



### **Slide # 1 Cover Slide**

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Speaker's Suggestion: show this slide when audience is filing into room and when you (and Rainin) are being introduced to audience

Estimated Module 1 duration 20 minutes, with workshop 30 minutes.

Recommended Equipment and Literature.

- Technical Paper (TBA)
- P-200 and L-200 with appropriate Tips
- Completion Certificate

Workshop Equipment (for 20 People)

- 10 P-200
- 10 L-200
- 1 pkg RT-250
- 1 pkg RT-L250
- Reservoirs

## Rainin Instrument, LLC



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# Improving Pipetting Techniques

for Better Accuracy  
and Performance



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### Slide #2 Introduction / Title Slide

Good morning/afternoon. My name is \_\_\_\_\_, and I am a Sales (Service) Representative for Rainin Instrument LLC, manufacturers and distributors of Advanced Ergonomic Manual and Electronic Pipettes.

I am here at the request of \_\_\_\_\_ and I appreciate the opportunity to speak with you today about improving your pipetting techniques for achieving better accuracy and performance.

# Improving pipetting techniques

## I. Basic Pipetting Techniques

A. Gravimetric Analysis

B. Workshop

## II. Applications

## III. Calibration and Preventive Maintenance

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### Slide #3 Presentation Overview

This seminar is arranged to cover three topics, or modules.

**The Goals of the Seminar** will be to review and discuss:

- 1) The basics of air-displacement pipetting and suggestions for improving technique and reducing pipetting errors
  - a) Gravimetric analysis of pipettes
- 2) Selecting a pipette and tip to fit your specific application; and
- 3) Pipette preventive maintenance

## Basic pipetting techniques



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- Pipette cycle
- Optimizing volume range
- Specifications
- Basic techniques
  - Minimizing errors
  - Workshop (optional)

I. Basic Pipetting Techniques

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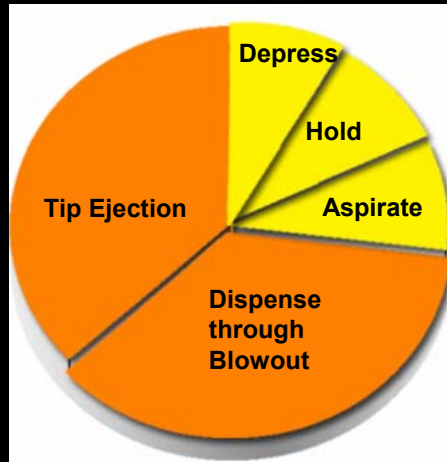
### Slide # 4 Basic Pipetting Techniques

In this module we will review the basics of pipetting, including:

- The sequence of steps involved in the pipetting cycle;
- How to select and work within the optimal volume range for your pipette;
- Basic design characteristics of air-displacement pipettes and their general specifications for accuracy and precision; and
- We will present and discuss the different pipetting techniques that you can begin to use immediately to achieve better accuracy and performance and minimize pipetting error.

Optional: At the conclusion of this presentation module, I'd like to conduct a brief workshop where you'll each be able to practice the basic pipetting techniques that will be covered in the seminar.

## Review pipetting cycle



Air-Displacement Pipette

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### Slide #5 Review Pipetting Cycle

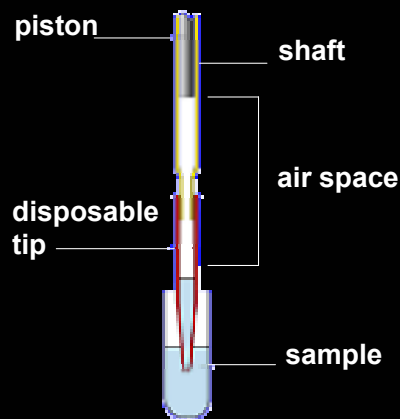
The pipetting cycle for air-displacement pipettes involves 5 steps, as illustrated in the pie-chart. I'm sure most of you are familiar with this cycle, but to review briefly: **(Demo with a pipette)**

- Step 1 is to depress the plunger from its rest, or home position, by pushing down on the button at the top of the pipette.
- The plunger button is advanced to the first stop, which is the hold point in Step 2 of the cycle.
- The pipette tip is then inserted into the liquid sample and to aspirate the sample (Step 3), the plunger button is released slowly, allowing the plunger to move upwards to its home position.
- Step 4 actually involves 2 components, dispense and blowout. To dispense your sample, depress the plunger button smoothly, passing the first stop position, advancing further past the hold position to the second stop to blowout any remaining sample liquid from the tip. The pipette tip is ejected in Step 5.

**Q:** Is the pie chart indicating time required?

**A:** The pie chart is actually indicating typical force required which you will learn more about

## Air-Displacement Pipette



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### Slide # 6 Air-Displacement Pipette

Perhaps greater than 95% of you are using an air-displacement pipette in your laboratory or research work.

**Air-displacement pipettes utilize a partial vacuum to draw liquid into the tip. The partial vacuum is created when the pipette piston is mechanically moved and down within the pipette body by using the pipette plunger.**

Since air at atmospheric pressure wants to fill the void space that a piston displaces, an air column is created inside the pipette capillary or tip. **The column of air, now under the pressure of a partial vacuum, will draw liquid into the tip.**

Air-displacement pipettes can be single or multi-channel, manually operated or electronic. Air-displacement pipettes are used for transfer of aqueous samples (properties similar to water) and general laboratory work.

**Q:** What about positive displacement pipettes?

**A:** I will cover that in the next module.

## Optimizing volume range

- Normal Range
  - 10% - 100% of volume  
Operating at 10% range requires good technique
- Optimizing Range
  - 35% - 100% of volume  
Less technique dependent  
Assures accuracy and precision

Optimizing volume range improves accuracy 0.5% - 1%

### Slide # 7 Optimizing Volume Range

In your laboratory or research work you may be using a 100 micro-liter pipette and perhaps you typically pipette 50 micro-liter samples, or 50% of the nominal range of the pipette.

By using an air-displacement pipette at 50% of its nominal volume, you were pipetting within the “optimized range” for the pipette.

What this means in terms of technique is that you optimized your ability to achieve the specified accuracy of the pipette, regardless of your level of pipetting skill and experience.

**Researchers and technicians who operate a pipette at 10% of its nominal range (for example – using a 100 micro-liter pipette to pipette 10 micro-liter samples) need to have reasonable pipetting skill to achieve the specified accuracy and precision.**

**Operating within a range of 35% of nominal volume or higher is less technique dependant and allows less skilled operators to pipette accurately and precisely.**

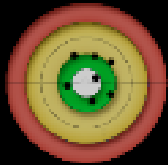
**Q:** Do you mean that when I use the pipette below 35%, it will be less accurate?

**A:** Yes, that is true. It will tend to be less accurate due to the reduced piston stroke length, which is fundamental to the performance for the pipette. For example, if given a choice between pipetting 40 micro-liters with a P-200 vs. a P-100, you could expect significantly better results using the P-100 due to the increased length in piston stroke travel.

**A:** If you were to refer to you published specifications, you will typically see that the margin of error is higher at the low volume setting. This is because ... [piston stroke length]

## Typical pipette specifications

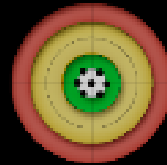
- Accuracy +/- 1%
- Precision 0.25% to 0.33%
  - Micropipette specifications are wider



Accurate,  
but not precise



Precise,  
but not accurate



Accurate  
and precise

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### Slide # 8 Pipette Specifications

Before we begin our review of specific pipetting techniques, I want to define pipette accuracy, as well as another important term – precision.

• **Accuracy is the ability of a pipette to give a response close to a true or nominal volume as indicated by the volume setting.** Typical accuracy specifications for air-displacement pipettes are approximately 1% for pipettes with nominal volume settings greater than 35%. For pipette volume settings less than 35%, the specifications can be as much as 3 times less accurate.

• **Precision is a qualitative term and is the ability of the pipette to provide closely similar responses.** A typical precision specification for air-displacement pipettes is about 1/3 to 1/4 of the accuracy specification. **Precision is often referred to as repeatability or sample reproducibility, and also as standard deviation.**

Now that we've reviewed the pipetting cycle and defined and discussed terms such as accuracy, precision and optimized volume range, I would like to discuss the basics of proper pipetting technique and review some recommended techniques to help you improve your pipetting results and achieve the best possible accuracy and precision in your work.

## Pipetting techniques

- Micrometer setting
- Tip immersion angle
- Tip immersion depth
- Pre-rinsing
- Aspiration rate
- Touch-off technique
- Consistency
- Hand-warming effects



### Slide # 9 Pipetting Techniques

Specifically, we will review the basics of:

- Proper micrometer setting techniques;
- Recommended Tip Immersion Angle and Depth;
- We'll discuss some lesser utilized techniques such as pre-rinsing and its benefits and drawbacks;
- Review the effects of sample aspiration rate on pipetting technique and results;
- Define and illustrate droplet touch-off, and
- Discuss the importance of consistency in pipetting technique;
- We will review the effects of handwarming on pipetting results

## Setting the micrometer

- Approach each volume in the same direction each time
- Turn micrometer 1/3 revolution above desired volume
- “Dial-down” to volume setting



Correctly setting the volume improves accuracy 0.5% - 1%

### Slide # 10 – Setting the Micrometer

**When setting the pipette micrometer, it's important to always approach the desired volume in the same direction each time. Recommended technique is to “dial down” to the desired volume setting, rotating the volume selector knob clockwise.**

When decreasing the volume setting from a higher to lower volume, simply dial down to the desired volume setting, but be careful not to overshoot the required position.

When increasing the volume setting from a lower volume to a higher volume, rotate the volume selector wheel or knob approximately 1/3 of a turn above the desired setting, and then slowly turn back clockwise to decrease the volume until you reach the desired setting.

**The “dial down” technique reduces the effects of mechanical backlash or slippage of the micrometer gears and assures better accuracy.**

## Tip immersion angle



**Incorrect** immersion angle



**Correct** immersion angle

Aspirating with pipette perpendicular improves accuracy 1% - 5%

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### Slide # 11 Tip Immersion Angle

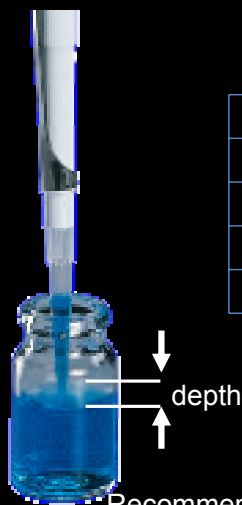
This slide clearly illustrates one of the most common incorrect pipetting techniques – incorrect immersion angle.

I'm sure that all of us have watched someone or have ourselves held a pipette at a 45 degree angle when aspirating a liquid sample.

**Rainin's recommendation is to keep the immersion angle as close to the vertical position as possible, or no greater than a 20 degree angle from the vertical.**

**Aspirating an sample at an angle of greater than 20 degrees has been shown to affect sample accuracy by 1% or more, particularly in micro-volume pipettes.**

## Tip immersion depth



Pipette size	Immersion depth
2 and 10 $\mu\text{L}$	1 mm
20 and 100 $\mu\text{L}$	2-3 mm
200 and 1000 $\mu\text{L}$	3-6 mm
5000 $\mu\text{L}$ and 10 mL	6-10 mm

Recommended immersion depths improve accuracy 1% - 5%

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### Slide # 12 Tip immersion depth

The immersion depth of your pipette tip can have a significant effect on your results.

If the tip is immersed too deeply, liquid will rise into the tip due to the effects of air pressure. In this case, more sample volume than is desired could be aspirated.

If the tip is not immersed deep enough, air could be aspirated into the tip and your pipette will not accurately aspirate the selected volume. It is also possible that insufficient tip immersion depth could result in sample splash-up effects. We will discuss the problems associated with sample splash-up later in this module.

**Rainin suggests maintaining the recommended immersion depths shown on this slide for accurate and precise results. As a general guideline, the pipette tip should just break the surface of the liquid sample.**

## Pre-rinsing pipette tips

- Pre-rinsing tip with same liquid that is being dispensed
- Aspirate with tip, and then dispense back into reservoir or to waste
- Provides identical contact surfaces for all aliquots

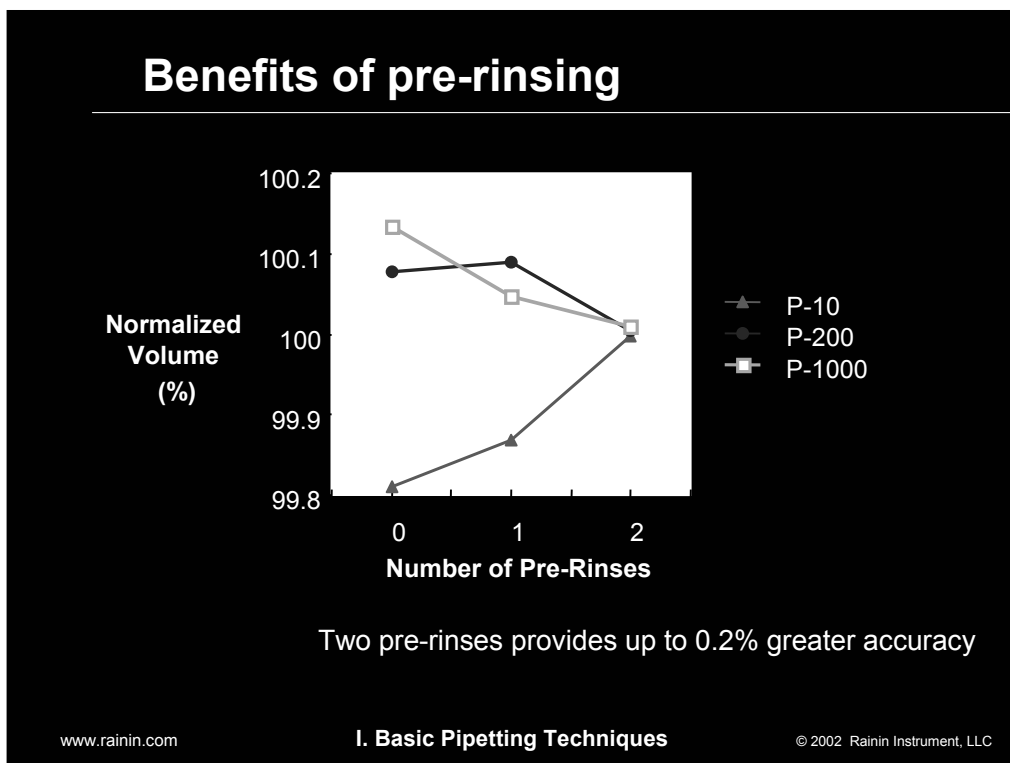


### Slide # 13 Pre-rinsing Pipette Tips

A majority of pipette users do not pre-rinse tips. However, **greater uniformity and precision of dispensing are usually obtained by providing identical contact surfaces for all sample aliquots.**

This is achieved by pre-rinsing, or pre-wetting the pipette tips with the same liquid that is being dispensed. **Rainin recommends two pre-rinses every time you change a tip and whenever critical reproducibility is required, especially with more viscous liquids.**

To pre-rinse, aspirate liquid sample with the tip and then dispense back into the original sample reservoir or to waste.



### Slide # 14 Benefits of Pre-rinsing

This slide illustrates one type of experiment using several different volume pipettes to demonstrate the effects of tip pre-rinsing on sample volume delivery. As shown on the graph, pre-rinsing pipette tips two times provides greater consistency in sample volume delivery in this experiment.

We should note, also, that a 0.2% volume error resulting from failure to pre-rinse tips is classified as a “small error,” or an error that would be of significance only to pipette calibrators and not to typical laboratory pipette users.

Conversely, pre-rinsing tips for samples that are not at ambient temperatures can result in much larger errors of 1 to 5% of volume.

**Q:** Why do different models behave differently when prerinsing?

**A:** Due to the physical characteristics of each model, (such as the amount of air column, orifice size, etc.) the behavior is not consistent. Regardless, variation in accuracy is all neutralized when two prerinses are performed.

## Aspiration rate effects

- Maintain smooth, controlled aspiration rates
- Aspiration too quickly causes
  - Liquid splash-up into shaft  
Piston and seal damage
  - Introduction of aerosols  
Sample cross-contamination



Consistent, controlled aspiration rates improve accuracy 1% - 5%

### Slide # 15 Aspiration Rate Effects

**When the pipette plunger button is released too rapidly, the aspirated liquid sample can cause several technique related problems in pipetting.**

**Introduction of aerosols is probably the most common effect**, and is caused by rapid plunger release which propels micro-sized liquid droplets onto the pipette shaft or internal components. These aerosol droplets can cause cross contamination when droplets from one sample are transferred to the next sample.

**Even more dramatic are the effects of liquid splash up.** Splash up also occurs when the plunger is released too quickly and liquid is propelled into the the internal mechanism of the pipette. In both cases – introduction or aerosols and liquid splash up – sample may come into direct contact with the air-displacement's pipette's piston and can cause piston damage if the sample is corrosive.

## Droplet touch-off

- Thin-wall, FinePoint™ tips provide maximum droplet dispensing
- Three techniques
  - 1) Along side-wall
  - 2) Above vessel/ liquid surface
  - 3) Directly into liquid



Correct touch-off improves accuracy 0.5% - 1%

### Slide # 16 Droplet Touch-off

When dispensing a sample, to assure that the remaining droplet dispenses fully and does not adhere to the tip end surface, Rainin recommends that you utilize one of the following techniques:

- **Remove the pipette tip from the receiving vessel by sliding the tip end up the side-wall and releasing any remaining droplet. This is the preferred technique for achieving higher accuracy and precision;**

or, alternatively, if your specific application does not allow dispensing along the vessel side-wall,

- **Use a FinePoint pipette tip and dispense the sample above the vessel (above liquid surface), or directly into the liquid**

**The reduced surface area at the orifice, or opening, of a thin-wall or FinePoint tip allows the droplet to fully release. The result is more accurate and precise droplet touch-off and better sample-to-sample reproducibility.** Due to the small sample volumes involved, droplet touch-off is more critical with micro-volume pipetting.

# Consistency

- Use consistent
  - Pipetting rhythm
  - Pressure on plunger
  - Speed and smoothness
- For best consistency
  - Use an electronic pipette
    - Provides optimum consistency
    - Requires less user technique



Consistency in pipetting can improve accuracy up to 5%

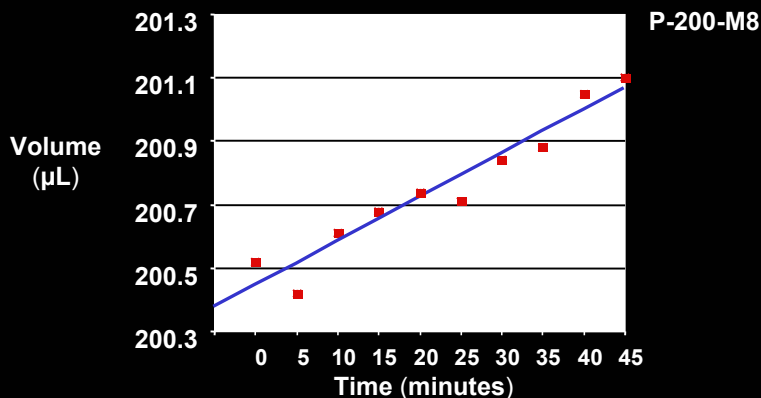
## Slide # 17 Consistency

Maintaining consistency in your pipetting technique is important to achieve high accuracy. Rainin recommends that you utilize:

- Consistent pipetting rhythm from sample-to-sample;
- for example – when using a macro-volume pipette (1 ML or greater), it is important to pause after sample pickup and allow the sample to fully aspirate before removing the tip from the liquid.
- Consistent pressure on the plunger at the first stop point, or hold position is important; - and -
- Consistent speed and smoothness when pressing and releasing the plunger should always be maintained.

By using an electronic pipette, a technician can achieve consistent sample pickup and dispensing which will eliminate most user-to-user technique variability and improve accuracy and repeatability.

## Hand-warming effects



Prolonged hand-warming introduces errors of 0.1% - 0.5%

### Slide # 18 Hand-Warming Effects

One additional effect related to pipetting technique is related to handwarming.

**During regular use, heat is transferred from the user's hand to the body of the pipette. Prolonged handling of the pipette, such as during microwell plate work can result in a noticeable deviation in pipette performance due to temperature variation** between the 1<sup>st</sup> sample aspirated with the pipette at ambient temperature, and later samples collected with a pipette warmed by the hand to within body temperature range.

What we know is that this graph shows one example of an experiment where prolonged handling of the pipette will cause a change in volume over time of as much as 0.4%. It is important to note that high quality pipette bodies are constructed with PVDF – a polymer with a low coefficient of heat transfer which acts as a good insulator against handwarming. **Pipette shafts should not be handled before and during pipetting activities, since shaft handwarming effects are more pronounced**

**Q:** Why did the volume increase over time?

**A:** In this particular case, the piston probably expanded due to heat transfer, which then increased the volume delivered. Depending on the type of construction of the pipette, such as the use of a less insulating plastic, this effect could be far more severe. On the other hand, in a microvolume pipette, you may see the opposite effect of less volume due to the expansion of the air column due to the smaller volume of air.

## Basic pipetting techniques

### summary

- Micrometer setting
- Tip immersion angle and depth
- Pre-rinsing
- Aspiration rate
- Touch-off technique
- Consistency
- Hand-warming effects

### Slide # 19 Basic Pipetting Techniques / Summary

At the beginning of the seminar, we reviewed the 5 steps of the pipetting cycle: depress, hold, aspirate, dispense and blowout, and tip ejection; we defined the accuracy and precision terms, and gave the rationale for operating a pipette in its optimal range of 35% to 100% of its nominal volume.

In our discussion of pipetting techniques, we explained how to set the micrometer by dialing down to the desired volume in the same direction each time to reduce the effects of gear backlash; we illustrated that optimal tip immersion depths should just break the surface of the liquid sample, with recommended tip immersion angles of no more than 20 degrees from the vertical. We discussed tip pre-rinsing and its benefits; and we reviewed the importance of maintaining smooth, controlled aspiration rates when pipetting. We illustrated recommended droplet touch-off technique and its importance in assuring repeatability; and finally, we stressed the importance of maintaining consistent pipetting rhythm, speed and smoothness, and we advised avoiding prolonged hand contact with a pipette.

#### Speaker's Option:

Now I'd like to conduct a brief workshop where you'll each be able to practice the basic pipetting techniques that we covered in the seminar.

## Errors in pipetting

Error Size	Error %	Technique
Small	0.1 - 0.5	<ul style="list-style-type: none"> <li>■ Pre-rinsing</li> <li>■ Hand-warming</li> </ul>
Medium	0.5 - 1.0	<ul style="list-style-type: none"> <li>■ Optimizing Volume</li> <li>■ Micrometer Setting</li> <li>■ Droplet Touch-Off</li> </ul>
Large	1.0 - 5.0	<ul style="list-style-type: none"> <li>■ Tip Immersion Depth/Angle</li> <li>■ Aspiration Rate</li> <li>■ Consistency</li> </ul>

Note: Small errors usually important to calibration technicians. Micropipette errors may be larger.

### Slide #20 Errors in Pipetting

Errors in pipetting can be classified as small, medium, or large. Our discussion and review of the magnitudes and examples of these errors will help you prioritize their significance to your application whether you are a pipette calibrator or pipette user. Regardless, the most important consideration should be that good pipetting technique = minimal errors = good performance.

▪ **Small errors** cause variations of less than 0.5% in the volume of sample delivered by a pipette vs. the desired, or selected volume. In fact the **noise of reproducibility of a pipette when transferred from user-to-user is in the range of 0.2 percent.**

▪ **Medium errors**, defined as 0.5 – 1.0 percent contributed error, result from some of the technique-related practices we previously discussed (**speaker's note: give examples from slide**)

▪ **Large errors**, 1.0 – 5.0%, become more important to most researchers using pipettes in their work and can be reduced or eliminated by practicing proper technique. (**Speakers Note: Give Examples from slide**)



**Slide # 21 Rainin logo**

If you are a technician or researcher who pipettes frequently in your daily work, then I hope that today you have gained some insight into the importance of practicing proper technique in pipetting, and that you will begin to put these techniques into practice in your work to achieve better pipetting accuracy and precision.

This concludes the seminar module on Basic Pipetting Techniques. Thank you very much for your attention.

Speaker's Option:

Now I'd like to conduct a brief workshop where you'll each be able to practice the basic pipetting techniques that we covered in the seminar.

-or - continue with seminar section on Gravimetric Analysis

## Gravimetric analysis

- Unit conversion
- Environmental conditions
- Gravimetric measurement
  - Z-factor correction
- Errors in pipetting

### Slide# 22 Gravimetric Analysis

This seminar [section] will cover gravimetric analysis and will include a discussion of the effects on pipetting performance and results caused by:

- Differences between environmental conditions in the laboratory vs. standard conditions as defined in physics; - and -
- We will recap the associated errors in pipetting caused by these factors.

## Review of physical units

Property	Units	Symbol	Conversions
Mass	Grams	g	$g = \text{cm}^3$
Volume	Liters	L	$\text{mL} = \text{cm}^3$
Pressure	Atmospheres	atm	760 mm (torr)
Temperature	Celsius	C	$^{\circ}\text{F} = \text{C}(9/5) + 32$

### Slide # 23 Review of Physical Units

Let's briefly review the basic units of measure that will be discussed in this seminar section –

- The basic unit of mass is the gram. An important expression in pipette calibration and measurement is the density equation, written as 1 gram equals 1 cubic centimeter, which we will define further in the next slide.
- Volume of liquid is expressed in liters; with 1 liter being equal to 1,000 milliliters. If we were to pour one milliliter of water from a graduated cylinder into a cube, it would occupy a volume of 1 cubic centimeter.
- Pressure is often expressed in inches of mercury or millibars. However, the unit of pressure we work with in pipette calibration and measurement is the atmosphere, equal to about 29.92 inches Hg. Finally, temperature and its conversion of units from degrees Fahrenheit to Celsius is well known to most people.

## Calibration laboratory conditions

- Temperature:  $21.5^{\circ} \pm 1^{\circ}\text{C}$
- Humidity: 45 – 75%
- Evaporation control



### Slide # 24 Calibration Laboratory Conditions

- **These are the conditions under which all Rainin and Gilson pipettes are calibrated. If your lab greatly deviates from these conditions, you could introduce errors into your measurements.**
- Temperature and humidity are self-explanatory; there is not a lot of tolerance in the temperature, essentially  $\pm 1$  degree C
- Our calibrators take extra precautions against evaporation when pipetting microvolumes -- volumes of  $10 \mu\text{l}$  or less. Liquids are dispensed into a small vessel that can be closed to control evaporation.

## Gravimetric measurement of water

- Gravimetrically measure water to determine volume
- DI water  $1 \text{ cm}^3 = 1 \text{ gram}$   
Water density @ standard conditions  $4^\circ\text{C}$  and  $1 \text{ atm}$
- Water density changes with temperature and pressure



### Slide # 25 Gravimetric Measurement of Water

- **The gravimetric method is the primary method recommended by pipette manufacturers and international standard organizations to determine the weight of water samples delivered by a pipette.**
- We've seen that a cubic centimeter of water is equal to 1 milliliter of volume, and that that same cubic centimeter has a measurable weight, which is constant at standard conditions. Therefore, we can say that 1 gram per cubic centimeter is the water density, or the mass of water divided by its volume. Mass is a constant term, unchanging under different conditions. For example a baseball has mass, but if you dropped a baseball into water it would seem lighter, due to the buoyancy effects of water. However its mass remains the same, wet or dry.
- Water density however, is not always equal to 1, and will actually change with changes in water temperature and pressure. We will see in the slide slide, how to correct for these temperature and density differences.

**Q:** I have heard of other methods, such as Spectrophotometry. Can you tell me about that?

**A:** Yes. It is considered secondary and is well known to have a range of uncertainty up to 1%. Gravimetric uncertainty is about  $\frac{1}{4}$  of a percent.

## Z-factor conversion

Water Temp.	Z-factor
19.0	1.0027
19.5	1.0028
20.0	1.0029
20.5	1.0030
21.0	1.0031
21.5	1.0032
22.0	1.0033
22.5	1.0034
23.0	1.0035

- Pressure= 1 atm
- Z-factor=  
1/ (water density – air density)
- Volume ( $\mu\text{L}$ )=  
Z-factor ( $\mu\text{L}/\text{mg}$ )  
 $\times$  Weight (mg)

### Slide # 26 Z-Factor Mass-to-Volume Conversion

- The Z-Factor we discussed in the section overview slide is illustrated on this chart as a conversion factor to get from mass to volume.
- **The Z-factor for pure de-ionized water, at 21 degrees C is 1.0031. Multiply this Z-factor by the weight of water measured gravimetrically on the balance to get the volume, either in microliters or milliliters.**

**Q:** What is the effect of change in barometric pressure?

**A:** The Z-factor will change in value at different barometric pressures, but typically only if a hurricane was outside your door, and only in the 4<sup>th</sup> significant digit.

**Q:** Why did your previous slide say 21.5 but this says 21?

**A:** The previous slide indicated room temperature. This chart indicates water temperature, which is typically one-half degree cooler, thus the difference.

## Errors in pipetting

Error Size	Error %	Technique / Effect
Small	0.1 - 0.5	<ul style="list-style-type: none"> <li>■ Pre-rinsing</li> <li>■ Hand-warming</li> <li>■ <b>Z-factor Calculations</b></li> </ul>
Medium	0.5 - 1.0	<ul style="list-style-type: none"> <li>■ Optimizing Volume</li> <li>■ Micrometer Setting</li> <li>■ Droplet Touch-Off</li> </ul>
Large	1.0 - 5.0	<ul style="list-style-type: none"> <li>■ Tip Immersion Depth/Angle</li> <li>■ Aspiration Rate</li> <li>■ Consistency</li> </ul>

Note: Small errors usually important to calibration technicians. Micropipette errors may be larger.

### Slide # 27 Errors in Pipetting / Magnitudes and Examples

**Small errors** cause variations of only 0.1 to 0.5% in the volume of sample delivered by a pipette vs. the desired, or selected volume. An example of introducing a small error would be neglecting to use the Z-factor correction when performing a pipette calibration, and then using that same pipette to perform your research work.

**Medium errors**, defined as 0.5 to 1.0 percent contributed error, result from some of the technique-related practices we previously discussed,

**Large errors**, 1.0 to 5.0%, become more important to most researchers using pipettes in their work and can be a result of poor pipetting technique.

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LLC**  
a METTLER TOLEDO  
Company

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**www.rainin.com**  
pipets@rainin.com

**Slide # 28 Closing slide (Rainin logo)**

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