

# Supplementary Material

RAINDROPS

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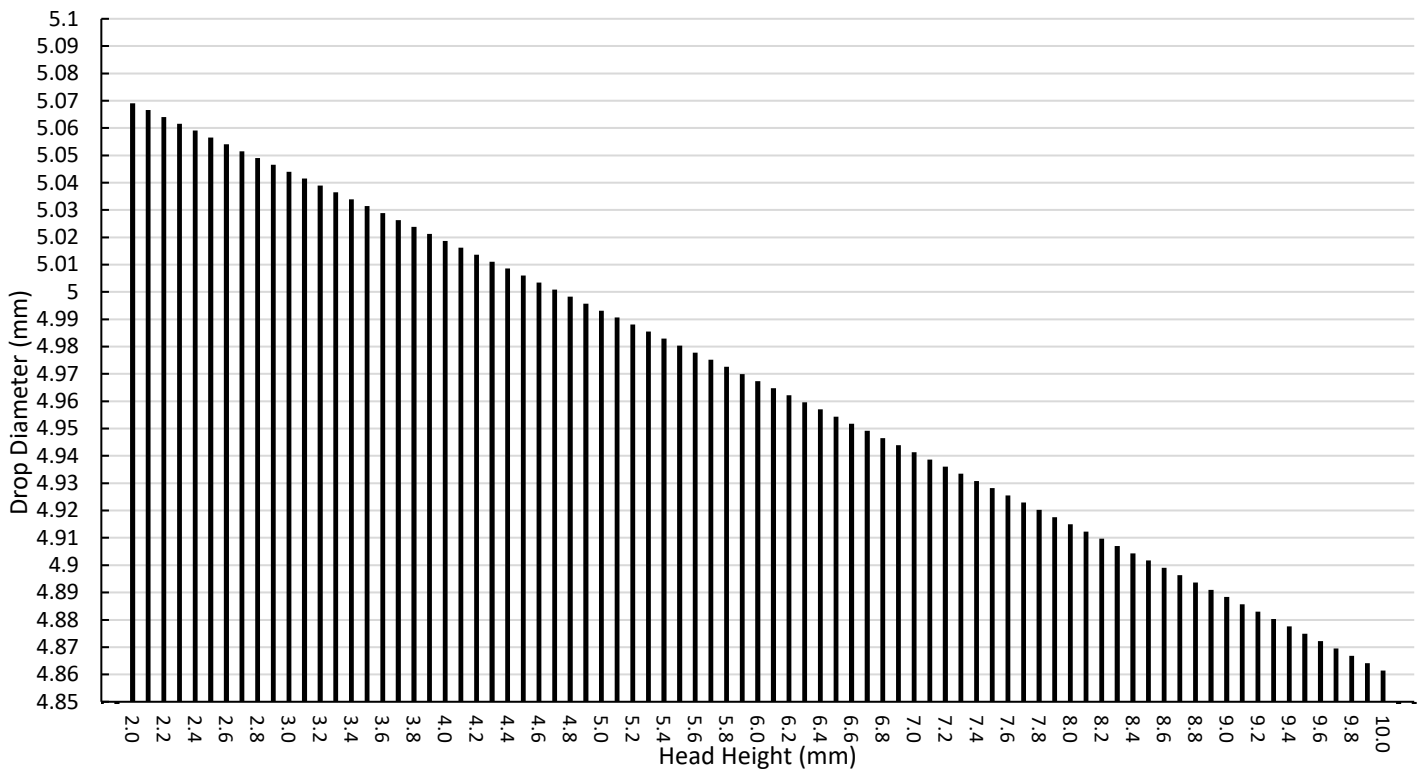
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## Introduction

All raw data from commissioning is found here. Any relevant discussion is found in the Commissioning chapter.

# Head Height vs Drop Diameter from Hummel et.al [34] Calculation



## One hundred drops mass measurements

Single Spherical Droplet Volume

$$V = \frac{4}{3}\pi r^3$$

$$V = \frac{4}{3}\pi(2.5)^3$$

$$V = 6.55 \times 10^{-8} \text{ m}^3$$

Tolerance – Maximum Limit

$$V = \frac{4}{3}\pi r^3$$

$$V = \frac{4}{3}\pi(2.75)^3$$

$$V = 8.71 \times 10^{-8} \text{ m}^3$$

$$V_{Max\_100\_Drops} = (50 \cdot 6.55 \times 10^{-8} \text{ m}^3) + (50 \times 8.71 \cdot 10^{-8} \text{ m}^3)$$

$$V_{Max} = 7.63 \times 10^{-6} \text{ m}^3$$

Tolerance – Minimum Limit

$$V = \frac{4}{3}\pi r^3$$

$$V = \frac{4}{3}\pi(2.25)^3$$

$$V = 4.77 \times 10^{-8} \text{ m}^3$$

$$V_{Min} = (50 \cdot 6.55 \times 10^{-8} \text{ m}^3) + (50 \times 4.77 \cdot 10^{-8} \text{ m}^3)$$

$$V_{Min} = 5.66 \times 10^{-6} \text{ m}^3$$

Results:

Table 1: Hole 1 Raw Data

Test	Mass (g)	Head Height (mm)	Beaker Mass (g)	Beaker Tare (g)
1	7.6	4.0	36.3	36.3
2	6.9	4.0	36.6	
3	6.9	4.0	36.6	
4	7.1	4.0	36.7	
5	7.0	3.5	36.7	
6	7.0	3.5	36.7	
7	7.1	3.5	36.7	
8	7.0	3.5	36.8	
9	7.0	3.0	36.7	
10	7.0	3.0	36.7	
<b>Average</b>	7.06			

Table 2: Hole 2 Raw Data

Test	Mass (g)	Head Height (mm)	Beaker Mass (g)	Beaker Tare (g)
1	7.2	4	36.3	36.3
2	6.9	4	36.4	
3	7.6	4	36.4	
4	7.5	4	36.5	
5	7.1	3.5	36.4	
6	7.6	3.5	36.4	
7	7.4	3	36.4	
8	7.1	3	36.3	
9	7.5	3.5	36.4	
10	6.9	3.5	36.4	
11	7.0	3.5	36.6	
12	6.9	3	36.5	
13	7.0	3.5	36.6	
14	7.0	3.5	36.6	
15	7.0	3.5	36.5	
16	6.9	3	36.5	
17	7.0	3	36.4	
18	7.1	3	36.6	
19	7.0	2.8	36.5	
<b>Average</b>	7.14			

Table 3: Hole 3 Raw Data

Test	Mass (g)	Head Height (mm)	Beaker Mass (g)	Beaker Tare (g)
1	5.6	4.0	36.6	36.3
2	5.4	4.0	36.6	
3	5.3	4.0	36.7	
4	5.8	3.5	36.7	
5	6.1	3.5	36.7	
6	6.5	3.5	36.7	
7	6.7	3.5	36.6	
8	6.4	3.0	36.6	
9	6.7	3.0	36.6	
10	6.8	2.9	36.6	
<b>Average</b>	<b>6.13</b>			

Table 4: Hole 4 Raw Data

Test	Mass (g)	Head Height (mm)	Beaker Mass (g)	Beaker Tare (g)
1	6.8	4.0	36.5	36.4
2	6.8	4.0	36.5	
3	6.8	3.7	36.6	
4	6.6	3.7	36.7	
5	6.9	3.5	36.6	
6	7	3.5	36.6	
7	7.1	3.0	36.6	
8	7.1	3.0	36.6	
9	7.1	3.0	36.6	
10	7.1	2.9	36.6	
<b>Average</b>	<b>6.93</b>			

Table 5: Hole 5 Raw Data

Test	Mass (g)	Head Height (mm)	Beaker Mass (g)	Beaker Tare (g)
1	6.9	4.0	36.3	36.2
2	6.9	4.0	36.3	
3	6.9	3.8	36.4	
4	7.0	3.8	36.4	
5	7.0	3.5	36.4	
6	7.1	3.0	36.4	
7	7.1	3.0	36.4	
8	7.1	3.0	36.4	
9	7.1	2.9	36.4	
10	7.0	2.8	36.3	
<b>Average</b>	<b>7.01</b>			

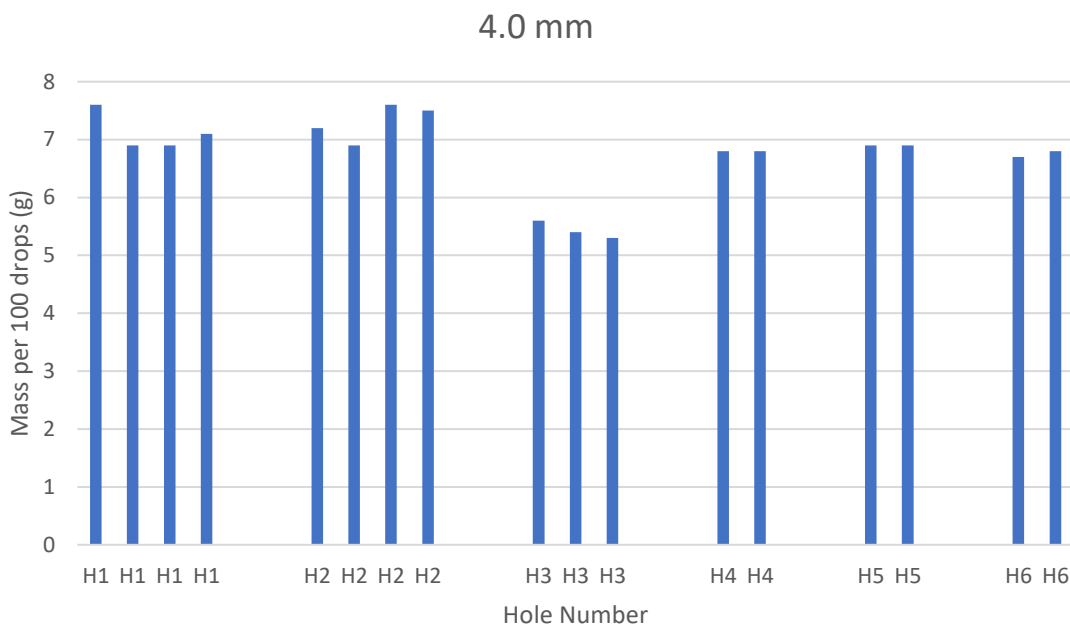


Table 6: Hole 6 Raw Data

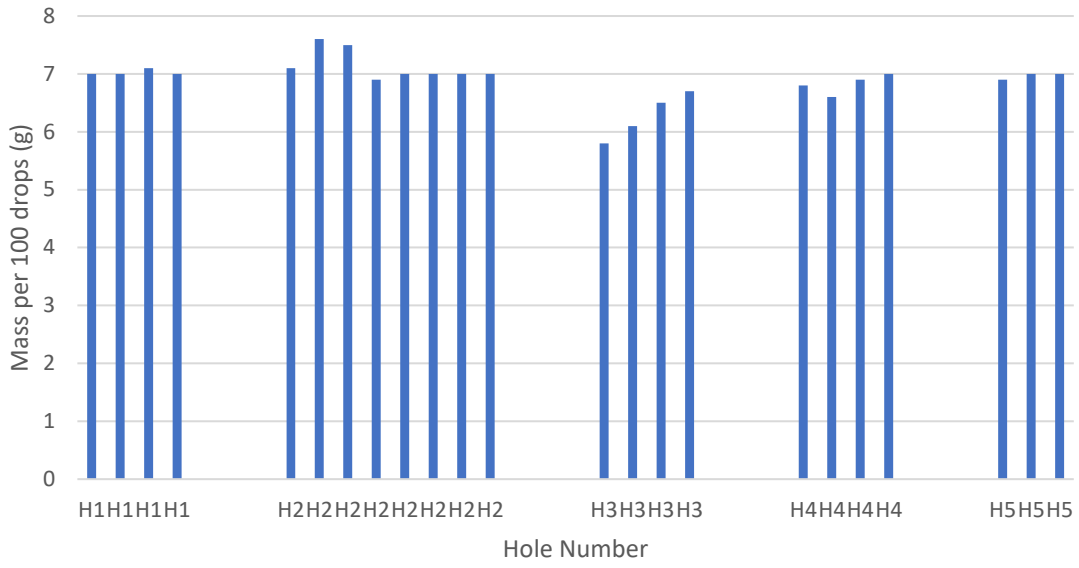
Test	Mass (g)	Head Height (mm)	Beaker Mass (g)	Beaker Tare (g)
1	6.7	4.0	36.3	36.3
2	6.8	4.0	36.2	
3	6.8	3.9	36.2	
4	6.7	3.9	36.4	
5	6.9	3.5	36.5	
6	6.8	3.5	36.4	
7	6.8	3.5	36.3	
8	6.9	3.0	36.3	
9	6.9	3.0	36.3	
10	6.9	3.0	36.4	
<b>Average</b>	<b>6.82</b>			

Droplet Mass vs Head Height:

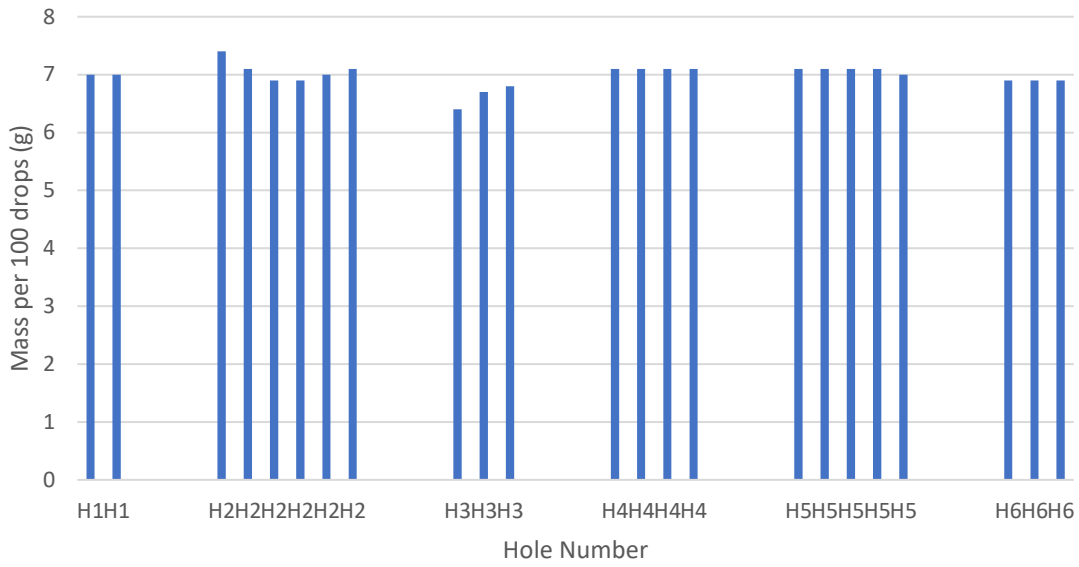
The droplet mass for 100 drops for a particular head height was observed too. Figures 2-4 display these results.



### 3.5 mm



### 3.0 mm



Experimental Droplet Diameter:

The average drop diameter for each hole was determined.

*Hole 1:*

$$7.06 \times 10^{-8} \text{ m}^3 = \frac{4}{3}\pi r^3$$

$$r = \sqrt[3]{\frac{7.06 \times 10^{-8} \text{ m}^3}{\frac{4}{3}\pi}}$$

$$r = 2.56 \times 10^{-3} \text{ m}$$

$$d = 5.13 \times 10^{-3} \text{ m}$$

$$\text{Percent difference} = \frac{5.13 \times 10^{-3} \text{ m}}{5.0 \times 10^{-3} \text{ m}} \times 100$$

$$\text{Percent difference} = 2.6\%$$

*Hole 2:*

$$7.14 \times 10^{-8} \text{ m}^3 = \frac{4}{3}\pi r^3$$

$$r = \sqrt[3]{\frac{7.14 \times 10^{-8} \text{ m}^3}{\frac{4}{3}\pi}}$$

$$r = 2.57 \times 10^{-3} \text{ m}$$

$$d = 5.15 \times 10^{-3} \text{ m}$$

$$\text{Percent difference} = \frac{5.15 \times 10^{-3} \text{ m}}{5.0 \times 10^{-3} \text{ m}} \times 100$$

$$\text{Percent difference} = 3.0\%$$

Hole 3:

$$6.13 \times 10^{-8} \text{ m}^3 = \frac{4}{3}\pi r^3$$

$$r = \sqrt[3]{\frac{6.13 \times 10^{-8} \text{ m}^3}{\frac{4}{3}\pi}}$$

$$r = 2.45 \times 10^{-3} \text{ m}$$

$$d = 4.89 \times 10^{-3} \text{ m}$$

$$\text{Percent difference} = \frac{4.89 \times 10^{-3} \text{ m}}{5.0 \times 10^{-3} \text{ m}} \times 100$$

$$\text{Percent difference} = -2.2\%$$

Hole 4:

$$6.93 \times 10^{-8} \text{ m}^3 = \frac{4}{3}\pi r^3$$

$$r = \sqrt[3]{\frac{6.93 \times 10^{-8} \text{ m}^3}{\frac{4}{3}\pi}}$$

$$r = 2.55 \times 10^{-3} \text{ m}$$

$$d = 5.10 \times 10^{-3} \text{ m}$$

$$\text{Percent difference} = \frac{4.89 \times 10^{-3} \text{ m}}{5.0 \times 10^{-3} \text{ m}} \times 100$$

$$\text{Percent difference} = 2.0\%$$

Hole 5:

$$7.01 \times 10^{-8} \text{ m}^3 = \frac{4}{3}\pi r^3$$

$$r = \sqrt[3]{\frac{7.01 \times 10^{-8} \text{ m}^3}{\frac{4}{3}\pi}}$$

$$r = 2.56 \times 10^{-3} \text{ m}$$

$$d = 5.12 \times 10^{-3} \text{ m}$$

$$\text{Percent difference} = \frac{4.89 \times 10^{-3} \text{ m}}{5.0 \times 10^{-3} \text{ m}} \times 100$$

$$\text{Percent difference} = 2.3\%$$

Hole 6:

$$6.82 \times 10^{-8} \text{ m}^3 = \frac{4}{3} \pi r^3$$

$$r = \sqrt[3]{\frac{6.82 \times 10^{-8} \text{ m}^3}{\frac{4}{3} \pi}}$$

$$r = 2.54 \times 10^{-3} \text{ m}$$

$$d = 5.07 \times 10^{-3} \text{ m}$$

$$\text{Percent difference} = \frac{4.89 \times 10^{-3} \text{ m}}{5.0 \times 10^{-3} \text{ m}} \times 100$$

$$\text{Percent difference} = 1.3\%$$

## Mass of Single Drops

### 5 mm Head Height Raw Tables

Table 7: Hole 1 Raw Data

Beaker Number	Dry Mass (mg)	Wet Mass (mg)	Expected Mass (mg)	Drop Mass (mg)	Absolute Difference	Percent Difference (%)
1	7827.8	7897.4	7893.3	69.6	4.1	6.3
2	7939.4	8008	8004.9	68.6	3.1	4.7
3	7883.2	7949.9	7948.7	66.7	1.2	1.8
4	7976.7	8044.5	8042.2	67.8	2.3	3.5
5	7967.8	8035	8033.3	67.2	1.7	2.6
				<b>Average (mg)</b>	67.98	
				<b>Expected (mg)</b>	65.5	
				<b>Average Difference (mg)</b>	2.48	
				<b>Average Percent Difference (%)</b>	3.8	

Table 8: Hole 2 Raw Data

Beaker Number	Dry Mass (mg)	Wet Mass (mg)	Expected Mass (mg)	Drop Mass (mg)	Absolute Difference	Percent Difference (%)
6	8042.9	8111.9	8108.4	69	3.5	5.3
7	7949.1	8017	8014.6	67.9	2.4	3.7
8	7978.9	8046.6	8044.4	67.7	2.2	3.4
9	7915	7967.8	7980.5	52.8	12.7	-19.4
10	7992.6	8061.2	8058.1	68.6	3.1	4.7
				<b>Average (mg)</b>	65.2	
				<b>Expected (mg)</b>	65.5	
				<b>Average Difference (mg)</b>	0.3	
				<b>Average Percent Difference (%)</b>	0.5	

Table 9: Hole 3 Raw Data

Beaker Number	Dry Mass (mg)	Wet Mass (mg)	Expected Mass (mg)	Drop Mass (mg)	Absolute Difference	Percent Difference (%)
1	7827.8	7894.5	7893.3	66.7	1.2	1.8
2	7939.4	8006.5	8004.9	67.1	1.6	2.4
3	7883.2	7949	7948.7	65.8	0.3	0.5
4	7976.7	8043.9	8042.2	67.2	1.7	2.6
5	7967.8	8035.7	8033.3	67.9	2.4	3.7
<b>Average (mg)</b>				66.94		
<b>Expected (mg)</b>				65.5		
<b>Average Difference (mg)</b>				1.44		
<b>Average Percent Difference (%)</b>				2.2		

Table 10: Hole 4 Raw Data

Beaker Number	Dry Mass (mg)	Wet Mass (mg)	Expected Mass (mg)	Drop Mass (mg)	Absolute Difference	Percent Difference (%)
6	8042.9	8113.7	8108.4	70.8	5.3	8.1
7	7949.1	8019.1	8014.6	70	4.5	6.9
8	7978.9	8048.4	8044.4	69.5	4	6.1
9	7915	7985.1	7980.5	70.1	4.6	7.0
10	7992.6	8061.7	8058.1	69.1	3.6	5.5
<b>Average (mg)</b>				69.9		
<b>Expected (mg)</b>				65.5		
<b>Average Difference (mg)</b>				4.4		
<b>Average Percent Difference (%)</b>				6.7		

Table 11: Hole 5 Raw Data

Beaker Number	Dry Mass (mg)	Wet Mass (mg)	Expected Mass (mg)	Drop Mass (mg)	Absolute Difference	Percent Difference (%)
1	7827.8	7892.5	7893.3	64.7	-0.8	-1.2
2	7939.4	8004	8004.9	64.6	-0.9	-1.4
3	7883.2	7947.5	7948.7	64.3	-1.2	-1.8
4	7976.7	8041.7	8042.2	65	-0.5	-0.8
5	7967.8	8037.3	8033.3	69.5	4	6.1
<b>Average (mg)</b>				65.62		
<b>Expected (mg)</b>				65.5		
<b>Average Difference (mg)</b>				0.12		
<b>Average Percent Difference (%)</b>				0.2		

Table 12: Hole 6 Raw Data

Beaker Number	Dry Mass (mg)	Wet Mass (mg)	Expected Mass (mg)	Drop Mass (mg)	Absolute Difference	Percent Difference (%)
6	8042.9	8109	8108.4	66.1	0.6	0.9
7	7949.1	8014.4	8014.6	65.3	-0.2	-0.3
8	7978.9	8056.8	8044.4	77.9	12.4	18.9
9	7915	7980.2	7980.5	65.2	-0.3	-0.5
10	7992.6	8057.6	8058.1	65	-0.5	-0.8
<b>Average (mg)</b>				67.9		
<b>Expected (mg)</b>				65.5		
<b>Average Difference (mg)</b>				2.4		
<b>Average Percent Difference (%)</b>				3.7		

Table 13: All Holes Radius Calculation and Percent Difference

	Average Drop Mass (mg)	Average Drop Mass (kg)	Average Drop Volume (m <sup>3</sup> )	Drop Radius (m)	Drop Radius (mm)	Percent Difference (%)
Hole 1	68.0	6.80E-05	6.80E-08	0.0025	2.53	1.3
Hole 2	65.2	6.52E-05	6.52E-08	0.0025	2.50	0.1
Hole 3	66.9	6.69E-05	6.69E-08	0.0025	2.52	0.8
Hole 4	69.9	6.99E-05	6.99E-08	0.0026	2.56	2.2
Hole 5	65.6	6.56E-05	6.56E-08	0.0025	2.50	0.1
Hole 6	67.9	6.79E-05	6.79E-08	0.0025	2.53	1.2
All	67.3	6.73E-05	6.73E-08	0.0025	2.52	0.9



#### 4 mm Head Height Data Tables

Table 14: Hole 1 Raw Data

Beaker Number	Dry Mass (mg)	Wet Mass (mg)	Expected Mass (mg)	Drop Mass (mg)	Absolute Difference	Percent Difference (%)
1	7827.8	7904.8	7893.3	77	11.5	17.6
2	7939.4	8015.8	8004.9	76.4	10.9	16.6
3	7883.2	7958	7948.7	74.8	9.3	14.2
4	7976.7	8052.1	8042.2	75.4	9.9	15.1
5	7967.8	8045.1	8033.3	77.3	11.8	18.0
6	8042.9	8120.3	8108.4	77.4	11.9	18.2
7	7949.1	8026	8014.6	76.9	11.4	17.4
8	7978.9	8055.2	8044.4	76.3	10.8	16.5
9	7915	7992	7980.5	77	11.5	17.6
10	7992.6	8070.1	8058.1	77.5	12	18.3
<b>Average (mg)</b>				76.6		
<b>Expected (mg)</b>				65.5		
<b>Average Difference (mg)</b>				11.1		
<b>Average Percent Difference (%)</b>				16.9		

Table 15: All Beakers Radius Calculation and Percent Difference

	Drop Mass (mg)	Drop Mass (kg)	Drop Volume (m <sup>3</sup> )	Drop Radius (m)	Drop Radius (mm)
Beaker 1	77.0	7.70E-05	7.70E-08	2.64E-03	2.64
Beaker 2	76.4	7.64E-05	7.64E-08	2.63E-03	2.6
Beaker 3	74.8	7.48E-05	7.48E-08	2.61E-03	2.61
Beaker 4	75.4	7.54E-05	7.54E-08	2.62E-03	2.6
Beaker 5	77.3	7.73E-05	7.73E-08	2.64E-03	2.64
Beaker 6	77.4	7.74E-05	7.74E-08	2.64E-03	2.6
Beaker 7	76.9	7.69E-05	7.69E-08	2.64E-03	2.64
Beaker 8	76.3	7.63E-05	7.63E-08	2.63E-03	2.6
Beaker 9	77.0	7.70E-05	7.70E-08	2.64E-03	2.64
Beaker 10	77.5	7.75E-05	7.75E-08	2.64E-03	2.6
Average	76.6	7.66E-05	7.66E-08	2.63E-03	2.63

## 6 mm Head Height Data Tables

Table 16: Hole 1 Raw Data Test 1

Beaker Number	Dry Mass (mg)	Wet Mass (mg)	Expected Mass (mg)	Drop Mass (mg)	Absolute Difference	Percent Difference (%)
1	7827.8	7911	7893.3	83.2	83.2	27.0
2	7939.4	8017.5	8004.9	78.1	78.1	19.2
3	7883.2	7960.4	7948.7	77.2	77.2	17.9
4	7976.7	8053.9	8042.2	77.2	77.2	17.9
5	7967.8	8045.5	8033.3	77.7	77.7	18.6
6	8042.9	8121.5	8108.4	78.6	78.6	20.0
7	7949.1	8027.8	8014.6	78.7	78.7	20.2
8	7978.9	8060.6	8044.4	81.7	81.7	24.7
9	7915	7991.6	7980.5	76.6	76.6	16.9
10	7992.6	8069.3	8058.1	76.7	76.7	17.1
<b>Average (mg)</b>				78.57		
<b>Expected (mg)</b>				65.5		
<b>Average Difference (mg)</b>				13.07		
<b>Average Percent Difference (%)</b>				20.0		

Table 17: Hole 1 Raw Data Test 2

Beaker Number	Dry Mass (mg)	Wet Mass (mg)	Expected Mass (mg)	Drop Mass (mg)	Absolute Difference	Percent Difference (%)
1	7827.8	7911	7893.3	83.2	83.2	27.0
2	7939.4	8017.5	8004.9	78.1	78.1	19.2
3	7883.2	7960.4	7948.7	77.2	77.2	17.9
4	7976.7	8053.9	8042.2	77.2	77.2	17.9
5	7967.8	8045.5	8033.3	77.7	77.7	18.6
6	8042.9	8121.5	8108.4	78.6	78.6	20.0
7	7949.1	8027.8	8014.6	78.7	78.7	20.2
8	7978.9	8060.6	8044.4	81.7	81.7	24.7
9	7915	7991.6	7980.5	76.6	76.6	16.9
10	7992.6	8069.3	8058.1	76.7	76.7	17.1
<b>Average (mg)</b>				78.57		
<b>Expected (mg)</b>				65.5		
<b>Average Difference (mg)</b>				13.07		
<b>Average Percent Difference (%)</b>				20.0		

Table 18: All Beakers Radius Calculation and Percent Difference

	Drop Mass (mg)	Drop Mass (kg)	Drop Volume (m <sup>3</sup> )	Drop Radius (m)	Drop Radius (mm)	Percent Difference (%)
Beaker 1	83.2	8.32E-05	8.32E-08	2.71E-03	2.71	8.3
Beaker 2	78.1	7.81E-05	7.81E-08	2.65E-03	2.7	6.1
Beaker 3	77.2	7.72E-05	7.72E-08	2.64E-03	2.64	5.7
Beaker 4	77.2	7.72E-05	7.72E-08	2.64E-03	2.6	5.7
Beaker 5	77.7	7.77E-05	7.77E-08	2.65E-03	2.65	5.9
Beaker 6	78.6	7.86E-05	7.86E-08	2.66E-03	2.7	6.3
Beaker 7	78.7	7.87E-05	7.87E-08	2.66E-03	2.66	6.3
Beaker 8	81.7	8.17E-05	8.17E-08	2.69E-03	2.7	7.7
Beaker 9	76.6	7.66E-05	7.66E-08	2.63E-03	2.63	5.4
Beaker 10	76.7	7.67E-05	7.67E-08	2.64E-03	2.6	5.4
Average	78.6	7.86E-05	7.86E-08	2.66E-03	2.66	6.3

Table 19: All Beakers Radius Calculation and Percent Difference

	Drop Mass (mg)	Drop Mass (kg)	Drop Volume (m <sup>3</sup> )	Drop Radius (m)	Drop Radius (mm)	Percent Difference (%)
Beaker 1	71.8	7.18E-05	7.18E-08	2.58E-03	2.58	3.1
Beaker 2	72.1	7.21E-05	7.21E-08	2.58E-03	2.6	3.3
Beaker 3	70.1	7.01E-05	7.01E-08	2.56E-03	2.56	2.3
Beaker 4	72.7	7.27E-05	7.27E-08	2.59E-03	2.6	3.6
Beaker 5	72.2	7.22E-05	7.22E-08	2.58E-03	2.58	3.3
Beaker 6	72.4	7.24E-05	7.24E-08	2.59E-03	2.6	3.4
Beaker 7	72.3	7.23E-05	7.23E-08	2.58E-03	2.58	3.4
Beaker 8	72.0	7.20E-05	7.20E-08	2.58E-03	2.6	3.2
Beaker 9	71.6	7.16E-05	7.16E-08	2.58E-03	2.58	3.0
Beaker 10	71.9	7.19E-05	7.19E-08	2.58E-03	2.6	3.2
Average	71.9	7.19E-05	7.19E-08	2.58E-03	2.58	3.2

## 10 mm Head Height Data Tables

Table 20: Hole 1 Raw Data

Beaker Number	Dry Mass (mg)	Wet Mass (mg)	Expected Mass (mg)	Drop Mass (mg)	Absolute Difference	Percent Difference (%)
1	7827.8	7890.2	7893.3	62.4	-3.1	-4.7
2	7939.4	8005.8	8004.9	66.4	0.9	1.4
3	7883.2	7948.4	7948.7	65.2	-0.3	-0.5
4	7976.7	8043.5	8042.2	66.8	1.3	2.0
5	7967.8	8034.9	8033.3	67.1	1.6	2.4
6	8042.9	8111.3	8108.4	68.4	2.9	4.4
7	7949.1	8017.3	8014.6	68.2	2.7	4.1
8	7978.9	8047.4	8044.4	68.5	3	4.6
9	7915	7985.6	7980.5	70.6	5.1	7.8
10	7992.6	8063.1	8058.1	70.5	5	7.6
<b>Average (mg)</b>				67.41		
<b>Expected (mg)</b>				65.5		
<b>Average Difference (mg)</b>				1.91		
<b>Average Percent Difference (%)</b>				2.9		

Table 21: All Beakers Radius Calculation and Percent Difference

	Drop Mass (mg)	Drop Mass (kg)	Drop Volume (m <sup>3</sup> )	Drop Radius (m)	Drop Radius (mm)	Percent Difference (%)
Beaker 1	62.4	6.24E-05	6.24E-08	2.46E-03	2.46	1.6
Beaker 2	66.4	6.64E-05	6.64E-08	2.51E-03	2.5	0.5
Beaker 3	65.2	6.52E-05	6.52E-08	2.50E-03	2.50	0.1
Beaker 4	66.8	6.68E-05	6.68E-08	2.52E-03	2.5	0.7
Beaker 5	67.1	6.71E-05	6.71E-08	2.52E-03	2.52	0.8
Beaker 6	68.4	6.84E-05	6.84E-08	2.54E-03	2.5	1.5
Beaker 7	68.2	6.82E-05	6.82E-08	2.53E-03	2.53	1.4
Beaker 8	68.5	6.85E-05	6.85E-08	2.54E-03	2.5	1.5
Beaker 9	70.6	7.06E-05	7.06E-08	2.56E-03	2.56	2.6
Beaker 10	70.5	7.05E-05	7.05E-08	2.56E-03	2.6	2.5
Average	67.4	6.74E-05	6.74E-08	2.52E-03	2.52	1.0

## Rainfall Rate Data

Table 22: Rainfall Rate Data

<b>Test</b>	<b>Rainfall Rate (mm/h)</b>
<b>1</b>	41.5
<b>2</b>	41.5
<b>3</b>	39.7
<b>4</b>	39.5
<b>5</b>	39.9
<b>6</b>	40.1
<b>7</b>	40.3
<b>8</b>	38.1
<b>9</b>	37.4
<b>10</b>	43.1
<b>AVG</b>	40.1