**Supplemental**

The supplemental material details the 90-day average simulated concentrations and cost estimates for all air pollution control device simulations identified in the manuscript. Tables A.1 through A-6 provide simulation results for the 2-heater models. Tables A-7 and A-8 provide data for 4-heater models. Table A9 and A.10 presents simulation data for simulations with twice the pit flow of the current operation (2Q), with two and four room heaters, respectively. Text formatting provides interpretation relative to the 10% OEL limit (bold if exceeded) and the industry recommendation (red and italicized, along with bold, if exceeded).

Because selection of fan and air pollution control systems in the US are more commonly made in English units, the conversion from m3 s-1 is to cfm is provided below.

|  |  |
| --- | --- |
| cfm | m3 s-1 |
| 500 | 0.24 |
| 1000 | 0.47 |
| 2000 | 0.94 |
| 4000 | 1.89 |

Table A.1 Shaker dust filtration unit performance, 2 heaters

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Device | Q,  m3 s-1 | Room Air Recirculation Ratio | 3 Month Average Concentration | | | | | 3 Month Operating Cost |  |
| Inhalable Dust, mg/m3 | Respirable Dust, mg/m3 | NH3, ppm | CO, ppm | CO2, ppm | % time <293 K |
| Baseline |  | Off | **1.68** | 0.17 | 0.17 | 0.32 | ***1989*** | $1,088 | 0 |
| SDC-140-2 | 0.24 | 0 | **1.31** | 0.14 | 0.13 | 0.37 | ***1907*** | $1,746 | 0 |
| SDC-140-2 | 0.24 | 25 | **1.31** | 0.14 | 0.14 | 0.36 | ***1927*** | $1,665 | 0 |
| SDC-140-2 | 0.24 | 50 | **1.31** | 0.14 | 0.15 | 0.35 | ***1944*** | $1,579 | 0 |
| SDC-140-2 | 0.24 | 75 | **1.31** | 0.14 | 0.16 | 0.34 | ***1965*** | $1,495 | 0 |
| SDC-140-2 | 0.24 | 100 | **1.31** | 0.14 | 0.17 | 0.32 | ***1989*** | $1,412 | 0 |
| SDC-140-3 | 0.47 | 0 | **1.07** | 0.11 | 0.11 | 0.37 | ***1795*** | $2,025 | 39 |
| SDC-140-3 | 0.47 | 25 | **1.07** | 0.11 | 0.12 | 0.37 | ***1854*** | $1,931 | 22 |
| SDC-140-3 | 0.47 | 50 | **1.07** | 0.11 | 0.13 | 0.37 | ***1907*** | $1,804 | 0 |
| SDC-140-3 | 0.47 | 75 | **1.07** | 0.11 | 0.15 | 0.35 | ***1944*** | $1,637 | 0 |
| SDC-140-3 | 0.47 | 100 | **1.07** | 0.11 | 0.17 | 0.32 | ***1989*** | $1,470 | 0 |
| SDC-280-5 | 0.94 | 0 | 0.78 | 0.08 | 0.08 | 0.29 | **1536** | $2,198 | 90 |
| SDC-280-5 | 0.94 | 25 | 0.78 | 0.08 | 0.09 | 0.33 | ***1660*** | $2,172 | 75 |
| SDC-280-5 | 0.94 | 50 | 0.78 | 0.08 | 0.11 | 0.37 | ***1795*** | $2,082 | 38 |
| SDC-280-5 | 0.94 | 75 | 0.78 | 0.08 | 0.13 | 0.37 | ***1907*** | $1,862 | 0 |
| SDC-280-5 | 0.94 | 100 | 0.78 | 0.08 | 0.17 | 0.32 | ***1989*** | $1,528 | 0 |

Table A.2 Cyclone performance

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Device | Q,  m3 s-1 | | Room Air Recirculation Ratio | | 3 Month Average Concentration | | | | | | | | | | 3 Month Operating Cost | |  |
| Inhalable Dust, mg/m3 | | Respirable Dust, mg/m3 | | NH3, ppm | | CO, ppm | | CO2, ppm | | % time <293 K |
| None, 2 heaters | | - | | Off | | **1.68** | | 0.17 | | 0.17 | | 0.32 | | ***1989*** | | $1,088 | 0 |
| **2 Heaters:** | |  | |  | |  | |  | |  | |  | |  | |  |  |
| Cyclone 12 | | 0.24 | | 0 | | **1.31** | | 0.14 | | 0.13 | | 0.37 | | ***1907*** | | $1,491 | 0 |
| Cyclone 12 | | 0.24 | | 25 | | **1.31** | | 0.14 | | 0.14 | | 0.36 | | ***1927*** | | $1,411 | 0 |
| Cyclone 12 | | 0.24 | | 50 | | **1.31** | | 0.14 | | 0.15 | | 0.35 | | ***1944*** | | $1,325 | 0 |
| Cyclone 12 | | 0.24 | | 75 | | **1.31** | | 0.14 | | 0.16 | | 0.34 | | ***1965*** | | $1,241 | 0 |
| Cyclone 12 | | 0.24 | | 100 | | **1.31** | | 0.14 | | 0.17 | | 0.32 | | ***1989*** | | $1,157 | 0 |
| Cyclone 16 | | 0.47 | | 0 | | **1.07** | | 0.11 | | 0.11 | | 0.37 | | ***1795*** | | $1,824 | 39 |
| Cyclone 16 | | 0.47 | | 25 | | **1.07** | | 0.11 | | 0.12 | | 0.37 | | ***1854*** | | $1,730 | 22 |
| Cyclone 16 | | 0.47 | | 50 | | **1.07** | | 0.12 | | 0.13 | | 0.37 | | ***1907*** | | $1,603 | 0 |
| Cyclone 16 | | 0.47 | | 75 | | **1.07** | | 0.12 | | 0.15 | | 0.35 | | ***1944*** | | $1,436 | 0 |
| Cyclone 16 | | 0.47 | | 100 | | **1.07** | | 0.12 | | 0.17 | | 0.32 | | ***1989*** | | $1,269 | 0 |
| Cyclone 20-3 | | 0.94 | | 0 | | 0.78 | | 0.08 | | 0.08 | | 0.29 | | **1536** | | $2,014 | 90 |
| Cyclone 20-3 | | 0.94 | | 25 | | 0.79 | | 0.08 | | 0.09 | | 0.33 | | ***1660*** | | $1,988 | 75 |
| Cyclone 20-3 | | 0.94 | | 50 | | 0.79 | | 0.09 | | 0.11 | | 0.37 | | ***1795*** | | $1,898 | 38 |
| Cyclone 20-3 | | 0.94 | | 75 | | 0.79 | | 0.09 | | 0.13 | | 0.37 | | ***1907*** | | $1,677 | 0 |
| Cyclone 20-3 | | 0.94 | | 100 | | 0.79 | | 0.09 | | 0.17 | | 0.32 | | ***1989*** | | $1,344 | 0 |
| **4 Heaters:** | |  | |  | |  | |  | |  | |  | |  | |  |  |
| Cyclone 16 | | 0.47 | | 0 | | **1.07** | | 0.11 | | 0.11 | | 0.39 | | ***1859*** | | $1,932 | 0 |
| Cyclone 16 | | 0.47 | | 25 | | **1.07** | | 0.11 | | 0.12 | | 0.38 | | ***1880*** | | $1,766 | 0 |
| Cyclone 20-3 | | 0.94 | | 0 | | 0.78 | | 0.08 | | 0.08 | | 0.43 | | ***1796*** | | $2,603 | 0 |
| Cyclone 20-3 | | 0.94 | | 25 | | 0.79 | | 0.08 | | 0.09 | | 0.41 | | ***1826*** | | $2,265 | 0 |
| Cyclone 20-3 | | 0.94 | | 50 | | 0.79 | | 0.09 | | 0.11 | | 0.40 | | ***1859*** | | $1,932 | 0 |

Table A.3 ESP performance, 2 heaters

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Device | Q,  m3 s-1 | Room Air Recirculation Ratio | 3 Month Average Concentration | | | | | 3 Month Operating Cost |  |
| Inhalable Dust, mg/m3 | Respirable Dust, mg/m3 | NH3, ppm | CO, ppm | CO2, ppm | % time <293 K |
| None |  | Off | **1.68** | 0.17 | 0.17 | 0.32 | ***1989*** | $1,088 | 0 |
| ESP SHN-10 | 0.24 | 0 | *n/a* |  |  |  |  |  |  |
| ESP SHN-10 | 0.24 | 25 | *n/a* |  |  |  |  |  |  |
| ESP SHN-10 | 0.24 | 50 | *n/a* |  |  |  |  |  |  |
| ESP SHN-10 | 0.24 | 75 | *n/a* |  |  |  |  |  |  |
| ESP SHN-10 | 0.24 | 100 | *n/a* |  |  |  |  |  |  |
| ESP SHN-10 | 0.47 | 0 | **1.07** | 0.11 | 0.11 | 0.37 | ***1795*** | $1,733 | 39 |
| ESP SHN-10 | 0.47 | 25 | **1.08** | 0.11 | 0.12 | 0.37 | ***1854*** | $1,640 | 22 |
| ESP SHN-10 | 0.47 | 50 | **1.08** | 0.11 | 0.13 | 0.37 | ***1907*** | $1,512 | 0 |
| ESP SHN-10 | 0.47 | 75 | **1.09** | 0.11 | 0.15 | 0.35 | ***1944*** | $1,346 | 0 |
| ESP SHN-10 | 0.47 | 100 | **1.10** | 0.11 | 0.17 | 0.32 | ***1989*** | $1,178 | 0 |
| ESP SHN-20 | 0.94 | 0 | 0.78 | 0.08 | 0.08 | 0.29 | **1536** | $1,934 | 90 |
| ESP SHN-20 | 0.94 | 25 | 0.79 | 0.08 | 0.09 | 0.33 | ***1660*** | $1,908 | 75 |
| ESP SHN-20 | 0.94 | 50 | 0.80 | 0.08 | 0.11 | 0.37 | ***1795*** | $1,818 | 38 |
| ESP SHN-20 | 0.94 | 75 | 0.81 | 0.08 | 0.13 | 0.37 | ***1907*** | $1,598 | 0 |
| ESP SHN-20 | 0.94 | 100 | 0.82 | 0.08 | 0.17 | 0.32 | ***1989*** | $1,264 | 0 |

Note: No ESP rated at 0.24 m3 s-1 was available

Table A.4 Trickle filter performance, 2 heaters

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Device | Q,  m3 s-1 | Room Air Recirculation Ratio | 3 Month Average Concentration | | | | | 3 Month Operating Cost |  |
| Inhalable Dust, mg/m3 | Respirable Dust, mg/m3 | NH3, ppm | CO, ppm | CO2, ppm | % time <293 K |
| None |  | Off | **1.68** | 0.17 | 0.17 | 0.32 | ***1989*** | $1,088 | 0 |
| Trickle Filter | 0.24 | 0 | **1.31** | 0.14 | 0.13 | 0.37 | ***1907*** | $1,451 | 0 |
| Trickle Filter | 0.24 | 25 | **1.31** | 0.14 | 0.14 | 0.36 | ***1927*** | $1,371 | 0 |
| Trickle Filter | 0.24 | 50 | **1.31** | 0.14 | 0.14 | 0.35 | ***1944*** | $1,285 | 0 |
| Trickle Filter | 0.24 | 75 | **1.31** | 0.14 | 0.14 | 0.34 | ***1965*** | $1,201 | 0 |
| Trickle Filter | 0.24 | 100 | **1.31** | 0.14 | 0.14 | 0.32 | ***1989*** | $1,117 | 0 |
| Trickle Filter | 0.47 | 0 | **1.07** | 0.11 | 0.11 | 0.37 | ***1795*** | $1,672 | 39 |
| Trickle Filter | 0.47 | 25 | **1.07** | 0.11 | 0.11 | 0.37 | ***1854*** | $1,578 | 22 |
| Trickle Filter | 0.47 | 50 | **1.07** | 0.11 | 0.12 | 0.37 | ***1907*** | $1,451 | 0 |
| Trickle Filter | 0.47 | 75 | **1.07** | 0.11 | 0.12 | 0.35 | ***1944*** | $1,285 | 0 |
| Trickle Filter | 0.47 | 100 | **1.07** | 0.11 | 0.12 | 0.32 | ***1989*** | $1,117 | 0 |
| Trickle Filter | 0.94 | 0 | 0.78 | 0.08 | 0.08 | 0.29 | **1536** | $1,788 | 90 |
| Trickle Filter | 0.94 | 25 | 0.79 | 0.08 | 0.08 | 0.33 | ***1660*** | $1,762 | 75 |
| Trickle Filter | 0.94 | 50 | 0.79 | 0.08 | 0.09 | 0.37 | ***1795*** | $1,672 | 38 |
| Trickle Filter | 0.94 | 75 | 0.79 | 0.08 | 0.09 | 0.37 | ***1907*** | $1,451 | 0 |
| Trickle Filter | 0.94 | 100 | 0.79 | 0.08 | 0.09 | 0.32 | ***1989*** | $1,117 | 0 |
| Trickle Filter | 1.89 | 0 | 0.51 | 0.05 | 0.05 | 0.19 | **1227** | $2,003 | 100 |
| Trickle Filter | 1.89 | 25 | 0.51 | 0.05 | 0.06 | 0.23 | **1351** | $2,003 | 99 |
| Trickle Filter | 1.89 | 50 | 0.51 | 0.05 | 0.06 | 0.29 | **1536** | $1,994 | 90 |
| Trickle Filter | 1.89 | 75 | 0.51 | 0.05 | 0.06 | 0.37 | ***1795*** | $1,879 | 39 |
| Trickle Filter | 1.89 | 100 | 0.51 | 0.05 | 0.06 | 0.32 | ***1989*** | $1,324 | 0 |

Table A.5 Wet dust collector performance, 2 heaters

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Device | Q,  m3 s-1 | Room Air Recirculation Ratio | 3 Month Average Concentration | | | | | 3 Month Operating Cost |  |
| Inhalable Dust, mg/m3 | Respirable Dust, mg/m3 | NH3, ppm | CO, ppm | CO2, ppm | % time <293 K |
| None |  | Off | **1.68** | 0.17 | 0.17 | 0.32 | ***1989*** | $1,088 | 0 |
| Whirl/Wet 5 | 0.24 | 0 | **1.31** | 0.14 | 0.13 | 0.37 | ***1907*** | $1,630 | 0 |
| Whirl/Wet 5 | 0.24 | 25 | **1.31** | 0.14 | 0.14 | 0.36 | ***1927*** | $1,549 | 0 |
| Whirl/Wet 5 | 0.24 | 50 | **1.31** | 0.14 | 0.14 | 0.35 | ***1944*** | $1,463 | 0 |
| Whirl/Wet 5 | 0.24 | 75 | **1.31** | 0.14 | 0.14 | 0.34 | ***1965*** | $1,380 | 0 |
| Whirl/Wet 5 | 0.24 | 100 | **1.31** | 0.14 | 0.14 | 0.32 | ***1989*** | $1,296 | 0 |
| Whirl/Wet 10 | 0.47 | 0 | **1.07** | 0.11 | 0.11 | 0.37 | ***1795*** | $1,990 | 39 |
| Whirl/Wet 10 | 0.47 | 25 | **1.07** | 0.11 | 0.11 | 0.37 | ***1854*** | $1,896 | 22 |
| Whirl/Wet 10 | 0.47 | 50 | **1.07** | 0.11 | 0.12 | 0.37 | ***1907*** | $1,769 | 0 |
| Whirl/Wet 10 | 0.47 | 75 | **1.07** | 0.11 | 0.12 | 0.35 | ***1944*** | $1,602 | 0 |
| Whirl/Wet 10 | 0.47 | 100 | **1.07** | 0.11 | 0.12 | 0.32 | ***1989*** | $1,435 | 0 |
| Whirl/Wet 22 | 0.94 | 0 | 0.78 | 0.08 | 0.08 | 0.29 | **1536** | $2,476 | 90 |
| Whirl/Wet 22 | 0.94 | 25 | 0.79 | 0.08 | 0.08 | 0.33 | ***1660*** | $2,450 | 75 |
| Whirl/Wet 22 | 0.94 | 50 | 0.79 | 0.08 | 0.09 | 0.37 | ***1795*** | $2,360 | 38 |
| Whirl/Wet 22 | 0.94 | 75 | 0.79 | 0.08 | 0.09 | 0.37 | ***1907*** | $2,140 | 0 |
| Whirl/Wet 22 | 0.94 | 100 | 0.79 | 0.08 | 0.09 | 0.32 | ***1989*** | $1,806 | 0 |

Table A.6 Cyclone + Trickle filter performance, 2 heaters

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Device | Q,  m3 s-1 | Room Air Recirculation Ratio | 3 Month Average Concentration | | | | | 3 Month Operating Cost |  |
| Inhalable Dust, mg/m3 | Respirable Dust, mg/m3 | NH3, ppm | CO, ppm | CO2, ppm | % time <293 K |
| None |  | Off | **1.68** | 0.17 | 0.17 | 0.32 | ***1989*** | $1,088 | 0 |
| Cyclone 12/TF | 0.24 | 0 | **1.31** | 0.14 | 0.13 | 0.37 | ***1907*** | $1,521 | 0 |
| Cyclone 12/TF | 0.24 | 25 | **1.31** | 0.14 | 0.14 | 0.36 | ***1927*** | $1,440 | 0 |
| Cyclone 12/TF | 0.24 | 50 | **1.31** | 0.14 | 0.14 | 0.35 | ***1944*** | $1,354 | 0 |
| Cyclone 12/TF | 0.24 | 75 | **1.31** | 0.14 | 0.14 | 0.34 | ***1965*** | $1,270 | 0 |
| Cyclone 12/TF | 0.24 | 100 | **1.31** | 0.14 | 0.14 | 0.32 | ***1989*** | $1,187 | 0 |
| Cyclone 16/TF | 0.47 | 0 | **1.07** | 0.11 | 0.11 | 0.37 | ***1795*** | $1,883 | 39 |
| Cyclone 16/TF | 0.47 | 25 | **1.07** | 0.11 | 0.11 | 0.37 | ***1854*** | $1,789 | 22 |
| Cyclone 16/TF | 0.47 | 50 | **1.07** | 0.11 | 0.12 | 0.37 | ***1907*** | $1,662 | 0 |
| Cyclone 16/TF | 0.47 | 75 | **1.07** | 0.11 | 0.12 | 0.35 | ***1944*** | $1,495 | 0 |
| Cyclone 16/TF | 0.47 | 100 | **1.07** | 0.11 | 0.12 | 0.32 | ***1989*** | $1,328 | 0 |
| Cyclone 20-3/TF | 0.94 | 0 | 0.78 | 0.08 | 0.08 | 0.29 | **1536** | $2,132 | 90 |
| Cyclone 20-3/TF | 0.94 | 25 | 0.78 | 0.08 | 0.08 | 0.33 | ***1660*** | $2,106 | 75 |
| Cyclone 20-3/TF | 0.94 | 50 | 0.78 | 0.08 | 0.09 | 0.37 | ***1795*** | $2,016 | 38 |
| Cyclone 20-3/TF | 0.94 | 75 | 0.78 | 0.08 | 0.09 | 0.37 | ***1907*** | $1,796 | 0 |
| Cyclone 20-3/TF | 0.94 | 100 | 0.78 | 0.08 | 0.09 | 0.32 | ***1989*** | $1,462 | 0 |

Table A.7 Trickle filter collector performance, 4 heaters

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Device | Q,  m3 s-1 | Room Air Recirculation Ratio | 3 Month Average Concentration | | | | | 3 Month Operating Cost |  |
| Inhalable Dust, mg/m3 | Respirable Dust, mg/m3 | NH3, ppm | CO, ppm | CO2, ppm | % time <293 K |
| None |  | Off | **1.68** | 0.17 | 0.17 | 0.32 | ***2002*** | $1,087 | 0 |
| Trickle Filter | 0.24 | 0 | **1.31** | 0.14 | 0.13 | 0.37 | ***1907*** | $1,448 | 0 |
| Trickle Filter | 0.24 | 25 | **1.31** | 0.14 | 0.14 | 0.36 | ***1925*** | $1,365 | 0 |
| Trickle Filter | 0.24 | 50 | **1.31** | 0.14 | 0.14 | 0.35 | ***1947*** | $1,282 | 0 |
| Trickle Filter | 0.24 | 75 | **1.31** | 0.14 | 0.14 | 0.33 | ***1972*** | $1,199 | 0 |
| Trickle Filter | 0.24 | 100 | **1.31** | 0.14 | 0.14 | 0.32 | ***2002*** | $1,116 | 0 |
| Trickle Filter | 0.47 | 0 | **1.07** | 0.11 | 0.11 | 0.40 | ***1859*** | $1,810 | 0 |
| Trickle Filter | 0.47 | 25 | **1.07** | 0.11 | 0.11 | 0.38 | ***1880*** | $1,644 | 0 |
| Trickle Filter | 0.47 | 50 | **1.07** | 0.11 | 0.12 | 0.37 | ***1907*** | $1,478 | 0 |
| Trickle Filter | 0.47 | 75 | **1.07** | 0.11 | 0.12 | 0.35 | ***1947*** | $1,312 | 0 |
| Trickle Filter | 0.47 | 100 | **1.07** | 0.11 | 0.12 | 0.32 | ***2002*** | $1,146 | 0 |
| Trickle Filter | 0.94 | 0 | 0.78 | 0.08 | 0.08 | 0.43 | ***1796*** | $2,540 | 0 |
| Trickle Filter | 0.94 | 25 | 0.79 | 0.08 | 0.08 | 0.41 | ***1826*** | $2,202 | 0 |
| Trickle Filter | 0.94 | 50 | 0.79 | 0.08 | 0.09 | 0.40 | ***1859*** | $1,869 | 0 |
| Trickle Filter | 0.94 | 75 | 0.79 | 0.08 | 0.09 | 0.37 | ***1907*** | $1,537 | 0 |
| Trickle Filter | 0.94 | 100 | 0.79 | 0.08 | 0.09 | 0.32 | ***2002*** | $1,205 | 0 |
| Trickle Filter | 1.89 | 0 | 0.511 | 0.053 | 0.053 | 0.377 | ***1573*** | $3,344 | 76 |
| Trickle Filter | 1.89 | 25 | 0.512 | 0.053 | 0.055 | 0.426 | ***1705*** | $3,156 | 35 |
| Trickle Filter | 1.89 | 50 | 0.513 | 0.053 | 0.058 | 0.433 | ***1796*** | $2,658 | 0 |
| Trickle Filter | 1.89 | 75 | 0.514 | 0.053 | 0.061 | 0.395 | ***1859*** | $1,987 | 0 |
| Trickle Filter | 1.89 | 100 | 0.515 | 0.053 | 0.064 | 0.320 | ***2002*** | $1,323 | 0 |

Table A.8 Wet dust collector performance, 4 heaters

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Device | Q,  m3 s-1 | Room Air Recirculation Ratio | 3 Month Average Concentration | | | | | 3 Month Operating Cost | % time <293 K |
| Inhalable Dust, mg/m3 | Respirable Dust, mg/m3 | NH3, ppm | CO, ppm | CO2, ppm |
| None |  | Off | **1.68** | 0.17 | 0.17 | 0.32 | ***2002*** | $1,087 | 0 |
| Whirl/Wet 5 | 0.24 | 0 | **1.31** | 0.14 | 0.13 | 0.37 | ***1907*** | $1,628 | 0 |
| Whirl/Wet 5 | 0.24 | 25 | **1.31** | 0.14 | 0.14 | 0.36 | ***1925*** | $1,545 | 0 |
| Whirl/Wet 5 | 0.24 | 50 | **1.31** | 0.14 | 0.14 | 0.35 | ***1947*** | $1,462 | 0 |
| Whirl/Wet 5 | 0.24 | 75 | **1.31** | 0.14 | 0.14 | 0.33 | ***1972*** | $1,379 | 0 |
| Whirl/Wet 5 | 0.24 | 100 | **1.31** | 0.14 | 0.14 | 0.32 | ***2002*** | $1,296 | 0 |
| Whirl/Wet 10 | 0.47 | 0 | **1.07** | 0.11 | 0.11 | 0.40 | ***1859*** | $2,101 | 0 |
| Whirl/Wet 10 | 0.47 | 25 | **1.07** | 0.11 | 0.11 | 0.38 | ***1880*** | $1,935 | 0 |
| Whirl/Wet 10 | 0.47 | 50 | **1.07** | 0.11 | 0.12 | 0.37 | ***1907*** | $1,768 | 0 |
| Whirl/Wet 10 | 0.47 | 75 | **1.07** | 0.11 | 0.12 | 0.35 | ***1947*** | $1,603 | 0 |
| Whirl/Wet 10 | 0.47 | 100 | **1.07** | 0.11 | 0.12 | 0.32 | ***2002*** | $1,437 | 0 |
| Whirl/Wet 22 | 0.94 | 0 | 0.78 | 0.08 | 0.08 | 0.43 | ***1796*** | $3,141 | 0 |
| Whirl/Wet 22 | 0.94 | 25 | 0.79 | 0.08 | 0.08 | 0.41 | ***1826*** | $2,803 | 0 |
| Whirl/Wet 22 | 0.94 | 50 | 0.79 | 0.08 | 0.09 | 0.40 | ***1859*** | $2,470 | 0 |
| Whirl/Wet 22 | 0.94 | 75 | 0.79 | 0.08 | 0.09 | 0.37 | ***1907*** | $2,138 | 0 |
| Whirl/Wet 22 | 0.94 | 100 | 0.79 | 0.08 | 0.09 | 0.32 | ***2002*** | $1,806 | 0 |

Table A.9 Trickle filter with pit fans at twice rated flow capacity, 2 heaters

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Device |  | Room Air Recirculation Ratio | 3 Month Average Concentration | | | | | 3 Month Operating Cost |  |
| Q,  m3 s-1 | Inhalable Dust, mg/m3 | Respirable Dust, mg/m3 | NH3, ppm | CO, ppm | CO2, ppm | % time <293 K |
| None |  | Off | 0.84 | 0.09 | 0.09 | 0.31 | **1477** | $1,828 | 84 |
| Trickle Filter | 0.24 | 0 | 0.74 | 0.08 | 0.08 | 0.27 | **1364** | $1,873 | 93 |
| Trickle Filter | 0.24 | 25 | 0.74 | 0.08 | 0.08 | 0.28 | **1390** | $1,871 | 92 |
| Trickle Filter | 0.24 | 50 | 0.74 | 0.08 | 0.08 | 0.29 | **1417** | $1,867 | 90 |
| Trickle Filter | 0.24 | 75 | 0.74 | 0.08 | 0.08 | 0.30 | **1447** | $1,863 | 87 |
| Trickle Filter | 0.24 | 100 | 0.74 | 0.08 | 0.08 | 0.31 | **1477** | $1,858 | 84 |
| Trickle Filter | 0.47 | 0 | 0.65 | 0.07 | 0.07 | 0.24 | **1271** | $1,905 | 98 |
| Trickle Filter | 0.47 | 25 | 0.65 | 0.07 | 0.07 | 0.26 | **1315** | $1,905 | 96 |
| Trickle Filter | 0.47 | 50 | 0.66 | 0.07 | 0.07 | 0.27 | **1364** | $1,902 | 93 |
| Trickle Filter | 0.47 | 75 | 0.66 | 0.07 | 0.07 | 0.29 | **1417** | $1,897 | 90 |
| Trickle Filter | 0.47 | 100 | 0.66 | 0.07 | 0.07 | 0.31 | **1477** | $1,887 | 84 |
| Trickle Filter | 0.94 | 0 | 0.54 | 0.06 | 0.06 | 0.20 | **1134** | $1,965 | 100 |
| Trickle Filter | 0.94 | 25 | 0.54 | 0.06 | 0.06 | 0.22 | **1196** | $1,965 | 100 |
| Trickle Filter | 0.94 | 50 | 0.53 | 0.06 | 0.06 | 0.24 | **1264** | $1,965 | 98 |
| Trickle Filter | 0.94 | 75 | 0.54 | 0.06 | 0.06 | 0.27 | **1364** | $1,961 | 93 |
| Trickle Filter | 0.94 | 100 | 0.54 | 0.06 | 0.06 | 0.31 | **1477** | $1,946 | 84 |
| Trickle Filter | 1.89 | 0 | 0.39 | 0.04 | 0.04 | 0.15 | **970** | $2,083 | 100 |
| Trickle Filter | 1.89 | 25 | 0.39 | 0.04 | 0.04 | 0.17 | **1040** | $2,083 | 100 |
| Trickle Filter | 1.89 | 50 | 0.39 | 0.04 | 0.04 | 0.20 | **1134** | $2,083 | 100 |
| Trickle Filter | 1.89 | 75 | 0.39 | 0.04 | 0.04 | 0.24 | **1271** | $2,083 | 98 |
| Trickle Filter | 1.89 | 100 | 0.39 | 0.04 | 0.05 | 0.31 | **1477** | $2,064 | 84 |

Table A.10 Trickle filter with pit fans at twice rated flow capacity**, 4 heaters**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Device |  | Room Air Recirculation Ratio | 3 Month Average Concentration | | | | | 3 Month Operating Cost |  |
| Q,  m3 s-1 | Inhalable Dust, mg/m3 | Respirable Dust, mg/m3 | NH3, ppm | CO, ppm | CO2, ppm | % time <293 K |
| None |  | Off | 0.84 | 0.09 | 0.09 | 0.42 | ***1687*** | $2,487 | 0 |
| Trickle Filter | 0.24 | 0 | 0.74 | 0.08 | 0.08 | 0.44 | ***1660*** | $2,688 | 0.5 |
| Trickle Filter | 0.24 | 25 | 0.74 | 0.08 | 0.08 | 0.44 | ***1668*** | $2,612 | 0 |
| Trickle Filter | 0.24 | 50 | 0.74 | 0.08 | 0.08 | 0.43 | ***1673*** | $2,527 | 0 |
| Trickle Filter | 0.24 | 75 | 0.74 | 0.08 | 0.08 | 0.43 | ***1679*** | $2,441 | 0 |
| Trickle Filter | 0.24 | 100 | 0.74 | 0.08 | 0.08 | 0.42 | ***1687*** | $2,356 | 0 |
| Trickle Filter | 0.47 | 0 | 0.66 | 0.07 | 0.07 | 0.44 | ***1612*** | $2,963 | 25 |
| Trickle Filter | 0.47 | 25 | 0.66 | 0.07 | 0.07 | 0.44 | ***1637*** | $2,851 | 15 |
| Trickle Filter | 0.47 | 50 | 0.66 | 0.07 | 0.07 | 0.44 | ***1660*** | $2,718 | 0.5 |
| Trickle Filter | 0.47 | 75 | 0.66 | 0.07 | 0.07 | 0.43 | ***1673*** | $2,557 | 0 |
| Trickle Filter | 0.47 | 100 | 0.66 | 0.07 | 0.07 | 0.42 | ***1687*** | $2,386 | 0 |
| Trickle Filter | 0.94 | 0 | 0.54 | 0.06 | 0.06 | 0.39 | **1488** | $3,282 | 64 |
| Trickle Filter | 0.94 | 25 | 0.54 | 0.06 | 0.06 | 0.42 | ***1556*** | $3,192 | 44 |
| Trickle Filter | 0.94 | 50 | 0.54 | 0.06 | 0.06 | 0.44 | ***1612*** | $3,022 | 25 |
| Trickle Filter | 0.94 | 75 | 0.54 | 0.06 | 0.06 | 0.44 | ***1660*** | $2,777 | 0.5 |
| Trickle Filter | 0.94 | 100 | 0.54 | 0.06 | 0.06 | 0.42 | ***1687*** | $2,445 | 0 |
| Trickle Filter | 1.89 | 0 | 0.84 | 0.09 | 0.09 | 0.42 | **1250** | $3,479 | 96 |
| Trickle Filter | 1.89 | 25 | 0.74 | 0.08 | 0.08 | 0.44 | **1356** | $3,463 | 89 |
| Trickle Filter | 1.89 | 50 | 0.74 | 0.08 | 0.08 | 0.44 | **1488** | $3,400 | 64 |
| Trickle Filter | 1.89 | 75 | 0.74 | 0.08 | 0.08 | 0.43 | ***1612*** | $3,140 | 25 |
| Trickle Filter | 1.89 | 100 | 0.74 | 0.08 | 0.08 | 0.43 | ***1687*** | $2,563 | 0 |

Table A.11 Summary of ranked systems including temperature data.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Category | Device | | Q, m3 s-1 | | % recirculation | | Pit Fan Capacity | | # of Heaters | | % Time < 20 oC | | 3-mo cost, US$ | | Capital Cost, US$ | | Per pig increase, US$ | | CO2, ppm |
| **1A: < 1 mg/m3 dust and <1540 ppm CO2** | | | | | | |  | |  | |  | |  | |  | |  | |  |
|  | *None met the CO2 criterion while meeting temperature criterion* | | | | | | | | | | | |  | |  | |  | |  |
|  | Trickle | | 0.94 | | 0 | | 1 | | 2 | | 90 | | 1788 | | 1100 | | 0.81 | | 1536 |
|  | **None** | | - | | - | | 2 | | 2 | | 84 | | 1828 | | 0 | | 0.86 | | 1477 |
|  | Trickle | | 0.24 | | 0 - 100 | | 2 | | 2 | | 84-93 | | 1858 - 1873 | | 950 | | 0.90 | | 1364-1477 |
|  | Trickle | | 0.47 | | 0 - 100 | | 2 | | 2 | | 84 - 98 | | 1887 - 1905 | | 1000 | | 0.93 | | 1271-1477 |
|  | Trickle | | 0.94 | | 0 - 100 | | 2 | | 2 | | 84 - 100 | | 1946 - 1965 | | 1100 | | 1.00 | | 1134-1447 |
|  | ESP | | 0.94 | | 0 | | 1 | | 2 | | 90 | | 1934 | | 6033 | | 0.98 | | 1536 |
|  | Trickle | | 1.89 | | 0 - 50 | | 1 | | 2 | | 90 - 100 | | 1994 - 2003 | | 1200 | | 1.05 | | 1227-1351 |
|  | Cyclone | | 0.94 | | 0 | | 1 | | 2 | | 90 | | 2014 | | 4224 | | 1.08 | | 1536 |
|  | Trickle | | 1.89 | | 0 - 100 | | 2 | | 2 | | 84 - 100 | | 2064 - 2083 | | 1200 | | 1.13 | | 970-1477 |
|  | Cyclone + Trickle | | 0.94 | | 0 | | 1 | | 2 | | 90 | | 2132 | | 5324 | | 1.21 | | 1536 |
|  | Shaker dust | | 0.94 | | 0 | | 1 | | 2 | | 90 | | 2198 | | 9282 | | 1.29 | | 1536 |
|  | Wet dust | | 0.94 | | 0 | | 1 | | 2 | | 90 | | 2476 | | 20997 | | 1.61 | | 1536 |
|  |  |  | |  | |  | |  | |  | |  | |  | |  | |  | | |

Pit fan capacity of “1” indicates current capacity (2 fans at 0.412 m3 s-1 each); “2” indicates doubling current capacity. Two heaters are standard at the test site; 4 indicates doubling the current capacity. Per pig increase is computed with 10 pigs/sow, the low end of typical production targets, which is more than the production targets of our educational test site (8).

Table A.11, continued

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Category | Device | Q, m3 s-1 | % recirculation | Pit Fan Capacity | # Heaters | % Time < 20 oC | 3-mo cost, US$ | Capital Cost, US$ | Per pig increase, US$ | CO2, ppm |
| **1B: < 1 mg/m3 dust, 1540 ppm < CO2 < 2500 ppm** | | | | |  |  |  |  |  |  |
|  | Trickle | 0.94 | 75 - 100 | 1 | 2 | 0 | 1117 - 1451 | 1100 | 0.04 | 1907 - 1989 |
|  | Trickle | 0.94 | 0 - 100 | 1 | 4 | 0 | 1205 - 2540 | 1100 | 0.14 | 1573 - 2002 |
|  | ESP | 0.94 | 75 - 100 | 1 | 2 | 0 | 1264 - 1598 | 6033 | 0.22 | 1907 - 1989 |
|  | Trickle | 1.89 | 50 - 100 | 1 | 4 | 0 | 1323 - 2658 | 1200 | 0.29 | 1796 - 2002 |
|  | Trickle | 1.89 | 100 | 1 | 2 | 0 | 1324 | 1200 | 0.29 | 1989 |
|  | Cyclone | 0.94 | 75 - 100 | 1 | 2 | 0 | 1344 - 1677 | 4224 | 0.31 | 1907 - 1989 |
|  | Cyclone + Trickle | 0.94 | 75 - 100 | 1 | 2 | 0 | 1462 - 1796 | 5324 | 0.41 | 1907-1989 |
|  | Shaker dust | 0.94 | 75 - 100 | 1 | 2 | 0 | 1528 - 1862 | 9282 | 0.54 | 1907 - 1989 |
|  | Wet dust | 0.94 | 75 - 100 | 1 | 2 | 0 | 1806 - 2140 | 20997 | 0.88 | 1907 - 1989 |
|  | Wet dust | 0.94 | 0 - 100 | 1 | 4 | 0 | 1806 - 3141 | 20997 | 0.88 | 1796 - 2002 |
|  | Cyclone | 0.94 | 0 - 50 | 1 | 4 | 0 | 1932 - 2603 | 4224 | 1.03 | 1796 - 2859 |
|  | Trickle | 0.24 | 25 - 100 | 2 | 4 | 0 | 2356 - 2612 | 950 | 1.55 | 1668 - 1687 |
|  | Trickle | 0.47 | 75 - 100 | 2 | 4 | 0 | 2386 - 2557 | 1000 | 1.59 | 1673 - 1687 |
|  | Trickle | 1.89 | 100 | 2 | 4 | 0 | 2563 | 1200 | 1.81 | 1687 |
|  | Cyclone + Trickle | 0.94 | 25 - 50 | 1 | 2 | 38 - 75 | 2016 - 2106 | 5324 | 1.08 | 1660-1795 |
|  | Trickle | 0.24 | 0 | 2 | 4 | 0.5 | 2688 | 950 | 1.86 | 1660 |
|  | Trickle | 0.47 | 0 - 50 | 2 | 4 | 0.5 - 25 | 2718 - 2963 | 1000 | 1.90 | 1612-1660 |
|  | Trickle | 1.89 | 75 | 2 | 4 | 25 | 3140 | 1200 | 2.39 | 1612 |
|  | Trickle | 1.89 | 75 | 1 | 2 | 39 | 1879 | 1200 | 0.92 | 1795 |
|  | Trickle | 0.94 | 25 - 100 | 2 | 4 | 0.5 - 44 | 2777 - 3192 | 1100 | 1.96 | 1556-1687 |
|  | Trickle | 0.94 | 25 - 50 | 1 | 2 | 38 - 75 | 1672 - 1762 | 1100 | 0.68 | 1795 |
|  | ESP | 0.94 | 25 - 50 | 1 | 2 | 38 - 90 | 1818 - 1908 | 6033 | 0.85 | 1660-1795 |
|  | Shaker dust | 0.94 | 25 - 50 | 1 | 2 | 38 - 75 | 2082 - 2170 | 9282 | 1.16 | 1660-1795 |
|  | Wet Dust | 0.94 | 25 - 50 | 1 | 2 | 38 - 75 | 2360 - 2450 | 20997 | 1.48 | 1660-1795 |
|  | Cyclone | 0.94 | 25 - 50 | 1 | 2 | 38 - 75 | 2898 - 2014 | 4224 | 2.10 | 1660-1795 |
|  | Trickle | 1.89 | 0 - 25 | 1 | 4 | 35 - 76 | 3156 - 3344 | 1200 | 2.40 | 1573-1705 |

Table A.11, continued

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Category | Device | Q, m3 s-1 | % recirculation | Pit Fan Capacity | # of Heaters | % Time < 20 oC | 3-mo cost, US$ | Capital Cost, US$ | Per pig increase, US$ | CO2, ppm |
| **2A: 1 mg/m3 < dust< 2.8 mg/m3; 1540 < CO2 <2500** | | | | |  |  |  |  |  |  |
|  | None | - | - | 1 | 2 | 0 | 1088 | 0 | *baseline* | 1989 |
|  | Trickle | 0.24 | 25 - 100 | 1 | 4 | 0 | 1116 - 1448 | 950 | 0.03 | 1925 - 2002 |
|  | Trickle | 0.47 | 50 - 100 | 1 | 2 | 0 | 1117 - 1451 | 1000 | 0.03 | 1907 - 1989 |
|  | Trickle | 0.24 | 25 - 100 | 1 | 2 | 0 | 1117 -1371 | 950 | 0.03 | 1927 - 1989 |
|  | Trickle | 0.47 | 50 - 100 | 1 | 4 | 0 | 1146 - 1810 | 1000 | 0.07 | 1907 - 2002 |
|  | Cyclone | 0.24 | 25 - 100 | 1 | 2 | 0 | 1157 - 1441 | 3297 | 0.08 | 1927 - 1989 |
|  | ESP | 0.47 | 50 - 100 | 1 | 2 | 0 | 1178 - 1512 | 4561 | 0.10 | 1907 - 1989 |
|  | Cyclone + Trickle | 0.24 | 25 - 100 | 1 | 2 | 0 | 1187 - 1440 | 4247 | 0.12 | 1927 - 1989 |
|  | Cyclone | 0.47 | 50 - 100 | 1 | 2 | 0 | 1269 - 1603 | 3735 | 0.21 | 1907 - 1989 |
|  | Wet dust | 0.24 | 25 - 100 | 1 | 2 | 0 | 1296 - 1549 | 16660 | 0.24 | 1927 - 1989 |
|  | Wet dust | 0.24 | 0 - 100 | 1 | 4 | 0 | 1296 - 1628 | 16660 | 0.24 | 1907 - 2002 |
|  | Cyclone + Trickle | 0.47 | 50 - 100 | 1 | 2 | 0 | 1328 - 1662 | 4734.65 | 0.28 | 1907 - 1989 |
|  | Shaker dust | 0.24 | 25 - 100 | 1 | 2 | 0 | 1412 - 1665 | 7475 | 0.38 | 1927 - 1989 |
|  | Wet dust | 0.47 | 50 - 100 | 1 | 2 | 0 | 1435 - 1769 | 17580 | 0.40 | 1907 - 1989 |
|  | Wet dust | 0.47 | 0 - 100 | 1 | 4 | 0 | 1437 - 2101 | 17580 | 0.41 | 1859 - 2002 |
|  | Shaker dust | 0.47 | 50 - 100 | 1 | 2 | 0 | 1470 - 1804 | 7747 | 0.42 | 1907 |
|  | Cyclone | 0.47 | 0 - 25 | 1 | 4 | 0 | 1766 - 1932 | 3735 | 0.44 | 1907 - 1989 |
|  | None | - | - | 2 | 4 | 0 | 2327 | 0 | 0.50 | 1907 |
|  | Trickle | 0.24 | 0 | 1 | 2 | 22 | 1451 | 9282 | 0.63 | 1907 |
|  | Cyclone | 0.24 | 0 | 1 | 2 | 22 | 1521 | 3297 | 0.77 | 1907 |
|  | Trickle | 0.47 | 0 - 25 | 1 | 2 | 22 - 39 | 1578 - 1672 | 1000 | 1.37 | 1796 - 1859 |
|  | Wet dust | 0.24 | 0 | 1 | 2 | 22 | 1628 | 16660 | 1.44 | 1687 |
|  | Wet dust | 0.47 | 0 - 25 | 1 | 2 | 22 - 39 | 1640 - 1733 | 17580 | 0.57 | 1795 - 1854 |
|  | Cyclone | 0.47 | 0 - 25 | 1 | 2 | 22 - 39 | 1730 - 1824 | 3735 | 0.64 | 1795 - 1854 |
|  | Shaker dust | 0.24 | 0 | 1 | 2 | 22 | 1746 | 7475 | 0.75 | 1795 - 1854 |
|  | Wet dust | 0.47 | 0 - 25 | 1 | 2 | 22 - 39 | 1896 - 1990 | 17580 | 0.94 | 1795 - 1854 |
|  | Shaker dust | 0.47 | 0 - 25 | 1 | 2 | 22 - 39 | 1931-2025 | 7747 | 0.98 | 1795 - 1854 |

Table A.12 Comparison of CO2 levels with alternative heater exhaust

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Device | Q,  m3 s-1 | Room Air Recirc Ratio | Pit Fan, Q Heaters | 3 Month Average Concentration | | | | | 3 Months Operating Cost | % Time too cold |
| Inhale, mg/m3 | Resp, mg/m3 | NH3, ppm | CO, ppm | CO2, ppm |
| Traditional heater CO / CO2 source | | | | | | | | | | |
| Trickle Filter | 0.24 | 25 | 1/2 | 1.310 | 0.136 | 0.137 | 0.361 | 1927 | $1,371 | 0 |
| Trickle Filter | 0.47 | 75 | 1/2 | 1.073 | 0.112 | 0.118 | 0.349 | 1944 | $1,314 | 0 |
|  |  |  |  |  |  |  |  |  |  |  |
| No heater CO / CO2 source | | | | | | | | | | |
| Trickle Filter | 0.24 | 25 | 1/2 | 1.310 | 0.136 | 0.137 | 0.000 | 1241 | $1,459 | 0 |
| Trickle Filter | 0.47 | 75 | 1/2 | 1.073 | 0.112 | 0.118 | 0.000 | 1279 | $1,373 | 0 |
|  |  |  |  |  |  |  |  |  |  |  |
| Percent reduction | | | | | | | | | | |
| Trickle Filter | 0.24 | 25 | 1/2 | 0% | 0% | 0% | 100% | 36% | -6% | - |
| Trickle Filter | 0.47 | 75 | 1/2 | 0% | 0% | 0% | 100% | 34% | -4% | - |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |