
		200 µL	0.6	1.2	0.2	0.4
30 µL – 300 µL	20 µL – 300 µL orange 55 mm	30 µL	2.5	0.75	0.7	0.21
		150 µL	1.0	1.5	0.3	0.45
		300 µL	0.6	1.8	0.2	0.6
100 µL – 1000 µL	50 µL – 1000 µL blue 71 mm	100 µL	3.0	3.0	0.6	0.6
		500 µL	1.0	5.0	0.2	1.0
		1000 µL	0.6	6.0	0.2	2.0
0.25 mL – 2.5 mL	0.25 mL – 2.5 mL red 115 mm	0.25 mL	4.8	12	1.2	3
		1.25 mL	0.8	10	0.2	2.5
		2.5 mL	0.6	15	0.2	5

Model	Testing tip epT.I.P.S.	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± µL	± %	± µL
0.5 mL – 5 mL	0.1 mL – 5 mL violet 120 mm	0.5 mL	2.4	12	0.6	3
		2.5 mL	1.2	30	0.25	6
		5.0 mL	0.6	30	0.15	7.5
0.5 mL – 5 mL	0.1 mL – 5 mL L violet 175 mm	0.5 mL	5.0	25	1.0	5.0
		2.5 mL	3.0	75	0.9	22.5
		5.0 mL	2.0	100	0.8	40
1 mL – 10 mL	1 mL – 10 mL turquoise 165 mm	1.0 mL	3.0	30	0.6	6
		5.0 mL	0.8	40	0.2	10
		10.0 mL	0.6	60	0.15	15
1 mL – 10 mL	1 mL – 10 mL L turquoise 243 mm	1.0 mL	6.0	6	1.0	10
		5.0 mL	3.0	150	0.9	45
		10.0 mL	2.0	200	0.7	70

9.8.3 Reference 2 – Variable volume multi-channel pipette

Model	Testing tip epT.I.P.S.	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± µL	± %	± µL
0.5 µL – 10 µL	0.1 µL – 20 µL medium gray 40 mm	0.5 µL	12.0	0.06	8.0	0.04
		1 µL	8.0	0.08	5.0	0.05
		5 µL	4.0	0.2	2.0	0.1
		10 µL	2.0	0.2	1.0	0.1
10 µL – 100 µL	2 µL – 200 µL yellow 53 mm	10 µL	3.0	0.3	2.0	0.2
		50 µL	1.0	0.5	0.8	0.4
		100 µL	0.8	0.8	0.3	0.3
30 µL – 300 µL	20 µL – 300 µL orange 55 mm	30 µL	3.0	0.9	1.0	0.3
		150 µL	1.0	1.5	0.5	0.75
		300 µL	0.6	1.8	0.3	0.9

9.9 Research – Error of measurement

9.9.1 Research – Fixed volume single-channel pipette

Model	Testing tip epT.I.P.S.	Error of measurement			
		Systematic error		Random error	
		± %	± µL	± %	± µL
10 µL	2 µL – 200 µL yellow 53 mm	1.2	0.12	0.6	0.06
20 µL		1.0	0.2	0.3	0.06
25 µL		1.0	0.25	0.3	0.075
50 µL		0.7	0.35	0.3	0.15
100 µL		0.6	0.6	0.2	0.2
200 µL	0.05 mL – 1 mL blue 71 mm	0.6	1.2	0.2	0.4
250 µL		0.6	1.5	0.2	0.5
500 µL		0.6	3.0	0.2	1.0
1000 µL		0.6	6.0	0.2	2.0

9.9.2 Research – Variable volume single-channel pipette

Model	Testing tip epT.I.P.S.	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± µL	± %	± µL
0.1 µL – 2.5 µL	0.1 µL – 10 µL dark gray 34 mm	0.25 µL	12.0	0.03	6.0	0.015
		1.25 µL	2.5	0.031	1.5	0.019
		2.5 µL	1.4	0.035	0.7	0.018
0,5 µL – 10 µL	0.5 µL – 20 µL L light gray 46 mm	1 µL	2.5	0.025	1.8	0.018
		5 µL	1.5	0.075	0.8	0.04
		10 µL	1.0	0.1	0.4	0.04
2 µL – 20 µL	2 µL – 200 µL0 yellow 53 mm	2 µL	5.0	0.1	1.5	0.03
		10 µL	1.2	0.12	0.6	0.06
		20 µL	1.0	0.2	0.3	0.06
10 µL – 100 µL	2 µL – 200 µL yellow 53 mm	10 µL	3.0	0.3	1.0	0.1
		50 µL	1.0	0.5	0.3	0.15
		100 µL	0.8	0.8	0.2	0.20

Model	Testing tip epT.I.P.S.	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± µL	± %	± µL
20 µL – 200 µL	2 µL– 200 µL yellow 53 mm	20 µL	2.5	0.5	0.7	0.14
		100 µL	1.0	1.0	0.3	0.3
		200 µL	0.6	1.2	0.2	0.4
100 µL – 1000 µL	0.05 mL – 1 mL blue 71 mm	100 µL	3.0	3.0	0.6	0.6
		500 µL	1.0	5.0	0.2	1.0
		1000 µL	0.6	6.0	0.2	2.0
0.5 mL – 5 mL	0.1 mL – 5 mL violet 120 mm	0.5 mL	2.4	12	0.6	3.0
		2.5 mL	1.2	30	0.25	6.25
		5.0 mL	0.6	30	0.15	7.5
1 mL – 10 mL	1 mL – 10 mL turquoise 165 mm	1.0 mL	3.0	30	0.6	6.0
		5.0 mL	0.8	40	0.2	10
		10.0 mL	0.6	60	0.15	15

9.9.3 Research – Variable volume multi-channel pipette

Model	Testing tip epT.I.P.S.	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± µL	± %	± µL
0.5 µL – 10 µL	0.5 µL – 20 µL L light gray 46 mm	1 µL	8.0	0.08	5.0	0.05
		5 µL	4.0	0.2	2.0	0.1
		10 µL	2.0	0.2	1.0	0.1
10 µL – 100 µL	2 µL – 200 µL yellow 53 mm	10 µL	3.0	0.3	2.0	0.2
		50 µL	1.0	0.5	0.8	0.4
		100 µL	0.8	0.8	0.3	0.3
30 µL – 300 µL	20 µL – 300 µL orange 55 mm	30 µL	3.0	0.9	1.0	0.3
		150 µL	1.0	1.5	0.5	0.75
		300 µL	0.6	1.8	0.3	0.9

9.10 Research plus – Error of measurement

9.10.1 Research plus – Fixed volume single-channel pipette

Model	Testing tip epT.I.P.S.	Error of measurement			
		Systematic error		Random error	
		± %	± µL	± %	± µL
10 µL	0.1 µL – 20 µL medium gray 40 mm	1.2	0.12	0.6	0.06
20 µL	0.5 µL – 20 µL L light gray 46 mm	0.8	0.16	0.3	0.06
10 µL	2 µL – 200 µL yellow 53 mm	1.2	0.12	0.6	0.06
20 µL		1.0	0.2	0.3	0.06
25 µL		1.0	0.25	0.3	0.08
50 µL		0.7	0.35	0.3	0.15
100 µL		0.6	0.6	0.2	0.2
200 µL		0.6	1.2	0.2	0.4
200 µL	50 µL – 1000 µL blue 71 mm	0.6	1.2	0.2	0.4
250 µL		0.6	1.5	0.2	0.5
500 µL		0.6	3.0	0.2	1.0
1000 µL		0.6	6.0	0.2	2.0

9.10.2 Research plus – Variable volume single-channel pipette

Model	Testing tip epT.I.P.S.	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± µL	± %	± µL
0.1 µL – 2.5 µL	0.1 µL – 10 µL dark gray 34 mm	0.1 µL	48	0.048	12	0.012
		0.25 µL	12	0.03	6.0	0.015
		1.25 µL	2.5	0.031	1.5	0.019
		2.5 µL	1.4	0.035	0.7	0.018
0.5 µL – 10 µL	0.1 µL – 20 µL medium gray 40 mm	0.5 µL	8.0	0.04	5.0	0.025
		1 µL	2.5	0.025	1.8	0.018
		5 µL	1.5	0.075	0.8	0.04
		10 µL	1.0	0.1	0.4	0.04
2 µL – 20 µL	0.5 µL – 20 µL L light gray 46 mm	2 µL	5.0	0.1	1.5	0.03
		10 µL	1.2	0.12	0.6	0.06
		20 µL	1.0	0.2	0.3	0.06
2 µL – 20 µL	2 µL – 200 µL yellow 53 mm	2 µL	5.0	0.1	1.5	0.03
		10 µL	1.2	0.12	0.6	0.06
		20 µLL	1.0	0.2	0.3	0.06
10 µL – 100 µL	2 µL – 200 µL yellow 53 mm	10 µL	3.0	0.3	1.0	0.1
		50 µL	1.0	0.5	0.3	0.15
		100 µL	0.8	0.8	0.2	0.2
20 µL – 200 µL	2 µL – 200 µL yellow 53 mm	20 µL	2.5	0.5	0.7	0.14
		100 µL	1.0	1.0	0.3	0.3
		200 µL	0.6	1.2	0.2	0.4
30 µL – 300 µL	20 µL – 300 µL orange 55 mm	30 µL	2.5	0.75	0.7	0.21
		150 µL	1.0	1.5	0.3	0.45
		300 µL	0.6	1.8	0.2	0.6
100 µL – 1000 µL	50 µL – 1000 µL blue 71 mm	100 µL	3.0	3.0	0.6	0.6
		500 µL	1.0	5.0	0.2	1.0
		1000 µL	0.6	6.0	0.2	2.0
0.5 mL – 5 mL	0.1 mL – 5 mL violet 120 mm	0.5 mL	2.4	12	0.6	3
		2.5 mL	1.2	30	0.25	6.25
		5.0 mL	0.6	30	0.15	7.5

Model	Testing tip epT.I.P.S.	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± µL	± %	± µL
0.5 mL – 5 mL	0.1 mL – 5 mL L violet 175 mm	0.5 mL	5.0	25	1.0	5
		2.5 mL	3.0	75	0.9	22.5
		5.0 mL	2.0	100	0.8	40
1 mL – 10 mL	1 mL – 10 mL turquoise 165 mm	1.0 mL	3.0	30	0.6	6
		5.0 mL	0.8	40	0.2	10
		10.0 mL	0.6	60	0.15	15
1 mL – 10 mL	1 mL – 10 mL L turquoise 243 mm	1.0 mL	6.0	60	1.0	10
		5.0 mL	3.0	150	0.9	45
		10.0 mL	2.0	200	0.7	70

9.10.3 Research plus – Variable volume multi-channel pipette

Model	Testing tip epT.I.P.S.	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± µL	± %	± µL
0.5 µL – 10 µL	0.1 µL – 20 µL medium gray 40 mm	0.5 µL	12	0.06	8.0	0.04
		1 µL	8.0	0.08	5.0	0.05
		5 µL	4.0	0.2	2.0	0.1
		10 µL	2.0	0.2	1.0	0.1
10 µL – 100 µL	2 µL – 200 µL yellow 53 mm	10 µL	3.0	0.3	2.0	0.2
		50 µL	1.0	0.5	0.8	0.4
		100 µL	0.8	0.8	0.3	0.3
30 µL – 300 µL	20 µL – 300 µL orange 55 mm	30 µL	3.0	0.9	1.0	0.3
		150 µL	1.0	1.5	0.5	0.75
		300 µL	0.6	1.8	0.3	0.9

9.11 Research pro – Error of measurement

9.11.1 Research pro – Variable volume single-channel pipette

Model	Testing tip epT.I.P.S.	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± µL	± %	± µL
0.5 µL – 10 µL	0.5 µL – 20 µL L light gray 46 mm	1 µL	2.5	0.025	1.8	0.018
		5 µL	1.5	0.075	0.8	0.04
		10 µL	1.0	0.1	0.4	0.04
5 µL – 100 µL	2 µL – 200 µL yellow 53 mm	10 µL	2.0	0.2	1.0	0.1
		50 µL	1.0	0.5	0.3	0.15
		100 µL	0.8	0.8	0.2	0.2
20 µL – 300 µL	20 µL – 300 µL orange 55 mm	30 µL	2.5	0.75	0.7	0.21
		150 µL	1.0	1.5	0.3	0.45
		300 µL	0.6	1.8	0.2	0.6
50 µL – 1000 µL	50 µL – 1000 µL blue 71 mm	100 µL	3.0	3.0	0.6	0.6
		500 µL	1.0	5.0	0.2	1.0
		1000 µL	0.6	6.0	0.2	2.0
100 µL – 5000 µL	0.1 mL – 5 mL violet 120 mm	0.5 mL	3.0	15	0.6	3.0
		2.5 mL	1.2	30	0.25	6.25
		5.0 mL	0.6	30	0.15	7.5

9.11.2 Research pro – Variable volume multi-channel pipette

Model	Testing tip epT.I.P.S.	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± µL	± %	± µL
0.5 µL – 10 µL	0.5 µL – 20 µL L light gray 46 mm	1 µL	5.0	0.05	3.0	0.03
		5 µL	3.0	0.15	1.5	0.075
		10 µL	2.0	0.2	0.8	0.08
5 µL – 100 µL	2 µL – 200 µL yellow 53 mm	10 µL	2.0	0.2	2.0	0.2
		50 µL	1.0	0.5	0.8	0.4
		100 µL	0.8	0.8	0.25	0.25
20 µL – 300 µL	20 µL – 300 µL orange 55 mm	30 µL	2.5	0.75	1.0	0.3
		150 µL	1.0	1.5	0.5	0.75
		300 µL	0.6	1.8	0.25	0.75
50 µL – 1250 µL	50 µL – 1250 µL green 76 mm	120 µL	6.0	7.2	0.9	1.08
		600 µL	2.7	16.2	0.4	2.4
		1200 µL	1.2	14.4	0.3	3.6

9.12 Top Buret M/H – Error of measurement

9.12.1 Top Buret H

Model H	Testing volume	Error of measurement			
		Systematic error		Random error	
		± %	± mL	± %	± mL
0.01 mL – 999.9 mL	5 mL	2.0	0.1	1.0	0.05
	25 mL	0.4	0.1	0.2	0.05
	50 mL	0.2	0.1	0.1	0.05

9.12.2 Top Buret M

Model M	Testing volume	Error of measurement			
		Systematic error		Random error	
		± %	± mL	± %	± mL
0.01 mL – 999.9 mL	2.5 mL	2.0	0.05	1.0	0.025
	12.5 mL	0.4	0.05	0.2	0.025
	25 mL	0.2	0.05	0.1	0.025

9.13 Varipette – Error of measurement

Model	Testing tip	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± mL	± %	± mL
2.5 mL – 10 mL	Varitip S-System	2.5 mL	1.0	0.025	0.2	0.005
		5 mL	0.4	0.02	0.2	0.01
		10 mL	0.3	0.03	0.2	0.02
1 mL – 10 mL	Varitip P	1 mL	0.6	0.006	0.2	0.002
		5 mL	0.5	0.025	0.1	0.005
		10 mL	0.3	0.03	0.1	0.01

9.13.1 Maxipettor – Error of measurement

Model	Testing tip	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± mL	± %	± mL
2.5 mL – 10 mL	Maxitip S-System	2.5 mL	1.0	0.025	0.2	0.005
		5 mL	0.4	0.02	0.2	0.01
		10 mL	0.3	0.03	0.2	0.02
1 mL – 10 mL	Maxitip P	1 mL	0.6	0.006	0.2	0.002
		5 mL	0.5	0.025	0.1	0.005
		10 mL	0.3	0.03	0.1	0.01

9.14 Varispenser/Varispenser plus – Error of measurement

9.14.1 Varispenser

Model	Testing volume	Error of measurement			
		Systematic error		Random error	
		± %	± mL	± %	± mL
0.5 mL – 2.5 mL	0.5 mL	6.0	0.015	1.0	0.0025
	1.25 mL	1.2	0.015	0.2	0.0025
	2.50 mL	0.6	0.015	0.1	0.0025
1 mL – 5 mL	1.00 mL	2.5	0.025	0.5	0.0050
	2.50 mL	1.0	0.025	0.2	0.0050
	5.00 mL	0.5	0.025	0.1	0.0050
2 mL – 10 mL	2.00 mL	2.5	0.050	0.5	0.0100
	5.00 mL	1.0	0.050	0.2	0.0100
	10.00 mL	0.5	0.050	0.1	0.0100
5 mL – 25 mL	5.00 mL	2.5	0.125	0.5	0.0250
	12.50 mL	1.0	0.125	0.2	0.0250
	25.00 mL	0.5	0.125	0.1	0.0250
10 mL – 50 mL	10.00 mL	2.5	0.250	0.5	0.0500
	25.00 mL	1.0	0.250	0.2	0.0500
	50.00 mL	0.5	0.250	0.1	0.0500
20 mL – 100 mL	20.00 mL	2.5	0.500	0.5	0.1000
	50.00 mL	1.0	0.500	0.2	0.1000
	100.00 mL	0.5	0.500	0.1	0.1000

9.14.2 Varispenser plus

Model	Testing volume	Error of measurement			
		Systematic error		Random error	
		± %	± mL	± %	± mL
0.5 mL – 2.5 mL	0.5 mL	6.0	0.015	1.0	0.0025
	1.25 mL	1.2	0.015	0.2	0.0025
	2.50 mL	0.6	0.015	0.1	0.0025
1 mL – 5 mL	1.00 mL	2.5	0.025	0.5	0.0050
	2.50 mL	1.0	0.025	0.2	0.0050
	5.00 mL	0.5	0.025	0.1	0.0050
2 mL – 10 mL	2.00 mL	2.5	0.050	0.5	0.0100
	5.00 mL	1.0	0.050	0.2	0.0100
	10.00 mL	0.5	0.050	0.1	0.0100
5 mL – 25 mL	5.00 mL	2.5	0.125	0.5	0.0250
	12.50 mL	1.0	0.125	0.2	0.0250
	25.00 mL	0.5	0.125	0.1	0.0250
10 mL – 50 mL	10.00 mL	2.5	0.250	0.5	0.0500
	25.00 mL	1.0	0.250	0.2	0.0500
	50.00 mL	0.5	0.250	0.1	0.0500
20 mL – 100 mL	20.00 mL	2.5	0.500	0.5	0.1000
	50.00 mL	1.0	0.500	0.2	0.1000
	100.00 mL	0.5	0.500	0.1	0.1000

9.15 Xplorer/Xplorer plus – Error of measurement

9.15.1 Xplorer/Xplorer plus – Variable volume single-channel pipette

Model	Testing tip epT.I.P.S.	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± µL	± %	± µL
0.5 µL – 10 µL	0.1 µL – 20 µL medium gray 40 mm	1 µL	2.5	0.025	1.8	0.018
		5 µL	1.5	0.075	0.8	0.04
		10 µL	1.0	0.1	0.4	0.04
5 µL – 100 µL	2 µL – 200 µL yellow 53 mm	10 µL	2.0	0.2	1.0	0.1
		50 µL	1.0	0.5	0.3	0.15
		100 µL	0.8	0.8	0.2	0.2
15 µL – 300 µL	15 µL – 300 µL orange 55 mm	30 µL	2.5	0.75	0.7	0.21
		150 µL	1.0	1.5	0.3	0.45
		300 µL	0.6	1.8	0.2	0.6
50 µL – 1000 µL	50 µL – 1000 µL blue 71 mm	100 µL	3.0	3.0	0.6	0.6
		500 µL	1.0	5.0	0.2	1
		1000 µL	0.6	6.0	0.2	2
0.2 mL – 5 mL	0.1 mL – 5 mL violet 120 mm	0.5 mL	3.0	15.0	0.6	3
		2.5 mL	1.2	30.0	0.25	6.25
		5 mL	0.6	30.0	0.15	7.5
0.5 mL – 10 mL	1 mL – 10 mL turquoise 165 mm	1 mL	3.0	30.0	0.60	6.0
		5 mL	0.8	40.0	0.20	10.0
		10 mL	0.6	60.0	0.15	15.0

9.15.2 Xplorer/Xplorer plus – Variable volume multi-channel pipette

Model	Testing tip epT.I.P.S.	Testing volume	Error of measurement			
			Systematic error		Random error	
			± %	± µL	± %	± µL
0.5 µL – 10 µL	0.1 µL – 20 µL medium gray 40 mm	1 µL	5.0	0.05	3.0	0.03
		5 µL	3.0	0.15	1.5	0.075
		10 µL	2.0	0.2	0.8	0.08
5 µL – 100 µL	2 µL – 200 µL yellow 53 mm	10 µL	2.0	0.2	2.0	0.2
		50 µL	1.0	0.5	0.8	0.4
		100 µL	0.8	0.8	0.25	0.25
15 µL – 300 µL	15 µL – 300 µL orange 55 mm	30 µL	2.5	0.75	1.0	0.3
		150 µL	1.0	1.5	0.5	0.75
		300 µL	0.6	1.8	0.25	0.75
50 µL – 1200 µL	50 µL – 1250 µL green 76 mm	120 µL	6.0	7.2	0.9	1.08
		600 µL	2.7	16.2	0.4	2.4
		1200 µL	1.2	14.4	0.3	3.6

9.16 Maximum permissible errors in accordance with EN 8655

The maximum permissible errors always refer to the complete pipette and pipette tip system. If the nominal volume of the pipette is between two values, the absolute maximum permissible errors for the next largest nominal volume apply. The absolute maximum permissible errors relating to the nominal volume apply to every selectable volume. In the following, an example for calculating the relative maximum permissible error of nominal volumes not listed in the ISO tables is given. The absolute and relative maximum permissible errors depending on the volume are also listed. For multi-channel pipettes, the maximum permissible errors are twice the value of those indicated for single-channel pipettes.

9.16.1 Example – Reference 2

The absolute errors of measurement of the nominal volume are applied to all other selectable volumes. For this purpose, the percentage error of measurement from the absolute error of measurement of nominal volumes must be calculated for the respective selectable volume.

100 % nominal volume:
- Nominal volume: 2500 µL
- Absolute systematic error: 40 µL
- Relative systematic error: 1.6 %
- Absolute random error: 15 µL
- Relative random error: 0.6 %

50 % nominal volume:
- Useful volume range: 1250 µL
- Absolute systematic error: 40 µL
- Relative systematic error: 3.2 %
- Absolute random error: 15 µL
- Relative random error: 1.2 %

10 % nominal volume:
- Useful volume range: 250 µL
- Absolute systematic error: 40 µL
- Relative systematic error: 16 %
- Absolute random error: 15 µL
- Relative random error: 6 %

9.16.2 Air-cushion pipettes with fixed and variable volume

- Reference
- Reference 2
- Research
- Research plus
- Research pro
- Xplorer
- Xplorer plus

Nominal volume	Maximum permissible errors			
	Systematic error		Random error	
	± %	± µL	± %	± µL
1 µL	5.0	0.05	5.0	0.05
2 µL	4.0	0.08	2.0	0.04
5 µL	2.5	0.125	1.5	0.075
10 µL	1.2	0.12	0.8	0.08
20 µL	1.0	0.2	0.5	0.1
50 µL	1.0	0.5	0.4	0.2
100 µL	0.8	0.8	0.3	0.3
200 µL	0.8	1.6	0.3	0.6
500 µL	0.8	4.0	0.3	1.5
1000 µL	0.8	8.0	0.3	3.0
2000 µL	0.8	16	0.3	6.0
5000 µL	0.8	40	0.3	15.0
10000 µL	0.6	60	0.3	30.0

9.16.3 Positive displacement pipettes

- Biomaster
- Varipette/Maxipettor

Nominal volume	Maximum permissible errors			
	Systematic error		Random error	
	± %	± µL	± %	± µL
5 µL	2.5	0.13	1.5	0.08
10 µL	2.0	0.2	1.0	0.1
20 µL	2.0	0.4	0.8	0.16
50 µL	1.4	0.7	0.6	0.3
100 µL	1.5	1.5	0.6	0.6
200 µL	1.5	3.0	0.4	0.8
500 µL	1.2	6.0	0.4	2.0
1000 µL	1.2	12.0	0.4	4.0

9.16.4 Multi-dispenser

- Multipette plus
- Multipette/Repeater E3
- Multipette/Repeater E3x
- Multipette/Repeater M4
- Multipette stream
- Multipette Xstream

Nominal volume	Maximum permissible errors			
	Systematic error		Random error	
	± %	± µL	± %	± µL
0.001 mL	5.0	0.05	5.0	0.05
0.002 mL	5.0	0.1	5.0	0.1
0.003 mL	2.5	0.075	3.5	0.11
0.01 mL	2.0	0.2	2.5	0.25
0.02 mL	1.5	0.3	2.0	0.4
0.05 mL	1.0	0.5	1.5	0.75
0.1 mL	1.0	1.0	1.0	1.0
0.2 mL	1.0	2.0	1.0	2.0
0.5 mL	1.0	5.0	0.6	3.0
1 mL	1.0	10	0.4	4.0
2 mL	0.8	16	0.4	8.0
5 mL	0.6	30	0.3	15
10 mL	0.5	50	0.3	30
25 mL	0.5	125	0.3	75
50 mL	0.5	250	0.25	125
100 mL	0.5	500	0.25	250
200 mL	0.5	1000	0.25	500

9.16.5 Single stroke dispenser

- Varispenser
- Varispenser plus

Nominal volume	Maximum permissible errors			
	Systematic error		Random error	
	± %	± µL	± %	± µL
0.01 mL	2.0	0.2	1.0	0.1
0.02 mL	2.0	0.4	0.5	0.1
0.05 mL	1.5	0.75	0.4	0.2
0.1 mL	1.5	1.5	0.3	0.3
0.2 mL	1.0	2.0	0.3	0.6
0.5 mL	1.0	5.0	0.2	1.0
1 mL	0.6	6.0	0.2	2.0
2 mL	0.6	12.0	0.2	4.0
5 mL	0.6	30.0	0.2	10.0
10 mL	0.6	60.0	0.2	20.0
25 mL	0.6	150.0	0.2	50.0
50 mL	0.6	300.0	0.2	100
100 mL	0.6	600.0	0.2	200
200 mL	0.6	1200	0.2	400

9.16.6 Piston-stroke burets

- Top Buret H
- Top Buret M

Nominal volume	Maximum permissible errors			
	Systematic error		Random error	
	± %	± µL	± %	± µL
≤ 1 mL	0.6	6.0	0.1	1.0
2 mL	0.5	10	0.1	2.0
5 mL	0.3	15	0.1	5.0
10 mL	0.3	30	0.1	10
20 mL	0.2	40	0.1	20
25 mL	0.2	50	0.1	25
50 mL	0.2	100	0.1	50
100 mL	0.2	200	0.1	100

10 Adjustment

Making an adjustment sets the dispensing volume in such a way that systematic error is minimized for the intended application.

An adjustment can be useful due to deviating calibration results or due to deviating conditions.

An adjustment does not influence the random error. The random error can be reduced by exchanging worn parts. The random error is also influenced by handling.

10.1 Adjusting in case of deviating calibration results

If the calibration results of mechanical pipettes are outside of the permissible thresholds, an adjustment may be necessary.

Compared to mechanical pipettes, an electronic pipette is adjusted with a fifth degree polynomial function along the complete stroke length. For this reason, the user cannot adjust an adjustment of the manufacturer. If the measuring results are outside of the manufacturer thresholds, the pipette is defective and should be sent to an authorized service.

10.1.1 Checking the reasons for a dispensing deviation

All external influencing factors must be ruled out before a pipette is adjusted.

- The tip cone is OK
- The pipette tip is compatible with the pipette
- The dispensing system is leak-tight (pipette and pipette tip)
- Test liquid was aspirated and dispensed 5 times (saturated air cushion)
- The test liquid, dispenser and ambient air have the same temperature
- The test liquid meets the ISO 3696 requirements
- Immersion depth during liquid aspiration complied with
- Liquid dispensing against the tube inner wall
- Pipetting speed is set correctly
- The balance resolution matches the testing volume
- No draft at weighing location
- Evaluation of measuring results performed correctly

▸ Decide if an adjustment is required.
▸ Adjust dispenser (see product information www.eppendorf.com/manuals).

The dispenser can also be sent to the authorized service for adjustment.

10.2 Adjusting in case of deviating conditions

The physical properties of liquids and the ambient conditions are significant influencing factors for piston-stroke pipettes. Mechanical and electronic pipettes can be adjusted to these conditions.

Changing the adjustment is useful in the following cases:

- Liquids whose physical properties (density, viscosity, surface tension, vapor pressure) differ significantly from those of water
- Capillary action during the immersion of the pipette tip (e.g., in the case of DMSO)
- Changes in the atmospheric pressure due to the altitude at which the pipette is used
- Pipette tips whose geometry differs significantly from standard tips (e.g., epT.I.P.S.)

▶ Adjust dispenser (see product information www.eppendorf.com/manuals).

Index

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