# Appendix A

Drawing of ESP

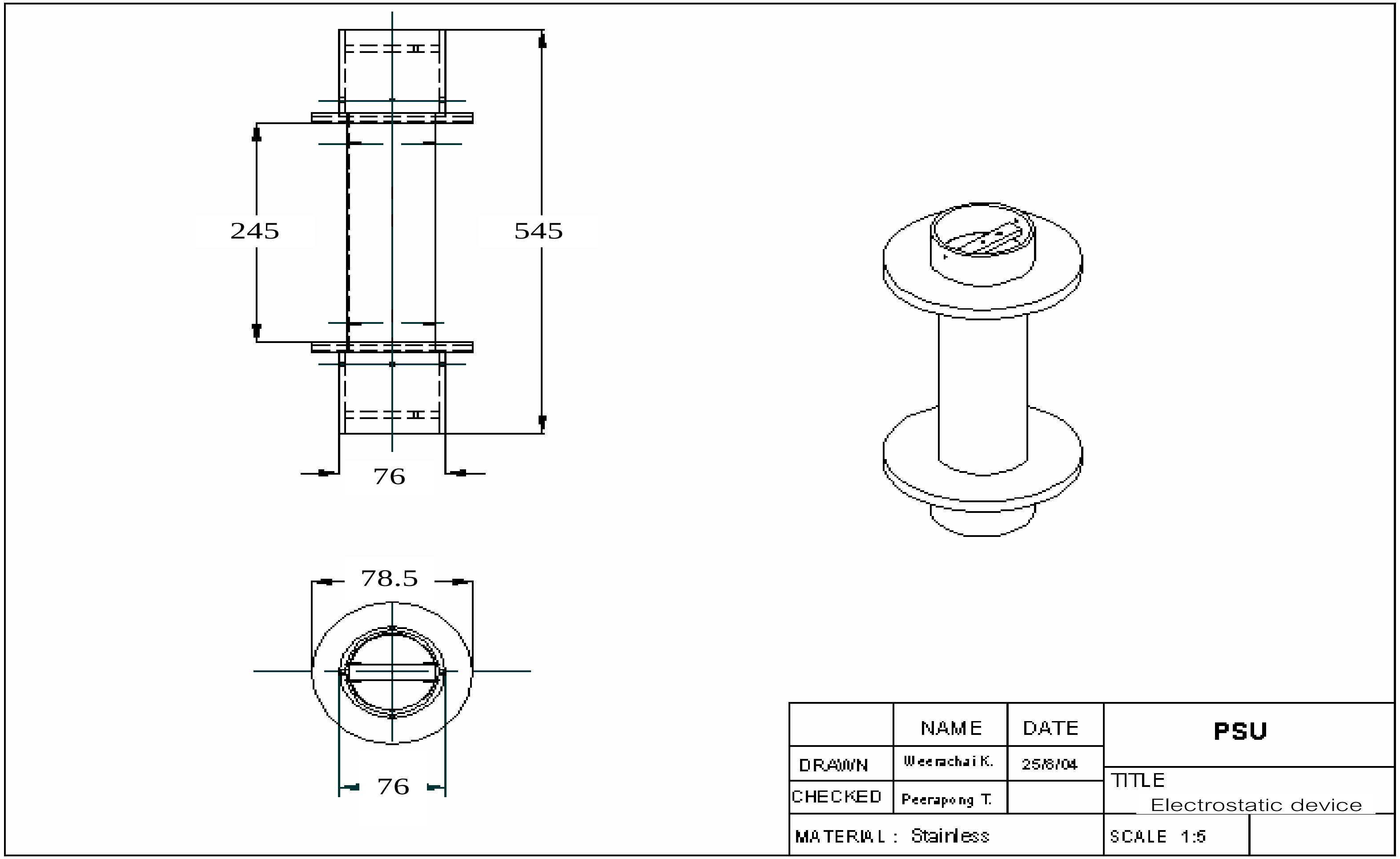
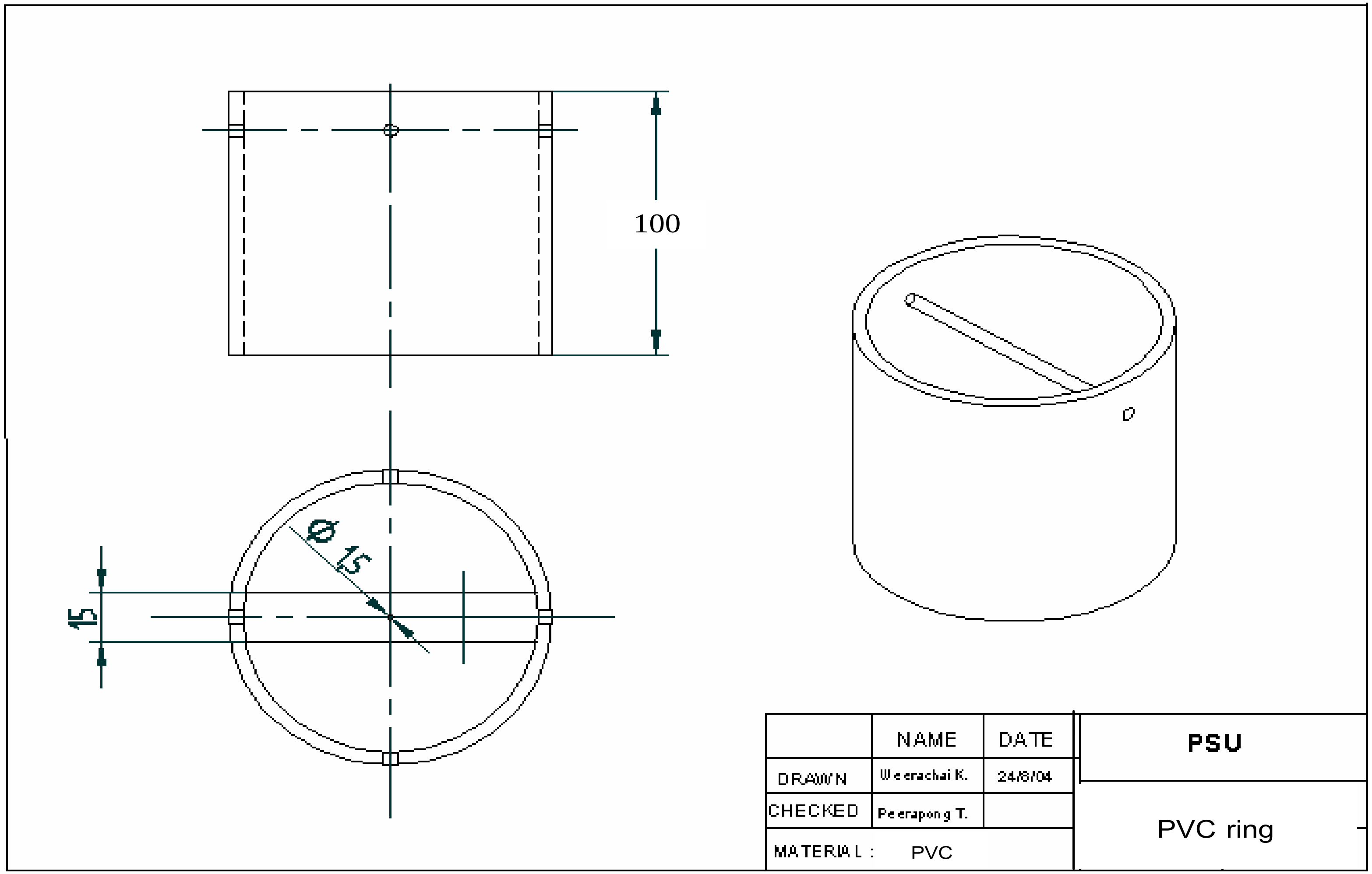


**Figure 1.** Model of the designed ESP.



| | NAME | DATE | PSU |
|---|---|---|---|
| DRAWN | Weerachai K. | 24/8/04 | |
| CHECKED | Peerapong T. | | PVC ring |
| MATERIAL : | PVC | | |

**Figure 2.** Model of PVC ring.

# Appendix B

## Input-output data

**Table 6.** The measured data of input-output voltage

| Measure no. 1 | | | |
|---|---|---|---|
| VAC (Volt) | DC-peak (Volt) | | Average (kVDC) |
| | Min. | Max. | |
| 0 | 0 | 0 | 0 |
| 20 | 300 | 1300 | 800 |
| 40 | 500 | 2000 | 1250 |
| 60 | 700 | 1800 | 1250 |
| 80 | 800 | 4000 | 2400 |
| 100 | 1100 | 5500 | 3300 |
| 120 | 1400 | 6400 | 3900 |
| 140 | 1600 | 7500 | 4550 |
| 160 | 1800 | 8100 | 4950 |
| 180 | 2400 | 9000 | 5700 |
| 200 | 3200 | 10200 | 6700 |
| 220 | 3300 | 12500 | 7900 |

| Measure no. 2 | | | |
|---|---|---|---|
| VAC (Volt) | DC-peak (Volt) | | Average (kVDC) |
| | Min. | Max. | |
| 0 | 0 | 0 | 0 |
| 20 | 300 | 1300 | 800 |
| 40 | 500 | 2100 | 1300 |
| 60 | 700 | 2700 | 1700 |
| 80 | 800 | 3900 | 2350 |
| 100 | 1000 | 5200 | 3100 |
| 120 | 1300 | 6000 | 3650 |
| 140 | 1400 | 7300 | 4350 |
| 160 | 1700 | 8000 | 4850 |
| 180 | 2400 | 9400 | 5900 |
| 200 | 3100 | 10300 | 6700 |
| 220 | 3200 | 11900 | 7550 |

# Appendix C

## Discharge current at various supply voltages

**Table 7.** The measured data of discharge current at various supply voltages

| Clean ESP | | | |
|---|---|---|---|
| VAC [V] | I [μA] | | |
| | 1 | 2 | 3 |
| 0 | 0 | 0 | 0 |
| 20 | 0 | 0 | 0 |
| 40 | 0 | 0 | 0 |
| 60 | 0 | 0 | 0 |
| 80 | 0 | * | * |
| 100 | * | * | * |
| 120 | * | * | * |
| 140 | * | * | * |
| 160 | * | * | * |
| 180 | 1.3 | 1.5 | 1.2 |
| 200 | 19 | 19 | 19 |
| 220 | 31 | 29 | 30 |

| Dust-loaded ESP | | | |
|---|---|---|---|
| VAC [V] | I [μA] | | |
| | 1 | 2 | 3 |
| 0 | 0 | 0 | 0 |
| 20 | 0 | 0 | 0 |
| 40 | 0 | 0 | 0 |
| 60 | 0 | 0 | 0 |
| 80 | 0 | 0 | 0 |
| 100 | 0 | 0 | 0 |
| 120 | 0 | 0 | 0 |
| 140 | 0 | 0 | 0 |
| 160 | 0 | 0 | 0 |
| 180 | 0 | 0 | 0 |
| 200 | 13 | 15 | 15 |
| 220 | 25 | 25 | 24 |

Note * can not be read accurately.

# Appendix D

## Collection efficiency data

| Q = 2.83 lpm (V=1.04 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 36418 | 22656 | 13762 | 37.79 |
| 2 | 34370 | 20648 | 13722 | 39.92 |
| 4 | 33021 | 20140 | 12881 | 39.01 |
| 6 | 30259 | 17670 | 12589 | 41.60 |
| average | 33517 | 20279 | 13239 | 39.58 |
| SD | 2582.25 | 2050.41 | 593.71 | 1.61 |

| Q = 10.83 lpm (V=3.77 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 39069 | 34966 | 4103 | 10.50 |
| 3 | 38120 | 35218 | 2902 | 7.61 |
| 5 | 37957 | 34544 | 3413 | 8.99 |
| 6 | 38957 | 35973 | 2984 | 7.66 |
| average | 38526 | 35175 | 3351 | 8.69 |
| SD | 568.39 | 600.14 | 549.44 | 1.37 |

| Q = 20.06 lpm (V=7.36 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 41042 | 37280 | 3762 | 9.17 |
| 2 | 40977 | 38682 | 2295 | 5.60 |
| 4 | 40650 | 38383 | 2267 | 5.58 |
| 5 | 40707 | 37101 | 3606 | 8.86 |
| average | 40844 | 37862 | 2983 | 7.30 |
| SD | 194.33 | 787.76 | 812.60 | 1.98 |

| Q = 30.03 lpm (V=11.02 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 3 | 35227 | 33909 | 1318 | 3.74 |
| 4 | 35638 | 32244 | 3394 | 9.52 |
| 5 | 35495 | 34346 | 1149 | 3.24 |
| 6 | 35708 | 32334 | 3374 | 9.45 |
| average | 35517 | 33208 | 2309 | 6.49 |
| SD | 212.69 | 1076.97 | 1243.53 | 3.47 |

| Q = 40.01 lpm (V=14.68 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 30028 | 28966 | 1062 | 3.54 |
| 3 | 29572 | 27451 | 2121 | 7.17 |
| 4 | 29677 | 28401 | 1276 | 4.30 |
| 5 | 29944 | 28230 | 1714 | 5.72 |
| average | 29805 | 28262 | 1543 | 5.18 |
| SD | 215.81 | 625.48 | 471.16 | 1.61 |

| V ; cm/s | % Efficiency | SD |
|---|---|---|
| 1.04 | 39.58 | 1.61 |
| 3.77 | 8.69 | 1.37 |
| 7.36 | 7.30 | 1.98 |
| 11.02 | 6.49 | 3.47 |
| 14.68 | 5.18 | 1.61 |

| Q = 2.83 lpm (V=1.04 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 34866 | 16898 | 17968 | 51.53 |
| 3 | 33795 | 16208 | 17587 | 52.04 |
| 4 | 34193 | 16142 | 18051 | 52.79 |
| 5 | 33692 | 15988 | 17704 | 52.55 |
| average | 34137 | 16309 | 17828 | 52.23 |
| SD | 532.15 | 403.34 | 218.16 | 0.56 |

| Q = 10.83 lpm (V=3.77 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 43010 | 35151 | 7859 | 18.27 |
| 3 | 42594 | 34691 | 7903 | 18.55 |
| 5 | 43022 | 35099 | 7923 | 18.42 |
| 6 | 43240 | 35151 | 8089 | 18.71 |
| average | 42967 | 35023 | 7944 | 18.49 |
| SD | 269.90 | 222.69 | 100.62 | 0.19 |

| Q = 20.06 lpm (V=7.36 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 38860 | 35754 | 3106 | 7.99 |
| 4 | 39525 | 36690 | 2835 | 7.17 |
| 5 | 39708 | 36838 | 2870 | 7.23 |
| 6 | 39721 | 35715 | 4006 | 10.09 |
| average | 39454 | 36249 | 3204 | 8.12 |
| SD | 405.66 | 597.66 | 547.88 | 1.36 |

| Q = 30.03 lpm (V=11.02 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 35429 | 33599 | 1830 | 5.17 |
| 3 | 35102 | 32926 | 2176 | 6.20 |
| 4 | 35900 | 33815 | 2085 | 5.81 |
| 5 | 35678 | 33653 | 2025 | 5.68 |
| average | 35527 | 33498 | 2029 | 5.71 |
| SD | 342.62 | 392.39 | 146.47 | 0.43 |

| Q = 40.01 lpm (V=14.68 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 29100 | 28163 | 937 | 3.22 |
| 2 | 29271 | 28445 | 826 | 2.82 |
| 4 | 29064 | 27821 | 1243 | 4.28 |
| 6 | 28966 | 27886 | 1080 | 3.73 |
| average | 29100 | 28079 | 1022 | 3.51 |
| SD | 127.14 | 285.67 | 180.60 | 0.63 |

| V ; cm/s | % Efficiency | SD |
|---|---|---|
| 1.04 | 52.23 | 0.56 |
| 3.77 | 18.49 | 0.19 |
| 7.36 | 8.12 | 1.36 |
| 11.02 | 5.71 | 0.43 |
| 14.68 | 3.51 | 0.63 |

| Q = 2.83 lpm (V=1.04 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 34900 | 8430 | 26470 | 75.85 |
| 3 | 34664 | 8883 | 25781 | 74.37 |
| 4 | 36227 | 8448 | 27779 | 76.68 |
| 6 | 36088 | 7260 | 28828 | 79.88 |
| average | 35470 | 8255 | 27215 | 76.70 |
| SD | 801.98 | 695.77 | 1357.85 | 2.33 |

| Q = 10.83 lpm (V=3.77 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 40222 | 21069 | 19153 | 47.62 |
| 2 | 39647 | 20266 | 19381 | 48.88 |
| 3 | 41142 | 21480 | 19662 | 47.79 |
| 5 | 40604 | 20036 | 20568 | 50.66 |
| average | 40404 | 20713 | 19691 | 48.74 |
| SD | 630.03 | 676.55 | 620.62 | 1.40 |

| Q = 20.06 lpm (V=7.36 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 42880 | 23725 | 19155 | 44.67 |
| 3 | 42946 | 24863 | 18083 | 42.11 |
| 4 | 42823 | 23673 | 19150 | 44.72 |
| 5 | 42478 | 23227 | 19251 | 45.32 |
| average | 42782 | 23872 | 18910 | 44.20 |
| SD | 208.64 | 697.45 | 553.12 | 1.43 |

| Q = 30.03 lpm (V=11.02 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 34802 | 24005 | 10797 | 31.02 |
| 3 | 36526 | 23209 | 13317 | 36.46 |
| 4 | 32421 | 23053 | 9368 | 28.89 |
| 6 | 36550 | 23578 | 12972 | 35.49 |
| average | 35075 | 23461 | 11614 | 32.97 |
| SD | 1949.30 | 424.10 | 1866.94 | 3.60 |

| Q = 40.01 lpm (V=14.68 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 29144 | 20521 | 8623 | 29.59 |
| 3 | 29738 | 20574 | 9164 | 30.82 |
| 4 | 29876 | 20839 | 9037 | 30.25 |
| 5 | 29592 | 20669 | 8923 | 30.15 |
| average | 29588 | 20651 | 8937 | 30.20 |
| SD | 317.59 | 139.64 | 231.17 | 0.50 |

| V ; cm/s | % Efficiency | SD |
|---|---|---|
| 1.04 | 76.70 | 2.33 |
| 3.77 | 48.74 | 1.40 |
| 7.36 | 44.20 | 1.43 |
| 11.02 | 32.97 | 3.60 |
| 14.68 | 30.20 | 0.50 |

| Q = 2.83 lpm (V=1.04 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 35029 | 46 | 34983 | 99.87 |
| 2 | 34447 | 37 | 34410 | 99.89 |
| 3 | 33405 | 59 | 33346 | 99.82 |
| 6 | 32476 | 43 | 32433 | 99.87 |
| average | 33839 | 46 | 33793 | 99.86 |
| SD | 1130.18 | 9.29 | 1132.28 | 0.03 |

| Q = 10.28 lpm (V=3.77 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 40482 | 352 | 40130 | 99.13 |
| 3 | 40145 | 441 | 39704 | 98.90 |
| 4 | 40267 | 360 | 39907 | 99.11 |
| 5 | 40827 | 322 | 40505 | 99.21 |
| average | 40430 | 369 | 40062 | 99.09 |
| SD | 298.95 | 50.87 | 343.06 | 0.13 |

| Q = 20.06 lpm (V=7.36 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 42633 | 3069 | 39564 | 92.80 |
| 3 | 42306 | 2765 | 39541 | 93.46 |
| 4 | 42670 | 2586 | 40084 | 93.94 |
| 5 | 42451 | 3269 | 39182 | 92.30 |
| average | 42515 | 2922 | 39593 | 93.13 |
| SD | 169.04 | 305.27 | 371.28 | 0.72 |

| Q = 30.03 lpm (V=11.02 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 36439 | 9517 | 26922 | 73.88 |
| 2 | 36492 | 9602 | 26890 | 73.69 |
| 4 | 36317 | 10373 | 25944 | 71.44 |
| 5 | 35803 | 8516 | 27287 | 76.21 |
| average | 36263 | 9502 | 26761 | 73.81 |
| SD | 315.14 | 761.81 | 573.51 | 1.95 |

| Q = 40.01 lpm (V=14.68 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 29810 | 11207 | 18603 | 62.41 |
| 2 | 29363 | 11414 | 17949 | 61.13 |
| 4 | 29149 | 9683 | 19466 | 66.78 |
| 5 | 28886 | 9838 | 19048 | 65.94 |
| average | 29302 | 10536 | 18767 | 64.06 |
| SD | 390.83 | 901.10 | 648.99 | 2.73 |

| V ; cm/s | % Efficiency | SD |
|---|---|---|
| 1.04 | 99.86 | 0.03 |
| 3.77 | 99.09 | 0.13 |
| 7.36 | 93.13 | 0.72 |
| 11.02 | 73.81 | 1.95 |
| 14.68 | 64.06 | 2.73 |

**Table 8.** Collection efficiency data for 0.3 micrometer at 100 VAC

| Q = 2.83 lpm (V=1.04 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 36418 | 34370 | 33980 | 33021 | 30513 | 30259 | 22656 | 20648 | 22698 | 20140 | 22551 | 17670 |
| 0.5 | 1552 | 1570 | 1513 | 1484 | 1391 | 1415 | 1171 | 1136 | 1082 | 1123 | 1138 | 989 |
| 0.7 | 205 | 215 | 187 | 206 | 196 | 178 | 155 | 143 | 136 | 158 | 147 | 110 |
| 1.0 | 151 | 150 | 161 | 155 | 132 | 140 | 127 | 124 | 116 | 129 | 124 | 106 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 |

| Q = 10.28 lpm (V=3.77 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 37966 | 37946 | 38120 | 38498 | 37957 | 37973 | 34966 | 38175 | 35218 | 37684 | 34544 | 35973 |
| 0.5 | 1439 | 1515 | 1432 | 1509 | 1500 | 1464 | 1705 | 1628 | 1572 | 1534 | 1496 | 1600 |
| 0.7 | 203 | 203 | 191 | 205 | 228 | 216 | 239 | 235 | 239 | 249 | 219 | 233 |
| 1.0 | 140 | 151 | 173 | 154 | 171 | 169 | 193 | 172 | 164 | 184 | 176 | 176 |
| 5.0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Q = 20.06 lpm (V=7.36 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 41042 | 40682 | 40672 | 40383 | 40101 | 40098 | 37280 | 38682 | 40775 | 38383 | 37101 | 39257 |
| 0.5 | 2007 | 1904 | 1930 | 1924 | 1972 | 2023 | 2104 | 2226 | 2253 | 2260 | 2065 | 2233 |
| 0.7 | 314 | 329 | 334 | 339 | 302 | 281 | 346 | 370 | 318 | 341 | 388 | 303 |
| 1.0 | 246 | 216 | 263 | 254 | 225 | 236 | 228 | 267 | 236 | 244 | 242 | 258 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Q = 30.03 lpm (V=11.02 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 35045 | 34767 | 34909 | 35244 | 35346 | 35334 | 34888 | 35235 | 33909 | 32244 | 34346 | 32334 |
| 0.5 | 1762 | 1814 | 1821 | 1750 | 1828 | 1853 | 1915 | 1913 | 1954 | 1958 | 1902 | 1947 |
| 0.7 | 277 | 278 | 274 | 266 | 300 | 319 | 333 | 310 | 331 | 318 | 329 | 322 |
| 1.0 | 237 | 215 | 249 | 202 | 200 | 230 | 230 | 245 | 211 | 239 | 235 | 258 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |

| Q = 40.01 lpm (V=14.68 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 29829 | 30028 | 29572 | 29401 | 29230 | 29493 | 27077 | 28966 | 27451 | 28401 | 28230 | 29497 |
| 0.5 | 1934 | 1961 | 1895 | 1846 | 1913 | 1911 | 1734 | 1928 | 1807 | 1842 | 1943 | 1827 |
| 0.7 | 355 | 305 | 304 | 301 | 298 | 320 | 291 | 312 | 278 | 285 | 288 | 276 |
| 1.0 | 234 | 238 | 237 | 213 | 214 | 207 | 233 | 243 | 226 | 237 | 198 | 231 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 7.** Collection efficiency data for 0.3 micrometer at 140 VAC

| Q = 2.83 lpm (V=1.04 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 34866 | 33888 | 33795 | 34193 | 33692 | 31816 | 16898 | 14214 | 16208 | 16142 | 15988 | 12215 |
| 0.5 | 1542 | 1508 | 1587 | 1565 | 1519 | 1472 | 1111 | 1052 | 1095 | 1062 | 1113 | 1053 |
| 0.7 | 200 | 179 | 210 | 193 | 188 | 193 | 153 | 136 | 147 | 160 | 173 | 148 |
| 1.0 | 137 | 153 | 144 | 153 | 147 | 123 | 134 | 120 | 106 | 135 | 107 | 129 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |

| Q = 10.28 lpm (V=3.77 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 37851 | 38860 | 39784 | 39525 | 36838 | 39721 | 35151 | 35754 | 34691 | 36690 | 35099 | 35151 |
| 0.5 | 1503 | 1583 | 1632 | 1569 | 1619 | 1612 | 1520 | 1479 | 1573 | 1569 | 1619 | 1521 |
| 0.7 | 215 | 239 | 232 | 207 | 231 | 239 | 206 | 222 | 223 | 207 | 231 | 234 |
| 1.0 | 140 | 191 | 202 | 190 | 196 | 161 | 153 | 156 | 162 | 190 | 196 | 180 |
| 5.0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |

| Q = 20.06 lpm (V=7.36 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 43010 | 42890 | 42594 | 43047 | 38099 | 43240 | 38151 | 35754 | 37691 | 36690 | 36838 | 35715 |
| 0.5 | 2249 | 2241 | 2224 | 2137 | 2149 | 2214 | 2052 | 2010 | 1937 | 2111 | 2149 | 2117 |
| 0.7 | 370 | 341 | 327 | 361 | 321 | 373 | 342 | 301 | 328 | 356 | 321 | 326 |
| 1.0 | 247 | 282 | 264 | 261 | 255 | 256 | 236 | 235 | 215 | 260 | 255 | 222 |
| 5.0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Q = 30.03 lpm (V=11.02 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 3555 | 35429 | 35102 | 32900 | 35678 | 35864 | 34281 | 33599 | 32926 | 33815 | 33653 | 33321 |
| 0.5 | 1869 | 1859 | 1847 | 1731 | 1940 | 1893 | 1871 | 1915 | 1798 | 1840 | 1855 | 1866 |
| 0.7 | 271 | 316 | 293 | 304 | 311 | 268 | 321 | 314 | 286 | 320 | 309 | 341 |
| 1.0 | 224 | 227 | 211 | 255 | 205 | 208 | 240 | 227 | 212 | 232 | 220 | 220 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Q = 40.01 lpm (V=14.68 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 29100 | 29271 | 28920 | 29064 | 29247 | 28966 | 28163 | 28445 | 28216 | 27821 | 27701 | 27886 |
| 0.5 | 1747 | 1858 | 1841 | 1891 | 1805 | 1827 | 1758 | 1679 | 1707 | 1758 | 1693 | 1611 |
| 0.7 | 275 | 311 | 275 | 285 | 273 | 300 | 292 | 291 | 292 | 297 | 279 | 287 |
| 1.0 | 196 | 218 | 243 | 208 | 206 | 244 | 211 | 216 | 202 | 212 | 213 | 188 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

**Table 6.** Collection efficiency data for 0.3 micrometer at 180 VAC

| Q = 2.83 lpm (V=1.04 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 34900 | 35293 | 34664 | 36227 | 35085 | 36088 | 8430 | 7452 | 8883 | 8448 | 7195 | 7260 |
| 0.5 | 1542 | 1614 | 1573 | 1596 | 1529 | 1648 | 966 | 885 | 886 | 909 | 1027 | 984 |
| 0.7 | 199 | 232 | 231 | 231 | 213 | 231 | 142 | 117 | 112 | 138 | 145 | 117 |
| 1.0 | 148 | 140 | 146 | 145 | 160 | 125 | 87 | 88 | 91 | 91 | 119 | 106 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Q = 10.28 lpm (V=3.77 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 40222 | 39647 | 41142 | 40546 | 40604 | 39974 | 21069 | 20266 | 21480 | 21506 | 20036 | 19684 |
| 0.5 | 1718 | 1582 | 1678 | 1668 | 1592 | 1651 | 840 | 801 | 870 | 900 | 802 | 776 |
| 0.7 | 252 | 222 | 238 | 262 | 250 | 225 | 131 | 108 | 130 | 116 | 107 | 106 |
| 1.0 | 192 | 186 | 218 | 167 | 185 | 166 | 81 | 96 | 95 | 71 | 74 | 77 |
| 5.0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Q = 20.06 lpm (V=7.36 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 43206 | 42880 | 42946 | 42823 | 42478 | 42753 | 26075 | 23725 | 24863 | 23673 | 23227 | 23305 |
| 0.5 | 2199 | 2137 | 2248 | 2192 | 2200 | 2254 | 1320 | 1197 | 1178 | 1201 | 1143 | 1208 |
| 0.7 | 370 | 362 | 340 | 351 | 411 | 346 | 197 | 179 | 169 | 167 | 152 | 187 |
| 1.0 | 251 | 245 | 261 | 236 | 273 | 260 | 152 | 129 | 137 | 104 | 127 | 130 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Q = 30.03 lpm (V=11.02 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 34599 | 34802 | 36526 | 32421 | 36726 | 36550 | 26154 | 24005 | 23209 | 23053 | 23200 | 23578 |
| 0.5 | 1793 | 1926 | 1934 | 1756 | 1984 | 1996 | 1427 | 1251 | 1231 | 1222 | 1189 | 1157 |
| 0.7 | 303 | 308 | 330 | 295 | 315 | 339 | 257 | 209 | 222 | 206 | 223 | 202 |
| 1.0 | 203 | 247 | 227 | 241 | 217 | 219 | 170 | 136 | 140 | 120 | 146 | 161 |
| 5.0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Q = 40.01 lpm (V=14.68 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 29286 | 29144 | 29738 | 29876 | 29592 | 29661 | 19654 | 20521 | 20574 | 20839 | 20669 | 19519 |
| 0.5 | 1841 | 1777 | 1907 | 1839 | 1847 | 1737 | 870 | 869 | 872 | 752 | 854 | 941 |
| 0.7 | 306 | 331 | 311 | 309 | 290 | 322 | 129 | 130 | 146 | 103 | 128 | 134 |
| 1.0 | 195 | 239 | 220 | 226 | 227 | 196 | 97 | 102 | 112 | 100 | 106 | 108 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

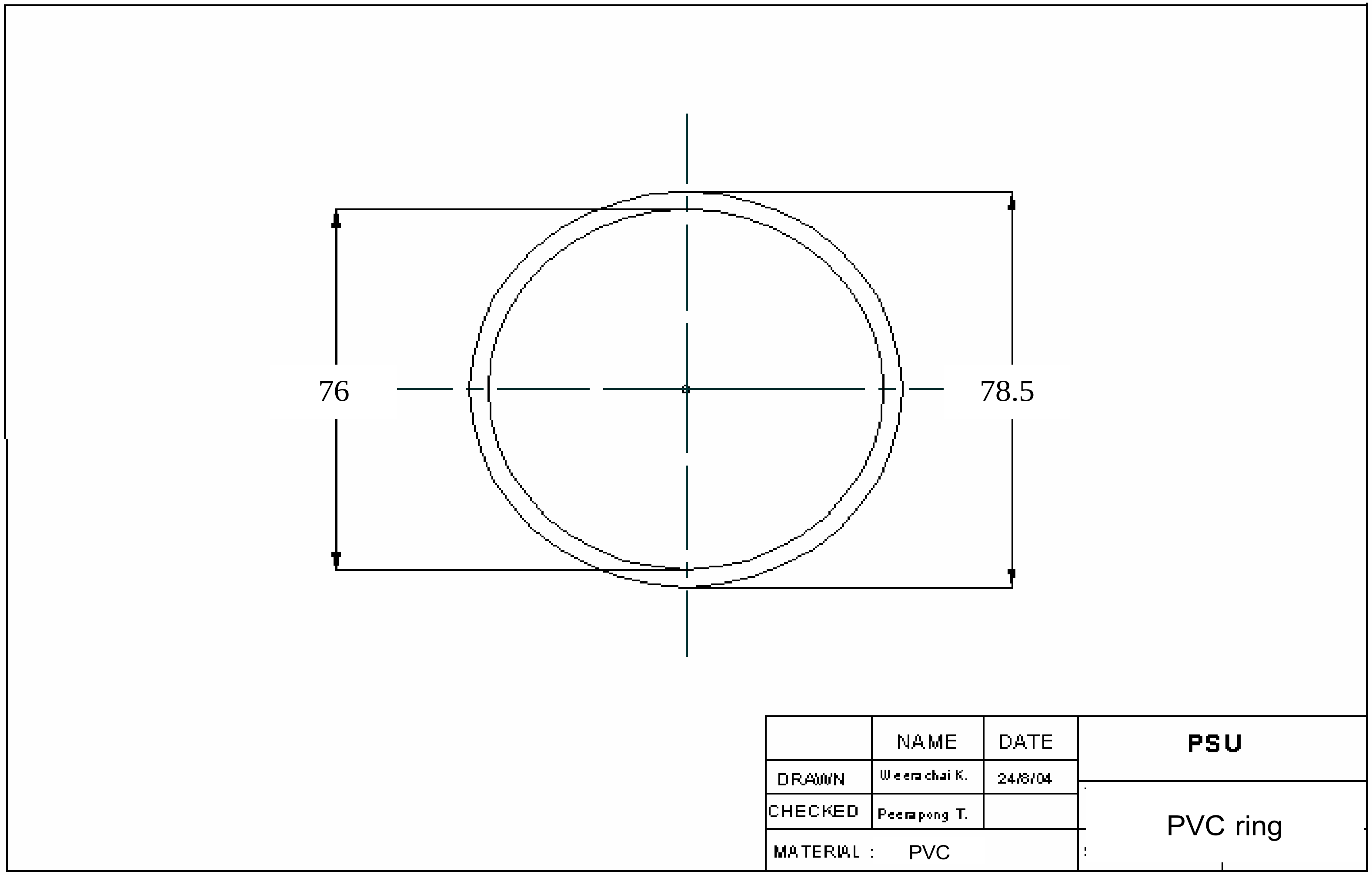


**Figure 3.** Model of PVC ring (continued).

**Table 5.** Collection efficiency data for 0.3 micrometer at 220 VAC

| Q = 2.83 lpm (V = 1.04 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; μm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 35029 | 34447 | 33405 | 32757 | 31987 | 32476 | 46 | 37 | 59 | 28 | 78 | 43 |
| 0.5 | 1563 | 1592 | 1509 | 1517 | 1514 | 1520 | 0 | 0 | 1 | 2 | 5 | 6 |
| 0.7 | 214 | 210 | 215 | 198 | 205 | 188 | 1 | 0 | 1 | 0 | 0 | 0 |
| 1.0 | 170 | 154 | 126 | 132 | 130 | 168 | 0 | 0 | 1 | 0 | 0 | 0 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Q = 10.83 lpm (V = 3.77 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; μm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 40247 | 40482 | 40145 | 40267 | 40827 | 39712 | 539 | 352 | 441 | 360 | 322 | 286 |
| 0.5 | 1620 | 1624 | 1559 | 1624 | 1644 | 1672 | 12 | 12 | 12 | 5 | 322 | 11 |
| 0.7 | 245 | 228 | 269 | 228 | 272 | 223 | 0 | 3 | 0 | 2 | 14 | 0 |
| 1.0 | 202 | 158 | 184 | 198 | 167 | 159 | 0 | 0 | 1 | 0 | 0 | 0 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Q = 20.06 lpm (V = 7.36 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; μm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 42633 | 42021 | 42306 | 42670 | 42451 | 43243 | 3069 | 3245 | 2765 | 2586 | 3269 | 2149 |
| 0.5 | 2119 | 2206 | 2210 | 2255 | 2155 | 2272 | 128 | 152 | 129 | 111 | 137 | 98 |
| 0.7 | 344 | 394 | 324 | 366 | 375 | 342 | 12 | 22 | 15 | 12 | 13 | 11 |
| 1.0 | 285 | 221 | 247 | 266 | 254 | 249 | 6 | 7 | 9 | 7 | 13 | 4 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Q = 30.03 lpm (V = 11.02 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; μm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 36439 | 36492 | 35925 | 36317 | 35803 | 36203 | 9517 | 9602 | 8982 | 10373 | 8516 | 5937 |
| 0.5 | 1947 | 1921 | 1957 | 1919 | 1892 | 1965 | 377 | 388 | 489 | 432 | 280 | 324 |
| 0.7 | 330 | 327 | 306 | 291 | 316 | 296 | 45 | 52 | 62 | 64 | 48 | 52 |
| 1.0 | 230 | 243 | 213 | 234 | 221 | 246 | 41 | 44 | 47 | 41 | 32 | 17 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Q = 40.01 lpm (V = 14.68 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; μm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 29810 | 29363 | 28886 | 29149 | 28886 | 29094 | 11207 | 11414 | 12459 | 9683 | 9838 | 12584 |
| 0.5 | 1841 | 1814 | 1828 | 1836 | 1751 | 1767 | 184 | 148 | 70 | 150 | 137 | 198 |
| 0.7 | 306 | 285 | 288 | 300 | 312 | 281 | 18 | 16 | 20 | 20 | 19 | 26 |
| 1.0 | 251 | 248 | 201 | 204 | 228 | 212 | 11 | 8 | 3 | 16 | 13 | 15 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Q = 2.83 lpm (V=1.04 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 42334 | 30939 | 11395 | 26.92 |
| 2 | 42023 | 31571 | 10452 | 24.87 |
| 3 | 43850 | 32869 | 10981 | 25.04 |
| 5 | 42575 | 31872 | 10703 | 25.14 |
| average | 42696 | 31813 | 10883 | 25.49 |
| SD | 802.15 | 804.37 | 404.11 | 0.96 |

| Q = 10.83 lpm (V=3.77 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 35836 | 30577 | 5259 | 14.68 |
| 3 | 35943 | 30777 | 5166 | 14.37 |
| 4 | 35761 | 30921 | 4840 | 13.53 |
| 5 | 35638 | 30287 | 5351 | 15.01 |
| average | 35795 | 30641 | 5154 | 14.40 |
| SD | 128.31 | 274.66 | 222.54 | 0.63 |

| Q = 20.06 lpm (V=7.36 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 37359 | 33769 | 3590 | 9.61 |
| 2 | 37357 | 33866 | 3491 | 9.34 |
| 4 | 37292 | 34926 | 2366 | 6.34 |
| 6 | 37052 | 35042 | 2010 | 5.42 |
| average | 37265 | 34401 | 2864 | 7.68 |
| SD | 145.37 | 676.30 | 795.30 | 2.11 |

| Q = 30.03 lpm (V=11.02 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 30940 | 29310 | 1630 | 5.27 |
| 3 | 31512 | 29989 | 1523 | 4.83 |
| 5 | 31220 | 29385 | 1835 | 5.88 |
| 6 | 31346 | 29623 | 1723 | 5.50 |
| average | 31255 | 29577 | 1678 | 5.37 |
| SD | 241.37 | 305.51 | 132.92 | 0.44 |

| Q = 40.01 lpm (V=14.68 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 32272 | 31675 | 597 | 1.85 |
| 3 | 32029 | 31481 | 548 | 1.71 |
| 4 | 32325 | 31746 | 579 | 1.79 |
| 6 | 32482 | 30768 | 1714 | 5.28 |
| average | 32277 | 31418 | 860 | 2.66 |
| SD | 187.85 | 447.25 | 570.03 | 1.75 |

| V ; cm/s | % Efficiency | SD |
|---|---|---|
| 1.04 | 25.49 | 0.96 |
| 3.77 | 14.40 | 0.63 |
| 7.36 | 7.68 | 2.11 |
| 11.02 | 5.37 | 0.44 |
| 14.68 | 2.66 | 1.75 |

| Q = 2.83 lpm (V=1.04 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 40154 | 22344 | 17810 | 44.35 |
| 3 | 41654 | 23125 | 18529 | 44.48 |
| 5 | 42671 | 23553 | 19118 | 44.80 |
| 6 | 41442 | 23615 | 17827 | 43.02 |
| average | 41480 | 23159 | 18321 | 44.17 |
| SD | 1034.16 | 585.53 | 628.13 | 0.79 |

| Q = 10.83 lpm (V=3.77 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 36086 | 30793 | 5293 | 14.67 |
| 3 | 36345 | 29484 | 6861 | 18.88 |
| 4 | 35962 | 29538 | 6424 | 17.86 |
| 6 | 36051 | 29403 | 6648 | 18.44 |
| average | 36111 | 29805 | 6307 | 17.46 |
| SD | 164.50 | 661.33 | 698.83 | 1.91 |

| Q = 20.06 lpm (V=7.36 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 36998 | 34225 | 2773 | 7.49 |
| 3 | 37026 | 34422 | 2604 | 7.03 |
| 4 | 37353 | 34334 | 3019 | 8.08 |
| 5 | 37147 | 34224 | 2923 | 7.87 |
| average | 37131 | 34301 | 2830 | 7.62 |
| SD | 161.51 | 95.63 | 181.38 | 0.46 |

| Q = 30.03 lpm (V=11.02 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 31612 | 29714 | 1898 | 6.00 |
| 3 | 31584 | 29859 | 1725 | 5.46 |
| 5 | 31738 | 30159 | 1579 | 4.98 |
| 6 | 31245 | 29698 | 1547 | 4.95 |
| average | 31545 | 29858 | 1687 | 5.35 |
| SD | 210.76 | 213.65 | 160.45 | 0.50 |

| Q = 40.01 lpm (V=14.68 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 33096 | 31043 | 2053 | 6.20 |
| 4 | 33454 | 31642 | 1812 | 5.42 |
| 5 | 33348 | 31454 | 1894 | 5.68 |
| 6 | 33506 | 31495 | 2011 | 6.00 |
| average | 33351 | 31409 | 1943 | 5.83 |
| SD | 182.27 | 256.69 | 109.98 | 0.35 |

| V ; cm/s | % Efficiency | SD |
|---|---|---|
| 1.04 | 44.17 | 0.79 |
| 3.77 | 17.46 | 1.91 |
| 7.36 | 7.62 | 0.46 |
| 11.02 | 5.35 | 0.50 |
| 14.68 | 5.83 | 0.35 |

| Q = 2.83 lpm (V=1.04 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 38843 | 12365 | 26478 | 68.17 |
| 2 | 38965 | 12509 | 26456 | 67.90 |
| 4 | 38102 | 13745 | 24357 | 63.93 |
| 5 | 38902 | 12262 | 26640 | 68.48 |
| average | 38703 | 12720 | 25983 | 67.13 |
| SD | 403.75 | 690.64 | 1086.93 | 2.14 |

| Q = 10.83 lpm (V=3.77 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 36729 | 17958 | 18771 | 51.11 |
| 3 | 36553 | 16341 | 20212 | 55.30 |
| 4 | 35882 | 20378 | 15504 | 43.21 |
| 5 | 36190 | 17851 | 18339 | 50.67 |
| average | 36339 | 18132 | 18207 | 50.07 |
| SD | 378.13 | 1669.47 | 1971.61 | 5.03 |

| Q = 20.06 lpm (V=7.36 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 37128 | 23741 | 13387 | 36.06 |
| 2 | 36762 | 23554 | 13208 | 35.93 |
| 4 | 36884 | 23886 | 12998 | 35.24 |
| 5 | 36963 | 24363 | 12600 | 34.09 |
| average | 36934 | 23886 | 13048 | 35.33 |
| SD | 153.36 | 345.82 | 338.49 | 0.90 |

| Q = 30.03 lpm (V=11.02 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 31532 | 22873 | 8659 | 27.46 |
| 3 | 31859 | 22377 | 9482 | 29.76 |
| 4 | 31693 | 21844 | 9849 | 31.08 |
| 5 | 31671 | 21832 | 9839 | 31.07 |
| average | 31689 | 22232 | 9457 | 29.84 |
| SD | 134.03 | 497.48 | 558.87 | 1.70 |

| Q = 40.01 lpm (V=14.68 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 33302 | 24653 | 8649 | 25.97 |
| 3 | 33588 | 25027 | 8561 | 25.49 |
| 4 | 33354 | 24127 | 9227 | 27.66 |
| 5 | 33007 | 24388 | 8619 | 26.11 |
| average | 33313 | 24549 | 8764 | 26.31 |
| SD | 238.79 | 384.41 | 310.82 | 0.94 |

| V ; cm/s | % Efficiency | SD |
|---|---|---|
| 1.04 | 67.13 | 2.14 |
| 3.77 | 50.07 | 5.03 |
| 7.36 | 35.33 | 0.90 |
| 11.02 | 29.84 | 1.70 |
| 14.68 | 26.31 | 0.94 |

| Q = 2.83 lpm (V=1.04 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 43854 | 25 | 43829 | 99.94 |
| 4 | 41882 | 30 | 41852 | 99.93 |
| 5 | 43559 | 24 | 43535 | 99.94 |
| 6 | 43302 | 25 | 43277 | 99.94 |
| เฉลี่ย | 43149 | 26 | 43123 | 99.94 |
| SD | 874.42 | 2.71 | 876.99 | 0.01 |

| Q = 10.83 lpm (V=3.77 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 36410 | 432 | 35978 | 98.81 |
| 3 | 36056 | 478 | 35578 | 98.67 |
| 4 | 36211 | 243 | 35968 | 99.33 |
| 5 | 36401 | 324 | 36077 | 99.11 |
| เฉลี่ย | 36270 | 369 | 35900 | 98.98 |
| SD | 169.35 | 106.07 | 220.39 | 0.29 |

| Q = 20.06 lpm (V=7.36 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 36957 | 10417 | 26540 | 71.81 |
| 3 | 36956 | 9573 | 27383 | 74.10 |
| 5 | 36995 | 9963 | 27032 | 73.07 |
| 6 | 37380 | 9318 | 28062 | 75.07 |
| เฉลี่ย | 37072 | 9818 | 27254 | 73.51 |
| SD | 206.13 | 479.53 | 639.94 | 1.40 |

| Q = 30.03 lpm (V=11.02 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 1 | 31670 | 12789 | 18881 | 59.62 |
| 3 | 31765 | 13085 | 18680 | 58.81 |
| 4 | 32102 | 11680 | 20422 | 63.62 |
| 6 | 31369 | 12315 | 19054 | 60.74 |
| เฉลี่ย | 31727 | 12467 | 19259 | 60.70 |
| SD | 301.93 | 613.21 | 790.09 | 2.10 |

| Q = 40.01 lpm (V=14.68 cm/s) | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 33225 | 17506 | 15719 | 47.31 |
| 4 | 33402 | 16238 | 17164 | 51.39 |
| 5 | 33200 | 17215 | 15985 | 48.15 |
| 6 | 33436 | 16420 | 17016 | 50.89 |
| เฉลี่ย | 33316 | 16845 | 16471 | 49.43 |
| SD | 120.46 | 611.80 | 725.48 | 2.01 |

| V ; cm/s | % Efficiency | SD |
|---|---|---|
| 1.04 | 99.94 | 0.01 |
| 3.77 | 98.98 | 0.29 |
| 7.36 | 73.51 | 1.40 |
| 11.02 | 60.70 | 2.10 |
| 14.68 | 49.43 | 2.01 |

**Table 12.** Collection efficiency data for 0.5 micrometer at 100 VAC

| Q = 2.83 lpm (V=1.04 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 16080 | 15928 | 15715 | 16029 | 16102 | 15941 | 12319 | 11199 | 11860 | 12690 | 10807 | 11677 |
| 0.5 | 42334 | 42023 | 43850 | 41372 | 42575 | 41599 | 30939 | 31571 | 32869 | 30877 | 31872 | 31990 |
| 0.7 | 3110 | 3140 | 3215 | 3113 | 3200 | 3312 | 2326 | 2105 | 2254 | 2188 | 2302 | 2249 |
| 1.0 | 1710 | 1820 | 1911 | 1672 | 1718 | 1848 | 1334 | 1166 | 1098 | 1042 | 1246 | 1170 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Q = 10.28 lpm (V=3.77 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 16772 | 16907 | 16805 | 18616 | 22160 | 22851 | 17587 | 17778 | 17442 | 18732 | 18329 | 18222 |
| 0.5 | 35836 | 36386 | 35943 | 35761 | 35638 | 35478 | 30577 | 32090 | 30777 | 30921 | 30287 | 35454 |
| 0.7 | 3609 | 3733 | 3706 | 3668 | 3672 | 3558 | 3668 | 3464 | 3510 | 3610 | 3639 | 3671 |
| 1.0 | 1651 | 1604 | 1629 | 1687 | 1747 | 1700 | 1657 | 1597 | 1591 | 1632 | 1627 | 1601 |
| 5.0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Q = 20.06 lpm (V=7.36 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 19416 | 19021 | 19376 | 19361 | 19020 | 18821 | 21540 | 22503 | 22553 | 22699 | 22467 | 22615 |
| 0.5 | 37359 | 37357 | 37506 | 37292 | 36881 | 37052 | 33769 | 33866 | 35070 | 34926 | 36056 | 35042 |
| 0.7 | 3961 | 3947 | 3997 | 4048 | 3964 | 3936 | 3804 | 3799 | 3852 | 3739 | 3890 | 3823 |
| 1.0 | 1809 | 1848 | 1802 | 1798 | 1728 | 1693 | 1672 | 1759 | 1712 | 1762 | 1763 | 1703 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |

| Q = 30.03 lpm (V=11.02 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 17265 | 16788 | 16852 | 16641 | 16695 | 16672 | 21386 | 21258 | 20869 | 21229 | 21163 | 20761 |
| 0.5 | 31333 | 30940 | 31512 | 31146 | 31220 | 31346 | 31139 | 29310 | 29989 | 30565 | 29385 | 29623 |
| 0.7 | 3317 | 3348 | 3397 | 3255 | 3388 | 3291 | 3141 | 3174 | 3264 | 3154 | 3203 | 3113 |
| 1.0 | 1509 | 1469 | 1537 | 1467 | 1500 | 1522 | 1380 | 1425 | 1412 | 1445 | 1419 | 1418 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Q = 40.01 lpm (V=14.68 cm/s) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 17959 | 17907 | 17655 | 18014 | 17648 | 17980 | 23538 | 23339 | 22659 | 23236 | 23297 | 22904 |
| 0.5 | 32349 | 32272 | 32029 | 32325 | 32288 | 32482 | 31522 | 31675 | 31481 | 31746 | 32053 | 30768 |
| 0.7 | 3385 | 3497 | 3377 | 3414 | 3478 | 3401 | 3306 | 3269 | 3203 | 3338 | 3327 | 3340 |
| 1.0 | 1568 | 1593 | 1544 | 1526 | 1504 | 1513 | 1465 | 1542 | 1492 | 1439 | 1510 | 1513 |
| 5.0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 |

# Appendix E

## Theoretical calculations for collection efficiency

# Collection Efficiency of ESP for 0.3 μm at 180 VAC

```
ClearAll["Global`*"]
```

**Some constants**

```
i=1*10^-6; (* corona discharge current *)
dp=0.3*10^-6; (* particle diameter *)
lambda=0.066*10^-6; (* mean free path *)
r=3.8*10^-2;   (* radius of the cylinder *)
d=7.6*10^-2;  (* diameter of the cylinder *)
L=24.5*10^-2; (* length of the cylinder *)
k=1.38*10^-23; (* Boltzmann's constant *)
Temp=293;  (* temperature *)
mu=1.820*10^-5; (* viscosity *)
e=1.6*10^-19; (* electron charge *)
epsilon=2.4; (* dielectric constant of PSL *)
```

**Geometry**

```
volume=Pi*r^2*L; (* volume of the cylinder *)
A1=2*Pi*r*L;  (* surface area of the cylinder *)
A2=(Pi*d^2)/4; (* cross section area of the cylinder *)
```

**Electric field strength inside a cylindrical tube:EE (180 V)**

```
W=8833.33;  (* Voltage *)
R=3.8*10^-2;
dw=0.5*10^-3;
dt=7.6*10^-2;
EE=W/(R*Log[dt/dw]);
```

**Cunningham correction factor**

```
Cc=1+2.52 lambda/dp;
```

**Time, Velocity, Flow**

```
Q[qq_]=qq*10^-3/60;
V=Q[qq]/A2;
t=volume/Q[qq];
```

**Diffusion charging**

```
Ni=i/(e*Zi*EE*A1); (* ion concentration *)
epsilon0=8.8542*10^-12; (* vacuum permittivity *)
kE=(4 Pi epsilon0)^-1 ; (* electrostatic constant *)
ci=9.79*10^3 mu^0.5 Temp^0.5 ; (* ion mean thermal velocity *)
ndiff[qq_]=dp*k*Temp/(2*kE*e^2)*Log[1+(Pi*kE*dp*ci*e^2*Ni*t)/(2*k*Temp)];
```

**Field charging**

```
Zi=1.7*10^-4; (* mobility of ions *)
nfield[qq_]=(3*epsilon)/(epsilon+2) * (EE*dp^2)/(4*kE*e) *
(Pi*kE*e*Zi*Ni*t/(1+Pi*kE*e*Zi*Ni*t));
```

**Combined Charging**

```
 nall[qq_]=ndiff[qq]+nfield[qq];
```

**Terminal electric velocity**

```
VTE[qq_]=nall[qq]*e*EE*Cc/(3*Pi*mu*dp);
```

**Collection efficiency**

```
 Eff[qq_]=(1-Exp[-VTE[qq]*A1/Q[qq]])*100;
 plot3=Plot[Eff[qq],{qq,0,50},PlotRange→{0,100},PlotStyle->RGBColor[1,0,0]]
```

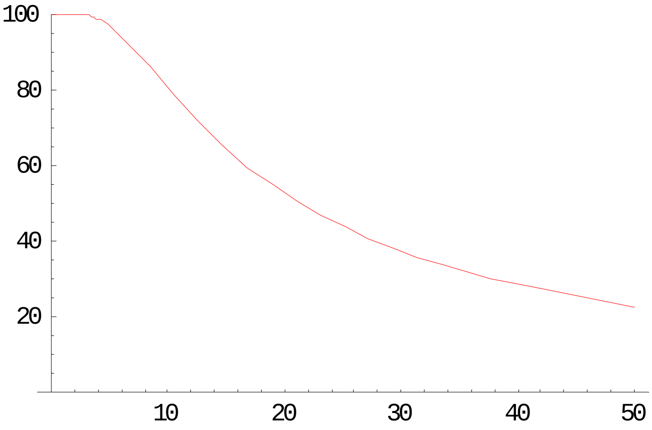


**Table 21.** Theoretical calculation data for 0.3 μm at 180 VAC

| V [cm/s] | Efficiency [%] |
|---|---|
| 1.04 | 99.87 |
| 3.77 | 79.51 |
| 7.36 | 52.46 |
| 11.02 | 37.41 |
| 14.68 | 28.58 |

## Collection Efficiency of ESP for 0.5 μm at 220 VAC

```
ClearAll["Global`*"]
```

### Some constants

```
i=35*10^-6; (* corona discharge current *)
dp=0.5*10^-6; (* particle diameter *)
lambda=0.066*10^-6; (* mean free path *)
r=3.8*10^-2;   (* radius of the cylinder *)
d=7.6*10^-2;  (* diameter of the cylinder *)
L=24.5*10^-2; (* length of the cylinder *)
k=1.38*10^-23; (* Boltzmann's constant *)
Temp=293;  (* temperature *)
mu=1.820*10^-5; (* viscosity *)
e=1.6*10^-19; (* electron charge *)
epsilon=2.4; (* dielectric constant of PSL *)
```

### Geometry

```
volume=Pi*r^2*L; (* volume of the cylinder *)
A1=2*Pi*r*L;  (* surface area of the cylinder *)
A2=(Pi*d^2)/4; (* cross section area of the cylinder *)
```

### Electric field strength inside a cylindrical tube:EE (220 V)

```
W=11733.33;  (* Voltage *)
R=3.8*10^-2;
dw=0.5*10^-3;
dt=7.6*10^-2;
EE=W/(R*Log[dt/dw]);
```

### Cunningham correction factor

```
Cc=1+2.52 lambda/dp;
```

**Time, Velocity, Flow**

```
Q[qq_]=qq*10^-3/60;
V=Q[qq]/A2;
t=volume/Q[qq];
```

**Diffusion charging**

```
Ni=i/(e*Zi*EE*A1); (* ion concentration *)
epsilon0=8.8542*10^-12; (* vacuum permittivity *)
kE=(4 Pi epsilon0)^-1 ; (* electrostatic constant *)
ci=9.79*10^3 mu^0.5 Temp^0.5;  (* ion mean thermal velocity *)
ndiff[qq_]=dp*k*Temp/(2*kE*e^2)*Log[1+(Pi*kE*dp*ci*e^2*Ni*t)/(2*k*Temp)];
```

**Field charging**

```
Zi=1.7*10^-4; (* mobility of ions *)
nfield[qq_]=(3*epsilon)/(epsilon+2) * (EE*dp^2)/(4*kE*e) *
(Pi*kE*e*Zi*Ni*t/(1+Pi*kE*e*Zi*Ni*t));
```

**Combined Charging**

```
 nall[qq_]=ndiff[qq]+nfield[qq];
```

**Terminal electric velocity**

```
VTE[qq_]=nall[qq]*e*EE*Cc/(3*Pi*mu*dp);
```

**Collection efficiency**

```
Eff[qq_]=(1-Exp[-VTE[qq]*A1/Q[qq]])*100;
plot3=Plot[Eff[qq],{qq,0,50},PlotRange→{0,100},PlotStyle->RGBColor[1,0,0]]
```

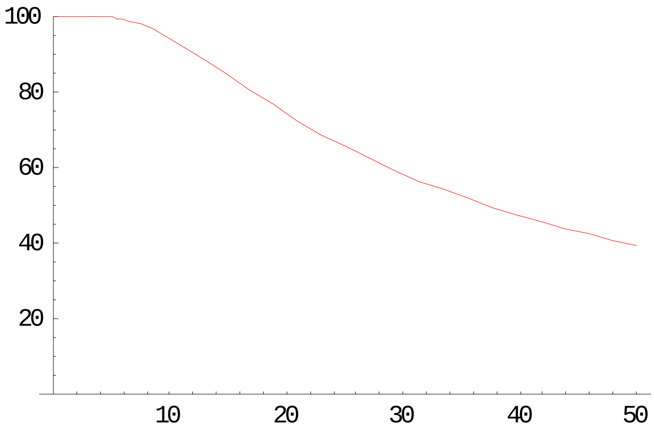


**Table 22.** Theoretical calculation data for 0.5 μm at 220 VAC

| V [cm/s] | Efficiency [%] |
|---|---|
| 1.04 | 100.00 |
| 3.77 | 93.91 |
| 7.36 | 74.25 |
| 11.02 | 58.30 |
| 14.68 | 47.26 |

## Collection Efficiency of ESP for 0.5 μm at 180 VAC

```
ClearAll["Global`*"]
```

**Some constants**

```
i=1*10^-6; (* corona discharge current *)
dp=0.5*10^-6; (* particle diameter *)
lambda=0.066*10^-6; (* mean free path *)
r=3.8*10^-2;   (* radius of the cylinder *)
d=7.6*10^-2;  (* diameter of the cylinder *)
L=24.5*10^-2; (* length of the cylinder *)
k=1.38*10^-23; (* Boltzmann's constant *)
Temp=293;  (* temperature *)
mu=1.820*10^-5; (* viscosity *)
e=1.6*10^-19; (* electron charge *)
epsilon=2.4; (* dielectric constant of PSL *)
```

**Geometry**

```
volume=Pi*r^2*L; (* volume of the cylinder *)
A1=2*Pi*r*L;  (* surface area of the cylinder *)
A2=(Pi*d^2)/4; (* cross section area of the cylinder *)
```

**Electric field strength inside a cylindrical tube:EE 180 V)**

```
W=8833.33;  (* Voltage *)
R=3.8*10^-2;
dw=0.5*10^-3;
dt=7.6*10^-2;
EE=W/(R*Log[dt/dw]);
```

**Cunningham correction factor**

```
Cc=1+2.52 lambda/dp;
```

**Time, Velocity, Flow**

```
Q[qq_]=qq*10^-3/60;
V=Q[qq]/A2;
t=volume/Q[qq];
```

**Diffusion charging**

```
Ni=i/(e*Zi*EE*A1); (* ion concentration *)
epsilon0=8.8542*10^-12; (* vacuum permittivity *)
kE=(4 Pi epsilon0)^-1 ; (* electrostatic constant *)
ci=9.79*10^3 mu^0.5 Temp^0.5;  (* ion mean thermal velocity *)
ndiff[qq_]=dp*k*Temp/(2*kE*e^2)*Log[1+(Pi*kE*dp*ci*e^2*Ni*t)/(2*k*Temp)];
```

**Field charging**

```
Zi=1.7*10^-4; (* mobility of ions *)
nfield[qq_]=(3*epsilon)/(epsilon+2) * (EE*dp^2)/(4*kE*e) *
(Pi*kE*e*Zi*Ni*t/(1+Pi*kE*e*Zi*Ni*t));
```

**Combined Charging**

```
nall[qq_]=ndiff[qq]+nfield[qq];
```

**Terminal electric velocity**

```
VTE[qq_]=nall[qq]*e*EE*Cc/(3*Pi*mu*dp);
```

**Collection efficiency**

```
Eff[qq_]=(1-Exp[-VTE[qq]*A1/Q[qq]])*100;
plot3=Plot[Eff[qq],{qq,0,50},PlotRange→{0,100},PlotStyle->RGBColor[1,0,0]]
```

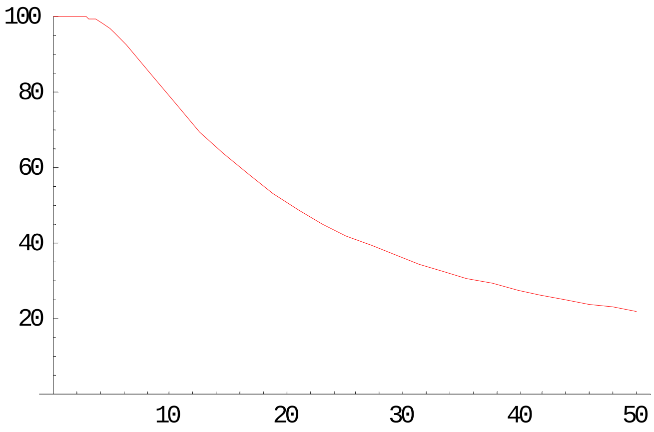


**Table 23.** Theoretical calculation data for 0.5 μm at 180 VAC

| V [cm/s] | Efficiency [%] |
|---|---|
| 1.04 | 99.80 |
| 3.77 | 77.64 |
| 7.36 | 50.76 |
| 11.02 | 36.16 |
| 14.68 | 27.66 |

## Collection Efficiency of ESP for 1.0 μm at 220 VAC

```
 ClearAll["Global`*"]
```

**Some constants**

```
i=35*10^-6; (* corona discharge current *)
dp=1.0*10^-6; (* particle diameter *)
lambda=0.066*10^-6; (* mean free path *)
r=3.8*10^-2;   (* radius of the cylinder *)
d=7.6*10^-2;  (* diameter of the cylinder *)
L=24.5*10^-2; (* length of the cylinder *)
k=1.38*10^-23; (* Boltzmann's constant *)
Temp=293;  (* temperature *)
mu=1.820*10^-5; (* viscosity *)
e=1.6*10^-19; (* electron charge *)
epsilon=2.4; (* dielectric constant of PSL *)
```

**Geometry**

```
volume=Pi*r^2*L; (* volume of the cylinder *)
A1=2*Pi*r*L;  (* surface area of the cylinder *)
A2=(Pi*d^2)/4; (* cross section area of the cylinder *)
```

**Electric field strength inside a cylindrical tube:EE (220 V)**

```
W=11733.33;  (* Voltage *)
R=3.8*10^-2;
dw=0.5*10^-3;
dt=7.6*10^-2;
EE=W/(R*Log[dt/dw]);
```

**Cunningham correction factor**

```
Cc=1+2.52 lambda/dp;
```

### Time, Velocity, Flow

```
Q[qq_]=qq*10^-3/60;
V=Q[qq]/A2;
t=volume/Q[qq];
```

### Diffusion charging

```
Ni=i/(e*Zi*EE*A1); (* ion concentration *)
epsilon0=8.8542*10^-12; (* vacuum permittivity *)
kE=(4 Pi epsilon0)^-1 ; (* electrostatic constant *)
ci=9.79*10^3 mu^0.5 Temp^0.5;  (* ion mean thermal velocity *)
ndiff[qq_]=dp*k*Temp/(2*kE*e^2)*Log[1+(Pi*kE*dp*ci*e^2*Ni*t)/(2*k*Temp)];
```

### Field charging

```
Zi=1.7*10^-4; (* mobility of ions *)
nfield[qq_]=(3*epsilon)/(epsilon+2) * (EE*dp^2)/(4*kE*e) *
(Pi*kE*e*Zi*Ni*t/(1+Pi*kE*e*Zi*Ni*t));
```

### Combined Charging

```
 nall[qq_]=ndiff[qq]+nfield[qq];
```

### Terminal electric velocity

```
VTE[qq_]=nall[qq]*e*EE*Cc/(3*Pi*mu*dp);
```

### Collection efficiency

```
Eff[qq_]=(1-Exp[-VTE[qq]*A1/Q[qq]])*100;
plot3=Plot[Eff[qq],{qq,0,50},PlotRange→{0,100},PlotStyle->RGBColor[1,0,0]]
```

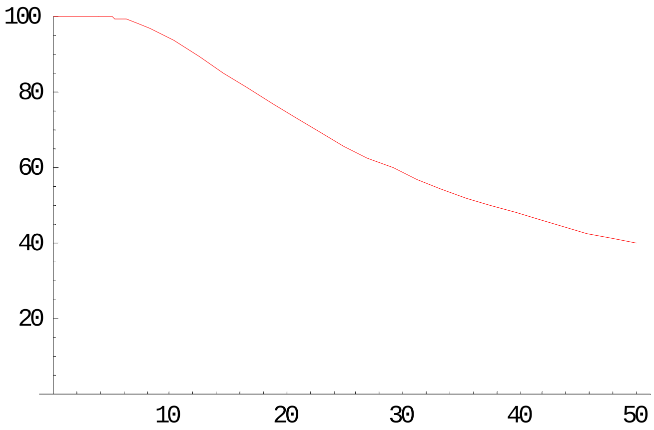


**Table 24.** Theoretical calculation data for 1.0 μm at 220 VAC

| V [cm/s] | Efficiency [%] |
|---|---|
| 1.04 | 100.00 |
| 3.77 | 93.84 |
| 7.36 | 74.36 |
| 11.02 | 58.58 |
| 14.68 | 47.63 |

# Collection Efficiency of ESP for 1.0 μm at 180 VAC

```
ClearAll["Global`*"]
```

**Some constants**

```
i=1*10^-6; (* corona discharge current *)
dp=1.0*10^-6; (* particle diameter *)
lambda=0.066*10^-6; (* mean free path *)
r=3.8*10^-2;   (* radius of the cylinder *)
d=7.6*10^-2;  (* diameter of the cylinder *)
L=24.5*10^-2; (* length of the cylinder *)
k=1.38*10^-23; (* Boltzmann's constant *)
Temp=293;  (* temperature *)
mu=1.820*10^-5; (* viscosity *)
e=1.6*10^-19; (* electron charge *)
epsilon=2.4; (* dielectric constant of PSL *)
```

**Geometry**

```
volume=Pi*r^2*L; (* volume of the cylinder *)
A1=2*Pi*r*L;  (* surface area of the cylinder *)
A2=(Pi*d^2)/4; (* cross section area of the cylinder *)
```

**Electric field strength inside a cylindrical tube:EE (180 V)**

```
W=8833.33;  (* Voltage *)
R=3.8*10^-2;
dw=0.5*10^-3;
dt=7.6*10^-2;
EE=W/(R*Log[dt/dw]);
```

**Cunningham correction factor**

```
Cc=1+2.52 lambda/dp;
```

### Time, Velocity, Flow

```
Q[qq_]=qq*10^-3/60;
V=Q[qq]/A2;
t=volume/Q[qq];
```

### Diffusion charging

```
Ni=i/(e*Zi*EE*A1); (* ion concentration *)
epsilon0=8.8542*10^-12; (* vacuum permittivity *)
kE=(4 Pi epsilon0)^-1 ; (* electrostatic constant *)
ci=9.79*10^3 mu^0.5 Temp^0.5;  (* ion mean thermal velocity *)
ndiff[qq_]=dp*k*Temp/(2*kE*e^2)*Log[1+(Pi*kE*dp*ci*e^2*Ni*t)/(2*k*Temp)];
```

### Field charging

```
Zi=1.7*10^-4; (* mobility of ions *)
nfield[qq_]=(3*epsilon)/(epsilon+2) * (EE*dp^2)/(4*kE*e) *
(Pi*kE*e*Zi*Ni*t/(1+Pi*kE*e*Zi*Ni*t));
```

### Combined Charging

```
nall[qq_]=ndiff[qq]+nfield[qq];
```

### Terminal electric velocity

```
 VTE[qq_]=nall[qq]*e*EE*Cc/(3*Pi*mu*dp);
```

### Collection efficiency

```
Eff[qq_]=(1-Exp[-VTE[qq]*A1/Q[qq]])*100;
plot3=Plot[Eff[qq],{qq,0,50},PlotRange→{0,100},PlotStyle->RGBColor[1,0,0]]
```

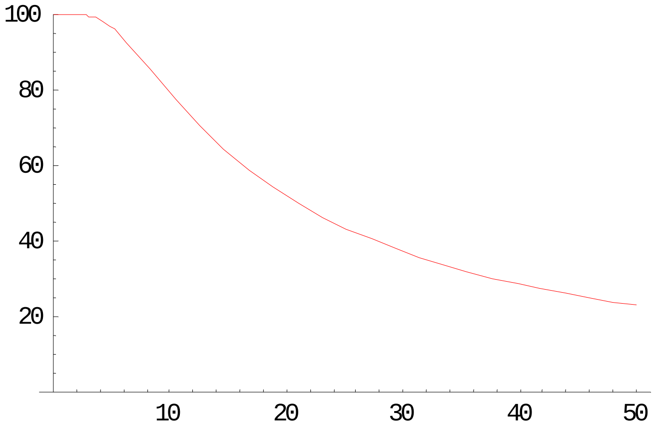


**Table 25**. Theoretical calculation data for 1.0 μm at 220 VAC

| V [cm/s] | Efficiency [%] |
|---|---|
| 1.04 | 99.80 |
| 3.77 | 78.28 |
| 7.36 | 51.81 |
| 11.02 | 37.24 |
| 14.68 | 28.67 |

## Collection Efficiency of ESP for 0.3 μm at 180 VAC

```
ClearAll["Global`*"]
```

### Some constants

```
i=1*10^-6; (* corona discharge current *)
dp=0.3*10^-6; (* particle diameter *)
lambda=0.066*10^-6; (* mean free path *)
r=3.8*10^-2;   (* radius of the cylinder *)
d=7.6*10^-2;  (* diameter of the cylinder *)
L=24.5*10^-2; (* length of the cylinder *)
k=1.38*10^-23; (* Boltzmann's constant *)
Temp=293;  (* temperature *)
mu=1.820*10^-5; (* viscosity *)
e=1.6*10^-19; (* electron charge *)
epsilon=2.4; (* dielectric constant of PSL *)
```

### Geometry

```
volume=Pi*r^2*L; (* volume of the cylinder *)
A1=2*Pi*r*L;  (* surface area of the cylinder *)
A2=(Pi*d^2)/4; (* cross section area of the cylinder *)
```

### Electric field strength inside a cylindrical tube:EE (180 V)

```
W=8833.33;  (* Voltage *)
R=3.8*10^-2;
dw=0.5*10^-3;
dt=7.6*10^-2;
EE=W/(R*Log[dt/dw]);
```

### Cunningham correction factor

```
Cc=1+2.52 lambda/dp;
```

### Time, Velocity, Flow

```
Q[qq_]=qq*10^-3/60;
V=Q[qq]/A2;
t=volume/Q[qq];
```

### Diffusion charging

```
Ni=i/(e*Zi*EE*A1); (* ion concentration *)
epsilon0=8.8542*10^-12; (* vacuum permittivity *)
kE=(4 Pi epsilon0)^-1 ; (* electrostatic constant *)
ci=9.79*10^3 mu^0.5 Temp^0.5 ; (* ion mean thermal velocity *)
ndiff[qq_]=dp*k*Temp/(2*kE*e^2)*Log[1+(Pi*kE*dp*ci*e^2*Ni*t)/(2*k*Temp)];
```

### Field charging

```
Zi=1.7*10^-4; (* mobility of ions *)
nfield[qq_]=(3*epsilon)/(epsilon+2) * (EE*dp^2)/(4*kE*e) *
(Pi*kE*e*Zi*Ni*t/(1+Pi*kE*e*Zi*Ni*t));
```

### Combined Charging

```
 nall[qq_]=ndiff[qq]+nfield[qq];
```

### Terminal electric velocity

```
VTE[qq_]=nall[qq]*e*EE*Cc/(3*Pi*mu*dp);
```

### Collection efficiency

```
 Eff[qq_]=(1-Exp[-VTE[qq]*A1/Q[qq]])*100;
 plot3=Plot[Eff[qq],{qq,0,50},PlotRange→{0,100},PlotStyle->RGBColor[1,0,0]]
```

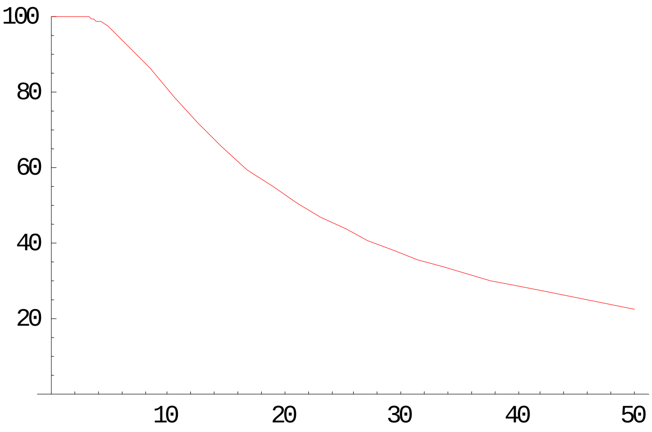


**Table 21.** Theoretical calculation data for 0.3 μm at 180 VAC

| V [cm/s] | Efficiency [%] |
|---|---|
| 1.04 | 99.87 |
| 3.77 | 79.51 |
| 7.36 | 52.46 |
| 11.02 | 37.41 |
| 14.68 | 28.58 |

# Collection Efficiency of ESP for 0.5 μm at 220 VAC

```
ClearAll["Global`*"]
```

## Some constants

```
i=35*10^-6; (* corona discharge current *)
dp=0.5*10^-6; (* particle diameter *)
lambda=0.066*10^-6; (* mean free path *)
r=3.8*10^-2;   (* radius of the cylinder *)
d=7.6*10^-2;  (* diameter of the cylinder *)
L=24.5*10^-2; (* length of the cylinder *)
k=1.38*10^-23; (* Boltzmann's constant *)
Temp=293;  (* temperature *)
mu=1.820*10^-5; (* viscosity *)
e=1.6*10^-19; (* electron charge *)
epsilon=2.4; (* dielectric constant of PSL *)
```

## Geometry

```
volume=Pi*r^2*L; (* volume of the cylinder *)
A1=2*Pi*r*L;  (* surface area of the cylinder *)
A2=(Pi*d^2)/4; (* cross section area of the cylinder *)
```

## Electric field strength inside a cylindrical tube:EE (220 V)

```
W=11733.33;  (* Voltage *)
R=3.8*10^-2;
dw=0.5*10^-3;
dt=7.6*10^-2;
EE=W/(R*Log[dt/dw]);
```

## Cunningham correction factor

```
Cc=1+2.52 lambda/dp;
```

### Time, Velocity, Flow

```
Q[qq_]=qq*10^-3/60;
V=Q[qq]/A2;
t=volume/Q[qq];
```

### Diffusion charging

```
Ni=i/(e*Zi*EE*A1); (* ion concentration *)
epsilon0=8.8542*10^-12; (* vacuum permittivity *)
kE=(4 Pi epsilon0)^-1 ; (* electrostatic constant *)
ci=9.79*10^3 mu^0.5 Temp^0.5;  (* ion mean thermal velocity *)
ndiff[qq_]=dp*k*Temp/(2*kE*e^2)*Log[1+(Pi*kE*dp*ci*e^2*Ni*t)/(2*k*Temp)];
```

### Field charging

```
Zi=1.7*10^-4; (* mobility of ions *)
nfield[qq_]=(3*epsilon)/(epsilon+2) * (EE*dp^2)/(4*kE*e) *
(Pi*kE*e*Zi*Ni*t/(1+Pi*kE*e*Zi*Ni*t));
```

### Combined Charging

```
 nall[qq_]=ndiff[qq]+nfield[qq];
```

### Terminal electric velocity

```
VTE[qq_]=nall[qq]*e*EE*Cc/(3*Pi*mu*dp);
```

### Collection efficiency

```
Eff[qq_]=(1-Exp[-VTE[qq]*A1/Q[qq]])*100;
plot3=Plot[Eff[qq],{qq,0,50},PlotRange→{0,100},PlotStyle->RGBColor[1,0,0]]
```

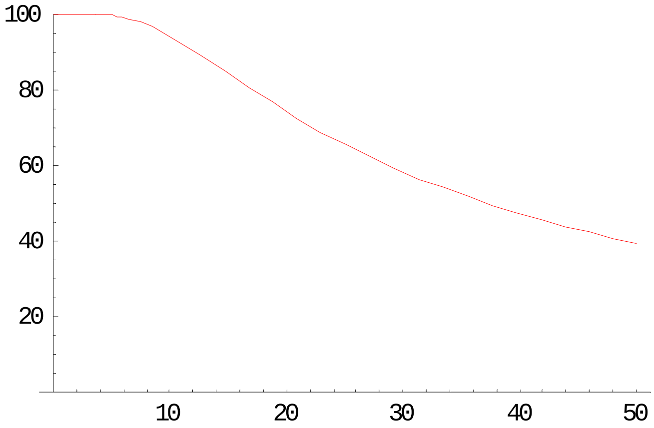


**Table 22.** Theoretical calculation data for 0.5 μm at 220 VAC

| V [cm/s] | Efficiency [%] |
|---|---|
| 1.04 | 100.00 |
| 3.77 | 93.91 |
| 7.36 | 74.25 |
| 11.02 | 58.30 |
| 14.68 | 47.26 |

# Collection Efficiency of ESP for 0.5 μm at 180 VAC

```
ClearAll["Global`*"]
```

**Some constants**

```
i=1*10^-6; (* corona discharge current *)
dp=0.5*10^-6; (* particle diameter *)
lambda=0.066*10^-6; (* mean free path *)
r=3.8*10^-2;   (* radius of the cylinder *)
d=7.6*10^-2;  (* diameter of the cylinder *)
L=24.5*10^-2; (* length of the cylinder *)
k=1.38*10^-23; (* Boltzmann's constant *)
Temp=293;  (* temperature *)
mu=1.820*10^-5; (* viscosity *)
e=1.6*10^-19; (* electron charge *)
epsilon=2.4; (* dielectric constant of PSL *)
```

**Geometry**

```
volume=Pi*r^2*L; (* volume of the cylinder *)
A1=2*Pi*r*L;  (* surface area of the cylinder *)
A2=(Pi*d^2)/4; (* cross section area of the cylinder *)
```

**Electric field strength inside a cylindrical tube:EE 180 V)**

```
W=8833.33;  (* Voltage *)
R=3.8*10^-2;
dw=0.5*10^-3;
dt=7.6*10^-2;
EE=W/(R*Log[dt/dw]);
```

**Cunningham correction factor**

```
Cc=1+2.52 lambda/dp;
```

### Time, Velocity, Flow

```
Q[qq_]=qq*10^-3/60;
V=Q[qq]/A2;
t=volume/Q[qq];
```

### Diffusion charging

```
Ni=i/(e*Zi*EE*A1); (* ion concentration *)
epsilon0=8.8542*10^-12; (* vacuum permittivity *)
kE=(4 Pi epsilon0)^-1 ; (* electrostatic constant *)
ci=9.79*10^3 mu^0.5 Temp^0.5;  (* ion mean thermal velocity *)
ndiff[qq_]=dp*k*Temp/(2*kE*e^2)*Log[1+(Pi*kE*dp*ci*e^2*Ni*t)/(2*k*Temp)];
```

### Field charging

```
Zi=1.7*10^-4; (* mobility of ions *)
nfield[qq_]=(3*epsilon)/(epsilon+2) * (EE*dp^2)/(4*kE*e) *
(Pi*kE*e*Zi*Ni*t/(1+Pi*kE*e*Zi*Ni*t));
```

### Combined Charging

```
nall[qq_]=ndiff[qq]+nfield[qq];
```

### Terminal electric velocity

```
VTE[qq_]=nall[qq]*e*EE*Cc/(3*Pi*mu*dp);
```

### Collection efficiency

```
Eff[qq_]=(1-Exp[-VTE[qq]*A1/Q[qq]])*100;
plot3=Plot[Eff[qq],{qq,0,50},PlotRange→{0,100},PlotStyle->RGBColor[1,0,0]]
```

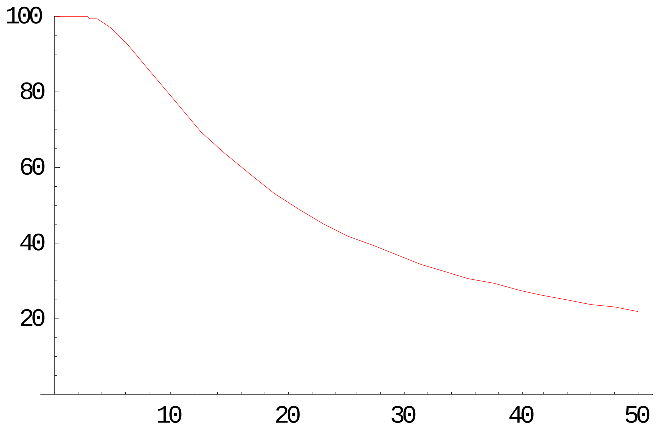


**Table 23.** Theoretical calculation data for 0.5 μm at 180 VAC

| V [cm/s] | Efficiency [%] |
|---|---|
| 1.04 | 99.80 |
| 3.77 | 77.64 |
| 7.36 | 50.76 |
| 11.02 | 36.16 |
| 14.68 | 27.66 |

# Collection Efficiency of ESP for 1.0 μm at 220 VAC

```
 ClearAll["Global`*"]
```

### Some constants

```
i=35*10^-6; (* corona discharge current *)
dp=1.0*10^-6; (* particle diameter *)
lambda=0.066*10^-6; (* mean free path *)
r=3.8*10^-2;   (* radius of the cylinder *)
d=7.6*10^-2;  (* diameter of the cylinder *)
L=24.5*10^-2; (* length of the cylinder *)
k=1.38*10^-23; (* Boltzmann's constant *)
Temp=293;  (* temperature *)
mu=1.820*10^-5; (* viscosity *)
e=1.6*10^-19; (* electron charge *)
epsilon=2.4; (* dielectric constant of PSL *)
```

### Geometry

```
volume=Pi*r^2*L; (* volume of the cylinder *)
A1=2*Pi*r*L;  (* surface area of the cylinder *)
A2=(Pi*d^2)/4; (* cross section area of the cylinder *)
```

### Electric field strength inside a cylindrical tube:EE (220 V)

```
W=11733.33;  (* Voltage *)
R=3.8*10^-2;
dw=0.5*10^-3;
dt=7.6*10^-2;
EE=W/(R*Log[dt/dw]);
```

### Cunningham correction factor

```
Cc=1+2.52 lambda/dp;
```

### Time, Velocity, Flow

```
Q[qq_]=qq*10^-3/60;
V=Q[qq]/A2;
t=volume/Q[qq];
```

### Diffusion charging

```
Ni=i/(e*Zi*EE*A1); (* ion concentration *)
epsilon0=8.8542*10^-12; (* vacuum permittivity *)
kE=(4 Pi epsilon0)^-1 ; (* electrostatic constant *)
ci=9.79*10^3 mu^0.5 Temp^0.5;  (* ion mean thermal velocity *)
ndiff[qq_]=dp*k*Temp/(2*kE*e^2)*Log[1+(Pi*kE*dp*ci*e^2*Ni*t)/(2*k*Temp)];
```

### Field charging

```
Zi=1.7*10^-4; (* mobility of ions *)
nfield[qq_]=(3*epsilon)/(epsilon+2) * (EE*dp^2)/(4*kE*e) *
(Pi*kE*e*Zi*Ni*t/(1+Pi*kE*e*Zi*Ni*t));
```

### Combined Charging

```
 nall[qq_]=ndiff[qq]+nfield[qq];
```

### Terminal electric velocity

```
VTE[qq_]=nall[qq]*e*EE*Cc/(3*Pi*mu*dp);
```

### Collection efficiency

```
Eff[qq_]=(1-Exp[-VTE[qq]*A1/Q[qq]])*100;
plot3=Plot[Eff[qq],{qq,0,50},PlotRange→{0,100},PlotStyle->RGBColor[1,0,0]]
```

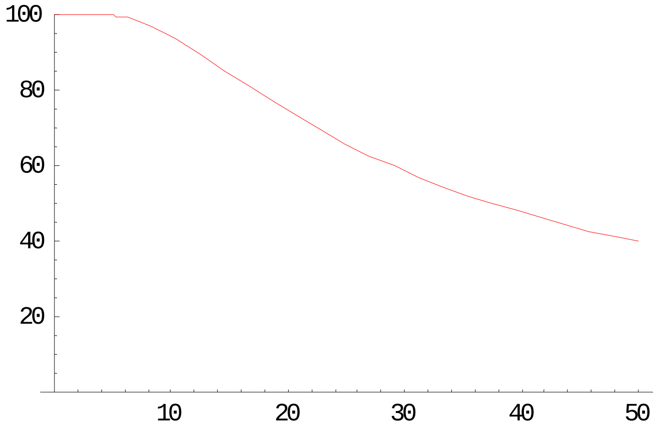


**Table 24.** Theoretical calculation data for 1.0 μm at 220 VAC

| V [cm/s] | Efficiency [%] |
|---|---|
| 1.04 | 100.00 |
| 3.77 | 93.84 |
| 7.36 | 74.36 |
| 11.02 | 58.58 |
| 14.68 | 47.63 |

# Collection Efficiency of ESP for 1.0 μm at 180 VAC

```
ClearAll["Global`*"]
```

**Some constants**

```
i=1*10^-6; (* corona discharge current *)
dp=1.0*10^-6; (* particle diameter *)
lambda=0.066*10^-6; (* mean free path *)
r=3.8*10^-2;   (* radius of the cylinder *)
d=7.6*10^-2;  (* diameter of the cylinder *)
L=24.5*10^-2; (* length of the cylinder *)
k=1.38*10^-23; (* Boltzmann's constant *)
Temp=293;  (* temperature *)
mu=1.820*10^-5; (* viscosity *)
e=1.6*10^-19; (* electron charge *)
epsilon=2.4; (* dielectric constant of PSL *)
```

**Geometry**

```
volume=Pi*r^2*L; (* volume of the cylinder *)
A1=2*Pi*r*L;  (* surface area of the cylinder *)
A2=(Pi*d^2)/4; (* cross section area of the cylinder *)
```

**Electric field strength inside a cylindrical tube:EE (180 V)**

```
W=8833.33;  (* Voltage *)
R=3.8*10^-2;
dw=0.5*10^-3;
dt=7.6*10^-2;
EE=W/(R*Log[dt/dw]);
```

**Cunningham correction factor**

```
Cc=1+2.52 lambda/dp;
```

**Time, Velocity, Flow**

```
Q[qq_]=qq*10^-3/60;
V=Q[qq]/A2;
t=volume/Q[qq];
```

**Diffusion charging**

```
Ni=i/(e*Zi*EE*A1); (* ion concentration *)
epsilon0=8.8542*10^-12; (* vacuum permittivity *)
kE=(4 Pi epsilon0)^-1 ; (* electrostatic constant *)
ci=9.79*10^3 mu^0.5 Temp^0.5;  (* ion mean thermal velocity *)
ndiff[qq_]=dp*k*Temp/(2*kE*e^2)*Log[1+(Pi*kE*dp*ci*e^2*Ni*t)/(2*k*Temp)];
```

**Field charging**

```
Zi=1.7*10^-4; (* mobility of ions *)
nfield[qq_]=(3*epsilon)/(epsilon+2) * (EE*dp^2)/(4*kE*e) *
(Pi*kE*e*Zi*Ni*t/(1+Pi*kE*e*Zi*Ni*t));
```

**Combined Charging**

```
nall[qq_]=ndiff[qq]+nfield[qq];
```

**Terminal electric velocity**

```
 VTE[qq_]=nall[qq]*e*EE*Cc/(3*Pi*mu*dp);
```

**Collection efficiency**

```
Eff[qq_]=(1-Exp[-VTE[qq]*A1/Q[qq]])*100;
plot3=Plot[Eff[qq],{qq,0,50},PlotRange→{0,100},PlotStyle->RGBColor[1,0,0]]
```

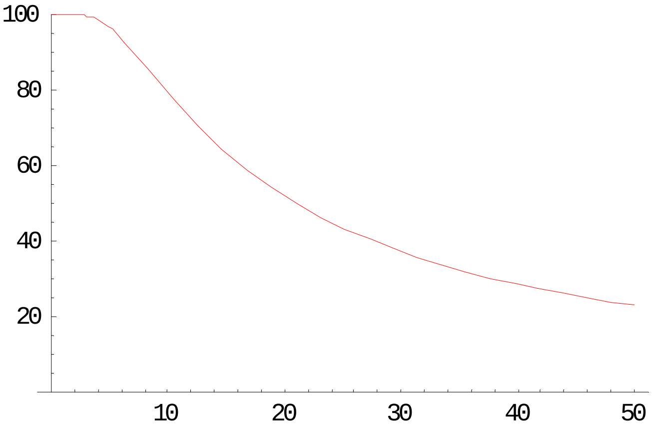


**Table 25**. Theoretical calculation data for 1.0 μm at 220 VAC

| V [cm/s] | Efficiency [%] |
|---|---|
| 1.04 | 99.80 |
| 3.77 | 78.28 |
| 7.36 | 51.81 |
| 11.02 | 37.24 |
| 14.68 | 28.67 |

# Appendix F

## Pressure drop data

**Table 26**. Pressure drop data

| Velocity, U (cm/s) | Pressure drop, ΔP (torr) | | | average | SD |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | | |
| 1.04 | 0.02 | 0.03 | 0.03 | 0.03 | 0.01 |
| 3.77 | 0.02 | 0.03 | 0.03 | 0.03 | 0.01 |
| 7.36 | 0.02 | 0.03 | 0.03 | 0.03 | 0.01 |
| 11.02 | 0.03 | 0.03 | 0.04 | 0.03 | 0.01 |
| 14.68 | 0.03 | 0.03 | 0.04 | 0.03 | 0.01 |

# Appendix G

Dust-loading data

**Table 27**. Dust-loading data

| t (s) | $M_{ESP,initial}$ (g) | $M_{ESP,final}$ (g) | $\Delta M_{ESP}$ (g) | Accumulative dust-loading |
|---|---|---|---|---|
| 30 | 1574.00 | 1579.07 | 5.07 | 5.07 |
| 60 | 1579.07 | 1583.67 | 4.60 | 9.67 |
| 90 | 1583.67 | 1587.94 | 4.27 | 13.94 |
| 120 | 1587.94 | 1592.00 | 4.06 | 18.00 |
| 150 | 1592.00 | 1595.14 | 3.14 | 21.14 |
| 180 | 1595.14 | 1598.34 | 3.20 | 24.34 |
| 210 | 1598.34 | 1601.64 | 3.30 | 27.64 |
| 240 | 1601.64 | 1605.28 | 3.64 | 31.28 |
| 270 | 1605.28 | 1608.74 | 3.46 | 34.74 |
| 300 | 1608.74 | 1611.38 | 2.64 | 37.38 |
| 330 | 1611.38 | 1614.18 | 2.8 | 40.18 |
| 360 | 1614.18 | 1616.54 | 2.36 | 42.54 |
| 390 | 1616.54 | 1619.31 | 2.77 | 45.31 |
| 420 | 1619.31 | 1621.93 | 2.62 | 47.93 |
| 450 | 1621.93 | 1624.06 | 2.13 | 50.06 |
| 480 | 1624.06 | 1625.11 | 1.05 | 51.11 |
| 510 | 1625.11 | 1626.57 | 1.46 | 52.57 |
| 540 | 1626.57 | 1627.63 | 1.06 | 53.63 |
| 570 | 1627.63 | 1628.54 | 0.91 | 54.54 |
| 600 | 1628.54 | 1628.92 | 0.38 | 54.92 |

Note $M_{ESP,initial}$ is initial mass of the ESP and $M_{ESP,final}$ is final mass of the ESP, respectively.

**Table 28**. Cvt data

| t [s] | $M_{initial}$ [g] | $M_{final}$ [g] | C [kg/m$^3$] | v [m/s] | E [%] | Cvt [kg/m$^2$] |
|---|---|---|---|---|---|---|
| 1800 | 0.2567 | 0.0650 | 0.0004 | 0.0735 | 74.6786 | 0.0566 |
| 3600 | 0.0783 | 0.0261 | 0.0001 | 0.0735 | 66.6667 | 0.0345 |
| 5400 | 0.1283 | 0.0454 | 0.0002 | 0.0735 | 64.6142 | 0.0849 |
| 7200 | 0.1615 | 0.0665 | 0.0003 | 0.0735 | 58.8235 | 0.1425 |
| 9000 | 0.2049 | 0.0881 | 0.0003 | 0.0735 | 57.0034 | 0.2260 |
| 10800 | 0.3204 | 0.1432 | 0.0005 | 0.0735 | 55.3059 | 0.4240 |
| 12600 | 0.1259 | 0.0674 | 0.0002 | 0.0735 | 46.4654 | 0.1944 |
| 14400 | 0.1736 | 0.0945 | 0.0003 | 0.0735 | 45.5645 | 0.3063 |
| 16200 | 0.2351 | 0.1330 | 0.0004 | 0.0735 | 43.4283 | 0.4667 |
| 18000 | 0.2250 | 0.1309 | 0.0004 | 0.0735 | 41.8222 | 0.4962 |
| 19800 | 0.2162 | 0.1272 | 0.0004 | 0.0735 | 41.1656 | 0.5245 |
| 21600 | 0.1181 | 0.0714 | 0.0002 | 0.0735 | 39.5428 | 0.3126 |
| 23400 | 0.2958 | 0.1826 | 0.0005 | 0.0735 | 38.2691 | 0.8481 |
| 25200 | 0.2373 | 0.1472 | 0.0004 | 0.0735 | 37.9688 | 0.7327 |
| 27000 | 0.0891 | 0.0554 | 0.0001 | 0.0735 | 37.8227 | 0.2948 |
| 28800 | 0.1496 | 0.0977 | 0.0002 | 0.0735 | 34.6925 | 0.5279 |
| 30600 | 0.1966 | 0.1584 | 0.0003 | 0.0735 | 19.4303 | 0.7371 |
| 32400 | 0.1035 | 0.0838 | 0.0002 | 0.0735 | 19.0338 | 0.4109 |
| 34200 | 0.0744 | 0.0610 | 0.0001 | 0.0735 | 18.0108 | 0.3118 |
| 36000 | 0.1174 | 0.0971 | 0.0002 | 0.0735 | 17.2913 | 0.5178 |

# Appendix H

## Laboratory collection efficiency for dust-loaded ESP

**Table 29.** Collection efficiency data for 1.0 micrometer with dust-loading for 30 minutes at 220 VAC

| | Q = 2.83 lpm (V=1.04 cm/s) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 13266 | 15051 | 14650 | 15313 | 15405 | 15328 | 152 | 71 | 15 | 18 | 20 | 23 |
| 0.5 | 16048 | 17294 | 17806 | 19654 | 19366 | 19401 | 202 | 104 | 19 | 19 | 15 | 17 |
| 0.7 | 20606 | 21681 | 21775 | 24138 | 25170 | 25769 | 227 | 108 | 15 | 12 | 15 | 16 |
| 1.0 | 54244 | 59519 | 60454 | 70016 | 69083 | 68560 | 502 | 230 | 238 | 219 | 211 | 224 |
| 5.0 | 2 | 6 | 3 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |

| | Q = 10.28 lpm (V=3.77 cm/s) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 9245 | 9049 | 8780 | 9628 | 9195 | 9317 | 327 | 340 | 277 | 173 | 237 | 254 |
| 0.5 | 12544 | 12943 | 11580 | 12417 | 13069 | 13203 | 300 | 261 | 211 | 152 | 157 | 158 |
| 0.7 | 16719 | 17609 | 14711 | 16580 | 18079 | 18305 | 330 | 341 | 295 | 139 | 204 | 199 |
| 1.0 | 43609 | 45704 | 39905 | 44146 | 45887 | 46169 | 1490 | 1769 | 1844 | 1784 | 1686 | 1477 |
| 5.0 | 2 | 0 | 1 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |

| | Q = 20.06 lpm (V=7.36 cm/s) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 7469 | 7596 | 7508 | 7486 | 7778 | 7704 | 549 | 606 | 436 | 446 | 439 | 435 |
| 0.5 | 10396 | 10065 | 10161 | 10295 | 11061 | 10212 | 401 | 458 | 556 | 560 | 401 | 503 |
| 0.7 | 14483 | 14125 | 14530 | 14541 | 14962 | 14451 | 533 | 663 | 580 | 633 | 504 | 536 |
| 1.0 | 35403 | 36384 | 36201 | 36388 | 36928 | 36997 | 6933 | 7337 | 6803 | 7271 | 7203 | 7294 |
| 5.0 | 1 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | Q = 30.03 lpm (V=11.02 cm/s) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 6683 | 6268 | 6860 | 6420 | 6427 | 6665 | 1480 | 891 | 568 | 857 | 911 | 936 |
| 0.5 | 10065 | 8887 | 9470 | 8522 | 9644 | 9781 | 2103 | 1374 | 867 | 1294 | 1169 | 949 |
| 0.7 | 13698 | 12392 | 12995 | 11993 | 12980 | 13273 | 2289 | 1523 | 878 | 1383 | 1356 | 1257 |
| 1.0 | 31025 | 29373 | 31676 | 29666 | 30734 | 30898 | 14855 | 15514 | 12788 | 13241 | 13575 | 13704 |
| 5.0 | 0 | 0 | 0 | 4 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |

| | Q = 40.01 lpm (V=14.68 cm/s) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diameter ; µm | upstream | | | | | | downstream | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0.3 | 4909 | 5121 | 6673 | 6236 | 6462 | 5967 | 2828 | 2643 | 2593 | 2433 | 2939 | 2765 |
| 0.5 | 7449 | 7794 | 9329 | 8540 | 8768 | 8393 | 3895 | 3314 | 3383 | 3319 | 3376 | 2983 |
| 0.7 | 9888 | 10792 | 11860 | 11276 | 11309 | 10928 | 5197 | 4639 | 4597 | 4018 | 4717 | 4085 |
| 1.0 | 22336 | 223949 | 22052 | 24359 | 21853 | 24047 | 11629 | 12965 | 12808 | 14475 | 12792 | 12874 |
| 5.0 | 3 | 0 | 1 | 4 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |

| Q = 2.83 lpm | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 59519 | 230 | 59289 | 99.61 |
| 3 | 60454 | 238 | 60216 | 99.61 |
| 4 | 70016 | 219 | 69797 | 99.69 |
| 6 | 68560 | 224 | 68336 | 99.67 |
| average | 64637 | 228 | 64410 | 99.65 |
| SD | 5416.49 | 8.18 | 5423.64 | 0.04 |

| Q = 10.28 lpm | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 45704 | 1769 | 43935 | 96.13 |
| 3 | 39905 | 1844 | 38061 | 95.38 |
| 4 | 44146 | 1784 | 42362 | 95.96 |
| 5 | 45887 | 1686 | 44201 | 96.33 |
| average | 43911 | 1771 | 42140 | 95.95 |
| SD | 2782.25 | 65.13 | 2837.68 | 0.41 |

| Q = 20.06 lpm | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 36384 | 7337 | 29047 | 79.83 |
| 4 | 36388 | 7271 | 29117 | 80.02 |
| 5 | 36928 | 7203 | 29725 | 80.49 |
| 6 | 36997 | 7294 | 29703 | 80.28 |
| average | 36674 | 7276 | 29398 | 80.16 |
| SD | 334.04 | 55.97 | 366.11 | 0.29 |

| Q = 30.03 lpm | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 3 | 31676 | 12788 | 18888 | 59.63 |
| 4 | 29666 | 13241 | 16425 | 55.37 |
| 5 | 30734 | 13575 | 17159 | 55.83 |
| 6 | 30898 | 13704 | 17194 | 55.65 |
| average | 30744 | 13327 | 17417 | 56.62 |
| SD | 827.55 | 408.88 | 1043.10 | 2.02 |

| Q = 40.01 lpm | | | | |
|---|---|---|---|---|
| no. | upstream | downstream | different | % Efficiency |
| 2 | 23949 | 12965 | 10984 | 45.86 |
| 3 | 22052 | 12808 | 9244 | 41.92 |
| 5 | 21853 | 12792 | 9061 | 41.46 |
| 6 | 24047 | 12874 | 11173 | 46.46 |
| average | 22975 | 12860 | 10116 | 43.93 |
| SD | 1184.44 | 78.63 | 1117.15 | 2.60 |

| V ; cm/s | % Efficiency | SD |
|---|---|---|
| 1.04 | 99.65 | 0.04 |
| 3.77 | 95.97 | 0.41 |
| 7.36 | 80.16 | 0.29 |
| 11.02 | 56.62 | 2.02 |
| 14.68 | 43.93 | 2.60 |