Precise Volume Dispense

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FTÅ systems offer several means of dispensing drops. This note will discuss the capabilities and limitations of each.

Classical Syringe Pump

The syringe and needle are filled with the test liquid and drops are dispensed by a stepper motor mechanism pressing the syringe plunger. This is the simplest dispense mechanism. The range of volume dispensed depends on the tip diameter. Since a wide range of tips are available, this is a flexible approach. Liquid may be deposited on a test surface by either pumping until the pendant drop falls off the tip or by forming some intermediate volume drop and then lowering the needle until the bottom of the drop touches the surface and the whole drop detaches. A practical range of volumes is 500ml to 20µl. While its flexibility is good, the precision is relatively poor. By precision, we mean what is actually deposited on the surface compared to what we desire. Precision is expressed as a percentage of the desired volume: a ±10% precision on 10µl means the actual volume is between 9 and 11µl. Two phenomena limit precision with the syringe:

- small drops have significant interfacial pressure from Laplace's formula $\Delta P = \gamma (1/R_1 + 1/R_2)$. This varying pressure interacts with any mechanical compliance in the pump (say, small air bubbles), causing the drop volume to deviate from the programmed volume.
- drops detaching from a tip leave a variable residual volume attached to the tip. In other words, not all the liquid outside the needle leaves the needle for the dispensed drop.

For these reasons, the syringe pump is thought to have a precision of ±10% of the dispensed volume. Notice this has nothing to do with stepper motor precision, which is much better.

Piezo Pumps

Very small volumes, say in the nanoliter and picoliter range, require a different kind of pump because a stepper motor can not reliably move a piston or plunger the ultra-short distances required for these volumes. FTÅ offers piezo pumps and special tips which can dispense drops from 50 picoliters to several hundred nanoliters. These are combined with a classical syringe pump to offer a system capable of 50pl to 20µl. While capable of very *small* drops, the precision of the piezo pump is actually worse than that of the syringe pump. The precision on 50pl drops is typically ±30%. This is somewhat compensated by the video software measuring the *actual* volume for each drop. While they are small, they are not precisely small.

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Airgap Dispense

Airgap systems use a syringe pump but in a different way. To begin with, think of a classical syringe pump and tip void of any liquid (just air inside). Place the tip in a beaker or vial of test liquid and run the pump backwards to withdraw, or pickup, a small amount of liquid, say 10µl. Remove the tip from the liquid source. There will now be 10µl inside the needle. We can show there will be essentially no liquid hanging down from the tip when the tip is removed from the source. Now place the needle over the sample and dispense *more* than 10µl volume. The entire quantity of liquid picked up will be dispensed (we don't care that a microliter or so of air will be also dispensed). The important point is that we can dispense 100% of what we picked up. Note that if we tried to dispense 50% of what we picked up, we would be back in the same situation as that first discussed for the classical syringe pump. So, as long as we dispense 100%, we can do it with essentially perfect (0%) precision.

This leaves us with only the question of how much was truly in the needle when we removed it from the source. An analysis based on pressures shows that the shape of the liquid across the needle tip after removal is essentially flat, and the *range* of volumes possible is limited by the volume of a hemisphere equal in radius to the tip radius. By choosing the tip size we can choose the uncertainty for a given total volume deposited. The table below shows representative values assuming water as the test fluid. Fluids with other surface tensions will vary slightly, but not in any major fashion since the surface tension effects tend to cancel one another. The Min and Max Dispense show the practical range of volume dispensed from each tip; a variety of factors affect each value so these do not follow any set formula. Since the Tip Uncertainty is set by the tip diameter, and therefore is fixed, the coefficient of variance COV will have a range based on the dispense volumes. The COV decreases as the actual volume dispensed increases. Intermediate sized tips are available which are not shown in the table.

Tip Gauge and OD	Min Dispense	Max Dispense	Tip Uncertainty	COV Range
18, 1.270mm	3µl	26µl	±535nl	±18%-2.1%
22, 0.711mm	2µl	15µl	±94nl	±4.7%-0.63%
27, 0.406mm	500nl	9µl	±18nl	±3.6%-0.20%
36, 0.090mm	24nl	190nl	±190pl	±0.80%-0.10%

In summary, small drops in the nanoliter to a few microliters range can be dispensed with variances less than one percent by using the airgap method coupled with tips of appropriate size. Finally, the syringe and tip are not actually operated void of any fluid. A system fluid, typically clean water, is used to fill the syringe itself. An airgap is left between the system fluid and the test fluid in such a way that the test fluid never touches a surface touched by the system fluid. Thus there is no chance for contamination.