Bulletin No.: CS-SUPPORT-CUP-CALIBRATION

Subject: Understanding Cup Calibration for the CS-APC Instruments

Cup Calibration Data & Volume Measurements on CS-APC Instruments

Cup calibration data is stored in the "CupCalibration.Setting" file and the data in the file that is supplied with the system is applicable to the standard Oakridge MC79 medicine cup. If sample cups are sourced from other manufactures, then new cup calibration data must be established for the new cup by carrying out the cup calibration procedure using the CINRG software. The cup calibration data establishes the relationship between the volume of liquid in the cup and the height of the liquid surface relative to a flat glass surface on which the cup sits.

The particle counters are fitted with a Baumer ultrasonic level sensor that is capable of measuring distances of 3mm to 150mm with an accuracy of 0.1mm. The sensor is mounted on the particle counter such that it is rigidly fixed in position and can only measure the distance to a target that is directly below the sensor. The distance measured is from the tip of the sensor snout to the target and the measurement is based on the time it takes for an ultrasonic sound wave to travel from the sensor to the target and back again. The sensor uses the velocity of sound in air to calculate the distance the sound wave would have travelled during the time it took for the wave to travel to the target and back again. Since the velocity of sound in air is dependent on air density, which is temperature dependent, the sensor has built in temperature compensation to maintain it's accuracy over a reasonable range of temperatures.

For accurate measurements targets must present a flat surface from which the ultrasonic wave can reflect off to maximize the wave energy that is returned to the sensor.

Typical targets for the particle counters are:-

- The glass table/carousel surface.
- The liquid surface in a sample cup containing an oil sample.
- The tops surface of an aluminum "Check Disc".

The system also uses measurements for empty cups and cups containing solvent, but these measurements lack precision and are only used as a means of detecting specific conditions during a sample run where precise measurements are not required.

Influence of Table Adjustments on Volume Measurement for the CS-APC-2 / 3

If a table adjustment is carried out on the CS-APC-2 / 3 particle counter, then the adjustment will invalidate all the "Table_To_Sensor_1-XX" parameters in the "Parameter.Settings" file which will produce errors in the sample height and sample volume calculations as the accuracy of the calculations is directly dependent on the accuracy of the values of the "Table_To_Sensor_1-XX" parameters. It is therefore essential to carry out a table measurement immediately after a table adjustment is completed to maintain the integrity of the sample height and volume calculations.

Influence of a table Maintenance on Volume Measurement for the CS-APC-22M

The CS-APC-22M does not have a table (carousel) adjustment procedure as the carousel is rigidly mounted to the central hub of the rotary axis. However, if table maintenance is carried out on the CS-APC-22M that involves the loosening or removal of the hub which secures the glass carousel in position then it is good practice to carrying out a new table measurement on completion of the maintenance to maintain the integrity of the sample height and volume calculations.

Important Note: *The Ultrasonic Level Sensor should have been powered up for at least 25 minutes before conducting a table measurement to ensure that thermal equilibrium of the device has been reached before any measurements take place. The device has internal temperature compensation, but this is not meant to handle the rapidly changing temperatures that occur when the device is first powered up. The level sensor is an ultrasonic sensor and uses the velocity of sound in air to calculate distances that it measures and because of this, solvent must never be used to collect cup calibration data because the solvent is volatile and quickly fills the air above the liquid with larger molecules that reduce the velocity of the ultrasonic sound waves, and this will cause positive errors in distance measurements.*

Collection of Cup Calibration Data

To collect cup calibration data a cup calibration needle must be installed on the sampling head of the particle counter and the needle plumbed to the solvent syringe using the delivery tubing provided for this purpose with the instrument. The sample syringe must be primed with a clean oil sample with a viscosity of 32 cSt @ 40°C or less so that the syringe can be used to deliver the oil in 1ml increments into the sample cup. The distance between the tip of the level sensor and the liquid surface is determined after each increment and the data stored is a file called "CupCalibration.Settings. The cap calibration process is covered in detail in the User Manual for the instrument.

The fist step in the collection of cup calibration data is to measure the distance between the tip of the level sensor and the glass table surface with no cup present (Measurement B) and is stored as the "No cup reading". An empty cup is then placed in position under the sensor and the distance between tip of the level sensor and the base of the cup is measured and stored as the empty cup reading. An oil sample is then added to the cup in 1ml increments up to a final volume of 30ml and the distance between the tip of the sensor and the liquid level is measured after each increment (Measurement A). The first three measurements have no value for the standard MC79 medicine cup because the dome in the base of the cup prevents meaningful measurement data from being collected. Only after enough oil has been added to the cup (3ml) to completely cover the dome can meaningful data be collected for height measurements.

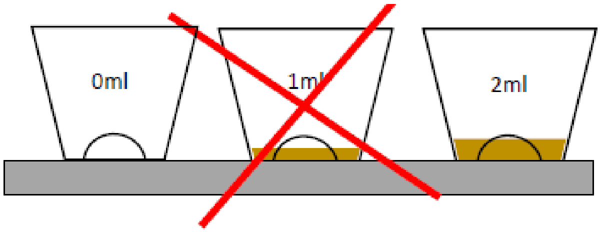


Figure 1 – *The first three cup measurements are not used for the calibration due to the nipple on the cup bottom.*

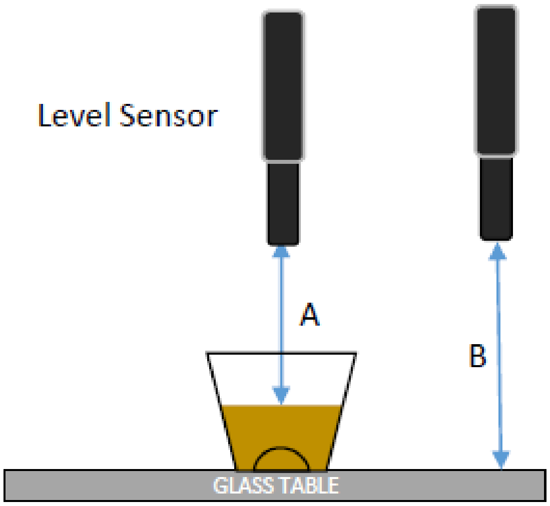
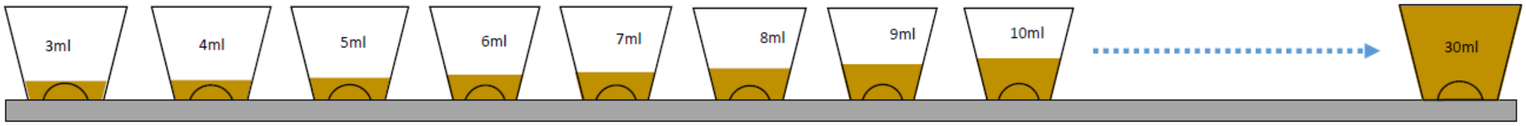


Figure 2 – *The "A" measurement is a series of measurements with increasing oil volume in the sample cup. The "B" measurement is from the tip of the sensor to the table surface.*

Figure 3 (below) – *Successive readings are taken from 3 ml of oil in the cup up to and including 30 ml of oil in the sample cup.*



Sample Height & Volume Determination at a Specific Sample Position

The sensor only measures the distance between the face of the level sensor tip and the liquid level in the sample cup. The height of the sample in the cup (Value C) is measured relative to the surface of the glass table and therefore must be calculated by subtracting measurement B from measurement A to yield Value C. Measurement A is recorded for each sample position during the “table measurement” procedure during instrument set up and the values are stored as system parameters in the “Parameters,Settings” file. These parameters (Table to Sensor_1-XX) cannot be changed manually and are re-written to the “Parameters.Settings” file whenever the table measurement procedure is implemented.

The volume of the sample in the cup is determined from the sample height measurement and the cup calibration data. The software reads the data from the “CupCalibration.Settings” file whenever the software is opened.

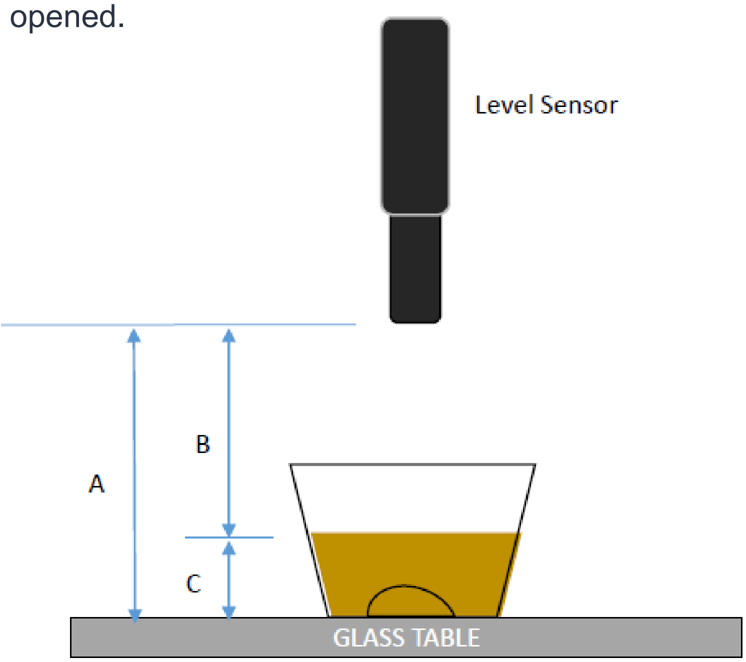


Figure 4 – *Sensor measurement heights:*

A = Sensor to table measurement at position XX (Parameter Value)
B = Sensor to liquid level Measurement.
C = Sample height relative to glass surface (Calculated Value A-B)

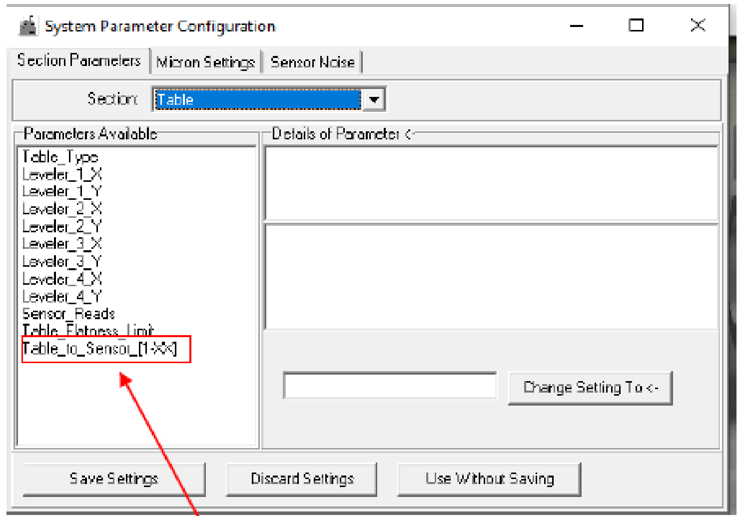


Figure 5 – *The parameters in the Table settings cannot be edited and are not displayed in the “Systems Parameters Configuration” window. The values are only re-written to the parameters file when the Table measurement routine is carried out.*

Sample Height vs. Volume Relationship

The software uses the cup calibration data to calculate the sample heights that are applicable to the volume of the oil that was in the cup when each distance measurement was conducted. This is done by subtracting the measured distance between the sensor and liquid surface in the cup from the measured distance between the sensor and glass table surface (i.e. the No_Cup reading).

Sample Volume Determination

The software will determine the volume of sample in a sample cup at position X by first obtaining the measurement from the level sensor for the distance between the sensor and the surface of the liquid in the cup. The height of the liquid in the cup at position X is then calculated by subtracting the measured value from the value of the Sensor to table parameter for position X. The software then looks for the two height data points in the height reference data that are closest to the measured height as well as the sample volumes that they correspond to. A linear extrapolation is then used to determine the sample volume that correspond to the sample height calculated for the sample in the sample cup at position X.

Example calculation:

Position X = sample position 10.
Value of parameter "Sensor to table_10" = 40.2 (Read by the software from the Parameters.Settings file)
Sensor reading for the sample in the sample cup at position 10 = 24.5
Calculated sample height is 40.2 –19.5 = 20.7mm
Closest Height pair = 20 and 20.8 mm and difference between them = 0.8mm (see red box "A" below)
Corresponding Volumes = 16 and 17ml and difference between them is 1.0ml
Height difference from closest value is 20.7 -20.8 = -0.1mm
Volume = 17 + (1 x (-0.1/1.1)) = 16.875ml.

Sample Volume Check Disk

An aluminum disc 19mm in height is supplied with the system and is intended to be used to check the volume measurement on a regular basis to ensure the system maintains it accuracy with respect to volume measurements. The height of the cylinder is equivalent to the height of 19mm of a sample cup corresponds to a volume of 15ml (see blue box "B").

The volume measurement can be checked using the "Measure Volume at Position" function available under the "Level Sensor" tab of the testing panel. It is best to remove the tray from the sample table before carrying out the test as it is easier to position the disc in the absence of the sample tray.

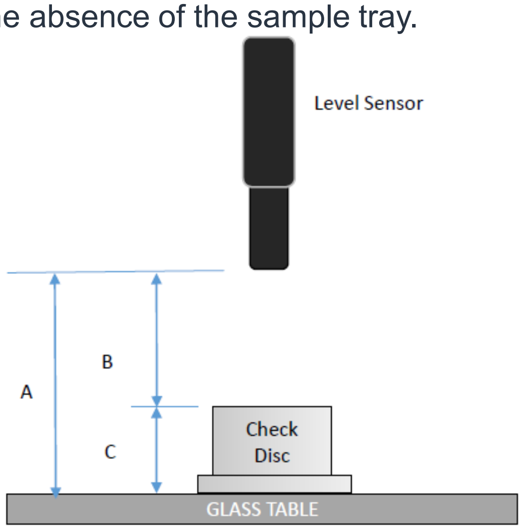


Figure 6 – *The Check Disc supplied with the instrument to check the volume measurement.*

To measure the volume at position x, simple enter the sample position into the small box on the right of the "Measure Volume at Position" button and click on the button. The sampling head will move to position x if not already there and attempt a volume measurement. This attempt should yield an error initially but if the aluminum disc is then placed on the glass surface immediately under the sensor and the ""Measure Volume at Position" button clicked a second time the software should return a value of 15 ± 0.2 ml.

The sensor is accurate to 0.1mm so the combined uncertainty of the two measurements needed to calculate the disc height will be ±0.2mm and this will translate into a volume uncertainty of ±0.2ml .

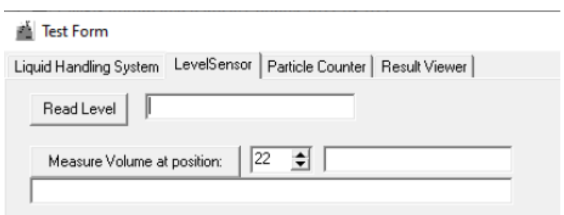


Figure 7 – *The Measure Volume at Position Test Form.*

Cup Calibration Data

	Volume	Reading	Height
	No_Cup	49.5	
	0	47.5	
	1	47.3	
	2	45.8	
	3	44.4	5.1
	4	43	6.5
	5	41.5	8.0
	6	40.3	9.2
	7	39	10.5
	8	37.8	11.7
	9	36.7	12.8
	10	35.7	13.8
	11	34.6	14.9
	12	33.6	15.9
	13	32.5	17.0
	14	31.6	17.9
B	15	30.5	19.0
A	16	29.5	20.0
A	17	28.7	20.8
	18	27.8	21.7
	19	26.9	22.6
	20	26.1	23.4
	21	25.3	24.2
	22	24.4	25.1
	23	23.6	25.9
	24	22.7	26.8
	25	22	27.5
	26	21.2	28.3
	27	20.5	29.0
	28	19.8	29.7
	29	19	30.5
	30	18.3	31.2