ASHRAE Research Project 1299-RP

Energy Implications of Filtration in Residential and Light-Commercial Construction

Final Report

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EXECUTIVE SUMMARY

The use of high-efficiency particle filters in heating, ventilating, and air-conditioning (HVAC) systems is a common strategy to control exposure to particulate matter in buildings. ASHRAE filtration standards provide valuable information to design engineers and building operators about filtration efficiency as well as pressure drop. Although higher-efficiency filters can protect occupants from exposure to particulate matter, they are widely assumed to have significant energy penalties associated with their use because they generally have a higher-pressure drop.

The energy consequences of higher-pressure drop filtration are well known in large commercial buildings and can be characterized if the fan properties, airflow rate through the system, and pressure drop across the filter are known. However, characterization of energy consequences of filtration in residential and light commercial buildings is more complex. First, introducing a higher-pressure drop filter to a smaller system will generally cause the fan to move less air, but the magnitudes of airflow rate reductions associated with higher-efficiency filters are not well known. Low airflow can have positive and negative effects on energy consumption for air-conditioning operation in smaller systems. The lower flow can degrade cooling performance, potentially leading to longer system cycle operation times. However, depending on the fan and motor efficiency curves, lower flow can cause the air handler fan to draw less power and the effect on the power draw of the outdoor compressor-condenser unit can be negligible due to continuous unsteady state operation of these systems. Second, higher-efficiency filtration can better protect cooling coils, which may lead to better air-conditioner performance. Third, many duct systems are located outside of the conditioned space and duct leaks can have a significant energy penalty. A higher-pressure drop filter installed at the air handling unit may lower system

pressure and cause less return duct leakage while a higher-pressure drop filter installed at a return grille can increase the system pressure and increase return duct leakage.

The goal of this research was to explore this complex network of filtration effects in smaller HVAC systems. To explore the effects of filters on energy consumption in real residential and light commercial buildings, we monitored 17 forced air HVAC systems in occupied buildings and two controlled test systems in an unoccupied test house on a research campus. The results from the investigation allow for an accurate assessment of the energy consequences of filtration and provide information to home and building owners, operators, designers and system installers to make decisions about higher-efficiency filtration.

In the first part of this study, we explored the underlying theoretical energy implications of higher-efficiency filters. The airflow and energy consequences of a higher-pressure drop filter in residential or light commercial HVAC systems depend on the pressure drop of the filter relative to the total pressure drop of the return side of the system, the system duct curve, the fan curve, the fan efficiency curve, and the location of the intersection of the fan and duct curves. In general, the underlying theory, in conjunction with data from literature, suggests that the energy effects of higher-efficiency filters in residential systems are likely small, and the magnitude of the effects of high-pressure drop filters on duct leakage, total power draw, and cooling capacity may be positive or negative.

In the field investigation portion of this study, measurements were made once per month for one year at each occupied residential and light commercial system with filters from three different MERV range categories. Measured parameters included system airflow, fan power draw, power draw of the outdoor compressor-condenser unit, cooling capacity, pressure drops across filters and coils, and duct leakage. Higher-efficiency (MERV 11-12) filters generally had a small impact on parameters related to cooling energy consumption in the residential and light

commercial test systems when compared to low-efficiency (MERV 2) filters. The median energy consequence of higher-efficiency filtration in the test systems was estimated as a decrease of approximately 16 kWh per ton of nominal capacity (5 kWh per kW of nominal capacity) per month of cooling season operation, albeit with large variation. Most of these small savings came from fan energy reductions. These results suggest that the link between higher-efficiency filters and energy use in smaller residential and light commercial systems is weak and that other factors should govern filter selection. The primary specific findings of the field investigation include:

- Median airflow rates were approximately 4-5% lower during fan-only operation for 16 of the field sites and 10-11% lower during cooling operation for 11 of the field sites with high-efficiency filters (MERV 11-12) installed versus low-efficiency filters (MERV 2);
- The median fan power draw decrease was approximately 1% during fan-only operation and 4% during cooling operation with high-MERV filters installed;
- Median supply and return duct leakage airflow rates decreased in the presence of high-MERV filters, although the change in leakage fractions was very small;
- Median cycle lengths were longer with a high-MERV filter in six of the fourteen applicable sites, longer with a low-MERV filters in seven sites, and approximately equal in one site;
- Many of the impacts of filters measured in the test sites were within the range of instrument uncertainty and repeated filter tests had similar impacts in many cases as different filter efficiency installations did; and
- Differences in energy use associated with different filters were much smaller than differences that could be ascribed to climatic variation (particularly outdoor temperature) and changes in operation.

In the controlled test house investigation, we present the results of a four-month long period of detailed energy monitoring in two independent HVAC systems in an unoccupied test home on a research campus. This setting was much more controlled than the field-testing, thus we could normalize the impacts of climate and thermostat operation. The results from the test house confirm the field-testing findings that the magnitude of potential energy impacts associated with higher-efficiency filters are small. No significant difference in energy consumption due to higher-efficiency filters was observed in the two test systems. The primary findings of the experimental investigation of the test house systems include:

- High-MERV filters decreased airflow rates by approximately 7% and 11% in each of the two test systems, relative to low-MERV filters;
- Mid-MERV filters decreased airflow rates by approximately 3% and 8% in each of the two test systems, relative to low-MERV filters;
- Fan power draw increased approximately 3-4% and the power draw of the outdoor unit decreased less than 1% in the presence of high-MERV filters compared to low-MERV filters;
- Fan power draw increased between 0-2% and the power draw of the outdoor unit decreased less than 1% in the presence of mid-MERV filters compared to low-MERV filters in one system and increased less than 1% in the other;
- Total capacity decreased approximately 3-4% in the presence of high-MERV filters;
- Total capacity decreased less than 1% in one system and approximately 6% in another system in the presence of mid-MERV filters; and
- The trends in daily energy consumption with outdoor temperature did not significantly differ between low- and high-MERV filter installations.

Overall, the results described herein suggest that higher-efficiency filters do not appear to have much of an impact on energy consumption in the smaller forced air systems in this investigation. The magnitudes of effects seen with different filters in the small cycling systems are small in comparison to the effects of more important parameters like thermostat settings, climatic conditions, refrigerant charge, and duct leakage. Many of the energy consequences of filter efficiency were small enough to be in the noise of variations of filters and installations and thus other factors should govern filter selection for residential and light commercial buildings.

TABLE OF CONTENTS

EXECUTIVE SUMMARY ..... **II**

TABLE OF CONTENTS ..... **VII**

LIST OF TABLES ..... **X**

LIST OF FIGURES ..... **XIV**

1. INTRODUCTION **1**

2. THEORY **3**
2.1 Fan Impacts 6
2.2 Outdoor Compressor-Condenser Unit Impacts 9
2.3 Duct Leakage Impacts 11

3. METHODOLOGY **14**
3.1 Field Site Systems Description 14
3.2 Test House Systems Description 16
3.3 Field Site Methodology and Equipment 17
3.4 Test House Methodology and Equipment 20
3.4.1 Fan Curve Determination Procedure 22
3.5 Calculation of Energy Consequences 23
3.6 Uncertainty 25
3.7 Statistical Analysis 26
3.7.1 Field Systems 27
3.7.1.1 Impacts of Filtration Efficiency (MERV) 27
3.7.1.2 Impacts of Filter Pressure Drop 28
3.7.1.3 Estimation of Energy Consequences during Cooling Mode 28
3.7.1.3.1 Discussion of binned analysis attempt 28
3.7.2 Test House Systems 29

4. RESULTS **31**
4.1 Field Sites 31
4.1.1 Detailed Field Site Descriptions 31
4.1.1.1 Site 1 31
4.1.1.2 Site 2 32
4.1.1.3 Site 3 33
4.1.1.4 Site 4 33
4.1.1.5 Site 5 34
4.1.1.6 Site 6 34
4.1.1.7 Site 7 34
4.1.1.8 Site 8 34
4.1.1.9 Site 9 34
4.1.1.10 Site 10 35
4.1.1.11 Site 11 35
4.1.1.12 Site 12 35
4.1.1.13 Site 13 36
4.1.1.14 Site 14 36
4.1.1.15 Site 15 36
4.1.1.16 Site 16 38
4.1.1.17 Site 17 39
4.1.2 Field Measurements 39

4.1.3 Research Question 1: What is the impact of filtration efficiency on the measured parameters? ...47
4.1.4 Research Question 2: How does filter pressure drop relate directly to the measured parameters? 51
4.1.5 Research Question 3: What is the likely range of energy consequences of filtration?....53
4.1.6 Examples of Important Factors for Specific Sites....60
4.1.6.1 Site 1....60
4.1.6.2 Site 2....61
4.1.6.3 Site 3....62
4.1.6.4 Site 4....62
4.1.6.5 Site 5....63
4.1.6.6 Site 6....63
4.1.6.7 Site 7....64
4.1.6.8 Site 8....64
4.1.6.9 Site 9....64
4.1.6.10 Site 10....65
4.1.6.11 Site 11....65
4.1.6.12 Site 12....65
4.1.6.13 Site 13....66
4.1.6.14 Site 14....66
4.1.6.15 Site 15....66
4.1.6.16 Site 16....67
4.1.6.17 Site 17....67
4.1.7 Detailed Cooling Energy Consumption Examples....68
4.1.7.1 Residential Example: Site 5....68
4.1.7.2 Light Commercial Example: Site 13....70
4.2 Test House Measurements....73
4.2.1 Test House Fan Curves....73
4.2.2 Continuous Measurements....74
4.2.3 Binned Analysis....80

5. THEORETICAL IMPLICATIONS AND EXAMPLE CALCULATION....85

6. LESSONS LEARNED AND RECOMMENDATIONS FOR FUTURE INVESTIGATIONS....91

7. CONCLUSIONS....94

8. REFERENCES....98

9. APPENDICES....101
Appendix A: Field Site Building and HVAC Characteristics....102
Appendix B: Full Results from Research Question 1....107
Appendix C: Full Results from Research Question 2....109
Appendix D: Full Tables for Field Sites (IP Units)....133
Appendix D.1: Filter Characteristics (IP)....134
Appendix D.2: Fan Characteristics (IP)....152
Appendix D.3: A/C Operation Characteristics (IP)....170
Appendix D.4: Site Duct Leakage Characteristics (IP)....188
Appendix D.5: Visit Specific Duct Leakage Measurements (IP)....190
Appendix D.6: Importance of Filter Pressure Drop (IP)....208
Appendix E: Full Tables for Field Sites (SI Units)....226
Appendix E.1: Filter Characteristics (SI)....227
Appendix E.2: Fan Characteristics (SI)....245
Appendix E.3: A/C Operation Characteristics (SI)....263
Appendix E.4: Site Duct Leakage Characteristics (SI)....281
Appendix E.5: Visit Specific Duct Leakage Measurements (SI)....283
Appendix E.6: Importance of Filter Pressure Drop (SI)....301
Appendix F: Full Tables for Test House Systems (IP Units)....319
Appendix F.1: Test House Filter Characteristics (IP)....320
Appendix F.2: Test House Fan Characteristics (IP)....322
Appendix F.3: Test House A/C Operation Characteristics (IP)....324
Appendix F.4: Test House Duct Leakage Characteristics (IP)....326

Appendix G: Full Tables for Test House Systems (SI Units)....328
Appendix G.1: Test House Filter Characteristics (SI)....329
Appendix G.2: Test House Fan Characteristics (SI)....331
Appendix G.3: Test House A/C Operation Characteristics (SI)....333
Appendix G.4: Test House Duct Leakage Characteristics (SI)....335
Appendix H: Binned Analysis for Test House Systems....337

LIST OF TABLES

Table 1. Test Site Characteristics 15
Table 2. Field Instrumentation 20
Table 3. Test House Instrumentation 21
Table 4. Estimates relative uncertainty of calculated quantities 26
Table 5. Description of indoor and outdoor temperature bins used in the test house analysis 30
Table 6. Impacts of Filter Efficiency on Measured Variables 48
Table 7. Impacts of Filter Pressure Drop on Measured Variables 52
Table 8. Impacts of Filter MERV on Duty Cycle and Power Draw 55
Table 9. Expected Change in Monthly Energy Consumption (Comparing High-MERV to Low-MERV filters) 58
Table 10. Filter and flow measurements of the test systems 75
Table 11. Performance measurements during cooling operation of the test systems 77
Table 12. Duct leakage measurements for the test systems 78
Table 13. Binned comparison results during cooling mode operation[1] 80
Table 14. Given conditions for theoretical analysis 87
Table 15. Parameter summary with low- and high-MERV filters 87
Table 16. Cooling coil capacity estimation for low- and high-MERV filters 88
Table 17. Energy balance on conditioned space with low- and high-MERV filters 90
Table 18. Building Characteristics 103
Table 19. HVAC Characteristics 104
Table 20. Estimated Filter Face Velocities: Residential Sites[1] 105
Table 21. Estimated Filter Face Velocities: Light Commercial Sites[1] 106
Table 23. Full results of Research Question 2 110
Table 24. Filter Characteristics: Site 1 (IP) 135
Table 25. Filter Characteristics: Site 2 (IP) 136
Table 26. Filter Characteristics: Site 3 (IP) 137
Table 27. Filter Characteristics: Site 4 (IP) 138
Table 28. Filter Characteristics: Site 5 (IP) 139
Table 29. Filter Characteristics: Site 6 (IP) 140
Table 30. Filter Characteristics: Site 7 (IP) 141
Table 31. Filter Characteristics: Site 8 (IP) 142
Table 32. Filter Characteristics: Site 9 (IP) 143
Table 33. Filter Characteristics: Site 10 (IP) 144
Table 34. Filter Characteristics: Site 11 (IP) 145
Table 35. Filter Characteristics: Site 12 (IP) 146
Table 36. Filter Characteristics: Site 13 (IP) 147
Table 37. Filter Characteristics: Site 14 (IP) 148
Table 38. Filter Characteristics: Site 15 (IP) 149
Table 39. Filter Characteristics: Site 16 (IP) 150
Table 40. Filter Characteristics: Site 17 (IP) 151
Table 41. Fan Characteristics: Site 1 (IP) 153
Table 42. Fan Characteristics: Site 2 (IP) 154
Table 43. Fan Characteristics: Site 3 (IP) 155
Table 44. Fan Characteristics: Site 4 (IP) 156
Table 45. Fan Characteristics: Site 5 (IP) 157
Table 46. Fan Characteristics: Site 6 (IP) 158
Table 47. Fan Characteristics: Site 7 (IP) 159
Table 48. Fan Characteristics: Site 8 (IP) 160
Table 49. Fan Characteristics: Site 9 (IP) 161
Table 50. Fan Characteristics: Site 10 (IP) 162
Table 51. Fan Characteristics: Site 11 (IP) 163
Table 52. Fan Characteristics: Site 12 (IP) 164
Table 53. Fan Characteristics: Site 13 (IP) 165
Table 54. Fan Characteristics: Site 14 (IP) 166
Table 55. Fan Characteristics: Site 15 (IP) 167

Table 56. Fan Characteristics: Site 16 (IP) 168
Table 57. Fan Characteristics: Site 17 (IP) 169
Table 58. A/C Operation Characteristics: Site 1 (IP) 171
Table 59. A/C Operation Characteristics: Site 2 (IP) 172
Table 60. A/C Operation Characteristics: Site 3 (IP) 173
Table 61. A/C Operation Characteristics: Site 4 (IP) 174
Table 62. A/C Operation Characteristics: Site 5 (IP) 175
Table 63. A/C Operation Characteristics: Site 6 (IP) 176
Table 64. A/C Operation Characteristics: Site 7 (IP) 177
Table 65. A/C Operation Characteristics: Site 8 (IP) 178
Table 66. A/C Operation Characteristics: Site 9 (IP) 179
Table 67. A/C Operation Characteristics: Site 10 (IP) 180
Table 68. A/C Operation Characteristics: Site 11 (IP) 181
Table 69. A/C Operation Characteristics: Site 12 (IP) 182
Table 70. A/C Operation Characteristics: Site 13 (IP) 183
Table 71. A/C Operation Characteristics: Site 14 (IP) 184
Table 72. A/C Operation Characteristics: Site 15 (IP) 185
Table 73. A/C Operation Characteristics: Site 16 (IP) 186
Table 74. A/C Operation Characteristics: Site 17 (IP) 187
Table 75. Site Duct Leakage Characteristics: All Sites (IP) 189
Table 76. Visit Specific Duct Leakage Measurements: Site 1 (IP) 191
Table 77. Visit Specific Duct Leakage Measurements: Site 2 (IP) 192
Table 78. Visit Specific Duct Leakage Measurements: Site 3 (IP) 193
Table 79. Visit Specific Duct Leakage Measurements: Site 4 (IP) 194
Table 80. Visit Specific Duct Leakage Measurements: Site 5 (IP) 195
Table 81. Visit Specific Duct Leakage Measurements: Site 6 (IP) 196
Table 82. Visit Specific Duct Leakage Measurements: Site 7 (IP) 197
Table 83. Visit Specific Duct Leakage Measurements: Site 8 (IP) 198
Table 84. Visit Specific Duct Leakage Measurements: Site 9 (IP) 199
Table 85. Visit Specific Duct Leakage Measurements: Site 10 (IP) 200
Table 86. Visit Specific Duct Leakage Measurements: Site 11 (IP) 201
Table 87. Visit Specific Duct Leakage Measurements: Site 12 (IP) 202
Table 88. Visit Specific Duct Leakage Measurements: Site 13 (IP) 203
Table 89. Visit Specific Duct Leakage Measurements: Site 14 (IP) 204
Table 90. Visit Specific Duct Leakage Measurements: Site 15 (IP) 205
Table 91. Visit Specific Duct Leakage Measurements: Site 16 (IP) 206
Table 92. Visit Specific Duct Leakage Measurements: Site 17 (IP) 207
Table 93. Importance of Filter Pressure Drop: Site 1 (IP) 209
Table 94. Importance of Filter Pressure Drop: Site 2 (IP) 210
Table 95. Importance of Filter Pressure Drop: Site 3 (IP) 211
Table 96. Importance of Filter Pressure Drop: Site 4 (IP) 212
Table 97. Importance of Filter Pressure Drop: Site 5 (IP) 213
Table 98. Importance of Filter Pressure Drop: Site 6 (IP) 214
Table 99. Importance of Filter Pressure Drop: Site 7 (IP) 215
Table 100. Importance of Filter Pressure Drop: Site 8 (IP) 216
Table 101. Importance of Filter Pressure Drop: Site 9 (IP) 217
Table 102. Importance of Filter Pressure Drop: Site 10 (IP) 218
Table 103. Importance of Filter Pressure Drop: Site 11 (IP) 219
Table 104. Importance of Filter Pressure Drop: Site 12 (IP) 220
Table 105. Importance of Filter Pressure Drop: Site 13 (IP) 221
Table 106. Importance of Filter Pressure Drop: Site 14 (IP) 222
Table 107. Importance of Filter Pressure Drop: Site 15 (IP) 223
Table 108. Importance of Filter Pressure Drop: Site 16 (IP) 224
Table 109. Importance of Filter Pressure Drop: Site 17 (IP) 225
Table 110. Filter Characteristics: Site 1 (SI) 228
Table 111. Filter Characteristics: Site 2 (SI) 229
Table 112. Filter Characteristics: Site 3 (SI) 230
Table 113. Filter Characteristics: Site 4 (SI) 231

Table 114. Filter Characteristics: Site 5 (SI) 232
Table 115. Filter Characteristics: Site 6 (SI) 233
Table 116. Filter Characteristics: Site 7 (SI) 234
Table 117. Filter Characteristics: Site 8 (SI) 235
Table 118. Filter Characteristics: Site 9 (SI) 236
Table 119. Filter Characteristics: Site 10 (SI) 237
Table 120. Filter Characteristics: Site 11 (SI) 238
Table 121. Filter Characteristics: Site 12 (SI) 239
Table 122. Filter Characteristics: Site 13 (SI) 240
Table 123. Filter Characteristics: Site 14 (SI) 241
Table 124. Filter Characteristics: Site 15 (SI) 242
Table 125. Filter Characteristics: Site 16 (SI) 243
Table 126. Filter Characteristics: Site 17 (SI) 244
Table 127. Fan Characteristics: Site 1 (SI) 246
Table 128. Fan Characteristics: Site 2 (SI) 247
Table 129. Fan Characteristics: Site 3 (SI) 248
Table 130. Fan Characteristics: Site 4 (SI) 249
Table 131. Fan Characteristics: Site 5 (SI) 250
Table 132. Fan Characteristics: Site 6 (SI) 251
Table 133. Fan Characteristics: Site 7 (SI) 252
Table 134. Fan Characteristics: Site 8 (SI) 253
Table 135. Fan Characteristics: Site 9 (SI) 254
Table 136. Fan Characteristics: Site 10 (SI) 255
Table 137. Fan Characteristics: Site 11 (SI) 256
Table 138. Fan Characteristics: Site 12 (SI) 257
Table 139. Fan Characteristics: Site 13 (SI) 258
Table 140. Fan Characteristics: Site 14 (SI) 259
Table 141. Fan Characteristics: Site 15 (SI) 260
Table 142. Fan Characteristics: Site 16 (SI) 261
Table 143. Fan Characteristics: Site 17 (SI) 262
Table 144. A/C Operation Characteristics: Site 1 (SI) 264
Table 145. A/C Operation Characteristics: Site 2 (SI) 265
Table 146. A/C Operation Characteristics: Site 3 (SI) 266
Table 147. A/C Operation Characteristics: Site 4 (SI) 267
Table 148. A/C Operation Characteristics: Site 5 (SI) 268
Table 149. A/C Operation Characteristics: Site 6 (SI) 269
Table 150. A/C Operation Characteristics: Site 7 (SI) 270
Table 151. A/C Operation Characteristics: Site 8 (SI) 271
Table 152. A/C Operation Characteristics: Site 9 (SI) 272
Table 153. A/C Operation Characteristics: Site 10 (SI) 273
Table 154. A/C Operation Characteristics: Site 11 (SI) 274
Table 155. A/C Operation Characteristics: Site 12 (SI) 275
Table 156. A/C Operation Characteristics: Site 13 (SI) 276
Table 157. A/C Operation Characteristics: Site 14 (SI) 277
Table 158. A/C Operation Characteristics: Site 15 (SI) 278
Table 159. A/C Operation Characteristics: Site 16 (SI) 279
Table 160. A/C Operation Characteristics: Site 17 (SI) 280
Table 161. Site Duct Leakage Characteristics: All Sites (SI) 282
Table 162. Visit Specific Duct Leakage Measurements: Site 1 (SI) 284
Table 163. Visit Specific Duct Leakage Measurements: Site 2 (SI) 285
Table 164. Visit Specific Duct Leakage Measurements: Site 3 (SI) 286
Table 165. Visit Specific Duct Leakage Measurements: Site 4 (SI) 287
Table 166. Visit Specific Duct Leakage Measurements: Site 5 (SI) 288
Table 167. Visit Specific Duct Leakage Measurements: Site 6 (SI) 289
Table 168. Visit Specific Duct Leakage Measurements: Site 7 (SI) 290
Table 169. Visit Specific Duct Leakage Measurements: Site 8 (SI) 291
Table 170. Visit Specific Duct Leakage Measurements: Site 9 (SI) 292
Table 171. Visit Specific Duct Leakage Measurements: Site 10 (SI) 293

Table 172. Visit Specific Duct Leakage Measurements: Site 11 (SI)....294
Table 173. Visit Specific Duct Leakage Measurements: Site 12 (SI)....295
Table 174. Visit Specific Duct Leakage Measurements: Site 13 (SI)....296
Table 175. Visit Specific Duct Leakage Measurements: Site 14 (SI)....297
Table 176. Visit Specific Duct Leakage Measurements: Site 15 (SI)....298
Table 177. Visit Specific Duct Leakage Measurements: Site 16 (SI)....299
Table 178. Visit Specific Duct Leakage Measurements: Site 17 (SI)....300
Table 179. Importance of Filter Pressure Drop: Site 1 (SI)....302
Table 180. Importance of Filter Pressure Drop: Site 2 (SI)....303
Table 181. Importance of Filter Pressure Drop: Site 3 (SI)....304
Table 182. Importance of Filter Pressure Drop: Site 4 (SI)....305
Table 183. Importance of Filter Pressure Drop: Site 5 (SI)....306
Table 184. Importance of Filter Pressure Drop: Site 6 (SI)....307
Table 185. Importance of Filter Pressure Drop: Site 7 (SI)....308
Table 186. Importance of Filter Pressure Drop: Site 8 (SI)....309
Table 187. Importance of Filter Pressure Drop: Site 9 (SI)....310
Table 188. Importance of Filter Pressure Drop: Site 10 (SI)....311
Table 189. Importance of Filter Pressure Drop: Site 11 (SI)....312
Table 190. Importance of Filter Pressure Drop: Site 12 (SI)....313
Table 191. Importance of Filter Pressure Drop: Site 13 (SI)....314
Table 192. Importance of Filter Pressure Drop: Site 14 (SI)....315
Table 193. Importance of Filter Pressure Drop: Site 15 (SI)....316
Table 194. Importance of Filter Pressure Drop: Site 16 (SI)....317
Table 195. Importance of Filter Pressure Drop: Site 17 (SI)....318
Table 196. Filter Characteristics: Test House (IP)....321
Table 197. Fan Characteristics: Test House (IP)....323
Table 198. A/C Operation Characteristics: Test House (IP)....325
Table 199. Duct Leakage Characteristics (IP)....327
Table 200. Filter Characteristics: Test House (SI)....330
Table 201. Fan Characteristics: Test House (SI)....332
Table 202. A/C Operation Characteristics: Test House (SI)....334
Table 203. Duct Leakage Characteristics (SI)....336
Table 204. TH Upflow System: Fan Power Draw (W)....338
Table 205. TH Downflow System: Fan Power Draw (W)....339
Table 206. TH Upflow System: Compressor Power Draw (W)....340
Table 207. TH Downflow System: Compressor Power Draw (W)....341
Table 208. TH Upflow System: Total Power Draw (W)....342
Table 209. TH Downflow System: Total Power Draw (W)....343
Table 210. TH Upflow System: Sensible Capacity (W)....344
Table 211. TH Downflow System: Sensible Capacity (W)....345
Table 212. TH Upflow System: Latent Capacity (W)....346
Table 213. TH Downflow System: Latent Capacity (W)....347
Table 214. TH Upflow System: Total Capacity (W)....348
Table 215. TH Downflow System: Total Capacity (W)....349
Table 216. TH Upflow System: System Efficiency (-)....350
Table 217. TH Downflow System: System Efficiency (-)....351
Table 218. TH Upflow System: System Airflow Rate (CFM)....352
Table 219. TH Downflow System: System Airflow Rate (CFM)....353
Table 220. TH Upflow System: Supply Leakage Airflow Rate (CFM)....354
Table 221. TH Downflow System: Supply Leakage Airflow Rate (CFM)....355
Table 222. TH Upflow System: Temperature Difference Across Coil (°C)....356
Table 223. TH Downflow System: Temperature Difference Across Coil (°C)....357
Table 224. TH Upflow System: Humidity Ratio Difference Across Coil (kg/kg)....358
Table 225. TH Downflow System: Humidity Ratio Difference Across Coil (kg/kg)....359

LIST OF FIGURES

Figure 1. Pressure distribution in a residential or light commercial HVAC system: a) System schematic, b) Static pressure distribution 4
Figure 2. System and fan curves for medium, high, and low pressure drop filters 7
Figure 3. Fan pressure, power, and efficiency curves for a) airfoil fans and b) forward curved low-pressure residential or light commercial fans 8
Figure 4. Example static pressure distribution for a residential system 12
Figure 5. Map of field sites (courtesy of Google Maps) 16
Figure 6. Unoccupied manufactured test house on the research campus 17
Figure 7. Custom-built data-logging box with a) external pressure transducers and b) internal energy logging equipment 18
Figure 8. Test house data acquisition system 21
Figure 9. Example steady-state flag procedure for the field systems 24
Figure 10. Image of the air handler at Site 1 as installed in a closet 31
Figure 11. Image of the air handler at Site 2 installed in a garage 32
Figure 12. Image of the return grille (on the right) and supply register (on the left) at Site 4 33
Figure 13. The two filter locations at Site 11: a) wall next to the air handler and b) ceiling 35
Figure 14. Image of the air handler, return plenum, and return ductwork at Site 15 37
Figure 15. Image of filters installed at Site 15 37
Figure 16. Image of the return opening at Site 16 38
Figure 17. Filter pressure drop and system airflow in residential systems operating in fan-only mode. 40
Figure 18. Filter pressure drop and system airflow in commercial systems operating in fan-only mode. Sites 9 and 12 are measuring the pressure through the entire return system, not just the filter pressure drop 41
Figure 19. System airflow rates measured with low-, mid-, and high-MERV filters installed in the test systems. Airflow rates are normalized by the cooling capacity of the system, although the airflow rates presented were measured in the fan-only mode. The primary scale is in IP units (CFM/ton) and the quantities in parentheses are in SI units ($(m^3/hr)/kW$). 42
Figure 20. System airflow rates (normalized by cooling capacity) measured in the cooling mode with low-, mid-, and high-MERV filters installed in the test systems. The primary scale is in IP units (CFM/ton) and the quantities in parentheses are in SI units ($(m^3/hr)/kW$). The dashed line indicates recommended airflow of 400 CFM/ton (193 ($(m^3/hr)/kW$)) 43
Figure 21. Fan power draw measurements of the test systems made during fan-only operation with low-, mid-, and high-MERV filters installed. 44
Figure 22. Example pressure, power, and temperature data from a field visit 45
Figure 23. Average fan and compressor power draws and flow reductions during the cooling season at each site with low-MERV (L) and high-MERV (H) filters installed. 46
Figure 24. Cycle lengths versus average outdoor temperature during each cycle recorded with low- and high-MERV filters installed at Site 5. 68
Figure 25. Cycle lengths versus the temperature difference between the beginning and end of each cycle recorded with low- and high-MERV filters installed at Site 5. 69
Figure 26. Cycle lengths versus average outdoor temperature for each cycle recorded at Site 13. 70
Figure 27. Cycle lengths versus average outdoor temperature for cycles less than one hour and outdoor temperatures greater than 20°C. 71
Figure 28. Cycle lengths versus average temperature difference between inside and outside measured at Site 13 with high- and low-MERV filters installed (with some outliers omitted). 72
Figure 29. Fan curves for a) the upflow and b) the downflow test systems 74
Figure 30. Pressure distribution with high- and low-MERV filters installed in a) the upflow test system and b) the downflow test system. 79
Figure 31. Daily energy consumption with high- and low-MERV filters in a) the upflow system and b) the downflow system. 83
Figure 32. RQ2 regression for fan power draw in the fan-only mode 111
Figure 33. RQ2 regression for coil pressure drop in the fan-only mode 112
Figure 34. RQ2 regression for system airflow rate in the fan-only mode 113
Figure 35. RQ2 regression for fan efficacy in the fan-only mode 114
Figure 36. RQ2 regression for supply duct leakage flow in the fan-only mode 115
Figure 37. RQ2 regression for return duct leakage flow in the fan-only mode 116
Figure 38. RQ2 regression for supply duct leakage fraction in the fan-only mode 117

Figure 39. RQ2 regression for return duct leakage fraction in the fan-only mode 118
Figure 40. RQ2 regression for fan power draw in the cooling mode....119
Figure 41. RQ2 regression for coil pressure drop in the cooling mode 120
Figure 42. RQ2 regression for system airflow rate in the cooling mode 121
Figure 43. RQ2 regression for fan efficacy in the cooling mode....122
Figure 44. RQ2 regression for supply duct leakage flow in the cooling mode....123
Figure 45. RQ2 regression for return duct leakage flow in the cooling mode....124
Figure 46. RQ2 regression for supply duct leakage fraction in the cooling mode....125
Figure 47. RQ2 regression for return duct leakage fraction in the cooling mode....126
Figure 48. RQ2 regression for compressor power draw in the cooling mode....127
Figure 49. RQ2 regression for sensible capacity in the cooling mode....128
Figure 50. RQ2 regression for latent capacity in the cooling mode....129
Figure 51. RQ2 regression for total capacity in the cooling mode 130
Figure 52. RQ2 regression for sensible heat ratio in the cooling mode 131
Figure 53. RQ2 regression for duct delivery effectiveness (DE) in the cooling 132

1. INTRODUCTION

High-efficiency filtration in forced air heating, ventilating, and air-conditioning (HVAC) systems is used to protect building equipment and occupants, but can also influence building energy consumption. The most widely used measure of filter efficiency in the United States is the Minimum Efficiency Reporting Value (MERV), as defined by ASHRAE Standard 52.2-2007 (ASHRAE, 2007). According to the method-of-test in the standard, low-MERV filters (MERV <4) are required to remove 20% of particles in the aerodynamic diameter size range of 3-10 μm with no requirements for removal of smaller particles. Mid-MERV filters (MERV 5-9) remove at least 20-85% of 3-10 μm particles and up to 50% of 1-3 μm particles. Higher-MERV filters (MERV 10-12) remove 85-90% 3-10 μm particles and up to 50-80% of 1-3 μm particles. Only very-high-MERV (MERV >13) filters remove submicron particles and have minimum efficiencies as high as 95% for all particle sizes, but these filters are generally not designed for use in HVAC systems in residential and light commercial buildings.

Filters with a high MERV typically have a greater pressure drop than a filter with a lower MERV. The energy consequences of a greater pressure drop due to filtration are well known for large commercial systems, but there is very limited information on the energy consequences of filtration and air cleaning in residential and light commercial applications. This makes it difficult for ASHRAE membership to make informed decisions about the costs and benefits of filtration strategies.

In large commercial systems, where fan and motor controls typically maintain required airflow rates, a higher-pressure drop filter causes the fan motor to draw more power to overcome the pressure drop and deliver the required amount of air, thus increasing energy consumption (e.g., Chimack and Sellers, 2000; Fisk et al., 2002; Yang et al., 2007). This association between energy use and filter pressure drop is widely assumed to hold true for smaller residential and light commercial systems, however, the energy consequences of filtration in residential and light commercial buildings are considerably more complicated and less well known. First,

introducing a higher-pressure drop filter in a smaller system will generally cause the fan to move less air, but the magnitudes of this reduction are system dependent and not widely known. Low airflow can have competing effects on the energy consumption of air-conditioning systems because the lower flow can degrade cooling performance, but the fan can also draw less power and add less heat to be removed by the system. Second, higher-efficiency filtration can better protect cooling coils, which may lead to better air-conditioner performance (e.g., Montgomery and Baker, 2006). Third, many duct systems are located outside of conditioned space and duct leaks can have a significant energy penalty. A higher-pressure drop filter installed at the air handling unit may lower system pressure and cause less return duct leakage while a higher-pressure drop filter installed at a return grille can increase the system pressure and increase return duct leakage.

The goal of this research was to explore the underlying theoretical implications of filters and conduct measurements that assess this complex network of filtration effects in smaller HVAC systems. The results from the investigation allow for an accurate assessment of the energy consequences of filtration and provide information to home and building owners, operators, designers and system installers to make decisions about filtration.

2. THEORY

Over 70% of residential and most light commercial buildings in the United States use central forced air distribution systems for heating and air-conditioning purposes (HUD, 2005). Most residential and light commercial air-conditioning systems are smaller direct expansion (DX) systems with the condenser and compressor located outside of the building envelope in the outdoor unit. The air handling unit (AHU) is usually positioned either inside the building envelope (e.g., closet or conditioned attic) or outside of conditioned space (e.g., vented attic or garage). Smaller HVAC systems usually use supply distribution ducts to provide cooling and heating throughout the building and typically have either return ducts or a direct intake from the conditioned space, depending on the configuration of the house and the location of the AHU. Air filters are typically installed in the return air stream at either the AHU or the return duct grille(s). The configuration of supply ducts, return ducts, supply registers, and return grilles, along with the position of individual components within the AHU (i.e., filter, fan, cooling coil and heating coils/heat exchanger) can vary and can affect the pressure distribution through the system. The system pressure distribution generally drives the source and magnitude of outdoor air infiltration since most existing smaller systems in the United States do not incorporate dedicated outdoor air ventilation (e.g., Chan et al., 2005; Sherman, 2008; Waring and Siegel, 2008).

Figure 1 presents a typical configuration of an AHU with both return and supply ducts and the corresponding pressure distribution in the system. It illustrates the change of static pressure due to airflow across the different components of the system. The magnitude of total static pressure that the AHU fan must overcome is generally less than 250 Pa in residential systems (ASHRAE, 2004a; Proctor and Parker, 2000). Almost all of the pressure potential is used to overcome friction introduced by different components of the system, outlined in Figure 1a. Figure 1b shows the static pressure distribution relative to the surrounding pressure in the occupied residence space.

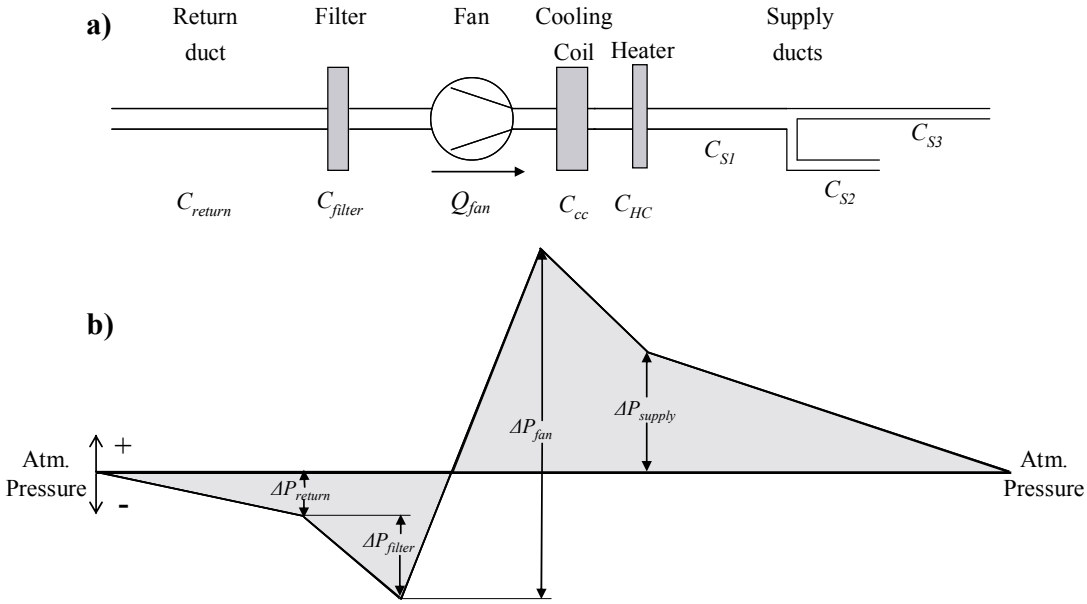


Figure 1. Pressure distribution in a residential or light commercial HVAC system: a) System schematic, b) Static pressure distribution

The static pressure drop across individual components of the system is proportional to the square of the airflow rate and a coefficient of proportionality, *C* (ASHRAE, 2005a). There are some filter and coil installations where either a combination of a linear and a squared term is used or an empirically derived exponent is used (e.g., Yang et al., 2007), but we focus on the classic form here. The coefficient, *C*, depends on component geometries and is constant for static system components such as return grilles, supply registers, ducts, and heating coils. The coefficient for a filter can increase as the filter becomes loaded over time and the pressure drop is increased. Similarly, the coefficient of proportionality for the cooling coil can also change as the moisture from air condenses on the surfaces, changing the geometry. However, this study considers only the effects of filter pressure drop on system operation.

Figure 1a illustrates that residential HVAC systems can be presented as systems of components connected in series, with duct branches connected in parallel. Equation (1)

represents the combination of the component coefficients in Figure 1a, resulting in a total equivalent coefficient of proportionality for the entire system, C_{total}.

$$C_{total} = C_{return} + C_{filter} + C_{CC} + C_{HC} + C_{S1} + \frac{C_{S2} + C_{S3}}{C_{S2} \cdot C_{S3}} \quad (1)$$

where

C_{total} = coefficient of proportionality for the entire system;
C_{return} = coefficient of proportionality for the return duct;
C_{filter} = coefficient of proportionality for the filter;
C_{CC} = coefficient of proportionality for the cooling coil;
C_{HC} = coefficient of proportionality for the heating coil;
C_{S1} = coefficient of proportionality for the first supply duct branch;
C_{S2} = coefficient of proportionality for the second supply duct branch; and
C_{S3} = coefficient of proportionality for the third supply duct branch.

Since the pressure loss in each component can be presented as a square function of airflow through the component and the geometry of all components remains constant (excluding the filter), the required pressure increase across the system fan, ΔP_{fan}, can be expressed as a function of the airflow rate, Q_{fan}, and C_{total}, as shown in Equation (2).

$$\Delta P_{fan} = C_{total} \cdot Q_{fan}^2 = (C_{filter} + C_{system}) \cdot Q_{fan}^2 \quad (2)$$

where

ΔP_{fan} = required pressure increase across the fan;
Q_{fan} = system airflow rate; and
C_{system} = coefficient of proportionality for the system, excluding the filter.

The filter coefficient, C_{filter}, generally increases with both filter efficiency and time as it loads. The filter coefficient and system coefficient, C_{system}, can be used to express the contribution of the filter on total pressure drop in a system (C_{filter} /(C_{filter} + C_{system})). The contribution of the filter to total system pressure drop depends on the system configuration, filter efficiency (MERV), and loading condition.

High-efficiency or high-pressure drop filters can influence energy use in three primary areas of residential HVAC systems: 1) the AHU fan, 2) the outdoor compressor-condenser unit, and 3) duct leakage. Each of these impacts is explored below.

2.1 FAN IMPACTS

The power draw of an AHU fan can be described as a function of the required pressure increase across the fan and the airflow rate as shown in Equation (3) (ASHRAE, 2004b).

$$W_{fan} = \frac{\Delta P_{fan} \cdot Q_{fan}}{\eta_{fan} \cdot \eta_{motor}} = \frac{C_{total} \cdot Q_{fan}^3}{\eta_{fan} \cdot \eta_{motor}} = \frac{(C_{filter} + C_{system}) \cdot Q_{fan}^3}{\eta_{fan} \cdot \eta_{motor}} \quad (3)$$

where

W_{fan} = coefficient of proportionality for the entire system;
η_{fan} = efficiency of the fan; and
η_{motor} = efficiency of the fan motor.

In HVAC systems where airflow remains constant by the use of variable speed fans and the efficiencies of the fan shaft and motor do not change with the airflow rate, the power draw of the fan is a linear function of the filter coefficient. Equation (3) indicates that, in this case, a 10% increase in total pressure drop would cause a 10% increase in fan electric power draw. However, most residential and many light commercial HVAC systems do not have controls to keep airflow rates constant and an increase of filter pressure drop will generally decrease the airflow rate (Parker et al., 1997).

Pressure and flow relationships for HVAC systems and fans can be characterized by system and fan curves as shown in Figure 2. In this theoretical example of a typical HVAC system without flow controls, replacing the mid-MERV filter with a high-MERV filter (i.e., increasing the filter pressure drop) increases the total system pressure and decreases the airflow rate, as the working point moves from point A to point B. The reverse effect occurs when decreasing the filter efficiency or pressure drop (moving from point A to point C in Figure 2).

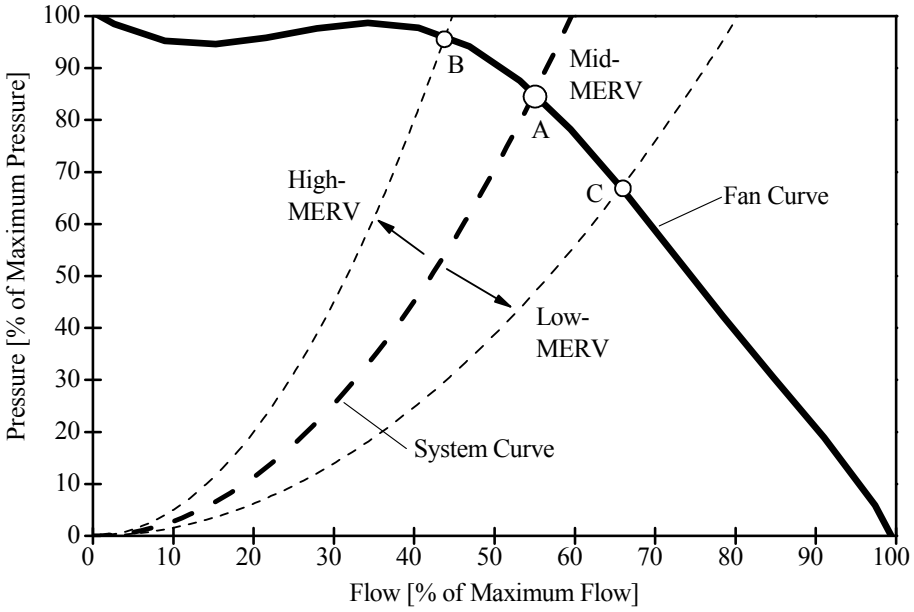


Figure 2. System and fan curves for medium, high, and low pressure drop filters

In the theoretical example in Figure 2, if a higher-efficiency filter increases total system pressure approximately 40%, the working point moves from point C to point B and airflow decreases approximately 30%. When the working point is along the concave part of the fan curve (such as point B in Figure 2), the magnitude of a decrease in airflow is greater than the magnitude of an increase in pressure and the energy delivered to the air (the product of $\Delta P_{fan} \cdot Q_{fan}$) decreases as ΔP_{fan} increases. When the working point is along the linear part of the fan curve (such as point C in Figure 2), the energy delivered to the air remains constant as long as a pressure increase or decrease keeps the working point within the linear range. The effect that airflow changes have on fan power draw depends on the magnitude of pressure drop, airflow, and fan and motor efficiencies shown in Equation (3).

Fan shaft efficiency, which defines the ratio of shaft torque that is converted to airflow, typically peaks in the central region of the airflow range and is generally lower at the high and low bounds of airflow rates. Fan motor efficiency, which defines the input energy that the motor converts to useful shaft torque, typically increases with the power delivered to the shaft.

Peak fan efficiencies in residential systems are generally less than 70% and peak motor efficiencies are generally between 30-70%, respectively (Sachs et al., 2002). Figure 3a and Figure 3b show pressure, efficiency, and power curves for two different fan types to illustrate how the shape of fan efficiency curves affects the fan power draw. Points A, B, and C provide theoretical working points for different pressure drop filters.

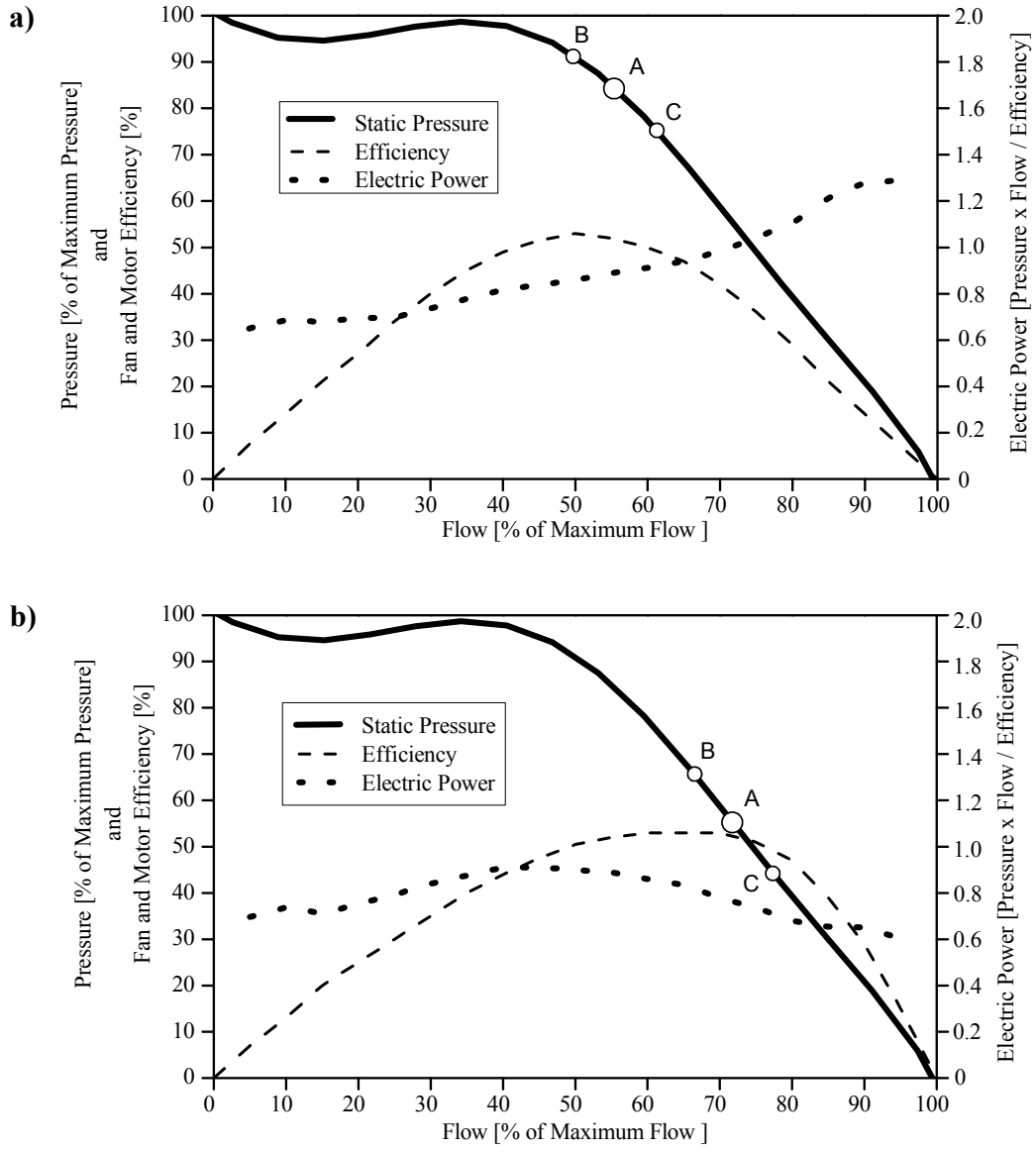


Figure 3. Fan pressure, power, and efficiency curves for a) airfoil fans and b) forward curved low-pressure residential or light commercial fans

For the airfoil fan represented in Figure 3a, a 10% increase in total pressure drop due to changing filters and moving from point A to point B would decrease airflow approximately 12% and decrease fan power draw approximately 8%. For the forward curved fan represented in Figure 3b, a 20% increase in pressure drop from point A to point B would decrease airflow approximately 7% and fan power draw would actually increase approximately 7%. Again, these working points are hypothetical points on two representative fan curves and do not represent actual measured values. However, they show the impact that the shape of the fan efficiency curve and the change in working point on the fan curve due to filters can have on fan power draw.

The fan and motor efficiency curves depend on the type of fan design, the properties of the electric motor, and the installation position of the fan in the AHU. Most residential units have sheet metal centrifugal fans with thin, forward-curved impeller blades that have a low maximum efficiency and approximately 90% of residential fans have permanent split capacitor (PSC) motors (Sachs et al., 2002). Alternative fan designs can include electronically commutated DC permanent magnet motors (ECM) whose pressure and flow relationships will behave differently than PSC motors, but they currently have a limited market share in residential systems.

2.2 OUTDOOR COMPRESSOR-CONDENSER UNIT IMPACTS

The effects of higher-pressure drop filters on the operation of outdoor compressor-condenser units are not well known, but diminished airflow across the cooling coil is known to affect: 1) heat transfer on the surface of the cooling coil, 2) the refrigerant evaporation process within the cooling coil, and 3) compressor operation. Reduced airflow due to filters can therefore influence the cooling capacity and overall energy consumption of DX cooling systems.

Heat transfer on the surface of the cooling coil defines how much sensible and latent energy the coil removes from the airstream. Reduced airflow will generally reduce convective heat transfer of sensible energy from the air to the surface of the cooling coil, which will

decrease sensible cooling capacity; however, this can lead to a lower cooling coil surface temperature and increase moisture removal capability. A lower airflow rate also enables a longer contact time between the air and coil surface area, which further increases dehumidification capacity. Because of these interacting effects, the magnitude of total cooling capacity reduction does not directly follow the magnitude of airflow reduction.

A decrease in cooling capacity can affect the refrigerant evaporation pressure and the refrigerant flow rate through the cooling coil. The impact depends on the type of expansion valve. In residential and light commercial DX systems with a thermostatic expansion valve (TXV), the refrigerant flow rate will vary with cooling capacity because the valve will control the flow of liquid refrigerant entering the evaporator to maintain the refrigerant vapor at the exit of the cooling coil at a relatively constant temperature and pressure. In DX systems with a capillary tube or orifice expansion valve, the evaporation pressure and temperature will vary with cooling capacity. Therefore, a decrease in cooling capacity will cause a lower evaporation pressure and potentially reduce the refrigerant flow rate. In systems with a TXV, a reduction of cooling capacity will not change the refrigeration efficiency considerably since the evaporation pressure does not change and the reduced refrigerant flow reduces the power draw of the compressor (Palani et al., 1992). In a DX system with a capillary tube or orifice expansion valve, a reduction in cooling capacity can decrease the efficiency of the cooling cycle but the power draw of the compressor may also decrease due to the reduced refrigerant flow rate.

Compounding refrigerant charge effects, the power draw and overall energy consumption of the outdoor unit also depends on the length of compressor operation and refrigerant charge. Most residential and light commercial systems often operate at non-ideal unsteady state conditions where any effects on capacity and efficiency are less well known. Most residential systems are either undercharged or overcharged (Downey and Proctor, 2002) and thus the effects of reduced airflow with high-efficiency filters at these non-ideal conditions are far less predictable by these theoretical considerations.

Using experimental measurements and simulations, researchers have shown that the net effect of low airflow is a decrease in cooling system efficiency because cooling capacity generally decreases more than the compressor-condenser unit power draw. For example, Rodriguez et al. (1996) showed that, in air-conditioner tests with an orifice expansion valve, a 10% reduction in airflow caused capacity to decrease by approximately 7%, power draw by less than 1%, and COP by approximately 6%. Reductions in capacity, power, draw and COP were approximately 10%, 1%, and 8%, respectively, with a 20% airflow rate reduction.

2.3 DUCT LEAKAGE IMPACTS

Many residential and light commercial duct systems are located partially or entirely outside of conditioned space and duct leaks (both conductive and convective) can have a significant energy penalty. Supply side leaks can lead to a direct energy penalty, as conditioned air is lost to the outside of a building. Return side leaks can lead to increased sensible and latent loads and diminished air-conditioning effectiveness (e.g., Siegel et al., 2000; O'Neal et al., 2002; Francisco et al., 2006).

An increased filter pressure drop can change return and supply side duct leakage by altering the pressure distribution in the duct system. The direction and magnitude of the impact on duct leakage due to changes in flow and pressure drop depends on the locations of the filter and the leaks. Increasing the pressure drop of a filter located at the air handler may cause lower return system pressure differences between the return grille and the filter because more of the total pressure drop occurs near the air handler, which can cause less return duct leakage. Similarly, an increase of the pressure drop of a filter at the return grille(s) in a system, such as the one in Figure 4, can lead to increased return system leakage and increased supply-side leakage because the pressure differential between the air in the ducts and the surrounding air can increase. An important aspect of duct leakage is that system impacts generally scale with the leakage fractions, defined as duct leakage divided by system airflow (ASHRAE, 2004c).

Because airflow also generally diminishes with a high-efficiency filter, this can serve to enhance or diminish any duct leakage impacts.

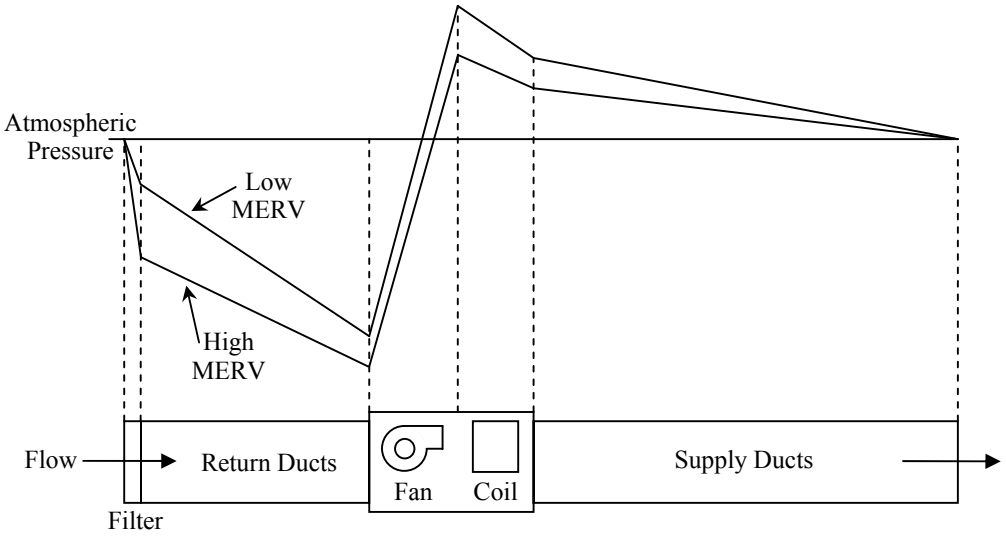


Figure 4. Example static pressure distribution for a residential system

Summarizing the previous sections, the airflow and energy consequences of a higher-pressure drop filter in residential HVAC systems depend on the pressure drop of the filter relative to that of the rest of the return side of the system, the system fan curve, the fan efficiency curve, and the location of the intersection of the fan and duct curves. In general, the underlying theory, in conjunction with values from literature, suggests that the energy effects of higher-efficiency filters in residential systems are likely small. In residential air-conditioner field tests, Parker et al. (1997) measured a 4-5% airflow rate reduction when replacing standard disposable filters with high-efficiency pleated filters. In three previous studies, a 5-10% reduction from recommended airflow rates (the range of airflow reductions most likely due to filters) has been shown to diminish total capacity, sensible capacity, and system efficiency by approximately 2-6%, increase latent capacity by approximately 1-3%, and diminish total power draw (fan + outdoor unit) by less than 1% (Palani et al., 1992; Rodriguez et al., 1996; Parker et al., 1997). The magnitude of the effects of filters on duct leakage, total power draw, and cooling capacity are not well characterized. We know of no direct research on the implications of filtration on

duct leakage, but a small decrease in duct leakage could have potentially large energy benefits, as capacity delivered to registers has been shown to increase 4-8% with a small 3% decrease in duct leakage (Walker et al., 1998).

3. METHODOLOGY

To support our theoretical work and experimentally investigate the energy consequences of higher-efficiency filters, we monitored 17 residential and light commercial forced air cooling systems at multiple occupied buildings and 2 residential air-conditioning systems in an unoccupied test house on a research campus. All test sites were located in Austin, Texas. Measured parameters included system airflow rate, power draw, cooling capacity, pressure drops across filters and coils, and duct leakage. Periodic measurements were made over the course of a year at each of the field sites with readily available filters with different MERV categories, as rated by the filter manufacturer. Continuous measurements on both systems in the test house were made with low, medium, and high efficiency filters over a period of seven months, although refrigerant charge and fan-speed changes limit the available data to four months. The purpose of this research was to assess how filter MERV and the corresponding measured pressure drop impact energy use in smaller air-conditioning systems.

3.1 FIELD SITE SYSTEMS DESCRIPTION

Seventeen systems were selected as a sample of convenience based on the willingness of the building owners and residents to have monitoring equipment installed and frequent visits from the field personnel. Table 1 summarizes the 17 test sites and Appendix A provides additional building and site characteristics (see Table 18 and Table 19). The first eight sites were residential buildings and the remaining nine were light commercial buildings. The light commercial buildings were all office spaces with some also serving a limited retail function. Each system served less than 2000 ft^2 (186 m^2) of floor area and rated air-conditioner cooling capacities ranged from 1.5 to 5.0 tons (5.3 to 17.6 kW). Sites 1-15 had typical permanent split capacitor (PSC) fans and Sites 16 and 17 had electronically commutated motor (ECM) fans. Most ductwork was located in unconditioned attics, with a few systems with ducts in other locations. Filters were located in return grilles or at the air handler. All of the test systems relied on infiltration for fresh air, rather than dedicated outdoor air ventilation.

Table 1. Test Site Characteristics

Site	Building Use	Floor Area, ft^2 (m^2)	Rated Cooling Capacity[1], tons (kW)	Ductwork Location	Air Handler Location	Number of Filters	Filter Location[2]
1	Residential	1830 (170)	4.0 (14)	Attic	Closet	1	Slot
2	Residential	1430 (133)	3.0 (11)	Attic	Garage	1	Slot
3	Residential	1080 (100)	2.5 (9)	Between floors	Closet	3	Grilles
4	Residential	320 (30)	1.5 (5)	Attic	Attic	1	Grille
5	Residential	1140 (106)	2.5 (9)	Attic	Attic	1	Grille
6	Residential	1500 (139)	3.0 (11)	Attic	Attic	1	Grille
7	Residential	1200 (111)	3.0 (11)	Between floors	Closet	1	Slot
8	Residential	1350 (125)	3.0 (11)	Attic	Garage	1	Slot
9	Commercial	1300 (121)	5.0 (18)	Attic	Attic	2	Grilles
10	Commercial	1300 (121)	3.5 (12)	Attic	Attic	2	Grilles
11	Commercial	1320 (123)	3.5 (12)	Attic	Attic	2	Grilles
12	Commercial	1860 (173)	5.0 (18)	Attic	Attic	3	Grilles
13	Commercial	1430 (133)	3.5 (12)	Attic	Closet	1	Slot
14	Commercial	980 (91)	3.0 (11)	Attic	Closet	1	Slot
15	Commercial	1000 (93)	2.5 (9)	Attic	Closet	2	Slot
16	Commercial	760 (71)	1.5 (5)	Outdoor	Outdoor closet	1	Grille
17	Commercial	280 (26)	1.5 (5)	Conditioned space	Closet	1	Slot

[1]Cooling capacity corresponds to the nominal capacity of the outdoor unit.
[2]Slot = Filter slot at the air handling unit, Grille(s) = Return grille(s).

The systems were located throughout the Austin, TX area and Figure 5 displays a map of the locations of field sites.

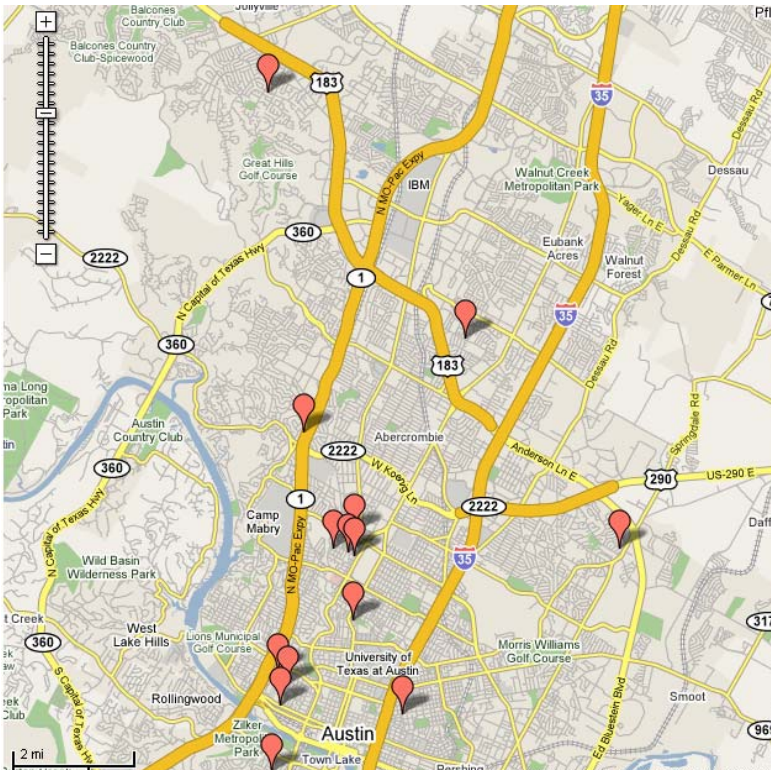


Figure 5. Map of field sites (courtesy of Google Maps)

3.2 TEST HOUSE SYSTEMS DESCRIPTION

The test house, an unoccupied 1,200 ft^2 (111 m^2) manufactured home, served as a controlled test site (shown in Figure 6). The house contained two independently operated 2.5-ton (8.8 kW) air-conditioning systems that were continuously monitored. The indoor AHUs were identical, but one system was installed in an upflow configuration, supplying air from ceiling registers, and the other was installed in a downflow configuration, supplying air from floor registers. The outdoor unit matched with the down-flowing system was a heat pump while the upflow outdoor unit had only cooling capabilities. Both systems had 15 kW electrical resistance heaters installed in the AHU. Neither unit had return ductwork but supply ductwork for both units was located in unconditioned spaces, in the attic for the upflow unit and in the crawl space for the downflow unit.



Figure 6. Unoccupied manufactured test house on the research campus

3.3 FIELD SITE METHODOLOGY AND EQUIPMENT

The test sites were visited once a month for a year, during which time three categories of filtration efficiency typically used in residential and light commercial systems were installed: low (MERV 2), medium (MERV 6-8), and high (MERV 11-12). More information about the filter installations can be found in Appendix A (see Table 20 and Table 21), which also estimate face velocities across cleanly installed filters. Each MERV category filter was left in place for three months and monitored four times: initially on the day of installation and after one, two, and three months of usage. The final three-month period was used to repeat an installation of one of the MERV categories to assess variation in the measurements. Unlike the other sites, Site 12 had only high-efficiency filters installed over the duration of the project because of a request by the building owner.

During each monthly visit, measurements were made in the fan-only mode by activating the switch at the thermostat. Individual systems were configured in different ways, but in most of the field sites the fan-only mode operated with lower a fan-speed (and airflow rate) than the speed during cooling mode. These fan-only measurements were intended to have the greatest consistency between measurements at a given site, including in the heating season. Pressure measurements were made using an Energy Conservatory DG-700 handheld digital manometer (uncertainty ±1% of reading), including the pressure drop across the filter(s) and cooling coil and the pressure differential between the occupied space and the supply and return plenums. A

custom-built data-logging box (shown in Figure 7) was then launched to record the pressure drop across the filter(s) and cooling coil and the power draw of the air handler fan in the fan-only mode for approximately 15 minutes at 10-second intervals. The data-logging box consisted of a Continental Control Systems (CCS) Wattnode AC true power meter (uncertainty ±0.45% of reading and ±0.05% of full-scale), two Setra pressure transducers (uncertainty ±1% of full-scale) connected to an Onset Flexsmart **(**uncertainty ±1% of full-scale**)**, and an Onset HOBO Energy Logger Pro. The box was connected to pressure taps, voltage taps, and 0-20 Amp CCS current transducers (uncertainty ±1% of reading). These taps and current transducers were permanently installed for the duration of the one-year test period and the data data-logging box were periodically attached to them.



a) **b)**

Figure 7. Custom-built data-logging box with a) external pressure transducers and b) internal energy logging equipment

During each monthly visit in the cooling season, measurements were made with each system in fan-only mode, then the equipment was left to monitor and log for approximately 24 hours with the thermostat operated normally by the building occupants. Also, during the cooling season visits, additional continuous measurements were made of the power draw of the outdoor

unit using the same instrumentation as described above and Onset HOBO U12 dataloggers for temperature and relative humidity measurements (uncertainty ±0.7°F (±0.4°C) and ±2.5% from 10% to 90% RH; 6-minute response time). Temperature and relative humidity measurements were taken outdoors, in the zone that contained the majority of the ductwork (often the attic), inside the return plenum, inside the supply plenum, and at a single supply register.

Duct leakage and airflow measurement tests were conducted during one visit over the course of the year long monitoring period. Duct leakage was measured using an Energy Conservatory Duct Blaster (uncertainty ±3% of flow reading) and Model 3 blower door in accordance with ASHRAE Standard 152-2004 (ASHRAE, 2004c). The Duct Blaster alone was used to make total (interior + exterior) leakage measurements and the blower door was added to make exterior leakage measurements. The tests were repeated with the return side of the system sealed off to separate supply and return leakage. Monthly estimates of duct leakage were assessed by correcting for changes in the supply plenum operating pressure observed during each visit and using a power-law flow-leakage approximation following the procedure described in the Duct Blaster manual (Energy Conservatory, 2007). System airflow rates were measured with an Energy Conservatory TrueFlow metering plate and DG-700 digital manometer (uncertainty ±7% of reading). Monthly corrections were made based on changes in the supply plenum pressure measured during each visit following the calculation procedure in the instrument manual (Energy Conservatory, 2006). Table 2 summarizes the equipment used in the field tests and the manufacturer-reported accuracies of each device.

Table 2. Field Instrumentation

Measurement	Units, IP (SI)	Equipment	Accuracy
Logged Measurements			
Pressure	IWC (Pa)	Setra 265 Transducer	±1% FS[1]
Power draw	V	CCS Wattnode	±0.45% of reading and ±0.05% FS
	A	CCS Current Transducer	±1% of reading
	W	Onset Energy Logger Pro	±1.5% of reading [2]
Temperature	°F (°C)	Onset HOBO U12	±0.7°F (±0.4°C)
Relative Humidity	%	Onset HOBO U12	±2.5% from 10% to 90% RH
Periodic Measurements			
Pressure	IWC (Pa)	Energy Conservatory DG-700	±1% of reading or 0.0006 IWC (0.15 Pa)
Airflow	CFM (m^3/hr)	Energy Conservatory TrueFlow Plate	±7% of reading[3]
Duct Leakage	CFM (m^3/hr)	Energy Conservatory Duct Blaster	±3% of reading or ±1 CFM (± 2 m^3/hr)

[1]Three models of pressure transducers were used in the field measurements with full-scale (FS) ranges of 0.25 IWC (62 Pa), 0.50 IWC (125 Pa), and 1.0 IWC (249 Pa).
[2]Voltage and amperage accuracies added in quadrature produced an uncertainty of ±1.2% in the power draw measurements. The estimated uncertainty was rounded to ±1.5% for use in this study because of unknown uncertainties associated with higher-order harmonics.
[3]Manufacturer's literature reports 7%, but conversations with the manufacturer suggest that a higher accuracy is appropriate for repeated measurements of flow differences, which led to the 5% uncertainty determination used in this work.

3.4 TEST HOUSE METHODOLOGY AND EQUIPMENT

Continental Control Systems (CCS) Wattnode AC true power meters were installed at each air handler fan and outdoor unit and connected to 0-20 A CCS current transducers. The power meters were connected to an Onset HOBO Energy Logger Pro and an Energy Conservatory Automated Performance Testing (APT) System was connected to pressure taps, temperature sensors, and relative humidity sensors. Both the Energy Logger Pro and the APT System were connected to a computerized data acquisition system. Pressure taps were installed before and after the filter, before and after the coil, and in the supply plenum on both air handlers. Indoor temperature and relative humidity sensors were installed before the filter and after the coil in both systems. Outdoor temperature and relative humidity were measured with a HOBO U12 datalogger. Airflow and duct leakage tests were conducted using an Energy Conservatory Duct Blaster and Model 3 Blower Door in accordance with ASHRAE Standard 152 (ASHRAE, 2004c). System airflow was measured with an Energy Conservatory TrueFlow metering plate and DG-700 digital manometer. The manufacturer reported accuracies for each

piece of equipment are listed in Table 3 and the test house data acquisition system is shown in Figure 8.

Table 3. Test House Instrumentation

Measurement	Units	Equipment	Accuracy
Logged Measurements			
Pressure	IWC (Pa)	Energy Conservatory Automatic Performance Testing System	±1% of reading
Power draw	V	CCS Wattnode	±0.45% of reading and ±0.05% FS
	A	CCS Current Transducer	±1% of reading
	W	Onset Energy Logger Pro	±1.5% of reading[1]
Temperature	°F (°C)	Energy Conservatory precision NTC thermistor	±0.45°F (±0.25°C) from 32-167°F (0-75°C)
Relative Humidity	%	Energy Conservatory thermostet polymer based capacitance sensor	±5% (from 0-90% RH); ±8% (at 90% RH)
Periodic Measurements			
Pressure	IWC (Pa)	Energy Conservatory DG-700	±1% of reading or 0.0006 IWC (0.15 Pa)
Airflow	CFM (m^3/hr)	Energy Conservatory TrueFlow Plate	±7% of reading[2]
Duct Leakage	CFM (m^3/hr)	Energy Conservatory Duct Blaster	±3% of reading or ±1 CFM (±2 m^3/hr)

[1]Voltage and amperage accuracies added in quadrature produced an uncertainty of ±1.2% in the power draw measurements. The estimated uncertainty was rounded to ±1.5% for use in this study because of unknown uncertainties associated with higher-order harmonics.
[2]Manufacturer's literature reports 7%, but conversations with the manufacturer suggest that a higher accuracy is appropriate for repeated measurements of flow differences, which led to the 5% uncertainty determination used in this work.

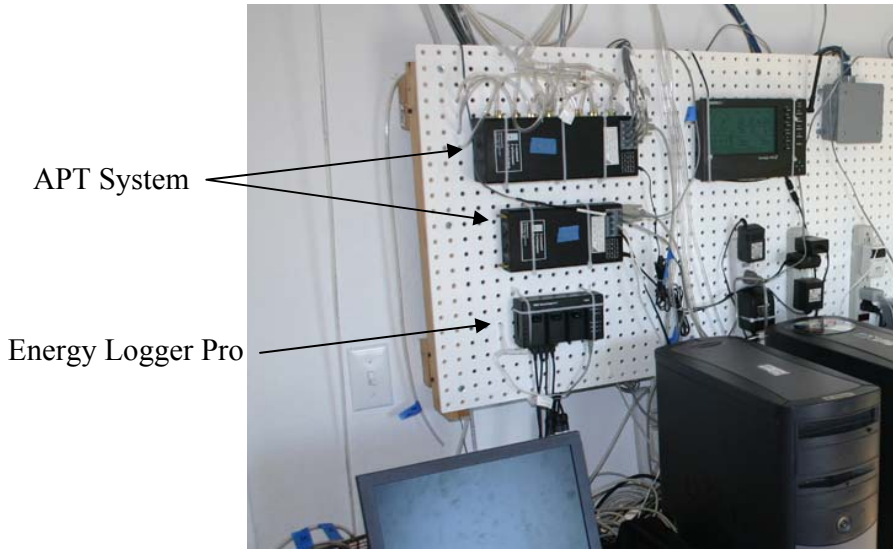


Figure 8. Test house data acquisition system

The two test systems were continuously monitored between May 2008 and November 2008 and three levels of readily available 1-inch (25.4 mm) filtration efficiency were installed: low-efficiency fiberglass panel filters (MERV < 4), medium-efficiency synthetic pleated filters (MERV 8), and high-efficiency synthetic pleated filters (MERV 11). Filter efficiencies are as reported by the manufacturer. There were seven months of total testing, but both systems needed refrigerant charge and fan speed adjustments. Therefore, the useful testing periods for low-MERV, mid-MERV, and high-MERV filters during the cooling season were approximately 7 weeks, 2 weeks, and 7 weeks, respectively. During the test periods, the all dataloggers were synchronized to record continuously at 10-second intervals. Outdoor temperature and relative humidity measurements were made at 15-minute intervals. The system fans operated continuously and programmable thermostats were kept at consistent schedules throughout the test periods. The thermostats alternated the daily times of operation of each unit so that they were never competing to meet the cooling load. Estimates of supply duct leakage were assessed at each collected data point by correcting for changes in the observed supply plenum operating pressure and using a power-law flow-leakage approximation following the procedure in the Duct Blaster manual (Energy Conservatory, 2007). System airflow was assessed at each data point based on corrections in the measured supply plenum operating pressure, following the calculation procedure in the TrueFlow manual (Energy Conservatory, 2006).

3.4.1 Fan Curve Determination Procedure

A series of experiments were conducted to establish fan curves and to characterize fan power draw and flow relationships for both systems in the test house. The procedure involved switching the systems to fan-only operation at the thermostat, blocking the filter slot with a solid plate, and holding it in place in varying positions to simulate an alteration in filter pressure drop. Airflow, fan power draw, filter pressure drop, coil pressure drop, and supply plenum operating pressure were measured and averaged at each simulated filter pressure drop condition. The total system pressure overcome by the AHU fan was calculated as the sum of filter pressure drop, coil pressure drop, and supply plenum operating pressure drop (Figure 1).

3.5 CALCULATION OF ENERGY CONSEQUENCES

Previous field studies have relied on the metrics of sensible capacity, latent capacity, and coefficient of performance (i.e., system efficiency) in attempts to address the complicated relationship between flow changes, system runtime, and overall energy consumption (e.g., Parker et al., 1997). We used the same metrics to describe the cooling performance of the systems using the measured data. The total capacity, q_t, calculation is shown in Equation (4). The first term defines sensible capacity and the second term defines latent capacity.

$$q_t = Q_{fan}\rho(C\Delta T + \Delta W h_{fg}) \tag{4}$$

where

q_t	=	total cooling capacity (BTU/hr, W);
Q_{fan}	=	volumetric flow rate of air (ft^3/hr, m^3/s) flowing through the cooling coil;
ρ	=	air density, assumed constant (0.075 lb_m/ft^3, 1.2 kg/m^3);
C	=	specific heat of air, assumed constant (0.24 BTU/(lb_m°F), 1.005 kJ/(kg K));
ΔT	=	temperature difference across the cooling coil (°F, K);
ΔW	=	humidity ratio difference across the cooling coil (lb_m/lb_m, kg/kg); and
h_{fg}	=	latent heat of vaporization for water, assumed constant (970 BTU/lb, 2257 kJ/kg).

The coefficient of performance, *COP*, calculation is shown in Equation (5).

$$COP = \frac{q_t}{W_{ou} + W_{fan}} \tag{5}$$

where

COP	=	coefficient of performance, or efficiency (-);
W_{ou}	=	power draw of the outdoor unit (W); and
W_{fan}	=	fan power draw (W).

The cooling capacities were analyzed during each recorded cycle only when the systems reached a period of steady-state operation. Measured observations were flagged in the analysis as steady-state when the supply plenum temperature did not vary for a period of at least 2

minutes by more than 0.9°F (0.5°C) from the lowest temperature recorded during a cycle. In the field measurements, steady-state cycles also had to be at least 6 minutes long due to the response time of the temperature and relative humidity instrumentation. Response time was not an issue in the test house measurements because the manufacturer-reported instrument response times were less than 2 minutes. Figure 9 is an example of the steady-state flag procedure from one of the cooling cycles recorded in one of the field test systems.

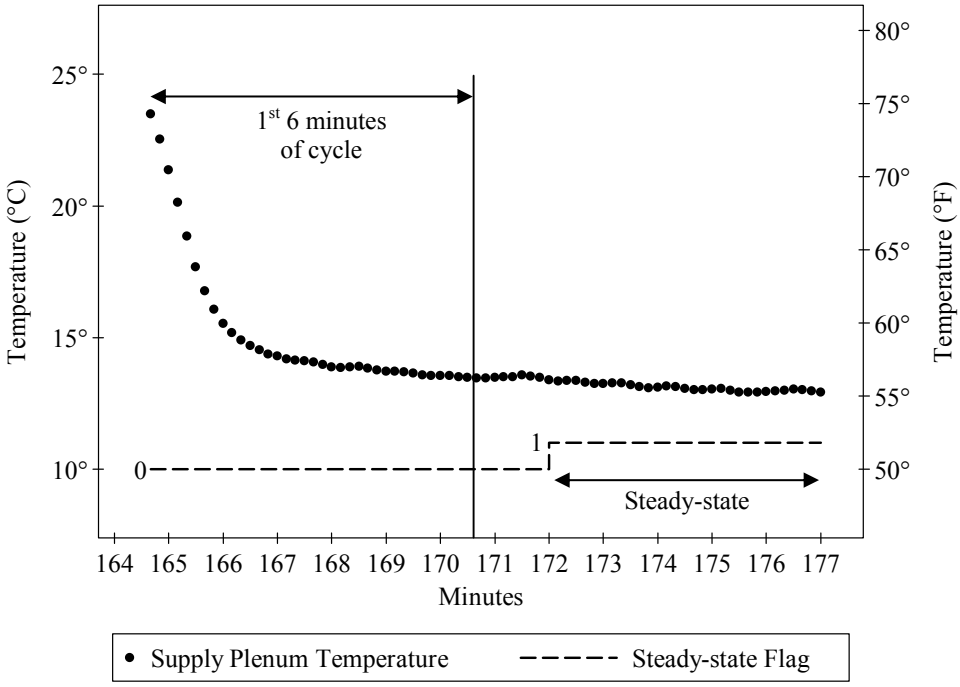


Figure 9. Example steady-state flag procedure for the field systems

Although the capacity and efficiency calculations in Equations (4) and (5) assess the cooling performance of a system, little is known about how changes in sensible capacity actually translate to thermostat readings to ultimately affect runtime and energy consumption. To address this, we also measured the energy consumption and runtime of the test systems. The amount of energy consumed during an air-conditioning cycle, E_{cyc}, is defined in Equation (6) as the total power draw of a cycle times the length of a cycle.

$$E_{cyc} = \left(W_{ou} + W_{fan}\right) \cdot l_{cyc} \quad (6)$$

where

E_{cyc} = energy consumed during an air-conditioning cycle (kWh); and
l_{cyc} = length of an air-conditioning cycle (hours).

Since the test house systems were continuously monitored, the amount of energy consumed by the test house air-conditioners during a day of testing, E_{daily}, is defined in Equation (7) as the sum of the energy consumed during all of the cycles throughout the 24 hours in a day.

$$E_{daily} = \sum_{t=0}^{t=24} E_{cyc} \quad (7)$$

where

E_{daily} = daily energy consumption of the air-conditioner (kWh); and
t = hour of the day.

3.6 UNCERTAINTY

The manufacturer-reported instrument accuracies propagate through many of the calculations involved in this report. Uncertainties of calculations are added in quadrature when applicable, according to ASHRAE Guideline 2-2005 (ASHRAE, 2005b). For example, Equation (4) provides the calculation for total capacity, while the first term is sensible capacity and the second term is latent capacity. The sensible capacity calculation includes both airflow rate and temperature measurement terms. The individual uncertainties are provided in Table 2 and Table 3 for the field measurements and test house measurements, respectively, but the uncertainty in the sensible capacity calculation is compounded as shown in Equation (8).

$$\delta_{sensible\ capacity} = \sqrt{\delta_{Q_a}^2 + \delta_{\Delta T}^2} \quad (8)$$

where

$\delta_{sensible\ capacity}$ = relative uncertainty in sensible capacity calculation;
δ_{Qa} = relative uncertainty in airflow rate measurement; and
$\delta_{\Delta T}$ = relative uncertainty in temperature differential measurement.

In the test house, for example, the relative uncertainty in airflow measurements is 5% and the absolute error in the temperature difference across the cooling coil is 0.25°C. Given that the average temperature differential across the coil is approximately 15°C, the relative uncertainty is approximately 1.7% ((0.25°C/15°C)). Adding the relative uncertainties in quadrature from Equation (8) provides an estimated relative uncertainty for sensible capacity in the test house of 5.3%.

Table 4 displays the estimated relative uncertainties for all calculated quantities in this report, using the procedure from Equation (8).

Table 4. Estimates relative uncertainty of calculated quantities

	Estimated Relative Uncertainty	
Quantity	Field Systems	Test House Systems
Fan Efficacy	5.2%	5.2%
Duct Leakage Fraction	5.8%	5.8%
Humidity Ratio	3.7%	8.2%
Sensible Capacity	5.7%	5.3%
Latent Capacity	6.2%	9.4%
Total Capacity	8.4%	11%
COP	8.5%	11%

3.7 STATISTICAL ANALYSIS

This section outlines the statistical analysis procedure for the field measurements and test house measurements separately.

3.7.1 Field Systems

Counting each field visit where a filter replacement occurred as two separate tests (one test with a 3-month-old filter followed immediately by a test with a brand new filter) and one missed visit each at Sites 11 and 12, a year of monthly tests at 17 sites resulted in 270 total visits. Approximately 43% of these visits occurred during the cooling season. The resulting dataset was analyzed to answer three specific research questions:

1. What is the impact of filtration efficiency (MERV) on airflow and parameters related to system energy use?
2. How do airflow and energy consequences relate directly to filter pressure drop?
3. What is the range of cooling energy consequences of filtration that is likely in residential and light commercial buildings?

The analysis and statistical procedures for each question are described below.

3.7.1.1 Impacts of Filtration Efficiency (MERV)

Dependent variables in this analysis that are potentially associated with energy consequences include: system airflow rate, power draw of the air handler fan, supply and return duct leakage to the exterior, fan efficacy (i.e., the volumetric flow per unit of power), power draw of the outdoor compressor unit, total capacity, sensible capacity, latent capacity, coefficient of performance, sensible heat ratio, and duct delivery efficiency. To address the impact of filter MERV on these quantities, each of these dependent variables were first averaged for each site visit then averaged again across a given filter MERV category, treating periods of repeated filter installations separately. To assess statistical variation between filter MERV categories, both a paired two-tailed t-test and a Wilcoxon signed-ranked (non-parametric) test were conducted. The tests compare the mean values of each dependent variable at each site between: (1) high- and low-MERV filters, (2) high- and mid-MERV filters, and (3) mid- and low-MERV filters. Statistical significance was assessed as $\alpha < 0.05$. Any significant findings were further explored by comparing the absolute magnitude of the differences with instrumentation uncertainty and comparing repetitions at the same site with the same MERV-category filter.

3.7.1.2 Impacts of Filter Pressure Drop

Filter pressure drop can be only weakly correlated with MERV category, particularly for used filters with increased pressure drop due to loading. To assess the impact of a change in filter pressure drop, regardless of MERV category, each dependent variable was first averaged for each visit at each site, then the change in each dependent variable was calculated and normalized to the value that was measured when a clean low-MERV filter was installed, since that condition existed at all sites but one (Site 12). A linear regression of each normalized dependent variable versus the measured filter pressure drop was performed, in which the filter pressure drop was also normalized to that measured with a clean low-MERV filter. The regression slope estimates the expected variable change due to an increase in filter pressure drop. Significance of the regression slope was determined when the 95% confidence interval did not contain zero, establishing upper and lower bound estimates on the expected variable change due to a change in filter pressure drop.

3.7.1.3 Estimation of Energy Consequences during Cooling Mode

The first two research questions attempt to isolate the effects that filters have on changes in individual energy-related parameters. In this analysis, the range of changes in actual cooling energy consumption (in kWh) due to filters was estimated according to changes measured in fan power draw, compressor power draw, and system runtime. These parameters will capture, in theory, any changes in other energy-related parameters, including duct leakage effects. This approach was taken with only low- and high-MERV filters to assess the maximum possible impact of filters in our systems. Across all sites, forty-five cooling visits occurred with low-MERV filters installed and fifty-four cooling visits occurred with high-MERV filters installed.

3.7.1.3.1 Discussion of binned analysis attempt

Indoor and outdoor conditions (i.e. outdoor temperature and the wet-bulb temperature entering the cooling coil) affect air conditioner performance and make it difficult to isolate the effects of filters. To address this, we initially attempted a process of binning the field data into

ranges of both 6 and 12 similar indoor and outdoor climatic conditions. Comparing filter efficiency categories (high vs. low, high vs. mid, and mid vs. low) and subsequently hunting for significant results yielded little correlation between the variables in the analysis and the chosen bin sizes and ranges. When split into six bins, only two variables (latent capacity and sensible capacity) revealed significant results – and only when comparing high-MERV to low-MERV and only in one bin each. Essentially, out of (6 bins × 5 variables × 3 MERV comparisons) 90 possible combinations, only two cells showed significance. Similarly, when split into twelve bins, only three of the five variables (compressor power draw, latent capacity, and sensible capacity) revealed significant results – two when comparing high-MERV to low-MERV and another when comparing a repetition and only in one bin apiece. Essentially, out of (12 bins × 5 variables × 3 MERV comparisons) 180 possible combinations, only three cells showed significance. The fundamental issue that occurs when dividing data into bins is that sample sizes in any given bin become small and especially because identical conditions have to occur with two different filter categories at the same site for a comparison to be made. This is the primary cause of the infrequent significance findings in the binned analysis. Thus, we relied on the analysis procedure in Section 3.7.1.3.

3.7.2 Test House Systems

Outdoor temperature and evaporator entering wet-bulb temperature are two conditions that are known to affect capacity, power draw, and system runtime. In real systems, thermostat settings by occupants are behavioral parameters that affect air-conditioner energy consumption as well. However, since the test house was unoccupied and programmable thermostats kept temperature set points constant throughout the test period, we were able to limit the confounding factors to climatic conditions alone. Accordingly, a binned analysis was conducted to isolate climatic effects from those possibly attributed to changes in filter MERV categories. The binned analysis compared data at 32 size ranges of similar outdoor dry bulb and indoor entering wet bulb conditions. The bins are described in Table 5.

Table 5. Description of indoor and outdoor temperature bins used in the test house analysis

Entering Wet Bulb, °F (°C)	Outdoor Dry Bulb, °F (°C)							
	73-77 (23-25)	77-81 (25-27)	81-84 (27-29)	84-88 (29-31)	88-91 (31-33)	91-95 (33-35)	95-99 (35-37)	99-102 (37-39)
63-64 (17-18)	1	2	3	4	5	6	7	8
64-66 (18-19)	9	10	11	12	13	14	15	16
66-68 (19-20)	17	18	19	20	21	22	23	24
68-70 (20-21)	25	26	27	28	29	30	31	32
	Bin Number (1-32)							

In the binned analysis, measured steady-state values are averaged across the size range of each bin for low-, medium-, and high-MERV filters. The differences between low- and high-MERV filters and between medium- and low-MERV filters are then calculated in each bin. At least 20 measured data points had to be collected in each bin with both filters installed for it to be considered a valid binned comparison. Bins were weighted equally in the analysis.

The final portion of results from the continuous measurements consists of analyzing trends in actual measured energy consumption by the two test systems. Since the thermostat set points were precisely controlled during the measurements, we investigated the actual measured change in daily energy consumption in the test systems as a function of only outdoor temperatures, as calculated in Equation (7). The analysis only compares measurements with high- and low-MERV filters installed in order to have the largest possible dataset for comparison.

4. RESULTS

4.1 FIELD SITES

This section first details the individual field sites and measurements, then summarizes the results from each of the three research questions, and finally describes individual system factors that may have influenced the results.

4.1.1 Detailed Field Site Descriptions

This section describes the test systems individually and in further detail to illustrate the types of systems included in the field tests. It also outlines any unique characteristics of individual systems that may affect their energy use.

4.1.1.1 Site 1

Figure 10 shows the air handler at Site 1 installed vertically in an interior closet, along with power and pressure taps that were used for the monthly measurements.



Figure 10. Image of the air handler at Site 1 as installed in a closet

Site 1 was the only system with a variable speed compressor. The air handler had one large return grille indoors at the base of the closet. The return plenum was wood construction and the filter was installed in the filter slot between the return plenum and the unit. Supply ductwork was located in the attic. The remaining systems with air handlers installed in a closet look similar to Site 1.

4.1.1.2 Site 2

Site 2 was installed vertically in a garage as shown in Figure 11. The system contained one large return grille on the other side of the wall in conditioned space. The return plenum was wood construction and the filter was installed at the filter slot between the return plenum and the unit. Supply ductwork was located in the attic. Although 20" by 20" (508 mm by 508 mm) filters were installed at Site 2, the actual area of airflow was considerably smaller (less than ½ of filter area).



Figure 11. Image of the air handler at Site 2 installed in a garage

4.1.1.3 Site 3

Site 3 served two floors and had filters installed at each of its three return grilles. The air handler was installed vertically in an interior closet on the second floor and two return grilles were installed in a wooden structure just below the air handler, similar to Site 1. The third return grille was located in the ceiling of the first floor. The filter pressure drop measurements reported at Site 3 are taken as the pressure difference between ambient conditions on the second floor and the return plenum side of one of the filters on the second floor. Site 3 was in the same building as Site 4 and supply ductwork was located between floors.

4.1.1.4 Site 4

Site 4 served the third floor of the same building in which Site 3 was located. The air handler was installed horizontally in the attic, located along with supply and return ductwork. Site 4 had one return grille located near the top of a tall wall with the filter installed just behind the grille. The accuracy of filter pressure measurements at Site 4 are suspect because the pressure tap was not able to be consistently and securely fastened like in the majority of the monitored systems. The filter pressure tap installed at the return grille is shown on the right in Figure 12, along with a supply register on the left.



Figure 12. Image of the return grille (on the right) and supply register (on the left) at Site 4

4.1.1.5 Site 5

Site 5 had the air handler installed horizontally in the attic, located along with supply and return ductwork. Both supply registers and the one return grille (with filter) were installed in the ceiling. The occupants of Site 5 tended to keep the thermostat at lower set points than some other residences. The filter had a tendency to become loaded more than other residences, potentially because the system ran often and it was the only building in which the owner had a pet (a longhaired Golden Retriever).

4.1.1.6 Site 6

Site 6 was essentially set up like Site 5.

4.1.1.7 Site 7

Site 7 was set up essentially like Site 1, with the air handler installed vertically in an interior closet, the filter installed between the air handler and wooden return plenum. However, Site 7 had two return grilles similar to Site 3: one installed in a hallway and one installed in a connecting bathroom (which is not allowed under most building codes, including those in Austin, TX). Supply ductwork was located between floors. Of potential interest, the average pressure drop across the coil at Site 7 was the greatest of all residential sites, suggesting the coil was fouled, potentially because of biological growth due to excess moisture from the return grille located in the bathroom.

4.1.1.8 Site 8

Site 8 was set up essentially like Site 2.

4.1.1.9 Site 9

Site 9 was located in the same office building as Site 10, but the building was split into two nearly identical but separate office spaces. The air handler was installed horizontally in the attic. Supply and return ductwork was also located in the attic with registers and grilles installed in the ceiling. Large filters (20” by 30”, 508 mm by 762 mm) were installed at the return grilles. The filter pressure drop could not be measured at Site 9 due to access reasons. Therefore, the

filter pressure drop measurements represent the difference between ambient indoor conditions and the return plenum.

4.1.1.10 Site 10

Site 10 was set up exactly like Site 9, with three exceptions: filters at Site 9 were smaller (20" by 20", 508 mm by 508 mm), pressure drop measurements were accessible across one of the filters at Site 9, and, although the two units served the same floor area, the outdoor unit was 3.5 tons (12.3 kW) compared to 5 tons (17.6 kW) at Site 9).

4.1.1.11 Site 11

Site 11 was located in a house that was converted to an art studio and classroom spaces. The air handler was installed horizontally in the partially-conditioned attic along with supply and return ductwork. Filter pressure drop was measured directly across one of the two filters (Figure 13a). Site 11 was tested as having the greatest amount of duct leakage of any of the systems in this investigation and generally had a difficult time meeting the cooling loads during the summer period.



a) **b)**

Figure 13. The two filter locations at Site 11: a) wall next to the air handler and b) ceiling

4.1.1.12 Site 12

Site 12 was a small single-story office building in a residential neighborhood that was an architecture office. The air handler was installed horizontally in the attic along with supply

ductwork. Most of the return ductwork was connected to wall cavities, which led to the three return grilles located throughout the office. Filter pressure drop measurements could not be made directly because of the distance between the air handler and the filters installed in the wall cavities; therefore, only return plenum pressure drops are reported. The owner of Site 12 preferred that high efficiency filters be installed at all times and generally kept fans running continuously when the office was occupied.

4.1.1.13 Site 13

Site 13 was located in a house that was converted into an office building and used by a non-profit organization. The unit was arranged like Site 1. Site 13 generally had the most workers occupying its space and thermostats were generally set the lowest of all the test sites in our study, which could explain some of the high filter loadings seen at Site 13.

4.1.1.14 Site 14

Site 14 was located in a house that was converted into an office building and was arranged like Site 13. The outdoor compressor unit failed during our study and was replaced with a newer unit, as noted in other sections of this report.

4.1.1.15 Site 15

Site 15 was a real-estate company located in an office building and had the oldest air handler in our study, installed vertically in a utility closet. The return plenum was made of plywood and return ductwork was made of sheet metal. Both were located within the closet as shown in Figure 14.



Figure 14. Image of the air handler, return plenum, and return ductwork at Site 15

Two filters were installed between the unit and the return plenum, but obstructions caused us to bend and shape filters in order to squeeze them into their locations, as shown in Figure 15. There was a large amount of bypass due to the piece of metal attempting to cover the blower housing which caused the air handler to remain propped open. Supply ductwork was located in an inaccessible attic.



Figure 15. Image of filters installed at Site 15

The HVAC system at Site 15 ran almost continuously during times of high outdoor temperatures and occupancy. Also, it had to be supplemented with several room air-conditioners in order to keep the space comfortable.

4.1.1.16 Site 16

Site 16 and Site 17 were located in the same office building that was used as an architecture practice. Site 16 was installed vertically in an outdoor closet and served the first floor of the office. There was no real supply or return ductwork but only plenums. The return opening was cut into the bottom of an interior wall as shown in Figure 16 (with the filter installed), and the supply opening was cut into the top of the same wall. Both openings were covered with custom metal grates. The air handlers in Sites 16 and 17 were the most efficient in our sample during fan-only mode as they contained ECM fans that operated at very low speeds during the fan-only mode, but accelerated during the cooling mode and operated at reduced efficacy.



Figure 16. Image of the return opening at Site 16

As Figure 16 shows, the filter had to be bent in order to fit into the custom opening, which created some bypass.

4.1.1.17 Site 17

Site 17 was located in the same custom office building as Site 16 and served an upstairs loft. Site 17 was installed vertically in a utility closet with a return opening cut similar to Site 16, with no return ductwork. The filter was installed at the slot between the unit and the return plenum. There was also no supply ductwork at Site 17 but the supply plenum was connected to a long slot diffuser that delivered air upwards from the long custom-built plenum along the vertical wall. Site 17 also had an ECM fan.

4.1.2 Field Measurements

Figure 17 (residential sites) and Figure 18 (light commercial sites) display the pressure drops measured across the filters, the corresponding airflow rates, and the filter MERV category installed during each field visit while operating in fan-only mode. Filter pressure drop values are averaged over the length of each fan-only operation period (typically about 15 minutes) and airflow rates are based on the supply plenum pressure measured at the beginning of each visit. Each bar represents a monthly site visit and filter changes are marked by an "X" on the x-axis. Error bars denote the larger of either the standard deviation of the measurements or the accuracy of the instrumentation. Due to limited access for sensor placement, Sites 9 and 12 report the pressure drop measured in the return plenum, and not the pressure drop directly across the filter as in the other sites.

Filter pressure drop generally increased with each month of filter life as filters were loaded over time, although a few sites (e.g., Sites 1, 3, 8, and 17) sometimes show an unexpected decrease. This decrease can be caused by several factors including uncertainty in pressure drop measurements or complex turbulent airflows and other interference around pressure taps positioned in the airstream before and after the filter. High- and mid-MERV category filters revealed generally higher filter pressure drops than low-MERV category filters, but little difference existed between high- and mid-MERV categories themselves.

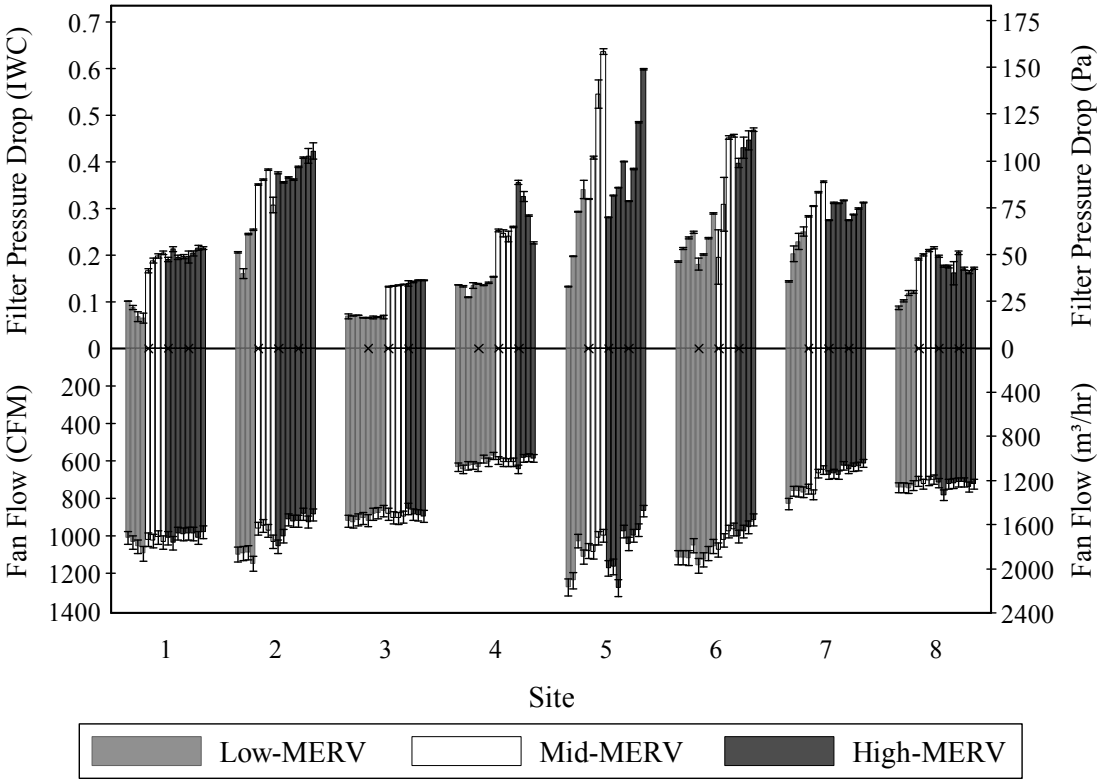


Figure 17. Filter pressure drop and system airflow in residential systems operating in fan-only mode.

The median pressure drop across low-, mid-, and high-MERV filters at all sites (excluding Sites 9 and 12) during the fan-only mode was 0.137 IWC (34 Pa), 0.213 IWC (53 Pa), and 0.221 IWC (55 Pa), respectively. In general, the field systems had very little filter bypass, suggesting that reported filter pressure drop readings are due to filter efficiency and loading conditions alone. The median airflow rate with low-, mid-, and high-MERV filters at all sites (excluding Site 12) during the fan-only mode was 939 ± 47 CFM (1595 ± 80 m^3 hr^{-1}), 988 ± 49 CFM (1679 ± 84 m^3 hr^{-1}), and 888 ± 44 CFM (1509 ± 75 m^3 hr^{-1}), respectively. The fan-only airflow rates were much lower in Sites 16 and 17 because they had ECM fans while all the others had PSC fans.

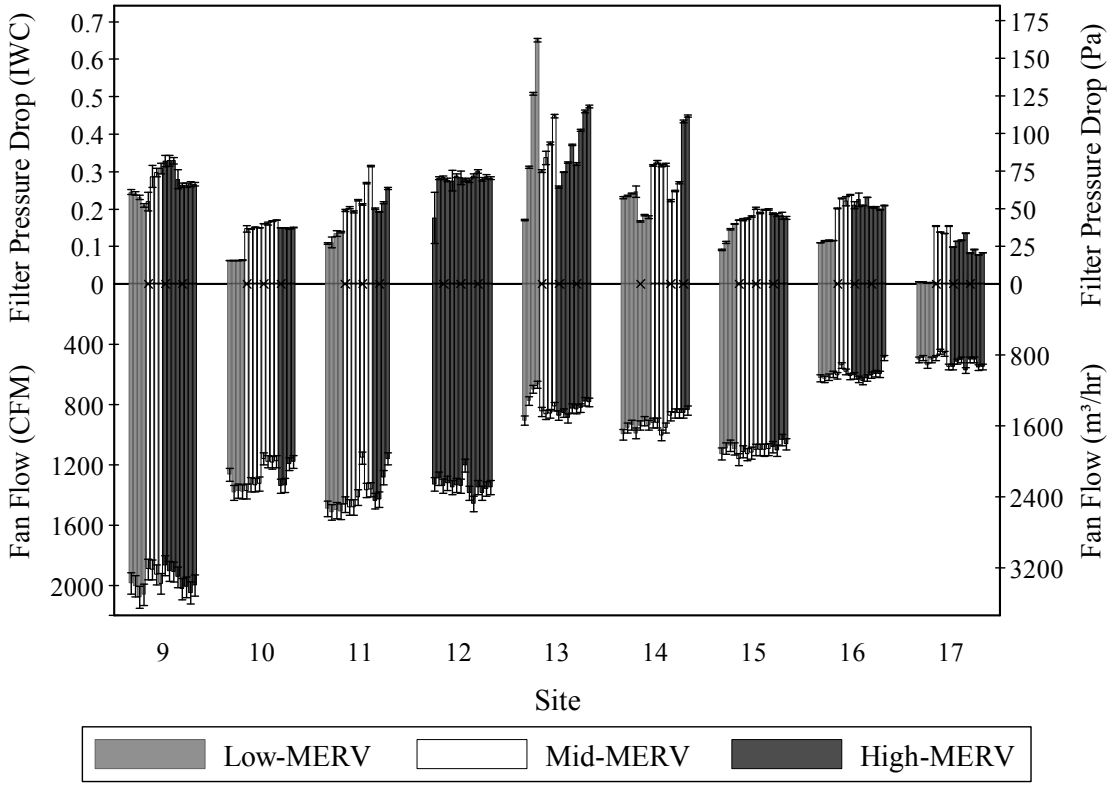


Figure 18. Filter pressure drop and system airflow in commercial systems operating in fan-only mode. Sites 9 and 12 are measuring the pressure through the entire return system, not just the filter pressure drop.

Figure 19 displays the ranges of system airflow rates, normalized by the cooling capacity of the outdoor unit (CFM/ton, $(m^3/hr)/kW$), that were measured during the fan-only mode with each of the three filter efficiency categories installed. The boxes show 25th, median, and 75th percentile measurements, the whiskers represent upper and lower adjacent values, and dots represent outlying values. Appendix D and E contain detailed tables of these measurements.

Normalized system airflow rates (in the fan-only mode) were scattered over a large range in the test systems and some fans operated at a different speed in the cooling mode. Normalized system airflow rates generally decreased as filter efficiency increased, but airflow reductions were often non-uniform with filter efficiency increases (e.g., Sites 9, 13, and 15). Some of the

scatter in airflow measurements with different filter efficiencies was larger than the median decrease (e.g., Sites 4, 5, 16, and 17).

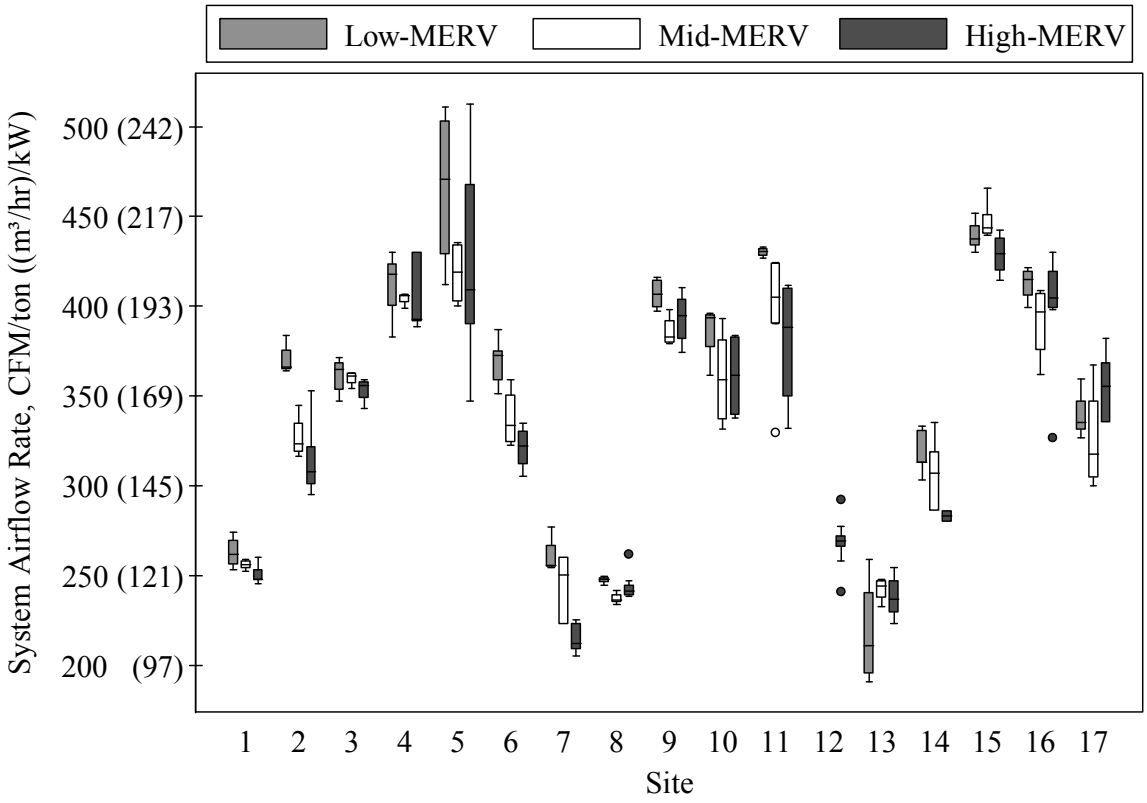


Figure 19. System airflow rates measured with low-, mid-, and high-MERV filters installed in the test systems. Airflow rates are normalized by the cooling capacity of the system, although the airflow rates presented were measured in the fan-only mode. The primary scale is in IP units (CFM/ton) and the quantities in parentheses are in SI units ($(m^3/hr)/kW$).

Figure 20 displays normalized system airflow rates measured in the cooling mode in the same manner as Figure 19. Since the systems were not always operating in the cooling mode, Figure 20 presents fewer data points recorded at fewer filter installations. It is worth noting that Sites 16 and 17 has much higher airflow rates in the cooling mode because of the ECM fan operation.

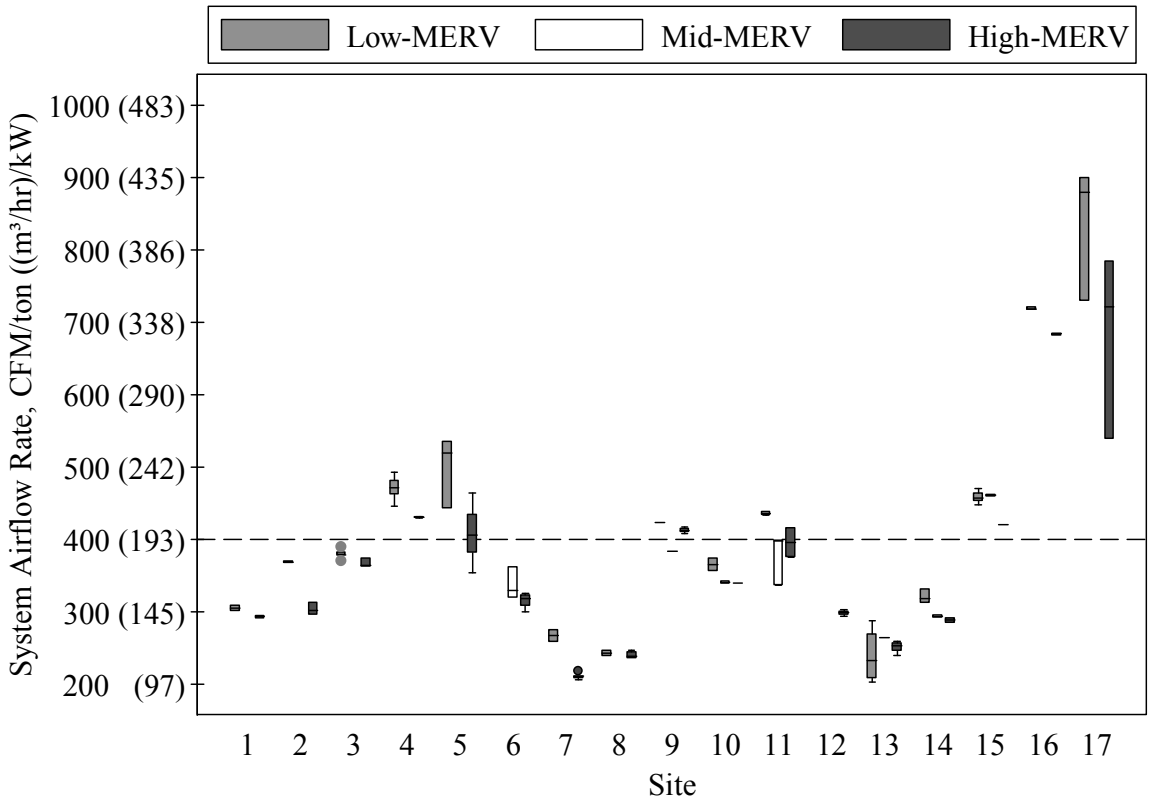


Figure 20. System airflow rates (normalized by cooling capacity) measured in the cooling mode with low-, mid-, and high-MERV filters installed in the test systems. The primary scale is in IP units (CFM/ton) and the quantities in parentheses are in SI units ((m^3/hr)/kW). The dashed line indicates recommended airflow of 400 CFM/ton (193 ((m^3/hr)/kW))

It is worth noting that many of the systems had low system airflow rates, i.e., below 400 CFM/ton (193 (m^3/hr)/kW) which is the typical manufacturers recommendation). This finding is consistent with Downey and Proctor (2002) who found that over 20% of systems had airflow rates that were too low. This finding is important for the analysis of energy consequences of filtration, as the impact of the overall low flow on energy use may be much larger than the small deviations in flow resulted from different filters.

Figure 21 displays the ranges of fan power draw measurements made during the fan-only mode with each of the three filter efficiency categories installed, similar to Figure 19.

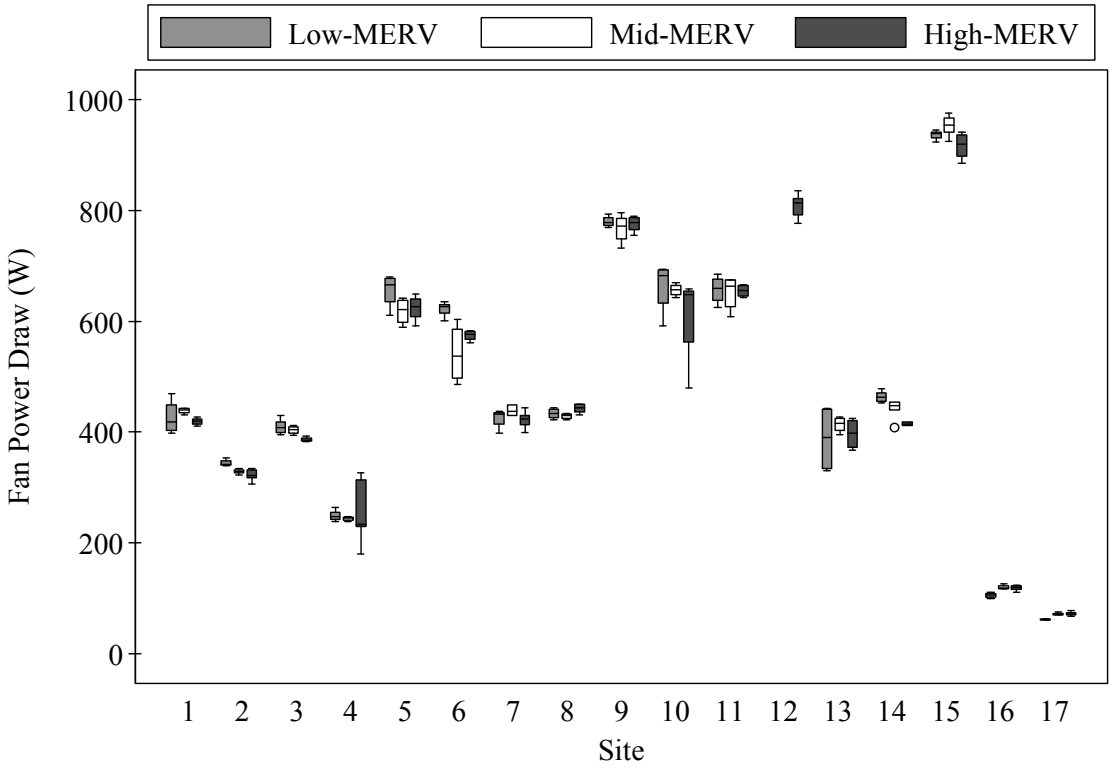


Figure 21. Fan power draw measurements of the test systems made during fan-only operation with low-, mid-, and high-MERV filters installed.

Measurements of fan power draw were scattered over a large range in the test systems due to the variety of equipment capacity and system airflow rates. Median fan power draw measurements were generally lowest with high-MERV filters installed, but the differences were often small and the ranges between filter efficiencies often overlapped. These results are generally consistent with Proctor and Parker (2000) who reported that fan power draw in residential HVAC systems ranged from 400 to 800 W. The ECM fans in Sites 16 and 17 drew the least amount of power in the fan-only mode.

The fan-only conditions shown in the previous figures existed at every site visit, but measurements were also conducted at the test sites during the cooling season. Cooling season measurements accounted for approximately 43% of the monthly visits, producing a dataset of 115 total visits in cooling mode, 55 in residential systems and 60 in light commercial systems.

Figure 22 displays an example of pressure, power, and temperature data collected during a 24-hour visit to one of field sites during normal cooling operation.

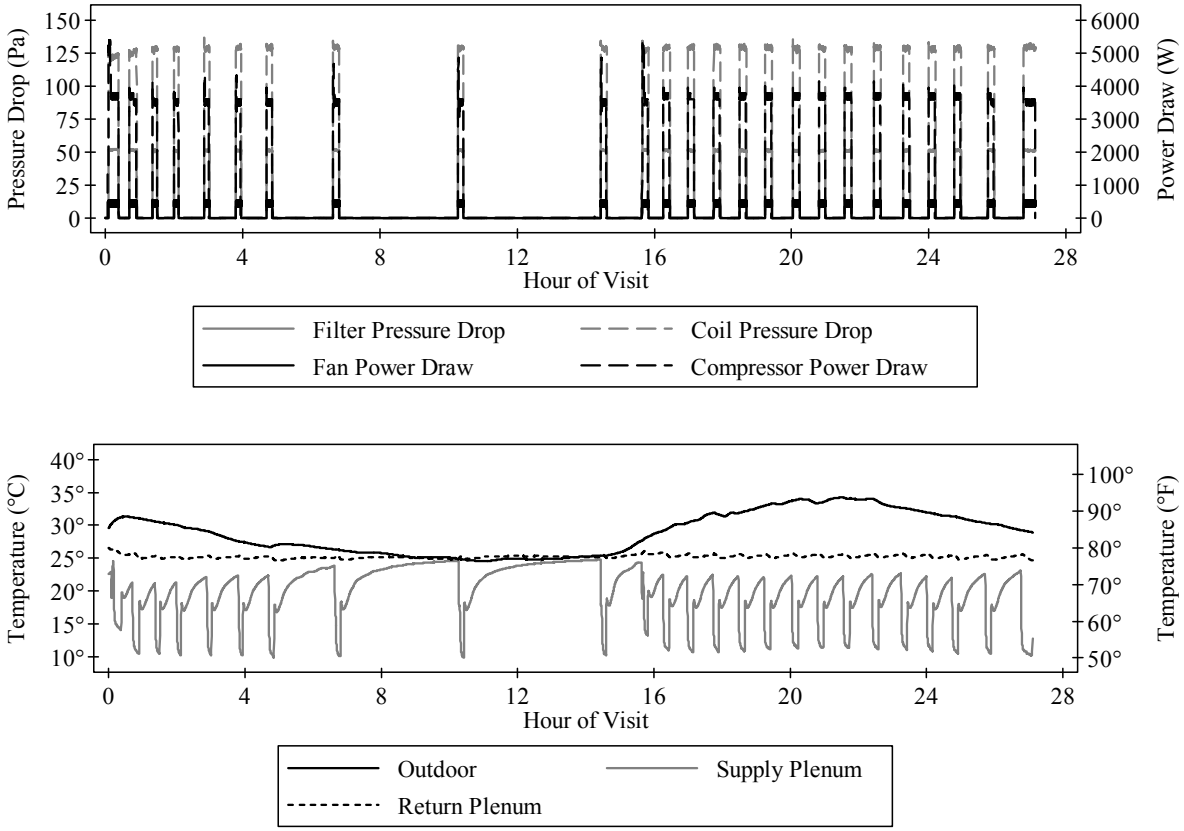


Figure 22. Example pressure, power, and temperature data from a field visit

Figure 23 displays the fan and compressor power draw of each system during the cooling season, averaged over the visits with low- and high-MERV filters installed. The amount of power draw of the fan and compressor are important parameters in characterizing system energy usage. Figure 23 also displays the average airflow rate reduction measured with high-MERV filters versus low-MERV filters during the cooling season. Each bar represents between 1 and 5 visits made with a particular MERV category installed and the error bars represent one standard deviation from the mean.

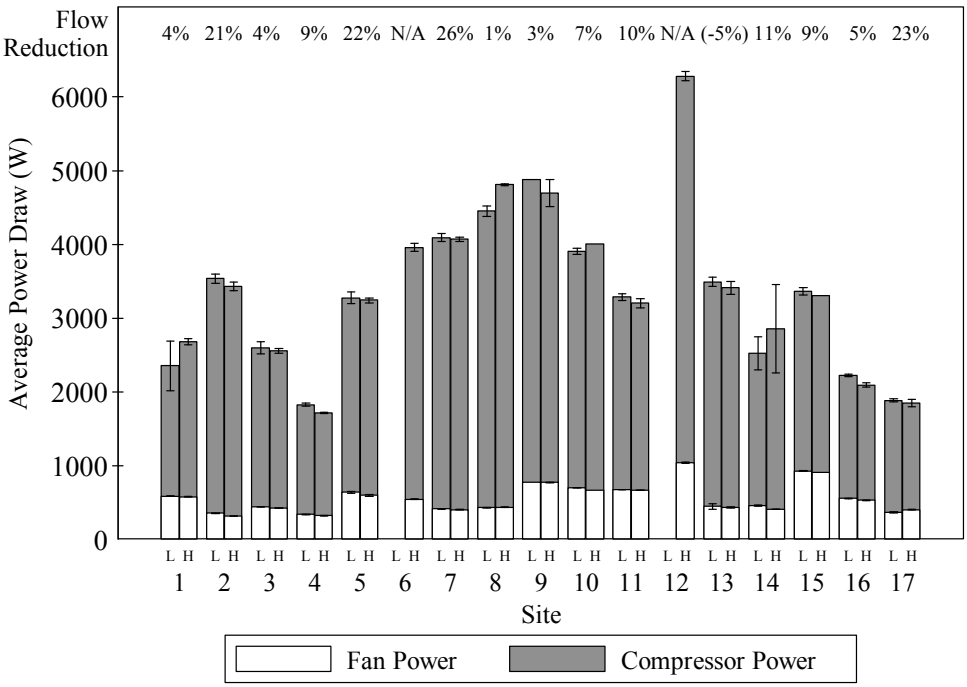


Figure 23. Average fan and compressor power draws and flow reductions during the cooling season at each site with low-MERV (L) and high-MERV (H) filters installed.

Sites 6 and 12 did not have a low-MERV filter installed during any cooling visits and Site 14 received an outdoor compressor unit replacement during this study, hence the large standard deviation in compressor power draw at that site. Average flow reductions are shown as high-MERV values relative to low-MERV values. Higher average airflow rates were measured with high-MERV filters only at Site 13. The residential and light commercial systems generally drew similar amounts of total power. On average, the power draw of the outdoor compressor unit dominated total system power draw, accounting for approximately 85% of total power draw in the residential systems and 80% in the light commercial systems. Most of this difference was because the light commercial system fans drew approximately 40% more power while having approximately 35% higher airflow rates, on average, than the residential sites. The median system had an approximately 9% lower airflow rate in the cooling mode with high-MERV filters installed versus low-MERV filters. Site 13 was the only system that had a greater airflow rate

with high-MERV filters installed, most likely because low-MERV filters were installed during a time of high system usage, and the filter eventually became loaded enough to have a greater pressure drop than any high-MERV measurement at that site (Figure 18).

In addition to compressor and fan power draw, system runtimes and cycle lengths are also important in assessing system energy consumption. The residential and light commercial systems behaved similarly in terms of system runtime. The median cycle length was approximately 8 minutes for both residential and light commercial systems. The commercial sites showed greater variation and longer runtimes overall, but the residential and light commercial systems generally behaved similarly. Approximately 25% of the recorded cycles were under 6 minutes long and had to be dropped from some of the analysis because they were shorter than the response time of the temperature and relative humidity sensors.

4.1.3 Research Question 1: What is the impact of filtration efficiency on the measured parameters?

The goal of this portion of the analysis is to compare low-MERV, mid-MERV, and high-MERV filters and specifically to investigate how filter efficiency influences parameters related to energy use in the test systems. Table 6 shows those dependent variables for which there are statistically significant differences between filter MERV categories. Table 6 also shows both a median percentage difference and a median absolute difference between each filter type, along with the number of systems, *n*, used in the statistical tests. Comparisons between mid- and high-MERV filters are not shown because the only significant difference in fan-only mode was a small change in duct leakage and there were only two or three sites to compare in cooling mode. No significant differences existed between mid- and low-MERV filters in cooling mode, likely because of the small sample size. The complete results from this analysis, including a full table with both significant and insignificant results, are provided in Appendix B.

Table 6. Impacts of Filter Efficiency on Measured Variables

		High-MERV vs. Low-MERV			Mid-MERV vs. Low-MERV		
	Dependent Variable, IP (SI)	**[%][1]**	**Absolute[1]**	**n[2]**	**[%][1]**	**Absolute[1]**	**n[2]**
Fan-Only Mode	Fan Power, W	**-1.1***	**-5***	16	-1.2	-5	16
	Filter Pressure Drop, IWC (Pa)	***+45****	***+0.096 (24)****	16	***+47****	***+0.11 (26)****	16
	Fan Flow, CFM (m^3 hr^{-1})	***-4.2****	***-59 (100)****	16	***-5.3****	***-40 (68)****	16
	Fan Efficacy, CFM W^{-1} (m^3 hr^{-1} W^{-1})	***-3.9****	***-0.08 (0.14)****	16	*-4.4*	*-0.09 (0.15)*	16
	Supply Duct Leakage Flow, CFM (m^3 hr^{-1})	-16	-8 (14)	14	***-44****	***-31 (53)****	14
	Return Duct Leakage Flow, CFM (m^3 hr^{-1})	-14	-3 (5)	13	*-44*	*-11 (19)*	13
Cooling Mode	Fan Power, W	***-4.0****	***-15****	11	+4.9	+24	2
	Filter Pressure Drop, IWC (Pa)	***+43****	***+0.13 (31)****	11	-9.6	-0.037 (9.3)	2
	Fan Flow, CFM (m^3 hr^{-1})	***-10****	***-96 (163)****	11	-0.3	-54 (92)	2
	Fan Efficacy, CFM W^{-1} (m^3 hr^{-1} W^{-1})	*-5.4*	*-0.11 (0.19)*	11	-5.5	-0.13 (0.22)	2
	Supply Duct Leakage Flow, CFM (m^3 hr^{-1})	***-14****	***-24 (41)****	9	+3.8	+5 (9)	3
	Return Duct Leakage Flow, CFM (m^3 hr^{-1})	***-19****	***-7 (12)****	8	+7.6	+11 (19)	2

[1]**Asterisk (*) and bold indicate p < 0.05 from paired t-test.** *Italics indicate p < 0.05 from Wilcoxon matched-pairs sign-rank test.*

[2]The maximum number of systems used in the filter comparison tests is 16 because one system (Site 12) required high-MERV filters be installed at all times. Three sites were excluded from supply duct leakage testing and four sites were excluded from return duct leakage testing due to scheduling conflicts with one building owner and because some ductwork was located within conditioned space, thus having no exterior leakage.

The results in Table 6 show that high-MERV filters introduced an approximately 45% greater pressure drop than low-MERV filters. High-MERV filters caused median airflow rates to decrease by approximately 4% in the fan-only period and by 10% in the cooling mode, relative to low-MERV filters. High-MERV filters decreased fan power draw by approximately 1% in the fan-only mode and 4% in the cooling mode relative to low-MERV filters. The net result of the changes in airflow and fan power is that high-MERV filters supplied approximately 4% less volumetric airflow per unit of power in the fan-only mode and 5% less in the cooling mode. Supply and return duct leakage flows both decreased in the presence of high-MERV filters, although the magnitudes of these changes are small and not always significant. The magnitude of flow reductions seen with higher-efficiency filters generally agrees with the flow reductions measured in Parker et al. (1997).

During cooling periods, median sensible capacity and compressor power draw, although not statistically significant, decreased by 10% and 2%, respectively, in systems with a high-MERV filter relative to a low-MERV filter. The magnitude of the decreases in sensible capacity and compressor power draw generally agrees with values seen in the literature with flow reductions of 10%. The reductions in fan power draw, compressor power draw, and duct leakage may reduce the increase in energy consumption expected with a decline in cooling capacity, although the measured reductions approach the bounds of instrument uncertainty, especially in fan-only mode.

All of the variables related to the operation of the air conditioner, including cooling capacity and compressor power draw, did not show any statistically significant differences between filters and thus are not reported in Table 3. One limitation of this analysis is that the cooling mode tests do not take into account climatic and behavioral conditions. Outdoor temperature and evaporator entering wet-bulb temperature are two climatic conditions that are known to affect capacity, power draw, and system runtime. Thermostat settings by occupants are behavioral parameters that affect air-conditioner energy consumption as well. Since these conditions were not controlled in the field tests, a binned analysis was conducted to attempt to isolate their effects from those possibly attributed to changes in filter MERV categories. The binned analysis compared data at similar outdoor dry bulb and indoor entering wet bulb conditions. The comparisons revealed no significant relationships, although this was likely due to the fact that there were very few possible comparisons of two different filters at the same site with the same outdoor and indoor conditions. Climatic and behavioral conditions were not a factor for the measurements at the test house and are discussed in detail in Section 4.2.

We have some confidence that neither a significant relationship nor a bias exists in the cooling mode data. This is due to the fact that filter type was only weakly correlated with outdoor temperatures. The median outdoor dry-bulb and evaporator entering wet-bulb temperatures at which systems with low-MERV filters operated was approximately 2.5°F (1.4°C) and 0.9°F (0.5°C) greater, respectively, than those recorded with high-MERV filters.

Also, a nonparametric extension of the Wilcoxon rank-sum test reveals that there appears to be no statistical trend in outdoor temperatures across MERV categories. This suggests that low-MERV filters and high-MERV filters were installed during similar outdoor temperature conditions. The same test, however, does reveal a slight, but significant, apparent trend in evaporator entering wet bulb temperatures across MERV categories. This indicates a possible bias regarding thermostat settings and that low-MERV filters were installed during periods of higher thermostat settings or higher indoor wet-bulb temperatures, although the magnitude of the difference is small.

The same binning approach that was used on the test house data (see Table 5 and associated description in the Methodology) was also attempted on individual field site data with high- and low-MERV filters. However, only seven systems had the steady-state measurements made during any of the bins of indoor and outdoor conditions. The maximum number of comparable bins was always less than 10 per site with a minimum number of one. The binned analysis of these few systems reveals a large amount of scatter in the field data, as the percentage differences of several variables measured with high-MERV filters versus low-MERV filters vary in magnitude and even in sign from site to site. The standard deviations across the small number of bins are also generally larger than the average percentage differences themselves.

Repeated tests at the same site with the same MERV filter did not have a statistically different filter pressure drop, but did reveal some statistically significant differences in fan-only mode parameters. Median fan power decreased 3% and median airflow decreased approximately 5% within filter MERV repetitions. Supply- and return- duct leakage flows both increased 26%. These values are all similar to the magnitude of the effects shown in Table 3, thus the impacts of filter efficiency on energy-related parameters were generally small enough to be in the noise caused by variations of filters samples, installation, and other factors. This suggests that the actual energy implications of filter MERV may be small as well.

4.1.4 Research Question 2: How does filter pressure drop relate directly to the measured parameters?

The goal of this portion of the analysis is to normalize the pressure drop across filters in each system, regardless of MERV category, and see how pressure drop influences parameters related to energy consumption. The analysis ignores Sites 9 and 12 because only the return plenum pressure drops were measured in the field (not the true filter pressure drops) and ignores Site 17 because measured filter pressure drops with low-MERV filters were often lower than instrument uncertainty. The normalization approach for each dependent and independent variable 1) subtracts the average variable measured with a clean low-MERV filter from the average variable measured at any monthly visit and 2) divides the average variable by the average variable measured with a clean low-MERV filter.

Table 7 summarizes significant results and shows the slope of the regression for all statistically significant changes in dependent variables, with upper and lower bounds according to a 95% confidence interval, and the number of data points (i.e., monthly site visits), *n*, used in the regression. A slope is taken to be significant ($\alpha < 0.05$) if the 95% confidence interval does not contain zero. A negative value in Table 7 means that the variable decreased as filter pressure drop increased and a positive value means that the variable increased. The larger the absolute value of the slope, the stronger the relationship. Note that there are generally 2-3 times the number of data points (i.e., site visits) used in the fan-only operation regressions compared to the cooling operation. Thus, the fan-only regressions are more representative of the entire sample than the cooling operation regressions. The complete results from this analysis, including a full table with both significant and insignificant results and plots of each regression, are provided in Appendix C.

Table 7. Impacts of Filter Pressure Drop on Measured Variables

	Normalized Dependent Variable, Compared to Clean Low-MERV Filter	Regression Slope ± 95% CI (%)[1]	n
Fan-only Mode	Fan Power	-1.8 ± 1.1	218
	Coil Pressure Drop	+15 ± 7.9	197
	Fan Flow	-6.7 ± 0.9	218
	Fan Efficacy	-4.6 ± 1.1	218
	Supply Duct Leakage Flow	-23 ± 3.6	169
	Return Duct Leakage Flow	-23 ± 3.4	201
	Supply Duct Leakage Fraction	+0.3 ± 0.1	170
	Return Duct Leakage Fraction	+0.2 ± 0.1	170
Cooling Mode	Fan Power	-4.7 ± 0.8	91
	Fan Flow	-8.6 ± 1.4	83
	Fan Efficacy	-4.3 ± 1.3	83
	Supply Duct Leakage Flow	-12 ± 1.9	77
	Return Duct Leakage Flow	-13 ± 2.1	70
	Supply Duct Leakage Fraction	+0.5 ± 0.1	77
	Return Duct Leakage Fraction	+0.2 ± 0.1	77
	Latent Capacity	-16 ± 8.9	73

[1]The regression slope refers to the change in dependent variable associated with a doubling of filter pressure drop.

According to the regressions, a doubling of the filter pressure drop (due either to loading or replacement with a higher-efficiency filter) would likely result in a 6-8% decrease in system airflow during fan-only operation and 7-10% during cooling operation. Other significant differences in both fan-only and cooling operation due to an increase in filter pressure drop include fan power, fan efficacy, duct leakage flows, and duct leakage fractions. These differences generally agree with the results based on filter efficiency described in Table 6. A doubling of filter pressure drop would likely result in a 1-3% decrease in fan power draw during fan-only periods and a 4-6% decrease in fan power draw during cooling modes. This suggests a potential energy benefit when switching from low to a higher-pressure drop filter. As filter pressure drop doubles, both supply- and return-side leakage airflow rates in the fan-only mode measured statistically significant decreases of 19-27% and 10-15% in the cooling mode, suggesting further potential energy benefits of higher-efficiency filters. However, since system airflow rates also diminished, the magnitude of changes in duct leakage fractions, which are the

important parameters for duct efficiency in ASHRAE Standard 152-2004, is less than 1%. Coil pressure drop increased 6-23% when filter pressure drop was with a doubled. However, we have limited confidence in the reliability of our coil pressure measurements as stable coil pressure readings were seldom achieved (this issue is commonly acknowledged by HVAC manufacturers). Finally, latent capacity, contrary to predictions in the background section of this report, decreased 7-25% in the field systems with a double of filter pressure drop. Much of this decrease can be attributed to decreases in system airflow (see Equation (4)).

The significant decrease in latent capacity could also be attributed to indoor and outdoor temperatures and sensible and latent cooling loads, as climatic conditions are not considered in this analysis. No significant changes in sensible capacity, total capacity, or outdoor compressor power draw were detected. This could be also attributed to climatic conditions. However, similar to the filter efficiency analysis, measured filter pressure drop is very weakly correlated with outdoor temperature and entering wet bulb temperature (correlation coefficients = -0.11 and -0.10, respectively), suggesting a minimal bias between filter installations and climatic conditions. Relative filter pressure drop, as compared to that measured with a clean-low MERV filter, is also weakly correlated with outdoor temperature (correlation coefficient = -0.16). However, relative filter pressure drop is more strongly correlated with indoor wet bulb temperature (correlation coefficient = -0.28), suggesting that the significant decrease in latent capacity measured with higher-pressure drop filters could be biased towards measurements made with lower indoor wet bulb temperatures and lower latent cooling loads.

4.1.5 Research Question 3: What is the likely range of energy consequences of filtration?

The goal of this analysis is to explore any possible connections between filter MERV category and energy consumption in the test systems. In theory, the decline in system airflow and therefore sensible capacity caused by high-efficiency filters would cause a system to run longer and consume more energy. At the same time, fan and compressor power draw may

decline to minimize additional energy consumed because of lengthened operation time. Although a significant reduction in system airflow occurred between low- and high-MERV filters in the test systems, identifying a statistical difference in cycle lengths due to filters proved difficult. Many statistical tests are not valid because unequal amounts of tests in the cooling season were conducted at different sites at different conditions, leading to a lack of independent comparisons. Thus, this analysis relies only on a summary approach of the cycle lengths and power draw measurements made in the test systems, first on a site-by-site basis and second on an overall statistical basis.

The median length for all cycles recorded at all sites (excluding Sites 6, 12, and 14) was 7.3 minutes with a low-MERV filter installed and 8.3 minutes with a high-MERV filter installed. However, cycle lengths were distributed over a wide range due in part to the variety of equipment, system sizing relative to load, and occupant behavior that produced a large scattering in the field data. Comparing only individual sites, median cycle lengths were longer with a high-MERV filter in six of the fourteen applicable sites, longer with a low-MERV filter in seven sites and approximately equal in one site.

Another useful comparison of cycle lengths is the measure of duty cycle, or the hours per day that the cooling system is running. Table 8 displays the average duty cycle measured at each site with low- and high-MERV filters installed, combined with the total power draw ($W_{fan} + W_{ou}$) at steady state operation, normalized by nominal cooling capacity to weight differently sized systems equally. Fundamentally, the measures of total power draw and system runtime will capture any energy consequences of changes in airflow, capacity, or duct leakage due to high-efficiency filters. Also, Table 8 shows the average change in energy consumption during one day of cooling operation, calculated as high-MERV values minus low-MERV values at each site. The observed change in daily energy consumption (kWh ton^{-1} day^{-1}, kWh kW^{-1} day^{-1}) is calculated from the average duty cycle and normalized power draw values for each MERV filter (Table 8), with high-MERV values minus low-MERV values. This means that a negative value represents energy savings with high-MERV filters installed.

Table 8. Impacts of Filter MERV on Duty Cycle and Power Draw

Site[1]	Duty Cycle, hours day^{-1}			Normalized Total Power, W ton^{-1} (W kW^{-1})			Change in Daily Energy Consumption[3]
	Low-MERV	High-MERV	Change[2]	Low-MERV	High-MERV	Change[2]	kWh ton^{-1} day^{-1} (kWh kW^{-1} day^{-1})
1	3.65	5.13	+1.49	550 (156)	671 (191)	+120 (+34)	+1.4 (+0.41)
2	3.25	2.31	-0.94	1180 (337)	1140 (325)	-40 (-11)	-1.2 (-0.34)
3	3.11	2.30	-0.82	1060 (301)	1010 (288)	-50 (-13)	-0.97 (-0.27)
4	5.77	7.14	+1.37	1210 (343)	1160 (330)	-50 (-13)	+1.3 (+0.38)
5	6.14	12.0	+5.90	1330 (379)	1280 (364)	-50 (-16)	+7.2 (+2.1)
7	3.41	6.21	+2.80	1360 (387)	1350 (385)	-10 (-2)	+3.8 (+1.1)
8	7.69	8.19	+0.50	1480 (421)	1600 (456)	+120 (+35)	+1.7 (+0.50)
9	5.71	5.27	-0.44	963 (274)	949 (270)	-14 (-4)	-0.50 (-0.14)
10	3.51	4.37	+0.86	1110 (315)	1150 (328)	+40 (+13)	+1.2 (+0.33)
11	10.3	10.7	+0.36	935 (266)	900 (256)	-35 (-10)	-0.03 (-0.01)
13	14.3	8.65	-5.62	956 (272)	953 (271)	-3 (-1)	-5.4 (-1.5)
15	11.2	4.01	-7.17	1370 (389)	1320 (376)	-50 (-13)	-10 (-2.8)
16	5.22	3.21	-2.02	1480 (420)	1400 (398)	-80 (-22)	-3.2 (-0.92)
17	6.98	1.80	-5.17	1250 (356)	1250 (355)	0 (0)	-6.5 (-1.8)
Mean	6.44	5.81	-0.63	1160 (330)	1150 (328)	-10 (-2)	-0.80 (-0.23)
Median	5.74	5.20	-0.04	1190 (340)	1160 (329)	-24 (-7)	-0.26 (-0.07)
Std. Dev.	3.40	3.19	3.48	255 (72.5)	241 (68.6)	62 (18)	4.4 (1.3)

[1]Sites 6, 12, and 14 are excluded from this analysis.
[2]Change is calculated as high-MERV values minus low-MERV values.
[3]Daily energy consumption for each filter MERV is calculated as the average daily duty cycle multiplied by the normalized total power draw.

Excluding Sites 6, 12, and 14, duty cycle lengths were longer with high-MERV filters in seven sites and shorter in seven sites. The median difference in duty cycles due to high-MERV filters was -0.04 hours, or under three minutes in a 24-hour day. Median normalized total power draw was approximately 24 W ton^{-1} (7 W kW^{-1}) lower with high-MERV filters relative to low-MERV filters. Although it is important to note that both mean and median daily energy consumption decreased slightly in the presence of high-MERV filters, the extreme values and the very large standard deviations in Table 8 reflect considerable scatter due to other dominating factors (i.e., climate and occupant behavior) that is not uncommon for field measurements.

The differences in duty cycle were greatest at Sites 5, 13, 15, and 17. Long cycle lengths with high-MERV filters were dominated by occupant thermostat settings, as the minimum return

air temperature was approximately 4°F (2.2°C) lower than that measured with low-MERV filters. Longer cycle lengths occurred at Site 13 with low-MERV filters primarily because both outdoor temperatures were greater and thermostat settings were lower. Site 15 was an old system that ran a large portion of the workday and was also affected by both outdoor temperatures and thermostat settings. Site 17 was affected primarily by greater outdoor temperatures recorded with low-MERV filters installed.

The differences in normalized total power draw were greatest at Sites 1, 8, and 16. Site 1 had a variable speed compressor that adjusted to an average outdoor temperature that was 2.7°F (1.5°C) higher with high-MERV filters installed. Maximum outdoor temperatures reached 97°F (36°C) at Site 8 during some cycles with high-MERV filters compared to 91°F (33°C) with low-MERV filters, causing the compressor to draw more power. Similarly, the average outdoor temperature at Site 16 was 91.4°F (33°C) with low-MERV filters installed compared to 81.5°F (27.5°C) with high-MERV filters installed.

The median change in daily energy consumption at the test sites was a decrease of 0.26 kWh ton^{-1} day^{-1} (0.07 kWh kW^{-1} day^{-1}) with high-MERV filters installed, suggesting potential small energy savings associated with higher-efficiency filters. However, the large standard deviation suggests that filters had a small impact on these systems in comparison with other factors. Similar to differences in duty cycle lengths and total power draw, the extreme values in Table 8 are explained by differences in outdoor temperature and thermostat settings in the field data. An example of this is that five of seven residential systems showed an increase in energy consumption with high-MERV filters (positive values in Table 8) and five of seven light commercial systems showed a decrease in energy consumption (negative values in Table 8). Given the scatter in the data, it is difficult to make a firm assessment. It may be that differences in the indoor conditions and the operation of these two types of buildings are important factors that govern the sign and magnitude of the energy implications of filters. In particular, the longer duty cycles and the greater fraction of operation during the day when outdoor temperature was higher may have contributed to this finding.

Given the complexity of interacting effects, we have limited confidence in the reliability of directly associating changes in energy consumption with filters efficiency in the field data, especially given the small magnitude of these effects and the large amount of scatter in the overall dataset. Instead, we defined a statistical matrix (Table 9) to estimate the range of possible energy consequences of high and low efficiency filtration using the distributions of total power draw and system runtime in Equation (6), extrapolated to a hypothetical month during the cooling season. Table 9 was constructed from the values in Table 8 that compares the differences of normalized total power draw and duty cycle fractions measured between high- and low-MERV filters at the 14 test sites with available data.

The top row in the matrix is from the distribution of the variable that compares the difference in normalized total power draw with high- and low-MERV filters at each site. The left-hand column in the matrix is from the distribution that compares the duty cycle between the two filter categories at each site. The cell values in Table 9 are the values from the power draw distribution multiplied by values from the duty cycle distribution, then multiplied by the number of hours in a 30-day month (720 hours), with low-MERV values subtracted from high-MERV values. The result is an estimate of the likely change in energy consumption during one month of cooling operation in the test systems, normalized by nominal cooling capacity. Table 9 is intended to provide data over the entire range of conceivable energy consequences of filters according to our test systems but does not reflect actual measured changes in energy consumption.

Table 9. Expected Change in Monthly Energy Consumption (Comparing High-MERV to Low-MERV filters)

ΔkWh per Ton (ΔkWh per kW) of Capacity per Month of Cooling[1]						
		Change in Duty Cycle				
Change in Normalized Filter Impact on Total Power Draw, W ton^{-1} (W kW^{-1})		5th percentile	25th percentile	50th percentile	75th percentile	95th percentile
		-7.2 hr d^{-1}	-2.0 hr d^{-1}	-0.04 hr d^{-1}	1.4 hr d^{-1}	5.9 hr d^{-1}
5th percentile	-78 (-22)	-330 (-93)	-97 (-28)	-32 (-9.0)	+44 (+13)	+230 (+66)
25th percentile	-45 (-13)	-270 (-75)	-77 (-22)	-23 (-6.6)	+40 (+11)	+200 (+56)
50th percentile	-24 (-7)	-210 (-59)	-60 (-17)	-16 (-4.6)	+34 (+10)	+160 (+45)
75th percentile	-2.9 (-1)	-210 (-59)	-58 (-17)	-13 (-3.7)	+39 (+11)	+170 (+48)
95th percentile	+120 (+35)	-300 (-86)	-78 (-22)	+0.2 (+0.1)	+88 (+25)	+310 (+87)

[1]Changes in power draw, duty cycle, and energy consumption due to filters are calculated as the value measured with a high-MERV filter installed minus that measured with a low-MERV filter installed.

Table 9, in accordance with Table 8, reveals that the median system from systems similar to those in our study would draw 24 W per ton (7 W per kW) less power and have a shorter duty cycle of approximately 0.04 hours per day. Projecting the values to a hypothetical 30-day month, the median system would likely consume approximately 16 kWh per ton (4.6 kWh per kW) less electricity with a high-MERV filter than with a low-MERV filter during a month of cooling operation, suggesting that the energy implications of filter selection are minor. Given the results described above for the other research questions and the large variations, this small savings is not likely to be statistically significant. Table 9 does suggest that in the absolute extremes, higher-efficiency filters can have large energy impacts, although that impact is slightly biased towards saving energy (using less energy with a higher-pressure drop filter) rather than using more energy.

The range of likely effects on energy consumption is large for both filter efficiency categories, which suggests the changes are affected mostly by other climatic and behavioral factors. The bottom quartile of systems ran less often during the cooling season with a high-MERV filter and higher-efficiency filters had decreased energy consumption. The top quartile of systems ran more often during the cooling season with high-MERV filters and higher-efficiency filters appear to have increased energy consumption. However, this is not a site-by-site analysis and the sites that experienced changes in power draw were not the same sites that observed

changes in duty cycle lengths. Table 9 represents only the range of potential energy consequences using the statistical distributions of power draw and duty cycles in the measured field data.

Given the results in Table 9, the systems at the extreme ends of both variables merit exploration. As previously mentioned, the sites in Table 8 that showed the largest difference of duty cycles between filters were affected most by varied occupant thermostat settings and somewhat by varied outdoor temperatures. The sites in Table 8 that showed the largest difference in total power draw between filters were dominated by compressor power draw values measured at different outdoor temperatures (e.g., Sites 5 and 7 had high-MERV filters installed at higher average outdoor temperatures and Sites 13-17 had high-MERV filters installed during times of lower average outdoor temperatures). Nevertheless, a decrease in energy consumption at the median values suggests that higher-efficiency filters, on average, had a small and likely energy-saving effect for these systems.

It is important to describe the major limitations of this investigation. The magnitude of energy consequences of filters seen herein was generally small, but the analysis does not capture the effects of filtration on other potentially important parameters like refrigerant charge or extremely low airflow rates. For example, if a poorly maintained system has low refrigerant charge or is already operating at very low airflow rates with low-efficiency filters, the additional, albeit small, decrease in airflow rate introduced by a higher-efficiency filter could be large enough to have more serious performance effects like ice formation on the evaporator coil.

The sample size of this investigation was limited, but given the cost of field measurements and the fact that some significant findings were found, the sample size appears reasonable. The sample was never intended to be representative of all small systems in the U.S., but the system characteristics generally concur with those found by others (i.e., Parker et al., 1997; Downey and Proctor, 2002). The test systems also varied widely in age, size, efficiency, and operational characteristics. Thermostats were controlled by the building occupants and the test sites were only visited once per month. Although this introduced confounding factors, such

as uncontrolled climatic conditions and thermostat operation, it also provides a more realistic assessment of the factors that really affect energy use associated with filters.

This study also focused on cooling system performance. This decision was made because it avoids combustion efficiency issues for non-electric heating and because flow has never been shown to affect heating capacity with the exception of heat pumps (Krafthefter and Bonne, 1986), which represent a small proportion of U.S. heating systems (there were none in our sample). Despite these limitations, the field portion of the investigation clearly suggests a weak and often counterintuitive association between filter efficiency or filter pressure drop and air-conditioner energy consumption in small residential and light commercial systems.

4.1.6 Examples of Important Factors for Specific Sites

Given the scatter in many findings in the field study, the purpose of this section is to explore factors that may have contributed to positive or negative energy consequences of filtration at each site. Specific factors that are analyzed include the importance of the filter relative to the overall system pressure drop, the size of the air-conditioner relative to the load, the importance of the air handler fan to overall energy consumption, the evidence of existing issues with the air-conditioning system that may serve to minimize the consequences of filtration (i.e., low refrigerant charge, low airflow, constricted ducts, duct leakage, etc.), as well climatic and operational variables.

4.1.6.1 Site 1

Table 8 indicates that Site 1 had a small increase (1.44 kWh ton^{-1} day^{-1} or 0.41 kWh kW^{-1} day^{-1}) in daily air-conditioning energy use when going from low-MERV to high-MERV filters). Site 1 is also the only site in the study that had a two-speed compressor. Much of the increase in energy use can likely be explained by the fact that during the 2nd visit with the low-MERV filter, the system largely stayed in the lower compressor speed, which draws less then half as much power as the higher speed and operates at a considerably higher-efficiency (IP Table 58 and SI

Table 144). This raises interesting issues when assessing the energy use of filters because the higher-MERV filter really did contribute to higher energy use, but the specific details of the conditions at each visit become very important. It is likely that a slightly different operation strategy or a slightly warmer outdoor temperature during that specific visit would have caused the compressor to run for longer at the higher speed during that one visit and minimized any differences between the filters.

In terms of the importance of the filter pressure drop, the filter represented approximately one-quarter of the total return-side pressure drop at this site with the low-MERV filter installed and a half of the return-side pressure drop with the high-MERV installed (IP Table 93 and SI Table 179). Table 41 and Table 127 indicate that the fan power draw was about 20-25% of the total system power draw at this site (and even higher when the compressor was operating at the lower stage). This was higher than the approximate average of 15% (Figure 23) suggesting that fan effects were likely large. The fact that the fan drew less power with the higher-MERV filter further emphasizes the likely importance of changes in the compressor power draw to the energy consequences. Also, this site had 73-77% of the manufacturers recommended flow of 400 CFM/ton with both filters which indicates that the lack of energy savings at this site may be due to the fact that the system had too little flow, no matter what filter was installed. This highlights the importance of general system maintenance and operation characteristics that have little to do with the filter.

4.1.6.2 Site 2

Table 8 indicates that Site 2 had a small decrease in daily air-conditioning energy use (1.21 kWh ton^{-1} day^{-1} or 0.34 kWh kW^{-1} day^{-1}) when going from low-MERV to high-MERV filters. Site 2 had an interesting filter installation in which the area of the filter that was exposed to airflow was much smaller than the filter itself (see Section 4.1.1.2). Given this restriction in airflow, the filter rack was the dominant pressure drop in the return side of the system and so the entire filter installation represented approximately 80-93% of the return-side pressure drop, depending on the pressure drop of the installed filter (IP Table 94 and SI Table 180). This raises

a site-specific question: would the small energy savings with a higher-MERV filter persist if a proper filter rack were installed that allowed all of the airflow to go through the filter? In this system, the fan was relatively efficient (approximately 50% more efficient than the fan in Site 1, for example) and the fan was approximately 10% of the total cooling system power draw. Therefore, the systemic effects were again important (IP Table 42 and SI Table 128). This raises further questions about the savings because it was, on average, cooler outside when the high-MERV filter was installed at this site (IP Table 59 and SI Table 145), which suggests caution when ascribing energy-savings to the installation of a higher-MERV filter. One final issue with this site was that it had among the shortest duty cycles, particularly when the higher-MERV filter was installed (Table 8). This was caused by the fact that the owners of this system chose to operate it infrequently relative to the other systems in the study and this likely had a big influence on the energy consumption of this system.

4.1.6.3 Site 3

Table 8 indicates that similar to Site 2, Site 3 had a small decrease in daily air-conditioning energy use (0.97 kWh ton^{-1} day^{-1} or 0.27 kWh kW^{-1} day^{-1}) when going from low-MERV to high-MERV filters. Also similar to Site 2, the duty cycle was very small for this site, highlighting again the importance of system operation and relative size to any energy savings. The filters represented almost the entire return-side pressure drop in this system and therefore should be important (IP Table 95 and SI Table 181). Having said that, the outside temperature was, on average, a few degrees higher with the low-MERV filters (IP Table 60 and SI Table 146), which may contribute to the savings at this site. This system had over 90% of the manufacturer recommended airflow with both filters installed indicating that low airflow probably did not overwhelm any energy consequences of filters in this system.

4.1.6.4 Site 4

Table 8 indicates that similar to Site 1, Site 4 had a small increase in daily air-conditioning energy use (1.33 kWh ton^{-1} day^{-1} or 0.38 kWh kW^{-1} day^{-1}) when going from low-

MERV to high-MERV filters. If we exclude a suspicious filter pressure drop measurement during the first visit at this site, the filter represented 56-57% of the system pressure drop with high-MERV filters and 39-48% with the low-MERV filters (IP Table 96 and SI Table 182). This 1.5 ton (5.3 kW) system was among the smallest in the study and hence the fan consumed a larger than average fraction of the total system power draw. This system also had high airflow, as much as 20% more then the recommended airflow with low-MERV filters (IP Table 96 and SI Table 182). The benefit of low-MERV filters at this site seems to be driven entirely by a very high sensible capacity during one visit (IP Table 61 and SI Table 147).

4.1.6.5 Site 5

Table 8 indicates that Site 5 had a large increase in daily air-conditioner energy consumption with high-MERV filters compared to low-MERV filters (7.20 kWh ton^{-1} day^{-1} or 2.05 kWh kW^{-1} day^{-1}). On average, system airflow rates were 15% lower (IP Table 45 and SI Table 131) and cycle lengths were 65% longer (IP Table 62 and SI Table 148) with high-MERV filters relative to low-MERV filters. However, high-MERV filters were also installed during periods of higher outdoor temperatures (IP Table 62 and SI Table 148), which could drive the measured energy savings associated with low-MERV filters at this location. The filter pressure drop represented 24-51% of system pressure drop with low-MERV filters and 44-71% with high-MERV filters (IP Table 97 and SI Table 183). Airflow rates were 11-34% greater than that recommended by the manufacturer with low-MERV filters and ranged from 12% lower to 16% higher with high-MERV filters (IP Table 97 and SI Table 183).

4.1.6.6 Site 6

Site 6 offered no comparison between low-MERV and high-MERV filters as low-MERV filters were never installed during the cooling season. Site 6 behaved similarly with both mid- and high-MERV filters installed during periods of similar outdoor temperatures.

4.1.6.7 Site 7

Table 8 indicates that Site 7 consumed more energy with high-MERV filters installed than with low-MERV filters installed (3.77 kWh ton^{-1} day^{-1} or 1.07 kWh kW^{-1} day^{-1}). System airflow decreased 17%, on average, with high-MERV filters installed relative to low-MERV filters (IP Table 47 and SI Table 133). This decrease sent airflow rates from already low values with low-MERV filters of 65-69% of that recommended by manufacturers to 51-55% of recommended rates (IP Table 99 and SI Table 185). Extremely low airflow could have led to the 25% longer average cycle lengths measured with high-MERV filters; however, the increased cycle lengths and energy consumption can at least partially be due to higher outdoor temperatures (IP Table 64 and SI Table 150).

4.1.6.8 Site 8

Table 8 indicates that Site 8 had a small increase in daily air-conditioner energy consumption with high-MERV filters installed compared to low-MERV filters (1.76 kWh ton^{-1} day^{-1} or 0.50 kWh kW^{-1} day^{-1}). However, none of the filter installations caused airflow rates to vary more than 7%. Therefore, the changes in energy consumption are not likely due to changes in filter behavior (IP Table 48 and SI Table 134) but in greater outdoor temperatures with high-MERV filters installed (IP Table 65 and SI Table 151). The filter represented 62-81% of total return-side pressure drop and system airflow rates were consistently low (59-62% of recommended rates) regardless of filter (IP Table 100 and SI Table 186).

4.1.6.9 Site 9

Table 8 indicates that Site 9 had a very small decrease in daily energy consumption measured with high-MERV filters installed relative to low-MERV filters (0.50 kWh ton^{-1} day^{-1} or 0.14 kWh kW^{-1} day^{-1}). System airflow rates were, on average, only 4% lower with high-MERV filters installed, which is within instrument uncertainty (IP Table 49 and SI Table 135). Thus, the savings due to high-MERV filters are most likely associated with lower outdoor

temperatures (IP Table 66 and SI Table 152). System airflow rates were consistently within 96-106% of recommended rates (IP Table 101 and SI Table 187).

4.1.6.10 Site 10

Table 8 indicates that Site 10 had a small increase in daily air-conditioner energy consumption (1.15 kWh ton^{-1} day^{-1} or 0.33 kWh kW^{-1} day^{-1}) with high-MERV filters installed relative to low-MERV filters as system airflow rates decreased 7%, on average (IP Table 50 and SI Table 136). However, the small energy savings with low-MERV filters installed is likely due to slightly lower outdoor temperatures (IP Table 67 and SI Table 153). The same tables show that Site 10 behaved similarly between Visit 2 (low-MERV) and Visit 11 (high-MERV) at similar test conditions. The small effect of filters at Site 10 could be caused by the small fraction of total return-side pressure drop that the filter represents (15-33% in IP Table 102 and SI Table 188). System airflow rates were always within 85-89% of that recommended by most manufacturers.

4.1.6.11 Site 11

Table 8 indicates essentially no change in energy consumption between low- and high-MERV filters (-0.03 kWh ton^{-1} day^{-1} or -0.01 kWh kW^{-1} day^{-1}) at Site 11, although average airflow rates decreased 12% with high-MERV filters. However, the negligible difference could also be due to lower average outdoor temperatures while high-MERV filters were installed (IP Table 68 and SI Table 154). Site 11 had such a large fraction of supply duct leakage (approximately 34% according to IP Table 86 and SI Table 172) that, even though air handler flow rates were consistently 84-110% of recommended rates (IP Table 103 and SI Table 189), filters may have had little impact on duct leakage-compromised air-conditioner performance.

4.1.6.12 Site 12

Site 12 offered no insight between different filter efficiencies since high-MERV filters were required at all times. The pressure drop across high efficiency filters did not vary drastically (IP Table 35 and SI Table 121) and neither did airflow rates (IP Table 52 and SI Table

138). System airflow rates were consistently low, from 73 to 76% of that recommended by manufacturers.

4.1.6.13 Site 13

Table 8 indicates that Site 13 benefited from high-MERV filters with energy savings of 5.39 kWh ton^{-1} day^{-1} (1.53 kWh kW^{-1} day^{-1}) relative to low-MERV filters. Site 13 was unique in that, on multiple monthly visits, low-MERV filters were loaded to a greater pressure drop than seen with any mid- or high-MERV filter installations (IP Table 36 and SI Table 122). This caused average airflow rates to actually be 9% lower with low-MERV filters installed (IP Table 53 and SI Table 139). The energy savings of high-MERV filters at Site 13 can also be attributed to lower average outdoor temperatures relative to low-MERV installations (IP Table 70 and SI Table 156). Filter pressure drop was, however, likely to affect air-conditioner performance because the filter represented all of the return-side pressure drop. Site 13 had very low airflow that varied between 51-72% of that recommended by manufacturers (IP Table 105 and SI Table 191).

4.1.6.14 Site 14

The outdoor unit at Site 14 failed and was replaced during the test period which, in conjunction with filter installation schedules and climate, provided that Site 14 did not offer a valid comparison between high and low efficiency filters. On average, high-MERV filters decreased system airflow approximately 10% relative to low-MERV filters.

4.1.6.15 Site 15

Table 8 indicates that high-MERV filters introduced large savings in daily energy consumption (-10.0 kWh ton^{-1} day^{-1} or -2.84 kWh kW^{-1} day^{-1}) at Site 15 relative to low-MERV filters. This was the largest difference in our study. Although the pressure drop directly across the filters changed with filter efficiency, Site 15 had a large amount of bypass that prevented airflow rates from changing dramatically. High-MERV filters decreased average airflow rates by 3% relative to low-MERV filters and mid-MERV filters were within 1% of low-MERV filters

(both within instrument uncertainty, IP Table 55 and SI Table 141). Thus, the energy savings of high-MERV filters must be related to outdoor conditions or occupant thermostat settings. As previously mentioned, Site 15 ran often at high temperature without meeting the cooling load and often requiring the use of window air-conditioner units. IP Table 72 and SI Table 158 indicate that low-MERV filters were indeed installed at higher average outdoor temperatures (with a greater standard deviation as well). With a low-MERV filter installed at Visit 9, Site 15 only ran 3 long cycles during the day (average 2.5 hour cycle length). At lower temperatures during Visit 7 with high-MERV filters installed, the unit ran approximately 5 cycles per day (with an average cycle length of 47 minutes).

4.1.6.16 Site 16

Table 8 indicates that high-MERV filters led to energy savings of 3.22 kWh ton^{-1} day^{-1} (0.92 kWh kW^{-1} day^{-1}) at Site 16. The ECM fans in Site 16 responded (in the cooling mode) to high-MERV filters by reducing airflow rates by 5% relative to low-MERV filters and drawing 5% less fan power (IP Table 56 and SI Table 142). The fans operated at a much higher speed during the cooling mode relative to the fan-only mode; airflow nearly doubled and fan power draw increased by a factor of 4-5, indicating that ECM motors function better at part-load conditions. The energy savings of high-MERV filters at Site 16 can be attributed somewhat to fan power reductions because the efficient outdoor compressor unit meant that fan power draw represented approximately one-third of total power draw. Lower outdoor temperatures, however, most likely played a greater role in the savings associated with high-MERV filters (IP Table 73 and SI Table 159).

4.1.6.17 Site 17

Table 8 indicates that high-MERV filters resulted in large daily energy savings of 6.48 kWh ton^{-1} day^{-1} (1.48 kWh kW^{-1} day^{-1}) relative to low-MERV filters. However, the equipment at Site 17 was the same as Site 16 and they were housed in the same building, so the same climatic effects apply. In addition, Site 17 served an upstairs loft of the building where the

majority of the occupants worked so it is reasonable that the same savings seen in Site 16 are more pronounced at Site 17.

4.1.7 Detailed Cooling Energy Consumption Examples

Given the importance of climatic conditions to air conditioner performance, this section attempts to detail the efforts to quantify the cycle lengths and energy consumption of one residential and one light commercial system with corrections for climatic conditions (analysis procedures that could not be applied to the entire sample due to data scarcity).

4.1.7.1 Residential Example: Site 5

Figure 24 displays the recorded cycle lengths versus the average outdoor temperature measured during individual cycles during some monthly visits with high- and low-MERV filters installed at Site 5. There are generally small differences between cycle lengths recorded with high- and low-MERV filters, but some measurements at higher temperature ranges suggest the system operated for longer periods with high-MERV filters than low-MERV filters at the same outdoor temperatures.

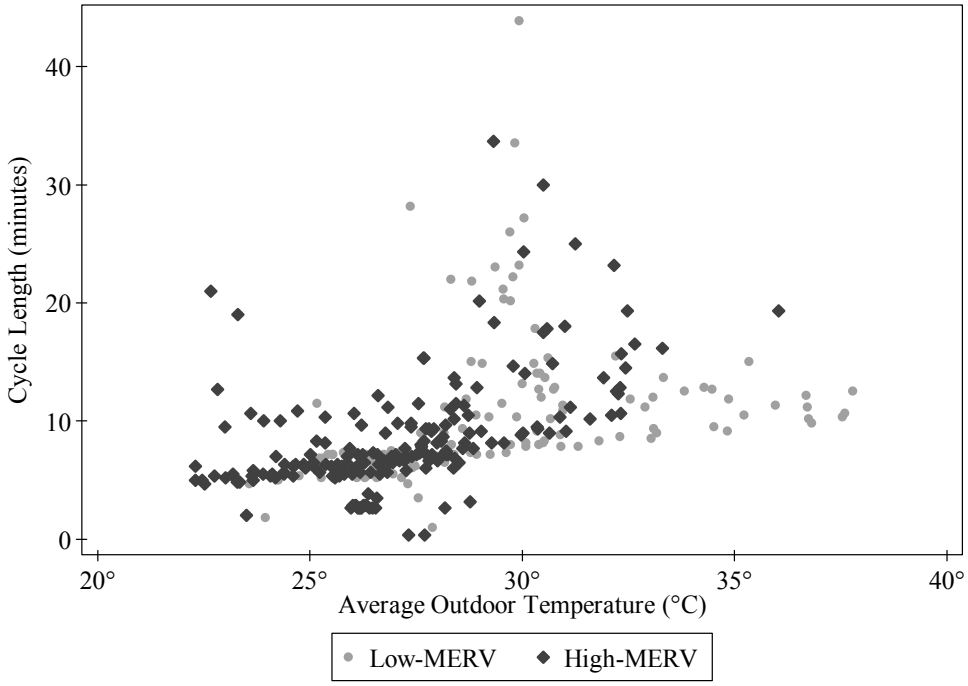


Figure 24. Cycle lengths versus average outdoor temperature during each cycle recorded with low- and high-MERV filters installed at Site 5.

Figure 24 does not account for thermostat settings, which can potentially explain some longer cycle lengths with different filters recorded at the same outdoor conditions. Exploring the same system in a different way to attempt to account for thermostat settings, Figure 25 displays individually recorded cycle lengths plotted versus the difference between the indoor temperature at the beginning and end of each cycle.

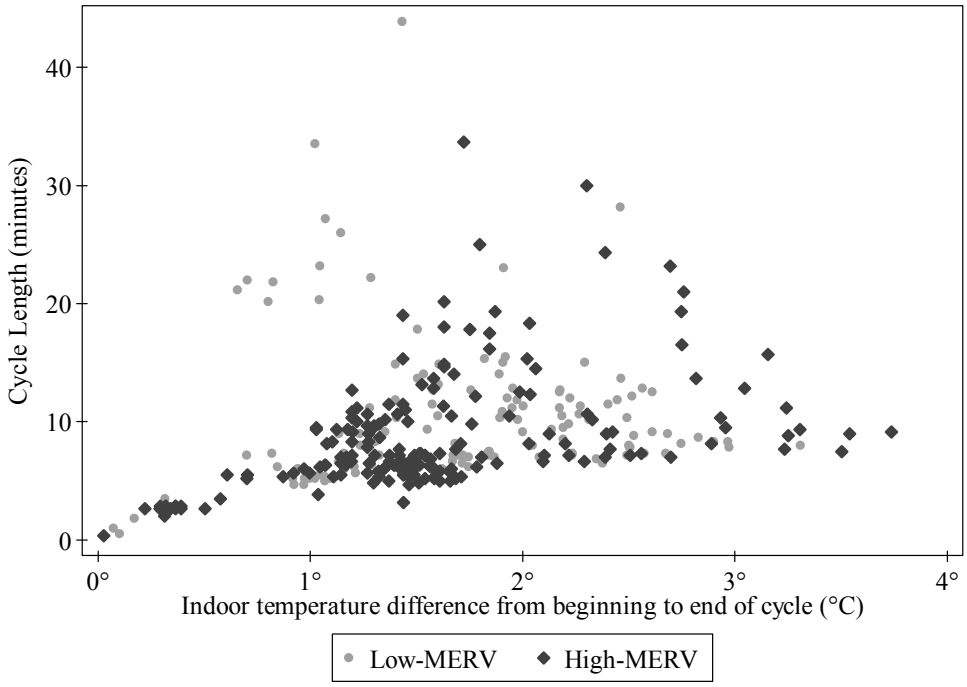


Figure 25. Cycle lengths versus the temperature difference between the beginning and end of each cycle recorded with low- and high-MERV filters installed at Site 5.

The HVAC system at Site 5 operated long enough to lower the indoor temperature 0-4 °C for all of the cycles pictured in Figure 25 while the majority of those cycles lowered the indoor temperature 1-2 °C. There is a large amount of scatter in these measurements suggesting that other factors influence energy consumption much more than filter selection.

4.1.7.2 Light Commercial Example: Site 13

Figure 26 displays recorded cycle lengths versus average outdoor temperature measured with high- and low-MERV filters installed in one light commercial system, Site 13.

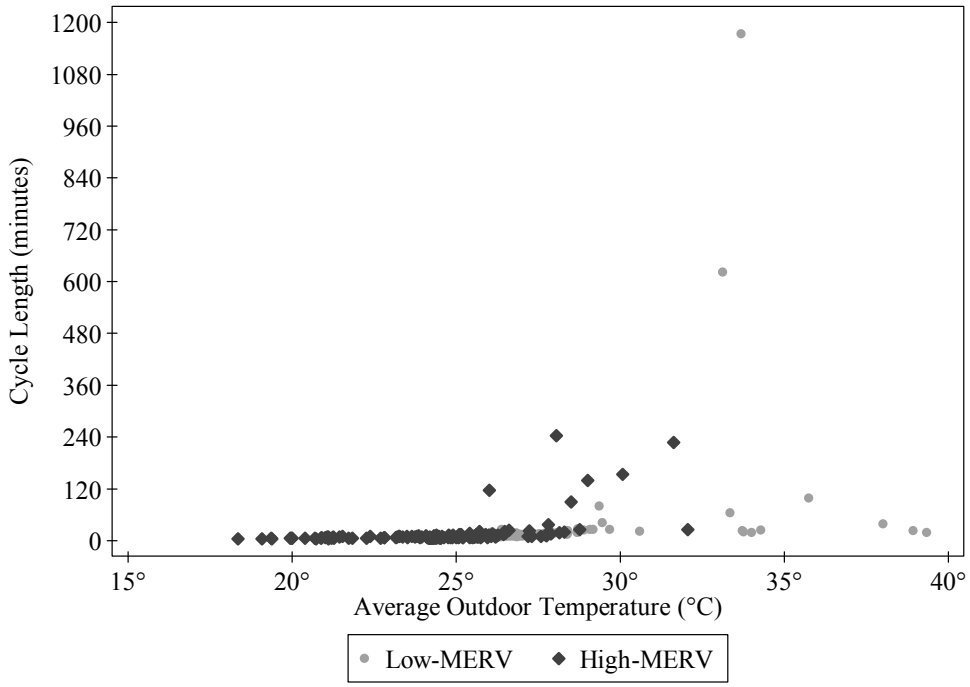


Figure 26. Cycle lengths versus average outdoor temperature for each cycle recorded at Site 13.

The magnitude of scatter is larger than the previous residential example as the longest recorded cycles lasted almost 20 hours and several others lasted longer than 2 hours. To explore the majority of these data further, Figure 27 isolates only cycles less than one hour in length measured at average outdoor temperatures greater than 20°C.

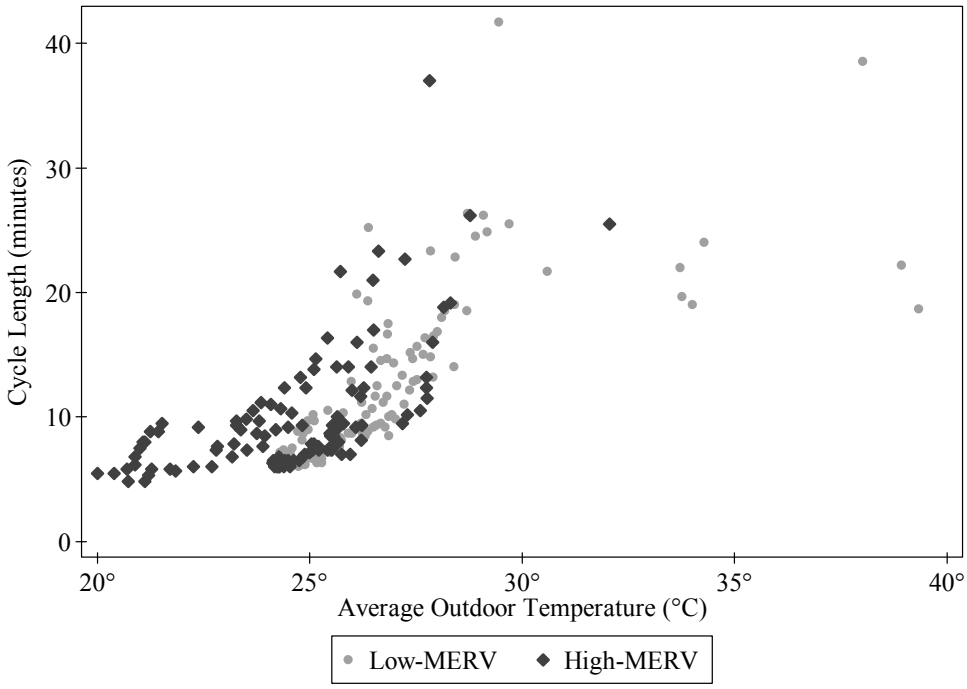


Figure 27. Cycle lengths versus average outdoor temperature for cycles less than one hour and outdoor temperatures greater than 20°C.

High-MERV filters were generally installed during periods of lower outdoor temperatures at this particular site. However, for similar outdoor temperatures (approximately 24-29°C), high-MERV filters do not appear to be associated with greater energy consumption. Similar to the residential site example, this analysis does not consider other factors such as thermostat settings. To explore the effects of thermostat settings on Site 13, Figure 28 displays individually recorded cycle lengths plotted versus the difference between the average outdoor temperature and the average indoor temperature recorded during the cycles in Figure 27.

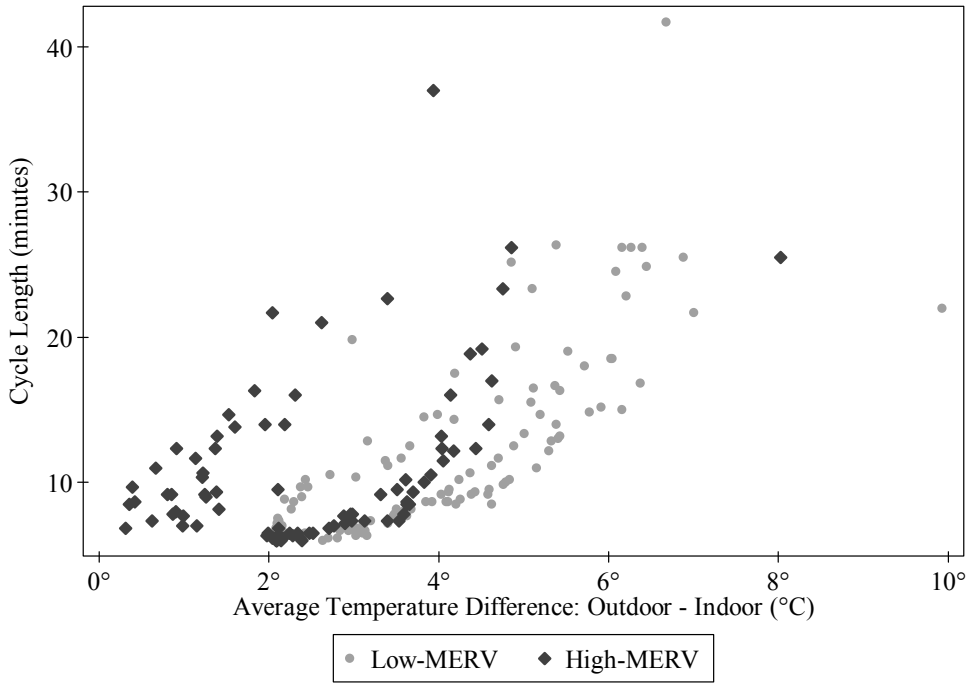


Figure 28. Cycle lengths versus average temperature difference between inside and outside measured at Site 13 with high- and low-MERV filters installed (with some outliers omitted).

The average difference between indoor and outdoor temperatures was generally smaller with high-MERV filters installed, but cycle lengths generally overlapped at similar temperature differences of approximately 2-5°C. Again, other factors than filter efficiency seem to dominate energy consumption in Site 13.

4.2 TEST HOUSE MEASUREMENTS

The following section details the results from the test system fan curve experiments and the results from the continuous operation monitoring periods.

4.2.1 Test House Fan Curves

Figure 29 displays the results from the fan curve determination test procedure for the two systems in the test house. The curves in Figure 29 present measured fan curves in the same manner as Figure 3 in the background section of this report. The results in Figure 29 show that the fan in the upflow test system appears to behave somewhat similarly to the hypothetical fan in Figure 3a and the fan in the downflow system behaved similarly to the fan in Figure 3b. However, the pressure, flow, and power relationships show more scatter in the actual measurements than in the hypothetical case. The results in Figure 29a and Figure 29b show that an increase in filter efficiency and pressure drop could cause fan power to either increase or decrease in both test house systems, depending upon the working points during actual system operation.

For example, as long as a filter does not cause the operating airflow rate to increase or decrease beyond approximately 880-970 CFM (1500-1650 m^3/hr) in the upflow system (Figure 29a), fan power draw will remain constant. In this system, both extremely high and low airflow rates will cause the fan to draw more power. However, if a higher-efficiency filter decreases the airflow rate, for example, approximately 15% from 1030 CFM to 880 CFM (1750 m^3/hr to 1500 m^3/hr) in the downflow system (Figure 29b), the fan will draw approximately 10% more power.

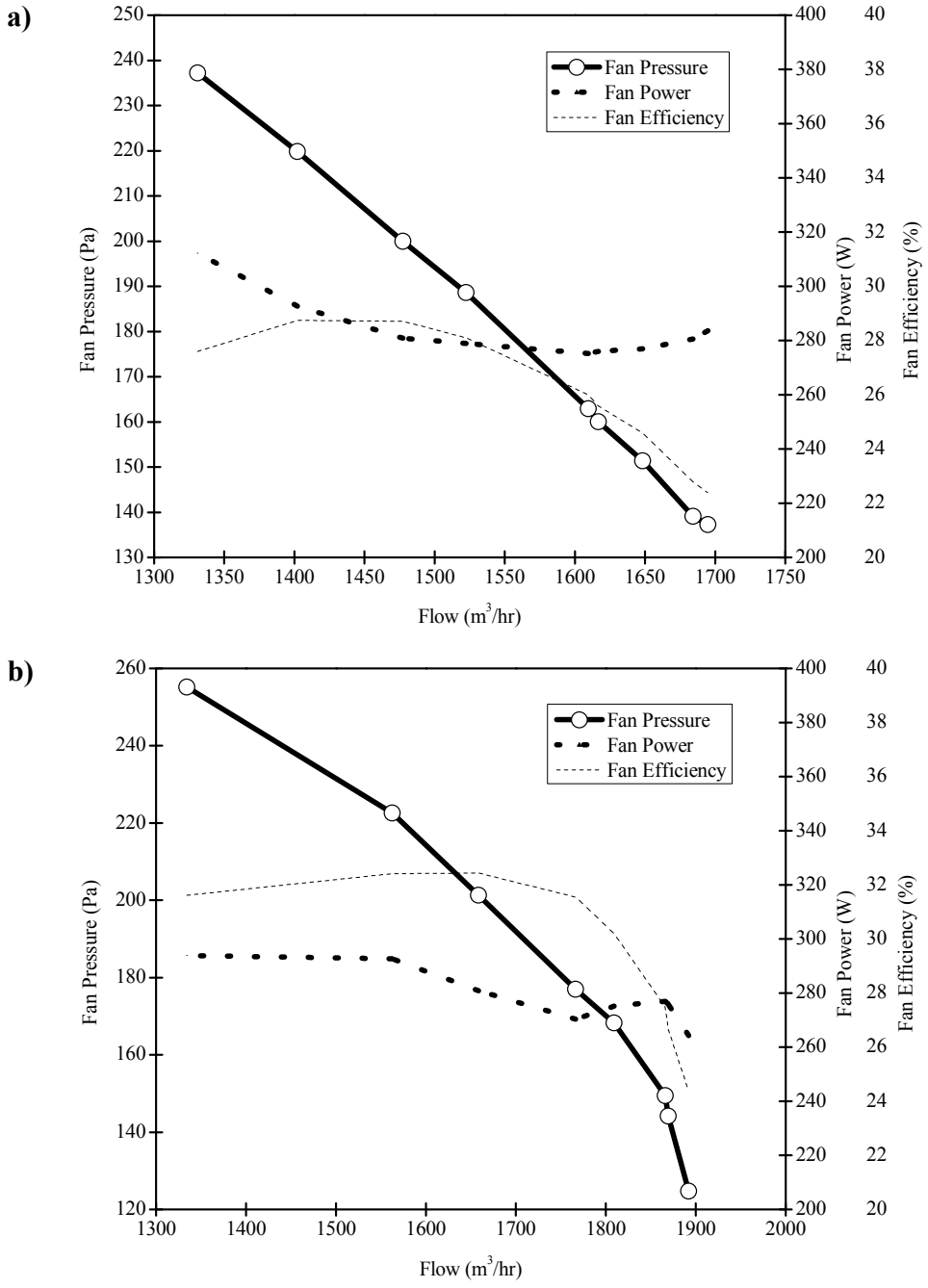


Figure 29. Fan curves for a) the upflow and b) the downflow test systems

4.2.2 Continuous Measurements

The following section describes the results of measurements made during the cooling operation periods with low, medium, and high efficiency filters. Both systems operated at the

same fan speed in cooling and fan-only modes. The next section makes a binned comparison between the values measured with high-MERV filters and low-MERV filters and between values measured with mid-MERV and low-MERV filters. Finally, the last section summarizes the daily energy consumption measured with high- and low-MERV filters installed in the test house.

The results from the continuous cooling operation periods are summarized in Table 10 and Table 11, and detailed tables of measurements are included in Appendices F and G. The measured values represent averages taken during steady-state operation, covering the entire life of a filter installation. The errors represent the larger of the standard deviation or instrument uncertainty in the measurements. Table 10 displays measurements related to the filter and air-handling units, while Table 11 describes the performance of the air-conditioning systems recorded regardless of the effects of indoor and outdoor temperature.

Table 10. Filter and flow measurements of the test systems

System	Filter Efficiency	Filter Life [days]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]	Total Fan Pressure [Pa]	System Airflow Rate [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]
Upflow	Low	52	25.8 ± 0.3	57.9 ± 1.3	163 ± 2.2	1660 ± 80	277 ± 3	6.0 ± 0.4
	Medium	11	47.1 ± 0.8	56.5 ± 1.2	179 ± 3.0	1610 ± 80	281 ± 3	5.7 ± 0.4
	High	51	78.7 ± 0.8	48.2 ± 1.2	196 ± 1.4	1550 ± 80	284 ± 3	5.5 ± 0.4
Downflow	Low	52	16.0 ± 2.4	74.8 ± 0.7	145 ± 2.6	1720 ± 90	264 ± 3	6.5 ± 0.5
	Medium	11	45.6 ± 0.6	69.8 ± 1.0	161 ± 3.5	1580 ± 80	267 ± 3	5.9 ± 0.4
	High	51	85.8 ± 0.9	59.0 ± 0.8	188 ± 1.6	1530 ± 80	273 ± 3	5.6 ± 0.4

Low-MERV and high-MERV filters were installed for approximately the same amount of time (50+ days) while mid-MERV filters were installed for a considerably shorter amount of time (11 days), as seen in Table 10. This schedule of filter installations was maintained to capture the effects of more extreme changes in filter efficiency. Filter pressure drops did not increase more than 5 Pa during any filter lifespan, suggesting that minimal dust loading occurred in the unoccupied test house. The pressure drops across mid-MERV filters were approximately 1.9 and 2.9 times larger than that across low-MERV filters in the upflow and downflow units,

respectively, while the pressure drops across high-MERV filters were approximately 3 and 5.5 times larger than that across low-MERV filters.

Airflow rates measured with high-MERV filters installed in the upflow and downflow system were 7% and 11% lower, respectively, than that with low-MERV filters installed. The decrease in airflow rates with higher-efficiency filters was greater than the 4-5% increase measured by Parker et al. (1997). Airflow rates measured with medium efficiency filters were approximately 3% and 8% lower than that with low efficiency filters installed in the upflow and downflow systems, respectively.

The AHU fans generally behaved in accordance with Figure 29, showing the lowest power draw with low-MERV filters and the highest power draw with high-MERV filters. As filter efficiency increased, fan efficacy (i.e., the amount of volumetric airflow moved by a unit of power) decreased. The pressure rise measured across the fans increased approximately 20% and 30% with high-MERV filters compared to low-MERV filters in the upflow and downflow systems, respectively. If fan efficiencies remained constant, a 20% increase in fan pressure and a 7% decrease in airflow would result in a 12% increase in fan power draw in the upflow system. Similarly, a 30% increase in fan pressure and an 11% decrease in airflow would result in a 16% increase in fan power draw in the downflow system. However, fan efficiencies vary with fan pressure and airflow as seen in Figure 29, so the decreases in airflow and increases in fan pressure combined to increase fan power draw by approximately 3% in both systems with high-MERV filers installed.

Table 11. Performance measurements during cooling operation of the test systems

System	Filter Efficiency	Outdoor Temp. (SD) [°C]	Return Air Wet Bulb Temperature (SD) [°C]	Outdoor Unit Power Draw [W]	Sensible Capacity (SD) [W]	Latent Capacity (SD) [W]	Total Capacity (SD) [W]	System Efficiency (SD) [-]
Upflow	Low	32.6 (4.4)	18.6 (0.6)	1402 ± 16	5250 (320)	1280 (200)	6530 (380)	4.0 (0.9)
	Medium	32.3 (4.4)	18.2 (0.5)	1397 ± 16	5260 (260)	1280 (180)	6540 (310)	4.0 (0.8)
	High	29.8 (4.0)	17.3 (1.0)	1280 ± 14	5680 (610)	980 (290)	6660 (670)	4.4 (1.0)
Downflow	Low	33.1 (4.1)	19.7 (0.6)	1853 ± 21	4450 (310)	1190 (200)	5640 (370)	2.7 (0.6)
	Medium	33.2 (3.9)	19.4 (0.6)	1860 ± 21	4210 (310)	1120 (190)	5330 (360)	2.5 (0.4)
	High	30.4 (3.5)	18.4 (1.1)	1749 ± 20	4780 (490)	1020 (220)	5800 (540)	2.9 (0.8)

[1]The results in Table 5 do not control for climatic conditions.

Although the outdoor compressor-condenser units were the same size, Table 11 shows that the downflow unit drew approximately 33% more power than the upflow unit, most likely because of the presence of the heat pump and potentially because of different refrigerant charge levels. Sensible capacity increased approximately 4-5% with high-MERV filters while latent capacity actually decreased approximately 15-25%, which is counterintuitive to our theoretical considerations. However, these values are most likely explained by the fact that high-MERV filters were installed during periods of approximately 2-3°C lower outdoor temperatures and 1.3°C lower entering wet bulb temperatures, on average, than low-MERV filters, suggesting these values are affected by the combination of both climatic conditions and filters. The combined effects of temperature, filter, and airflow changes also caused a 6-9% decrease in outdoor unit power draw, a 2-3% increase in sensible capacity, and a 7-10% increase in overall efficiency (COP) with high-MERV filters compared to low-MERV filters. However, these effects are most likely biased because of climatic conditions and the binned analysis, described later, isolates the effects of climatic conditions.

Table 12 describes duct leakage measurements made with the different filters installed in the two test systems. Since there were no return ducts in either system, there is no return-side duct leakage and the reported leakage values are for the supply-side only.

Table 12. Duct leakage measurements for the test systems

System	Filter Efficiency	System Airflow Rate [m^3/hr]	Supply Leakage to Exterior [m^3/hr]	Supply Leakage Fraction[1] [%]
Upflow	Low	1660 ± 80	37 ± 2	2.2 ± 6%
	Medium	1610 ± 80	36 ± 2	2.2 ± 6%
	High	1550 ± 80	34 ± 2	2.2 ± 6%
Downflow	Low	1720 ± 90	197 ± 6	11.4 ± 6%
	Medium	1580 ± 80	183 ± 6	11.6 ± 6%
	High	1530 ± 80	178 ± 5	11.6 ± 6%

The downflow system had more supply-side duct leakage than the upflow system. The upflow system was very tight with less than 3% of system airflow lost by duct leakage. The downflow system lost approximately 12% of supply airflow by duct leakage. Although the magnitude of supply-side duct leakage airflow generally decreased as filter efficiency increased and airflow rates decreased, the fraction of duct leakage to system airflow did not change.

Figure 30 displays pressure distribution diagrams for the two test systems, averaged with high- and low-MERV filters installed. Filters were located at the return side of the AHU, but because there are no return ducts, this pressure distribution diagram is not directly comparable to the system represented in Figure 4 in the background section. The test systems thus cannot offer insight into return duct leakage changes likely due to filters.

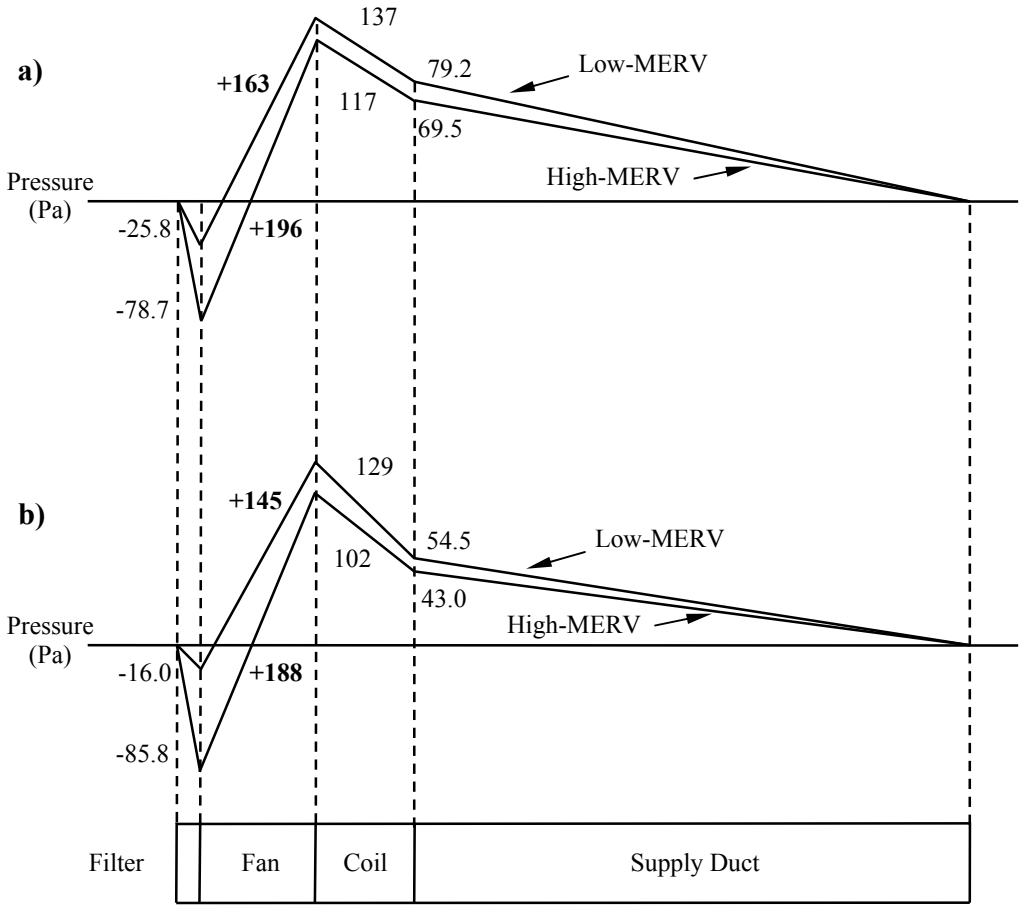


Figure 30. Pressure distribution with high- and low-MERV filters installed in a) the upflow test system and b) the downflow test system.

The total pressure rise across the fan increased in both systems with high-MERV filters installed compared to low-MERV filters, which partially explains the increase in fan power draw. The total pressure rise across the fan increased approximately 20% in the upflow system and approximately 30% in the downflow system with high-MERV filters installed. The decreases in supply operating pressure of approximately 13% in the upflow system and 20% in the downflow system with high-MERV filters relate directly to the measured decreases in airflow and supply leakage flow. Coil pressure drops decreased approximately 17% in the upflow system and approximately 21% in the downflow system with high-MERV filters.

4.2.3 Binned Analysis

To separate climatic effects from filter effects in the test systems, Table 13 shows the results of the binned analysis (bins are described in Table 5 and detailed binned measurements are included in Appendix H). This analysis shows the effect of filtration on operational parameters related to energy consumption recorded during similar climatic conditions in the cooling mode. Table 13 compares both high-MERV filters to low-MERV filters and mid-MERV filters to low-MERV filters. Reported values are the mean percentage differences in a given parameter averaged across all bins. The values in each bin were average values measured during steady-state operation with each type of filter installed. The percentage differences for values measured with high- and mid-MERV filters are compared to those measured with low-MERV filters. Negative values mean that the measured parameter was lower with a high- or mid-MERV filter and positive values mean high- or mid-MERV filters increased the parameter.

Table 13. Binned comparison results during cooling mode operation[1]

	Upflow System		Downflow System	
Variable	High vs. Low	Medium vs. Low	High vs. Low	Medium vs. Low
Fan Power Draw	+3.3%	+2.1%	+4.0%	+0.5%
Outdoor Unit Power Draw	-0.8%	+0.5%	-0.1%	+0.6%
Total Power Draw	-0.1%	+0.8%	+0.4%	+0.5%
System Airflow	-6.8%	-2.9%	-10.9%	-8.4%
Supply Leakage Airflow	-8.4%	-3.0%	-9.4%	-6.8%
Temperature Difference Across Coil	+4.5%	+0.5%	+7.8%	+0.7%
Humidity Ratio Difference Across Coil	+1.5%	+9.7%	+8.5%	+9.8%
Sensible Capacity	-2.6%	-2.5%	-4.0%	-8.0%
Latent Capacity	-5.5%	+6.5%	-3.3%	-0.1%
Total Capacity	-3.1%	-0.8%	-3.8%	-6.4%
COP	-3.1%	-2.0%	-4.2%	-7.3%

[1]Table reports average differences measured with high-MERV filters compared to low-MERV filters and medium-MERV filters compared to low-MERV filters. The differences are first averaged during steady-state operation period in each bin.

The binned analysis should isolate any climatic effects by comparing each parameter at similar indoor and outdoor environmental conditions. Similar to the previous results, fan power

draw increased approximately 3-4% in the test systems with high-MERV filters compared to low-MERV filters and increased approximately 0-2% with mid-MERV filters compared to low-MERV filters. High-MERV filters reduced the power draw of the outdoor unit less than 1% in both systems and medium-MERV filters increased outdoor unit power draw less than 1% in both systems. The net effect on total power draw (i.e., fan + outdoor unit power draw) was less than 1% in both systems with both medium- and high-efficiency filters. Given the instrument uncertainty on power draw (±1.5%), no observable change in total power draw due to filters was measured.

The binned analysis shows that the decrease of system airflow due to high-MERV filters during the cooling mode was approximately 7% and 11% in the upflow and downflow systems, respectively. Similarly, airflow decreased approximately 3% and 8% in the upflow and downflow systems, respectively, with medium-MERV filters installed compared to low-MERV filters. The airflow reductions are generally greater than that found by Parker et al. (1997). The supply leakage airflow rate decreased approximately 9-11% with high-MERV filters and 3-7% with medium-MERV filters, although no change was seen in leakage fraction. Sensible, latent, and total capacity decreased approximately 3-6% with high-MERV filters installed compared to low-MERV filters and had more scattered effects with medium-MERV filters installed. Capacity reductions were largely linked to airflow reductions because both temperature and absolute humidity differences across the cooling coil actually increased in the presence of high-MERV and mid-MERV filters. The net effect of high-MERV filters was approximately a 3% decrease in system efficiency in the upflow system and a 4% decrease in system efficiency in the downflow system. The decreases in efficiency are similar to those predicted in the background section and are similar to those reported in the literature due to a 5-10% airflow reduction (Palani et al., 1992; Rodriguez et al., 1996; Parker et al., 1997). The net effect of medium-MERV filters was approximately a 2% decrease in system efficiency in the upflow system and a 7% decrease in system efficiency in the downflow system. The discrepancy in efficiency measured in the two

test systems with medium efficiency filters suggests that the effects of higher-pressure drop filters are not entirely predictable.

Although changes in capacity and efficiency were measured between filter installations in the test house data, the magnitudes are generally small and within instrument uncertainty. The total power and sensible capacity results suggest that the test systems drew about the same amount of power with higher-efficiency filters as low-efficiency filters but had to run 2-4% longer to meet the cooling load with high-MERV filters and 2-8% longer with medium-MERV filters. However, little is known about the connections between the measurements of sensible capacity and how that actually affects thermostat readings and system runtime in real environments. Since the thermostat set points were precisely controlled during the measurements, we investigated the actual measured change in daily energy consumption in the test systems with high- and low-MERV filters only as a function of outdoor temperature. Only high- and low-MERV filters are used in this analysis because the extended monitoring times provided more data than the medium-MERV tests.

Figure 31 compares the daily energy consumption recorded in the two test systems with high- and low-MERV filters installed. The data points in Figure 31 are taken only during overlapping average daily outdoor temperature ranges (between 25°C and 30°C) and only during days when 24 hours of data were recorded. There are 24 full days with low-MERV filters installed and 16 full days with high-MERV filters installed to compare daily energy consumption. A linear regression is performed on the data points across the outdoor temperature range and the 95% confidence interval is displayed in Figure 31.

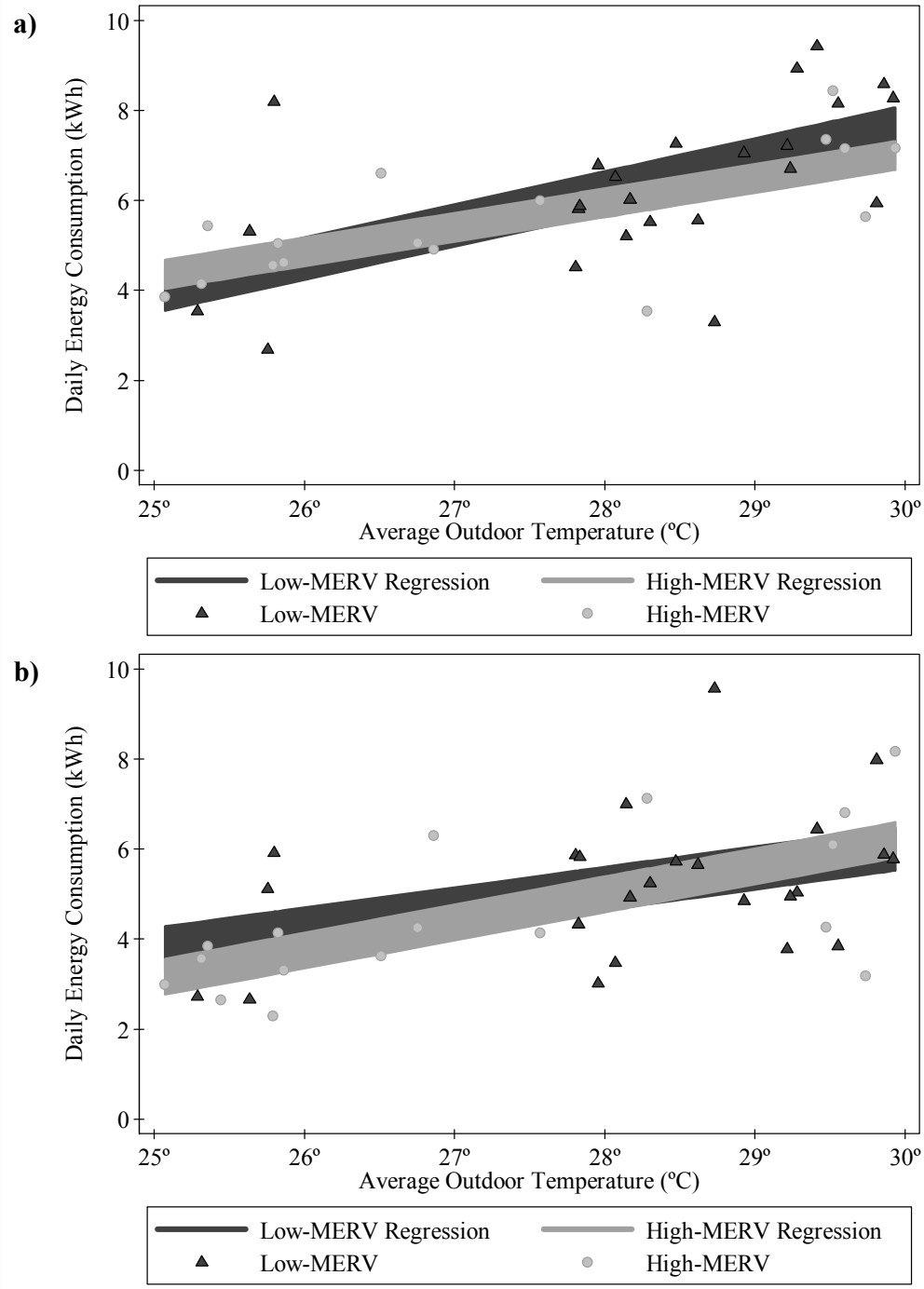


Figure 31. Daily energy consumption with high- and low-MERV filters in a) the upflow system and b) the downflow system.

According to Figure 31, the 95% confidence intervals of the relationship between daily energy consumption and average outdoor temperature overlap between the two types of filters in both test systems. The difference in the 95% confidence intervals of the regressions for low-MERV filters and high-MERV filters are not statistically significant for either test house system, suggesting that higher-efficiency filters did not cause the test systems to use more energy. Energy consumption can be affected by environmental factors other than the ones we controlled (e.g., solar radiation, wind speed, or temporal distribution of outdoor temperatures). However, given the overlapping relationships for low- and high-MERV filters, the results in Figure 31 show that there was no significant change in daily energy consumption in the test systems due to higher efficiency filters. Both the small differences and the directional variations in regression slopes with high and low efficiency filters in the two test systems suggest that the energy consequences of higher-efficiency filters were not only small but also unpredictable.

5. THEORETICAL IMPLICATIONS AND EXAMPLE CALCULATION

The following section combines the results from both the test house and field investigations to predict the energy consequences of low- and high-MERV filters installed in an air-conditioning system at a set of given theoretical conditions. The results from both investigations are included in an attempt to overcome limitations from each investigation. Although the two test house systems provided continuous measurements that were free of confounding climatic and occupant behavior factors, other limitations existed. The filters did not load very much over their service lives, the systems did not have return air ducts located in unconditioned space thus no return duct leakage from the exterior, and both systems were new, from the same manufacturer, and installed similarly and thus were not representative of a broad range of equipment, maintenance and operation issues. Conversely, the 17 field sites provided some insight on the effects of filters on duct leakage on a range of systems operated under realistic conditions, but other parameters related to air-conditioner performance dominated any changes from filters and it was difficult to decouple and filter effects from climatic and operational parameters (see Section 4.1.6). This theoretical analysis combines the results from both investigations to estimate potential changes in delivered cooling capacity due to higher-efficiency filters.

Equation (4) describes the calculation of total cooling capacity as an energy balance on the cooling coil. The term includes sensible and latent cooling capacity of the cooling coil, as shown in Equation (9) and Equation (10).

$$q_{sensible} = Q_{fan}\rho C\Delta T \tag{9}$$

and

$$q_{latent} = Q_{fan}\rho\Delta W h_{fg} \tag{10}$$

where

$q_{sensible}$	=	sensible cooling capacity (BTU/hr, W);
q_{latent}	=	latent cooling capacity (BTU/hr, W);
Q_{fan}	=	volumetric flow rate of air (ft^3/hr, m^3/s) flowing through the cooling coil;
ρ	=	air density, assumed constant (0.075 lb_m/ft^3, 1.2 kg/m^3);
C	=	specific heat of air (0.24 BTU/(lb_m°F), 1.005 kJ/(kg K));
ΔT	=	temperature difference across the cooling coil (°F, K);
ΔW	=	humidity ratio difference across the cooling coil (lb_m/lb_m, g/kg); and
h_{fg}	=	latent heat of vaporization for water (970 BTU/lb, 2257 kJ/kg).

An energy balance can also be performed on the conditioned space to establish the amount of energy required, as a function of supply air and room air. The sensible and latent energy balances are described in Equation (11) and Equation (12), respectively.

$$q_{room,sensible} = Q_{fan}\rho C(T_r - T_s) \tag{11}$$

where

$q_{room,sensible}$	=	sensible energy required to condition the space (BTU/hr, W);
T_r	=	temperature of room air (°F, K); and
T_s	=	temperature of supply air (°F, K).

and

$$q_{room,latent} = Q_{fan}\rho(W_r - W_s)h_{fg} \tag{12}$$

where

$q_{room,latent}$	=	latent energy required to condition the space (BTU/hr, W);
W_r	=	humidity ratio of room air (lb_m/lb_m, kg/kg); and
W_s	=	humidity ratio of supply air (lb_m/lb_m, kg/kg).

This analysis uses the theoretical conditions given in Table 14 for an air-conditioning system with return ductwork installed in an attic and parameters given in Table 15 with low- and high-MERV filters, as taken from the test house and field results. The system is assumed to have an airflow rate of 940 CFM (1600 m^3/hr), 10% return air duct leakage from the hot attic, and no supply leakage with a low-MERV filter installed.

Table 14. Given conditions for theoretical analysis

Given Conditions	Room	Attic
Dry bulb temperature	78.8°F (26°C)	122°F (50°C)[1]
Relative humidity	50%	20%
Humidity ratio	0.0105 lb/lb (kg/kg)	0.0155 lb/lb (kg/kg)
Wet bulb temperature	66.9°F (19.4°C)	84.0°F (28.9°C)

[1] This attic temperature represents the 99th percentile of attic temperatures recorded at all field sites.

Table 15 shows that the system airflow rate decreases 10% with a high-MERV filter, in accordance with the field results in Table 6 and the test house results in Table 13. The temperature and humidity ratio difference across the coil increases from 49.1°F (9.5°C) and 0.0018 lb/lb (kg/kg) with a low-MERV filter (average values from the test house systems in Table 222, Table 223, Table 224, and Table 225) to 50.4°F (10.2°C) and 0.0019 lb/lb (kg/kg) with a high-MERV filter (the average increase from Table 13). The return leakage airflow rate decreases 15% with a high-MERV filter, from 94 CFM (160 m^3/hr) with a low-MERV filter to 80 CFM (136 m^3/hr) in accordance with the results in Table 6.

Table 15. Parameter summary with low- and high-MERV filters

	Low-MERV	High-MERV
Airflow rate, Q_{fan}	940 CFM (1600 m^3/hr)	850 CFM (1440 m^3/hr)
Temperature difference across coil, ΔT	49.1°F (9.5°C)	50.4°F (10.2°C)
Humidity ratio difference across coil, ΔW	0.0018 lb/lb (kg/kg)	0.0019 lb/lb (kg/kg)
Return leakage fraction	10%	9.4%
Return leakage airflow rate	94 CFM (160 m^3/hr)	80 CFM (136 m^3/hr)

Given the parameters in Table 15 and the capacity calculations in Equation (9) and Equation (10), Table 16 provides an estimate of the difference in cooling coil capacity with low- and high-MERV filters installed in the theoretical system (without considering the effects of duct leakage).

Table 16. Cooling coil capacity estimation for low- and high-MERV filters

Cooling Coil Capacity	Low-MERV, BTU/hr (W)	High-MERV, BTU/hr (W)	% Difference
Sensible capacity, $q_{sensible}$	17270 (5062)	16705 (4896)	-3.3%
Latent capacity, q_{latent}	7385 (2165)	7023 (2058)	-4.9%
Total capacity, q_{total}	24656 (7226)	23728 (6954)	-3.8%

Generally in agreement with the test house results in Table 13, sensible capacity decreases approximately 3%, latent capacity decreases approximately 5%, and total capacity decreases approximately 4%. Although these results suggest the system will have to run 3-5% longer to meet the cooling load, this capacity analysis does not consider the potential effects of return air leakage. Since return air leakage changes between filter installations, the air temperature and humidity ratio can change in the return plenum as more or less air infiltrates from the attic to mix with return air from conditioned space. Increased return air temperature from increased duct leakage can increase the supply air temperature, potentially lowering cooling capacity. Equation (13) calculates the temperature entering the cooling coil as a mixture of return air and attic air leakage. This analysis assumes well-insulated ducts and minimal conduction gains. Similarly, Equation (14) calculates the entering humidity ratio.

$$T_{mix} = \frac{Q_r}{Q_{fan}} T_r + \frac{Q_{leak}}{Q_{fan}} T_{attic} \quad (13)$$

where

T_{mix} = temperature of return plenum air mixture entering the cooling coil (°F, K);
Q_r = volumetric airflow rate returned from conditioned space (ft^3/hr, m^3/s);
Q_{leak} = volumetric airflow rate of leakage from the attic (ft^3/hr, m^3/s); and
T_{attic} = temperature of attic air (°F, K).

$$W_{mix} = \frac{Q_r}{Q_{fan}} W_r + \frac{Q_{leak}}{Q_{fan}} W_{attic} \quad (14)$$

where

W_{mix} = humidity ratio of return plenum air mixture entering the cooling coil (lb_m/lb_m, kg/kg); and
W_{attic} = humidity ratio of attic air (lb_m/lb_m, kg/kg).

Using the values in

Table 14 and Table 15, the entering return plenum air mixture is 83.1°F (28.4°C) and has a humidity ratio of 0.0110 lb/lb (kg/kg) with a low-MERV filter and the change in return leakage with a high-MERV filter provides a 82.9°F (28.3°C) mixture with a 0.0109 lb/lb (kg/kg) humidity ratio. Since the temperature and humidity ratio differences across the coil are known for low- and high-MERV filters, as reported in Table 15, the supply air temperature can be calculated using Equation (15) and the supply humidity ratio can be calculated from Equation (16).

$$T_s = T_{mix} - \Delta T \quad (15)$$

and

$$W_s = W_{mix} - \Delta W \quad (16)$$

The supply air temperature and humidity ratio are calculated as 66°F (18.9°C) and 0.0092 lb/lb (kg/kg) with a low-MERV filter and 64.6°F (18.1°C) and 0.0090 lb/lb (kg/kg) with a high-

MERV filter. Using these supply air values, the attic and room conditions given in Table 14, the airflow changes in Table 15, Equation (11), and Equation (12), Table 17 estimates the change in room energy balance between low- and high-MERV filters.

Table 17. Energy balance on conditioned space with low- and high-MERV filters

Room Energy Balance	Low-MERV, BTU/hr (W)	High-MERV, BTU/hr (W)	% Difference
Sensible balance, $q_{room,sensible}$	12907 (3783)	12938 (3792)	+0.2%
Latent balance, $q_{room,latent}$	5334 (1563)	5545 (1625)	+4.0%
Total balance, $q_{room,total}$	18241 (5346)	18483 (5417)	+1.3%

The small reduction in return air leakage due to a high-MERV filter alters the sensible energy balance on the conditioned space by less than 1% at the given conditions. At the theoretical conditions, the latent energy required increases approximately 4% and the total energy required increases approximately 1%. In this example, a 10% reduction in airflow due to a higher-efficiency filter does not alter the sensible cooling energy required because a longer contact time with the cooling coil and a small decrease in return air leakage both combine to deliver air at a lower temperature. This suggests that a system controlled simply by a thermostat will not operate any longer with a high-MERV filter than with a low-MERV filter at these conditions and, at most, just over 1% more energy is required to completely cool and dehumidify the space at these conditions.

This analysis did not include fan effects, duct conduction gains, as well as non-steady state operation that is typical of an operating air conditioner, but does suggest that at the theoretical conditions proposed here, the findings of minimal energy consequences from high-efficiency filters is reasonable.

6. LESSONS LEARNED AND RECOMMENDATIONS FOR FUTURE INVESTIGATIONS

The goal of this chapter is to explore some of the limitations of this research project and make recommendations for future similar investigations. An important overall statement is that despite some important limitations, this project provided a remarkably consistent set of findings. Theory, uncontrolled field measurements, and controlled test-house experiments all suggest minimal energy consequences from higher-efficiency filters in smaller HVAC systems with cycling operation. The finding of some statistically significant results suggests that this lack of a large effect is real and robust. Although the findings are contrary to conventional wisdom, we believe that these results present a compelling set of conclusions and hope that these results are disseminated within ASHRAE and to relevant decision makers in government and industry. Some specific recommendations for dissemination are included below.

By far the biggest limitation of this work is the sample size. As in many such investigations, the sample size was constrained by available funds, but a larger sample would have allowed for a more robust investigation of the site-specific factors discussed in Section 4.1.6. In retrospect, if the study focused entirely on residential buildings, rather than on both residential and light commercial buildings, the conclusions might have been more robust. However, given the similarities between both types of buildings in this study, we anticipate that this would not alter the findings. There is also value in including light commercial buildings given their ubiquity and the fact that there is limited research on them.

Another area that may benefit from improvement would be the approach used in the study. At the time of the proposal, we considered testing each building continuously for a six-week period, with two weeks for each filter installion and running the fans continuously during the testing. The advantage is that we would have seen less climatic variability as well as fewer issues with sensor placement and other changes in measurement equipment that happen over a

year. The disadvantages of this approach include an unusual filter loading condition, potentially a very small amount of loading as we saw in the test house investigation, and increased challenges in recruiting the sites. Yet another approach would have been to have not used real filters in this investigation and instead used a low-MERV filter and increasingly blocked off some of the area to achieve a higher-pressure drop. Testing could be completed at each filter pressure drop for as long as possible to comprise a specified range of climatic conditions and operation conditions. This would have allowed for normalization of these factors at the field site and potentially also could have allowed for less testing at each site and the inclusion of more sites. Given the variation in filters, even those with the same MERV, we believe that this may be an appropriate approach for a follow-up investigation.

In addition to a research project with a larger sample, we also believe that this type of investigation should be completed in large commercial buildings. Even though the energy consequences of filters are thought to be linear with pressure drop (see Equation (3)) for systems that adjust flow, we are not convinced that this relationship has been adequately explored. In particular, fan efficiency (both shaft and aerodynamic efficiencies), as well as variable-frequency drive efficiency, may be functions of filter pressure drop and should be investigated. At the very least, such measurements will provide a valuable database of fan efficacy in real buildings, which is sorely lacking in the literature. Also, filter bypass affects filter pressure drop and flow (Ward and Siegel, 2005) and can affect duct leakage (VerShaw et al., 2009) and thus the details of filter installation may affect energy use. Given the ubiquity of filter bypass, this should also likely be included in such an investigation.

Although this project focused on energy consequences, there are important filter effectiveness issues that should likely be addressed by future ASHRAE research. In particular, given the short duty cycles, even efficient filters may not remove as many contaminants of concern as we assume. This issue, combined with filter installation and duct leakage issues discussed above as well as changes in filter performance that can occur, a robust investigation of

the impact of filters on indoor particle particle concentrations in residences would be useful to the ASHRAE community.

Lastly, we believe that the results from this investigation are compelling enough to disseminate further. Specifically:

- Several federal agencies[1,2] draw a link between increased energy use and filter pressure drop. These agencies should likely re-evaluate this information for smaller HVAC systems that operate in a cycling manner.
- Several residential filter manufacturers make similar claims and should either provide data that demonstrates such findings or consider avoiding making this claim.
- The ASHRAE community would likely benefit from inclusion of this information in relevant handbook chapters, especially the overall concept that filters should be selected for reasons besides energy consumption.

Perhaps the most important finding is the reinforcement of many articles in the literature that point to the common issues in residential and light commercial buildings (incorrect refrigerant charge, insufficient airflow, duct leakage, undersized return duct systems, etc.). The owners and operators of the over 100 million central air-conditioning systems in residential and light commercial buildings throughout the US would likely benefit considerably more from the avoidance and correction of these problems than from any small energy consequences of filtration.

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[1] United States Environmental Protection Agency and Department of Energy: Energy Star. http://www.energystar.gov/index.cfm?c=heat_cool.pr_hvac. "A dirty filter will slow down air flow and make the system work harder to keep you warm or cool — wasting energy."

[2] United States Department of Energy, Office of Energy Efficiency and Renewable Energy. http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12390 "The most important maintenance task that will ensure the efficiency of your air conditioner is to routinely replace or clean its filters. Clogged, dirty filters block normal air flow and reduce a system's efficiency significantly…. Keeping the filter clean can lower your air conditioner's energy consumption by 5%–15%."

7. CONCLUSIONS

The purpose of this research was to investigate the energy consequences of higher-efficiency HVAC filters in air-conditioning systems in small residential and light commercial buildings. Smaller residential and light commercial systems do not behave like large commercial variable volume systems and the energy consequences of filters are consequently more complex. The first goal of this report was to explore the underlying theory and estimate the potential impacts of filters from values in the literature. The second goal was to evaluate the effects of filters in occupied residential and light commercial buildings in Austin, Texas. The third goal was to evaluate the effects of filters in an unoccupied manufactured test house in Austin, Texas. Finally, the last goal was to combine the measured results and predict the likely effects of filters on small HVAC systems.

First, the airflow and energy consequences of a higher-pressure drop filter in residential and light commercial HVAC systems depend on the pressure drop of the filter relative to that of the rest of the return side of the system, the system fan curve, the fan efficiency curve, and the location of the intersection of the fan and duct curves. However, the magnitude of the effects of filters on duct leakage, total power draw, and cooling capacity are not well characterized. In general, a review of the underlying theory behind pressure drop and flow relationships in conjunction with values from literature suggest that the energy effects of higher-efficiency filters in small air-conditioning systems are likely small and that they would probably increase energy consumption by less than 5% and may even lead to energy savings in some buildings.

Second, field measurements of 17 residential and light commercial forced-air cooling systems were conducted in Austin, Texas to assess the energy implications of higher-efficiency

- Median airflow rates were approximately 4-5% lower during fan-only operation for 16 of the sites and 10-11% lower during cooling operation for 11 of the sites with high-efficiency filters (MERV 11-12) installed versus low-efficiency filters (MERV 2);
- The median fan power draw decrease was approximately 1% during fan-only operation and 4% during cooling operation with high-MERV filters installed;
- Median supply and return duct leakage airflow rates decreased in the presence of high-MERV filters, although the change in leakage fractions were very small;
- Median cycle lengths were longer with a high-MERV filter in six of the fourteen applicable sites, longer with a low-MERV filters in seven sites, and approximately equal in one site;
- Likely energy consequences of high-MERV filters suggest a median energy reduction of 16 kWh per ton of installed capacity (5 kWh per kW) per month when compared to low-MERV filters, albeit with considerable scatter;
- Many of the impacts of filters measured in the test sites were within the range of instrument uncertainty and repeated filter tests had similar impacts in many cases as different filter efficiency installations did; and
- Climatic variation and factors relating to system operation, installation and maintenance appear to be considerably more important than the small energy consequences associated with different filter pressure drops.

Third, measurements were conducted on two residential air-conditioning systems in an unoccupied test house in Austin, Texas. The primary findings of the experimental investigation of the test systems include:

- High-MERV filters decreased airflow rates by approximately 7% and 11% in each of the two systems, relative to low-MERV filters;
- Mid-MERV filters decreased airflow rates by approximately 3% and 8% in each of the two systems, relative to low-MERV filters;
- Fan power draw increased approximately 3-4% and the power draw of the outdoor units decreased less than 1% in the presence of high-MERV filters compared to low-MERV filters;
- Fan power draw increased between 0-2% and outdoor unit power draw decreased less than 1% in the presence of mid-MERV filters compared to low-MERV filters in one system and increased less than 1% in the other;
- Total capacity decreased approximately 3-4% in the presence of high-MERV filters;
- Total capacity decreased less than 1% in one system and approximately 7% in another system in the presence of mid-MERV filters; and
- Daily energy consumption did not significantly differ between low- and high-MERV filter installations.

Fourth, this report uses the test results in conjunction with theoretical relationships to estimate that the overall effect of high-efficiency filters on the energy consumption of a smaller air-conditioning system at a specific set of climate conditions is minimal. Using the combined airflow, power, capacity, and duct leakage changes measured in the field sites and the test house systems, the analysis reveals that higher-efficiency filters can deliver essentially the same amount of cooling energy while drawing essentially the same amount of power as a low efficiency filter.

The results of the first field study show that widely available higher-efficiency filters (MERV 11-12) generally had a small impact on parameters related to energy consumption in the

residential and light commercial air-conditioning systems when compared to lower efficiency filters (MERV 2). Although high efficiency filters decreased airflow rates in the test systems approximately 4-11%, power draw of the air handler fans decreased approximately 1-4% and no significant difference in system runtimes were observed. Thus, the likely energy consequence of high-MERV filters in the test systems was a median energy reduction of 16 kWh per ton of installed capacity (5 kWh per kW) per month of cooling season operation.

The theoretical investigation and literature review of the likely effects of filters predicted that filters would have a small effect on energy consumption in residential air-conditioning systems. The 5-10% airflow reduction likely due to filters could lead to a 2-6% increase in energy consumption, but limited evidence to precisely quantify this effect exists in the published literature. The results of the second study on two air-conditioning systems in an unoccupied test house reveal that higher-efficiency filters (MERV 11) decreased airflow rates 7-11% relative to low efficiency filters (MERV < 4) and medium efficiency filters (MERV 8) decreased airflow rates 3-8% relative to low efficiency filters. Although high-MERV filters decreased measured cooling capacity 3-4%, no significant difference was observed in daily energy consumption in the test systems due to higher-efficiency filters.

This report challenges the assumption that higher-efficiency filters increase energy consumption in residential and light commercial HVAC systems. The results of a theoretical investigation and two field studies suggest that the energy consequences of higher-efficiency filters are small in smaller air-conditioning systems and that other factors should govern filter selection. Thus, high efficiency HVAC filters can potentially reduce exposure to airborne particles with minimal energy penalties. The results from this investigation allow home and building owners, operators, designers and system installers to make informed decisions about filtration.

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9. APPENDICES

Appendix A: Field Site Building and HVAC Characteristics

Table 18. Building Characteristics

Site	Use	Number of Stories	Floor Area, ft^2 [m^2]	Volume, ft^3 [m^3]	Distance to major highway, mi [km]
1	Residential	1	1830 [170]	15600 [442]	0.6 [1.0]
2	Residential	2	1430 [133]	11400 [323]	0.4 [0.6]
3	Residential	2	1080 [100]	12200 [346]	0.2 [0.3]
4	Residential	1	320 [30]	3800 [108]	0.2 [0.3]
5	Residential	1	1140 [106]	10300 [292]	1.0 [1.6]
6	Residential	1	1500 [139]	12000 [340]	0.6 [1.0]
7	Residential	1	1200 [111]	9600 [272]	0.4 [0.6]
8	Residential	1	1350 [125]	11400 [323]	0.3 [0.5]
9	Commercial	1	1300 [121]	15500 [439]	0.1 [0.2]
10	Commercial	1	1300 [121]	15500 [439]	0.1 [0.2]
11	Commercial	2	1320 [123]	12400 [351]	1.0 [1.6]
12	Commercial	1	1860 [173]	14900 [422]	0.9 [1.4]
13	Commercial	1	1430 [133]	12200 [346]	0.4 [0.6]
14	Commercial	1	980 [91]	7800 [221]	1.0 [1.6]
15	Commercial	1	1000 [93]	8200 [232]	1.0 [1.6]
16	Commercial	1	760 [71]	9400 [266]	0.2 [0.3]
17	Commercial	1	280 [26]	2100 [59]	0.2 [0.3]

Table 19. HVAC Characteristics

Site	Rated Cooling Capacity, tons [kW]	Heating Type[1]	Duct Location[2]	# of Supply Registers	# of Return Grilles	# of Filters	Filter Location	Filter Size[3] in [mm]	Air Handler Location
1	4 [14.1]	NG	Attic	11	1	1	Unit filter slot	20×25 [508×635]	Closet
2	3 [10.6]	E	Attic	6	1	1	Unit filter slot	20×20 [508×508]	Garage
3	2.5 [8.8]	NG	CS	9	3	3	Return grilles	12×24 [305×610]	Closet
4	1.5 [5.3]	NG	Attic	4	1	1	Return grille	12×24 [305×610]	Attic
5	2.5 [8.8]	NG	Attic	6	1	1	Return grille	20×20 [508×508]	Attic
6	3 [10.6]	NG	Attic	12	1	1	Return grille	14×30 [356×762]	Attic
7	3 [10.6]	NG	CS	7	2	1	Unit filter slot	14×25 [356×635]	Closet
8	3 [10.6]	NG	Attic	9	1	1	Unit filter slot	16×25 [406×635]	Garage
9	5 [17.6]	E	Attic	11	2	2	Return grilles	20×30 [508×762]	Attic
10	3.5 [12.3]	E	Attic	12	2	2	Return grilles	20×20 [508×508]	Attic
11	3.5 [12.3]	NG	Attic	9	2	2	Return grilles	16×20 [406×508] & 20×20 [508×508]	Attic
12	5 [17.6]	NG	Attic	12	3	3	Return grilles	12×24 [305×610]	Attic
13	3.5 [12.3]	NG	Attic	8	1	1	Unit filter slot	16×25 [406×635]	Closet
14	3 [10.6]	NG	Attic	8	2	1	Unit filter slot	12×24 [305×610]	Closet
15	2.5 [8.8]	NG	Attic	12	1	2	Unit filter slot	16×25 [406×635] & 14×25 [356×635]	Closet
16	1.5 [5.3]	NG	Outdoor	1	1	1	Return grille	14×25 [356×635]	Outdoor closet
17	1.5 [5.3]	NG	CS	1	1	1	Unit filter slot	20×20 [508×508]	Closet

[1] NG = Natural Gas, E = Electric
[2] CS = Conditioned Space
[3] All filters were 1 inch [25.4 mm] thick

Table 20. Estimated Filter Face Velocities: Residential Sites[1]

Site	Size, inches [mm]	MERV	Media[2]	Approximate Face Velocity, ft/min [m/s] Fan-only	Cooling
1	20×25 [508×635]	Low	Fiberglass	290 [1.5]	350 [1.8]
		Medium	Pleated synthetic	290 [1.5]	n/a
		High	Pleated synthetic (c)	290 [1.5]	n/a
2	20×20 [508×508]	Low	Fiberglass	500 [2.5]	500 [2.5]
		Medium	Pleated synthetic	430 [2.2]	n/a
		High	Pleated synthetic (c)	450 [2.3]	n/a
3	12×24 [305×610]	Low	Fiberglass	150 [0.8]	160 [0.8]
		Medium	Pleated synthetic	150 [0.8]	n/a
		High	Pleated synthetic (c)	140 [0.7]	150 [0.8]
4	12×24 [305×610]	Low	Fiberglass	320 [1.6]	370 [1.9]
		Medium	Pleated synthetic	300 [1.5]	n/a
		High	Pleated synthetic (c)	320 [1.6]	320 [1.6]
5	20×20 [508×508]	Low	Fiberglass	460 [2.3]	480 [2.4]
		Medium	Pleated synthetic	390 [2.0]	n/a
		High	Pleated synthetic (c)	400 [2.0]	390 [2.0]
6	14×30 [356×762]	Low	Fiberglass	390 [2.0]	n/a
		Medium	Pleated synthetic	370 [1.9]	370 [1.9]
		High	Pleated synthetic	340 [1.7]	330 [1.7]
7	14×25 [356×635]	Low	Fiberglass	340 [1.7]	340 [1.7]
		Medium	Pleated synthetic	310 [1.6]	n/a
		High	Pleated synthetic (c)	270 [1.4]	270 [1.4]
8	16×25 [406×635]	Low	Fiberglass	270 [1.4]	270 [1.4]
		Medium	Pleated synthetic	260 [1.3]	n/a
		High	Pleated synthetic (c)	260 [1.3]	250 [1.3]

[1] Face velocity estimations are shown for newly installed filters alone, or averaged across multiple clean filter installations

[2] "(c)" indicates the filter has an electrostatic charge

Table 21. Estimated Filter Face Velocities: Light Commercial Sites[1]

Site	Size, inches [mm]	MERV	Media[2]	Approximate Face Velocity, ft/min [m/s] Fan-only	Cooling
9	20×30 [508×762]	Low	Fiberglass	210 [1.1]	n/a
		Medium	Pleated synthetic	200 [1.0]	200 [1.0]
		High	Pleated synthetic (c)	210 [1.1]	220 [1.1]
10	20×20 [508×508]	Low	Fiberglass	230 [1.2]	220 [1.1]
		Medium	Pleated synthetic	230 [1.2]	n/a
		High	Pleated synthetic (c)	240 [1.2]	n/a
11	16×20 [406×508] 20×20 [508×508]	Low	Fiberglass	250 [1.3]	260 [1.3]
		Medium	Pleated synthetic	220 [1.1]	200 [1.0]
		High	Pleated synthetic (c)	240 [1.2]	n/a
12	12×24 [305×610]	Low	n/a	n/a	n/a
		Medium	n/a	n/a	n/a
		High	Pleated synthetic (c)	220 [1.1]	250 [1.3]
13	16×25 [406×635]	Low	Fiberglass	330 [1.7]	360 [1.8]
		Medium	Pleated synthetic	310 [1.6]	330 [1.7]
		High	Pleated synthetic (c)	310 [1.6]	330 [1.7]
14	12×24 [305×610]	Low	Fiberglass	480 [2.4]	480 [2.4]
		Medium	Pleated synthetic	450 [2.3]	440 [2.2]
		High	Pleated synthetic	430 [2.2]	440 [2.2]
15	16×25 [406×635] 14×25 [356×635]	Low	Fiberglass	220 [1.1]	230 [1.2]
		Medium	Pleated synthetic	220 [1.1]	220 [1.1]
		High	Pleated synthetic (c)	210 [1.1]	n/a
16	14×25 [356×635]	Low	Fiberglass	260 [1.3]	450 [2.3]
		Medium	Pleated synthetic	250 [1.3]	n/a
		High	Pleated synthetic (c)	250 [1.3]	420 [2.1]
17	20×20 [508×508]	Low	Fiberglass	180 [0.9]	480 [2.4]
		Medium	Pleated synthetic	180 [0.9]	n/a
		High	Pleated synthetic (c)	190 [1.0]	420 [2.1]

[1] Face velocity estimations are shown for newly installed filters alone, or averaged across multiple clean filter installations

[2] "(c)" indicates the filter has an electrostatic charge

Appendix B: Full Results from Research Question 1

Table 22. Full results of Research Question 1

		High-MERV vs. Low-MERV			High-MERV vs. Mid-MERV			Mid-MERV vs. Low-MERV			Rep vs. Original	
	Dependent Variable	[%]	Absolute	n	[%]	Absolute	n	[%]	Absolute	n	[%]	n
Fan Only Mode	Fan Power (W)	***-1.1****	***-5****	16	-1.6	-4	16	-1.2	-5	16	***-3.3****	16
	Filter Pressure Drop (Pa)	***45****	***23.9****	16	-0.7	-0.4	16	***46.8****	***26****	16	3.3	16
	Coil Pressure Drop (Pa)	-5.3	-0.4	16	4.8	1.4	16	*-13.2*	*-3.9*	16	-1.9	16
	Fan Flow (CFM)	***-4.2****	***-59****	16	-1.8	-15	16	***-5.3****	***-40****	16	***-4.6****	16
	Fan Efficacy (CFM/W)	***-3.9****	***-0.08****	16	0.4	0.01	16	*-4.4*	*-0.09*	16	-0.5	16
	Supply Duct Leakage Flow (CFM)	-16.4	-8	14	***18.2****	***15****	14	***-43.9****	***-31****	14	***26.3****	14
	Return Duct Leakage Flow (CFM)	-13.7	-3	13	***18.2****	***8****	13	*-43.8*	*-11*	13	***25.6****	13
	Supply Leakage Fraction (-)	*0.06*	*0.0005*	15	*0.13*	*0.0009*	15	0.02	0.0002	15	***0.1****	15
	Return Leakage Fraction (-)	0.02	0.0002	15	*0.04*	*0.0004*	15	0.01	0.0001	15	*0.05*	*15*
Cooling Mode	Fan Power (W)	***-4****	***-15****	11	-8.8	-42	2	4.9	24	2	-0.6	7
	Filter Pressure Drop (Pa)	***43.1****	***31****	11	23.9	25.2	2	-9.6	-9.3	2	6.6	7
	Coil Pressure Drop (Pa)	-13.1	-4.0	11	17.6	10.9	2	-43.4	-27.4	2	-3.9	7
	Fan Flow (CFM)	***-10.2****	***-96****	11	*-5.7*	*-53*	2	-0.3	-54	2	-0.8	7
	Fan Efficacy (CFM/W)	*-5.4*	*-0.11*	11	1.4	0.03	2	-5.5	-0.13	2	0.9	7
	Supply Duct Leakage Flow (CFM)	***-13.7****	***-24****	9	*3.9*	*3*	3	3.8	5	3	-1.0	7
	Return Duct Leakage Flow (CFM)	***-18.9****	***-7****	8	*-2.0*	*-2*	2	7.6	11	2	-1.5	6
	Supply Leakage Fraction (-)	0.6	0.0034	10	-0.2	-0.0026	2	-1.3	-0.0100	2	0.0	7
	Return Leakage Fraction (-)	*0.2*	*0.0015*	10	0.0	-0.0003	2	-1.4	-0.0118	2	0.0	7
	Compressor Power Draw (W)	-1.9	-41	11	-1.9	-54	2	0.9	13	2	-2.6	7
	Sensible Capacity (W)	-10.6	-558	11	11.3	670	2	-9.6	-325	2	2.8	7
	Latent Capacity (W)	-5.4	-95	11	-35.8	-624	2	13.6	634	2	-7.9	7
	Total Capacity (W)	-9.3	-653	11	7.1	418	2	3.5	309	2	0.1	7
	Sensible Heat Ratio (-)	-0.5	-0.004	11	17.9	0.151	2	-14.1	-0.078	2	3.7	7
	Delivery Effectiveness (-)	-1.2	-0.011	10	22.0	0.850	2	7.8	0.085	2	-2.3	7

Asterisk (*) and bold indicate P < 0.05 from paired t-test.

Italics indicate P < 0.05 from Wilcoxon matched-pairs sign-rank test.

Appendix C: Full Results from Research Question 2

Table 23. Full results of Research Question 2

		Linear Regression			95% Confidence Interval	
	Normalized Dependent Variable	Slope	Standard Error	n[1]	Lower Bound	Upper Bound
Fan Only Mode	*Fan Power**	*-0.018*	*0.005*	*218*	*-0.028*	*-0.007*
	*Coil Pressure Drop**	*0.147*	*0.040*	*197*	*0.068*	*0.226*
	*Fan Flow**	*-0.067*	*0.004*	*218*	*-0.075*	*-0.058*
	*Fan Efficacy**	*-0.046*	*0.006*	*218*	*-0.057*	*-0.035*
	*Supply Duct Leakage Flow**	*-0.226*	*0.018*	*169*	*-0.262*	*-0.190*
	*Return Duct Leakage Flow**	*-0.233*	*0.017*	*201*	*-0.267*	*-0.199*
	*Supply Duct Leakage Fraction**	*0.003*	*0.000*	*170*	*0.003*	*0.004*
	*Return Duct Leakage Fraction**	*0.002*	*0.000*	*170*	*0.001*	*0.002*
Cooling Mode	*Fan Power**	*-0.047*	*0.004*	*91*	*-0.056*	*-0.039*
	Coil Pressure Drop	0.093	0.063	83	-0.032	0.218
	*Fan Flow**	*-0.086*	*0.007*	*83*	*-0.100*	*-0.073*
	*Fan Efficacy**	*-0.043*	*0.006*	*83*	*-0.055*	*-0.030*
	*Supply Duct Leakage Flow**	*-0.121*	*0.009*	*77*	*-0.140*	*-0.102*
	*Return Duct Leakage Flow**	*-0.126*	*0.011*	*70*	*-0.147*	*-0.104*
	*Supply Duct Leakage Fraction**	*0.005*	*0.001*	*77*	*0.003*	*0.006*
	*Return Duct Leakage Fraction**	*0.002*	*0.000*	*77*	*0.001*	*0.003*
	Compressor Power Draw	-0.007	0.012	83	-0.030	0.016
	Sensible Capacity	-0.021	0.030	75	-0.080	0.038
	*Latent Capacity**	*-0.163*	*0.045*	*73*	*-0.252*	*-0.074*
	Total Capacity	-0.038	0.035	75	-0.109	0.032
	Sensible Heat Ratio	0.033	0.017	75	-0.001	0.066
	Delivery Effectiveness	0.009	0.007	69	-0.005	0.023

[1]Excludes Sites 9, 12, and 17

Asterisk (*) and italics indicate statistically significant results.

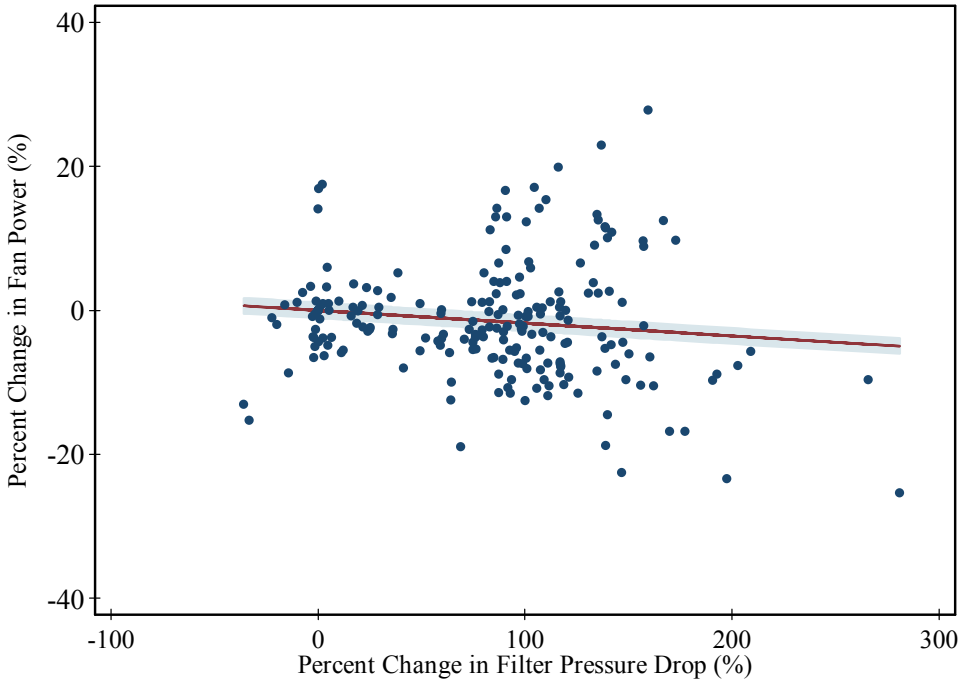


Figure 32. RQ2 regression for fan power draw in the fan-only mode

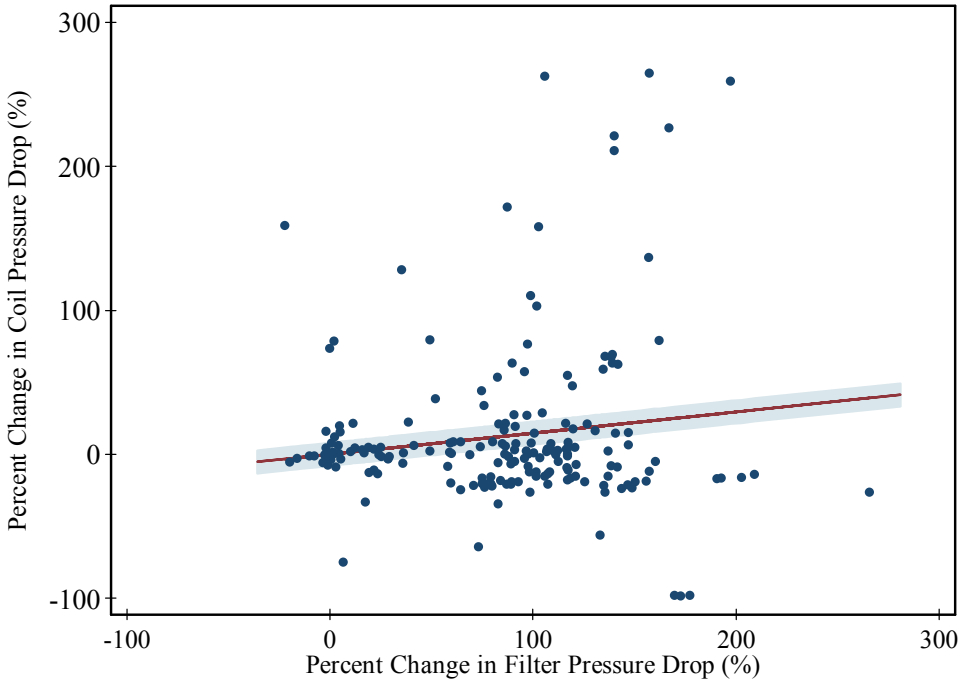


Figure 33. RQ2 regression for coil pressure drop in the fan-only mode

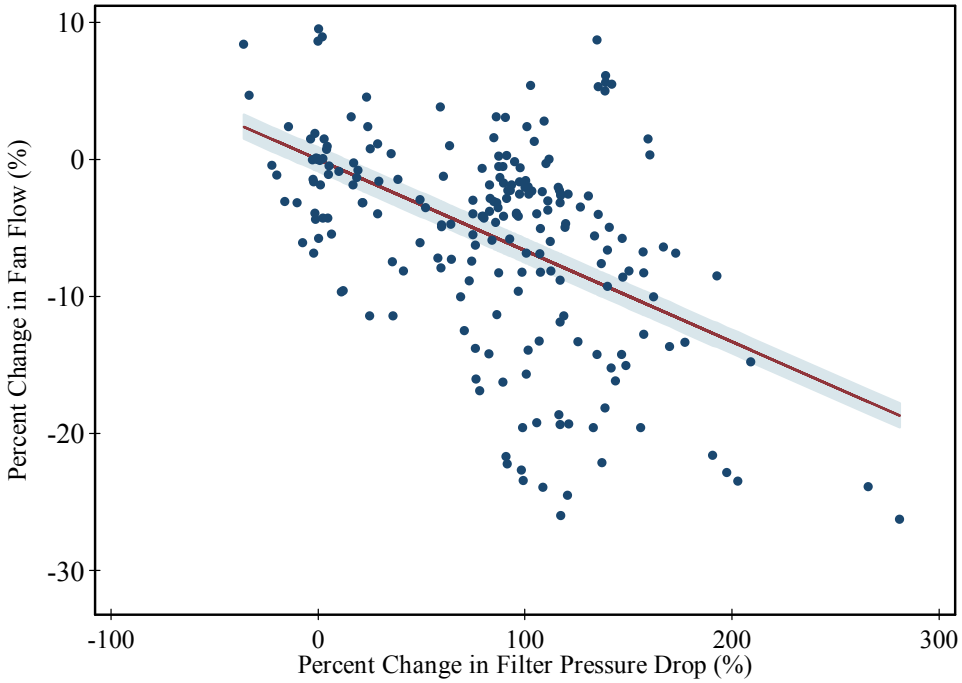


Figure 34. RQ2 regression for system airflow rate in the fan-only mode

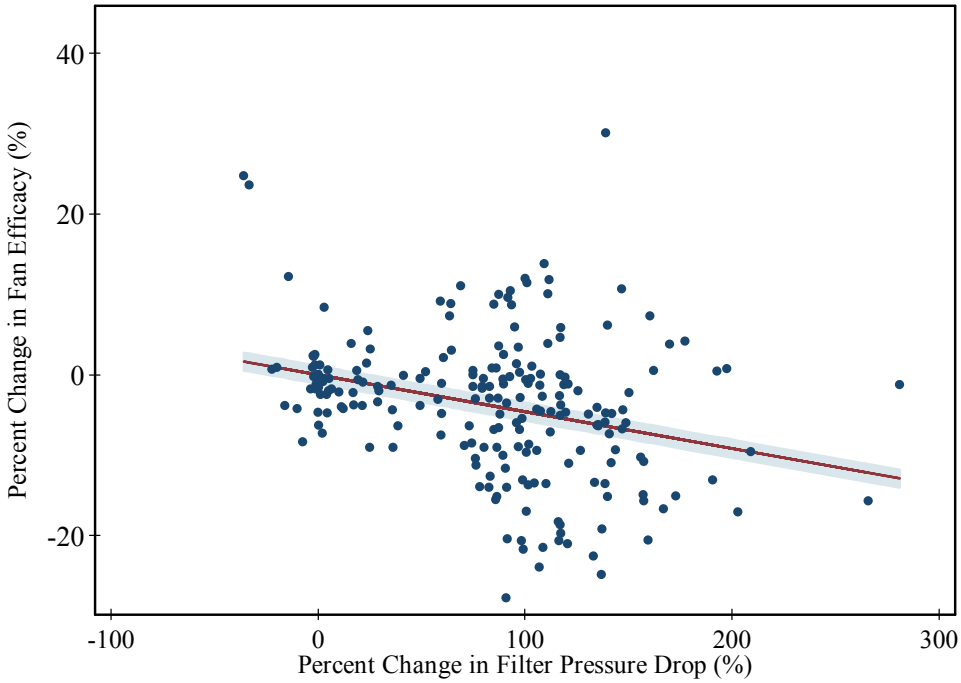


Figure 35. RQ2 regression for fan efficacy in the fan-only mode

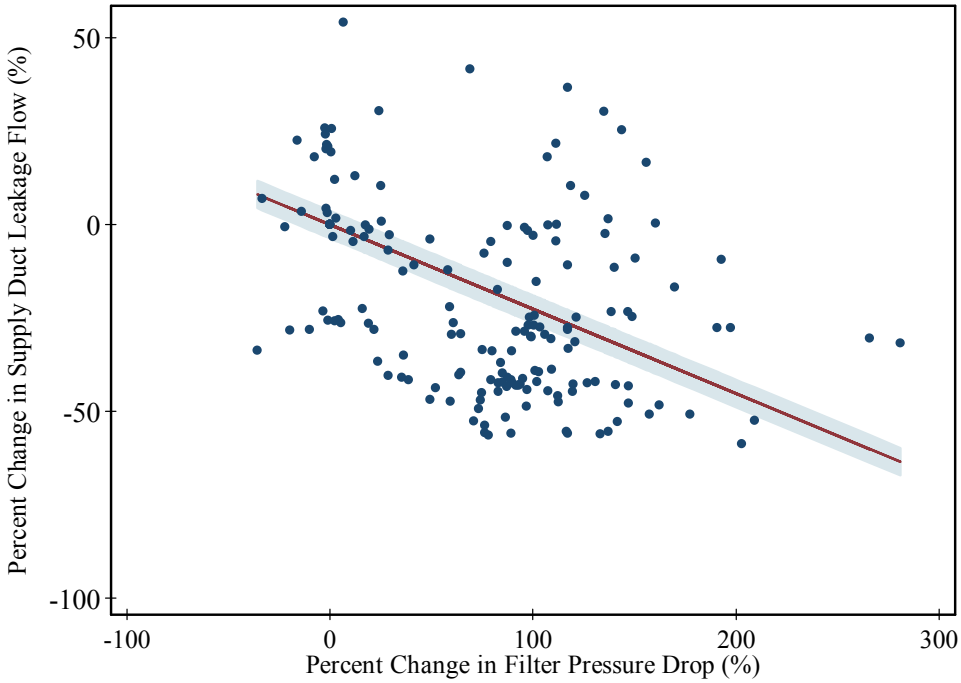


Figure 36. RQ2 regression for supply duct leakage flow in the fan-only mode

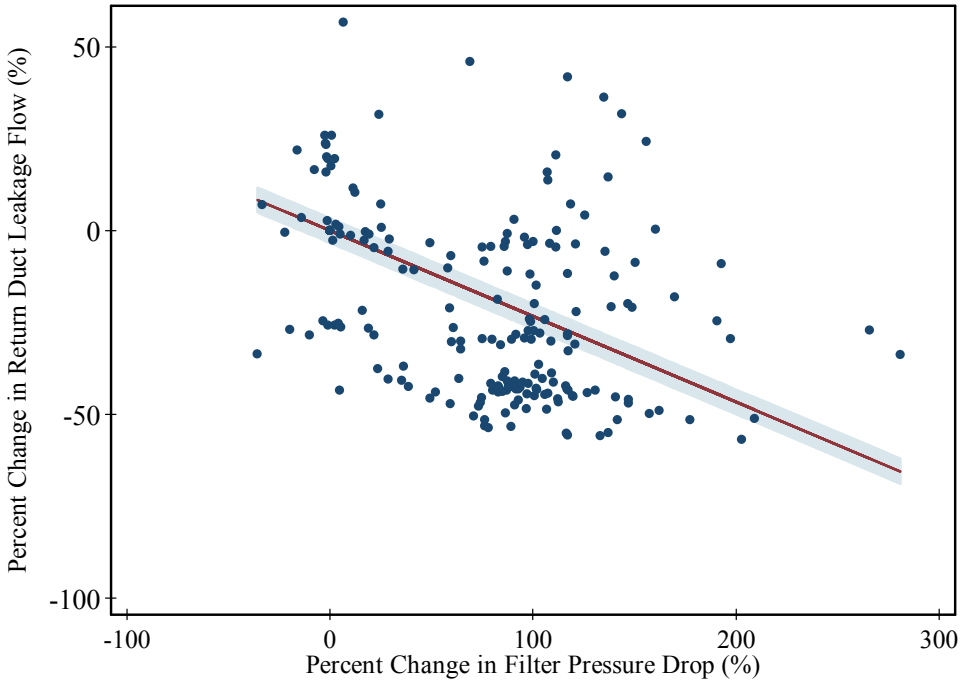


Figure 37. RQ2 regression for return duct leakage flow in the fan-only mode

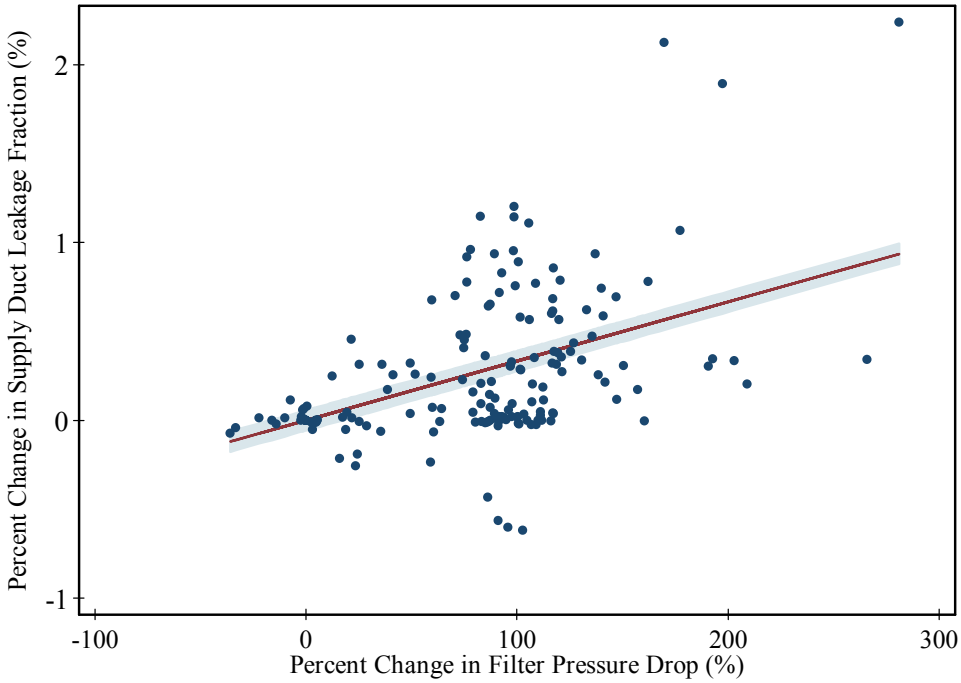


Figure 38. RQ2 regression for supply duct leakage fraction in the fan-only mode

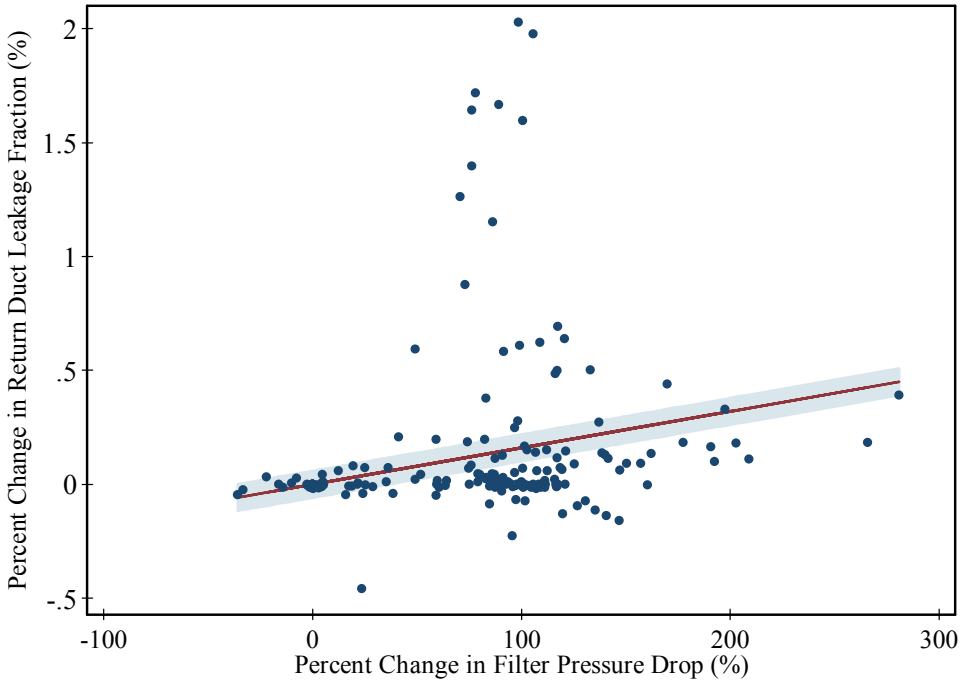


Figure 39. RQ2 regression for return duct leakage fraction in the fan-only mode

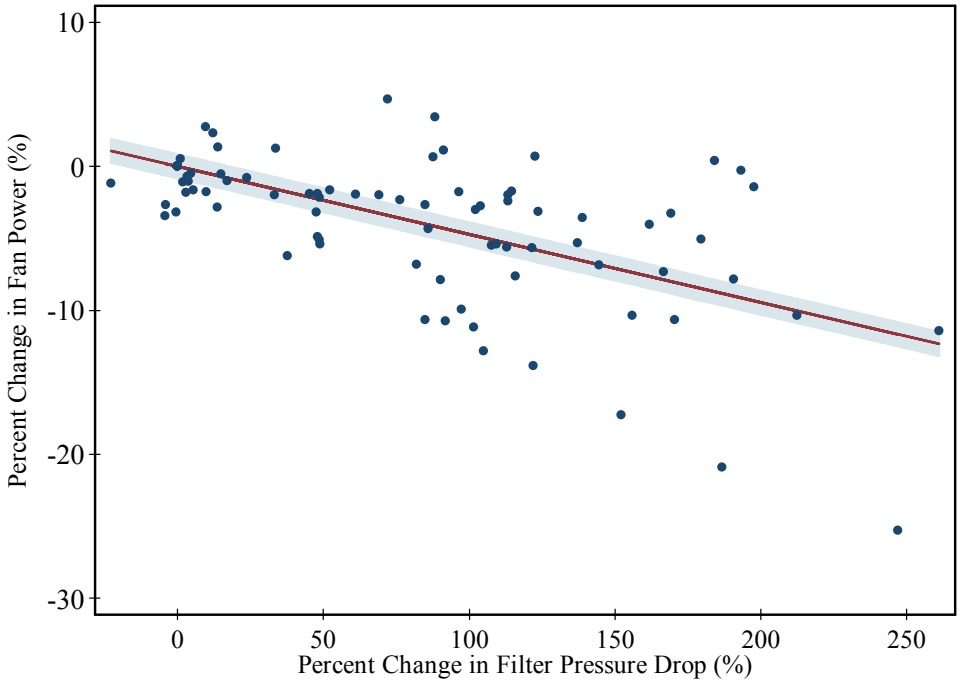


Figure 40. RQ2 regression for fan power draw in the cooling mode

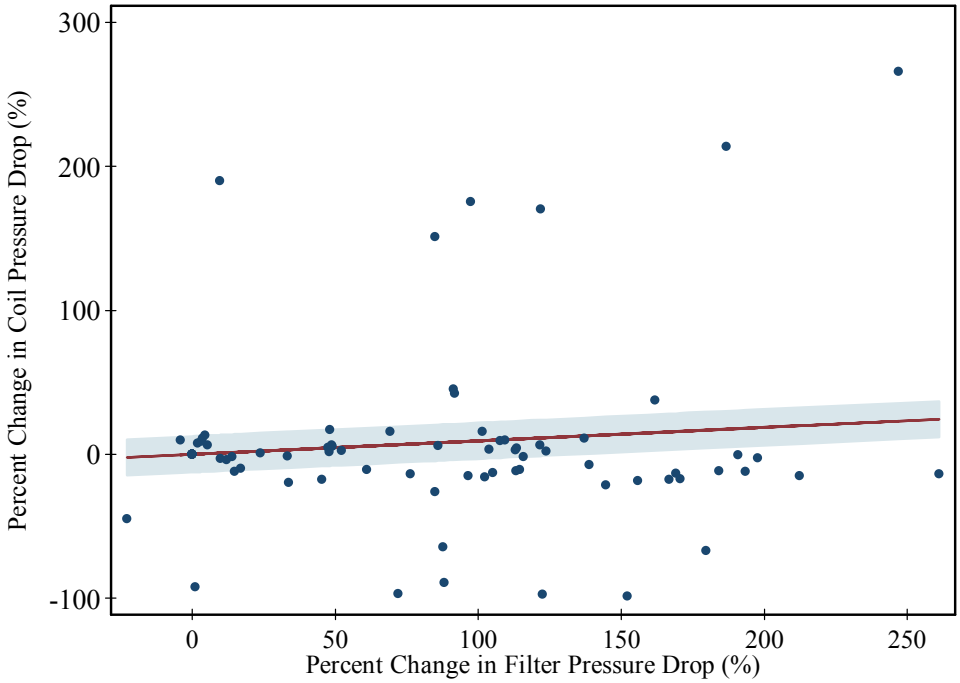


Figure 41. RQ2 regression for coil pressure drop in the cooling mode

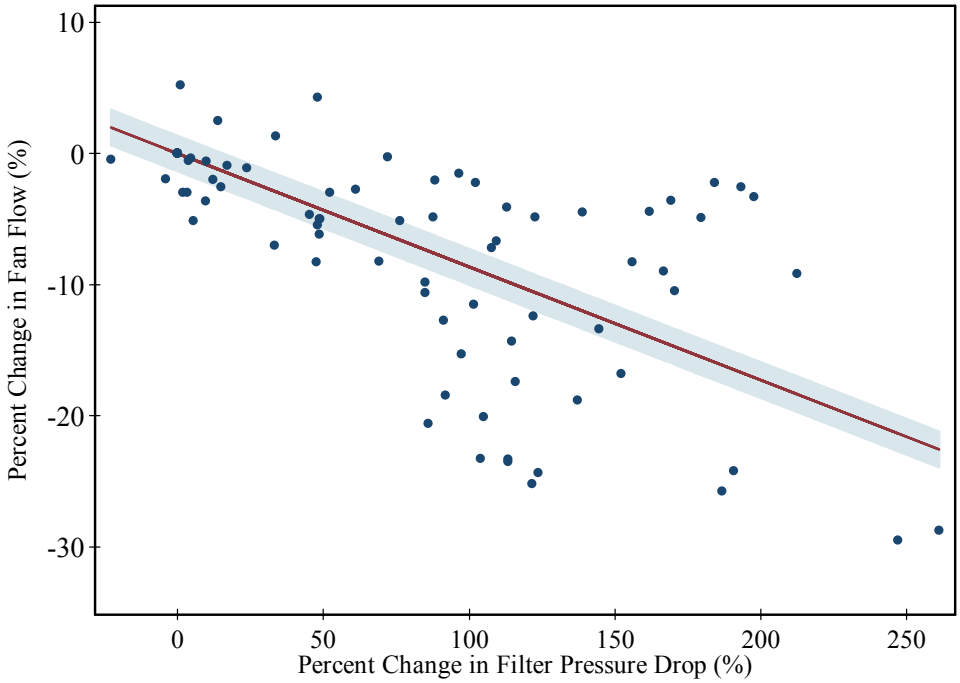


Figure 42. RQ2 regression for system airflow rate in the cooling mode

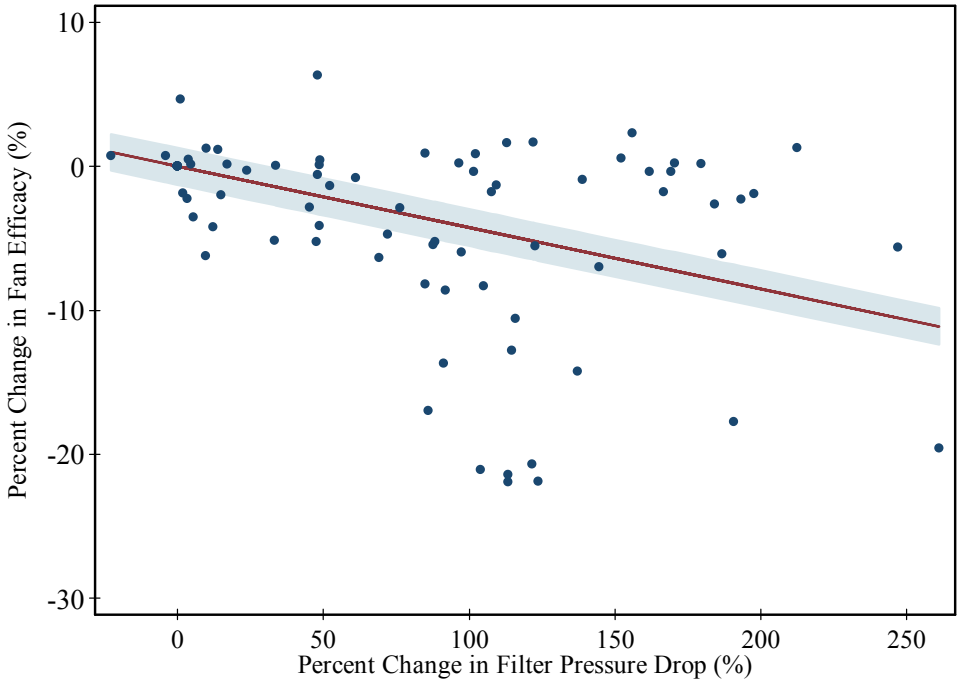


Figure 43. RQ2 regression for fan efficacy in the cooling mode

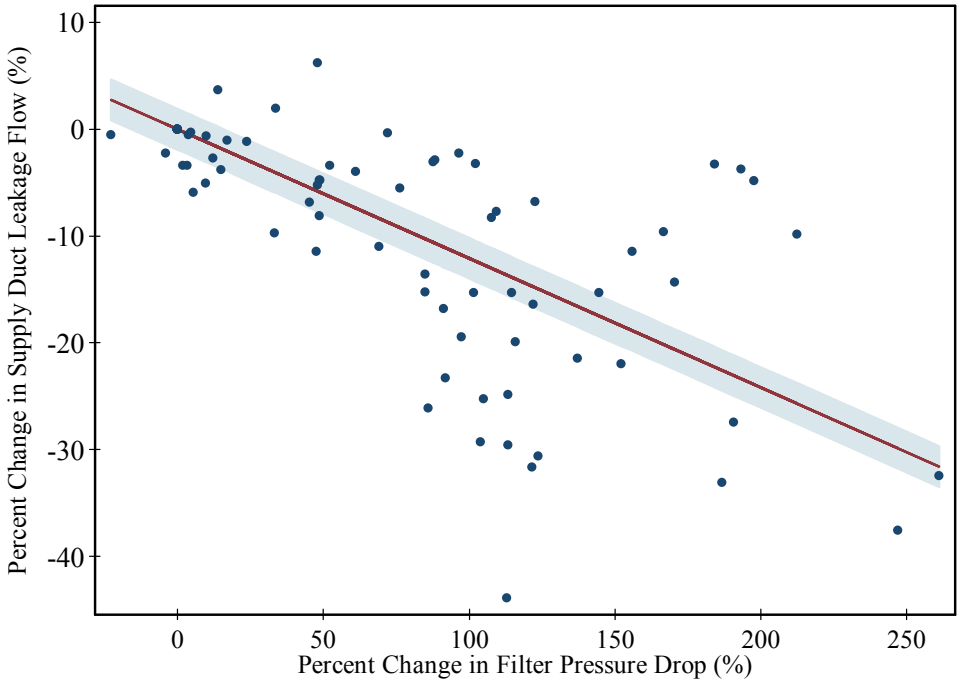


Figure 44. RQ2 regression for supply duct leakage flow in the cooling mode

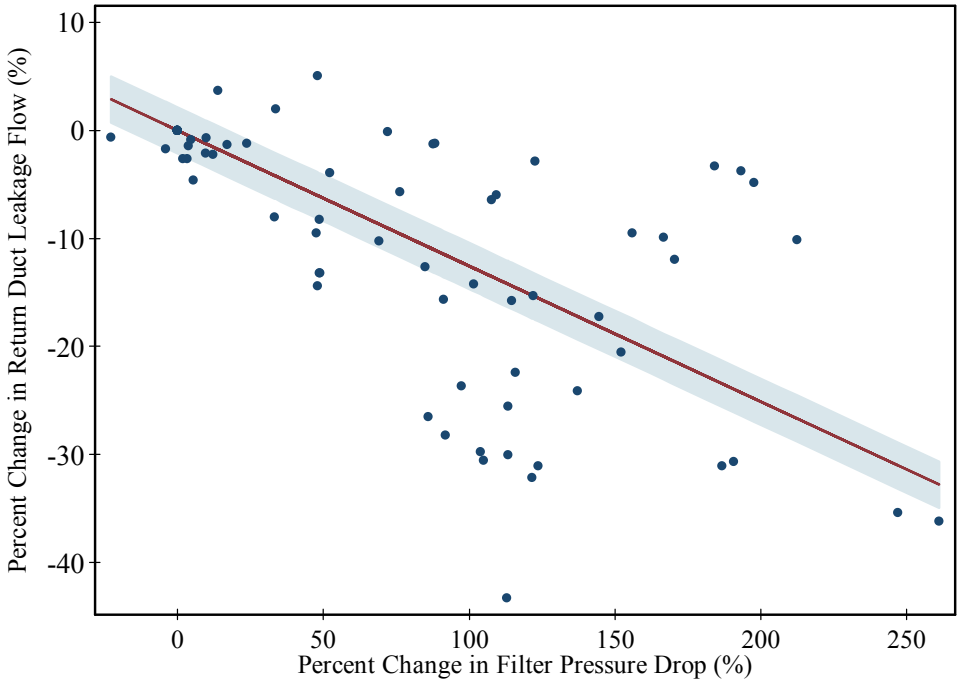


Figure 45. RQ2 regression for return duct leakage flow in the cooling mode

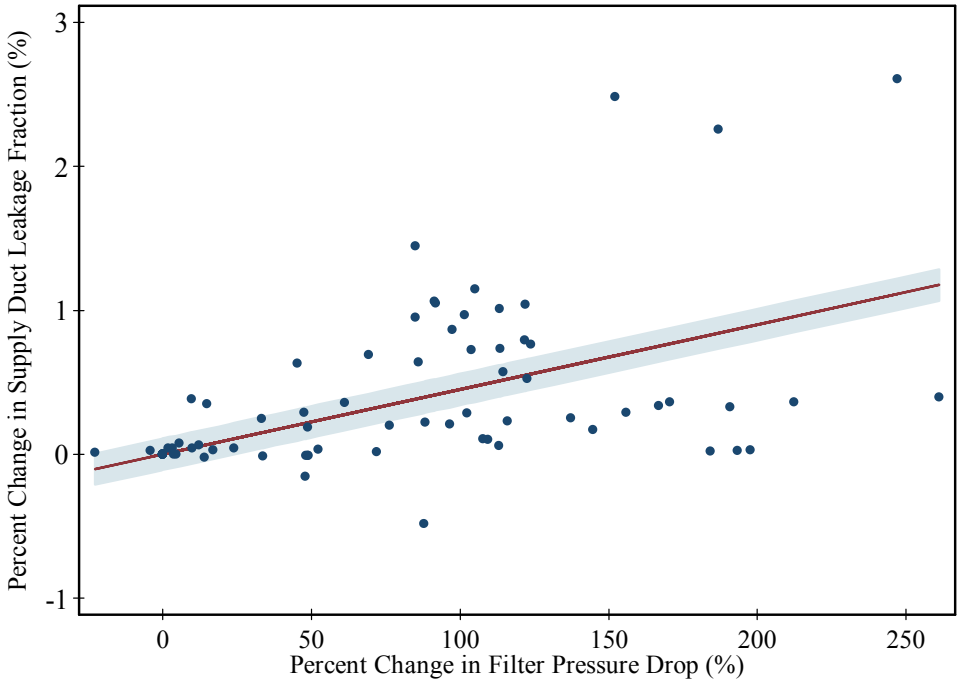


Figure 46. RQ2 regression for supply duct leakage fraction in the cooling mode

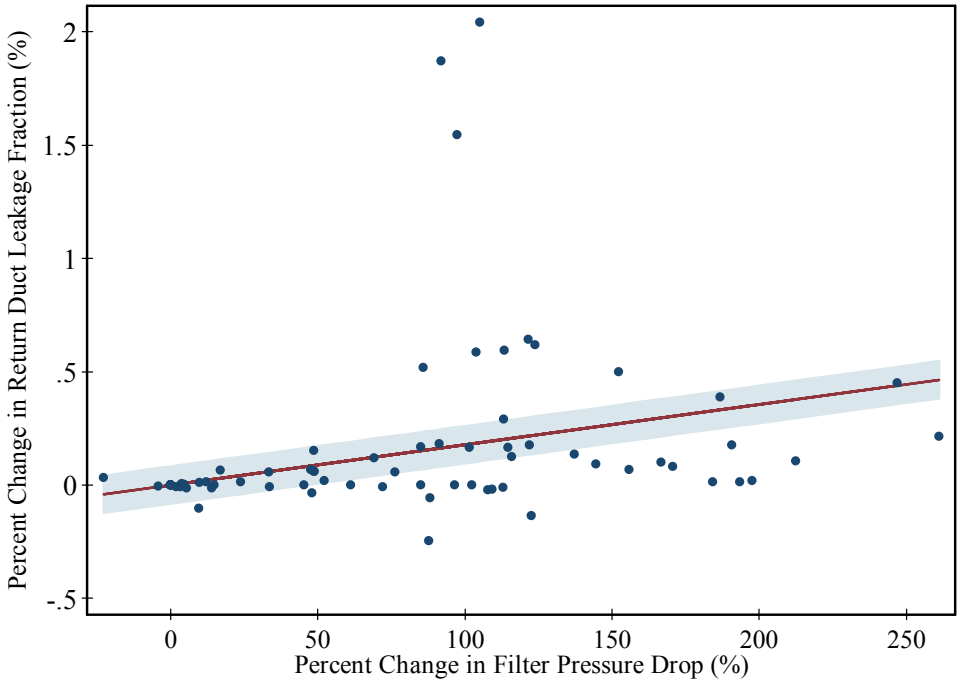


Figure 47. RQ2 regression for return duct leakage fraction in the cooling mode

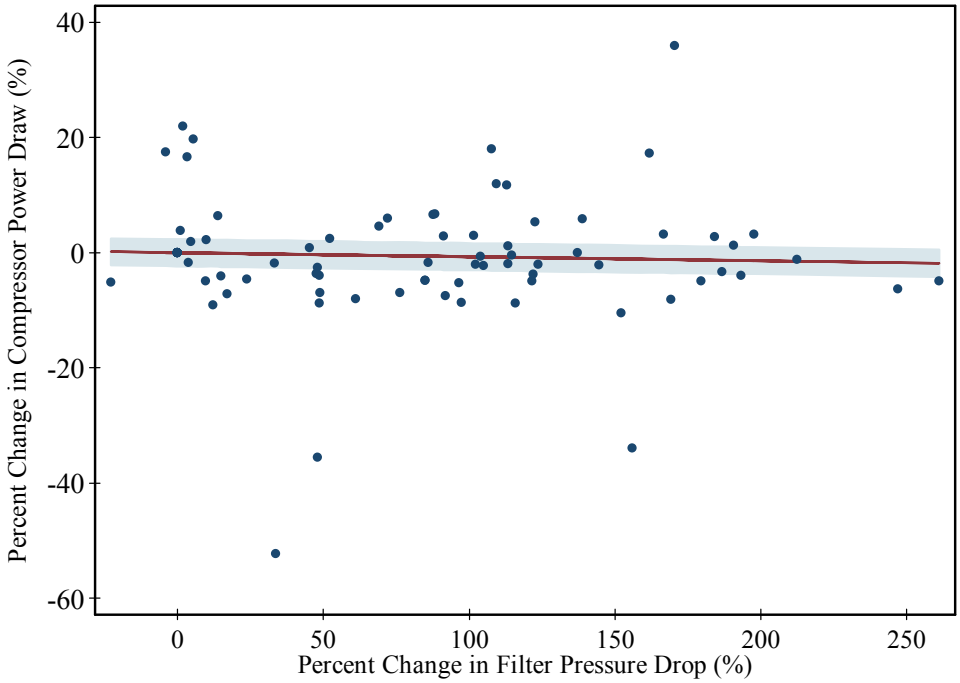


Figure 48. RQ2 regression for compressor power draw in the cooling mode

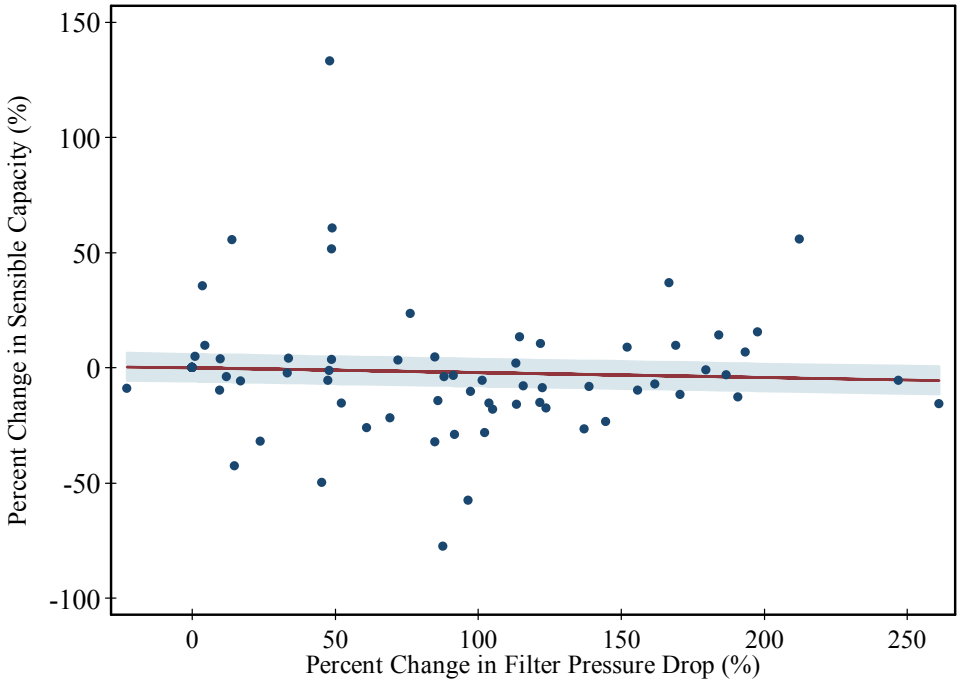


Figure 49. RQ2 regression for sensible capacity in the cooling mode

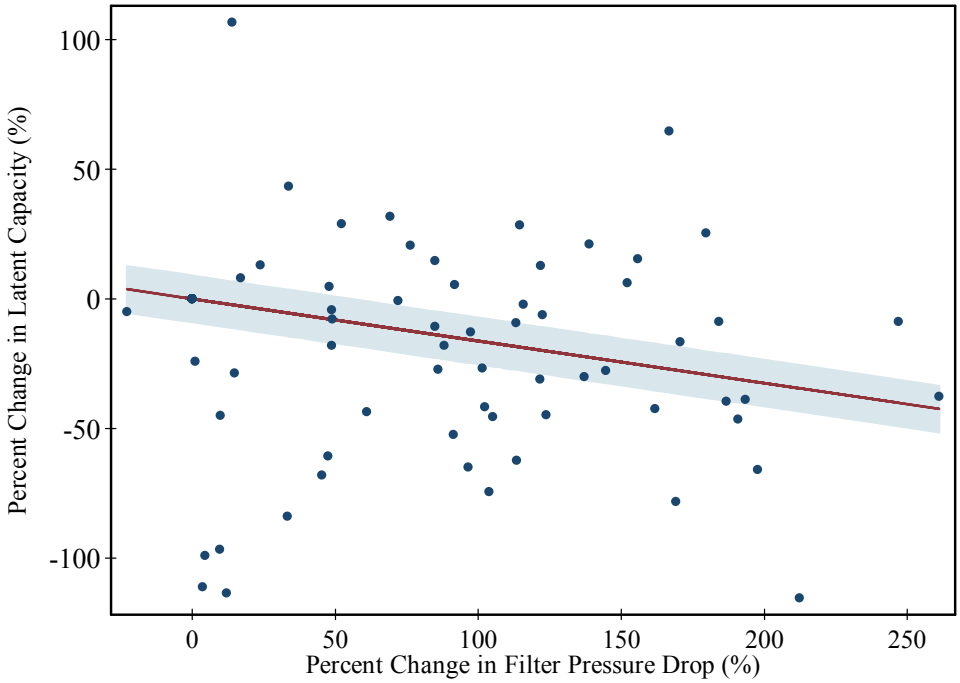


Figure 50. RQ2 regression for latent capacity in the cooling mode

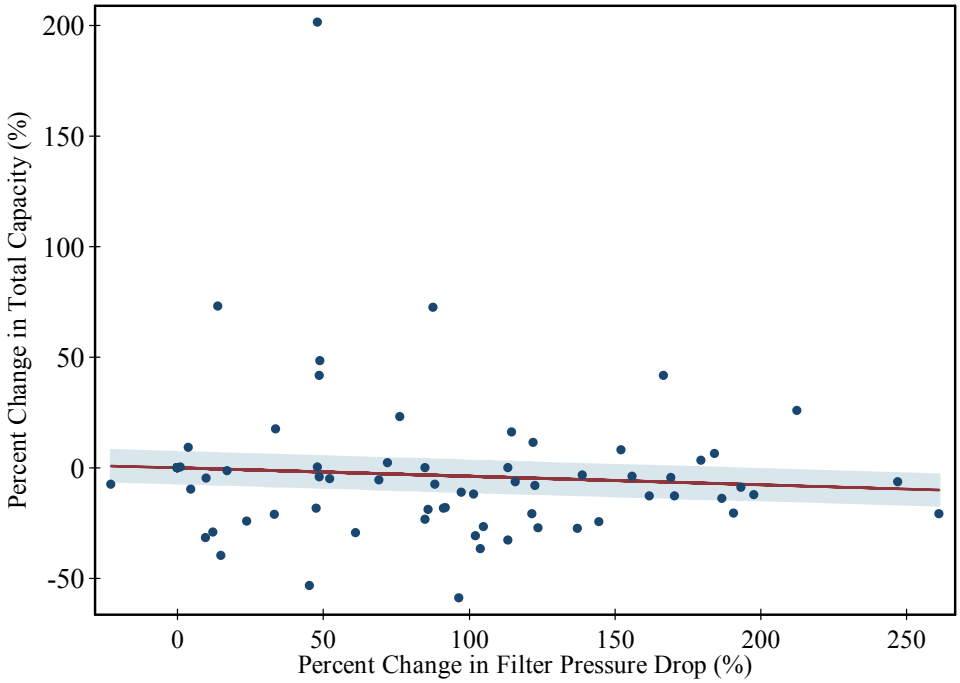


Figure 51. RQ2 regression for total capacity in the cooling mode

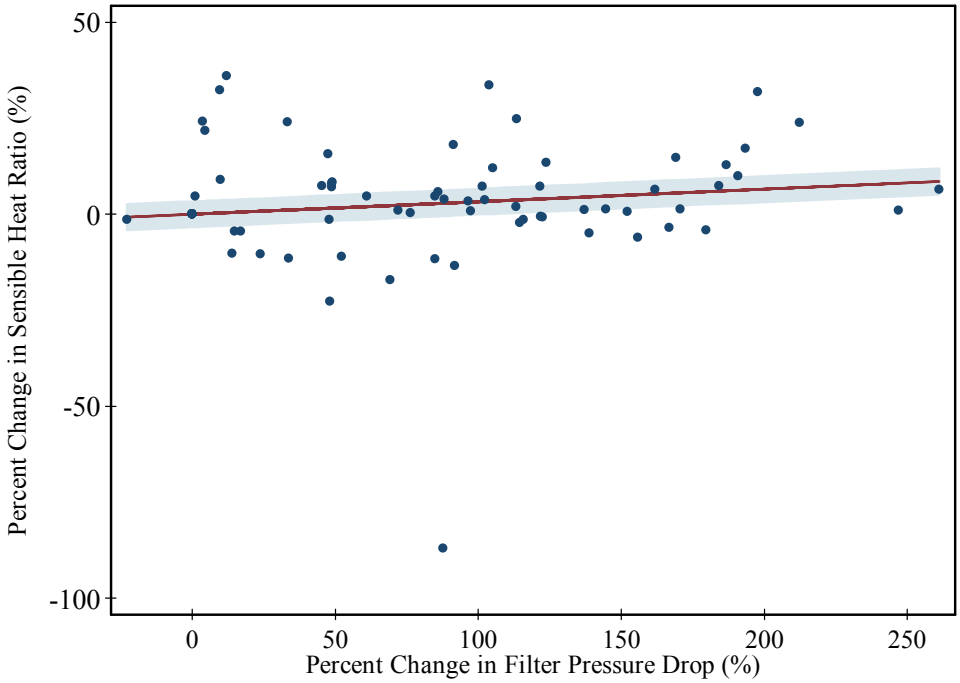


Figure 52. RQ2 regression for sensible heat ratio in the cooling mode

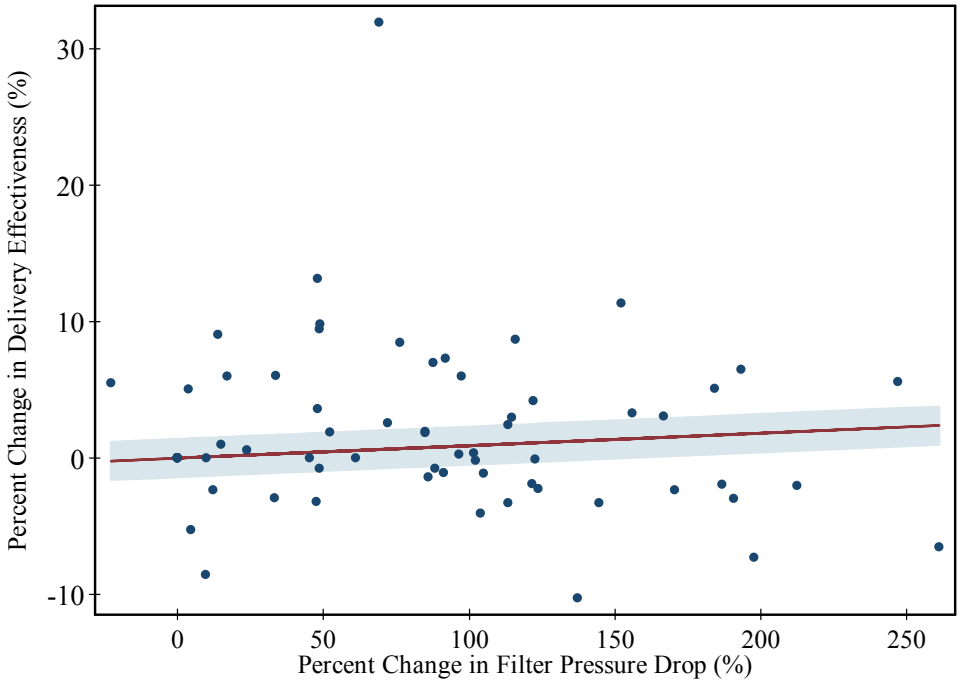


Figure 53. RQ2 regression for duct delivery effectiveness (DE) in the cooling

Appendix D: Full Tables for Field Sites (IP Units)

Appendix D.1: Filter Characteristics (IP)

Table 24. Filter Characteristics: Site 1 (IP)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]
1	2	0	0.102 ± 0.001*	0.237 ± 0.002*	0.088 ± 0.008	0.082 ± 0.003
2	2	30	0.087 ± 0.005	0.047 ± 0.003	0.117 ± 0.007	0.066 ± 0.003
3	2	59	0.068 ± 0.011	0.062 ± 0.010	0.100 ± 0.006	0.080 ± 0.009
4	2	88	0.065 ± 0.010	0.065 ± 0.013		
5	7	0	0.166 ± 0.004	0.053 ± 0.004		
6	7	35	0.188 ± 0.005	0.052 ± 0.005		
7	7	68	0.198 ± 0.005	0.051 ± 0.005		
8	7	95	0.204 ± 0.004	0.055 ± 0.004		
9	11	0	0.190 ± 0.005	0.044 ± 0.004		
10	11	29	0.213 ± 0.005	0.048 ± 0.004		
11	11	62	0.195 ± 0.005	0.041 ± 0.005		
12	11	91	0.197 ± 0.005	0.041 ± 0.005		
13	11	0	0.196 ± 0.012	0.048 ± 0.005		
14	11	27	0.204 ± 0.005	0.047 ± 0.005	0.249 ± 0.003*	0.073 ± 0.007
15	11	55	0.215 ± 0.006	0.048 ± 0.005	0.257 ± 0.007	0.072 ± 0.007
16	11	86	0.215 ± 0.003	0.054 ± 0.005	0.261 ± 0.006	0.080 ± 0.006

* Manual pressure reading from DG-700

Table 25. Filter Characteristics: Site 2 (IP)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]
1	2	0	0.206 ± 0.002	0.099 ± 0.003	0.219 ± 0.003	0.107 ± 0.003
2	2	27	0.160 ± 0.011	0.255 ± 0.003	0.169 ± 0.004	0.059 ± 0.022
3	2	59	0.246 ± 0.003	0.086 ± 0.003	0.256 ± 0.003	0.096 ± 0.001
4	2	93	0.254 ± 0.002	0.085 ± 0.003		
5	6	0	0.351 ± 0.001	0.077 ± 0.003		
6	6	26	0.362 ± 0.002	0.078 ± 0.003		
7	6	63	0.383 ± 0.001	0.104 ± 0.009		
8	6	93	0.307 ± 0.016	0.177 ± 0.017		
9	11	0	0.376 ± 0.002	0.065 ± 0.003		
10	11	22	0.356 ± 0.002	0.035 ± 0.003		
11	11	52	0.366 ± 0.002	0.078 ± 0.003		
12	11	84	0.362 ± 0.002	0.076 ± 0.003		
13	11	0	0.389 ± 0.002	0.078 ± 0.003		
14	11	29	0.409 ± 0.001	0.207 ± 0.029	0.420 ± 0.002	0.152 ± 0.045
15	11	56	0.412 ± 0.016	0.900 ± 0.047	0.432 ± 0.003	0.293 ± 0.066
16	11	83	0.423 ± 0.018	0.358 ± 0.042	0.449 ± 0.005	0.093 ± 0.050

Table 26. Filter Characteristics: Site 3 (IP)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]
1	11	0	0.139 ± 0.006	0.193 ± 0.010	0.149 ± 0.005	0.233 ± 0.009
2	11	27	0.142 ± 0.003	0.186 ± 0.002	0.150 ± 0.009	0.234 ± 0.015
3	11	56	0.146 ± 0.003	0.187 ± 0.004	0.152 ± 0.011	0.219 ± 0.017
4	11	82	0.146 ± 0.003	0.184 ± 0.003		
5	6	0	0.132 ± 0.003	0.181 ± 0.003		
6	6	31	0.133 ± 0.003	0.187 ± 0.003		
7	6	66	0.135 ± 0.003	0.188 ± 0.004		
8	6	99	0.137 ± 0.003	0.181 ± 0.004		
9	2	0	0.069 ± 0.005	0.187 ± 0.015		
10	2	23	0.070 ± 0.003	0.198 ± 0.002		
11	2	57	0.071 ± 0.000	0.180 ± 0.009		
12	2	84	0.066 ± 0.001	0.183 ± 0.004	0.069 ± 0.004	0.234 ± 0.016
13	2	0	0.066 ± 0.001	0.185 ± 0.004	0.071 ± 0.005	0.213 ± 0.017
14	2	34	0.066 ± 0.003	0.181 ± 0.004	0.073 ± 0.005	0.229 ± 0.016
15	2	60	0.067 ± 0.001	0.185 ± 0.005	0.074 ± 0.005	0.232 ± 0.017
16	2	78	0.068 ± 0.004	0.179 ± 0.004	0.075 ± 0.005	0.226 ± 0.017

Table 27. Filter Characteristics: Site 4 (IP)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]
1	11	0	0.356 ± 0.004	0.054 ± 0.001*	0.245 ± 0.012	0.055 ± 0.005
2	11	30	0.325 ± 0.011	0.037 ± 0.003	0.324 ± 0.015	0.059 ± 0.006
3	11	59	0.285 ± 0.001	0.031 ± 0.003	0.338 ± 0.016	0.056 ± 0.005
4	11	85	0.226 ± 0.002	0.027 ± 0.003		
5	6	0	0.253 ± 0.002	0.030 ± 0.003		
6	6	31	0.247 ± 0.007	0.028 ± 0.003		
7	6	66	0.240 ± 0.012	0.029 ± 0.003		
8	6	99	0.260 ± 0.001	0.029 ± 0.003		
9	2	0	0.136 ± 0.001	0.034 ± 0.003		
10	2	23	0.133 ± 0.002	0.034 ± 0.003		
11	2	57	0.110 ± 0.001	0.034 ± 0.003		
12	2	84	0.135 ± 0.006	0.038 ± 0.003	0.170 ± 0.008	0.079 ± 0.008
13	2	1	0.138 ± 0.001	0.039 ± 0.003	0.178 ± 0.008	0.059 ± 0.004
14	2	35	0.135 ± 0.001	0.042 ± 0.003	0.177 ± 0.008	0.070 ± 0.006
15	2	61	0.141 ± 0.001	0.041 ± 0.003	0.183 ± 0.008	0.069 ± 0.006
16	2	79	0.153 ± 0.001	0.044 ± 0.003	0.202 ± 0.011	0.069 ± 0.006

* Manual pressure reading from DG-700

Table 28. Filter Characteristics: Site 5 (IP)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]
1	2	0	0.132 ± 0.003	0.149 ± 0.022	0.132 ± 0.009	0.140 ± 0.009
2	2	27	0.198 ± 0.003	0.152 ± 0.008	0.201 ± 0.007	0.144 ± 0.011
3	2	57	0.293 ± 0.001	0.139 ± 0.010	0.285 ± 0.022	0.137 ± 0.015
4	2	87	0.341 ± 0.020	0.132 ± 0.011		
5	6	0	0.320 ± 0.001	0.136 ± 0.008		
6	6	27	0.409 ± 0.003	0.128 ± 0.009		
7	6	66	0.546 ± 0.030	0.113 ± 0.007		
8	6	96	0.636 ± 0.006	0.101 ± 0.006		
9	11	0	0.281 ± 0.001	0.142 ± 0.010		
10	11	35	0.327 ± 0.001	0.159 ± 0.013		
11	11	61	0.345 ± 0.001	0.142 ± 0.011	0.323 ± 0.016	0.110 ± 0.007
12	11	98	0.401 ± 0.001	0.125 ± 0.007		
13	11	0	0.316 ± 0.001	0.137 ± 0.007	0.314 ± 0.013	0.155 ± 0.011
14	11	29	0.385 ± 0.001	0.124 ± 0.006	0.384 ± 0.013	0.139 ± 0.011
15	11	63	0.484 ± 0.002	0.110 ± 0.006	0.477 ± 0.018	0.121 ± 0.010
16	11	92	0.598 ± 0.001	0.100 ± 0.005	0.582 ± 0.029	0.118 ± 0.008

Table 29. Filter Characteristics: Site 6 (IP)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]
1	7	0	0.195 ± 0.058	0.032 ± 0.013	0.258 ± 0.015	0.074 ± 0.007
2	7	34	0.309 ± 0.058	0.129 ± 0.024	0.350 ± 0.018	0.146 ± 0.008
3	7	63	0.452 ± 0.004	0.102 ± 0.004		
4	7	90	0.456 ± 0.002	0.099 ± 0.003		
5	2	0	0.186 ± 0.002	0.131 ± 0.003		
6	2	28	0.214 ± 0.002	0.130 ± 0.003		
7	2	64	0.237 ± 0.003	0.127 ± 0.003		
8	2	98	0.249 ± 0.002	0.121 ± 0.003		
9	2	0	0.181 ± 0.013	0.128 ± 0.009		
10	2	28	0.202 ± 0.002	0.132 ± 0.003		
11	2	63	0.236 ± 0.001	0.125 ± 0.003		
12	2	87	0.289 ± 0.002	0.118 ± 0.003		
13	11	0	0.397 ± 0.010	0.106 ± 0.003	0.381 ± 0.020	0.138 ± 0.008
14	11	33	0.430 ± 0.023	0.101 ± 0.005	0.421 ± 0.020	0.131 ± 0.007
15	11	60	0.446 ± 0.021	0.098 ± 0.003	0.435 ± 0.023	0.125 ± 0.008
16	11	103	0.469 ± 0.004	0.105 ± 0.002	0.456 ± 0.018	0.127 ± 0.005

Table 30. Filter Characteristics: Site 7 (IP)

Visit	Filter MERV	Filter Age [days]	Fan Only Mode: Filter Pressure Drop [in. H_2O]	Fan Only Mode: Coil Pressure Drop [in. H_2O]	Cooling Mode: Filter Pressure Drop [in. H_2O]	Cooling Mode: Coil Pressure Drop [in. H_2O]
1	2	0	0.144 ± 0.003	0.452 ± 0.007	0.139 ± 0.003	0.488 ± 0.005
2	2	34	0.203 ± 0.017	0.479 ± 0.040	0.206 ± 0.001	0.515 ± 0.004
3	2	62	0.229 ± 0.018	0.487 ± 0.023		
4	2	87	0.250 ± 0.010	0.475 ± 0.002		
5	6	0	0.283 ± 0.001	0.462 ± 0.002		
6	6	25	0.305 ± 0.001	0.462 ± 0.002		
7	6	65	0.335 ± 0.001	0.197 ± 0.050		
8	6	92	0.358 ± 0.001	0.470 ± 0.002		
9	11	0	0.275 ± 0.001	0.497 ± 0.002		
10	11	36	0.312 ± 0.001	0.470 ± 0.003		
11	11	69	0.311 ± 0.001	0.468 ± 0.002		
12	11	96	0.317 ± 0.001	0.473 ± 0.005	0.310 ± 0.003	0.499 ± 0.006
13	11	0	0.275 ± 0.001	0.485 ± 0.005	0.258 ± 0.004	0.516 ± 0.006
14	11	33	0.286 ± 0.001	0.487 ± 0.005	0.283 ± 0.004	0.504 ± 0.007
15	11	62	0.300 ± 0.001	0.485 ± 0.005	0.296 ± 0.003	0.508 ± 0.004
16	11	92	0.312 ± 0.001	0.488 ± 0.005	0.307 ± 0.002	0.519 ± 0.004

Table 31. Filter Characteristics: Site 8 (IP)

Visit	Filter MERV	Filter Age	Fan Only Mode		Cooling Mode	
			Filter Pressure Drop	Coil Pressure Drop	Filter Pressure Drop	Coil Pressure Drop
		[days]	[in. H_2O]	[in. H_2O]	[in. H_2O]	[in. H_2O]
1	2	0	0.087 ± 0.004	0.055 ± 0.003	0.091 ± 0.005	0.059 ± 0.003
2	2	31	0.102 ± 0.003	0.037 ± 0.002	0.100 ± 0.009	0.172 ± 0.022
3	2	62	0.118 ± 0.005	0.127 ± 0.020		
4	2	88	0.121 ± 0.003	0.068 ± 0.003		
5	6	0	0.191 ± 0.003	0.065 ± 0.003		
6	6	28	0.201 ± 0.003	0.064 ± 0.003		
7	6	63	0.210 ± 0.003	0.064 ± 0.003		
8	6	91	0.215 ± 0.003	0.064 ± 0.003		
9	11	0	0.197 ± 0.003	0.067 ± 0.003		
10	11	37	0.177 ± 0.003	0.143 ± 0.029		
11	11	69	0.176 ± 0.003	0.113 ± 0.009		
12	11	99	0.161 ± 0.025	0.060 ± 0.019		
13	11	0	0.205 ± 0.003	0.041 ± 0.007	0.203 ± 0.010	0.002 ± 0.003
14	11	30	0.170 ± 0.003	0.087 ± 0.015	0.171 ± 0.008	0.021 ± 0.027
15	11	56	0.163 ± 0.003	0.252 ± 0.024	0.157 ± 0.009	0.002 ± 0.002
16	11	98	0.172 ± 0.003	0.098 ± 0.045	0.171 ± 0.004	0.006 ± 0.009

Table 32. Filter Characteristics: Site 9 (IP)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop† [in. H_2O]	Coil Pressure Drop [in. H_2O]	Filter Pressure Drop† [in. H_2O]	Coil Pressure Drop [in. H_2O]
1	7	0	0.220 ± 0.025	0.372 ± 0.035	0.233 ± 0.026	0.389 ± 0.035
2	7	28	0.287 ± 0.030	0.356 ± 0.034	0.340 ± 0.031	0.403 ± 0.029
3	7	58	0.298 ± 0.012	0.396 ± 0.009		
4	7	82	0.308 ± 0.014	0.384 ± 0.010		
5	11	0	0.328 ± 0.015	0.369 ± 0.009		
6	11	44	0.329 ± 0.015	0.368 ± 0.009		
7	11	81	0.329 ± 0.009	0.353 ± 0.014		
8	11	126	0.279 ± 0.026	0.406 ± 0.020		
9	2	0	0.245 ± 0.006	0.408 ± 0.007		
10	2	11	0.242 ± 0.005	0.409 ± 0.010		
11	2	50	0.231 ± 0.006	0.433 ± 0.009	0.236 ± 0.017	0.346 ± 0.096
12	2	97	0.209 ± 0.005	0.452 ± 0.008		
13	11	0	0.264 ± 0.006	0.415 ± 0.007	0.273 ± 0.016	0.451 ± 0.026
14	11	32	0.263 ± 0.006	0.115 ± 0.066	0.275 ± 0.017	0.205 ± 0.122
15	11	64	0.267 ± 0.006	0.444 ± 0.010	0.275 ± 0.022	0.447 ± 0.036
16	11	92	0.266 ± 0.005	0.432 ± 0.010	0.272 ± 0.017	0.467 ± 0.032

† Measuring return plenum pressure drop rather than directly across the filter

Table 33. Filter Characteristics: Site 10 (IP)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]
1	2	0	0.063 ± 0.003	0.217 ± 0.046	0.063 ± 0.004	0.248 ± 0.017
2	2	29	0.063 ± 0.001	0.212 ± 0.011	0.063 ± 0.004	0.020 ± 0.030
3	2	58	0.063 ± 0.003	0.375 ± 0.007		
4	2	82	0.064 ± 0.003	0.387 ± 0.008		
5	6	0	0.147 ± 0.009	0.345 ± 0.037		
6	6	44	0.148 ± 0.001	0.364 ± 0.005		
7	6	81	0.152 ± 0.001	0.352 ± 0.007		
8	6	109	0.150 ± 0.003	0.363 ± 0.005		
9	11	0	0.150 ± 0.003	0.367 ± 0.005		
10	11	28	0.150 ± 0.003	0.353 ± 0.009		
11	11	62	0.147 ± 0.003	0.918 ± 0.016	0.149 ± 0.006	0.230 ± 0.077
12	11	114	0.151 ± 0.003	0.696 ± 0.050		
13	7	0	0.162 ± 0.003	0.790 ± 0.042		
14	7	32	0.161 ± 0.004	0.513 ± 0.008	0.164 ± 0.007	0.341 ± 0.078
15	7	64	0.168 ± 0.003	0.708 ± 0.007*	0.168 ± 0.012	0.215 ± 0.073
16	7	92	0.171 ± 0.003	0.566 ± 0.006*	0.175 ± 0.013	0.082 ± 0.060

* Manual pressure reading from DG-700

Table 34. Filter Characteristics: Site 11 (IP)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]
1	2	0	0.108 ± 0.002	0.319 ± 0.002	0.101 ± 0.003	0.322 ± 0.010
2	2	30	0.111 ± 0.014	0.290 ± 0.037	0.111 ± 0.003	0.312 ± 0.006
3	2	57	0.135 ± 0.008	0.314 ± 0.018	0.125 ± 0.003	0.325 ± 0.002
4	2	86	0.139 ± 0.003	0.309 ± 0.003*		
5	6	0	0.197 ± 0.003	0.300 ± 0.001		
6	6	29	0.204 ± 0.003	0.296 ± 0.001		
7	6	65	0.193 ± 0.003	0.253 ± 0.003		
8	6	93	0.223 ± 0.002	0.251 ± 0.003		
9	11	0	0.201 ± 0.002	0.252 ± 0.003		
10	11	27	0.193 ± 0.003	0.269 ± 0.002	0.177 ± 0.024	0.278 ± 0.004
11	11	60	0.217 ± 0.003	0.279 ± 0.002	0.216 ± 0.006	0.288 ± 0.006
12	11	94	0.255 ± 0.003	0.269 ± 0.003		
13	6	0	0.213 ± 0.002	0.279 ± 0.003	0.215 ± 0.002	0.285 ± 0.004
14	6	30	0.269 ± 0.002	0.258 ± 0.003	0.268 ± 0.003	0.266 ± 0.003
15	6	64	0.315 ± 0.002	0.265 ± 0.002	0.314 ± 0.004	0.274 ± 0.002

* Manual pressure reading from DG-700

Table 35. Filter Characteristics: Site 12 (IP)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop† [in. H_2O]	Coil Pressure Drop [in. H_2O]	Filter Pressure Drop† [in. H_2O]	Coil Pressure Drop [in. H_2O]
1	12	0	n/a	n/a	0.294 ± 0.020	0.093 ± 0.006
2	12	35	0.177 ± 0.068	0.079 ± 0.033		
3	12	59	0.282 ± 0.004	0.080 ± 0.003		
4	12	87	0.284 ± 0.005	0.084 ± 0.003		
5	11	0	0.277 ± 0.005	0.084 ± 0.003		
6	11	36	0.276 ± 0.028	0.082 ± 0.008		
7	11	72	0.289 ± 0.004	0.083 ± 0.003		
8	11	98	0.284 ± 0.017	0.081 ± 0.005		
9	11	0	0.278 ± 0.004	0.084 ± 0.003		
10	11	35	0.276 ± 0.005	0.081 ± 0.003		
11	11	61	0.289 ± 0.005	0.070 ± 0.003	0.326 ± 0.006	0.082 ± 0.003
12	11	93	0.301 ± 0.005	0.074 ± 0.003		
13	11	0	0.280 ± 0.005	0.076 ± 0.003	0.309 ± 0.011	0.084 ± 0.003
14	11	27	0.286 ± 0.005	0.075 ± 0.003	0.313 ± 0.007	0.082 ± 0.003
15	11	71	0.282 ± 0.004	0.073 ± 0.003	0.311 ± 0.007	0.083 ± 0.003

† Measuring return plenum pressure drop rather than directly across the filter

Table 36. Filter Characteristics: Site 13 (IP)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]
1	6	0	0.301 ± 0.004	0.245 ± 0.008	0.340 ± 0.010	0.272 ± 0.012
2	6	30	0.337 ± 0.019	0.233 ± 0.036		
3	6	63	0.375 ± 0.003	0.271 ± 0.021		
4	6	98	0.448 ± 0.004	0.328 ± 0.019		
5	11	0	0.260 ± 0.003	0.254 ± 0.015		
6	11	25	0.299 ± 0.002	0.264 ± 0.029		
7	11	56	0.324 ± 0.002	0.300 ± 0.018		
8	11	86	0.371 ± 0.002	0.284 ± 0.018	0.405 ± 0.012	0.271 ± 0.019
9	2	0	0.171 ± 0.002	0.184 ± 0.017	0.201 ± 0.008	0.235 ± 0.019
10	2	32	0.312 ± 0.003	0.282 ± 0.003*	0.384 ± 0.008	0.340 ± 0.003*
11	2	62	0.508 ± 0.004	0.660 ± 0.007*	0.577 ± 0.017	0.736 ± 0.007*
12	2	94	0.651 ± 0.004	0.791 ± 0.009	0.698 ± 0.025	0.858 ± 0.033
13	11	0	0.320 ± 0.003	0.499 ± 0.007	0.372 ± 0.014	0.589 ± 0.008
14	11	30	0.410 ± 0.003	0.571 ± 0.006*	0.446 ± 0.006	0.634 ± 0.006*
15	11	57	0.461 ± 0.004	0.641 ± 0.007*	0.507 ± 0.033	0.717 ± 0.007*
16	11	87	0.474 ± 0.004	0.644 ± 0.007*		

* Manual pressure reading from DG-700

Table 37. Filter Characteristics: Site 14 (IP)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]
1	7	0	0.317 ± 0.002	0.293 ± 0.014		
2	7	26	0.326 ± 0.003	0.315 ± 0.010		
3	7	55	0.316 ± 0.002	0.294 ± 0.008		
4	7	91	0.319 ± 0.004	0.315 ± 0.010		
5	2	0	0.230 ± 0.002	0.299 ± 0.008		
6	2	28	0.236 ± 0.002	0.305 ± 0.014		
7	2	55	0.242 ± 0.002	0.301 ± 0.012		
8	2	87	0.247 ± 0.015	0.290 ± 0.024	0.241 ± 0.011	0.311 ± 0.021
9	11	0	0.434 ± 0.003	0.242 ± 0.012	0.416 ± 0.014	0.251 ± 0.016
10	11	30	0.448 ± 0.003	0.235 ± 0.008	0.440 ± 0.008	0.254 ± 0.011
11	7	0	0.223 ± 0.003	0.303 ± 0.015	0.217 ± 0.008	0.303 ± 0.016
12	7	28	0.248 ± 0.002	0.305 ± 0.015	0.240 ± 0.005	0.321 ± 0.016
13	7	58	0.270 ± 0.002	0.294 ± 0.019		
14	2	0	0.167 ± 0.001	0.283 ± 0.012	0.163 ± 0.006	0.306 ± 0.017
15	2	28	0.184 ± 0.003	0.288 ± 0.007	0.182 ± 0.007	0.295 ± 0.014
16	2	62	0.179 ± 0.004	0.287 ± 0.007		

Table 38. Filter Characteristics: Site 15 (IP)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]
1	7	0	0.170 ± 0.002*	0.018 ± 0.001*		
2	7	39	0.172 ± 0.003	0.018 ± 0.003		
3	7	67	0.174 ± 0.003	0.018 ± 0.003		
4	7	98	0.180 ± 0.002	0.017 ± 0.003		
5	11	0	0.188 ± 0.002	0.016 ± 0.003		
6	11	30	0.184 ± 0.003	0.016 ± 0.003		
7	11	59	0.181 ± 0.010	0.014 ± 0.003	0.178 ± 0.005	0.014 ± 0.003
8	11	92	0.176 ± 0.004	0.015 ± 0.003		
9	2	0	0.091 ± 0.003	0.019 ± 0.003	0.096 ± 0.003	0.018 ± 0.003
10	2	36	0.111 ± 0.003	0.016 ± 0.003	0.111 ± 0.003	0.016 ± 0.003
11	2	62	0.146 ± 0.001	0.015 ± 0.003	0.140 ± 0.002	0.015 ± 0.003
12	2	92	0.160 ± 0.001	0.015 ± 0.003	0.155 ± 0.002	0.017 ± 0.003
13	7	0	0.202 ± 0.002	0.016 ± 0.003	0.195 ± 0.004	0.016 ± 0.003
14	7	28	0.190 ± 0.001	0.016 ± 0.003	0.190 ± 0.003	0.016 ± 0.003
15	7	60	0.198 ± 0.001	0.017 ± 0.003		
16	7	90	0.199 ± 0.002	0.016 ± 0.003		

* Manual pressure reading from DG-700

Table 39. Filter Characteristics: Site 16 (IP)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]
1	6	0	0.202 ± 0.003	0.185 ± 0.004		
2	6	35	0.228 ± 0.001	0.155 ± 0.005		
3	6	66	0.221 ± 0.012	0.175 ± 0.015		
4	6	104	0.238 ± 0.002	0.185 ± 0.007		
5	11	0	0.211 ± 0.010	0.182 ± 0.010		
6	11	31	0.226 ± 0.018	0.196 ± 0.007		
7	11	59	0.210 ± 0.001	0.194 ± 0.002*	0.478 ± 0.008	0.546 ± 0.005*
8	11	87	0.231 ± 0.001	0.156 ± 0.009		
9	2	0	0.110 ± 0.001	0.153 ± 0.011	0.323 ± 0.010	0.466 ± 0.029
10	2	28	0.115 ± 0.001	0.153 ± 0.010	0.335 ± 0.009	0.518 ± 0.034
11	2	56	0.116 ± 0.001	0.176 ± 0.005	0.338 ± 0.009	0.527 ± 0.021
12	2	84	0.115 ± 0.001	0.182 ± 0.006		
13	11	0	0.205 ± 0.002	0.185 ± 0.003	0.480 ± 0.018	0.495 ± 0.020
14	11	33	0.205 ± 0.001	0.178 ± 0.003	0.481 ± 0.019	0.493 ± 0.022
15	11	64	0.199 ± 0.001	0.166 ± 0.003		
16	11	90	0.210 ± 0.001	0.157 ± 0.003		

* Manual pressure reading from DG-700

Table 40. Filter Characteristics: Site 17 (IP)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]
1	6	0	0.155 ± 0.003	0.125 ± 0.003		
2	6	35	0.138 ± 0.003	0.133 ± 0.003		
3	6	66	0.135 ± 0.003	0.146 ± 0.003		
4	6	104	0.155 ± 0.001	0.142 ± 0.003		
5	11	0	0.099 ± 0.001	0.183 ± 0.003		
6	11	31	0.114 ± 0.003	0.195 ± 0.001		
7	11	59	0.117 ± 0.000	0.208 ± 0.002*	0.274 ± 0.004	0.703 ± 0.007*
8	11	87	0.135 ± 0.001	0.179 ± 0.017		
9	2	0	0.006 ± 0.003	0.182 ± 0.001	0.023 ± 0.003	0.660 ± 0.016
10	2	28	0.005 ± 0.003	0.194 ± 0.001	0.016 ± 0.003	0.747 ± 0.025
11	2	56	0.003 ± 0.003	0.200 ± 0.001	0.008 ± 0.003	0.771 ± 0.029
12	2	84	0.005 ± 0.003	0.211 ± 0.001		
13	11	0	0.083 ± 0.000	0.230 ± 0.004	0.204 ± 0.005	0.641 ± 0.020
14	11	33	0.092 ± 0.003	0.182 ± 0.001	0.202 ± 0.006	0.659 ± 0.025
15	11	64	0.079 ± 0.003	0.193 ± 0.001		
16	11	90	0.084 ± 0.003	0.192 ± 0.001		

* Manual pressure reading from DG-700

Appendix D.2: Fan Characteristics (IP)

Table 41. Fan Characteristics: Site 1 (IP)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]
1	2	0	1010 ± 70	470 ± 5	2.16 ± 0.15	1210 ± 80	581 ± 7	2.07 ± 0.15
2	2	30	1040 ± 70	429 ± 5	2.42 ± 0.17	1220 ± 90	589 ± 7	2.07 ± 0.15
3	2	59	1060 ± 70	398 ± 4	2.66 ± 0.19	1240 ± 90	589 ± 7	2.10 ± 0.15
4	2	88	1100 ± 80	408 ± 5	2.69 ± 0.19			
5	7	0	1020 ± 70	442 ± 5	2.31 ± 0.16			
6	7	35	1030 ± 70	439 ± 5	2.34 ± 0.17			
7	7	68	1010 ± 70	442 ± 5	2.28 ± 0.16			
8	7	95	1040 ± 70	431 ± 5	2.40 ± 0.17			
9	11	0	1010 ± 70	428 ± 5	2.37 ± 0.17			
10	11	29	1040 ± 70	424 ± 5	2.45 ± 0.17			
11	11	62	990 ± 70	419 ± 5	2.36 ± 0.17			
12	11	91	990 ± 70	424 ± 5	2.34 ± 0.17			
13	11	0	990 ± 70	415 ± 5	2.38 ± 0.17			
14	11	27	990 ± 70	411 ± 5	2.41 ± 0.17	1180 ± 80	584 ± 7	2.02 ± 0.14
15	11	55	1010 ± 70	420 ± 5	2.41 ± 0.17	1170 ± 80	580 ± 6	2.03 ± 0.14
16	11	86	980 ± 70	414 ± 5	2.37 ± 0.17	1170 ± 80	573 ± 6	2.03 ± 0.14

Table 42. Fan Characteristics: Site 2 (IP)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]
1	2	0	1100 ± 80	343 ± 4	3.21 ± 0.23	1110 ± 80	358 ± 4	3.11 ± 0.22
2	2	27	1100 ± 80	339 ± 4	3.23 ± 0.23	1110 ± 80	353 ± 4	3.13 ± 0.22
3	2	59	1090 ± 80	342 ± 4	3.19 ± 0.23	1100 ± 80	354 ± 4	3.11 ± 0.22
4	2	93	1150 ± 80	353 ± 4	3.26 ± 0.23			
5	6	0	960 ± 70	329 ± 4	2.93 ± 0.21			
6	6	26	950 ± 70	330 ± 4	2.88 ± 0.20			
7	6	63	980 ± 70	334 ± 4	2.92 ± 0.21			
8	6	93	1030 ± 70	323 ± 4	3.20 ± 0.23			
9	11	0	1060 ± 70	335 ± 4	3.17 ± 0.22			
10	11	22	1000 ± 70	333 ± 4	3.01 ± 0.21			
11	11	52	920 ± 60	331 ± 4	2.76 ± 0.20			
12	11	84	920 ± 60	324 ± 4	2.85 ± 0.20			
13	11	0	920 ± 60	319 ± 4	2.89 ± 0.20			
14	11	29	890 ± 60	317 ± 4	2.79 ± 0.20	910 ± 60	319 ± 4	2.84 ± 0.20
15	11	56	930 ± 60	320 ± 4	2.90 ± 0.21	940 ± 70	322 ± 4	2.92 ± 0.21
16	11	83	890 ± 60	306 ± 3	2.91 ± 0.21	890 ± 60	312 ± 3	2.85 ± 0.20

Table 43. Fan Characteristics: Site 3 (IP)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]
1	11	0	860 ± 60	393 ± 4	2.18 ± 0.15	910 ± 60	425 ± 5	2.13 ± 0.15
2	11	27	890 ± 60	386 ± 4	2.30 ± 0.16	910 ± 60	425 ± 5	2.14 ± 0.15
3	11	56	890 ± 60	385 ± 4	2.32 ± 0.16	940 ± 70	424 ± 5	2.20 ± 0.16
4	11	82	900 ± 60	383 ± 4	2.34 ± 0.17			
5	6	0	890 ± 60	394 ± 4	2.24 ± 0.16			
6	6	31	910 ± 60	408 ± 5	2.22 ± 0.16			
7	6	66	910 ± 60	412 ± 5	2.20 ± 0.16			
8	6	99	900 ± 60	402 ± 5	2.24 ± 0.16			
9	2	0	920 ± 60	420 ± 5	2.20 ± 0.16			
10	2	23	930 ± 60	430 ± 5	2.16 ± 0.15			
11	2	57	920 ± 60	416 ± 5	2.20 ± 0.16			
12	2	84	910 ± 60	401 ± 4	2.27 ± 0.16	960 ± 70	437 ± 5	2.19 ± 0.15
13	2	0	920 ± 60	412 ± 5	2.23 ± 0.16	980 ± 70	449 ± 5	2.17 ± 0.15
14	2	34	890 ± 60	395 ± 4	2.24 ± 0.16	950 ± 70	444 ± 5	2.13 ± 0.15
15	2	60	880 ± 60	405 ± 5	2.18 ± 0.15	950 ± 70	446 ± 5	2.12 ± 0.15
16	2	78	870 ± 60	398 ± 4	2.18 ± 0.15	930 ± 60	442 ± 5	2.09 ± 0.15

Table 44. Fan Characteristics: Site 4 (IP)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]
1	11	3	650 ± 50	n/a	n/a	650 ± 50	326 ± 4	1.98 ± 0.14
2	11	30	590 ± 40	314 ± 4	1.87 ± 0.13	650 ± 50	324 ± 4	1.99 ± 0.14
3	11	59	580 ± 40	234 ± 3	2.49 ± 0.18	650 ± 50	320 ± 4	2.02 ± 0.14
4	11	85	590 ± 40	230 ± 3	2.57 ± 0.18			
5	6	0	600 ± 40	238 ± 3	2.51 ± 0.18			
6	6	31	610 ± 40	246 ± 3	2.48 ± 0.18			
7	6	66	610 ± 40	244 ± 3	2.50 ± 0.18			
8	6	99	610 ± 40	248 ± 3	2.46 ± 0.17			
9	2	0	640 ± 40	258 ± 3	2.46 ± 0.17			
10	2	23	650 ± 50	264 ± 3	2.45 ± 0.17			
11	2	57	630 ± 40	250 ± 3	2.51 ± 0.18			
12	2	84	630 ± 40	245 ± 3	2.55 ± 0.18	720 ± 50	336 ± 4	2.15 ± 0.15
13	2	1	640 ± 40	252 ± 3	2.52 ± 0.18	740 ± 50	348 ± 4	2.13 ± 0.15
14	2	35	590 ± 40	238 ± 3	2.48 ± 0.18	690 ± 50	337 ± 4	2.06 ± 0.15
15	2	61	610 ± 40	245 ± 3	2.48 ± 0.18	710 ± 50	342 ± 4	2.07 ± 0.15
16	2	79	570 ± 40	240 ± 3	2.39 ± 0.17	670 ± 50	338 ± 4	1.98 ± 0.14

Table 45. Fan Characteristics: Site 5 (IP)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]
1	2	0	1280 ± 90	674 ± 8	1.89 ± 0.13	1340 ± 90	660 ± 7	2.03 ± 0.14
2	2	27	1240 ± 90	680 ± 8	1.82 ± 0.13	1300 ± 90	649 ± 7	2.00 ± 0.14
3	2	57	1030 ± 70	611 ± 7	1.69 ± 0.12	1110 ± 80	610 ± 7	1.81 ± 0.13
4	2	87	1110 ± 80	659 ± 7	1.69 ± 0.12			
5	6	0	1080 ± 80	642 ± 7	1.69 ± 0.12			
6	6	27	1090 ± 80	635 ± 7	1.71 ± 0.12			
7	6	66	1010 ± 70	608 ± 7	1.67 ± 0.12			
8	6	96	1000 ± 70	590 ± 7	1.69 ± 0.12			
9	11	0	1170 ± 80	649 ± 7	1.81 ± 0.13			
10	11	35	1170 ± 80	644 ± 7	1.81 ± 0.13			
11	11	61	1280 ± 90	630 ± 7	2.03 ± 0.14	1160 ± 80	615 ± 7	1.89 ± 0.13
12	11	98	980 ± 70	622 ± 7	1.57 ± 0.11			
13	11	0	1050 ± 70	638 ± 7	1.64 ± 0.12	1090 ± 80	625 ± 7	1.74 ± 0.12
14	11	29	1000 ± 70	608 ± 7	1.65 ± 0.12	1020 ± 70	608 ± 7	1.67 ± 0.12
15	11	63	970 ± 70	609 ± 7	1.60 ± 0.11	950 ± 70	585 ± 7	1.63 ± 0.12
16	11	92	870 ± 60	592 ± 7	1.47 ± 0.10	890 ± 60	566 ± 6	1.56 ± 0.11

Table 46. Fan Characteristics: Site 6 (IP)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]
1	7	0	1080 ± 80	604 ± 7	1.78 ± 0.13	1090 ± 80	586 ± 7	1.85 ± 0.13
2	7	34	1030 ± 70	508 ± 6	2.02 ± 0.14	990 ± 70	565 ± 6	1.75 ± 0.12
3	7	63	980 ± 70	486 ± 5	2.01 ± 0.14			
4	7	90	970 ± 70	567 ± 6	1.71 ± 0.12			
5	2	0	1120 ± 80	631 ± 7	1.77 ± 0.13			
6	2	28	1120 ± 80	630 ± 7	1.77 ± 0.13			
7	2	64	1120 ± 80	630 ± 7	1.78 ± 0.13			
8	2	98	1050 ± 70	607 ± 7	1.74 ± 0.12			
9	2	0	1160 ± 80	624 ± 7	1.86 ± 0.13			
10	2	28	1130 ± 80	635 ± 7	1.78 ± 0.13			
11	2	63	1090 ± 80	624 ± 7	1.75 ± 0.12			
12	2	87	1060 ± 70	601 ± 7	1.76 ± 0.12			
13	11	0	1000 ± 70	583 ± 7	1.72 ± 0.12	980 ± 70	555 ± 6	1.76 ± 0.12
14	11	33	980 ± 70	574 ± 6	1.70 ± 0.12	960 ± 70	554 ± 6	1.73 ± 0.12
15	11	60	960 ± 70	580 ± 6	1.65 ± 0.12	950 ± 70	539 ± 6	1.76 ± 0.12
16	11	103	920 ± 60	562 ± 6	1.63 ± 0.12	900 ± 60	533 ± 6	1.69 ± 0.12

Table 47. Fan Characteristics: Site 7 (IP)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]
1	2	0	830 ± 60	433 ± 5	1.92 ± 0.14	830 ± 60	419 ± 5	1.97 ± 0.14
2	2	34	760 ± 50	398 ± 4	1.92 ± 0.14	780 ± 50	410 ± 5	1.89 ± 0.13
3	2	62	770 ± 50	431 ± 5	1.78 ± 0.13			
4	2	87	770 ± 50	438 ± 5	1.76 ± 0.12			
5	6	0	750 ± 50	430 ± 5	1.75 ± 0.12			
6	6	25	780 ± 50	438 ± 5	1.78 ± 0.13			
7	6	65	670 ± 50	449 ± 5	1.49 ± 0.11			
8	6	92	650 ± 50	n/a	n/a			
9	11	0	680 ± 50	n/a	n/a			
10	11	36	670 ± 50	429 ± 5	1.56 ± 0.11			
11	11	69	680 ± 50	444 ± 5	1.52 ± 0.11			
12	11	96	630 ± 40	414 ± 5	1.52 ± 0.11	630 ± 40	406 ± 5	1.54 ± 0.11
13	11	0	650 ± 50	423 ± 5	1.53 ± 0.11	660 ± 50	401 ± 4	1.64 ± 0.12
14	11	33	640 ± 40	423 ± 5	1.50 ± 0.11	630 ± 40	408 ± 5	1.56 ± 0.11
15	11	62	630 ± 40	419 ± 5	1.51 ± 0.11	630 ± 40	411 ± 5	1.54 ± 0.11
16	11	92	620 ± 40	399 ± 4	1.54 ± 0.11	620 ± 40	395 ± 4	1.56 ± 0.11

Table 48. Fan Characteristics: Site 8 (IP)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]
1	2	0	750 ± 50	422 ± 5	1.76 ± 0.13	740 ± 50	425 ± 5	1.74 ± 0.12
2	2	31	740 ± 50	438 ± 5	1.70 ± 0.12	720 ± 50	437 ± 5	1.64 ± 0.12
3	2	62	750 ± 50	430 ± 5	1.74 ± 0.12			
4	2	88	730 ± 50	444 ± 5	1.65 ± 0.12			
5	6	0	710 ± 50	422 ± 5	1.68 ± 0.12			
6	6	28	730 ± 50	432 ± 5	1.68 ± 0.12			
7	6	63	710 ± 50	434 ± 5	1.63 ± 0.12			
8	6	91	700 ± 50	427 ± 5	1.64 ± 0.12			
9	11	0	720 ± 50	450 ± 5	1.60 ± 0.11			
10	11	37	790 ± 50	447 ± 5	1.76 ± 0.12			
11	11	69	730 ± 50	451 ± 5	1.61 ± 0.11			
12	11	99	720 ± 50	439 ± 5	1.64 ± 0.12			
13	11	0	720 ± 50	433 ± 5	1.65 ± 0.12	710 ± 50	429 ± 5	1.65 ± 0.12
14	11	30	720 ± 50	431 ± 5	1.66 ± 0.12	710 ± 50	428 ± 5	1.65 ± 0.12
15	11	56	740 ± 50	450 ± 5	1.65 ± 0.12	740 ± 50	445 ± 5	1.66 ± 0.12
16	11	98	730 ± 50	442 ± 5	1.64 ± 0.12	730 ± 50	440 ± 5	1.65 ± 0.12

Table 49. Fan Characteristics: Site 9 (IP)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]
1	7	0	1900 ± 130	767 ± 9	2.47 ± 0.18	1920 ± 130	784 ± 9	2.45 ± 0.17
2	7	28	1900 ± 130	732 ± 8	2.59 ± 0.18			
3	7	58	1930 ± 140	777 ± 9	2.48 ± 0.18			
4	7	82	1990 ± 140	796 ± 9	2.50 ± 0.18			
5	11	0	1870 ± 130	789 ± 9	2.37 ± 0.17			
6	11	44	1910 ± 130	786 ± 9	2.42 ± 0.17			
7	11	81	1910 ± 130	781 ± 9	2.45 ± 0.17			
8	11	126	1950 ± 140	775 ± 9	2.51 ± 0.18			
9	2	0	1990 ± 140	782 ± 9	2.54 ± 0.18			
10	2	11	2010 ± 140	793 ± 9	2.53 ± 0.18			
11	2	50	2080 ± 150	776 ± 9	2.68 ± 0.19	2120 ± 150	778 ± 9	2.72 ± 0.19
12	2	97	2060 ± 140	770 ± 9	2.68 ± 0.19			
13	11	0	2030 ± 140	755 ± 8	2.68 ± 0.19	2070 ± 140	768 ± 9	2.69 ± 0.19
14	11	32	2010 ± 140	770 ± 9	2.61 ± 0.19	2050 ± 140	774 ± 9	2.65 ± 0.19
15	11	64	2050 ± 140	790 ± 9	2.60 ± 0.18	2090 ± 150	787 ± 9	2.65 ± 0.19
16	11	92	2000 ± 140	762 ± 9	2.62 ± 0.19	2040 ± 140	770 ± 9	2.65 ± 0.19

Table 50. Fan Characteristics: Site 10 (IP)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]
1	2	0	1270 ± 90	591 ± 7	2.14 ± 0.15	1250 ± 90	696 ± 8	1.79 ± 0.13
2	2	29	1390 ± 100	691 ± 8	2.01 ± 0.14	1310 ± 90	700 ± 8	1.87 ± 0.13
3	2	58	1380 ± 100	674 ± 8	2.04 ± 0.14			
4	2	82	1380 ± 100	695 ± 8	1.99 ± 0.14			
5	6	0	1380 ± 100	670 ± 8	2.05 ± 0.15			
6	6	44	1330 ± 90	665 ± 7	2.00 ± 0.14			
7	6	81	1340 ± 90	655 ± 7	2.04 ± 0.14			
8	6	109	1330 ± 90	660 ± 7	2.01 ± 0.14			
9	11	0	1340 ± 90	659 ± 7	2.04 ± 0.14			
10	11	28	1340 ± 90	480 ± 5	2.79 ± 0.20			
11	11	62	1200 ± 80	645 ± 7	1.85 ± 0.13	1190 ± 80	671 ± 8	1.77 ± 0.13
12	11	114	1180 ± 80	651 ± 7	1.82 ± 0.13			
13	7	0	1160 ± 80	644 ± 7	1.80 ± 0.13			
14	7	32	1180 ± 80	648 ± 7	1.82 ± 0.13	1190 ± 80	668 ± 7	1.78 ± 0.13
15	7	64	1190 ± 80	665 ± 7	1.78 ± 0.13	1200 ± 80	673 ± 8	1.78 ± 0.13
16	7	92	1180 ± 80	649 ± 7	1.82 ± 0.13	1190 ± 80	661 ± 7	1.79 ± 0.13

Table 51. Fan Characteristics: Site 11 (IP)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]
1	2	0	1490 ± 100	668 ± 7	2.24 ± 0.16	1540 ± 110	681 ± 8	2.25 ± 0.16
2	2	30	1520 ± 110	625 ± 7	2.42 ± 0.17	1530 ± 110	669 ± 7	2.28 ± 0.16
3	2	57	1500 ± 110	652 ± 7	2.31 ± 0.16	1520 ± 110	675 ± 8	2.25 ± 0.16
4	2	86	1510 ± 110	685 ± 8	2.20 ± 0.16			
5	6	0	1470 ± 100	675 ± 8	2.17 ± 0.15			
6	6	29	1490 ± 100	668 ± 7	2.22 ± 0.16			
7	6	65	1480 ± 100	675 ± 8	2.20 ± 0.16			
8	6	93	1420 ± 100	664 ± 7	2.14 ± 0.15			
9	11	0	1440 ± 100	663 ± 7	2.17 ± 0.15			
10	11	27	1430 ± 100	649 ± 7	2.20 ± 0.16	1460 ± 100	665 ± 7	2.19 ± 0.16
11	11	60	1290 ± 90	666 ± 7	1.93 ± 0.14	1320 ± 90	669 ± 7	1.97 ± 0.14
12	11	94	1160 ± 80	643 ± 7	1.81 ± 0.13			
13	6	0	1150 ± 80	650 ± 7	1.77 ± 0.13	1180 ± 80	664 ± 7	1.77 ± 0.13
14	6	30	1370 ± 100	627 ± 7	2.19 ± 0.16	1400 ± 100	631 ± 7	2.21 ± 0.16
15	6	64	1370 ± 100	608 ± 7	2.25 ± 0.16	1390 ± 100	610 ± 7	2.28 ± 0.16

Table 52. Fan Characteristics: Site 12 (IP)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]
1	12	0	1440 ± 100	n/a	n/a	n/a	1071 ± 12	n/a
2	12	35	1330 ± 90	821 ± 9	1.62 ± 0.11			
3	12	59	1290 ± 90	815 ± 9	1.58 ± 0.11			
4	12	87	1340 ± 90	833 ± 9	1.61 ± 0.11			
5	11	0	1320 ± 90	835 ± 9	1.58 ± 0.11			
6	11	36	1350 ± 90	817 ± 9	1.65 ± 0.12			
7	11	72	1340 ± 90	823 ± 9	1.63 ± 0.12			
8	11	98	1340 ± 90	814 ± 9	1.65 ± 0.12			
9	11	0	1200 ± 80	822 ± 9	1.47 ± 0.10			
10	11	35	1390 ± 100	804 ± 9	1.73 ± 0.12			
11	11	61	1460 ± 100	777 ± 9	1.88 ± 0.13	1500 ± 100	1037 ± 12	1.44 ± 0.10
12	11	93	1350 ± 90	788 ± 9	1.71 ± 0.12			
13	11	0	1390 ± 100	800 ± 9	1.74 ± 0.12	1520 ± 110	1040 ± 12	1.46 ± 0.10
14	11	27	1360 ± 100	792 ± 9	1.72 ± 0.12	1490 ± 100	1035 ± 12	1.44 ± 0.10
15	11	71	1350 ± 90	780 ± 9	1.73 ± 0.12	1470 ± 100	1037 ± 12	1.41 ± 0.10

Table 53. Fan Characteristics: Site 13 (IP)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]
1	6	0	850 ± 60	428 ± 5	1.99 ± 0.14	920 ± 60	493 ± 6	1.87 ± 0.13
2	6	30	870 ± 60	410 ± 5	2.12 ± 0.15			
3	6	63	860 ± 60	422 ± 5	2.04 ± 0.14			
4	6	98	820 ± 60	396 ± 4	2.06 ± 0.15			
5	11	0	870 ± 60	425 ± 5	2.06 ± 0.15			
6	11	25	860 ± 60	418 ± 5	2.05 ± 0.15			
7	11	56	890 ± 60	424 ± 5	2.10 ± 0.15			
8	11	86	830 ± 60	404 ± 5	2.05 ± 0.15	890 ± 60	447 ± 5	1.99 ± 0.14
9	2	0	910 ± 60	442 ± 5	2.05 ± 0.15	1010 ± 70	504 ± 6	2.00 ± 0.14
10	2	32	780 ± 50	441 ± 5	1.76 ± 0.12	880 ± 60	509 ± 6	1.73 ± 0.12
11	2	62	700 ± 50	339 ± 4	2.06 ± 0.15	750 ± 50	398 ± 4	1.88 ± 0.13
12	2	94	670 ± 50	330 ± 4	2.02 ± 0.14	710 ± 50	376 ± 4	1.89 ± 0.13
13	11	0	830 ± 60	392 ± 4	2.12 ± 0.15	910 ± 60	450 ± 5	2.02 ± 0.14
14	11	30	820 ± 60	378 ± 4	2.17 ± 0.15	880 ± 60	434 ± 5	2.03 ± 0.14
15	11	57	780 ± 50	368 ± 4	2.13 ± 0.15	840 ± 60	417 ± 5	2.01 ± 0.14
16	11	87	790 ± 50	368 ± 4	2.13 ± 0.15			

Table 54. Fan Characteristics: Site 14 (IP)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]
1	7	0	920 ± 60	448 ± 5	2.06 ± 0.15			
2	7	26	920 ± 60	408 ± 5	2.26 ± 0.16			
3	7	55	1010 ± 70	444 ± 5	2.27 ± 0.16			
4	7	91	960 ± 70	451 ± 5	2.12 ± 0.15			
5	2	0	1000 ± 70	463 ± 5	2.16 ± 0.15			
6	2	28	960 ± 70	458 ± 5	2.09 ± 0.15			
7	2	55	940 ± 70	456 ± 5	2.06 ± 0.15			
8	2	87	990 ± 70	453 ± 5	2.19 ± 0.16	1000 ± 70	449 ± 5	2.22 ± 0.16
9	11	0	860 ± 60	418 ± 5	2.05 ± 0.15	880 ± 60	410 ± 5	2.14 ± 0.15
10	11	30	840 ± 60	412 ± 5	2.04 ± 0.14	860 ± 60	409 ± 5	2.09 ± 0.15
11	7	0	880 ± 60	440 ± 5	1.99 ± 0.14	890 ± 60	448 ± 5	1.98 ± 0.14
12	7	28	860 ± 60	454 ± 5	1.89 ± 0.13	880 ± 60	443 ± 5	1.98 ± 0.14
13	7	58	860 ± 60	454 ± 5	1.89 ± 0.13			
14	2	0	940 ± 70	470 ± 5	2.00 ± 0.14	960 ± 70	457 ± 5	2.09 ± 0.15
15	2	28	910 ± 60	478 ± 5	1.90 ± 0.13	940 ± 70	468 ± 5	2.00 ± 0.14
16	2	62	940 ± 70	471 ± 5	1.99 ± 0.14			

Table 55. Fan Characteristics: Site 15 (IP)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]
1	7	0	1160 ± 80	960 ± 11	1.21 ± 0.09			
2	7	39	1110 ± 80	974 ± 11	1.14 ± 0.08			
3	7	67	1130 ± 80	976 ± 11	1.16 ± 0.08			
4	7	98	1120 ± 80	960 ± 11	1.17 ± 0.08			
5	11	0	1080 ± 80	942 ± 11	1.15 ± 0.08			
6	11	30	1110 ± 80	930 ± 10	1.19 ± 0.08			
7	11	59	1040 ± 70	911 ± 10	1.14 ± 0.08	1050 ± 70	913 ± 10	1.15 ± 0.08
8	11	92	1060 ± 70	886 ± 10	1.20 ± 0.09			
9	2	0	1130 ± 80	939 ± 11	1.20 ± 0.09	1180 ± 80	938 ± 11	1.25 ± 0.09
10	2	36	1090 ± 80	945 ± 11	1.16 ± 0.08	1150 ± 80	932 ± 10	1.23 ± 0.09
11	2	62	1080 ± 80	939 ± 11	1.14 ± 0.08	1120 ± 80	920 ± 10	1.22 ± 0.09
12	2	92	1100 ± 80	924 ± 10	1.19 ± 0.08	1140 ± 80	919 ± 10	1.24 ± 0.09
13	7	0	1100 ± 80	926 ± 10	1.19 ± 0.08	1150 ± 80	909 ± 10	1.26 ± 0.09
14	7	28	1100 ± 80	942 ± 11	1.17 ± 0.08	1160 ± 80	921 ± 10	1.26 ± 0.09
15	7	60	1100 ± 80	942 ± 11	1.17 ± 0.08			
16	7	90	1100 ± 80	949 ± 11	1.16 ± 0.08			

Table 56. Fan Characteristics: Site 16 (IP)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]
1	6	0	610 ± 40	117 ± 1	5.20 ± 0.37			
2	6	35	540 ± 40	120 ± 1	4.52 ± 0.32			
3	6	66	580 ± 40	118 ± 1	4.94 ± 0.35			
4	6	104	610 ± 40	126 ± 1	4.87 ± 0.34			
5	11	0	610 ± 40	119 ± 1	5.12 ± 0.36			
6	11	31	630 ± 40	123 ± 1	5.15 ± 0.37			
7	11	59	650 ± 50	123 ± 1	5.26 ± 0.37	1020 ± 70	531 ± 6	1.93 ± 0.14
8	11	87	620 ± 40	121 ± 1	5.15 ± 0.36			
9	2	0	630 ± 40	105 ± 1	5.95 ± 0.42	1080 ± 80	559 ± 6	1.94 ± 0.14
10	2	28	630 ± 40	111 ± 1	5.67 ± 0.40	1080 ± 80	553 ± 6	1.95 ± 0.14
11	2	56	620 ± 40	106 ± 1	5.83 ± 0.41	1080 ± 80	556 ± 6	1.94 ± 0.14
12	2	84	600 ± 40	100 ± 1	5.99 ± 0.42			
13	11	0	610 ± 40	120 ± 1	5.05 ± 0.36	1030 ± 70	530 ± 6	1.94 ± 0.14
14	11	33	600 ± 40	119 ± 1	5.03 ± 0.36	1030 ± 70	528 ± 6	1.95 ± 0.14
15	11	64	600 ± 40	111 ± 1	5.42 ± 0.38			
16	11	90	490 ± 30	114 ± 1	4.30 ± 0.30			

Table 57. Fan Characteristics: Site 17 (IP)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]
1	6	0	490 ± 30	71 ± 1	6.95 ± 0.49			
2	6	35	450 ± 30	70 ± 1	6.43 ± 0.46			
3	6	66	460 ± 30	72 ± 1	6.47 ± 0.46			
4	6	104	550 ± 40	75 ± 1	7.37 ± 0.52			
5	11	0	550 ± 40	72 ± 1	7.70 ± 0.55			
6	11	31	520 ± 40	77 ± 1	6.68 ± 0.47			
7	11	59	500 ± 40	75 ± 1	6.71 ± 0.48	810 ± 60	413 ± 5	1.96 ± 0.14
8	11	87	570 ± 40	70 ± 1	8.17 ± 0.58			
9	2	0	500 ± 40	61 ± 1	8.25 ± 0.59	1320 ± 90	342 ± 4	3.86 ± 0.27
10	2	28	490 ± 30	62 ± 1	7.93 ± 0.56	1350 ± 90	379 ± 4	3.57 ± 0.25
11	2	56	540 ± 40	63 ± 1	8.56 ± 0.61	1090 ± 80	381 ± 4	2.87 ± 0.20
12	2	84	500 ± 40	61 ± 1	8.21 ± 0.58			
13	11	0	500 ± 40	72 ± 1	6.99 ± 0.50	1180 ± 80	402 ± 5	2.93 ± 0.21
14	11	33	500 ± 40	73 ± 1	6.88 ± 0.49	1080 ± 80	398 ± 4	2.72 ± 0.19
15	11	64	560 ± 40	68 ± 1	8.16 ± 0.58			
16	11	90	550 ± 40	71 ± 1	7.79 ± 0.55			

Appendix D.3: A/C Operation Characteristics (IP)

Table 58. A/C Operation Characteristics: Site 1 (IP)

Visit	Outdoor Temperature (SD) [°F]	Return Air Wet Bulb Temperature (SD) [°F]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [BTU/hr]	Latent Capacity (SD) [BTU/hr]	Total Capacity (SD) [BTU/hr]	System Efficiency (SD) [(BTU/hr)/W]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	85.3 (3.6)	67.3 (0.5)	6.8 (1.9)	60.4	2090 ± 20	19200 (580)	9970 (520)	29170 (780)	10.9 (0.7)	290 (90)
2	81.6 (2.6)	69.7 (0.2)	4.7 (1.4)	30.7	1000 ± 10	20000 (100)	14290 (200)	34280 (230)	21.6 (1.8)	120 (40)
3	79.6 (1.4)	68.7 (0.3)	5.0 (1.0)	20.7	2220 ± 20	29850 (2200)	20600 (2010)	50450 (2980)	10.8 (0.8)	210 (60)
14	83.1 (3.6)	65.6 (1.1)	9.1 (10.8)	40.7	2150 ± 20	21940 (2560)	9080 (2810)	31020 (3810)	11.1 (1.3)	410 (570)
15	80.7 (0.7)	n/a	5.8 (0.4)	17.2	n/a	n/a	n/a	n/a	n/a	n/a
16	88.8 (5.2)	67.9 (0.6)	7.2 (2.0)	63.2	2160 ± 20	22200 (700)	3380 (840)	25580 (1100)	9.3 (0.7)	320 (100)

* The “n/a” term represents excluded values during cycle times that did not reach steady-state operation

Table 59. A/C Operation Characteristics: Site 2 (IP)

Visit	Outdoor Temperature (SD) [°F]	Return Air Wet Bulb Temperature (SD) [°F]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [BTU/hr]	Latent Capacity (SD) [BTU/hr]	Total Capacity (SD) [BTU/hr]	System Efficiency (SD) [(BTU/hr)/W]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	91.0 (4.8)	66.5 (1.8)	21.3 (22.6)	20.1	3320 ± 40	19460 (800)	9080 (930)	28540 (1230)	7.7 (1.0)	1300 (1420)
2	84.1 (2.1)	68.6 (1.9)	12.7 (13.5)	8.5	3150 ± 40	17720 (810)	8630 (1040)	26350 (1320)	7.5 (0.2)	740 (810)
3	81.2 (1.6)	68.0 (1.4)	21.3 (22.4)	2.9	3080 ± 30	18350 (700)	9800 (710)	28150 (990)	8.2 (0.4)	1220 (1310)
14	79.9 (0.7)	68.6 (1.5)	15.3 (10.5)	6.7	3070 ± 30	13800 (1090)	9570 (650)	23360 (1270)	6.9 (0.5)	870 (590)
15	78.9 (1.2)	66.9 (1.5)	15.0 (13.9)	4.1	3030 ± 30	17430 (890)	7920 (630)	25350 (1090)	7.6 (0.2)	840 (780)
16	86.5 (4.0)	67.1 (1.4)	16.9 (23.9)	14.8	3240 ± 40	15970 (520)	4940 (670)	20920 (840)	5.9 (0.6)	1010 (1510)

Table 60. A/C Operation Characteristics: Site 3 (IP)

Visit	Outdoor Temperature (SD) [°F]	Return Air Wet Bulb Temperature (SD) [°F]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [BTU/hr]	Latent Capacity (SD) [BTU/hr]	Total Capacity (SD) [BTU/hr]	System Efficiency (SD) [(BTU/hr)/W]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	90.7 (1.6)	65.3 (0.5)	5.8 (0.8)	20.5	2210 ± 20	19770 (140)	3590 (310)	23360 (340)	12.4 (6.8)	250 (40)
2	83.8 (2.6)	66.4 (1.3)	6.8 (3.8)	27.3	2090 ± 20	20060 (360)	6960 (500)	27020 (620)	10.9 (2.1)	280 (160)
3	83.6 (3.1)	65.8 (0.9)	6.0 (4.8)	18.2	2090 ± 20	20750 (40)	8530 (330)	29280 (330)	11.4 (0.5)	250 (210)
12	88.0 (3.4)	67.1 (1.6)	8.1 (5.2)	19.5	2200 ± 20	21460 (420)	8940 (560)	30400 (700)	12.1 (5.6)	350 (230)
13	78.4 (0.3)	n/a	5.5 (0.4)	5.4	n/a	n/a	n/a	n/a	n/a	220 (20)
14	92.5 (5.6)	67.4 (1.9)	7.2 (5.6)	36.4	2280 ± 30	21420 (410)	8450 (600)	29870 (730)	11.1 (2.9)	320 (270)
15	89.1 (4.8)	66.6 (0.4)	6.3 (1.2)	41.2	2180 ± 20	21300 (280)	9280 (480)	30580 (560)	12.7 (7.0)	280 (60)
16	90.5 (4.9)	67.1 (0.9)	6.6 (2.7)	33.6	2240 ± 30	21590 (370)	7710 (610)	29290 (710)	11.0 (4.5)	300 (130)

* The “n/a” term represents excluded values during cycle times that did not reach steady-state operation

Table 61. A/C Operation Characteristics: Site 4 (IP)

Visit	Outdoor Temperature (SD) [°F]	Return Air Wet Bulb Temperature (SD) [°F]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [BTU/hr]	Latent Capacity (SD) [BTU/hr]	Total Capacity (SD) [BTU/hr]	System Efficiency (SD) [(BTU/hr)/W]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	87.9 (3.3)	66.9 (0.6)	10.6 (5.3)	49.2	1450 ± 20	10100 (580)	3400 (390)	13500 (700)	7.7 (1.5)	300 (160)
2	83.5 (2.4)	67.7 (1.1)	8.9 (4.5)	43.4	1410 ± 20	11500 (480)	4460 (570)	15960 (740)	9.3 (1.0)	240 (130)
3	84.4 (2.8)	66.3 (0.6)	8.2 (3.2)	34.3	1380 ± 20	13440 (430)	3810 (360)	17250 (560)	10.1 (1.1)	220 (100)
12	86.8 (4.6)	71.9 (0.7)	10.8 (6.4)	31.0	1440 ± 20	17210 (410)	10820 (500)	28040 (650)	15.8 (1.6)	300 (190)
13	77.2 (1.5)	n/a	6.5 (1.0)	19.6	n/a	n/a	n/a	n/a	n/a	170 (30)
14	93.5 (4.4)	67.1 (1.0)	10.4 (10.5)	49.8	1540 ± 20	11140 (440)	2200 (280)	13340 (520)	7.2 (1.0)	300 (330)
15	88.1 (4.9)	66.7 (1.2)	8.7 (13.2)	35.1	1470 ± 20	12420 (790)	2600 (380)	15030 (870)	8.4 (1.0)	250 (400)
16	90.4 (4.7)	67.2 (0.7)	9.4 (14.6)	47.6	1510 ± 20	10960 (420)	900 (500)	11860 (650)	6.5 (1.3)	270 (460)

* The “n/a” term represents excluded values during cycle times that did not reach steady-state operation

Table 62. A/C Operation Characteristics: Site 5 (IP)

Visit	Outdoor Temperature (SD) [°F]	Return Air Wet Bulb Temperature (SD) [°F]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [BTU/hr]	Latent Capacity (SD) [BTU/hr]	Total Capacity (SD) [BTU/hr]	System Efficiency (SD) [(BTU/hr)/W]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	87.2 (6.4)	66.1 (0.9)	10.2 (8.6)	55.8	2690 ± 30	24020 (640)	7350 (760)	31370 (990)	9.6 (2.3)	570 (480)
2	84.1 (3.0)	68.0 (1.0)	12.2 (8.8)	39.0	2760 ± 30	20310 (880)	9480 (1140)	29790 (1440)	8.8 (0.8)	680 (510)
3	76.3 (3.8)	63.7 (0.3)	5.3 (1.8)	11.1	2450 ± 30	22140 (750)	7190 (350)	29330 (830)	14.3 (21.2)	270 (100)
11	81.6 (5.1)	62.6 (0.9)	11.1 (16.0)	43.5	2630 ± 30	18390 (980)	5320 (1630)	23700 (1900)	7.4 (1.7)	600 (900)
13	86.3 (6.0)	64.5 (0.9)	14.1 (42.0)	48.8	2690 ± 30	17630 (1050)	5140 (1060)	22770 (1490)	6.9 (2.0)	790 (2400)
14	91.9 (10.2)	66.8 (2.2)	22.6 (92.6)	43.6	2730 ± 30	20940 (1000)	3930 (1820)	24870 (2080)	7.6 (1.6)	1310 (5510)
15	88.7 (5.1)	65.1 (1.4)	19.3 (61.4)	44.7	2560 ± 30	20280 (820)	4580 (440)	24860 (930)	8.0 (2.0)	1030 (3360)
16	84.7 (4.0)	68.9 (1.4)	9.2 (10.1)	64.1	2610 ± 30	21990 (670)	8650 (1140)	30650 (1320)	9.7 (1.6)	480 (550)

Table 63. A/C Operation Characteristics: Site 6 (IP)

Visit	Outdoor Temperature (SD) [°F]	Return Air Wet Bulb Temperature (SD) [°F]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [BTU/hr]	Latent Capacity (SD) [BTU/hr]	Total Capacity (SD) [BTU/hr]	System Efficiency (SD) [(BTU/hr)/W]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	83.8 (5.0)	65.6 (2.1)	11.4 (5.7)	38.9	3350 ± 40	18140 (1620)	3870 (1990)	22010 (2570)	5.7 (1.0)	750 (380)
2	80.7 (3.0)	64.4 (1.7)	10.4 (12.1)	37.8	3300 ± 40	8920 (1740)	1430 (1440)	10340 (2260)	2.7 (0.8)	670 (790)
13	83.4 (3.4)	65.5 (0.7)	8.9 (2.8)	50.6	3420 ± 40	18780 (900)	2170 (2170)	20960 (2350)	5.5 (1.2)	600 (190)
14	84.6 (5.8)	60.9 (3.3)	13.7 (17.5)	49.2	3260 ± 40	18900 (1240)	-10 (1160)	18890 (1700)	5.0 (0.8)	880 (1090)
16	89.6 (3.8)	63.8 (2.5)	21.6 (18.7)	24.1	3530 ± 40	16160 (2500)	-1280 (1370)	14880 (2850)	3.8 (1.2)	1420 (1230)

Table 64. A/C Operation Characteristics: Site 7 (IP)

Visit	Outdoor Temperature (SD) [°F]	Return Air Wet Bulb Temperature (SD) [°F]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [BTU/hr]	Latent Capacity (SD) [BTU/hr]	Total Capacity (SD) [BTU/hr]	System Efficiency (SD) [(BTU/hr)/W]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	85.3 (1.2)	68.6 (0.7)	9.5 (2.1)	18.4	3750 ± 40	20880 (470)	11770 (1030)	32650 (1130)	7.8 (0.4)	660 (150)
2	86.7 (4.6)	65.5 (0.9)	10.9 (2.7)	22.1	3600 ± 40	21610 (1300)	9650 (820)	31260 (1530)	7.8 (0.7)	740 (190)
12	87.1 (6.2)	67.1 (1.4)	15.7 (11.3)	21.1	3670 ± 40	17200 (660)	6500 (760)	23700 (1010)	5.8 (0.4)	1070 (780)
13	87.8 (6.2)	67.4 (1.3)	11.2 (2.2)	34.7	3690 ± 40	17890 (740)	8550 (990)	26440 (1240)	6.5 (0.4)	770 (150)
14	91.0 (7.0)	64.6 (1.3)	13.3 (5.2)	39.3	3730 ± 40	17690 (760)	3000 (560)	20690 (940)	5.0 (0.4)	910 (360)
15	90.7 (7.5)	64.7 (1.0)	12.5 (2.5)	31.8	3680 ± 40	17540 (880)	4430 (1220)	21960 (1500)	5.4 (0.7)	850 (190)
16	85.5 (4.2)	67.5 (1.1)	10.8 (1.6)	20.3	3560 ± 40	17700 (520)	8110 (1230)	25800 (1340)	6.5 (0.6)	720 (110)

Table 65. A/C Operation Characteristics: Site 8 (IP)

Visit	Outdoor Temperature (SD) [°F]	Return Air Wet Bulb Temperature (SD) [°F]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [BTU/hr]	Latent Capacity (SD) [BTU/hr]	Total Capacity (SD) [BTU/hr]	System Efficiency (SD) [(BTU/hr)/W]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	86.5 (4.6)	63.3 (2.3)	69.1 (64.2)	8.2	4120 ± 50	20940 (360)	7120 (900)	28060 (970)	6.2 (0.3)	5270 (4870)
2	84.5 (4.5)	61.4 (1.9)	37.3 (40.7)	9.6	3920 ± 40	18900 (920)	230 (1170)	19130 (1490)	4.4 (0.8)	2760 (3050)
13	86.3 (4.5)	60.8 (1.2)	83.4 (104.4)	6.6	4340 ± 50	19120 (920)	6680 (740)	25810 (1180)	5.4 (0.6)	6740 (8510)
14	91.0 (6.5)	62.3 (2.2)	102.4 (130.6)	5.9	4370 ± 50	20020 (800)	4290 (750)	24310 (1100)	5.4 (5.3)	8460 (11170)
15	85.6 (5.6)	63.2 (2.1)	52.6 (70.3)	5.9	4370 ± 50	21600 (1210)	7070 (1020)	28670 (1590)	6.0 (0.4)	4290 (5720)
16	87.0 (4.4)	62.3 (1.5)	76.0 (79.4)	6.7	4400 ± 50	20140 (1130)	5830 (260)	25970 (1150)	5.4 (0.4)	6290 (6820)

Table 66. A/C Operation Characteristics: Site 9 (IP)

Visit	Outdoor Temperature (SD) [°F]	Return Air Wet Bulb Temperature (SD) [°F]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [BTU/hr]	Latent Capacity (SD) [BTU/hr]	Total Capacity (SD) [BTU/hr]	System Efficiency (SD) [(BTU/hr)/W]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	78.8 (4.0)	63.0 (0.7)	4.8 (2.0)	62.5	4050 ± 50	31950 (2010)	3730 (1890)	35680 (2760)	7.4 (1.0)	370 (170)
11	86.2 (7.1)	66.0 (0.7)	6.1 (1.7)	56.6	4100 ± 50	30430 (1010)	4320 (1530)	34760 (1840)	7.3 (2.2)	480 (160)
13	90.7 (5.4)	66.0 (2.3)	12.2 (30.5)	37.6	4220 ± 50	29410 (4350)	4240 (2170)	33640 (4860)	6.8 (1.8)	1010 (2620)
14	91.5 (6.1)	64.6 (1.2)	9.3 (5.1)	71.7	4160 ± 50	25490 (4280)	2310 (2340)	27800 (4880)	5.7 (1.8)	760 (450)
15	71.7 (4.0)	n/a	5.4 (1.3)	22.5	n/a	n/a	n/a	n/a	n/a	380 (100)
16	84.7 (0.8)	n/a	4.0 (2.2)	4.2	n/a	n/a	n/a	n/a	n/a	310 (170)

* The “n/a” term represents excluded values during cycle times that did not reach steady-state operation

Table 67. A/C Operation Characteristics: Site 10 (IP)

Visit	Outdoor Temperature (SD) [°F]	Return Air Wet Bulb Temperature (SD) [°F]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [BTU/hr]	Latent Capacity (SD) [BTU/hr]	Total Capacity (SD) [BTU/hr]	System Efficiency (SD) [(BTU/hr)/W]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	80.4 (2.7)	61.5 (1.0)	7.5 (2.7)	19.9	3150 ± 40	22120 (490)	4230 (570)	26350 (750)	7.0 (1.1)	280 (100)
2	83.6 (3.8)	61.6 (1.1)	10.3 (8.9)	26.4	3270 ± 40	23200 (650)	3200 (800)	26400 (1030)	6.7 (1.3)	680 (610)
11	84.3 (4.6)	61.1 (0.8)	10.4 (6.0)	25.3	3340 ± 40	20320 (1190)	5120 (740)	25440 (1400)	6.7 (3.6)	690 (380)
14	94.6 (3.7)	61.1 (0.9)	17.5 (13.7)	30.7	3700 ± 40	20540 (1280)	2430 (530)	22970 (1380)	5.3 (1.0)	1260 (980)
15	75.7 (3.2)	59.3 (0.5)	6.5 (2.5)	25.9	2890 ± 30	24240 (310)	920 (360)	25170 (470)	7.6 (2.7)	380 (160)
16	78.4 (3.7)	n/a	5.6 (0.7)	33.7	n/a	n/a	n/a	n/a	n/a	340 (50)

* The “n/a” term represents excluded values during cycle times that did not reach steady-state operation

Table 68. A/C Operation Characteristics: Site 11 (IP)

Visit	Outdoor Temperature (SD) [°F]	Return Air Wet Bulb Temperature (SD) [°F]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [BTU/hr]	Latent Capacity (SD) [BTU/hr]	Total Capacity (SD) [BTU/hr]	System Efficiency (SD) [(BTU/hr)/W]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	85.9 (8.6)	62.4 (1.6)	24.1 (46.5)	40.1	2630 ± 30	25300 (520)	5380 (660)	30680 (840)	9.3 (0.9)	1350 (2700)
2	82.9 (4.8)	62.0 (1.1)	14.8 (22.5)	35.9	2690 ± 30	26250 (600)	2950 (570)	29200 (830)	8.7 (0.9)	830 (1300)
3	78.2 (4.6)	61.2 (0.4)	43.3 (90.8)	8.4	2510 ± 30	17220 (1800)	6080 (900)	23290 (2010)	7.4 (1.3)	2380 (5050)
10	75.4 (9.0)	61.2 (2.7)	19.5 (35.6)	25.0	2450 ± 30	31250 (1860)	6480 (1060)	37730 (2140)	12.1 (0.9)	1020 (1970)
11	79.0 (5.0)	63.5 (1.1)	20.5 (21.6)	39.0	2620 ± 30	28720 (1060)	6910 (750)	35620 (1300)	10.9 (1.0)	1120 (1240)
13	88.1 (7.2)	61.3 (1.9)	222.4 (314.2)	6.2	2660 ± 30	25790 (1370)	4890 (580)	30670 (1490)	9.2 (0.6)	12910 (18120)
14	86.9 (6.0)	62.6 (1.3)	27.5 (66.3)	35.1	2720 ± 30	34620 (1780)	8870 (1020)	43490 (2060)	13.0 (1.3)	1560 (3910)
15	80.0 (6.1)	60.4 (1.6)	19.8 (31.1)	38.9	2600 ± 30	39390 (2690)	-840 (1510)	38550 (3090)	12.0 (1.8)	1070 (1770)

Table 69. A/C Operation Characteristics: Site 12 (IP)

Visit	Outdoor Temperature (SD) [°F]	Return Air Wet Bulb Temperature (SD) [°F]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [BTU/hr]	Latent Capacity (SD) [BTU/hr]	Total Capacity (SD) [BTU/hr]	System Efficiency (SD) [(BTU/hr)/W]	Electricity Consumption per Cycle (SD) [Wh/cycle]
11	87.7 (7.3)	66.7 (0.6)	6.7 (2.7)	30.5	5120 ± 60	30050 (2490)	2950 (6970)	32990 (7410)	5.5 (1.9)	670 (280)
13	89.6 (6.1)	65.1 (0.4)	5.9 (3.3)	75.1	5350 ± 60	33710 (670)	9080 (470)	42790 (820)	6.6 (0.2)	590 (370)
14	91.5 (6.3)	64.1 (0.7)	11.3 (6.3)	31.9	5340 ± 60	33430 (2800)	-550 (2440)	32890 (3720)	5.2 (0.8)	1190 (610)
15	92.3 (2.3)	64.0 (0.8)	6.9 (3.5)	34.1	5140 ± 60	33940 (3350)	6190 (2650)	40130 (4270)	6.5 (1.5)	680 (370)

Table 70. A/C Operation Characteristics: Site 13 (IP)

Visit	Outdoor Temperature (SD) [°F]	Return Air Wet Bulb Temperature (SD) [°F]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [BTU/hr]	Latent Capacity (SD) [BTU/hr]	Total Capacity (SD) [BTU/hr]	System Efficiency (SD) [(BTU/hr)/W]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	82.8 (3.0)	63.8 (0.6)	26.0 (11.8)	36.1	3240 ± 40	15590 (220)	11400 (1020)	26990 (1040)	7.2 (0.4)	1620 (720)
8	85.2 (4.8)	63.8 (0.6)	32.4 (57.3)	15.7	3190 ± 40	18810 (520)	6340 (340)	25150 (630)	6.9 (0.4)	1970 (3560)
9	91.1 (9.0)	61.7 (1.1)	22.9 (7.1)	5.4	3100 ± 30	19920 (490)	8660 (600)	28580 (770)	7.9 (0.3)	1360 (430)
10	91.1 (10.6)	61.1 (2.9)	152.9 (383.1)	8.9	3190 ± 40	19230 (290)	4110 (210)	23340 (350)	6.3 (0.2)	10090 (25560)
11	89.5 (5.8)	59.6 (1.8)	39.5 (111.6)	30.2	2990 ± 30	19330 (540)	5230 (490)	24560 (720)	7.2 (0.4)	2310 (6660)
12	79.6 (2.6)	59.9 (0.9)	10.5 (4.9)	70.4	2900 ± 30	18840 (240)	7890 (810)	26730 (840)	8.1 (0.4)	570 (280)
13	80.9 (4.2)	61.4 (1.9)	16.5 (40.9)	45.0	2950 ± 30	20820 (690)	7720 (660)	28540 (950)	8.3 (0.4)	930 (2330)
14	77.9 (4.1)	61.5 (1.0)	15.6 (22.0)	37.6	2980 ± 30	22030 (540)	9770 (630)	31800 (830)	9.3 (0.5)	880 (1280)
15	74.1 (3.8)	64.4 (0.7)	8.3 (1.7)	28.8	2770 ± 30	21710 (320)	9190 (890)	30900 (950)	9.7 (0.7)	440 (90)

Table 71. A/C Operation Characteristics: Site 14 (IP)

Visit	Outdoor Temperature (SD) [°F]	Return Air Wet Bulb Temperature (SD) [°F]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [BTU/hr]	Latent Capacity (SD) [BTU/hr]	Total Capacity (SD) [BTU/hr]	System Efficiency (SD) [(BTU/hr)/W]	Electricity Consumption per Cycle (SD) [Wh/cycle]
8	75.8 (1.6)	62.9 (0.7)	14.9 (4.8)	12.2	1560 ± 20	19890 (570)	6370 (850)	26260 (1020)	13.3 (3.0)	500 (160)
9	84.6 (3.3)	65.1 (1.6)	24.8 (22.3)	8.6	1600 ± 20	18180 (870)	7020 (620)	25200 (1060)	12.6 (1.0)	830 (740)
10	96.5 (7.9)	64.2 (0.8)	60.3 (109.8)	18.2	3300 ± 40	17790 (500)	5080 (430)	22870 (650)	6.2 (0.5)	3840 (7120)
11*	89.7 (6.3)	63.6 (1.5)	24.7 (50.5)	32.3	2380 ± 30	19690 (660)	980 (710)	20670 (970)	7.4 (1.0)	1170 (2510)
12	87.2 (5.0)	63.3 (1.0)	43.0 (69.4)	14.6	2340 ± 30	19030 (870)	2390 (930)	21420 (1270)	7.7 (0.9)	2020 (3310)
14	88.9 (4.0)	65.2 (1.1)	19.0 (19.5)	28.9	2420 ± 30	20140 (1000)	6090 (1150)	26230 (1520)	9.2 (1.4)	910 (940)
15	77.6 (3.8)	60.1 (0.5)	9.7 (2.3)	9.8	2200 ± 20	19370 (1090)	-830 (900)	18540 (1420)	7.1 (2.3)	430 (90)

* The outdoor condenser unit was replaced prior to visit 11

Table 72. A/C Operation Characteristics: Site 15 (IP)

Visit	Outdoor Temperature (SD) [°F]	Return Air Wet Bulb Temperature (SD) [°F]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [BTU/hr]	Latent Capacity (SD) [BTU/hr]	Total Capacity (SD) [BTU/hr]	System Efficiency (SD) [(BTU/hr)/W]	Electricity Consumption per Cycle (SD) [Wh/cycle]
7	88.9 (3.7)	62.3 (2.2)	47.3 (27.0)	5.1	2390 ± 30	16920 (1720)	6740 (1220)	23660 (2110)	7.2 (1.0)	2620 (1470)
9	92.4 (7.1)	65.8 (1.8)	152.0 (142.4)	3.0	2510 ± 30	24950 (890)	5880 (630)	30830 (1090)	8.9 (0.4)	8950 (8490)
10	92.3 (10.0)	63.6 (2.7)	220.9 (253.2)	3.9	2410 ± 30	14340 (1380)	4190 (1510)	18530 (2040)	5.5 (0.2)	12870 (15130)
11	92.5 (4.7)	63.1 (1.4)	212.3 (167.9)	3.8	2530 ± 30	12500 (2990)	1870 (1100)	14380 (3190)	4.2 (0.9)	12620 (10200)
12	82.8 (4.9)	60.6 (2.6)	275.8 (143.8)	2.0	2310 ± 30	18450 (1710)	3310 (1160)	21760 (2070)	6.8 (1.7)	15490 (8770)
13	83.4 (3.2)	62.0 (1.1)	83.9 (132.2)	5.0	2460 ± 30	17930 (1990)	3420 (480)	21350 (2050)	6.5 (2.3)	4800 (7660)
14	78.6 (1.8)	58.7 (0.4)	108.2 (169.1)	2.9	2380 ± 30	10580 (1770)	2050 (1070)	12630 (2070)	3.9 (1.0)	6010 (9440)

Table 73. A/C Operation Characteristics: Site 16 (IP)

Visit	Outdoor Temperature (SD) [°F]	Return Air Wet Bulb Temperature (SD) [°F]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [BTU/hr]	Latent Capacity (SD) [BTU/hr]	Total Capacity (SD) [BTU/hr]	System Efficiency (SD) [(BTU/hr)/W]	Electricity Consumption per Cycle (SD) [Wh/cycle]
7	90.2 (4.6)	69.6 (0.6)	49.9 (31.7)	7.2	1620 ± 20	19380 (1030)	11190 (500)	30580 (1150)	14.2 (0.7)	1790 (1140)
9	95.0 (7.8)	65.6 (1.0)	14.4 (19.4)	33.9	1670 ± 20	8320 (1020)	1830 (650)	10140 (1210)	4.6 (0.8)	530 (720)
10	88.8 (4.2)	65.9 (1.2)	21.6 (34.1)	15.1	1640 ± 20	11270 (850)	-210 (460)	11070 (970)	5.1 (0.5)	780 (1250)
11	99.7 (1.6)	66.9 (0.4)	17.8 (7.0)	7.1	1700 ± 20	9130 (290)	10 (400)	9140 (500)	4.1 (0.3)	670 (270)
13	80.7 (2.2)	62.4 (0.3)	7.3 (4.5)	21.8	1520 ± 20	12600 (360)	1750 (270)	14360 (450)	7.0 (0.6)	250 (160)
14	82.0 (0.9)	62.8 (0.5)	10.6 (7.5)	5.5	1550 ± 20	13360 (310)	1680 (340)	15040 (470)	7.2 (0.5)	370 (260)

Table 74. A/C Operation Characteristics: Site 17 (IP)

Visit	Outdoor Temperature (SD) [°F]	Return Air Wet Bulb Temperature (SD) [°F]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [BTU/hr]	Latent Capacity (SD) [BTU/hr]	Total Capacity (SD) [BTU/hr]	System Efficiency (SD) [(BTU/hr)/W]	Electricity Consumption per Cycle (SD) [Wh/cycle]
7	91.3 (1.9)	68.2 (1.3)	9.0 (2.9)	11.4	1550 ± 20	10230 (370)	3080 (680)	13310 (770)	6.8 (0.5)	290 (90)
9	96.2 (6.6)	67.2 (0.5)	14.8 (14.8)	25.8	1560 ± 20	17100 (480)	3620 (860)	20720 (980)	10.9 (0.9)	470 (470)
10	89.3 (4.3)	69.0 (2.0)	20.0 (40.9)	13.1	1470 ± 20	13990 (610)	5420 (690)	19410 (920)	10.6 (1.2)	620 (1280)
11	89.8 (6.8)	69.7 (0.5)	5.4 (5.7)	114.3	1520 ± 20	14980 (420)	2970 (420)	17950 (590)	9.3 (0.7)	170 (180)
13	82.4 (2.2)	66.3 (0.2)	5.3 (4.9)	26.9	1440 ± 20	16200 (190)	4010 (380)	20210 (430)	11.2 (2.5)	160 (150)
14	79.7 (3.0)	66.2 (0.8)	3.6 (1.8)	22.0	1350 ± 20	14770 (280)	590 (360)	15360 (450)	10.4 (7.0)	110 (50)

Appendix D.4: Site Duct Leakage Characteristics (IP)

Table 75. Site Duct Leakage Characteristics: All Sites (IP)

	Total Leakage				Exterior Leakage				Total Leakage			Exterior Leakage		
	Supply + Return		Supply		Supply + Return		Supply		Supply + Return	Supply	Return	Supply + Return	Supply	Return
Site	C	n	C	n	C	n	C	n	Q_{25}	Q_{25}	Q_{25}	Q_{25}	Q_{25}	Q_{25}
	[CFM/Pa^n]		[CFM/Pa^n]		[CFM/Pa^n]		[CFM/Pa^n]		[CFM]	[CFM]	[CFM]	[CFM]	[CFM]	[CFM]
1	17.3	0.632	9.3	0.675	4.7	0.734	2.9	0.734	132	82	50	50	31	19
2	122.1	0.612	46.2	0.642	43.2	0.728	28.0	0.652	875	365	509	449	228	221
3	31.2	0.604	22.8	0.583	17.2	0.550	11.8	0.582	218	149	70	101	77	24
4	7.9	0.637	7.9	0.591	6.3	0.652	6.8	0.590	61	53	8	51	45	6
5	16.3	0.646	18.3	0.598	10.2	0.705	15.1	0.580	131	125	5	98	98	1
6	26.7	0.646	14.3	0.743	18.1	0.677	12.6	0.719	213	157	57	160	127	33
7	32.7	0.646	17.6	0.644	13.9	0.661	8.0	0.656	262	140	122	117	66	51
8	34.2	0.693	28.8	0.624	49.2	0.528	16.2	0.725	318	215	103	269	167	102
9	44.1	0.610	12.1	0.682	35.6	0.620	10.4	0.624	314	108	206	262	77	185
10[1]	untested								-	-	-	-	-	-
11	82.7	0.646	74.6	0.590	78.7	0.593	59.5	0.586	663	498	165	530	392	138
12	90.7	0.523	25.8	0.642	50.8	0.588	14.8	0.661	489	204	285	337	124	213
13	41.8	0.642	34.0	0.604	33.1	0.664	25.1	0.675	330	237	93	281	220	61
14	56.2	0.614	38.5	0.588	22.4	0.654	12.3	0.702	406	255	151	184	118	67
15[2]	94.3	0.619	untested		28.7	0.735	untested		692	692	-	306	306	-
16	18.2	0.661	7.5	0.602	17.1	0.639	9.5	0.476	153	52	101	134	44	90
17[3]	untested								-	-	-	-	-	-

[1] Site 10 was omitted due to complications with the owner's schedule

[2] Site 15 was only tested for total leakage, as the supply and return were not physically possible to separate from each other. However, the return duct was located entirely in conditioned space so there is zero return leakage to the exterior

[3] Site 17 was not tested for leakage because the system is completely housed in conditioned space

Appendix D.5: Visit Specific Duct Leakage Measurements (IP)

Table 76. Visit Specific Duct Leakage Measurements: Site 1 (IP)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[CFM]	Supply [CFM]	Return [CFM]			[CFM]	Supply [CFM]	Return [CFM]					
1	1010 ± 70	19 ± 1	12 ± 1	98.2%	98.9%	1210 ± 80	23 ± 1	14 ± 1	98.1%	98.8%	89.7%	n/a	0.81
2	1040 ± 70	19 ± 1	12 ± 1	98.1%	98.8%	1220 ± 90	24 ± 1	15 ± 1	98.1%	98.8%	89.8%	n/a	0.86
3	1060 ± 70	20 ± 1	12 ± 1	98.1%	98.8%	1240 ± 90	24 ± 1	15 ± 1	98.1%	98.8%	90.0%	n/a	0.89
4	1100 ± 80	21 ± 1	13 ± 1	98.1%	98.8%								
5	1020 ± 70	19 ± 1	12 ± 1	98.2%	98.9%								
6	1030 ± 70	19 ± 1	12 ± 1	98.2%	98.9%								
7	1010 ± 70	19 ± 1	12 ± 1	98.2%	98.9%								
8	1040 ± 70	19 ± 1	12 ± 1	98.1%	98.8%								
9	1010 ± 70	19 ± 1	12 ± 1	98.2%	98.9%								
10	1040 ± 70	19 ± 1	12 ± 1	98.1%	98.8%								
11	990 ± 70	18 ± 1	11 ± 1	98.2%	98.9%								
12	990 ± 70	18 ± 1	11 ± 1	98.2%	98.9%								
13	990 ± 70	18 ± 1	11 ± 1	98.2%	98.9%								
14	990 ± 70	18 ± 1	11 ± 1	98.2%	98.9%	1180 ± 80	22 ± 1	14 ± 1	98.1%	98.8%	89.5%	n/a	0.85
15	1010 ± 70	19 ± 1	12 ± 1	98.2%	98.9%	1170 ± 80	22 ± 1	14 ± 1	98.1%	98.8%	89.5%	n/a	0.87
16	980 ± 70	18 ± 1	11 ± 1	98.2%	98.9%	1170 ± 80	22 ± 1	14 ± 1	98.1%	98.8%	89.4%	n/a	0.75

Table 77. Visit Specific Duct Leakage Measurements: Site 2 (IP)

	Fan Only Mode					Cooling Mode							
		Leakage to Exterior					Leakage to Exterior						
Visit	System Air Flow [CFM]	Supply [CFM]	Return [CFM]	Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow [CFM]	Supply [CFM]	Return [CFM]	Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
1	1100 ± 80	166 ± 5	150 ± 4	84.9%	86.4%	1110 ± 80	166 ± 5	150 ± 4	85.0%	86.5%	93.3%	n/a	0.76
2	1100 ± 80	165 ± 5	149 ± 4	84.9%	86.4%	1110 ± 80	165 ± 5	149 ± 4	85.0%	86.5%	93.3%	n/a	0.80
3	1090 ± 80	165 ± 5	148 ± 4	84.9%	86.5%	1100 ± 80	165 ± 5	148 ± 4	85.1%	86.6%	93.3%	n/a	0.80
4	1150 ± 80	176 ± 5	161 ± 5	84.7%	86.0%								
5	960 ± 70	140 ± 4	121 ± 4	85.5%	87.5%								
6	950 ± 70	137 ± 4	118 ± 4	85.6%	87.6%								
7	980 ± 70	142 ± 4	123 ± 4	85.4%	87.4%								
8	1030 ± 70	153 ± 5	135 ± 4	85.2%	86.9%								
9	1060 ± 70	158 ± 5	141 ± 4	85.1%	86.7%								
10	1000 ± 70	147 ± 4	129 ± 4	85.3%	87.1%								
11	920 ± 60	131 ± 4	111 ± 3	85.7%	87.9%								
12	920 ± 60	132 ± 4	113 ± 3	85.7%	87.8%								
13	920 ± 60	132 ± 4	112 ± 3	85.7%	87.8%								
14	890 ± 60	125 ± 4	105 ± 3	85.9%	88.1%	910 ± 60	128 ± 4	108 ± 3	85.9%	88.1%	91.9%	n/a	0.81
15	930 ± 70	133 ± 4	114 ± 3	85.7%	87.8%	940 ± 70	134 ± 4	114 ± 3	85.8%	87.8%	92.2%	n/a	0.80
16	890 ± 60	126 ± 4	106 ± 3	85.8%	88.1%	890 ± 60	124 ± 4	104 ± 3	86.0%	88.3%	91.7%	n/a	0.75

Table 78. Visit Specific Duct Leakage Measurements: Site 3 (IP)

	Fan Only Mode					Cooling Mode							
		Leakage to Exterior					Leakage to Exterior						
Visit	System Air Flow [CFM]	Supply [CFM]	Return [CFM]	Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow [CFM]	Supply [CFM]	Return [CFM]	Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
1	860 ± 60	71 ± 2	23 ± 1	91.7%	97.3%	910 ± 60	74 ± 2	24 ± 1	91.8%	97.4%	93.8%	n/a	0.87
2	890 ± 60	74 ± 2	24 ± 1	91.6%	97.3%	910 ± 60	75 ± 2	24 ± 1	91.8%	97.4%	93.8%	n/a	0.88
3	890 ± 60	75 ± 2	24 ± 1	91.6%	97.3%	940 ± 70	77 ± 2	25 ± 1	91.7%	97.4%	94.0%	n/a	dropped
4	900 ± 60	75 ± 2	24 ± 1	91.6%	97.3%								
5	890 ± 60	74 ± 2	24 ± 1	91.6%	97.3%								
6	910 ± 60	76 ± 2	24 ± 1	91.6%	97.3%								
7	910 ± 60	76 ± 2	24 ± 1	91.6%	97.3%								
8	900 ± 60	75 ± 2	24 ± 1	91.6%	97.3%								
9	920 ± 60	78 ± 2	25 ± 1	91.6%	97.3%								
10	930 ± 70	78 ± 2	25 ± 1	91.6%	97.3%								
11	920 ± 60	77 ± 2	25 ± 1	91.6%	97.3%								
12	910 ± 60	76 ± 2	24 ± 1	91.6%	97.3%	960 ± 70	79 ± 2	25 ± 1	91.7%	97.4%	94.1%	n/a	0.88
13	920 ± 60	77 ± 2	25 ± 1	91.6%	97.3%	980 ± 70	81 ± 2	26 ± 1	91.7%	97.4%	94.2%	n/a	dropped
14	890 ± 60	74 ± 2	24 ± 1	91.6%	97.3%	950 ± 70	78 ± 2	25 ± 1	91.7%	97.4%	94.1%	n/a	0.88
15	880 ± 60	74 ± 2	24 ± 1	91.6%	97.3%	950 ± 70	78 ± 2	25 ± 1	91.7%	97.4%	94.1%	n/a	0.88
16	870 ± 60	72 ± 2	23 ± 1	91.7%	97.3%	930 ± 70	76 ± 2	24 ± 1	91.7%	97.4%	93.9%	n/a	0.88

Table 79. Visit Specific Duct Leakage Measurements: Site 4 (IP)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[CFM]	Supply [CFM]	Return [CFM]			[CFM]	Supply [CFM]	Return [CFM]					
1	650 ± 50	34 ± 1	3 ± 1	94.7%	99.5%	650 ± 50	34 ± 1	3 ± 1	94.8%	99.5%	96.5%	99.3%	0.86
2	590 ± 40	30 ± 1	3 ± 1	94.8%	99.6%	650 ± 50	34 ± 1	3 ± 1	94.8%	99.5%	96.5%	99.3%	0.88
3	580 ± 40	30 ± 1	3 ± 1	94.8%	99.6%	650 ± 50	34 ± 1	3 ± 1	94.8%	99.5%	96.5%	99.3%	0.89
4	590 ± 40	30 ± 1	3 ± 1	94.8%	99.6%								
5	600 ± 40	31 ± 1	3 ± 1	94.8%	99.5%								
6	610 ± 40	32 ± 1	3 ± 1	94.8%	99.5%								
7	610 ± 40	32 ± 1	3 ± 1	94.8%	99.5%								
8	610 ± 40	32 ± 1	3 ± 1	94.8%	99.5%								
9	640 ± 40	33 ± 1	3 ± 1	94.8%	99.5%								
10	650 ± 50	34 ± 1	3 ± 1	94.7%	99.5%								
11	630 ± 40	33 ± 1	3 ± 1	94.8%	99.5%								
12	630 ± 40	33 ± 1	3 ± 1	94.8%	99.5%	720 ± 50	38 ± 1	4 ± 1	94.7%	99.4%	96.8%	99.4%	0.91
13	640 ± 40	33 ± 1	3 ± 1	94.8%	99.5%	740 ± 50	39 ± 1	5 ± 1	94.7%	99.4%	96.9%	99.4%	0.90
14	590 ± 40	31 ± 1	3 ± 1	94.8%	99.6%	690 ± 50	37 ± 1	4 ± 1	94.7%	99.4%	96.7%	99.4%	0.85
15	610 ± 40	32 ± 1	3 ± 1	94.8%	99.5%	710 ± 50	37 ± 1	4 ± 1	94.7%	99.4%	96.8%	99.4%	0.89
16	570 ± 40	30 ± 1	2 ± 1	94.9%	99.6%	670 ± 50	35 ± 1	4 ± 1	94.8%	99.5%	96.6%	99.4%	0.87

Table 80. Visit Specific Duct Leakage Measurements: Site 5 (IP)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[CFM]	Supply [CFM]	Return [CFM]			[CFM]	Supply [CFM]	Return [CFM]					
1	1280 ± 90	95 ± 3	27 ± 1	92.6%	97.9%	1340 ± 90	95 ± 3	27 ± 1	92.9%	98.0%	94.1%	98.9%	0.78
2	1240 ± 90	92 ± 3	26 ± 1	92.6%	97.9%	1300 ± 90	92 ± 3	26 ± 1	92.9%	98.0%	93.9%	98.8%	0.79
3	1030 ± 70	74 ± 2	20 ± 1	92.8%	98.0%	1110 ± 80	76 ± 2	21 ± 1	93.1%	98.1%	92.9%	98.7%	0.85
4	1110 ± 80	81 ± 2	22 ± 1	92.7%	98.0%								
5	1080 ± 80	78 ± 2	22 ± 1	92.8%	98.0%								
6	1090 ± 80	79 ± 2	22 ± 1	92.7%	98.0%								
7	1010 ± 70	73 ± 2	20 ± 1	92.8%	98.0%								
8	1000 ± 70	72 ± 2	19 ± 1	92.8%	98.1%								
9	1170 ± 80	86 ± 3	24 ± 1	92.7%	98.0%								
10	1170 ± 80	86 ± 3	24 ± 1	92.7%	98.0%								
11	1280 ± 90	95 ± 3	27 ± 1	92.6%	97.9%	1160 ± 80	81 ± 2	22 ± 1	93.1%	98.1%	93.2%	98.7%	0.75
12	980 ± 70	70 ± 2	19 ± 1	92.9%	98.1%								
13	1050 ± 70	75 ± 2	21 ± 1	92.8%	98.0%	1090 ± 80	75 ± 2	20 ± 1	93.1%	98.1%	92.8%	98.6%	0.70
14	1000 ± 70	72 ± 2	20 ± 1	92.8%	98.1%	1020 ± 70	69 ± 2	19 ± 1	93.2%	98.2%	92.3%	98.5%	0.76
15	970 ± 70	69 ± 2	19 ± 1	92.9%	98.1%	950 ± 70	64 ± 2	17 ± 1	93.3%	98.2%	91.8%	98.4%	0.73
16	870 ± 60	61 ± 2	16 ± 1	93.0%	98.1%	890 ± 60	59 ± 2	16 ± 1	93.4%	98.2%	91.2%	98.3%	0.76

Table 81. Visit Specific Duct Leakage Measurements: Site 6 (IP)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[CFM]	Supply [CFM]	Return [CFM]			[CFM]	Supply [CFM]	Return [CFM]					
1	1080 ± 80	64 ± 2	13 ± 1	94.1%	98.8%	1090 ± 80	64 ± 2	13 ± 1	94.1%	98.8%	90.6%	98.2%	0.78
2	1030 ± 70	59 ± 2	12 ± 1	94.2%	98.8%	990 ± 70	56 ± 2	11 ± 1	94.4%	98.9%	89.7%	98.0%	dropped
3	980 ± 70	55 ± 2	11 ± 1	94.3%	98.9%	960 ± 70	53 ± 2	10 ± 1	94.4%	98.9%	89.4%	98.0%	
4	970 ± 70	55 ± 2	11 ± 1	94.3%	98.9%								
5	1120 ± 80	67 ± 2	14 ± 1	94.0%	98.8%								
6	1120 ± 80	67 ± 2	14 ± 1	94.0%	98.8%								
7	1120 ± 80	68 ± 2	14 ± 1	94.0%	98.8%								
8	1050 ± 70	62 ± 2	13 ± 1	94.1%	98.8%								
9	1160 ± 80	71 ± 2	15 ± 1	93.9%	98.7%								
10	1130 ± 80	68 ± 2	14 ± 1	94.0%	98.8%								
11	1090 ± 80	65 ± 2	13 ± 1	94.0%	98.8%								
12	1060 ± 70	62 ± 2	13 ± 1	94.1%	98.8%								
13	1000 ± 70	58 ± 2	12 ± 1	94.3%	98.9%	980 ± 70	55 ± 2	11 ± 1	94.4%	98.9%	89.6%	98.0%	0.73
14	980 ± 70	55 ± 2	11 ± 1	94.3%	98.9%	960 ± 70	53 ± 2	10 ± 1	94.4%	98.9%	89.4%	98.0%	0.81
15	960 ± 70	54 ± 2	11 ± 1	94.4%	98.9%	950 ± 70	52 ± 2	10 ± 1	94.5%	98.9%	89.3%	97.9%	dropped
16	920 ± 60	51 ± 2	10 ± 1	94.5%	98.9%	900 ± 60	49 ± 1	9 ± 1	94.6%	99.0%	88.8%	97.8%	0.72

Table 82. Visit Specific Duct Leakage Measurements: Site 7 (IP)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[CFM]	Supply [CFM]	Return [CFM]			[CFM]	Supply [CFM]	Return [CFM]					
1	830 ± 60	71 ± 2	55 ± 2	91.4%	93.4%	830 ± 60	69 ± 2	53 ± 2	91.6%	93.5%	90.1%	n/a	0.86
2	760 ± 50	64 ± 2	49 ± 1	91.7%	93.6%	780 ± 50	64 ± 2	49 ± 1	91.8%	93.7%	89.5%	n/a	0.85
3	770 ± 50	64 ± 2	49 ± 1	91.6%	93.6%								
4	770 ± 50	64 ± 2	50 ± 1	91.6%	93.5%								
5	750 ± 50	62 ± 2	48 ± 1	91.7%	93.6%								
6	780 ± 50	66 ± 2	51 ± 2	91.6%	93.5%								
7	670 ± 50	53 ± 2	41 ± 1	92.0%	93.8%								
8	650 ± 50	52 ± 2	40 ± 1	92.1%	93.9%								
9	680 ± 50	54 ± 2	42 ± 1	92.0%	93.8%								
10	670 ± 50	54 ± 2	41 ± 1	92.0%	93.8%								
11	680 ± 50	54 ± 2	42 ± 1	92.0%	93.8%								
12	630 ± 40	49 ± 1	38 ± 1	92.1%	94.0%	630 ± 40	48 ± 1	37 ± 1	92.3%	94.1%	87.2%	n/a	0.84
13	650 ± 50	51 ± 2	39 ± 1	92.1%	93.9%	660 ± 50	51 ± 2	39 ± 1	92.2%	94.0%	87.8%	n/a	0.85
14	640 ± 40	50 ± 2	38 ± 1	92.1%	93.9%	630 ± 40	49 ± 1	38 ± 1	92.3%	94.1%	87.4%	n/a	0.82
15	630 ± 40	50 ± 1	38 ± 1	92.1%	94.0%	630 ± 40	49 ± 1	37 ± 1	92.3%	94.1%	87.3%	n/a	0.83
16	620 ± 40	48 ± 1	37 ± 1	92.2%	94.0%	620 ± 40	47 ± 1	36 ± 1	92.3%	94.1%	87.0%	n/a	0.84

Table 83. Visit Specific Duct Leakage Measurements: Site 8 (IP)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[CFM]	Supply [CFM]	Return [CFM]			[CFM]	Supply [CFM]	Return [CFM]					
1	750 ± 50	153 ± 5	46 ± 1	79.4%	93.8%	740 ± 50	150 ± 4	46 ± 1	79.8%	93.8%	87.8%	n/a	0.67
2	740 ± 50	153 ± 5	46 ± 1	79.4%	93.8%	720 ± 50	142 ± 4	45 ± 1	80.1%	93.7%	87.4%	n/a	0.61
3	750 ± 50	154 ± 5	46 ± 1	79.4%	93.8%								
4	730 ± 50	150 ± 4	46 ± 1	79.6%	93.8%								
5	710 ± 50	143 ± 4	45 ± 1	79.9%	93.7%								
6	730 ± 50	147 ± 4	45 ± 1	79.7%	93.7%								
7	710 ± 50	142 ± 4	45 ± 1	79.9%	93.7%								
8	700 ± 50	141 ± 4	45 ± 1	80.0%	93.7%								
9	720 ± 50	145 ± 4	45 ± 1	79.8%	93.7%								
10	790 ± 60	165 ± 5	47 ± 1	78.9%	93.9%								
11	730 ± 50	148 ± 4	45 ± 1	79.7%	93.7%								
12	720 ± 50	146 ± 4	45 ± 1	79.7%	93.7%								
13	720 ± 50	144 ± 4	45 ± 1	79.8%	93.7%	710 ± 50	140 ± 4	44 ± 1	80.2%	93.7%	87.2%	n/a	0.67
14	720 ± 50	150 ± 5	46 ± 1	79.0%	93.6%	710 ± 50	145 ± 4	45 ± 1	79.4%	93.6%	87.2%	n/a	0.72
15	740 ± 50	152 ± 5	46 ± 1	79.5%	93.8%	740 ± 50	149 ± 4	46 ± 1	79.8%	93.8%	87.8%	n/a	0.69
16	730 ± 50	147 ± 4	45 ± 1	79.7%	93.7%	730 ± 50	146 ± 4	45 ± 1	80.0%	93.8%	87.6%	n/a	0.67

Table 84. Visit Specific Duct Leakage Measurements: Site 9 (IP)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[CFM]	Supply [CFM]	Return [CFM]			[CFM]	Supply [CFM]	Return [CFM]					
1	1900 ± 130	80 ± 2	191 ± 6	95.8%	89.9%	1920 ± 130	80 ± 2	192 ± 6	95.8%	90.0%	95.3%	98.2%	0.53
2	1900 ± 130	80 ± 2	192 ± 6	95.8%	89.9%								
3	1930 ± 140	82 ± 2	196 ± 6	95.8%	89.9%								
4	1990 ± 140	82 ± 2	195 ± 6	95.9%	90.2%								
5	1870 ± 130	81 ± 2	195 ± 6	95.6%	89.6%								
6	1910 ± 130	80 ± 2	193 ± 6	95.8%	89.9%								
7	1910 ± 130	81 ± 2	193 ± 6	95.8%	89.9%								
8	1950 ± 140	72 ± 2	171 ± 5	96.3%	91.2%								
9	1990 ± 140	73 ± 2	176 ± 5	96.3%	91.2%								
10	2010 ± 140	74 ± 2	178 ± 5	96.3%	91.1%								
11	2080 ± 150	78 ± 2	186 ± 6	96.3%	91.1%	2120 ± 150	77 ± 2	185 ± 6	96.3%	91.3%	95.7%	98.4%	0.57
12	2060 ± 140	77 ± 2	184 ± 6	96.3%	91.1%								
13	2030 ± 140	75 ± 2	180 ± 5	96.3%	91.1%	2070 ± 140	75 ± 2	180 ± 5	96.4%	91.3%	95.6%	98.3%	0.61
14	2010 ± 140	74 ± 2	179 ± 5	96.3%	91.1%	2050 ± 140	74 ± 2	179 ± 5	96.4%	91.3%	95.6%	98.3%	0.50
15	2050 ± 140	76 ± 2	183 ± 5	96.3%	91.1%	2090 ± 150	76 ± 2	182 ± 5	96.4%	91.3%	95.6%	98.4%	dropped
16	2000 ± 140	74 ± 2	177 ± 5	96.3%	91.1%	2040 ± 140	74 ± 2	177 ± 5	96.4%	91.3%	95.6%	98.3%	dropped

Table 85. Visit Specific Duct Leakage Measurements: Site 10 (IP)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[CFM]	Supply [CFM]	Return [CFM]			[CFM]	Supply [CFM]	Return [CFM]					

Duct leakage testing was not performed at Site 10

Table 86. Visit Specific Duct Leakage Measurements: Site 11 (IP)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[CFM]	Supply [CFM]	Return [CFM]			[CFM]	Supply [CFM]	Return [CFM]					
1	1490 ± 100	508 ± 15	138 ± 4	66.0%	90.7%	1540 ± 110	513 ± 15	140 ± 4	66.6%	90.9%	95.5%	98.3%	0.59
2	1520 ± 110	516 ± 15	141 ± 4	65.9%	90.7%	1530 ± 110	510 ± 15	139 ± 4	66.6%	90.9%	95.5%	98.3%	0.59
3	1500 ± 110	512 ± 15	139 ± 4	66.0%	90.7%	1520 ± 110	507 ± 15	138 ± 4	66.6%	90.9%	95.5%	98.3%	dropped
4	1510 ± 110	514 ± 15	140 ± 4	65.9%	90.7%								
5	1470 ± 100	498 ± 15	135 ± 4	66.0%	90.8%								
6	1490 ± 100	505 ± 15	138 ± 4	66.0%	90.7%								
7	1480 ± 100	504 ± 15	137 ± 4	66.0%	90.7%								
8	1420 ± 100	480 ± 14	131 ± 4	66.1%	90.8%								
9	1440 ± 100	489 ± 15	133 ± 4	66.1%	90.8%								
10	1430 ± 100	486 ± 15	132 ± 4	66.1%	90.8%	1460 ± 100	485 ± 15	132 ± 4	66.7%	90.9%	95.3%	98.2%	0.64
11	1290 ± 90	432 ± 13	117 ± 4	66.4%	90.9%	1320 ± 90	435 ± 13	118 ± 4	67.0%	91.0%	94.8%	98.0%	0.61
12	1160 ± 80	388 ± 12	105 ± 3	66.6%	91.0%								
13	1150 ± 80	385 ± 12	104 ± 3	66.6%	91.0%	1180 ± 80	385 ± 12	104 ± 3	67.2%	91.2%	94.2%	97.8%	0.61
14	1370 ± 100	464 ± 14	126 ± 4	66.2%	90.8%	1400 ± 100	464 ± 14	126 ± 4	66.8%	91.0%	95.1%	98.1%	0.61
15	1370 ± 100	462 ± 14	125 ± 4	66.2%	90.8%	1390 ± 100	463 ± 14	126 ± 4	66.8%	91.0%	95.1%	98.1%	0.58

Table 87. Visit Specific Duct Leakage Measurements: Site 12 (IP)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[CFM]	Supply [CFM]	Return [CFM]			[CFM]	Supply [CFM]	Return [CFM]					
1	1440 ± 100	150 ± 5	250 ± 7	89.6%	82.6%								
2	1330 ± 90	135 ± 4	229 ± 7	89.8%	82.8%								
3	1290 ± 90	130 ± 4	222 ± 7	89.9%	82.8%								
4	1340 ± 90	137 ± 4	231 ± 7	89.8%	82.7%								
5	1320 ± 90	134 ± 4	228 ± 7	89.8%	82.8%								
6	1350 ± 90	138 ± 4	234 ± 7	89.8%	82.7%								
7	1340 ± 90	137 ± 4	231 ± 7	89.8%	82.7%								
8	1340 ± 90	137 ± 4	231 ± 7	89.8%	82.7%								
9	1200 ± 80	119 ± 4	206 ± 6	90.1%	82.9%								
10	1390 ± 100	143 ± 4	240 ± 7	89.7%	82.7%								
11	1460 ± 100	153 ± 5	254 ± 8	89.5%	82.6%	1500 ± 110	152 ± 5	253 ± 8	89.8%	83.1%	91.5%	n/a	0.78
12	1350 ± 90	138 ± 4	233 ± 7	89.8%	82.7%								
13	1390 ± 100	143 ± 4	240 ± 7	89.7%	82.7%	1520 ± 110	155 ± 5	256 ± 8	89.8%	83.1%	91.6%	n/a	0.77
14	1360 ± 100	140 ± 4	235 ± 7	89.7%	82.7%	1490 ± 100	152 ± 5	252 ± 8	89.8%	83.1%	91.5%	n/a	0.74
15	1350 ± 90	138 ± 4	233 ± 7	89.8%	82.7%	1470 ± 100	148 ± 4	247 ± 7	89.9%	83.1%	91.3%	n/a	0.78

Table 88. Visit Specific Duct Leakage Measurements: Site 13 (IP)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[CFM]	Supply [CFM]	Return [CFM]			[CFM]	Supply [CFM]	Return [CFM]					
1	850 ± 60	150 ± 5	42 ± 1	82.3%	95.0%	920 ± 60	166 ± 5	46 ± 1	82.0%	95.0%	89.6%	n/a	0.90
2	870 ± 60	155 ± 5	43 ± 1	82.2%	95.0%								
3	860 ± 60	153 ± 5	43 ± 1	82.2%	95.0%								
4	820 ± 60	142 ± 4	40 ± 1	82.5%	95.1%								
5	870 ± 60	156 ± 5	44 ± 1	82.1%	95.0%								
6	860 ± 60	152 ± 5	43 ± 1	82.2%	95.0%								
7	890 ± 60	160 ± 5	45 ± 1	82.0%	95.0%								
8	830 ± 60	145 ± 4	41 ± 1	82.5%	95.1%	890 ± 60	158 ± 5	44 ± 1	82.3%	95.0%	89.2%	n/a	0.69
9	910 ± 60	164 ± 5	46 ± 1	81.9%	95.0%	1010 ± 70	187 ± 6	52 ± 2	81.5%	94.9%	90.4%	n/a	0.68
10	780 ± 50	133 ± 4	38 ± 1	82.8%	95.1%	880 ± 60	155 ± 5	43 ± 1	82.3%	95.1%	89.1%	n/a	0.68
11	700 ± 50	116 ± 3	33 ± 1	83.5%	95.3%	750 ± 50	125 ± 4	36 ± 1	83.3%	95.3%	87.3%	n/a	0.67
12	670 ± 50	109 ± 3	31 ± 1	83.7%	95.3%	710 ± 50	116 ± 3	33 ± 1	83.6%	95.3%	86.6%	n/a	0.72
13	830 ± 60	146 ± 4	41 ± 1	82.4%	95.1%	910 ± 60	161 ± 5	45 ± 1	82.3%	95.0%	89.4%	n/a	0.70
14	820 ± 60	144 ± 4	40 ± 1	82.5%	95.1%	880 ± 60	156 ± 5	44 ± 1	82.3%	95.0%	89.1%	n/a	0.71
15	780 ± 50	134 ± 4	38 ± 1	82.8%	95.1%	840 ± 60	146 ± 4	41 ± 1	82.6%	95.1%	88.6%	n/a	0.76
16	790 ± 60	135 ± 4	38 ± 1	82.8%	95.1%								

Table 89. Visit Specific Duct Leakage Measurements: Site 14 (IP)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[CFM]	Supply [CFM]	Return [CFM]			[CFM]	Supply [CFM]	Return [CFM]					
1	920 ± 60	72 ± 2	44 ± 1	92.2%	95.2%								
2	920 ± 60	72 ± 2	45 ± 1	92.1%	95.2%								
3	1010 ± 70	82 ± 2	49 ± 1	91.9%	95.1%								
4	960 ± 70	76 ± 2	46 ± 1	92.0%	95.1%								
5	1000 ± 70	81 ± 2	49 ± 1	91.9%	95.1%								
6	960 ± 70	76 ± 2	46 ± 1	92.0%	95.2%								
7	940 ± 70	74 ± 2	45 ± 1	92.1%	95.2%								
8	990 ± 70	80 ± 2	48 ± 1	91.9%	95.1%	1000 ± 70	79 ± 2	48 ± 1	92.1%	95.2%	93.2%	n/a	0.86
9	860 ± 60	65 ± 2	41 ± 1	92.4%	95.2%	880 ± 60	66 ± 2	41 ± 1	92.5%	95.3%	92.3%	n/a	0.86
10	840 ± 60	63 ± 2	40 ± 1	92.4%	95.2%	860 ± 60	63 ± 2	40 ± 1	92.6%	95.3%	92.1%	n/a	0.81
11	880 ± 60	67 ± 2	42 ± 1	92.3%	95.2%	890 ± 60	67 ± 2	42 ± 1	92.5%	95.3%	92.4%	n/a	0.81
12	860 ± 60	65 ± 2	41 ± 1	92.4%	95.2%	880 ± 60	66 ± 2	41 ± 1	92.5%	95.3%	92.3%	n/a	0.81
13	860 ± 60	65 ± 2	41 ± 1	92.4%	95.2%								
14	940 ± 70	74 ± 2	45 ± 1	92.1%	95.2%	960 ± 70	74 ± 2	45 ± 1	92.2%	95.3%	92.9%	n/a	0.83
15	910 ± 60	71 ± 2	44 ± 1	92.2%	95.2%	940 ± 70	72 ± 2	44 ± 1	92.3%	95.3%	92.8%	n/a	0.81
16	940 ± 70	74 ± 2	45 ± 1	92.1%	95.2%								

Table 90. Visit Specific Duct Leakage Measurements: Site 15 (IP)

	Fan Only Mode					Cooling Mode							
		Leakage to Exterior					Leakage to Exterior						
Visit	System Air Flow [CFM]	Supply [CFM]	Return [CFM]	Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow [CFM]	Supply [CFM]	Return [CFM]	Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
1	1160 ± 80	270 ± 8	n/a	76.8%	100%								
2	1110 ± 80	253 ± 8		77.3%	100%								
3	1130 ± 80	259 ± 8		77.1%	100%								
4	1120 ± 80	255 ± 8		77.2%	100%								
5	1080 ± 80	243 ± 7		77.6%	100%								
6	1110 ± 80	250 ± 8		77.4%	100%								
7	1040 ± 70	227 ± 7		78.1%	100%	1050 ± 70	216 ± 6		79.4%	100%	93.4%	n/a	0.76
8	1060 ± 70	236 ± 7		77.8%	100%								
9	1130 ± 80	258 ± 8		77.2%	100%	1180 ± 80	255 ± 8		78.3%	100%	94.1%	n/a	0.75
10	1090 ± 80	246 ± 7		77.5%	100%	1150 ± 80	246 ± 7		78.5%	100%	94.0%	n/a	0.75
11	1080 ± 80	240 ± 7		77.7%	100%	1120 ± 80	238 ± 7		78.8%	100%	93.8%	n/a	0.75
12	1100 ± 80	246 ± 7		77.5%	100%	1140 ± 80	245 ± 7		78.5%	100%	93.9%	n/a	0.75
13	1100 ± 80	248 ± 7		77.4%	100%	1150 ± 80	247 ± 7		78.5%	100%	94.0%	n/a	0.74
14	1100 ± 80	249 ± 7		77.4%	100%	1160 ± 80	250 ± 7		78.4%	100%	94.0%	n/a	0.75
15	1100 ± 80	249 ± 7		77.4%	100%								
16	1100 ± 80	248 ± 7		77.5%	100%								

Table 91. Visit Specific Duct Leakage Measurements: Site 16 (IP)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[CFM]	Supply [CFM]	Return [CFM]			[CFM]	Supply [CFM]	Return [CFM]					
1	610 ± 40	24 ± 1	Below detection	96.1%	100%								
2	540 ± 40	21 ± 1		96.1%	100%								
3	580 ± 40	23 ± 1		96.1%	100%								
4	610 ± 40	24 ± 1		96.1%	100%								
5	610 ± 40	24 ± 1		96.1%	100%								
6	630 ± 40	25 ± 1		96.1%	100%								
7	650 ± 50	25 ± 1		96.1%	100%	1020 ± 70	40 ± 1	6 ± 1	96.1%	99.4%	94.5%	n/a	0.91
8	620 ± 40	24 ± 1		96.1%	100%								
9	630 ± 40	24 ± 1		96.1%	100%	1080 ± 80	42 ± 1	7 ± 1	96.1%	99.3%	94.8%	n/a	0.81
10	630 ± 40	25 ± 1		96.1%	100%	1080 ± 80	42 ± 1	7 ± 1	96.1%	99.3%	94.7%	n/a	0.85
11	620 ± 40	24 ± 1		96.1%	100%	1080 ± 80	42 ± 1	7 ± 1	96.1%	99.3%	94.7%	n/a	0.76
12	600 ± 40	23 ± 1		96.1%	100%								
13	610 ± 40	24 ± 1		96.1%	100%	1030 ± 70	40 ± 1	6 ± 1	96.1%	99.4%	94.5%	n/a	0.88
14	600 ± 40	23 ± 1		96.1%	100%	1030 ± 70	40 ± 1	6 ± 1	96.1%	99.4%	94.5%	n/a	0.88
15	600 ± 40	23 ± 1		96.1%	100%								
16	490 ± 30	22 ± 1		95.6%	100%								

Table 92. Visit Specific Duct Leakage Measurements: Site 17 (IP)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[CFM]	Supply [CFM]	Return [CFM]			[CFM]	Supply [CFM]	Return [CFM]					

Duct leakage testing was not performed at Site 17

Appendix D.6: Importance of Filter Pressure Drop (IP)

Table 93. Importance of Filter Pressure Drop: Site 1 (IP)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	ΔSystem Air Flow, relative to 400 CFM/ton [CFM]	[%]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop
1	2	0	0.100	0.355	29%	0.135	0.426	-395	75%	21%
2	2	30	0.105	0.331	26%	0.139	0.442	-379	76%	26%
3	2	59	0.110	0.302	22%	0.142	0.412	-365	77%	24%
4	2	88	0.118	0.310	21%					
5	7	0	0.102	0.390	43%					
6	7	35	0.103	0.406	46%					
7	7	68	0.100	0.407	49%					
8	7	95	0.105	0.430	48%					
9	11	0	0.100	0.427	45%					
10	11	29	0.106	0.429	50%					
11	11	62	0.096	0.381	51%					
12	11	91	0.096	0.390	50%					
13	11	0	0.096	0.401	49%					
14	11	27	0.096	0.394	52%	0.129	0.498	-422	74%	50%
15	11	55	0.100	0.411	52%	0.128	0.505	-426	73%	51%
16	11	86	0.094	0.404	53%	0.126	0.510	-435	73%	51%

Table 94. Importance of Filter Pressure Drop: Site 2 (IP)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	ΔSystem Air Flow, relative to 400 CFM/ton [CFM]	[%]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop
1	2	0	0.124	0.249	83%	0.124	0.261	-89	93%	84%
2	2	27	0.123	0.203	79%	0.123	0.212	-94	92%	80%
3	2	59	0.122	0.288	85%	0.122	0.298	-99	92%	86%
4	2	93	0.135	0.297	85%					
5	6	0	0.095	0.388	90%					
6	6	26	0.092	0.398	91%					
7	6	63	0.097	0.422	91%					
8	6	93	0.109	0.343	90%					
9	11	0	0.115	0.414	91%					
10	11	22	0.103	0.395	90%					
11	11	52	0.086	0.406	90%					
12	11	84	0.087	0.399	91%					
13	11	0	0.087	0.420	93%					
14	11	29	0.080	0.442	92%	0.082	0.454	-294	75%	92%
15	11	56	0.088	0.447	92%	0.089	0.471	-259	78%	92%
16	11	83	0.081	0.456	93%	0.079	0.484	-312	74%	93%

Table 95. Importance of Filter Pressure Drop: Site 3 (IP)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	ΔSystem Air Flow, relative to 400 CFM/ton [CFM]	[%]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop
1	11	0	0.178	n/a	n/a	0.191	n/a	-95	90%	n/a
2	11	27	0.190	0.149	96%	0.193	0.157	-90	91%	95%
3	11	56	0.192	0.149	98%	0.204	0.160	-65	94%	95%
4	11	82	0.195	0.149	98%					
5	6	0	0.189	0.132	100%					
6	6	31	0.198	0.135	98%					
7	6	66	0.199	0.133	100%					
8	6	99	0.195	0.140	98%					
9	2	0	0.205	0.072	95%					
10	2	23	0.208	0.073	96%					
11	2	57	0.203	0.071	100%					
12	2	84	0.199	0.071	93%	0.213	0.077	-44	96%	89%
13	2	0	0.205	0.072	92%	0.221	0.078	-25	98%	92%
14	2	34	0.189	0.072	92%	0.209	0.078	-54	95%	93%
15	2	60	0.187	0.070	95%	0.209	0.079	-54	95%	93%
16	2	78	0.182	0.072	94%	0.199	0.080	-75	93%	94%

Table 96. Importance of Filter Pressure Drop: Site 4 (IP)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	ΔSystem Air Flow, relative to 400 CFM/ton [CFM]	[%]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop
1	11	3	0.123	n/a	n/a	0.122	0.575	46	108%	43%
2	11	30	0.102	0.471	69%	0.121	0.578	45	108%	56%
3	11	59	0.101	0.490	58%	0.123	0.594	48	108%	57%
4	11	85	0.103	0.486	46%					
5	6	0	0.106	0.431	59%					
6	6	31	0.110	0.443	56%					
7	6	66	0.111	0.446	54%					
8	6	99	0.110	0.433	60%					
9	2	0	0.120	0.329	41%					
10	2	23	0.123	0.342	39%					
11	2	57	0.117	0.327	34%					
12	2	84	0.116	0.334	40%	0.152	0.436	123	121%	39%
13	2	1	0.120	0.324	43%	0.160	0.441	140	123%	40%
14	2	35	0.104	0.304	44%	0.140	0.416	93	115%	43%
15	2	61	0.110	0.316	45%	0.146	0.424	107	118%	43%
16	2	79	0.098	0.316	48%	0.131	0.420	69	112%	48%

Table 97. Importance of Filter Pressure Drop: Site 5 (IP)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	ΔSystem Air Flow, relative to 400 CFM/ton [CFM]	[%]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop
1	2	0	0.192	0.557	24%	0.192	0.557	339	134%	24%
2	2	27	0.181	0.587	34%	0.181	0.587	299	130%	34%
3	2	57	0.125	0.629	47%	0.131	0.634	106	111%	45%
4	2	87	0.146	0.674	51%					
5	6	0	0.138	0.662	48%					
6	6	27	0.139	0.706	58%					
7	6	66	0.121	0.801	68%					
8	6	96	0.118	0.852	75%					
9	11	0	0.162	0.641	44%					
10	11	35	0.160	0.658	50%					
11	11	61	0.193	0.658	52%	0.144	0.656	160	116%	49%
12	11	98	0.113	0.707	57%					
13	11	0	0.129	0.665	48%	0.127	0.665	87	109%	47%
14	11	29	0.118	0.702	55%	0.111	0.705	15	101%	55%
15	11	63	0.111	0.777	62%	0.098	0.765	-46	95%	62%
16	11	92	0.089	0.836	71%	0.084	0.836	-115	88%	70%

Table 98. Importance of Filter Pressure Drop: Site 6 (IP)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	ΔSystem Air Flow, relative to 400 CFM/ton [CFM]	[%]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop
1	7	0	0.077	0.320	61%	0.077	0.320	-113	91%	81%
2	7	34	0.070	0.382	81%	0.064	0.390	-211	82%	90%
3	7	63	0.064	0.500	90%	0.060	0.500	-242	80%	100%
4	7	90	0.062	0.502	91%					
5	2	0	0.083	0.238	78%					
6	2	28	0.083	0.268	80%					
7	2	64	0.084	0.282	84%					
8	2	98	0.074	0.299	83%					
9	2	0	0.090	0.239	76%					
10	2	28	0.085	0.255	79%					
11	2	63	0.080	0.289	82%					
12	2	87	0.074	0.314	92%					
13	11	0	0.067	0.432	92%	0.062	0.430	-223	81%	89%
14	11	33	0.064	0.453	95%	0.060	0.453	-239	80%	93%
15	11	60	0.061	0.470	95%	0.059	0.474	-252	79%	92%
16	11	103	0.056	0.502	93%	0.053	0.500	-299	75%	91%

Table 99. Importance of Filter Pressure Drop: Site 7 (IP)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	ΔSystem Air Flow, relative to 400 CFM/ton [CFM]	[%]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop
1	2	0	0.226	0.180	80%	0.216	0.174	-374	69%	80%
2	2	34	0.190	0.234	87%	0.190	0.237	-425	65%	87%
3	2	62	0.191	0.267	86%					
4	2	87	0.193	0.282	89%					
5	6	0	0.184	0.313	90%					
6	6	25	0.199	0.333	92%					
7	6	65	0.146	0.365	92%					
8	6	92	0.139	0.386	93%					
9	11	0	0.149	0.307	90%					
10	11	36	0.147	0.343	91%					
11	11	69	0.149	0.343	91%					
12	11	96	0.129	0.344	92%	0.124	0.337	-575	52%	92%
13	11	0	0.136	0.313	88%	0.136	0.296	-544	55%	87%
14	11	33	0.132	0.323	89%	0.127	0.320	-566	53%	88%
15	11	62	0.131	0.330	91%	0.127	0.325	-568	53%	91%
16	11	92	0.123	0.340	92%	0.121	0.341	-582	51%	90%

Table 100. Importance of Filter Pressure Drop: Site 8 (IP)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	ΔSystem Air Flow, relative to 400 CFM/ton [CFM]	[%]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop
1	2	0	0.178	0.141	62%	0.173	0.159	-458	62%	57%
2	2	31	0.178	0.155	66%	0.161	0.148	-485	60%	67%
3	2	62	0.180	0.171	69%					
4	2	88	0.173	0.177	68%					
5	6	0	0.162	0.251	76%					
6	6	28	0.169	0.256	78%					
7	6	63	0.161	0.290	72%					
8	6	91	0.158	0.266	81%					
9	11	0	0.166	0.248	80%					
10	11	37	0.198	0.242	73%					
11	11	69	0.170	0.234	75%					
12	11	99	0.168	0.225	72%					
13	11	0	0.164	0.266	77%	0.157	0.261	-494	59%	78%
14	11	30	0.174	0.225	76%	0.166	0.227	-494	59%	75%
15	11	56	0.176	0.228	71%	0.172	0.221	-460	62%	71%
16	11	98	0.169	0.231	75%	0.166	0.232	-473	61%	74%

Table 101. Importance of Filter Pressure Drop: Site 9 (IP)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop[1]	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	ΔSystem Air Flow, relative to 400 CFM/ton [CFM]	[%]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop[1]
1	7	0	0.212	0.320	n/a	0.214	0.322	-80	96%	n/a
2	7	28	0.213	0.303						
3	7	58	0.220	0.303						
4	7	82	0.219	0.327						
5	11	0	0.219	0.336						
6	11	44	0.215	0.326						
7	11	81	0.216	0.340						
8	11	126	0.178	0.278						
9	2	0	0.185	0.236						
10	2	11	0.189	0.237						
11	2	50	0.203	0.224		0.201	0.238	115	106%	
12	2	97	0.199	0.214						
13	11	0	0.192	0.260		0.192	0.257	65	103%	
14	11	32	0.190	0.269		0.190	0.272	54	103%	
15	11	64	0.197	0.268		0.196	0.277	87	104%	
16	11	92	0.187	0.271		0.188	0.284	43	102%	

[1] Filter pressure drop is not directly measured at Site 9 due to access limitations

Table 102. Importance of Filter Pressure Drop: Site 10 (IP)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	ΔSystem Air Flow, relative to 400 CFM/ton [CFM]	[%]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop
1	2	0	0.185	n/a	n/a	0.177	n/a	-154	89%	n/a
2	2	29	0.222	0.430	15%					
3	2	58	0.218	0.426	15%					
4	2	82	0.234	0.445	14%					
5	6	0	0.207	0.506	29%					
6	6	44	0.205	0.513	29%					
7	6	81	0.206	0.506	30%					
8	6	109	0.204	0.506	30%					
9	11	0	0.208	0.508	30%					
10	11	28	0.206	0.506	30%					
11	11	62	0.165	0.498	29%	0.161	0.500	-210	85%	30%
12	11	114	0.161	0.502	30%					
13	7	0	0.156	0.507	32%					
14	7	32	0.161	0.516	31%	0.162	0.538	-209	85%	30%
15	7	64	0.162	0.537	31%	0.164	0.546	-199	86%	31%
16	7	92	0.160	0.525	33%	0.160	0.537	-215	85%	33%

Table 103. Importance of Filter Pressure Drop: Site 11 (IP)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	ΔSystem Air Flow, relative to 400 CFM/ton [CFM]	[%]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop
1	2	0	0.312	0.109	99%	0.318	0.108	135	110%	93%
2	2	30	0.321	0.116	96%	0.314	0.119	126	109%	93%
3	2	57	0.316	0.135	100%	0.311	0.136	118	108%	92%
4	2	86	0.319	0.148	93%					
5	6	0	0.301	0.201	98%					
6	6	29	0.309	0.211	97%					
7	6	65	0.308	0.223	86%					
8	6	93	0.284	0.221	100%					
9	11	0	0.292	0.198	100%					
10	11	27	0.289	0.193	100%	0.288	0.192	56	104%	92%
11	11	60	0.237	0.217	100%	0.239	0.217	-85	94%	99%
12	11	94	0.197	0.243	100%					
13	6	0	0.195	0.210	100%	0.195	0.210	-223	84%	100%
14	6	30	0.267	0.261	100%	0.267	0.259	-3	100%	100%
15	6	64	0.265	0.314	100%	0.266	0.316	-6	100%	100%

Table 104. Importance of Filter Pressure Drop: Site 12 (IP)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop[1]	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	ΔSystem Air Flow, relative to 400 CFM/ton [CFM]	[%]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop[1]
1	12	0	0.268	n/a	n/a					n/a
2	12	35	0.230	0.283						
3	12	59	0.216	0.281						
4	12	87	0.233	0.288						
5	11	0	0.227	0.281						
6	11	36	0.237	0.291						
7	11	72	0.233	0.295						
8	11	98	0.233	0.295						
9	11	0	0.188	0.280						
10	11	35	0.250	0.281						
11	11	61	0.277	0.318		0.274	0.320	-503	75%	
12	11	93	0.236	0.283						
13	11	0	0.250	0.266		0.281	0.294	-484	76%	
14	11	27	0.240	0.274		0.273	0.311	-506	75%	
15	11	71	0.236	0.274		0.263	0.311	-533	73%	

[1] Filter pressure drop is not directly measured at Site 12 due to access limitations

Table 105. Importance of Filter Pressure Drop: Site 13 (IP)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	ΔSystem Air Flow, relative to 400 CFM/ton [CFM]	[%]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop
1	6	0	0.114	0.301	100%	0.132	0.340	-476	66%	100%
2	6	30	0.119	0.337	100%					
3	6	63	0.117	0.375	100%					
4	6	98	0.105	0.448	100%					
5	11	0	0.121	0.260	100%					
6	11	25	0.116	0.299	100%					
7	11	56	0.125	0.324	100%					
8	11	86	0.108	0.371	100%	0.123	0.405	-509	64%	100%
9	2	0	0.129	0.171	100%	0.157	0.201	-393	72%	100%
10	2	32	0.095	0.312	100%	0.119	0.384	-521	63%	100%
11	2	62	0.077	0.508	100%	0.086	0.577	-652	53%	100%
12	2	94	0.070	0.651	100%	0.078	0.698	-690	51%	100%
13	11	0	0.109	0.320	100%	0.126	0.372	-492	65%	100%
14	11	30	0.107	0.410	100%	0.120	0.446	-518	63%	100%
15	11	57	0.096	0.461	100%	0.109	0.507	-562	60%	100%
16	11	87	0.097	0.474	100%					

Table 106. Importance of Filter Pressure Drop: Site 14 (IP)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	ΔSystem Air Flow, relative to 400 CFM/ton [CFM]	[%]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop
1	7	0	0.100	0.394	81%					
2	7	26	0.100	0.400	82%					
3	7	55	0.119	0.388	81%					
4	7	91	0.108	0.392	81%					
5	2	0	0.118	0.306	75%					
6	2	28	0.108	0.312	76%					
7	2	55	0.104	0.320	75%					
8	2	87	0.116	0.354	70%	0.113	0.353	-204	83%	68%
9	11	0	0.087	0.493	88%	0.087	0.476	-324	73%	87%
10	11	30	0.083	0.507	88%	0.083	0.500	-345	71%	88%
11	7	0	0.090	0.304	73%	0.090	0.297	-312	74%	73%
12	7	28	0.087	0.330	75%	0.087	0.322	-324	73%	75%
13	7	58	0.087	0.351	77%					
14	2	0	0.104	0.238	70%	0.104	0.235	-245	80%	69%
15	2	28	0.098	0.276	66%	0.100	0.279	-264	78%	65%
16	2	62	0.104	0.271	66%					

Table 107. Importance of Filter Pressure Drop: Site 15 (IP)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	ΔSystem Air Flow, relative to 400 CFM/ton [CFM]	[%]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop
1	7	0	0.169	0.251	68%					
2	7	39	0.155	0.256	67%					
3	7	67	0.160	0.256	68%					
4	7	98	0.157	0.259	70%					
5	11	0	0.147	0.265	71%					
6	11	30	0.153	0.259	71%					
7	11	59	0.134	0.251	72%	0.125	0.252	50	105%	71%
8	11	92	0.141	0.231	76%					
9	2	0	0.159	0.176	52%	0.157	0.182	175	117%	53%
10	2	36	0.149	0.192	58%	0.149	0.188	145	114%	59%
11	2	62	0.144	0.235	62%	0.143	0.228	120	112%	62%
12	2	92	0.150	0.243	66%	0.149	0.239	143	114%	65%
13	7	0	0.151	0.268	75%	0.150	0.263	149	115%	74%
14	7	28	0.152	0.259	73%	0.152	0.258	157	116%	73%
15	7	60	0.152	0.267	74%					
16	7	90	0.151	0.265	75%					

Table 108. Importance of Filter Pressure Drop: Site 16 (IP)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	ΔSystem Air Flow, relative to 400 CFM/ton [CFM]	[%]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop
1	6	0	0.055	0.200	100%					
2	6	35	0.044	0.234	97%					
3	6	66	0.051	0.232	96%					
4	6	104	0.056	0.240	99%					
5	11	0	0.055	0.214	99%					
6	11	31	0.060	0.227	99%					
7	11	59	0.062	0.211	100%	0.165	0.485	423	171%	99%
8	11	87	0.058	0.219	100%					
9	2	0	0.058	0.102	100%	0.184	0.307	482	180%	100%
10	2	28	0.059	0.108	100%	0.182	0.317	476	179%	100%
11	2	56	0.057	0.111	100%	0.183	0.338	478	180%	100%
12	2	84	0.053	0.115	100%					
13	11	0	0.055	0.205	100%	0.166	0.495	428	171%	97%
14	11	33	0.053	0.211	97%	0.166	0.504	428	171%	95%
15	11	64	0.053	0.202	98%					
16	11	90	0.046	0.217	97%					

Table 109. Importance of Filter Pressure Drop: Site 17 (IP)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [in. H_2O]	Return Plenum Pressure [in. H_2O]	ΔSystem Air Flow, relative to 400 CFM/ton [CFM]	[%]	Filter Pressure Drop as Fraction of Return Plenum Pressure Drop
1	6	0	0.008	0.157	98%					
2	6	35	0.006	0.149	93%					
3	6	66	0.007	0.146	92%					
4	6	104	0.010	0.162	96%					
5	11	0	0.010	0.109	90%					
6	11	31	0.008	0.127	90%					
7	11	59	0.008	0.127	92%	0.010	0.322	208	135%	85%
8	11	87	0.010	0.144	94%					
9	2	0	0.008	n/a	n/a	0.026	n/a	720	220%	n/a
10	2	28	0.008	0.019	27%	0.027	0.064	750	225%	25%
11	2	56	0.009	0.015	16%	0.018	0.056	494	182%	14%
12	2	84	0.008	0.016	29%					
13	11	0	0.008	0.093	88%	0.020	0.243	578	196%	84%
14	11	33	0.008	0.111	82%	0.017	0.256	482	180%	79%
15	11	64	0.008	0.089	88%					
16	11	90	0.010	0.095	89%					

Appendix E: Full Tables for Field Sites (SI Units)

Appendix E.1: Filter Characteristics (SI)

Table 110. Filter Characteristics: Site 1 (SI)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]
1	2	0	25.3 ± 0.3*	59.0 ± 0.6*	21.8 ± 2.0	20.4 ± 0.6
2	2	30	21.7 ± 1.3	11.7 ± 0.6	29.1 ± 1.7	16.4 ± 0.6
3	2	59	16.9 ± 2.7	15.3 ± 2.6	24.8 ± 1.5	20.0 ± 2.2
4	2	88	16.2 ± 2.6	16.3 ± 3.2		
5	7	0	41.4 ± 1.1	13.3 ± 0.9		
6	7	35	46.8 ± 1.2	13.0 ± 1.2		
7	7	68	49.3 ± 1.3	12.8 ± 1.3		
8	7	95	50.8 ± 0.9	13.6 ± 1.0		
9	11	0	47.4 ± 1.2	11.0 ± 1.0		
10	11	29	52.9 ± 1.2	12.0 ± 1.1		
11	11	62	48.5 ± 1.3	10.1 ± 1.3		
12	11	91	49.0 ± 1.2	10.3 ± 1.2		
13	11	0	48.8 ± 3.1	12.0 ± 1.3		
14	11	27	50.6 ± 1.3	11.7 ± 1.3	61.9 ± 0.6*	18.1 ± 1.9
15	11	55	53.6 ± 1.4	11.8 ± 1.2	63.9 ± 1.7	17.9 ± 1.7
16	11	86	53.5 ± 0.8	13.4 ± 1.2	64.8 ± 1.5	19.8 ± 1.4

* Manual pressure reading from DG-700

Table 111. Filter Characteristics: Site 2 (SI)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]
1	2	0	51.1 ± 0.5	24.5 ± 0.6	54.5 ± 0.7	26.5 ± 0.6
2	2	27	39.9 ± 2.6	63.5 ± 0.7	42.0 ± 0.9	14.6 ± 5.4
3	2	59	61.1 ± 0.6	21.3 ± 0.1	63.7 ± 0.6	23.9 ± 0.2
4	2	93	63.2 ± 0.4	21.2 ± 0.6		
5	6	0	87.3 ± 0.4	19.2 ± 0.6		
6	6	26	90.1 ± 0.4	19.4 ± 0.6		
7	6	63	95.3 ± 0.3	25.9 ± 2.2		
8	6	93	76.4 ± 4.1	44.0 ± 4.2		
9	11	0	93.6 ± 0.5	16.1 ± 0.6		
10	11	22	88.6 ± 0.4	8.7 ± 0.6		
11	11	52	91.1 ± 0.4	19.5 ± 0.6		
12	11	84	90.2 ± 0.4	18.9 ± 0.6		
13	11	0	96.9 ± 0.4	19.4 ± 0.6		
14	11	29	101.7 ± 0.4	51.5 ± 7.3	104.5 ± 0.6	37.7 ± 11.2
15	11	56	102.6 ± 4.0	223.9 ± 11.6	107.5 ± 0.6	73.0 ± 16.4
16	11	83	105.3 ± 4.4	89.0 ± 10.5	111.6 ± 1.3	23.1 ± 12.3

Table 112. Filter Characteristics: Site 3 (SI)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]
1	11	0	34.7 ± 1.6	48.0 ± 2.4	37.0 ± 1.1	57.9 ± 2.1
2	11	27	35.4 ± 0.6	46.2 ± 0.5	37.2 ± 2.2	58.1 ± 3.7
3	11	56	36.3 ± 0.6	46.4 ± 1.0	37.9 ± 2.7	54.5 ± 4.2
4	11	82	36.4 ± 0.6	45.7 ± 0.9		
5	6	0	32.8 ± 0.6	45.0 ± 0.8		
6	6	31	33.1 ± 0.6	46.4 ± 0.6		
7	6	66	33.6 ± 0.6	46.7 ± 1.1		
8	6	99	34.0 ± 0.6	45.1 ± 0.9		
9	2	0	17.1 ± 1.4	46.6 ± 3.7		
10	2	23	17.4 ± 0.6	49.1 ± 0.5		
11	2	57	17.7 ± 0.1	44.9 ± 2.2		
12	2	84	16.4 ± 0.2	45.5 ± 1.1	17.1 ± 1.0	58.1 ± 4.0
13	2	0	16.3 ± 0.2	46.1 ± 1.0	17.8 ± 1.4	52.9 ± 4.3
14	2	34	16.5 ± 0.8	44.9 ± 1.1	18.1 ± 1.2	56.9 ± 4.0
15	2	60	16.6 ± 0.2	46.0 ± 1.3	18.4 ± 1.3	57.7 ± 4.2
16	2	78	16.8 ± 0.9	44.5 ± 1.0	18.8 ± 1.3	56.3 ± 4.2

Table 113. Filter Characteristics: Site 4 (SI)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]
1	11	0	88.6 ± 1.1	13.5 ± 0.1*	61.0 ± 3.0	13.8 ± 1.1
2	11	30	80.9 ± 2.7	9.3 ± 0.6	80.5 ± 3.7	14.6 ± 1.4
3	11	59	70.8 ± 0.3	7.8 ± 0.6	84.1 ± 4.0	14.0 ± 1.2
4	11	85	56.2 ± 0.5	6.8 ± 0.6		
5	6	0	62.8 ± 0.6	7.4 ± 0.6		
6	6	31	61.4 ± 1.8	7.0 ± 0.6		
7	6	66	59.7 ± 2.9	7.2 ± 0.6		
8	6	99	64.8 ± 0.3	7.3 ± 0.6		
9	2	0	33.8 ± 0.2	8.4 ± 0.6		
10	2	23	33.0 ± 0.4	8.5 ± 0.6		
11	2	57	27.4 ± 0.2	8.6 ± 0.6		
12	2	84	33.5 ± 1.5	9.4 ± 0.6	42.4 ± 2.0	19.7 ± 2.0
13	2	1	34.5 ± 0.2	9.7 ± 0.6	44.3 ± 2.1	14.6 ± 1.0
14	2	35	33.5 ± 0.2	10.5 ± 0.7	44.1 ± 2.0	17.5 ± 1.6
15	2	61	35.0 ± 0.3	10.1 ± 0.6	45.5 ± 2.0	17.2 ± 1.6
16	2	79	38.0 ± 0.2	11.0 ± 0.8	50.3 ± 2.7	17.1 ± 1.5

* Manual pressure reading from DG-700

Table 114. Filter Characteristics: Site 5 (SI)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]
1	2	0	32.9 ± 0.6	37.2 ± 5.5	32.9 ± 2.2	34.8 ± 2.1
2	2	27	49.2 ± 0.6	37.9 ± 2.0	50.1 ± 1.8	35.7 ± 2.7
3	2	57	72.9 ± 0.2	34.5 ± 2.6	71.0 ± 5.4	34.2 ± 3.7
4	2	87	84.8 ± 4.9	32.7 ± 2.7		
5	6	0	79.6 ± 0.3	33.9 ± 2.0		
6	6	27	101.8 ± 0.7	31.9 ± 2.3		
7	6	66	135.7 ± 7.5	28.1 ± 1.7		
8	6	96	158.3 ± 1.4	25.1 ± 1.5		
9	11	0	70.0 ± 0.2	35.2 ± 2.6		
10	11	35	81.4 ± 0.2	39.5 ± 3.1		
11	11	61	85.8 ± 0.2	35.3 ± 2.7	80.5 ± 3.9	27.4 ± 1.7
12	11	98	99.7 ± 0.2	31.1 ± 1.8		
13	11	0	78.6 ± 0.2	34.1 ± 1.8	78.0 ± 3.4	38.7 ± 2.6
14	11	29	95.8 ± 0.3	30.9 ± 1.4	95.6 ± 3.3	34.7 ± 2.8
15	11	63	120.5 ± 0.4	27.3 ± 1.5	118.8 ± 4.4	30.1 ± 2.4
16	11	92	148.7 ± 0.4	25.0 ± 1.3	144.9 ± 7.1	29.2 ± 2.1

Table 115. Filter Characteristics: Site 6 (SI)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]
1	7	0	48.6 ± 14.5	8.0 ± 3.2	64.2 ± 3.8	18.5 ± 1.7
2	7	34	76.9 ± 14.3	32.0 ± 6.0	87.1 ± 4.5	36.4 ± 2.0
3	7	63	112.4 ± 0.9	25.3 ± 1.1		
4	7	90	113.4 ± 0.6	24.6 ± 0.6		
5	2	0	46.2 ± 0.4	32.6 ± 0.6		
6	2	28	53.3 ± 0.4	32.5 ± 0.6		
7	2	64	58.9 ± 0.6	31.6 ± 0.6		
8	2	98	61.9 ± 0.5	30.1 ± 0.6		
9	2	0	44.9 ± 3.2	31.8 ± 2.3		
10	2	28	50.2 ± 0.4	32.7 ± 0.6		
11	2	63	58.7 ± 0.3	31.1 ± 0.6		
12	2	87	71.9 ± 0.5	29.4 ± 0.6		
13	11	0	98.9 ± 2.5	26.5 ± 0.6	94.8 ± 5.0	34.4 ± 2.0
14	11	33	107.0 ± 5.6	25.2 ± 1.3	104.9 ± 4.9	32.6 ± 1.7
15	11	60	111.1 ± 5.2	24.4 ± 0.6	108.2 ± 5.6	31.1 ± 1.9
16	11	103	116.6 ± 1.0	26.1 ± 0.5	113.5 ± 4.4	31.5 ± 1.2

Table 116. Filter Characteristics: Site 7 (SI)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]
1	2	0	35.7 ± 0.6	112.4 ± 1.8	34.5 ± 0.6	121.3 ± 1.3
2	2	34	50.5 ± 4.2	119.2 ± 10.0	51.3 ± 0.2	128.2 ± 1.1
3	2	62	56.9 ± 4.4	121.2 ± 5.8		
4	2	87	62.3 ± 2.5	118.1 ± 0.4		
5	6	0	70.4 ± 0.3	115.0 ± 0.5		
6	6	25	75.9 ± 0.4	115.0 ± 0.5		
7	6	65	83.3 ± 0.4	49.0 ± 12.3		
8	6	92	89.0 ± 0.4	117.0 ± 0.6		
9	11	0	68.5 ± 0.2	123.7 ± 0.5		
10	11	36	77.6 ± 0.3	116.9 ± 0.7		
11	11	69	77.3 ± 0.2	116.4 ± 0.6		
12	11	96	78.9 ± 0.3	117.6 ± 1.2	77.2 ± 0.7	124.1 ± 1.4
13	11	0	68.5 ± 0.2	120.6 ± 1.3	64.1 ± 0.9	128.5 ± 1.4
14	11	33	71.2 ± 0.2	121.1 ± 1.2	70.3 ± 1.0	125.3 ± 1.7
15	11	62	74.7 ± 0.3	120.6 ± 1.2	73.6 ± 0.9	126.5 ± 1.1
16	11	92	77.7 ± 0.2	121.5 ± 1.2	76.5 ± 0.4	129.1 ± 1.0

Table 117. Filter Characteristics: Site 8 (SI)

Visit	Filter MERV	Filter Age	Fan Only Mode		Cooling Mode	
			Filter Pressure Drop	Coil Pressure Drop	Filter Pressure Drop	Coil Pressure Drop
		[days]	[Pa]	[Pa]	[Pa]	[Pa]
1	2	0	21.7 ± 1.0	13.8 ± 0.6	22.7 ± 1.3	14.7 ± 0.6
2	2	31	25.4 ± 0.6	9.2 ± 0.5	24.8 ± 2.1	42.7 ± 5.4
3	2	62	29.3 ± 1.3	31.5 ± 5.1		
4	2	88	30.0 ± 0.7	16.9 ± 0.6		
5	6	0	47.6 ± 0.6	16.2 ± 0.6		
6	6	28	50.0 ± 0.6	16.0 ± 0.6		
7	6	63	52.1 ± 0.6	15.8 ± 0.6		
8	6	91	53.5 ± 0.6	15.9 ± 0.6		
9	11	0	49.1 ± 0.7	16.7 ± 0.6		
10	11	37	43.9 ± 0.6	35.6 ± 7.2		
11	11	69	43.7 ± 0.7	28.0 ± 2.3		
12	11	99	40.1 ± 6.2	14.8 ± 4.8		
13	11	0	51.0 ± 0.8	10.1 ± 1.8	50.4 ± 2.5	0.4 ± 0.7
14	11	30	42.4 ± 0.7	21.7 ± 3.6	42.5 ± 1.9	5.2 ± 6.7
15	11	56	40.6 ± 0.6	62.6 ± 6.0	39.0 ± 2.2	0.5 ± 0.5
16	11	98	42.8 ± 0.6	24.3 ± 11.1	42.6 ± 1.0	1.6 ± 2.2

Table 118. Filter Characteristics: Site 9 (SI)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop† [Pa]	Coil Pressure Drop [Pa]	Filter Pressure Drop† [Pa]	Coil Pressure Drop [Pa]
1	7	0	54.7 ± 6.3	92.6 ± 8.8	57.9 ± 6.6	96.7 ± 8.7
2	7	28	71.4 ± 7.4	88.6 ± 8.5	84.6 ± 7.7	100.4 ± 7.1
3	7	58	74.1 ± 2.9	98.5 ± 2.2		
4	7	82	76.7 ± 3.4	95.4 ± 2.5		
5	11	0	81.7 ± 3.7	91.9 ± 2.2		
6	11	44	82.0 ± 3.6	91.6 ± 2.2		
7	11	81	81.8 ± 2.3	87.7 ± 3.5		
8	11	126	69.5 ± 6.4	101.1 ± 4.9		
9	2	0	61.1 ± 1.6	101.5 ± 1.8		
10	2	11	60.1 ± 1.3	101.7 ± 2.6		
11	2	50	57.5 ± 1.5	107.8 ± 2.2	58.7 ± 4.3	86.2 ± 23.9
12	2	97	52.0 ± 1.2	112.4 ± 2.0		
13	11	0	65.7 ± 1.5	103.2 ± 1.7	67.9 ± 3.9	112.2 ± 6.5
14	11	32	65.4 ± 1.4	28.7 ± 16.4	68.5 ± 4.3	51.0 ± 30.4
15	11	64	66.3 ± 1.5	110.6 ± 2.6	68.5 ± 5.4	111.3 ± 9.0
16	11	92	66.3 ± 1.4	107.4 ± 2.4	67.7 ± 4.3	116.3 ± 7.9

† Measuring return plenum pressure drop rather than directly across the filter

Table 119. Filter Characteristics: Site 10 (SI)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]
1	2	0	15.6 ± 0.6	53.9 ± 11.4	15.6 ± 1.0	61.7 ± 4.1
2	2	29	15.7 ± 0.2	52.6 ± 2.7	15.7 ± 0.9	4.9 ± 7.3
3	2	58	15.6 ± 0.6	93.4 ± 1.7		
4	2	82	16.0 ± 0.6	96.2 ± 1.9		
5	6	0	36.6 ± 2.2	85.7 ± 9.1		
6	6	44	36.8 ± 0.2	90.6 ± 1.2		
7	6	81	37.8 ± 0.1	87.5 ± 1.8		
8	6	109	37.2 ± 0.6	90.3 ± 1.2		
9	11	0	37.3 ± 0.6	91.2 ± 1.3		
10	11	28	37.3 ± 0.6	87.9 ± 2.2		
11	11	62	36.5 ± 0.6	228.5 ± 4.0	37.2 ± 1.4	57.2 ± 19.2
12	11	114	37.5 ± 0.6	173.2 ± 12.5		
13	7	0	40.2 ± 0.6	196.5 ± 10.6		
14	7	32	40.1 ± 1.1	127.6 ± 2.1	40.7 ± 1.9	84.8 ± 19.4
15	7	64	41.7 ± 0.6	176.1 ± 1.8*	41.9 ± 2.9	53.5 ± 18.2
16	7	92	42.6 ± 0.6	140.7 ± 1.4*	43.5 ± 3.2	20.3 ± 14.8

* Manual pressure reading from DG-700

Table 120. Filter Characteristics: Site 11 (SI)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]
1	2	0	26.8 ± 0.5	79.3 ± 0.4	25.0 ± 0.9	80.2 ± 2.4
2	2	30	27.6 ± 3.6	72.3 ± 9.3	27.5 ± 0.7	77.7 ± 1.5
3	2	57	33.6 ± 2.0	78.0 ± 4.5	31.0 ± 0.6	80.9 ± 0.4
4	2	86	34.5 ± 0.6	76.8 ± 0.8*		
5	6	0	49.0 ± 0.6	74.5 ± 0.2		
6	6	29	50.7 ± 0.7	73.7 ± 0.3		
7	6	65	48.0 ± 0.8	63.0 ± 0.7		
8	6	93	55.5 ± 0.4	62.6 ± 0.8		
9	11	0	50.1 ± 0.5	62.7 ± 0.6		
10	11	27	48.0 ± 0.6	66.8 ± 0.5	44.1 ± 5.9	69.2 ± 1.0
11	11	60	54.0 ± 0.6	69.5 ± 0.4	53.7 ± 1.4	71.6 ± 1.5
12	11	94	63.5 ± 0.7	67.0 ± 0.8		
13	6	0	53.1 ± 0.5	69.3 ± 0.8	53.4 ± 0.6	70.9 ± 0.9
14	6	30	67.0 ± 0.5	64.1 ± 0.7	66.8 ± 0.8	66.2 ± 0.8
15	6	64	78.3 ± 0.4	66.0 ± 0.6	78.2 ± 1.0	68.2 ± 0.6

* Manual pressure reading from DG-700

Table 121. Filter Characteristics: Site 12 (SI)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop† [Pa]	Coil Pressure Drop [Pa]	Filter Pressure Drop† [Pa]	Coil Pressure Drop [Pa]
1	12	0	n/a	n/a	73.1 ± 4.9	23.2 ± 1.4
2	12	35	44.0 ± 17.0	19.7 ± 8.2		
3	12	59	70.1 ± 1.0	19.8 ± 0.6		
4	12	87	70.7 ± 1.1	20.8 ± 0.6		
5	11	0	69.0 ± 1.2	21.0 ± 0.6		
6	11	36	68.6 ± 6.9	20.4 ± 2.1		
7	11	72	71.9 ± 1.1	20.7 ± 0.6		
8	11	98	70.5 ± 4.3	20.3 ± 1.3		
9	11	0	69.2 ± 1.0	20.9 ± 0.6		
10	11	35	68.7 ± 1.2	20.1 ± 0.6		
11	11	61	71.9 ± 1.3	17.5 ± 0.6	81.1 ± 1.6	20.3 ± 0.6
12	11	93	74.9 ± 1.2	18.4 ± 0.6		
13	11	0	69.5 ± 1.3	18.9 ± 0.6	76.9 ± 2.7	20.8 ± 0.8
14	11	27	71.2 ± 1.3	18.6 ± 0.6	77.9 ± 1.8	20.4 ± 0.6
15	11	71	70.2 ± 1.0	18.1 ± 0.6	77.3 ± 1.7	20.7 ± 0.6

† Measuring return plenum pressure drop rather than directly across the filter

Table 122. Filter Characteristics: Site 13 (SI)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]
1	6	0	74.9 ± 1.0	61.0 ± 2.0	84.6 ± 2.5	67.7 ± 3.0
2	6	30	83.8 ± 4.6	57.9 ± 9.0		
3	6	63	93.3 ± 0.9	67.4 ± 5.2		
4	6	98	111.5 ± 1.1	81.7 ± 4.8		
5	11	0	64.6 ± 0.7	63.3 ± 3.7		
6	11	25	74.3 ± 0.4	65.7 ± 7.2		
7	11	56	80.7 ± 0.5	74.6 ± 4.5		
8	11	86	92.3 ± 0.5	70.6 ± 4.6	100.8 ± 3.1	67.5 ± 4.8
9	2	0	42.5 ± 0.4	45.7 ± 4.2	50.0 ± 2.0	58.4 ± 4.8
10	2	32	77.6 ± 0.8	70.1 ± 0.7*	95.7 ± 1.9	84.7 ± 0.8*
11	2	62	126.5 ± 0.9	164.1 ± 1.6*	143.4 ± 4.1	183.0 ± 1.8*
12	2	94	162.0 ± 1.1	196.8 ± 2.2	173.5 ± 6.3	213.6 ± 8.2
13	11	0	79.7 ± 0.8	124.2 ± 1.7	92.5 ± 3.4	146.4 ± 2.1
14	11	30	102.1 ± 0.7	142.1 ± 1.4*	111.0 ± 1.5	157.8 ± 1.6*
15	11	57	114.7 ± 1.0	159.6 ± 1.6*	126.1 ± 8.2	178.3 ± 1.8*
16	11	87	118.0 ± 0.9	160.3 ± 1.6*		

* Manual pressure reading from DG-700

Table 123. Filter Characteristics: Site 14 (SI)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]
1	7	0	78.9 ± 0.4	72.8 ± 3.4		
2	7	26	81.1 ± 0.8	78.4 ± 2.5		
3	7	55	78.6 ± 0.6	73.2 ± 1.9		
4	7	91	79.3 ± 1.0	78.5 ± 2.4		
5	2	0	57.3 ± 0.5	74.5 ± 1.9		
6	2	28	58.7 ± 0.5	75.9 ± 3.5		
7	2	55	60.1 ± 0.4	74.8 ± 3.0		
8	2	87	61.4 ± 3.9	72.2 ± 6.0	59.9 ± 2.8	77.5 ± 5.1
9	11	0	108.0 ± 0.8	60.3 ± 2.9	103.5 ± 3.6	62.3 ± 3.9
10	11	30	111.4 ± 0.8	58.4 ± 2.1	109.5 ± 2.1	63.3 ± 2.7
11	7	0	55.5 ± 0.7	75.4 ± 3.8	53.9 ± 1.9	75.4 ± 4.0
12	7	28	61.8 ± 0.6	75.8 ± 3.8	59.7 ± 1.2	79.9 ± 3.9
13	7	58	67.2 ± 0.6	73.1 ± 4.8		
14	2	0	41.4 ± 0.4	70.3 ± 3.0	40.5 ± 1.5	76.3 ± 4.3
15	2	28	45.7 ± 0.6	71.5 ± 1.8	45.4 ± 1.8	73.3 ± 3.4
16	2	62	44.5 ± 0.9	71.4 ± 1.7		

Table 124. Filter Characteristics: Site 15 (SI)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]
1	7	0	42.3 ± 0.4*	4.6 ± 0.1*		
2	7	39	42.7 ± 0.6	4.5 ± 0.6		
3	7	67	43.4 ± 0.6	4.4 ± 0.6		
4	7	98	44.9 ± 0.4	4.2 ± 0.6		
5	11	0	46.7 ± 0.5	3.9 ± 0.6		
6	11	30	45.8 ± 0.8	3.9 ± 0.6		
7	11	59	45.1 ± 2.4	3.4 ± 0.6	44.4 ± 1.3	3.4 ± 0.6
8	11	92	43.8 ± 0.9	3.7 ± 0.6		
9	2	0	22.7 ± 0.7	4.6 ± 0.6	24.0 ± 0.7	4.6 ± 0.6
10	2	36	27.6 ± 0.6	4.1 ± 0.6	27.6 ± 0.7	4.0 ± 0.6
11	2	62	36.3 ± 0.4	3.7 ± 0.6	34.9 ± 0.5	3.8 ± 0.6
12	2	92	39.7 ± 0.3	3.8 ± 0.6	38.7 ± 0.6	4.1 ± 0.6
13	7	0	50.2 ± 0.6	3.9 ± 0.6	48.5 ± 1.0	3.9 ± 0.6
14	7	28	47.3 ± 0.4	4.0 ± 0.6	47.2 ± 0.7	3.9 ± 0.6
15	7	60	49.2 ± 0.3	4.2 ± 0.6		
16	7	90	49.4 ± 0.4	4.1 ± 0.6		

* Manual pressure reading from DG-700

Table 125. Filter Characteristics: Site 16 (SI)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]
1	6	0	50.2 ± 0.6	46.0 ± 0.9		
2	6	35	56.7 ± 0.2	38.5 ± 1.1		
3	6	66	55.0 ± 3.0	43.4 ± 3.7		
4	6	104	59.2 ± 0.4	46.0 ± 1.8		
5	11	0	52.4 ± 2.4	45.2 ± 2.5		
6	11	31	56.1 ± 4.5	48.9 ± 1.6		
7	11	59	52.3 ± 0.3	48.3 ± 0.5*	119.0 ± 2.0	135.9 ± 1.4*
8	11	87	57.6 ± 0.2	38.8 ± 2.3		
9	2	0	27.4 ± 0.1	38.0 ± 2.8	80.4 ± 2.4	116.0 ± 7.2
10	2	28	28.6 ± 0.2	38.1 ± 2.5	83.4 ± 2.2	128.9 ± 8.6
11	2	56	28.8 ± 0.3	43.8 ± 1.3	84.0 ± 2.1	131.1 ± 5.2
12	2	84	28.7 ± 0.1	45.4 ± 1.5		
13	11	0	51.1 ± 0.5	46.0 ± 0.8	119.5 ± 4.4	123.2 ± 5.1
14	11	33	50.9 ± 0.3	44.3 ± 0.8	119.7 ± 4.8	122.6 ± 5.5
15	11	64	49.4 ± 0.2	41.2 ± 0.7		
16	11	90	52.3 ± 0.2	39.1 ± 0.7		

* Manual pressure reading from DG-700

Table 126. Filter Characteristics: Site 17 (SI)

			Fan Only Mode		Cooling Mode	
Visit	Filter MERV	Filter Age [days]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]
1	6	0	38.4 ± 0.6	31.0 ± 0.6		
2	6	35	34.4 ± 0.6	33.2 ± 0.6		
3	6	66	33.5 ± 0.6	36.3 ± 0.6		
4	6	104	38.6 ± 0.2	35.3 ± 0.6		
5	11	0	24.6 ± 0.1	45.6 ± 0.6		
6	11	31	28.4 ± 0.6	48.6 ± 0.3		
7	11	59	29.2 ± 0.1	51.7 ± 0.5*	68.1 ± 1.1	175.0 ± 1.8*
8	11	87	33.6 ± 0.3	44.5 ± 4.2		
9	2	0	1.6 ± 0.6	45.3 ± 0.3	5.6 ± 0.6	164.3 ± 4.1
10	2	28	1.3 ± 0.6	48.3 ± 0.4	4.0 ± 0.6	185.8 ± 6.3
11	2	56	0.6 ± 0.6	49.7 ± 0.3	1.9 ± 0.6	191.9 ± 7.2
12	2	84	1.1 ± 0.6	52.5 ± 0.3		
13	11	0	20.6 ± 0.1	57.1 ± 1.0	50.8 ± 1.2	159.5 ± 5.0
14	11	33	22.8 ± 0.6	45.2 ± 0.4	50.2 ± 1.4	163.9 ± 6.2
15	11	64	19.6 ± 0.6	48.0 ± 0.2		
16	11	90	20.9 ± 0.6	47.7 ± 0.2		

* Manual pressure reading from DG-700

Appendix E.2: Fan Characteristics (SI)

Table 127. Fan Characteristics: Site 1 (SI)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]
1	2	0	1720 ± 120	470 ± 5	3.66 ± 0.26	2050 ± 140	581 ± 7	3.52 ± 0.25
2	2	30	1760 ± 120	429 ± 5	4.11 ± 0.29	2070 ± 150	589 ± 7	3.52 ± 0.25
3	2	59	1800 ± 130	398 ± 4	4.53 ± 0.32	2100 ± 150	589 ± 7	3.56 ± 0.25
4	2	88	1860 ± 130	408 ± 5	4.57 ± 0.32			
5	7	0	1740 ± 120	442 ± 5	3.93 ± 0.28			
6	7	35	1750 ± 120	439 ± 5	3.98 ± 0.28			
7	7	68	1720 ± 120	442 ± 5	3.88 ± 0.27			
8	7	95	1760 ± 120	431 ± 5	4.08 ± 0.29			
9	11	0	1720 ± 120	428 ± 5	4.03 ± 0.29			
10	11	29	1770 ± 120	424 ± 5	4.17 ± 0.30			
11	11	62	1680 ± 120	419 ± 5	4.01 ± 0.28			
12	11	91	1690 ± 120	424 ± 5	3.98 ± 0.28			
13	11	0	1680 ± 120	415 ± 5	4.05 ± 0.29			
14	11	27	1680 ± 120	411 ± 5	4.10 ± 0.29	2000 ± 140	584 ± 7	3.43 ± 0.24
15	11	55	1720 ± 120	420 ± 5	4.09 ± 0.29	1990 ± 140	580 ± 6	3.44 ± 0.24
16	11	86	1670 ± 120	414 ± 5	4.03 ± 0.29	1980 ± 140	573 ± 6	3.45 ± 0.24

Table 128. Fan Characteristics: Site 2 (SI)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]
1	2	0	1870 ± 130	343 ± 4	5.46 ± 0.39	1890 ± 130	358 ± 4	5.28 ± 0.37
2	2	27	1860 ± 130	339 ± 4	5.49 ± 0.39	1880 ± 130	353 ± 4	5.32 ± 0.38
3	2	59	1860 ± 130	342 ± 4	5.42 ± 0.38	1870 ± 130	354 ± 4	5.29 ± 0.37
4	2	93	1960 ± 140	353 ± 4	5.54 ± 0.39			
5	6	0	1640 ± 110	329 ± 4	4.98 ± 0.35			
6	6	26	1610 ± 110	330 ± 4	4.89 ± 0.35			
7	6	63	1660 ± 120	334 ± 4	4.96 ± 0.35			
8	6	93	1760 ± 120	323 ± 4	5.43 ± 0.39			
9	11	0	1800 ± 130	335 ± 4	5.38 ± 0.38			
10	11	22	1700 ± 120	333 ± 4	5.11 ± 0.36			
11	11	52	1550 ± 110	331 ± 4	4.70 ± 0.33			
12	11	84	1570 ± 110	324 ± 4	4.85 ± 0.34			
13	11	0	1570 ± 110	319 ± 4	4.91 ± 0.35			
14	11	29	1500 ± 110	317 ± 4	4.74 ± 0.34	1540 ± 110	319 ± 4	4.82 ± 0.34
15	11	56	1580 ± 110	320 ± 4	4.93 ± 0.35	1600 ± 110	322 ± 4	4.96 ± 0.35
16	11	83	1510 ± 110	306 ± 3	4.94 ± 0.35	1510 ± 110	312 ± 3	4.84 ± 0.34

Table 129. Fan Characteristics: Site 3 (SI)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]
1	11	0	1460 ± 100	393 ± 4	3.71 ± 0.26	1540 ± 110	425 ± 5	3.62 ± 0.26
2	11	27	1510 ± 110	386 ± 4	3.91 ± 0.28	1550 ± 110	425 ± 5	3.64 ± 0.26
3	11	56	1520 ± 110	385 ± 4	3.94 ± 0.28	1590 ± 110	424 ± 5	3.74 ± 0.27
4	11	82	1530 ± 110	383 ± 4	3.98 ± 0.28			
5	6	0	1500 ± 110	394 ± 4	3.81 ± 0.27			
6	6	31	1540 ± 110	408 ± 5	3.77 ± 0.27			
7	6	66	1540 ± 110	412 ± 5	3.74 ± 0.26			
8	6	99	1530 ± 110	402 ± 5	3.80 ± 0.27			
9	2	0	1570 ± 110	420 ± 5	3.73 ± 0.26			
10	2	23	1580 ± 110	430 ± 5	3.67 ± 0.26			
11	2	57	1560 ± 110	416 ± 5	3.74 ± 0.27			
12	2	84	1540 ± 110	401 ± 4	3.85 ± 0.27	1620 ± 110	437 ± 5	3.71 ± 0.26
13	2	0	1560 ± 110	412 ± 5	3.80 ± 0.27	1660 ± 120	449 ± 5	3.69 ± 0.26
14	2	34	1500 ± 110	395 ± 4	3.81 ± 0.27	1610 ± 110	444 ± 5	3.62 ± 0.26
15	2	60	1500 ± 100	405 ± 5	3.70 ± 0.26	1610 ± 110	446 ± 5	3.60 ± 0.26
16	2	78	1470 ± 100	398 ± 4	3.71 ± 0.26	1570 ± 110	442 ± 5	3.56 ± 0.25

Table 130. Fan Characteristics: Site 4 (SI)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]
1	11	3	1100 ± 80	n/a	n/a	1100 ± 80	326 ± 4	3.36 ± 0.24
2	11	30	1000 ± 70	314 ± 4	3.18 ± 0.23	1100 ± 80	324 ± 4	3.38 ± 0.24
3	11	59	990 ± 70	234 ± 3	4.23 ± 0.30	1100 ± 80	320 ± 4	3.44 ± 0.24
4	11	85	1000 ± 70	230 ± 3	4.36 ± 0.31			
5	6	0	1020 ± 70	238 ± 3	4.27 ± 0.30			
6	6	31	1030 ± 70	246 ± 3	4.21 ± 0.30			
7	6	66	1040 ± 70	244 ± 3	4.25 ± 0.30			
8	6	99	1030 ± 70	248 ± 3	4.18 ± 0.30			
9	2	0	1080 ± 80	258 ± 3	4.18 ± 0.30			
10	2	23	1100 ± 80	264 ± 3	4.16 ± 0.29			
11	2	57	1070 ± 70	250 ± 3	4.27 ± 0.30			
12	2	84	1060 ± 70	245 ± 3	4.33 ± 0.31	1230 ± 90	336 ± 4	3.66 ± 0.26
13	2	1	1080 ± 80	252 ± 3	4.28 ± 0.30	1260 ± 90	348 ± 4	3.61 ± 0.26
14	2	35	1010 ± 70	238 ± 3	4.22 ± 0.30	1180 ± 80	337 ± 4	3.50 ± 0.25
15	2	61	1030 ± 70	245 ± 3	4.21 ± 0.30	1200 ± 80	342 ± 4	3.52 ± 0.25
16	2	79	980 ± 70	240 ± 3	4.06 ± 0.29	1140 ± 80	338 ± 4	3.36 ± 0.24

Table 131. Fan Characteristics: Site 5 (SI)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]
1	2	0	2170 ± 150	674 ± 8	3.22 ± 0.23	2270 ± 160	660 ± 7	3.45 ± 0.24
2	2	27	2110 ± 150	680 ± 8	3.10 ± 0.22	2210 ± 150	649 ± 7	3.40 ± 0.24
3	2	57	1750 ± 120	611 ± 7	2.86 ± 0.20	1880 ± 130	610 ± 7	3.08 ± 0.22
4	2	87	1890 ± 130	659 ± 7	2.87 ± 0.20			
5	6	0	1840 ± 130	642 ± 7	2.87 ± 0.20			
6	6	27	1850 ± 130	635 ± 7	2.91 ± 0.21			
7	6	66	1720 ± 120	608 ± 7	2.83 ± 0.20			
8	6	96	1700 ± 120	590 ± 7	2.88 ± 0.20			
9	11	0	1990 ± 140	649 ± 7	3.07 ± 0.22			
10	11	35	1980 ± 140	644 ± 7	3.08 ± 0.22			
11	11	61	2180 ± 150	630 ± 7	3.45 ± 0.24	1970 ± 140	615 ± 7	3.20 ± 0.23
12	11	98	1660 ± 120	622 ± 7	2.67 ± 0.19			
13	11	0	1780 ± 120	638 ± 7	2.78 ± 0.20	1850 ± 130	625 ± 7	2.95 ± 0.21
14	11	29	1700 ± 120	608 ± 7	2.80 ± 0.20	1720 ± 120	608 ± 7	2.83 ± 0.20
15	11	63	1650 ± 120	609 ± 7	2.71 ± 0.19	1620 ± 110	585 ± 7	2.77 ± 0.20
16	11	92	1470 ± 100	592 ± 7	2.49 ± 0.18	1500 ± 110	566 ± 6	2.65 ± 0.19

Table 132. Fan Characteristics: Site 6 (SI)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]
1	7	0	1830 ± 130	604 ± 7	3.03 ± 0.21	1850 ± 130	586 ± 7	3.15 ± 0.22
2	7	34	1740 ± 120	508 ± 6	3.43 ± 0.24	1680 ± 120	565 ± 6	2.97 ± 0.21
3	7	63	1660 ± 120	486 ± 5	3.42 ± 0.24			
4	7	90	1640 ± 120	567 ± 6	2.90 ± 0.21			
5	2	0	1900 ± 130	631 ± 7	3.01 ± 0.21			
6	2	28	1900 ± 130	630 ± 7	3.02 ± 0.21			
7	2	64	1900 ± 130	630 ± 7	3.02 ± 0.21			
8	2	98	1790 ± 130	607 ± 7	2.95 ± 0.21			
9	2	0	1970 ± 140	624 ± 7	3.16 ± 0.22			
10	2	28	1920 ± 130	635 ± 7	3.02 ± 0.21			
11	2	63	1860 ± 130	624 ± 7	2.98 ± 0.21			
12	2	87	1800 ± 130	601 ± 7	2.99 ± 0.21			
13	11	0	1710 ± 120	583 ± 7	2.93 ± 0.21	1660 ± 120	555 ± 6	2.99 ± 0.21
14	11	33	1660 ± 120	574 ± 6	2.89 ± 0.20	1630 ± 110	554 ± 6	2.95 ± 0.21
15	11	60	1620 ± 110	580 ± 6	2.80 ± 0.20	1610 ± 110	539 ± 6	2.99 ± 0.21
16	11	103	1560 ± 110	562 ± 6	2.77 ± 0.20	1530 ± 110	533 ± 6	2.87 ± 0.20

Table 133. Fan Characteristics: Site 7 (SI)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]
1	2	0	1410 ± 100	433 ± 5	3.26 ± 0.23	1400 ± 100	419 ± 5	3.35 ± 0.24
2	2	34	1300 ± 90	398 ± 4	3.26 ± 0.23	1320 ± 90	410 ± 5	3.21 ± 0.23
3	2	62	1300 ± 90	431 ± 5	3.02 ± 0.21			
4	2	87	1310 ± 90	438 ± 5	2.98 ± 0.21			
5	6	0	1280 ± 90	430 ± 5	2.97 ± 0.21			
6	6	25	1330 ± 90	438 ± 5	3.03 ± 0.21			
7	6	65	1130 ± 80	449 ± 5	2.53 ± 0.18			
8	6	92	1110 ± 80	n/a	n/a			
9	11	0	1150 ± 80	n/a	n/a			
10	11	36	1140 ± 80	429 ± 5	2.65 ± 0.19			
11	11	69	1150 ± 80	444 ± 5	2.59 ± 0.18			
12	11	96	1070 ± 70	414 ± 5	2.58 ± 0.18	1060 ± 70	406 ± 5	2.61 ± 0.19
13	11	0	1100 ± 80	423 ± 5	2.59 ± 0.18	1110 ± 80	401 ± 4	2.78 ± 0.20
14	11	33	1080 ± 80	423 ± 5	2.55 ± 0.18	1080 ± 80	408 ± 5	2.64 ± 0.19
15	11	62	1070 ± 80	419 ± 5	2.56 ± 0.18	1070 ± 80	411 ± 5	2.61 ± 0.19
16	11	92	1040 ± 70	399 ± 4	2.62 ± 0.19	1050 ± 70	395 ± 4	2.66 ± 0.19

Table 134. Fan Characteristics: Site 8 (SI)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]
1	2	0	1270 ± 90	422 ± 5	3.00 ± 0.21	1260 ± 90	425 ± 5	2.96 ± 0.21
2	2	31	1260 ± 90	438 ± 5	2.88 ± 0.20	1210 ± 90	437 ± 5	2.78 ± 0.20
3	2	62	1270 ± 90	430 ± 5	2.96 ± 0.21			
4	2	88	1250 ± 90	444 ± 5	2.81 ± 0.20			
5	6	0	1210 ± 80	422 ± 5	2.86 ± 0.20			
6	6	28	1230 ± 90	432 ± 5	2.85 ± 0.20			
7	6	63	1200 ± 80	434 ± 5	2.77 ± 0.20			
8	6	91	1190 ± 80	427 ± 5	2.79 ± 0.20			
9	11	0	1220 ± 90	450 ± 5	2.71 ± 0.19			
10	11	37	1330 ± 90	447 ± 5	2.98 ± 0.21			
11	11	69	1230 ± 90	451 ± 5	2.74 ± 0.19			
12	11	99	1230 ± 90	439 ± 5	2.79 ± 0.20			
13	11	0	1210 ± 90	433 ± 5	2.81 ± 0.20	1200 ± 80	429 ± 5	2.80 ± 0.20
14	11	30	1210 ± 90	431 ± 5	2.82 ± 0.20	1200 ± 80	428 ± 5	2.80 ± 0.20
15	11	56	1260 ± 90	450 ± 5	2.80 ± 0.20	1260 ± 90	445 ± 5	2.82 ± 0.20
16	11	98	1230 ± 90	442 ± 5	2.79 ± 0.20	1240 ± 90	440 ± 5	2.81 ± 0.20

Table 135. Fan Characteristics: Site 9 (SI)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]
1	7	0	3220 ± 230	767 ± 9	4.20 ± 0.30	3260 ± 230	784 ± 9	4.16 ± 0.29
2	7	28	3230 ± 230	732 ± 8	4.41 ± 0.31			
3	7	58	3280 ± 230	777 ± 9	4.22 ± 0.30			
4	7	82	3380 ± 240	796 ± 9	4.25 ± 0.30			
5	11	0	3180 ± 220	789 ± 9	4.03 ± 0.29			
6	11	44	3240 ± 230	786 ± 9	4.12 ± 0.29			
7	11	81	3250 ± 230	781 ± 9	4.16 ± 0.29			
8	11	126	3310 ± 230	775 ± 9	4.27 ± 0.30			
9	2	0	3380 ± 240	782 ± 9	4.32 ± 0.31			
10	2	11	3410 ± 240	793 ± 9	4.30 ± 0.30			
11	2	50	3540 ± 250	776 ± 9	4.56 ± 0.32	3590 ± 250	778 ± 9	4.62 ± 0.33
12	2	97	3500 ± 250	770 ± 9	4.55 ± 0.32			
13	11	0	3440 ± 240	755 ± 8	4.56 ± 0.32	3510 ± 250	768 ± 9	4.57 ± 0.32
14	11	32	3420 ± 240	770 ± 9	4.44 ± 0.31	3490 ± 240	774 ± 9	4.51 ± 0.32
15	11	64	3480 ± 240	790 ± 9	4.41 ± 0.31	3550 ± 250	787 ± 9	4.51 ± 0.32
16	11	92	3400 ± 240	762 ± 9	4.46 ± 0.32	3470 ± 240	770 ± 9	4.51 ± 0.32

Table 136. Fan Characteristics: Site 10 (SI)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]
1	2	0	2150 ± 150	591 ± 7	3.64 ± 0.26	2120 ± 150	696 ± 8	3.04 ± 0.22
2	2	29	2350 ± 160	691 ± 8	3.41 ± 0.24	2230 ± 160	700 ± 8	3.18 ± 0.23
3	2	58	2340 ± 160	674 ± 8	3.46 ± 0.25			
4	2	82	2340 ± 160	695 ± 8	3.37 ± 0.24			
5	6	0	2340 ± 160	670 ± 8	3.49 ± 0.25			
6	6	44	2260 ± 160	665 ± 7	3.40 ± 0.24			
7	6	81	2270 ± 160	655 ± 7	3.46 ± 0.25			
8	6	109	2260 ± 160	660 ± 7	3.42 ± 0.24			
9	11	0	2280 ± 160	659 ± 7	3.46 ± 0.25			
10	11	28	2270 ± 160	480 ± 5	4.73 ± 0.34			
11	11	62	2030 ± 140	645 ± 7	3.15 ± 0.22	2020 ± 140	671 ± 8	3.01 ± 0.21
12	11	114	2010 ± 140	651 ± 7	3.09 ± 0.22			
13	7	0	1970 ± 140	644 ± 7	3.07 ± 0.22			
14	7	32	2000 ± 140	648 ± 7	3.09 ± 0.22	2020 ± 140	668 ± 7	3.03 ± 0.21
15	7	64	2010 ± 140	665 ± 7	3.03 ± 0.21	2040 ± 140	673 ± 8	3.03 ± 0.21
16	7	92	2000 ± 140	649 ± 7	3.09 ± 0.22	2010 ± 140	661 ± 7	3.05 ± 0.22

Table 137. Fan Characteristics: Site 11 (SI)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]
1	2	0	2540 ± 180	668 ± 7	3.80 ± 0.27	2610 ± 180	681 ± 8	3.83 ± 0.27
2	2	30	2570 ± 180	625 ± 7	4.12 ± 0.29	2590 ± 180	669 ± 7	3.88 ± 0.27
3	2	57	2560 ± 180	652 ± 7	3.92 ± 0.28	2580 ± 180	675 ± 8	3.82 ± 0.27
4	2	86	2570 ± 180	685 ± 8	3.74 ± 0.27			
5	6	0	2490 ± 170	675 ± 8	3.69 ± 0.26			
6	6	29	2520 ± 180	668 ± 7	3.78 ± 0.27			
7	6	65	2520 ± 180	675 ± 8	3.74 ± 0.26			
8	6	93	2410 ± 170	664 ± 7	3.63 ± 0.26			
9	11	0	2450 ± 170	663 ± 7	3.69 ± 0.26			
10	11	27	2430 ± 170	649 ± 7	3.74 ± 0.27	2470 ± 170	665 ± 7	3.72 ± 0.26
11	11	60	2180 ± 150	666 ± 7	3.28 ± 0.23	2230 ± 160	669 ± 7	3.34 ± 0.24
12	11	94	1970 ± 140	643 ± 7	3.07 ± 0.22			
13	6	0	1960 ± 140	650 ± 7	3.02 ± 0.21	2000 ± 140	664 ± 7	3.01 ± 0.21
14	6	30	2330 ± 160	627 ± 7	3.72 ± 0.26	2370 ± 170	631 ± 7	3.76 ± 0.27
15	6	64	2320 ± 160	608 ± 7	3.82 ± 0.27	2370 ± 170	610 ± 7	3.88 ± 0.28

Table 138. Fan Characteristics: Site 12 (SI)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]
1	12	0	2440 ± 170	n/a	n/a	n/a	1071 ± 12	n/a
2	12	35	2260 ± 160	821 ± 9	2.75 ± 0.20			
3	12	59	2190 ± 150	815 ± 9	2.69 ± 0.19			
4	12	87	2280 ± 160	833 ± 9	2.74 ± 0.19			
5	11	0	2250 ± 160	835 ± 9	2.69 ± 0.19			
6	11	36	2300 ± 160	817 ± 9	2.81 ± 0.20			
7	11	72	2270 ± 160	823 ± 9	2.76 ± 0.20			
8	11	98	2280 ± 160	814 ± 9	2.80 ± 0.20			
9	11	0	2050 ± 140	822 ± 9	2.49 ± 0.18			
10	11	35	2360 ± 170	804 ± 9	2.93 ± 0.21			
11	11	61	2480 ± 170	777 ± 9	3.19 ± 0.23	2540 ± 180	1037 ± 12	2.45 ± 0.17
12	11	93	2290 ± 160	788 ± 9	2.91 ± 0.21			
13	11	0	2360 ± 170	800 ± 9	2.95 ± 0.21	2580 ± 180	1040 ± 12	2.48 ± 0.18
14	11	27	2310 ± 160	792 ± 9	2.92 ± 0.21	2540 ± 180	1035 ± 12	2.45 ± 0.17
15	11	71	2290 ± 160	780 ± 9	2.94 ± 0.21	2490 ± 170	1037 ± 12	2.40 ± 0.17

Table 139. Fan Characteristics: Site 13 (SI)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]
1	6	0	1440 ± 100	428 ± 5	3.37 ± 0.24	1570 ± 110	493 ± 6	3.18 ± 0.23
2	6	30	1470 ± 100	410 ± 5	3.60 ± 0.26			
3	6	63	1460 ± 100	422 ± 5	3.47 ± 0.25			
4	6	98	1380 ± 100	396 ± 4	3.50 ± 0.25			
5	11	0	1480 ± 100	425 ± 5	3.49 ± 0.25			
6	11	25	1450 ± 100	418 ± 5	3.48 ± 0.25			
7	11	56	1510 ± 110	424 ± 5	3.57 ± 0.25			
8	11	86	1400 ± 100	404 ± 5	3.48 ± 0.25	1510 ± 110	447 ± 5	3.38 ± 0.24
9	2	0	1540 ± 110	442 ± 5	3.48 ± 0.25	1710 ± 120	504 ± 6	3.40 ± 0.24
10	2	32	1320 ± 90	441 ± 5	2.99 ± 0.21	1490 ± 100	509 ± 6	2.93 ± 0.21
11	2	62	1190 ± 80	339 ± 4	3.50 ± 0.25	1270 ± 90	398 ± 4	3.19 ± 0.23
12	2	94	1130 ± 80	330 ± 4	3.44 ± 0.24	1210 ± 80	376 ± 4	3.21 ± 0.23
13	11	0	1410 ± 100	392 ± 4	3.60 ± 0.26	1540 ± 110	450 ± 5	3.43 ± 0.24
14	11	30	1400 ± 100	378 ± 4	3.69 ± 0.26	1500 ± 100	434 ± 5	3.46 ± 0.24
15	11	57	1330 ± 90	368 ± 4	3.61 ± 0.26	1420 ± 100	417 ± 5	3.42 ± 0.24
16	11	87	1330 ± 90	368 ± 4	3.62 ± 0.26			

Table 140. Fan Characteristics: Site 14 (SI)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]
1	7	0	1560 ± 110	448 ± 5	3.49 ± 0.25			
2	7	26	1570 ± 110	408 ± 5	3.84 ± 0.27			
3	7	55	1710 ± 120	444 ± 5	3.85 ± 0.27			
4	7	91	1630 ± 110	451 ± 5	3.61 ± 0.26			
5	2	0	1700 ± 120	463 ± 5	3.67 ± 0.26			
6	2	28	1620 ± 110	458 ± 5	3.55 ± 0.25			
7	2	55	1590 ± 110	456 ± 5	3.50 ± 0.25			
8	2	87	1690 ± 120	453 ± 5	3.72 ± 0.26	1690 ± 120	449 ± 5	3.77 ± 0.27
9	11	0	1460 ± 100	418 ± 5	3.49 ± 0.25	1490 ± 100	410 ± 5	3.63 ± 0.26
10	11	30	1430 ± 100	412 ± 5	3.46 ± 0.25	1450 ± 100	409 ± 5	3.55 ± 0.25
11	7	0	1490 ± 100	440 ± 5	3.38 ± 0.24	1510 ± 110	448 ± 5	3.36 ± 0.24
12	7	28	1460 ± 100	454 ± 5	3.21 ± 0.23	1490 ± 100	443 ± 5	3.36 ± 0.24
13	7	58	1460 ± 100	454 ± 5	3.21 ± 0.23			
14	2	0	1600 ± 110	470 ± 5	3.39 ± 0.24	1620 ± 110	457 ± 5	3.55 ± 0.25
15	2	28	1550 ± 110	478 ± 5	3.23 ± 0.23	1590 ± 110	468 ± 5	3.40 ± 0.24
16	2	62	1590 ± 110	471 ± 5	3.38 ± 0.24			

Table 141. Fan Characteristics: Site 15 (SI)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]
1	7	0	1980 ± 140	960 ± 11	2.06 ± 0.15			
2	7	39	1890 ± 130	974 ± 11	1.94 ± 0.14			
3	7	67	1920 ± 130	976 ± 11	1.97 ± 0.14			
4	7	98	1910 ± 130	960 ± 11	1.99 ± 0.14			
5	11	0	1840 ± 130	942 ± 11	1.95 ± 0.14			
6	11	30	1880 ± 130	930 ± 10	2.02 ± 0.14			
7	11	59	1760 ± 120	911 ± 10	1.93 ± 0.14	1780 ± 120	913 ± 10	1.95 ± 0.14
8	11	92	1810 ± 130	886 ± 10	2.04 ± 0.14			
9	2	0	1920 ± 130	939 ± 11	2.04 ± 0.14	2000 ± 140	938 ± 11	2.13 ± 0.15
10	2	36	1860 ± 130	945 ± 11	1.97 ± 0.14	1950 ± 140	932 ± 10	2.09 ± 0.15
11	2	62	1830 ± 130	939 ± 11	1.94 ± 0.14	1900 ± 130	920 ± 10	2.07 ± 0.15
12	2	92	1860 ± 130	924 ± 10	2.01 ± 0.14	1940 ± 140	919 ± 10	2.11 ± 0.15
13	7	0	1870 ± 130	926 ± 10	2.02 ± 0.14	1950 ± 140	909 ± 10	2.15 ± 0.15
14	7	28	1870 ± 130	942 ± 11	1.99 ± 0.14	1970 ± 140	921 ± 10	2.13 ± 0.15
15	7	60	1870 ± 130	942 ± 11	1.99 ± 0.14			
16	7	90	1870 ± 130	949 ± 11	1.97 ± 0.14			

Table 142. Fan Characteristics: Site 16 (SI)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]
1	6	0	1030 ± 70	117 ± 1	8.84 ± 0.63			
2	6	35	920 ± 60	120 ± 1	7.69 ± 0.55			
3	6	66	990 ± 70	118 ± 1	8.39 ± 0.60			
4	6	104	1040 ± 70	126 ± 1	8.27 ± 0.59			
5	11	0	1030 ± 70	119 ± 1	8.70 ± 0.62			
6	11	31	1080 ± 80	123 ± 1	8.75 ± 0.62			
7	11	59	1100 ± 80	123 ± 1	8.94 ± 0.63	1740 ± 120	531 ± 6	3.27 ± 0.23
8	11	87	1060 ± 70	121 ± 1	8.74 ± 0.62			
9	2	0	1060 ± 70	105 ± 1	10.11 ± 0.72	1840 ± 130	559 ± 6	3.29 ± 0.23
10	2	28	1070 ± 80	111 ± 1	9.64 ± 0.68	1830 ± 130	553 ± 6	3.31 ± 0.23
11	2	56	1050 ± 70	106 ± 1	9.91 ± 0.70	1830 ± 130	556 ± 6	3.30 ± 0.23
12	2	84	1020 ± 70	100 ± 1	10.18 ± 0.72			
13	11	0	1030 ± 70	120 ± 1	8.58 ± 0.61	1750 ± 120	530 ± 6	3.30 ± 0.23
14	11	33	1010 ± 70	119 ± 1	8.54 ± 0.61	1750 ± 120	528 ± 6	3.31 ± 0.23
15	11	64	1020 ± 70	111 ± 1	9.20 ± 0.65			
16	11	90	830 ± 60	114 ± 1	7.30 ± 0.52			

Table 143. Fan Characteristics: Site 17 (SI)

			Fan Only Mode			Cooling Mode		
Visit	Filter MERV	Filter Age [days]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]	System Air Flow [m^3/hr]	Air Handler Power Draw [W]	Efficacy [(m^3/hr)/W]
1	6	0	830 ± 60	71 ± 1	11.81 ± 0.84			
2	6	35	760 ± 50	70 ± 1	10.92 ± 0.77			
3	6	66	790 ± 60	72 ± 1	10.99 ± 0.78			
4	6	104	940 ± 70	75 ± 1	12.51 ± 0.89			
5	11	0	940 ± 70	72 ± 1	13.09 ± 0.93			
6	11	31	870 ± 60	77 ± 1	11.34 ± 0.80			
7	11	59	850 ± 60	75 ± 1	11.39 ± 0.81	1370 ± 100	413 ± 5	3.32 ± 0.24
8	11	87	970 ± 70	70 ± 1	13.87 ± 0.98			
9	2	0	850 ± 60	61 ± 1	14.02 ± 0.99	2240 ± 160	342 ± 4	6.55 ± 0.46
10	2	28	830 ± 60	62 ± 1	13.48 ± 0.96	2290 ± 160	379 ± 4	6.06 ± 0.43
11	2	56	920 ± 60	63 ± 1	14.54 ± 1.03	1860 ± 130	381 ± 4	4.88 ± 0.35
12	2	84	850 ± 60	61 ± 1	13.96 ± 0.99			
13	11	0	850 ± 60	72 ± 1	11.87 ± 0.84	2000 ± 140	402 ± 5	4.98 ± 0.35
14	11	33	850 ± 60	73 ± 1	11.70 ± 0.83	1840 ± 130	398 ± 4	4.62 ± 0.33
15	11	64	940 ± 70	68 ± 1	13.87 ± 0.98			
16	11	90	940 ± 70	71 ± 1	13.24 ± 0.94			

Appendix E.3: A/C Operation Characteristics (SI)

Table 144. A/C Operation Characteristics: Site 1 (SI)

Visit	Outdoor Temperature (SD) [°C]	Return Air Wet Bulb Temperature (SD) [°C]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [W]	Latent Capacity (SD) [W]	Total Capacity (SD) [W]	System Efficiency (SD) [-]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	29.6 (2.0)	19.6 (0.3)	6.8 (1.9)	60.4	2090 ± 20	5630 (170)	2920 (150)	8550 (230)	3.20 (0.20)	290 (90)
2	27.6 (1.5)	20.9 (0.1)	4.7 (1.4)	30.7	1000 ± 10	5860 (30)	4190 (60)	10050 (70)	6.32 (0.54)	120 (40)
3	26.4 (0.8)	20.4 (0.2)	5.0 (1.0)	20.7	2220 ± 20	8750 (640)	6040 (590)	14790 (870)	3.17 (0.22)	210 (60)
14	28.4 (2.0)	18.7 (0.6)	9.1 (10.8)	40.7	2150 ± 20	6430 (750)	2660 (820)	9090 (1120)	3.24 (0.39)	410 (570)
15	27.1 (0.4)	n/a	5.8 (0.4)	17.2	n/a	n/a	n/a	n/a	n/a	n/a
16	31.5 (2.9)	20.0 (0.3)	7.2 (2.0)	63.2	2160 ± 20	6510 (210)	990 (250)	7500 (320)	2.72 (0.19)	320 (100)

* The “n/a” term represents excluded values during cycle times that did not reach steady-state operation

Table 145. A/C Operation Characteristics: Site 2 (SI)

Visit	Outdoor Temperature (SD) [°C]	Return Air Wet Bulb Temperature (SD) [°C]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [W]	Latent Capacity (SD) [W]	Total Capacity (SD) [W]	System Efficiency (SD) [-]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	32.8 (2.7)	19.2 (1.0)	21.3 (22.6)	20.1	3320 ± 40	5700 (240)	2660 (270)	8370 (360)	2.25 (0.29)	1300 (1420)
2	28.9 (1.2)	20.4 (1.1)	12.7 (13.5)	8.5	3150 ± 40	5190 (240)	2530 (300)	7720 (390)	2.21 (0.07)	740 (810)
3	27.3 (0.9)	20.0 (0.8)	21.3 (22.4)	2.9	3080 ± 30	5380 (200)	2870 (210)	8250 (290)	2.40 (0.12)	1220 (1310)
14	26.6 (0.4)	20.4 (0.8)	15.3 (10.5)	6.7	3070 ± 30	4040 (320)	2800 (190)	6850 (370)	2.03 (0.14)	870 (590)
15	26.0 (0.6)	19.4 (0.8)	15.0 (13.9)	4.1	3030 ± 30	5110 (260)	2320 (180)	7430 (320)	2.22 (0.07)	840 (780)
16	30.3 (2.2)	19.5 (0.8)	16.9 (23.9)	14.8	3240 ± 40	4680 (150)	1450 (200)	6130 (250)	1.73 (0.16)	1010 (1510)

Table 146. A/C Operation Characteristics: Site 3 (SI)

Visit	Outdoor Temperature (SD) [°C]	Return Air Wet Bulb Temperature (SD) [°C]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [W]	Latent Capacity (SD) [W]	Total Capacity (SD) [W]	System Efficiency (SD) [-]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	32.6 (0.9)	18.5 (0.3)	5.8 (0.8)	20.5	2210 ± 20	5790 (40)	1050 (90)	6850 (100)	3.64 (1.99)	250 (40)
2	28.8 (1.5)	19.1 (0.7)	6.8 (3.8)	27.3	2090 ± 20	5880 (110)	2040 (150)	7920 (180)	3.20 (0.62)	280 (160)
3	28.7 (1.7)	18.8 (0.5)	6.0 (4.8)	18.2	2090 ± 20	6080 (10)	2500 (100)	8580 (100)	3.33 (0.15)	250 (210)
12	31.1 (1.9)	19.5 (0.9)	8.1 (5.2)	19.5	2200 ± 20	6290 (120)	2620 (160)	8910 (200)	3.54 (1.65)	350 (230)
13	25.8 (0.2)	n/a	5.5 (0.4)	5.4	n/a	n/a	n/a	n/a	n/a	220 (20)
14	33.6 (3.1)	19.7 (1.0)	7.2 (5.6)	36.4	2280 ± 30	6280 (120)	2480 (180)	8750 (210)	3.24 (0.86)	320 (270)
15	31.7 (2.7)	19.2 (0.2)	6.3 (1.2)	41.2	2180 ± 20	6240 (80)	2720 (140)	8960 (160)	3.72 (2.06)	280 (60)
16	32.5 (2.7)	19.5 (0.5)	6.6 (2.7)	33.6	2240 ± 30	6330 (110)	2260 (180)	8590 (210)	3.23 (1.31)	300 (130)

* The “n/a” term represents excluded values during cycle times that did not reach steady-state operation

Table 147. A/C Operation Characteristics: Site 4 (SI)

Visit	Outdoor Temperature (SD) [°C]	Return Air Wet Bulb Temperature (SD) [°C]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [W]	Latent Capacity (SD) [W]	Total Capacity (SD) [W]	System Efficiency (SD) [-]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	31.1 (1.9)	19.4 (0.4)	10.6 (5.3)	49.2	1450 ± 20	2960 (170)	1000 (110)	3960 (210)	2.27 (0.44)	300 (160)
2	28.6 (1.4)	19.8 (0.6)	8.9 (4.5)	43.4	1410 ± 20	3370 (140)	1310 (170)	4680 (220)	2.72 (0.29)	240 (130)
3	29.1 (1.5)	19.1 (0.3)	8.2 (3.2)	34.3	1380 ± 20	3940 (130)	1120 (110)	5060 (160)	2.96 (0.33)	220 (100)
12	30.5 (2.6)	22.2 (0.4)	10.8 (6.4)	31.0	1440 ± 20	5040 (120)	3170 (150)	8220 (190)	4.64 (0.47)	300 (190)
13	25.1 (0.8)	n/a	6.5 (1.0)	19.6	n/a	n/a	n/a	n/a	n/a	170 (30)
14	34.1 (2.5)	19.5 (0.6)	10.4 (10.5)	49.8	1540 ± 20	3260 (130)	640 (80)	3910 (150)	2.11 (0.28)	300 (330)
15	31.2 (2.7)	19.3 (0.6)	8.7 (13.2)	35.1	1470 ± 20	3640 (230)	760 (110)	4400 (260)	2.45 (0.30)	250 (400)
16	32.5 (2.6)	19.6 (0.4)	9.4 (14.6)	47.6	1510 ± 20	3210 (120)	260 (150)	3480 (190)	1.89 (0.37)	270 (460)

* The “n/a” term represents excluded values during cycle times that did not reach steady-state operation

Table 148. A/C Operation Characteristics: Site 5 (SI)

Visit	Outdoor Temperature (SD) [°C]	Return Air Wet Bulb Temperature (SD) [°C]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [W]	Latent Capacity (SD) [W]	Total Capacity (SD) [W]	System Efficiency (SD) [-]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	30.6 (3.5)	18.9 (0.5)	10.2 (8.6)	55.8	2690 ± 30	7040 (190)	2150 (220)	9200 (290)	2.81 (0.68)	570 (480)
2	28.9 (1.7)	20.0 (0.5)	12.2 (8.8)	39.0	2760 ± 30	5950 (260)	2780 (330)	8730 (420)	2.58 (0.23)	680 (510)
3	24.6 (2.1)	17.6 (0.2)	5.3 (1.8)	11.1	2450 ± 30	6490 (220)	2110 (100)	8590 (240)	4.19 (6.21)	270 (100)
11	27.5 (2.8)	17.0 (0.5)	11.1 (16.0)	43.5	2630 ± 30	5390 (290)	1560 (480)	6950 (560)	2.17 (0.50)	600 (900)
13	30.2 (3.3)	18.0 (0.5)	14.1 (42.0)	48.8	2690 ± 30	5170 (310)	1510 (310)	6670 (440)	2.03 (0.58)	790 (2400)
14	33.3 (5.6)	19.3 (1.2)	22.6 (92.6)	43.6	2730 ± 30	6140 (290)	1150 (530)	7290 (610)	2.22 (0.46)	1310 (5510)
15	31.5 (2.8)	18.4 (0.8)	19.3 (61.4)	44.7	2560 ± 30	5940 (240)	1340 (130)	7280 (270)	2.35 (0.59)	1030 (3360)
16	29.3 (2.2)	20.5 (0.8)	9.2 (10.1)	64.1	2610 ± 30	6450 (200)	2540 (330)	8980 (390)	2.83 (0.48)	480 (550)

Table 149. A/C Operation Characteristics: Site 6 (SI)

Visit	Outdoor Temperature (SD) [°C]	Return Air Wet Bulb Temperature (SD) [°C]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [W]	Latent Capacity (SD) [W]	Total Capacity (SD) [W]	System Efficiency (SD) [-]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	28.8 (2.8)	18.7 (1.2)	11.4 (5.7)	38.9	3350 ± 40	5320 (470)	1130 (580)	6450 (750)	1.66 (0.28)	750 (380)
2	27.0 (1.6)	18.0 (0.9)	10.4 (12.1)	37.8	3300 ± 40	2610 (510)	420 (420)	3030 (660)	0.79 (0.24)	670 (790)
13	28.6 (1.9)	18.6 (0.4)	8.9 (2.8)	50.6	3420 ± 40	5510 (270)	640 (630)	6140 (690)	1.60 (0.37)	600 (190)
14	29.2 (3.2)	16.1 (1.8)	13.7 (17.5)	49.2	3260 ± 40	5540 (360)	0 (340)	5540 (500)	1.48 (0.23)	880 (1090)
16	32.0 (2.1)	17.7 (1.4)	21.6 (18.7)	24.1	3530 ± 40	4740 (730)	-380 (400)	4360 (840)	1.11 (0.35)	1420 (1230)

Table 150. A/C Operation Characteristics: Site 7 (SI)

Visit	Outdoor Temperature (SD) [°C]	Return Air Wet Bulb Temperature (SD) [°C]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [W]	Latent Capacity (SD) [W]	Total Capacity (SD) [W]	System Efficiency (SD) [-]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	29.6 (0.7)	20.3 (0.4)	9.5 (2.1)	18.4	3750 ± 40	6120 (140)	3450 (300)	9570 (330)	2.30 (0.11)	660 (150)
2	30.4 (2.5)	18.6 (0.5)	10.9 (2.7)	22.1	3600 ± 40	6330 (380)	2830 (240)	9160 (450)	2.29 (0.20)	740 (190)
12	30.6 (3.5)	19.5 (0.8)	15.7 (11.3)	21.1	3670 ± 40	5040 (190)	1900 (220)	6950 (300)	1.70 (0.12)	1070 (780)
13	31.0 (3.4)	19.6 (0.7)	11.2 (2.2)	34.7	3690 ± 40	5240 (220)	2500 (290)	7750 (360)	1.90 (0.13)	770 (150)
14	32.8 (3.9)	18.1 (0.7)	13.3 (5.2)	39.3	3730 ± 40	5180 (220)	880 (160)	6060 (280)	1.47 (0.12)	910 (360)
15	32.6 (4.2)	18.2 (0.6)	12.5 (2.5)	31.8	3680 ± 40	5140 (260)	1300 (360)	6440 (440)	1.58 (0.20)	850 (190)
16	29.7 (2.3)	19.7 (0.6)	10.8 (1.6)	20.3	3560 ± 40	5190 (150)	2380 (360)	7560 (390)	1.92 (0.16)	720 (110)

Table 151. A/C Operation Characteristics: Site 8 (SI)

Visit	Outdoor Temperature (SD) [°C]	Return Air Wet Bulb Temperature (SD) [°C]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [W]	Latent Capacity (SD) [W]	Total Capacity (SD) [W]	System Efficiency (SD) [-]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	30.3 (2.5)	17.4 (1.3)	69.1 (64.2)	8.2	4120 ± 50	6140 (100)	2090 (260)	8220 (280)	1.81 (0.09)	5270 (4870)
2	29.1 (2.5)	16.4 (1.1)	37.3 (40.7)	9.6	3920 ± 40	5540 (270)	70 (340)	5610 (440)	1.30 (0.23)	2760 (3050)
13	30.2 (2.5)	16.0 (0.6)	83.4 (104.4)	6.6	4340 ± 50	5600 (270)	1960 (220)	7560 (350)	1.60 (0.19)	6740 (8510)
14	32.8 (3.6)	16.8 (1.2)	102.4 (130.6)	5.9	4370 ± 50	5870 (230)	1260 (220)	7120 (320)	1.58 (1.56)	8460 (11170)
15	29.8 (3.1)	17.3 (1.2)	52.6 (70.3)	5.9	4370 ± 50	6330 (360)	2070 (300)	8400 (460)	1.75 (0.12)	4290 (5720)
16	30.5 (2.4)	16.9 (0.8)	76.0 (79.4)	6.7	4400 ± 50	5900 (330)	1710 (80)	7610 (340)	1.58 (0.13)	6290 (6820)

Table 152. A/C Operation Characteristics: Site 9 (SI)

Visit	Outdoor Temperature (SD) [°C]	Return Air Wet Bulb Temperature (SD) [°C]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [W]	Latent Capacity (SD) [W]	Total Capacity (SD) [W]	System Efficiency (SD) [-]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	26.0 (2.2)	17.2 (0.4)	4.8 (2.0)	62.5	4050 ± 50	9360 (590)	1090 (550)	10460 (810)	2.17 (0.30)	370 (170)
11	30.1 (4.0)	18.9 (0.4)	6.1 (1.7)	56.6	4100 ± 50	8920 (300)	1270 (450)	10190 (540)	2.13 (0.64)	480 (160)
13	32.6 (3.0)	18.9 (1.3)	12.2 (30.5)	37.6	4220 ± 50	8620 (1280)	1240 (640)	9860 (1430)	1.99 (0.52)	1010 (2620)
14	33.0 (3.4)	18.1 (0.7)	9.3 (5.1)	71.7	4160 ± 50	7470 (1250)	680 (690)	8150 (1430)	1.66 (0.52)	760 (450)
15	22.0 (2.2)	n/a	5.4 (1.3)	22.5	n/a	n/a	n/a	n/a	n/a	380 (100)
16	29.3 (0.4)	n/a	4.0 (2.2)	4.2	n/a	n/a	n/a	n/a	n/a	310 (170)

* The “n/a” term represents excluded values during cycle times that did not reach steady-state operation

Table 153. A/C Operation Characteristics: Site 10 (SI)

Visit	Outdoor Temperature (SD) [°C]	Return Air Wet Bulb Temperature (SD) [°C]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [W]	Latent Capacity (SD) [W]	Total Capacity (SD) [W]	System Efficiency (SD) [-]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	26.9 (1.5)	16.4 (0.5)	7.5 (2.7)	19.9	3150 ± 40	6480 (140)	1240 (170)	7720 (220)	2.06 (0.31)	280 (100)
2	28.7 (2.1)	16.5 (0.6)	10.3 (8.9)	26.4	3270 ± 40	6800 (190)	940 (230)	7740 (300)	1.97 (0.38)	680 (610)
11	29.0 (2.5)	16.2 (0.4)	10.4 (6.0)	25.3	3340 ± 40	5960 (350)	1500 (220)	7460 (410)	1.97 (1.04)	690 (380)
14	34.8 (2.0)	16.1 (0.5)	17.5 (13.7)	30.7	3700 ± 40	6020 (370)	710 (160)	6730 (410)	1.57 (0.30)	1260 (980)
15	24.3 (1.8)	15.2 (0.3)	6.5 (2.5)	25.9	2890 ± 30	7110 (90)	270 (100)	7380 (140)	2.24 (0.78)	380 (160)
16	25.8 (2.1)	n/a	5.6 (0.7)	33.7	n/a	n/a	n/a	n/a	n/a	340 (50)

* The “n/a” term represents excluded values during cycle times that did not reach steady-state operation

Table 154. A/C Operation Characteristics: Site 11 (SI)

Visit	Outdoor Temperature (SD) [°C]	Return Air Wet Bulb Temperature (SD) [°C]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [W]	Latent Capacity (SD) [W]	Total Capacity (SD) [W]	System Efficiency (SD) [-]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	30.0 (4.8)	16.9 (0.9)	24.1 (46.5)	40.1	2630 ± 30	7410 (150)	1580 (190)	8990 (250)	2.72 (0.27)	1350 (2700)
2	28.3 (2.6)	16.7 (0.6)	14.8 (22.5)	35.9	2690 ± 30	7690 (180)	870 (170)	8560 (240)	2.55 (0.26)	830 (1300)
3	25.6 (2.6)	16.2 (0.2)	43.3 (90.8)	8.4	2510 ± 30	5050 (530)	1780 (260)	6830 (590)	2.16 (0.37)	2380 (5050)
10	24.1 (5.0)	16.2 (1.5)	19.5 (35.6)	25.0	2450 ± 30	9160 (550)	1900 (310)	11060 (630)	3.54 (0.25)	1020 (1970)
11	26.1 (2.8)	17.5 (0.6)	20.5 (21.6)	39.0	2620 ± 30	8420 (310)	2020 (220)	10440 (380)	3.18 (0.30)	1120 (1240)
13	31.2 (4.0)	16.3 (1.1)	222.4 (314.2)	6.2	2660 ± 30	7560 (400)	1430 (170)	8990 (440)	2.70 (0.18)	12910 (18120)
14	30.5 (3.3)	17.0 (0.7)	27.5 (66.3)	35.1	2720 ± 30	10150 (520)	2600 (300)	12750 (600)	3.80 (0.37)	1560 (3910)
15	26.7 (3.4)	15.8 (0.9)	19.8 (31.1)	38.9	2600 ± 30	11540 (790)	-250 (440)	11300 (910)	3.52 (0.52)	1070 (1770)

Table 155. A/C Operation Characteristics: Site 12 (SI)

Visit	Outdoor Temperature (SD) [°C]	Return Air Wet Bulb Temperature (SD) [°C]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [W]	Latent Capacity (SD) [W]	Total Capacity (SD) [W]	System Efficiency (SD) [-]	Electricity Consumption per Cycle (SD) [Wh/cycle]
11	30.9 (4.1)	19.3 (0.3)	6.7 (2.7)	30.5	5120 ± 60	8810 (730)	860 (2040)	9670 (2170)	1.61 (0.56)	670 (280)
13	32.0 (3.4)	18.4 (0.2)	5.9 (3.3)	75.1	5350 ± 60	9880 (200)	2660 (140)	12540 (240)	1.94 (0.07)	590 (370)
14	33.0 (3.5)	17.9 (0.4)	11.3 (6.3)	31.9	5340 ± 60	9800 (820)	-160 (720)	9640 (1090)	1.51 (0.24)	1190 (610)
15	33.5 (1.3)	17.8 (0.5)	6.9 (3.5)	34.1	5140 ± 60	9950 (980)	1810 (780)	11760 (1250)	1.92 (0.44)	680 (370)

Table 156. A/C Operation Characteristics: Site 13 (SI)

Visit	Outdoor Temperature (SD) [°C]	Return Air Wet Bulb Temperature (SD) [°C]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [W]	Latent Capacity (SD) [W]	Total Capacity (SD) [W]	System Efficiency (SD) [-]	Electricity Consumption per Cycle (SD) [Wh/cycle]
1	28.2 (1.7)	17.6 (0.3)	26.0 (11.8)	36.1	3240 ± 40	4570 (60)	3340 (300)	7910 (310)	2.12 (0.11)	1620 (720)
8	29.6 (2.6)	17.7 (0.3)	32.4 (57.3)	15.7	3190 ± 40	5510 (150)	1860 (100)	7370 (180)	2.02 (0.11)	1970 (3560)
9	32.8 (5.0)	16.5 (0.6)	22.9 (7.1)	5.4	3100 ± 30	5840 (140)	2540 (170)	8380 (230)	2.33 (0.08)	1360 (430)
10	32.8 (5.9)	16.2 (1.6)	152.9 (383.1)	8.9	3190 ± 40	5630 (80)	1210 (60)	6840 (100)	1.85 (0.06)	10090 (25560)
11	31.9 (3.2)	15.3 (1.0)	39.5 (111.6)	30.2	2990 ± 30	5670 (160)	1530 (140)	7200 (210)	2.12 (0.12)	2310 (6660)
12	26.4 (1.4)	15.5 (0.5)	10.5 (4.9)	70.4	2900 ± 30	5520 (70)	2310 (240)	7830 (250)	2.39 (0.11)	570 (280)
13	27.1 (2.3)	16.4 (1.1)	16.5 (40.9)	45.0	2950 ± 30	6100 (200)	2260 (190)	8370 (280)	2.44 (0.12)	930 (2330)
14	25.5 (2.3)	16.4 (0.5)	15.6 (22.0)	37.6	2980 ± 30	6460 (160)	2860 (180)	9320 (240)	2.72 (0.15)	880 (1280)
15	23.4 (2.1)	18.0 (0.4)	8.3 (1.7)	28.8	2770 ± 30	6360 (90)	2690 (260)	9060 (280)	2.84 (0.20)	440 (90)

Table 157. A/C Operation Characteristics: Site 14 (SI)

Visit	Outdoor Temperature (SD) [°C]	Return Air Wet Bulb Temperature (SD) [°C]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [W]	Latent Capacity (SD) [W]	Total Capacity (SD) [W]	System Efficiency (SD) [-]	Electricity Consumption per Cycle (SD) [Wh/cycle]
8	24.3 (0.9)	17.2 (0.4)	14.9 (4.8)	12.2	1560 ± 20	5830 (170)	1870 (250)	7700 (300)	3.89 (0.87)	500 (160)
9	29.2 (1.8)	18.4 (0.9)	24.8 (22.3)	8.6	1600 ± 20	5330 (250)	2060 (180)	7390 (310)	3.69 (0.30)	830 (740)
10	35.8 (4.4)	17.9 (0.5)	60.3 (109.8)	18.2	3300 ± 40	5210 (150)	1490 (120)	6700 (190)	1.81 (0.15)	3840 (7120)
11*	32.1 (3.5)	17.5 (0.8)	24.7 (50.5)	32.3	2380 ± 30	5770 (190)	290 (210)	6060 (280)	2.16 (0.28)	1170 (2510)
12	30.6 (2.8)	17.4 (0.6)	43.0 (69.4)	14.6	2340 ± 30	5580 (250)	700 (270)	6280 (370)	2.27 (0.27)	2020 (3310)
14	31.6 (2.2)	18.4 (0.6)	19.0 (19.5)	28.9	2420 ± 30	5900 (290)	1780 (340)	7690 (450)	2.69 (0.41)	910 (940)
15	25.4 (2.1)	15.6 (0.3)	9.7 (2.3)	9.8	2200 ± 20	5680 (320)	-240 (260)	5430 (410)	2.09 (0.68)	430 (90)

* The outdoor condenser unit was replaced prior to visit 11

Table 158. A/C Operation Characteristics: Site 15 (SI)

Visit	Outdoor Temperature (SD) [°C]	Return Air Wet Bulb Temperature (SD) [°C]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [W]	Latent Capacity (SD) [W]	Total Capacity (SD) [W]	System Efficiency (SD) [-]	Electricity Consumption per Cycle (SD) [Wh/cycle]
7	31.6 (2.0)	16.8 (1.2)	47.3 (27.0)	5.1	2390 ± 30	4960 (500)	1980 (360)	6940 (620)	2.12 (0.30)	2620 (1470)
9	33.5 (4.0)	18.8 (1.0)	152.0 (142.4)	3.0	2510 ± 30	7310 (260)	1720 (190)	9040 (320)	2.62 (0.12)	8950 (8490)
10	33.5 (5.5)	17.5 (1.5)	220.9 (253.2)	3.9	2410 ± 30	4200 (400)	1230 (440)	5430 (600)	1.62 (0.06)	12870 (15130)
11	33.6 (2.6)	17.3 (0.8)	212.3 (167.9)	3.8	2530 ± 30	3660 (880)	550 (320)	4210 (930)	1.23 (0.28)	12620 (10200)
12	28.2 (2.7)	15.9 (1.5)	275.8 (143.8)	2.0	2310 ± 30	5410 (500)	970 (340)	6380 (610)	1.99 (0.49)	15490 (8770)
13	28.5 (1.8)	16.7 (0.6)	83.9 (132.2)	5.0	2460 ± 30	5250 (580)	1000 (140)	6260 (600)	1.89 (0.68)	4800 (7660)
14	25.9 (1.0)	14.8 (0.2)	108.2 (169.1)	2.9	2380 ± 30	3100 (520)	600 (310)	3700 (610)	1.13 (0.29)	6010 (9440)

Table 159. A/C Operation Characteristics: Site 16 (SI)

Visit	Outdoor Temperature (SD) [°C]	Return Air Wet Bulb Temperature (SD) [°C]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [W]	Latent Capacity (SD) [W]	Total Capacity (SD) [W]	System Efficiency (SD) [-]	Electricity Consumption per Cycle (SD) [Wh/cycle]
7	32.3 (2.6)	20.9 (0.3)	49.9 (31.7)	7.2	1620 ± 20	5680 (300)	3280 (150)	8960 (340)	4.16 (0.19)	1790 (1140)
9	35.0 (4.3)	18.7 (0.5)	14.4 (19.4)	33.9	1670 ± 20	2440 (300)	540 (190)	2970 (350)	1.34 (0.22)	530 (720)
10	31.6 (2.3)	18.8 (0.6)	21.6 (34.1)	15.1	1640 ± 20	3300 (250)	-60 (130)	3240 (280)	1.48 (0.15)	780 (1250)
11	37.6 (0.9)	19.4 (0.2)	17.8 (7.0)	7.1	1700 ± 20	2680 (90)	0 (120)	2680 (150)	1.19 (0.09)	670 (270)
13	27.1 (1.2)	16.9 (0.2)	7.3 (4.5)	21.8	1520 ± 20	3690 (110)	510 (80)	4210 (130)	2.05 (0.18)	250 (160)
14	27.8 (0.5)	17.1 (0.3)	10.6 (7.5)	5.5	1550 ± 20	3920 (90)	490 (100)	4410 (140)	2.12 (0.16)	370 (260)

Table 160. A/C Operation Characteristics: Site 17 (SI)

Visit	Outdoor Temperature (SD) [°C]	Return Air Wet Bulb Temperature (SD) [°C]	Average Cycle Length (SD) [minutes]	Cycle Frequency [cycles/day]	Compressor Power Draw [W]	Sensible Capacity (SD) [W]	Latent Capacity (SD) [W]	Total Capacity (SD) [W]	System Efficiency (SD) [-]	Electricity Consumption per Cycle (SD) [Wh/cycle]
7	32.9 (1.0)	20.1 (0.7)	9.0 (2.9)	11.4	1550 ± 20	3000 (110)	900 (200)	3900 (230)	1.99 (0.16)	290 (90)
9	35.7 (3.7)	19.5 (0.3)	14.8 (14.8)	25.8	1560 ± 20	5010 (140)	1060 (250)	6070 (290)	3.20 (0.27)	470 (470)
10	31.8 (2.4)	20.5 (1.1)	20.0 (40.9)	13.1	1470 ± 20	4100 (180)	1590 (200)	5690 (270)	3.10 (0.35)	620 (1280)
11	32.1 (3.8)	20.9 (0.3)	5.4 (5.7)	114.3	1520 ± 20	4390 (120)	870 (120)	5260 (170)	2.73 (0.19)	170 (180)
13	28.0 (1.2)	19.0 (0.1)	5.3 (4.9)	26.9	1440 ± 20	4750 (60)	1170 (110)	5920 (130)	3.30 (0.72)	160 (150)
14	26.5 (1.7)	19.0 (0.5)	3.6 (1.8)	22.0	1350 ± 20	4330 (80)	170 (110)	4500 (130)	3.04 (2.05)	110 (50)

Appendix E.4: Site Duct Leakage Characteristics (SI)

Table 161. Site Duct Leakage Characteristics: All Sites (SI)

	Total Leakage				Exterior Leakage				Total Leakage			Exterior Leakage		
	Supply + Return		Supply		Supply + Return		Supply		Supply + Return	Supply	Return	Supply + Return	Supply	Return
Site	C	n	C	n	C	n	C	n	Q_{25}	Q_{25}	Q_{25}	Q_{25}	Q_{25}	Q_{25}
	[$(m^3/hr)/Pa^n$]		[$(m^3/hr)/Pa^n$]		[$(m^3/hr)/Pa^n$]		[$(m^3/hr)/Pa^n$]		[m^3/hr]	[m^3/hr]	[m^3/hr]	[m^3/hr]	[m^3/hr]	[m^3/hr]
1	29.4	0.632	15.9	0.675	8.0	0.734	5.0	0.734	225	140	85	85	53	33
2	207.5	0.612	78.5	0.642	73.4	0.728	47.5	0.652	1486	620	866	763	388	376
3	53.1	0.604	38.7	0.583	29.2	0.550	20.0	0.582	371	253	118	172	130	42
4	13.4	0.637	13.5	0.591	10.7	0.652	11.5	0.590	104	90	13	87	77	10
5	27.8	0.646	31.1	0.598	17.3	0.705	25.6	0.580	222	213	9	167	166	1
6	45.4	0.646	24.3	0.743	30.7	0.677	21.3	0.719	363	266	97	271	216	55
7	55.5	0.646	29.9	0.644	23.7	0.661	13.6	0.656	444	237	207	199	112	86
8	58.1	0.693	48.9	0.624	83.6	0.528	27.5	0.725	540	365	175	457	283	174
9	74.9	0.610	20.5	0.682	60.6	0.620	17.6	0.624	534	184	350	446	131	315
10[1]	untested								-	-	-	-	-	-
11	140.6	0.646	126.8	0.590	133.6	0.593	101.1	0.586	1126	846	280	901	666	235
12	154.1	0.523	43.8	0.642	86.3	0.588	25.1	0.661	831	346	485	572	211	362
13	71.0	0.642	57.7	0.604	56.3	0.664	42.7	0.675	561	403	158	478	374	104
14	95.5	0.614	65.3	0.588	38.1	0.654	20.9	0.702	690	433	256	313	200	113
15[2]	160.2	0.619	untested		28.7	48.8	untested		1176	1176	-	520	520	-
16	31.0	0.661	12.7	0.602	29.1	0.639	16.1	0.476	260	88	172	227	75	153
17[3]	untested								-	-	-	-	-	-

[1] Site 10 was omitted due to complications with the owner's schedule

[2] Site 15 was only tested for total leakage, as the supply and return were not physically possible to separate from each other. However, the return duct was located entirely in conditioned space so there is zero return leakage to the exterior

[3] Site 17 was not tested for leakage because the system is completely housed in conditioned space

Appendix E.5: Visit Specific Duct Leakage Measurements (SI)

Table 162. Visit Specific Duct Leakage Measurements: Site 1 (SI)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]			[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]					
1	1720 ± 120	32 ± 2	20 ± 2	98.2%	98.9%	2050 ± 140	39 ± 2	24 ± 2	98.1%	98.8%	89.7%	n/a	0.81
2	1760 ± 120	33 ± 2	20 ± 2	98.1%	98.8%	2070 ± 140	40 ± 2	25 ± 2	98.1%	98.8%	89.8%	n/a	0.86
3	1800 ± 130	34 ± 2	21 ± 2	98.1%	98.8%	2100 ± 150	41 ± 2	25 ± 2	98.1%	98.8%	90.0%	n/a	0.89
4	1860 ± 130	36 ± 2	22 ± 2	98.1%	98.8%								
5	1740 ± 120	32 ± 2	20 ± 2	98.2%	98.9%								
6	1750 ± 120	32 ± 2	20 ± 2	98.2%	98.9%								
7	1720 ± 120	31 ± 2	20 ± 2	98.2%	98.9%								
8	1760 ± 120	33 ± 2	20 ± 2	98.1%	98.8%								
9	1720 ± 120	32 ± 2	20 ± 2	98.2%	98.9%								
10	1770 ± 120	33 ± 2	20 ± 2	98.1%	98.8%								
11	1680 ± 120	31 ± 2	19 ± 2	98.2%	98.9%								
12	1690 ± 120	31 ± 2	19 ± 2	98.2%	98.9%								
13	1680 ± 120	31 ± 2	19 ± 2	98.2%	98.9%								
14	1680 ± 120	31 ± 2	19 ± 2	98.2%	98.9%	2000 ± 140	38 ± 2	24 ± 2	98.1%	98.8%	89.5%	n/a	0.85
15	1720 ± 120	32 ± 2	20 ± 2	98.2%	98.9%	1990 ± 140	38 ± 2	24 ± 2	98.1%	98.8%	89.5%	n/a	0.87
16	1670 ± 120	30 ± 2	19 ± 2	98.2%	98.9%	1980 ± 140	37 ± 2	23 ± 2	98.1%	98.8%	89.4%	n/a	0.75

Table 163. Visit Specific Duct Leakage Measurements: Site 2 (SI)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]			[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]					
1	1870 ± 130	282 ± 8	255 ± 8	84.9%	86.4%	1890 ± 130	282 ± 8	255 ± 8	85.0%	86.5%	93.3%	n/a	0.76
2	1860 ± 130	281 ± 8	253 ± 8	84.9%	86.4%	1880 ± 130	281 ± 8	253 ± 8	85.0%	86.5%	93.3%	n/a	0.80
3	1860 ± 130	279 ± 8	251 ± 8	84.9%	86.5%	1870 ± 130	279 ± 8	251 ± 8	85.1%	86.6%	93.3%	n/a	0.80
4	1960 ± 140	300 ± 9	274 ± 8	84.7%	86.0%								
5	1640 ± 110	237 ± 7	205 ± 6	85.5%	87.5%								
6	1610 ± 110	233 ± 7	200 ± 6	85.6%	87.6%								
7	1660 ± 120	241 ± 7	209 ± 6	85.4%	87.4%								
8	1760 ± 120	260 ± 8	230 ± 7	85.2%	86.9%								
9	1800 ± 130	269 ± 8	239 ± 7	85.1%	86.7%								
10	1700 ± 120	250 ± 8	219 ± 7	85.3%	87.1%								
11	1550 ± 110	222 ± 7	189 ± 6	85.7%	87.9%								
12	1570 ± 110	225 ± 7	191 ± 6	85.7%	87.8%								
13	1570 ± 110	224 ± 7	191 ± 6	85.7%	87.8%								
14	1500 ± 110	212 ± 6	178 ± 5	85.9%	88.1%	1540 ± 110	217 ± 6	183 ± 5	85.9%	88.1%	91.9%	n/a	0.81
15	1580 ± 110	226 ± 7	193 ± 6	85.7%	87.8%	1600 ± 110	228 ± 7	194 ± 6	85.8%	87.8%	92.2%	n/a	0.80
16	1510 ± 110	214 ± 6	180 ± 5	85.8%	88.1%	1510 ± 110	211 ± 6	177 ± 5	86.0%	88.3%	91.7%	n/a	0.75

Table 164. Visit Specific Duct Leakage Measurements: Site 3 (SI)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor,	Return Leakage Factor,	System Air Flow	Leakage to Exterior		Supply Leakage Factor,	Return Leakage Factor,	Supply Conduction Fraction,	Return Conduction Fraction,	Delivery Effectiveness
Visit	[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]	α_s	α_r	[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]	α_s	α_r	β_s	β_r	
1	1460 ± 100	121 ± 4	39 ± 2	91.7%	97.3%	1540 ± 110	126 ± 4	41 ± 2	91.8%	97.4%	93.8%	n/a	0.87
2	1510 ± 110	126 ± 4	40 ± 2	91.6%	97.3%	1550 ± 110	127 ± 4	41 ± 2	91.8%	97.4%	93.8%	n/a	0.88
3	1520 ± 110	127 ± 4	41 ± 2	91.6%	97.3%	1590 ± 110	131 ± 4	42 ± 2	91.7%	97.4%	94.0%	n/a	dropped
4	1530 ± 110	128 ± 4	41 ± 2	91.6%	97.3%								
5	1500 ± 110	126 ± 4	40 ± 2	91.6%	97.3%								
6	1540 ± 110	129 ± 4	41 ± 2	91.6%	97.3%								
7	1540 ± 110	129 ± 4	41 ± 2	91.6%	97.3%								
8	1530 ± 110	128 ± 4	41 ± 2	91.6%	97.3%								
9	1570 ± 110	132 ± 4	42 ± 2	91.6%	97.3%								
10	1580 ± 110	133 ± 4	42 ± 2	91.6%	97.3%								
11	1560 ± 110	131 ± 4	42 ± 2	91.6%	97.3%								
12	1540 ± 110	130 ± 4	41 ± 2	91.6%	97.3%	1620 ± 110	135 ± 4	43 ± 2	91.7%	97.4%	94.1%	n/a	0.88
13	1560 ± 110	132 ± 4	42 ± 2	91.6%	97.3%	1660 ± 120	138 ± 4	43 ± 2	91.7%	97.4%	94.2%	n/a	dropped
14	1500 ± 110	126 ± 4	40 ± 2	91.6%	97.3%	1610 ± 110	133 ± 4	42 ± 2	91.7%	97.4%	94.1%	n/a	0.88
15	1500 ± 110	125 ± 4	40 ± 2	91.6%	97.3%	1610 ± 110	133 ± 4	42 ± 2	91.7%	97.4%	94.1%	n/a	0.88
16	1470 ± 100	123 ± 4	40 ± 2	91.7%	97.3%	1570 ± 110	130 ± 4	41 ± 2	91.7%	97.4%	93.9%	n/a	0.88

Table 165. Visit Specific Duct Leakage Measurements: Site 4 (SI)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]			[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]					
1	1100 ± 80	58 ± 2	6 ± 2	94.7%	99.5%	1100 ± 80	57 ± 2	6 ± 2	94.8%	99.5%	96.5%	99.3%	0.86
2	1000 ± 70	52 ± 2	4 ± 2	94.8%	99.6%	1100 ± 80	57 ± 2	6 ± 2	94.8%	99.5%	96.5%	99.3%	0.88
3	990 ± 70	51 ± 2	4 ± 2	94.8%	99.6%	1100 ± 80	57 ± 2	6 ± 2	94.8%	99.5%	96.5%	99.3%	0.89
4	1000 ± 70	52 ± 2	4 ± 2	94.8%	99.6%								
5	1020 ± 70	53 ± 2	5 ± 2	94.8%	99.5%								
6	1030 ± 70	54 ± 2	5 ± 2	94.8%	99.5%								
7	1040 ± 70	54 ± 2	5 ± 2	94.8%	99.5%								
8	1030 ± 70	54 ± 2	5 ± 2	94.8%	99.5%								
9	1080 ± 80	57 ± 2	5 ± 2	94.8%	99.5%								
10	1100 ± 80	58 ± 2	6 ± 2	94.7%	99.5%								
11	1070 ± 70	56 ± 2	5 ± 2	94.8%	99.5%								
12	1060 ± 70	55 ± 2	5 ± 2	94.8%	99.5%	1230 ± 90	65 ± 2	7 ± 2	94.7%	99.4%	96.8%	99.4%	0.91
13	1080 ± 80	57 ± 2	5 ± 2	94.8%	99.5%	1260 ± 90	67 ± 2	8 ± 2	94.7%	99.4%	96.9%	99.4%	0.90
14	1010 ± 70	52 ± 2	5 ± 2	94.8%	99.6%	1180 ± 80	62 ± 2	7 ± 2	94.7%	99.4%	96.7%	99.4%	0.85
15	1030 ± 70	54 ± 2	5 ± 2	94.8%	99.5%	1200 ± 80	64 ± 2	7 ± 2	94.7%	99.4%	96.8%	99.4%	0.89
16	980 ± 70	50 ± 2	4 ± 2	94.9%	99.6%	1140 ± 80	60 ± 2	6 ± 2	94.8%	99.5%	96.6%	99.4%	0.87

Table 166. Visit Specific Duct Leakage Measurements: Site 5 (SI)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]			[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]					
1	2170 ± 150	162 ± 5	46 ± 2	92.6%	97.9%	2270 ± 160	162 ± 5	46 ± 2	92.9%	98.0%	94.1%	98.9%	0.78
2	2110 ± 150	156 ± 5	44 ± 2	92.6%	97.9%	2210 ± 150	156 ± 5	44 ± 2	92.9%	98.0%	93.9%	98.8%	0.79
3	1750 ± 120	126 ± 4	34 ± 2	92.8%	98.0%	1880 ± 130	129 ± 4	35 ± 2	93.1%	98.1%	92.9%	98.7%	0.85
4	1890 ± 130	138 ± 4	38 ± 2	92.7%	98.0%								
5	1840 ± 130	133 ± 4	37 ± 2	92.8%	98.0%								
6	1850 ± 130	134 ± 4	37 ± 2	92.7%	98.0%								
7	1720 ± 120	124 ± 4	34 ± 2	92.8%	98.0%								
8	1700 ± 120	122 ± 4	33 ± 2	92.8%	98.1%								
9	1990 ± 140	146 ± 4	41 ± 2	92.7%	98.0%								
10	1980 ± 140	145 ± 4	41 ± 2	92.7%	98.0%								
11	2180 ± 150	162 ± 5	46 ± 2	92.6%	97.9%	1970 ± 140	137 ± 4	38 ± 2	93.1%	98.1%	93.2%	98.7%	0.75
12	1660 ± 120	118 ± 4	32 ± 2	92.9%	98.1%								
13	1780 ± 120	128 ± 4	35 ± 2	92.8%	98.0%	1850 ± 130	127 ± 4	35 ± 2	93.1%	98.1%	92.8%	98.6%	0.70
14	1700 ± 120	122 ± 4	33 ± 2	92.8%	98.1%	1720 ± 120	117 ± 4	32 ± 2	93.2%	98.2%	92.3%	98.5%	0.76
15	1650 ± 120	118 ± 4	32 ± 2	92.9%	98.1%	1620 ± 110	109 ± 3	29 ± 2	93.3%	98.2%	91.8%	98.4%	0.73
16	1470 ± 100	103 ± 3	27 ± 2	93.0%	98.1%	1500 ± 110	100 ± 3	26 ± 2	93.4%	98.2%	91.2%	98.3%	0.76

Table 167. Visit Specific Duct Leakage Measurements: Site 6 (SI)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]			[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]					
1	1830 ± 130	108 ± 3	22 ± 2	94.1%	98.8%	1850 ± 130	108 ± 3	22 ± 2	94.1%	98.8%	90.6%	98.2%	0.78
2	1740 ± 120	101 ± 3	20 ± 2	94.2%	98.8%	1680 ± 120	95 ± 3	19 ± 2	94.4%	98.9%	89.7%	98.0%	dropped
3	1660 ± 120	94 ± 3	19 ± 2	94.3%	98.9%	1630 ± 110	90 ± 3	18 ± 2	94.4%	98.9%	89.4%	98.0%	
4	1640 ± 110	93 ± 3	18 ± 2	94.3%	98.9%								
5	1900 ± 130	114 ± 3	24 ± 2	94.0%	98.8%								
6	1900 ± 130	114 ± 3	24 ± 2	94.0%	98.8%								
7	1900 ± 130	115 ± 3	24 ± 2	94.0%	98.8%								
8	1790 ± 130	105 ± 3	21 ± 2	94.1%	98.8%								
9	1970 ± 140	121 ± 4	25 ± 2	93.9%	98.7%								
10	1920 ± 130	116 ± 3	24 ± 2	94.0%	98.8%								
11	1860 ± 130	111 ± 3	23 ± 2	94.0%	98.8%								
12	1800 ± 130	106 ± 3	21 ± 2	94.1%	98.8%								
13	1710 ± 120	98 ± 3	20 ± 2	94.3%	98.9%	1660 ± 120	93 ± 3	18 ± 2	94.4%	98.9%	89.6%	98.0%	0.73
14	1660 ± 120	94 ± 3	19 ± 2	94.3%	98.9%	1630 ± 110	91 ± 3	18 ± 2	94.4%	98.9%	89.4%	98.0%	0.81
15	1620 ± 110	91 ± 3	18 ± 2	94.4%	98.9%	1610 ± 110	89 ± 3	17 ± 2	94.5%	98.9%	89.3%	97.9%	dropped
16	1560 ± 110	86 ± 3	17 ± 2	94.5%	98.9%	1530 ± 110	83 ± 2	16 ± 2	94.6%	99.0%	88.8%	97.8%	0.72

Table 168. Visit Specific Duct Leakage Measurements: Site 7 (SI)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]			[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]					
1	1410 ± 100	121 ± 4	94 ± 3	91.4%	93.4%	1400 ± 100	118 ± 4	91 ± 3	91.6%	93.5%	90.1%	n/a	0.86
2	1300 ± 90	108 ± 3	83 ± 3	91.7%	93.6%	1320 ± 90	108 ± 3	83 ± 3	91.8%	93.7%	89.5%	n/a	0.85
3	1300 ± 90	109 ± 3	84 ± 3	91.6%	93.6%								
4	1310 ± 90	109 ± 3	84 ± 3	91.6%	93.5%								
5	1280 ± 90	106 ± 3	82 ± 2	91.7%	93.6%								
6	1330 ± 90	112 ± 3	86 ± 3	91.6%	93.5%								
7	1130 ± 80	91 ± 3	70 ± 2	92.0%	93.8%								
8	1110 ± 80	88 ± 3	68 ± 2	92.1%	93.9%								
9	1150 ± 80	92 ± 3	71 ± 2	92.0%	93.8%								
10	1140 ± 80	91 ± 3	70 ± 2	92.0%	93.8%								
11	1150 ± 80	92 ± 3	71 ± 2	92.0%	93.8%								
12	1070 ± 70	84 ± 3	64 ± 2	92.1%	94.0%	1060 ± 70	82 ± 2	63 ± 2	92.3%	94.1%	87.2%	n/a	0.84
13	1100 ± 80	87 ± 3	67 ± 2	92.1%	93.9%	1110 ± 80	87 ± 3	67 ± 2	92.2%	94.0%	87.8%	n/a	0.85
14	1080 ± 80	85 ± 3	65 ± 2	92.1%	93.9%	1080 ± 80	83 ± 2	64 ± 2	92.3%	94.1%	87.4%	n/a	0.82
15	1070 ± 70	85 ± 3	65 ± 2	92.1%	94.0%	1070 ± 70	83 ± 2	64 ± 2	92.3%	94.1%	87.3%	n/a	0.83
16	1040 ± 70	81 ± 2	62 ± 2	92.2%	94.0%	1050 ± 70	80 ± 2	62 ± 2	92.3%	94.1%	87.0%	n/a	0.84

Table 169. Visit Specific Duct Leakage Measurements: Site 8 (SI)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]			[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]					
1	1270 ± 90	260 ± 8	78 ± 2	79.4%	93.8%	1260 ± 90	255 ± 8	78 ± 2	79.8%	93.8%	87.8%	n/a	0.67
2	1260 ± 90	260 ± 8	78 ± 2	79.4%	93.8%	1210 ± 80	242 ± 7	76 ± 2	80.1%	93.7%	87.4%	n/a	0.61
3	1270 ± 90	262 ± 8	79 ± 2	79.4%	93.8%								
4	1250 ± 90	255 ± 8	78 ± 2	79.6%	93.8%								
5	1210 ± 80	243 ± 7	76 ± 2	79.9%	93.7%								
6	1230 ± 90	250 ± 8	77 ± 2	79.7%	93.7%								
7	1200 ± 80	242 ± 7	76 ± 2	79.9%	93.7%								
8	1190 ± 80	239 ± 7	76 ± 2	80.0%	93.7%								
9	1220 ± 90	247 ± 7	77 ± 2	79.8%	93.7%								
10	1330 ± 90	281 ± 8	81 ± 2	78.9%	93.9%								
11	1230 ± 90	251 ± 8	77 ± 2	79.7%	93.7%								
12	1230 ± 90	249 ± 7	77 ± 2	79.7%	93.7%								
13	1210 ± 80	245 ± 7	76 ± 2	79.8%	93.7%	1200 ± 80	237 ± 7	75 ± 2	80.2%	93.7%	87.2%	n/a	0.67
14	1210 ± 80	256 ± 8	78 ± 2	79.0%	93.6%	1200 ± 80	247 ± 7	77 ± 2	79.4%	93.6%	87.2%	n/a	0.72
15	1260 ± 90	258 ± 8	78 ± 2	79.5%	93.8%	1260 ± 90	254 ± 8	78 ± 2	79.8%	93.8%	87.8%	n/a	0.69
16	1230 ± 90	251 ± 8	77 ± 2	79.7%	93.7%	1240 ± 90	247 ± 7	77 ± 2	80.0%	93.8%	87.6%	n/a	0.67

Table 170. Visit Specific Duct Leakage Measurements: Site 9 (SI)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]			[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]					
1	3220 ± 230	136 ± 4	325 ± 10	95.8%	89.9%	3260 ± 230	136 ± 4	327 ± 10	95.8%	90.0%	95.3%	98.2%	0.53
2	3230 ± 230	136 ± 4	326 ± 10	95.8%	89.9%								
3	3280 ± 230	139 ± 4	332 ± 10	95.8%	89.9%								
4	3380 ± 240	139 ± 4	332 ± 10	95.9%	90.2%								
5	3180 ± 220	138 ± 4	331 ± 10	95.6%	89.6%								
6	3240 ± 230	137 ± 4	327 ± 10	95.8%	89.9%								
7	3250 ± 230	137 ± 4	328 ± 10	95.8%	89.9%								
8	3310 ± 230	121 ± 4	291 ± 9	96.3%	91.2%								
9	3380 ± 240	125 ± 4	298 ± 9	96.3%	91.2%								
10	3410 ± 240	126 ± 4	302 ± 9	96.3%	91.1%								
11	3540 ± 250	132 ± 4	316 ± 9	96.3%	91.1%	3590 ± 250	131 ± 4	314 ± 9	96.3%	91.3%	95.7%	98.4%	0.57
12	3500 ± 250	130 ± 4	312 ± 9	96.3%	91.1%								
13	3440 ± 240	128 ± 4	306 ± 9	96.3%	91.1%	3510 ± 250	127 ± 4	305 ± 9	96.4%	91.3%	95.6%	98.3%	0.61
14	3420 ± 240	127 ± 4	303 ± 9	96.3%	91.1%	3490 ± 240	127 ± 4	303 ± 9	96.4%	91.3%	95.6%	98.3%	0.50
15	3480 ± 240	130 ± 4	310 ± 9	96.3%	91.1%	3550 ± 250	129 ± 4	309 ± 9	96.4%	91.3%	95.6%	98.4%	dropped
16	3400 ± 240	126 ± 4	301 ± 9	96.3%	91.1%	3470 ± 240	126 ± 4	301 ± 9	96.4%	91.3%	95.6%	98.3%	dropped

Table 171. Visit Specific Duct Leakage Measurements: Site 10 (SI)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]			[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]					

Duct leakage testing was not performed at Site 10

Table 172. Visit Specific Duct Leakage Measurements: Site 11 (SI)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]			[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]					
1	2540 ± 180	863 ± 26	235 ± 7	66.0%	90.7%	2610 ± 180	872 ± 26	238 ± 7	66.6%	90.9%	95.5%	98.3%	0.59
2	2570 ± 180	877 ± 26	239 ± 7	65.9%	90.7%	2590 ± 180	866 ± 26	236 ± 7	66.6%	90.9%	95.5%	98.3%	0.59
3	2560 ± 180	870 ± 26	237 ± 7	66.0%	90.7%	2580 ± 180	861 ± 26	235 ± 7	66.6%	90.9%	95.5%	98.3%	dropped
4	2570 ± 180	874 ± 26	238 ± 7	65.9%	90.7%								
5	2490 ± 170	846 ± 25	230 ± 7	66.0%	90.8%								
6	2520 ± 180	858 ± 26	234 ± 7	66.0%	90.7%								
7	2520 ± 180	857 ± 26	233 ± 7	66.0%	90.7%								
8	2410 ± 170	816 ± 24	222 ± 7	66.1%	90.8%								
9	2450 ± 170	830 ± 25	226 ± 7	66.1%	90.8%								
10	2430 ± 170	825 ± 25	224 ± 7	66.1%	90.8%	2470 ± 170	824 ± 25	224 ± 7	66.7%	90.9%	95.3%	98.2%	0.64
11	2180 ± 150	735 ± 22	199 ± 6	66.4%	90.9%	2230 ± 160	738 ± 22	200 ± 6	67.0%	91.0%	94.8%	98.0%	0.61
12	1970 ± 140	660 ± 20	178 ± 5	66.6%	91.0%								
13	1960 ± 140	655 ± 20	177 ± 5	66.6%	91.0%	2000 ± 140	655 ± 20	177 ± 5	67.2%	91.2%	94.2%	97.8%	0.61
14	2330 ± 160	788 ± 24	214 ± 6	66.2%	90.8%	2370 ± 170	788 ± 24	214 ± 6	66.8%	91.0%	95.1%	98.1%	0.61
15	2320 ± 160	785 ± 24	213 ± 6	66.2%	90.8%	2370 ± 170	786 ± 24	213 ± 6	66.8%	91.0%	95.1%	98.1%	0.58

Table 173. Visit Specific Duct Leakage Measurements: Site 12 (SI)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]			[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]					
1	2440 ± 170	255 ± 8	425 ± 13	89.6%	82.6%								
2	2260 ± 160	230 ± 7	390 ± 12	89.8%	82.8%								
3	2190 ± 150	221 ± 7	377 ± 11	89.9%	82.8%								
4	2280 ± 160	232 ± 7	393 ± 12	89.8%	82.7%								
5	2250 ± 160	228 ± 7	387 ± 12	89.8%	82.8%								
6	2300 ± 160	235 ± 7	397 ± 12	89.8%	82.7%								
7	2270 ± 160	232 ± 7	393 ± 12	89.8%	82.7%								
8	2280 ± 160	232 ± 7	393 ± 12	89.8%	82.7%								
9	2050 ± 140	202 ± 6	350 ± 10	90.1%	82.9%								
10	2360 ± 170	243 ± 7	408 ± 12	89.7%	82.7%								
11	2480 ± 170	260 ± 8	432 ± 13	89.5%	82.6%	2540 ± 180	259 ± 8	429 ± 13	89.8%	83.1%	91.5%	n/a	0.78
12	2290 ± 160	234 ± 7	396 ± 12	89.8%	82.7%								
13	2360 ± 170	243 ± 7	408 ± 12	89.7%	82.7%	2580 ± 180	263 ± 8	435 ± 13	89.8%	83.1%	91.6%	n/a	0.77
14	2310 ± 160	237 ± 7	400 ± 12	89.7%	82.7%	2540 ± 180	258 ± 8	428 ± 13	89.8%	83.1%	91.5%	n/a	0.74
15	2290 ± 160	234 ± 7	396 ± 12	89.8%	82.7%	2490 ± 170	252 ± 8	420 ± 13	89.9%	83.1%	91.3%	n/a	0.78

Table 174. Visit Specific Duct Leakage Measurements: Site 13 (SI)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]			[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]					
1	1440 ± 100	255 ± 8	72 ± 2	82.3%	95.0%	1570 ± 110	282 ± 8	79 ± 2	82.0%	95.0%	89.6%	n/a	0.90
2	1470 ± 100	263 ± 8	74 ± 2	82.2%	95.0%								
3	1460 ± 100	260 ± 8	73 ± 2	82.2%	95.0%								
4	1380 ± 100	242 ± 7	68 ± 2	82.5%	95.1%								
5	1480 ± 100	265 ± 8	74 ± 2	82.1%	95.0%								
6	1450 ± 100	258 ± 8	72 ± 2	82.2%	95.0%								
7	1510 ± 110	272 ± 8	76 ± 2	82.0%	95.0%								
8	1400 ± 100	246 ± 7	69 ± 2	82.5%	95.1%	1510 ± 110	268 ± 8	75 ± 2	82.3%	95.0%	89.2%	n/a	0.69
9	1540 ± 110	278 ± 8	78 ± 2	81.9%	95.0%	1710 ± 120	317 ± 10	88 ± 3	81.5%	94.9%	90.4%	n/a	0.68
10	1320 ± 90	226 ± 7	64 ± 2	82.8%	95.1%	1490 ± 100	264 ± 8	74 ± 2	82.3%	95.1%	89.1%	n/a	0.68
11	1190 ± 80	196 ± 6	56 ± 2	83.5%	95.3%	1270 ± 90	212 ± 6	60 ± 2	83.3%	95.3%	87.3%	n/a	0.67
12	1130 ± 80	185 ± 6	53 ± 2	83.7%	95.3%	1210 ± 80	198 ± 6	57 ± 2	83.6%	95.3%	86.6%	n/a	0.72
13	1410 ± 100	248 ± 7	70 ± 2	82.4%	95.1%	1540 ± 110	274 ± 8	76 ± 2	82.3%	95.0%	89.4%	n/a	0.70
14	1400 ± 100	244 ± 7	69 ± 2	82.5%	95.1%	1500 ± 110	265 ± 8	74 ± 2	82.3%	95.0%	89.1%	n/a	0.71
15	1330 ± 90	228 ± 7	65 ± 2	82.8%	95.1%	1420 ± 100	247 ± 7	70 ± 2	82.6%	95.1%	88.6%	n/a	0.76
16	1330 ± 90	230 ± 7	65 ± 2	82.8%	95.1%								

Table 175. Visit Specific Duct Leakage Measurements: Site 14 (SI)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]			[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]					
1	1560 ± 110	123 ± 4	75 ± 2	92.2%	95.2%								
2	1570 ± 110	123 ± 4	76 ± 2	92.1%	95.2%								
3	1710 ± 120	139 ± 4	84 ± 3	91.9%	95.1%								
4	1630 ± 110	130 ± 4	79 ± 2	92.0%	95.1%								
5	1700 ± 120	138 ± 4	83 ± 2	91.9%	95.1%								
6	1620 ± 110	129 ± 4	79 ± 2	92.0%	95.2%								
7	1590 ± 110	126 ± 4	77 ± 2	92.1%	95.2%								
8	1690 ± 120	136 ± 4	82 ± 2	91.9%	95.1%	1690 ± 120	134 ± 4	81 ± 2	92.1%	95.2%	93.2%	n/a	0.86
9	1460 ± 100	111 ± 3	70 ± 2	92.4%	95.2%	1490 ± 100	111 ± 3	70 ± 2	92.5%	95.3%	92.3%	n/a	0.86
10	1430 ± 100	108 ± 3	68 ± 2	92.4%	95.2%	1450 ± 100	108 ± 3	68 ± 2	92.6%	95.3%	92.1%	n/a	0.81
11	1490 ± 100	114 ± 3	71 ± 2	92.3%	95.2%	1510 ± 110	114 ± 3	71 ± 2	92.5%	95.3%	92.4%	n/a	0.81
12	1460 ± 100	111 ± 3	70 ± 2	92.4%	95.2%	1490 ± 100	111 ± 3	70 ± 2	92.5%	95.3%	92.3%	n/a	0.81
13	1460 ± 100	111 ± 3	70 ± 2	92.4%	95.2%								
14	1600 ± 110	126 ± 4	77 ± 2	92.1%	95.2%	1620 ± 110	126 ± 4	77 ± 2	92.2%	95.3%	92.9%	n/a	0.83
15	1550 ± 110	121 ± 4	74 ± 2	92.2%	95.2%	1590 ± 110	122 ± 4	75 ± 2	92.3%	95.3%	92.8%	n/a	0.81
16	1590 ± 110	126 ± 4	77 ± 2	92.1%	95.2%								

Table 176. Visit Specific Duct Leakage Measurements: Site 15 (SI)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]			[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]					
1	1980 ± 140	458 ± 14	n/a	76.8%	100%			n/a					
2	1890 ± 130	429 ± 13		77.3%	100%								
3	1920 ± 130	440 ± 13		77.1%	100%								
4	1910 ± 130	434 ± 13		77.2%	100%								
5	1840 ± 130	413 ± 12		77.6%	100%								
6	1880 ± 130	425 ± 13		77.4%	100%								
7	1760 ± 120	386 ± 12		78.1%	100%	1780 ± 120	368 ± 11		79.4%	100%	93.4%	n/a	0.76
8	1810 ± 130	401 ± 12		77.8%	100%								
9	1920 ± 130	438 ± 13		77.2%	100%	2000 ± 140	434 ± 13		78.3%	100%	94.1%	n/a	0.75
10	1860 ± 130	418 ± 13		77.5%	100%	1950 ± 140	418 ± 13		78.5%	100%	94.0%	n/a	0.75
11	1830 ± 130	408 ± 12		77.7%	100%	1900 ± 130	404 ± 12		78.8%	100%	93.8%	n/a	0.75
12	1860 ± 130	418 ± 13		77.5%	100%	1940 ± 140	417 ± 13		78.5%	100%	93.9%	n/a	0.75
13	1870 ± 130	422 ± 13		77.4%	100%	1950 ± 140	420 ± 13		78.5%	100%	94.0%	n/a	0.74
14	1870 ± 130	423 ± 13		77.4%	100%	1970 ± 140	424 ± 13		78.4%	100%	94.0%	n/a	0.75
15	1870 ± 130	423 ± 13		77.4%	100%								
16	1870 ± 130	421 ± 13		77.5%	100%								

Table 177. Visit Specific Duct Leakage Measurements: Site 16 (SI)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]			[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]					
1	1030 ± 70	40 ± 1	Below detection	96.1%	100%								
2	920 ± 60	36 ± 1		96.1%	100%								
3	990 ± 70	39 ± 1		96.1%	100%								
4	1040 ± 70	41 ± 1		96.1%	100%								
5	1030 ± 70	40 ± 1		96.1%	100%								
6	1080 ± 80	42 ± 1		96.1%	100%								
7	1100 ± 80	43 ± 1		96.1%	100%	1740 ± 120	68 ± 2	11 ± 2	96.1%	99.4%	94.5%	n/a	0.91
8	1060 ± 70	41 ± 1		96.1%	100%								
9	1060 ± 70	41 ± 1		96.1%	100%	1840 ± 130	72 ± 2	12 ± 2	96.1%	99.3%	94.8%	n/a	0.81
10	1070 ± 70	42 ± 1		96.1%	100%	1830 ± 130	71 ± 2	12 ± 2	96.1%	99.3%	94.7%	n/a	0.85
11	1050 ± 70	41 ± 1		96.1%	100%	1830 ± 130	71 ± 2	12 ± 2	96.1%	99.3%	94.7%	n/a	0.76
12	1020 ± 70	40 ± 1		96.1%	100%								
13	1030 ± 70	40 ± 1		96.1%	100%	1750 ± 120	68 ± 2	11 ± 2	96.1%	99.4%	94.5%	n/a	0.88
14	1010 ± 70	40 ± 1		96.1%	100%	1750 ± 120	68 ± 2	11 ± 2	96.1%	99.4%	94.5%	n/a	0.88
15	1020 ± 70	40 ± 1		96.1%	100%								
16	830 ± 60	37 ± 1		95.6%	100%								

Table 178. Visit Specific Duct Leakage Measurements: Site 17 (SI)

	Fan Only Mode					Cooling Mode							
	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	System Air Flow	Leakage to Exterior		Supply Leakage Factor, α_s	Return Leakage Factor, α_r	Supply Conduction Fraction, β_s	Return Conduction Fraction, β_r	Delivery Effectiveness
Visit	[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]			[m^3/hr]	Supply [m^3/hr]	Return [m^3/hr]					

Duct leakage testing was not performed at Site 17

Appendix E.6: Importance of Filter Pressure Drop (SI)

Table 179. Importance of Filter Pressure Drop: Site 1 (SI)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	ΔSystem Air Flow, relative to 200 (m^3/hr)/kW [m^3/hr]	[%]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop
1	2	0	24.9	88.3	29%	33.6	106.0	-753	73%	21%
2	2	30	26.1	82.4	26%	34.5	110.0	-726	74%	26%
3	2	59	27.3	75.2	22%	35.3	102.4	-702	75%	24%
4	2	88	29.3	77.2	21%					
5	7	0	25.4	97.0	43%					
6	7	35	25.7	101.0	46%					
7	7	68	24.8	101.3	49%					
8	7	95	26.1	106.9	48%					
9	11	0	25.0	106.3	45%					
10	11	29	26.3	106.7	50%					
11	11	62	23.8	94.8	51%					
12	11	91	24.0	97.1	50%					
13	11	0	23.8	99.8	49%					
14	11	27	23.9	97.9	52%	32.1	123.9	-799	71%	50%
15	11	55	24.9	102.3	52%	31.9	125.6	-805	71%	51%
16	11	86	23.4	100.5	53%	31.4	126.8	-821	71%	51%

Table 180. Importance of Filter Pressure Drop: Site 2 (SI)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	ΔSystem Air Flow, relative to 200 (m^3/hr)/kW [m^3/hr]	[%]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop
1	2	0	30.8	61.9	83%	30.8	65.0	-212	90%	84%
2	2	27	30.6	50.5	79%	30.6	52.6	-221	89%	80%
3	2	59	30.3	71.5	85%	30.3	74.1	-229	89%	86%
4	2	93	33.7	74.0	85%					
5	6	0	23.6	96.5	90%					
6	6	26	22.9	99.1	91%					
7	6	63	24.2	105.0	91%					
8	6	93	27.2	85.3	90%					
9	11	0	28.5	103.0	91%					
10	11	22	25.6	98.4	90%					
11	11	52	21.3	101.1	90%					
12	11	84	21.7	99.3	91%					
13	11	0	21.6	104.5	93%					
14	11	29	19.9	110.0	92%	20.5	113.1	-561	73%	92%
15	11	56	21.9	111.1	92%	22.1	117.1	-501	76%	92%
16	11	83	20.1	113.4	93%	19.7	120.5	-591	72%	93%

Table 181. Importance of Filter Pressure Drop: Site 3 (SI)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	ΔSystem Air Flow, relative to 200 (m^3/hr)/kW [m^3/hr]	[%]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop
1	11	0	44.2	n/a	n/a	47.5	n/a	-212	88%	n/a
2	11	27	47.3	37.0	96%	48.0	39.0	-204	88%	95%
3	11	56	47.8	37.0	98%	50.7	39.9	-161	91%	95%
4	11	82	48.4	37.0	98%					
5	6	0	47.0	32.9	100%					
6	6	31	49.3	33.7	98%					
7	6	66	49.4	33.1	100%					
8	6	99	48.6	34.8	98%					
9	2	0	51.1	18.0	95%					
10	2	23	51.7	18.1	96%					
11	2	57	50.5	17.7	100%					
12	2	84	49.5	17.6	93%	53.0	19.2	-126	93%	89%
13	2	0	50.9	17.8	92%	55.1	19.4	-93	95%	92%
14	2	34	47.0	17.9	92%	51.9	19.5	-143	92%	93%
15	2	60	46.6	17.5	95%	51.9	19.7	-143	92%	93%
16	2	78	45.3	17.9	94%	49.6	19.9	-178	90%	94%

Table 182. Importance of Filter Pressure Drop: Site 4 (SI)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	ΔSystem Air Flow, relative to 200 (m^3/hr)/kW [m^3/hr]	[%]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop
1	11	3	30.7	n/a	n/a	30.3	143.0	48	105%	43%
2	11	30	25.4	117.3	69%	30.2	143.9	46	104%	56%
3	11	59	25.1	121.8	58%	30.5	147.9	51	105%	57%
4	11	85	25.6	120.9	46%					
5	6	0	26.4	107.2	59%					
6	6	31	27.4	110.1	56%					
7	6	66	27.5	110.9	54%					
8	6	99	27.4	107.7	60%					
9	2	0	29.9	81.9	41%					
10	2	23	30.7	85.1	39%					
11	2	57	29.1	81.4	34%					
12	2	84	28.8	83.0	40%	37.9	108.6	178	117%	39%
13	2	1	29.8	80.5	43%	39.7	109.7	207	120%	40%
14	2	35	25.9	75.7	44%	34.8	103.6	127	112%	43%
15	2	61	27.3	78.6	45%	36.3	105.5	151	114%	43%
16	2	79	24.3	78.6	48%	32.5	104.6	87	108%	48%

Table 183. Importance of Filter Pressure Drop: Site 5 (SI)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	ΔSystem Air Flow, relative to 200 (m^3/hr)/kW [m^3/hr]	[%]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop
1	2	0	47.8	138.7	24%	47.8	138.7	525	130%	24%
2	2	27	45.0	146.0	34%	45.0	146.0	457	126%	34%
3	2	57	31.1	156.5	47%	32.6	157.8	129	107%	45%
4	2	87	36.4	167.8	51%					
5	6	0	34.3	164.8	48%					
6	6	27	34.7	175.7	58%					
7	6	66	30.1	199.2	68%					
8	6	96	29.3	212.0	75%					
9	11	0	40.3	159.4	44%					
10	11	35	39.9	163.7	50%					
11	11	61	48.1	163.7	52%	35.9	163.1	221	113%	49%
12	11	98	28.0	175.9	57%					
13	11	0	32.0	165.4	48%	31.5	165.4	97	106%	47%
14	11	29	29.4	174.6	55%	27.5	175.4	-26	99%	55%
15	11	63	27.7	193.2	62%	24.3	190.3	-129	93%	62%
16	11	92	22.1	208.0	71%	20.9	208.0	-246	86%	70%

Table 184. Importance of Filter Pressure Drop: Site 6 (SI)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	ΔSystem Air Flow, relative to 200 (m^3/hr)/kW [m^3/hr]	[%]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop
1	7	0	19.2	79.6	61%	19.2	79.5	-253	88%	81%
2	7	34	17.4	95.0	81%	15.9	97.1	-420	80%	90%
3	7	63	15.8	124.3	90%	14.9	124.5	-472	78%	100%
4	7	90	15.5	125.0	91%					
5	2	0	20.7	59.2	78%					
6	2	28	20.7	66.6	80%					
7	2	64	20.8	70.2	84%					
8	2	98	18.4	74.5	83%					
9	2	0	22.3	59.4	76%					
10	2	28	21.1	63.5	79%					
11	2	63	19.8	71.8	82%					
12	2	87	18.5	78.0	92%					
13	11	0	16.7	107.6	92%	15.5	106.9	-440	79%	89%
14	11	33	15.8	112.7	95%	15.0	112.8	-467	78%	93%
15	11	60	15.1	117.0	95%	14.6	117.9	-489	77%	92%
16	11	103	13.9	124.8	93%	13.2	124.5	-569	73%	91%

Table 185. Importance of Filter Pressure Drop: Site 7 (SI)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	ΔSystem Air Flow, relative to 200 (m^3/hr)/kW [m^3/hr]	[%]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop
1	2	0	56.2	44.7	80%	53.8	43.3	-697	67%	80%
2	2	34	47.3	58.2	87%	47.3	59.0	-783	63%	87%
3	2	62	47.6	66.3	86%					
4	2	87	48.1	70.2	89%					
5	6	0	45.8	77.8	90%					
6	6	25	49.6	82.8	92%					
7	6	65	36.3	90.8	92%					
8	6	92	34.5	96.1	93%					
9	11	0	37.1	76.4	90%					
10	11	36	36.5	85.3	91%					
11	11	69	37.1	85.2	91%					
12	11	96	32.0	85.7	92%	30.8	83.8	-1038	51%	92%
13	11	0	33.9	77.8	88%	33.9	73.7	-985	53%	87%
14	11	33	32.9	80.3	89%	31.7	79.5	-1023	51%	88%
15	11	62	32.5	82.1	91%	31.5	80.9	-1026	51%	91%
16	11	92	30.7	84.7	92%	30.1	84.9	-1050	50%	90%

Table 186. Importance of Filter Pressure Drop: Site 8 (SI)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	ΔSystem Air Flow, relative to 200 (m^3/hr)/kW [m^3/hr]	[%]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop
1	2	0	44.4	35.2	62%	43.1	39.5	-839	60%	57%
2	2	31	44.2	38.6	66%	40.1	36.8	-885	58%	67%
3	2	62	44.8	42.4	69%					
4	2	88	43.1	43.9	68%					
5	6	0	40.3	62.5	76%					
6	6	28	42.0	63.8	78%					
7	6	63	40.1	72.0	72%					
8	6	91	39.4	66.2	81%					
9	11	0	41.3	61.6	80%					
10	11	37	49.3	60.3	73%					
11	11	69	42.2	58.2	75%					
12	11	99	41.7	55.9	72%					
13	11	0	40.9	66.1	77%	39.1	65.0	-901	57%	78%
14	11	30	43.3	55.9	76%	41.3	56.4	-901	57%	75%
15	11	56	43.9	56.8	71%	42.9	55.1	-843	60%	71%
16	11	98	42.1	57.4	75%	41.4	57.7	-865	59%	74%

Table 187. Importance of Filter Pressure Drop: Site 9 (SI)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop[1]	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	ΔSystem Air Flow, relative to 200 (m^3/hr)/kW [m^3/hr]	[%]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop[1]
1	7	0	52.8	79.5	n/a	53.2	80.0	-238	93%	n/a
2	7	28	53.0	75.3						
3	7	58	54.7	75.3						
4	7	82	54.6	81.4						
5	11	0	54.4	83.7						
6	11	44	53.4	81.2						
7	11	81	53.7	84.5						
8	11	126	44.2	69.1						
9	2	0	46.0	58.8						
10	2	11	46.9	58.9						
11	2	50	50.4	55.8		50.0	59.3	93	103%	
12	2	97	49.5	53.3						
13	11	0	47.8	64.7		47.7	63.9	8	100%	
14	11	32	47.2	66.9		47.2	67.7	-10	100%	
15	11	64	49.0	66.8		48.7	68.8	46	101%	
16	11	92	46.6	67.4		46.7	70.7	-29	99%	

[1] Filter pressure drop is not directly measured at Site 9 due to access limitations

Table 188. Importance of Filter Pressure Drop: Site 10 (SI)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	ΔSystem Air Flow, relative to 200 (m^3/hr)/kW [m^3/hr]	[%]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop
1	2	0	46.0	n/a	n/a	44.0	n/a	-333	86%	n/a
2	2	29	55.2	107.0	15%					
3	2	58	54.3	106.0	15%					
4	2	82	58.1	110.6	14%					
5	6	0	51.5	125.8	29%					
6	6	44	51.0	127.7	29%					
7	6	81	51.2	126.0	30%					
8	6	109	50.7	126.0	30%					
9	11	0	51.8	126.4	30%					
10	11	28	51.3	125.9	30%					
11	11	62	41.0	123.8	29%	40.1	124.5	-428	83%	30%
12	11	114	40.1	124.8	30%					
13	7	0	38.7	126.2	32%					
14	7	32	40.0	128.5	31%	40.2	133.8	-426	83%	30%
15	7	64	40.3	133.6	31%	40.9	135.8	-410	83%	31%
16	7	92	39.9	130.5	33%	39.8	133.6	-437	82%	33%

Table 189. Importance of Filter Pressure Drop: Site 11 (SI)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	ΔSystem Air Flow, relative to 200 (m^3/hr)/kW [m^3/hr]	[%]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop
1	2	0	77.7	27.0	99%	79.0	26.8	158	106%	93%
2	2	30	79.8	28.8	96%	78.1	29.7	143	106%	93%
3	2	57	78.7	33.5	100%	77.4	33.8	129	105%	92%
4	2	86	79.3	36.9	93%					
5	6	0	75.0	50.1	98%					
6	6	29	76.9	52.4	97%					
7	6	65	76.7	55.5	86%					
8	6	93	70.6	54.9	100%					
9	11	0	72.7	49.2	100%					
10	11	27	71.9	47.9	100%	71.7	47.8	24	101%	92%
11	11	60	59.0	54.0	100%	59.5	54.1	-216	91%	99%
12	11	94	49.1	60.4	100%					
13	6	0	48.5	52.2	100%	48.5	52.2	-450	82%	100%
14	6	30	66.5	64.9	100%	66.5	64.4	-76	97%	100%
15	6	64	66.0	78.0	100%	66.2	78.5	-82	97%	100%

Table 190. Importance of Filter Pressure Drop: Site 12 (SI)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop[1]	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	ΔSystem Air Flow, relative to 200 (m^3/hr)/kW [m^3/hr]	[%]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop[1]
1	12	0	66.8	n/a	n/a					n/a
2	12	35	57.1	70.3						
3	12	59	53.8	69.8						
4	12	87	58.0	71.7						
5	11	0	56.4	69.9						
6	11	36	59.0	72.3						
7	11	72	57.9	73.4						
8	11	98	58.0	73.4						
9	11	0	46.8	69.7						
10	11	35	62.2	69.8						
11	11	61	68.9	79.1		68.2	79.6	-957	73%	
12	11	93	58.8	70.3						
13	11	0	62.2	66.3		69.9	73.2	-924	74%	
14	11	27	59.8	68.1		67.9	77.4	-962	73%	
15	11	71	58.7	68.1		65.5	77.5	-1008	71%	

[1] Filter pressure drop is not directly measured at Site 12 due to access limitations

Table 191. Importance of Filter Pressure Drop: Site 13 (SI)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	ΔSystem Air Flow, relative to 200 (m^3/hr)/kW [m^3/hr]	[%]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop
1	6	0	28.3	74.9	100%	32.8	84.6	-880	64%	100%
2	6	30	29.6	83.8	100%					
3	6	63	29.1	93.3	100%					
4	6	98	26.1	111.5	100%					
5	11	0	30.0	64.6	100%					
6	11	25	28.8	74.3	100%					
7	11	56	31.1	80.7	100%					
8	11	86	26.8	92.3	100%	30.5	100.8	-936	62%	100%
9	2	0	32.2	42.5	100%	39.0	50.0	-739	70%	100%
10	2	32	23.7	77.6	100%	29.7	95.7	-957	61%	100%
11	2	62	19.2	126.5	100%	21.5	143.4	-1179	52%	100%
12	2	94	17.5	162.0	100%	19.4	173.5	-1244	49%	100%
13	11	0	27.1	79.7	100%	31.4	92.5	-907	63%	100%
14	11	30	26.5	102.1	100%	29.9	111.0	-951	61%	100%
15	11	57	24.0	114.7	100%	27.0	126.1	-1026	58%	100%
16	11	87	24.2	118.0	100%					

Table 192. Importance of Filter Pressure Drop: Site 14 (SI)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	ΔSystem Air Flow, relative to 200 (m^3/hr)/kW [m^3/hr]	[%]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop
1	7	0	24.9	97.9	81%					
2	7	26	25.0	99.4	82%					
3	7	55	29.7	96.7	81%					
4	7	91	26.9	97.6	81%					
5	2	0	29.3	76.2	75%					
6	2	28	26.8	77.6	76%					
7	2	55	25.8	79.7	75%					
8	2	87	28.9	88.1	70%	28.1	87.9	-408	81%	68%
9	11	0	21.6	122.7	88%	21.7	118.5	-612	71%	87%
10	11	30	20.7	126.1	88%	20.7	124.3	-647	69%	88%
11	7	0	22.5	75.6	73%	22.3	73.8	-591	72%	73%
12	7	28	21.6	82.1	75%	21.7	80.1	-612	71%	75%
13	7	58	21.6	87.4	77%					
14	2	0	25.9	59.1	70%	25.8	58.4	-477	77%	69%
15	2	28	24.3	68.8	66%	24.8	69.5	-510	76%	65%
16	2	62	25.8	67.4	66%					

Table 193. Importance of Filter Pressure Drop: Site 15 (SI)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	ΔSystem Air Flow, relative to 200 (m^3/hr)/kW [m^3/hr]	[%]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop
1	7	0	42.1	62.4	68%					
2	7	39	38.5	63.6	67%					
3	7	67	39.8	63.8	68%					
4	7	98	39.1	64.5	70%					
5	11	0	36.5	65.8	71%					
6	11	30	38.0	64.5	71%					
7	11	59	33.3	62.5	72%	31.2	62.8	34	102%	71%
8	11	92	35.1	57.5	76%					
9	2	0	39.6	43.9	52%	39.1	45.4	246	114%	53%
10	2	36	37.1	47.7	58%	37.1	46.9	195	111%	59%
11	2	62	35.9	58.4	62%	35.5	56.7	153	109%	62%
12	2	92	37.2	60.3	66%	37.0	59.5	192	111%	65%
13	7	0	37.6	66.8	75%	37.4	65.4	202	112%	74%
14	7	28	37.7	64.5	73%	37.9	64.3	216	112%	73%
15	7	60	37.8	66.4	74%					
16	7	90	37.5	65.9	75%					

Table 194. Importance of Filter Pressure Drop: Site 16 (SI)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	ΔSystem Air Flow, relative to 200 (m^3/hr)/kW [m^3/hr]	[%]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop
1	6	0	13.7	49.7	100%					
2	6	35	10.9	58.2	97%					
3	6	66	12.6	57.6	96%					
4	6	104	13.9	59.8	99%					
5	11	0	13.7	53.2	99%					
6	11	31	14.9	56.5	99%					
7	11	59	15.4	52.4	100%	41.0	120.7	688	166%	99%
8	11	87	14.4	54.4	100%					
9	2	0	14.5	25.3	100%	45.9	76.3	788	175%	100%
10	2	28	14.8	26.9	100%	45.4	78.9	778	174%	100%
11	2	56	14.2	27.6	100%	45.6	84.0	782	174%	100%
12	2	84	13.3	28.5	100%					
13	11	0	13.6	51.1	100%	41.4	123.2	697	166%	97%
14	11	33	13.2	52.4	97%	41.4	125.5	697	166%	95%
15	11	64	13.3	50.3	98%					
16	11	90	11.4	54.1	97%					

Table 195. Importance of Filter Pressure Drop: Site 17 (SI)

			Fan Only Mode			Cooling Mode				
Visit	Filter MERV	Filter Age [days]	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop	Supply Plenum Pressure [Pa]	Return Plenum Pressure [Pa]	ΔSystem Air Flow, relative to 200 (m^3/hr)/kW [m^3/hr]	[%]	Filter Pressure Drop Fraction of Return Plenum Pressure Drop
1	6	0	1.9	39.0	98%					
2	6	35	1.6	37.0	93%					
3	6	66	1.7	36.3	92%					
4	6	104	2.4	40.3	96%					
5	11	0	2.4	27.2	90%					
6	11	31	2.1	31.5	90%					
7	11	59	2.0	31.7	92%	2.4	80.2	323	131%	85%
8	11	87	2.6	35.7	94%					
9	2	0	2.0	n/a	n/a	6.4	n/a	1193	214%	n/a
10	2	28	1.9	4.8	27%	6.7	15.9	1244	218%	25%
11	2	56	2.3	3.8	16%	4.4	14.0	809	177%	14%
12	2	84	2.0	3.9	29%					
13	11	0	2.0	23.3	88%	5.1	60.6	951	191%	84%
14	11	33	2.0	27.7	82%	4.3	63.8	788	175%	79%
15	11	64	1.9	22.2	88%					
16	11	90	2.4	23.6	89%					

Appendix F: Full Tables for Test House Systems (IP Units)

Appendix F.1: Test House Filter Characteristics (IP)

Table 196. Filter Characteristics: Test House (IP)

TH System	Filter MERV	Filter Age [days]	Fan Only Mode		Cooling Mode	
			Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]	Filter Pressure Drop [in. H_2O]	Coil Pressure Drop [in. H_2O]
Upflow	Low	52	0.104 ± 0.005	0.212 ± 0.004	0.104 ± 0.001	0.224 ± 0.006
	Medium	11	0.186 ± 0.005	0.204 ± 0.006	0.190 ± 0.004	0.221 ± 0.006
	High	51	0.310 ± 0.003	0.185 ± 0.003	0.316 ± 0.003	0.190 ± 0.005
Downflow	Low	52	0.063 ± 0.006	0.288 ± 0.003	0.064 ± 0.010	0.297 ± 0.004
	Medium	11	0.179 ± 0.003	0.266 ± 0.005	0.182 ± 0.003	0.277 ± 0.006
	High	51	0.343 ± 0.004	0.229 ± 0.002	0.345 ± 0.004	0.234 ± 0.004

Appendix F.2: Test House Fan Characteristics (IP)

Table 197. Fan Characteristics: Test House (IP)

TH System	Filter MERV	Filter Age [days]	Fan Only Mode			Cooling Mode		
			System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]	System Air Flow [CFM]	Air Handler Power Draw [W]	Efficacy [CFM/W]
Upflow	Low	52	976 ± 68	282 ± 3	3.461 ± 0.245	980 ± 69	277 ± 3	3.537 ± 0.251
	Medium	11	937 ± 66	278 ± 3	3.365 ± 0.239	949 ± 66	281 ± 3	3.376 ± 0.239
	High	51	902 ± 63	287 ± 3	3.141 ± 0.223	913 ± 64	285 ± 3	3.208 ± 0.227
Downflow	Low	52	1012 ± 71	268 ± 3	3.773 ± 0.267	1013 ± 71	264 ± 3	3.840 ± 0.272
	Medium	11	915 ± 64	267 ± 3	3.427 ± 0.243	927 ± 65	265 ± 3	3.502 ± 0.248
	High	51	896 ± 63	278 ± 3	3.221 ± 0.228	903 ± 63	274 ± 3	3.295 ± 0.234

Appendix F.3: Test House A/C Operation Characteristics (IP)

Table 198. A/C Operation Characteristics: Test House (IP)

TH System	Filter MERV	Outdoor Temperature (SD) [°F]	Return Air Wet Bulb Temperature (SD) [°F]	Compressor Power Draw [W]	Sensible Capacity (SD) [BTU/hr]	Latent Capacity (SD) [BTU/hr]	Total Capacity (SD) [BTU/hr]	System Efficiency (SD) [(BTU/hr)/W]
Upflow	Low	89.6 (8.1)	66.4 (1.4)	1391 ± 16	15825 (3845)	4381 (1409)	18050 (4090)	12.28 (3.58)
	Medium	88.9 (8.3)	65.7 (1.3)	1378 ± 15	16207 (3177)	4381 (1675)	20570 (3580)	12.59 (3.34)
	High	84.7 (7.6)	64.0 (2)	1276 ± 14	16586 (5053)	3269 (1426)	19860 (5250)	12.86 (4.47)
Downflow	Low	91.0 (7.6)	68.0 (1.3)	1836 ± 21	13767 (3395)	4357 (1791)	18120 (3860)	8.73 (2.9)
	Medium	91.4 (7.4)	67.3 (1.3)	1846 ± 21	13344 (2470)	3951 (1931)	17300 (3140)	8.29 (2.56)
	High	86.2 (6.5)	65.7 (2.0)	1736 ± 19	14416 (4258)	3832 (1692)	18250 (4570)	9.18 (3.48)

Appendix F.4: Test House Duct Leakage Characteristics (IP)

Table 199. Duct Leakage Characteristics (IP)

		Fan Only Mode			Cooling Mode		
TH System	MERV	System Air Flow [CFM]	Supply Leakage to Exterior [CFM]	Supply Leakage Fraction [%]	System Air Flow [CFM]	Supply Leakage to Exterior [CFM]	Supply Leakage Fraction [%]
Upflow	3	976 ± 68	22 ± 1	2.3%	980 ± 69	22 ± 1	2.2%
	8	937 ± 66	21 ± 1	2.3%	949 ± 66	21 ± 1	2.2%
	11	902 ± 63	20 ± 1	2.2%	913 ± 64	20 ± 1	2.2%
Downflow	3	1012 ± 71	117 ± 3	11.5%	1013 ± 71	116 ± 3	11.4%
	8	915 ± 64	108 ± 3	11.8%	927 ± 65	108 ± 3	11.6%
	11	896 ± 63	105 ± 3	11.7%	903 ± 63	105 ± 3	11.6%

Appendix G: Full Tables for Test House Systems (SI Units)

Appendix G.1: Test House Filter Characteristics (SI)

Table 200. Filter Characteristics: Test House (SI)

TH System	Filter MERV	Filter Age [days]	Fan Only Mode		Cooling Mode	
			Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]	Filter Pressure Drop [Pa]	Coil Pressure Drop [Pa]
Upflow	Low	52	25.9 ± 1.2	52.8 ± 1.0	25.9 ± 0.3	55.9 ± 1.6
	Medium	11	46.4 ± 1.2	50.8 ± 1.6	47.2 ± 0.9	55.0 ± 1.6
	High	51	77.2 ± 0.8	46.1 ± 0.8	78.7 ± 0.8	47.2 ± 1.2
Downflow	Low	52	15.6 ± 1.4	71.8 ± 0.7	16.0 ± 2.4	73.9 ± 1.0
	Medium	11	44.5 ± 0.7	66.3 ± 1.3	45.4 ± 0.8	68.9 ± 1.6
	High	51	85.4 ± 0.9	56.9 ± 0.6	85.8 ± 0.9	58.2 ± 0.9

Appendix G.2: Test House Fan Characteristics (SI)

Table 201. Fan Characteristics: Test House (SI)

TH System	Filter MERV	Filter Age [days]	Fan Only Mode: System Air Flow [m^3/hr]	Fan Only Mode: Air Handler Power Draw [W]	Fan Only Mode: Efficacy [(m^3/hr)/W]	Cooling Mode: System Air Flow [m^3/hr]	Cooling Mode: Air Handler Power Draw [W]	Cooling Mode: Efficacy [(m^3/hr)/W]
Upflow	Low	52	1658 ± 116	282 ± 3	5.88 ± 0.42	1665 ± 117	277 ± 3	6.01 ± 0.43
	Medium	11	1592 ± 111	278 ± 3	5.72 ± 0.41	1612 ± 113	281 ± 3	5.74 ± 0.41
	High	51	1532 ± 107	287 ± 3	5.34 ± 0.38	1551 ± 109	285 ± 3	5.45 ± 0.39
Downflow	Low	52	1719 ± 120	268 ± 3	6.41 ± 0.45	1721 ± 120	264 ± 3	6.52 ± 0.46
	Medium	11	1555 ± 109	267 ± 3	5.82 ± 0.41	1575 ± 110	265 ± 3	5.95 ± 0.42
	High	51	1522 ± 107	278 ± 3	5.47 ± 0.39	1534 ± 107	274 ± 3	5.60 ± 0.40

Appendix G.3: Test House A/C Operation Characteristics (SI)

Table 202. A/C Operation Characteristics: Test House (SI)

TH System	Filter MERV	Outdoor Temperature (SD) [°C]	Return Air Wet Bulb Temperature (SD) [°C]	Compressor Power Draw [W]	Sensible Capacity (SD) [W]	Latent Capacity (SD) [W]	Total Capacity (SD) [W]	System Efficiency (SD) [-]
Upflow	Low	32.0 (4.5)	19.1 (0.8)	1391 ± 16	4638 (1127)	1284 (413)	5920 (1200)	3.60 (1.05)
	Medium	31.6 (4.6)	18.7 (0.7)	1378 ± 15	4750 (931)	1284 (491)	6030 (1050)	3.69 (0.98)
	High	29.3 (4.2)	17.8 (1.1)	1276 ± 14	4861 (1481)	958 (418)	5820 (1540)	3.77 (1.31)
Downflow	Low	32.8 (4.2)	20.0 (0.7)	1836 ± 21	4035 (995)	1277 (525)	5310 (1130)	2.56 (0.85)
	Medium	33.0 (4.1)	19.6 (0.7)	1846 ± 21	3911 (724)	1158 (566)	5070 (920)	2.43 (0.75)
	High	30.1 (3.6)	18.7 (1.1)	1736 ± 19	4225 (1248)	1123 (496)	5350 (1340)	2.69 (1.02)

Appendix G.4: Test House Duct Leakage Characteristics (SI)

Table 203. Duct Leakage Characteristics (SI)

		Fan Only Mode			Cooling Mode		
TH System	MERV	System Air Flow [m^3/hr]	Supply Leakage to Exterior [m^3/hr]	Supply Leakage Fraction [%]	System Air Flow [m^3/hr]	Supply Leakage to Exterior [m^3/hr]	Supply Leakage Fraction [%]
Upflow	3	1658 ± 116	37 ± 2	2.3%	1665 ± 117	37 ± 2	2.2%
	8	1592 ± 111	36 ± 2	2.3%	1612 ± 113	36 ± 2	2.2%
	11	1532 ± 107	34 ± 2	2.2%	1551 ± 109	34 ± 2	2.2%
Downflow	3	1719 ± 120	199 ± 6	11.5%	1721 ± 120	197 ± 6	11.4%
	8	1555 ± 109	183 ± 6	11.8%	1575 ± 110	183 ± 6	11.6%
	11	1522 ± 107	178 ± 5	11.7%	1534 ± 107	178 ± 5	11.6%

Appendix H: Binned Analysis for Test House Systems

Table 204. TH Upflow System: Fan Power Draw (W)

Low-MERV: Fan Power Draw [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	268 (51)	275 (95)	274 (239)	277 (111)	275 (415)	276 (659)	278 (823)	278 (1263)
18-19	275 (603)	277 (1204)	276 (1071)	276 (1242)	277 (1207)	278 (2289)	278 (2925)	278 (1305)
19-20	274 (564)	277 (1036)	276 (829)	277 (536)	279 (716)	279 (1255)	278 (1213)	279 (396)
20-21	0 (0)	295 (11)	285 (12)	300 (3)	0 (0)	270 (2)	270 (18)	0 (0)

Mid-MERV: Fan Power Draw [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	292 (29)	286 (58)	284 (363)	282 (185)	282 (147)	283 (96)	282 (894)	284 (482)
18-19	283 (327)	280 (460)	283 (445)	278 (401)	283 (251)	271 (636)	282 (1013)	280 (208)
19-20	180 (1)	286 (39)	282 (39)	283 (54)	281 (25)	270 (10)	278 (22)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	180 (1)	0 (0)	0 (0)	0 (0)	0 (0)

High-MERV: Fan Power Draw [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	287 (237)	286 (353)	284 (443)	283 (574)	284 (709)	283 (421)	288 (133)	0 (0)
18-19	282 (205)	286 (377)	287 (449)	286 (250)	283 (457)	285 (910)	286 (298)	270 (4)
19-20	0 (0)	291 (21)	284 (40)	287 (67)	288 (77)	280 (61)	0 (0)	0 (0)
20-21	0 (0)	295 (0)	285 (0)	300 (0)	0 (0)	270 (0)	270 (0)	0 (0)

Table 205. TH Downflow System: Fan Power Draw (W)

Low-MERV: Fan Power Draw [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	264 (30)	266 (73)	0 (0)
18-19	262 (94)	267 (58)	270 (24)	261 (69)	262 (227)	262 (683)	262 (1081)	263 (658)
19-20	263 (567)	264 (890)	263 (1148)	264 (1168)	265 (1533)	263 (1950)	263 (2039)	265 (1575)
20-21	263 (362)	264 (468)	263 (579)	262 (632)	264 (794)	263 (1438)	264 (2211)	263 (440)

Mid-MERV: Fan Power Draw [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	270 (24)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
18-19	188 (45)	191 (17)	237 (19)	273 (35)	271 (143)	259 (265)	269 (361)	270 (528)
19-20	273 (110)	274 (256)	268 (434)	268 (397)	266 (434)	260 (526)	268 (438)	269 (237)
20-21	270 (4)	180 (1)	0 (0)	262 (22)	270 (96)	270 (283)	272 (191)	269 (135)

High-MERV: Fan Power Draw [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	272 (133)	273 (216)	272 (385)	273 (675)	273 (609)	274 (140)	275 (19)	0 (0)
18-19	275 (68)	275 (241)	272 (431)	274 (506)	274 (670)	274 (392)	280 (27)	0 (0)
19-20	275 (87)	275 (218)	274 (265)	275 (432)	271 (512)	273 (565)	274 (492)	0 (0)
20-21	0 (0)	272 (59)	0 (0)	0 (0)	270 (14)	275 (161)	274 (126)	0 (0)

Table 206. TH Upflow System: Compressor Power Draw (W)

Low-MERV: Compressor Power Draw [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	1108 (51)	1186 (95)	1235 (239)	1291 (111)	1355 (415)	1427 (659)	1520 (823)	1572 (1263)
18-19	1133 (603)	1196 (1204)	1269 (1071)	1332 (1242)	1383 (1207)	1447 (2289)	1516 (2925)	1568 (1305)
19-20	1135 (564)	1209 (1036)	1277 (829)	1332 (536)	1368 (716)	1449 (1255)	1511 (1213)	1597 (396)
20-21	0 (0)	1113 (11)	1260 (12)	1440 (3)	0 (0)	1530 (2)	1470 (18)	0 (0)

Mid-MERV: Compressor Power Draw [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	1099 (29)	1226 (58)	1269 (363)	1305 (185)	1391 (147)	1429 (96)	1511 (894)	1571 (482)
18-19	1134 (327)	1192 (460)	1265 (445)	1331 (401)	1407 (251)	1471 (636)	1520 (1013)	1553 (208)
19-20	1080 (1)	1200 (39)	1302 (39)	1313 (54)	1397 (25)	1386 (10)	1481 (22)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	1260 (1)	0 (0)	0 (0)	0 (0)	0 (0)

High-MERV: Compressor Power Draw [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	1120 (237)	1181 (353)	1223 (443)	1271 (574)	1328 (709)	1402 (421)	1456 (133)	0 (0)
18-19	1111 (205)	1183 (377)	1256 (449)	1305 (250)	1366 (457)	1443 (910)	1468 (298)	1530 (4)
19-20	0 (0)	1234 (21)	1292 (40)	1362 (67)	1403 (77)	1419 (61)	0 (0)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table 207. TH Downflow System: Compressor Power Draw (W)

Low-MERV: Compressor Power Draw [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1926 (30)	1997 (73)	0 (0)
18-19	1543 (94)	1608 (58)	1538 (24)	1675 (69)	1796 (227)	1899 (683)	1971 (1081)	2014 (658)
19-20	1556 (567)	1623 (890)	1681 (1148)	1752 (1168)	1833 (1533)	1888 (1950)	1950 (2039)	2015 (1575)
20-21	1586 (362)	1634 (468)	1701 (579)	1770 (632)	1830 (794)	1887 (1438)	1937 (2211)	1958 (440)

Mid-MERV: Compressor Power Draw [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	1665 (24)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
18-19	1656 (45)	1768 (17)	1762 (19)	1764 (35)	1833 (143)	1921 (265)	1981 (361)	2010 (528)
19-20	1573 (110)	1642 (256)	1709 (434)	1757 (397)	1832 (434)	1898 (526)	1940 (438)	1970 (237)
20-21	1575 (4)	1620 (1)	0 (0)	1800 (22)	1796 (96)	1845 (283)	1890 (191)	1927 (135)

High-MERV: Compressor Power Draw [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	1566 (133)	1613 (216)	1656 (385)	1732 (675)	1780 (609)	1867 (140)	1933 (19)	0 (0)
18-19	1586 (68)	1621 (241)	1678 (431)	1751 (506)	1778 (670)	1829 (392)	1787 (27)	0 (0)
19-20	1546 (87)	1613 (218)	1695 (265)	1748 (432)	1826 (512)	1884 (565)	1913 (492)	0 (0)
20-21	0 (0)	1663 (59)	0 (0)	0 (0)	1903 (14)	1896 (161)	1929 (126)	0 (0)

Table 208. TH Upflow System: Total Power Draw (W)

Low-MERV: Total Power Draw [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	1376 (51)	1461 (95)	1509 (239)	1568 (111)	1629 (415)	1703 (659)	1799 (823)	1849 (1263)
18-19	1408 (603)	1473 (1204)	1545 (1071)	1608 (1242)	1660 (1207)	1724 (2289)	1795 (2925)	1846 (1305)
19-20	1409 (564)	1486 (1036)	1553 (829)	1609 (536)	1646 (716)	1728 (1255)	1789 (1213)	1876 (396)
20-21	0 (0)	1407 (11)	1545 (12)	1740 (3)	0 (0)	1800 (2)	1740 (18)	0 (0)

Mid-MERV: Total Power Draw [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	1390 (29)	1511 (58)	1554 (363)	1587 (185)	1673 (147)	1712 (96)	1793 (894)	1855 (482)
18-19	1417 (327)	1472 (460)	1548 (445)	1609 (401)	1690 (251)	1741 (636)	1802 (1013)	1833 (208)
19-20	1260 (1)	1486 (39)	1583 (39)	1597 (54)	1678 (25)	1656 (10)	1759 (22)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	1440 (1)	0 (0)	0 (0)	0 (0)	0 (0)

High-MERV: Total Power Draw [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	1407 (237)	1467 (353)	1507 (443)	1554 (574)	1613 (709)	1685 (421)	1745 (133)	0 (0)
18-19	1393 (205)	1469 (377)	1543 (449)	1590 (250)	1649 (457)	1728 (910)	1754 (298)	1800 (4)
19-20	0 (0)	1526 (21)	1575 (40)	1650 (67)	1690 (77)	1700 (61)	0 (0)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table 209. TH Downflow System: Total Power Draw (W)

Low-MERV: Total Power Draw [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2190 (30)	2264 (73)	0 (0)
18-19	1806 (94)	1874 (58)	1808 (24)	1936 (69)	2058 (227)	2162 (683)	2234 (1081)	2277 (658)
19-20	1819 (567)	1887 (890)	1944 (1148)	2015 (1168)	2098 (1533)	2151 (1950)	2213 (2039)	2280 (1575)
20-21	1849 (362)	1898 (468)	1964 (579)	2032 (632)	2095 (794)	2150 (1438)	2201 (2211)	2221 (440)

Mid-MERV: Total Power Draw [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	1935 (24)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
18-19	1844 (45)	1959 (17)	1999 (19)	2037 (35)	2103 (143)	2180 (265)	2250 (361)	2280 (528)
19-20	1846 (110)	1915 (256)	1977 (434)	2025 (397)	2098 (434)	2158 (526)	2208 (438)	2239 (237)
20-21	1845 (4)	1800 (1)	0 (0)	2062 (22)	2066 (96)	2115 (283)	2163 (191)	2196 (135)

High-MERV: Total Power Draw [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	1838 (133)	1885 (216)	1928 (385)	2005 (675)	2052 (609)	2141 (140)	2207 (19)	0 (0)
18-19	1861 (68)	1896 (241)	1950 (431)	2025 (506)	2052 (670)	2103 (392)	2067 (27)	0 (0)
19-20	1821 (87)	1888 (218)	1969 (265)	2023 (432)	2097 (512)	2157 (565)	2187 (492)	0 (0)
20-21	0 (0)	1934 (59)	0 (0)	0 (0)	2173 (14)	2171 (161)	2203 (126)	0 (0)

Table 210. TH Upflow System: Sensible Capacity (W)

Low-MERV: Sensible Capacity [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	5674 (51)	5685 (95)	5590 (239)	5617 (111)	5528 (415)	5684 (659)	5660 (823)	5693 (1263)
18-19	5244 (603)	5288 (1204)	5247 (1071)	5249 (1242)	5289 (1207)	5304 (2289)	5296 (2925)	5268 (1305)
19-20	4887 (564)	4961 (1036)	4972 (829)	4905 (536)	4885 (716)	4900 (1255)	5022 (1213)	4955 (396)
20-21	0 (0)	4134 (11)	4355 (12)	4254 (3)	0 (0)	4654 (2)	4395 (18)	0 (0)

Mid-MERV: Sensible Capacity [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	5406 (29)	5468 (58)	5451 (363)	5468 (185)	5424 (147)	5415 (96)	5517 (894)	5470 (482)
18-19	5175 (327)	5142 (460)	5173 (445)	5190 (401)	5156 (251)	5122 (636)	5172 (1013)	5147 (208)
19-20	4996 (1)	4827 (39)	5073 (39)	4911 (54)	4991 (25)	4668 (10)	4537 (22)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	4102 (1)	0 (0)	0 (0)	0 (0)	0 (0)

High-MERV: Sensible Capacity [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	5663 (237)	5706 (353)	5763 (443)	5336 (574)	5735 (709)	5629 (421)	5367 (133)	0 (0)
18-19	5180 (205)	5048 (377)	5061 (449)	5048 (250)	5041 (457)	5130 (910)	5184 (298)	5011 (4)
19-20	0 (0)	4796 (21)	4692 (40)	4700 (67)	4585 (77)	4866 (61)	0 (0)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table 211. TH Downflow System: Sensible Capacity (W)

Low-MERV: Sensible Capacity [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	5314 (30)	4775 (73)	0 (0)
18-19	5176 (94)	5057 (58)	5151 (24)	5155 (69)	4667 (227)	4904 (683)	4670 (1081)	4575 (658)
19-20	4587 (567)	4516 (890)	4540 (1148)	4485 (1168)	4520 (1533)	4565 (1950)	4412 (2039)	4552 (1575)
20-21	4280 (362)	4223 (468)	4297 (579)	4262 (632)	4264 (794)	4189 (1438)	4215 (2211)	4226 (440)

Mid-MERV: Sensible Capacity [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	4384 (24)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
18-19	4906 (45)	4861 (17)	4296 (19)	4260 (35)	4336 (143)	4603 (265)	4550 (361)	4587 (528)
19-20	4186 (110)	4261 (256)	4242 (434)	4230 (397)	4153 (434)	4102 (526)	4001 (438)	4021 (237)
20-21	3773 (4)	3755 (1)	0 (0)	3947 (22)	3772 (96)	3804 (283)	3761 (191)	3848 (135)

High-MERV: Sensible Capacity [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	5158 (133)	5198 (216)	5154 (385)	5109 (675)	5157 (609)	4983 (140)	5307 (19)	0 (0)
18-19	4837 (68)	4808 (241)	4862 (431)	4786 (506)	4856 (670)	4650 (392)	4526 (27)	0 (0)
19-20	4244 (87)	4222 (218)	4345 (265)	4322 (432)	4312 (512)	4232 (565)	4225 (492)	0 (0)
20-21	0 (0)	4059 (59)	0 (0)	0 (0)	4066 (14)	4002 (161)	4012 (126)	0 (0)

Table 212. TH Upflow System: Latent Capacity (W)

Low-MERV: Latent Capacity [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	1236 (51)	1185 (95)	1196 (239)	1160 (111)	1139 (415)	1031 (659)	1029 (823)	965 (1263)
18-19	1480 (603)	1442 (1204)	1411 (1071)	1338 (1242)	1258 (1207)	1205 (2289)	1175 (2925)	1130 (1305)
19-20	1656 (564)	1610 (1036)	1577 (829)	1548 (536)	1486 (716)	1382 (1255)	1307 (1213)	1231 (396)
20-21	0 (0)	1703 (11)	1777 (12)	1558 (3)	0 (0)	1452 (2)	1526 (18)	0 (0)

Mid-MERV: Latent Capacity [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	1465 (29)	1346 (58)	1284 (363)	1204 (185)	1152 (147)	1159 (96)	1086 (894)	1011 (482)
18-19	1525 (327)	1490 (460)	1435 (445)	1387 (401)	1318 (251)	1268 (636)	1250 (1013)	1205 (208)
19-20	1773 (1)	1792 (39)	1715 (39)	1705 (54)	1536 (25)	1379 (10)	1316 (22)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	1741 (1)	0 (0)	0 (0)	0 (0)	0 (0)

High-MERV: Latent Capacity [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	1084 (237)	1056 (353)	1010 (443)	944 (574)	928 (709)	923 (421)	1080 (133)	0 (0)
18-19	1434 (205)	1418 (377)	1368 (449)	1315 (250)	1261 (457)	1220 (910)	1179 (298)	1170 (4)
19-20	0 (0)	1520 (21)	1504 (40)	1461 (67)	1438 (77)	1320 (61)	0 (0)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table 213. TH Downflow System: Latent Capacity (W)

Low-MERV: Latent Capacity [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	772 (30)	852 (73)	0 (0)
18-19	1301 (94)	1260 (58)	1186 (24)	1139 (69)	1059 (227)	976 (683)	882 (1081)	861 (658)
19-20	1437 (567)	1354 (890)	1308 (1148)	1250 (1168)	1197 (1533)	1141 (1950)	1037 (2039)	965 (1575)
20-21	1588 (362)	1580 (468)	1469 (579)	1391 (632)	1335 (794)	1306 (1438)	1245 (2211)	1235 (440)

Mid-MERV: Latent Capacity [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	1009 (24)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
18-19	1628 (45)	1573 (17)	1309 (19)	1118 (35)	1010 (143)	1124 (265)	886 (361)	841 (528)
19-20	1377 (110)	1322 (256)	1267 (434)	1185 (397)	1143 (434)	1126 (526)	1056 (438)	989 (237)
20-21	1391 (4)	1354 (1)	0 (0)	1320 (22)	1312 (96)	1265 (283)	1224 (191)	1158 (135)

High-MERV: Latent Capacity [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	1006 (133)	952 (216)	919 (385)	880 (675)	821 (609)	797 (140)	642 (19)	0 (0)
18-19	1161 (68)	1132 (241)	1076 (431)	978 (506)	968 (670)	1003 (392)	1068 (27)	0 (0)
19-20	1412 (87)	1388 (218)	1268 (265)	1247 (432)	1187 (512)	1142 (565)	1107 (492)	0 (0)
20-21	0 (0)	1506 (59)	0 (0)	0 (0)	1209 (14)	1275 (161)	1213 (126)	0 (0)

Table 214. TH Upflow System: Total Capacity (W)

Low-MERV: Total Capacity [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	6910 (51)	6870 (95)	6787 (239)	6777 (111)	6667 (415)	6715 (659)	6689 (823)	6659 (1263)
18-19	6724 (603)	6730 (1204)	6659 (1071)	6587 (1242)	6547 (1207)	6509 (2289)	6471 (2925)	6398 (1305)
19-20	6543 (564)	6571 (1036)	6550 (829)	6453 (536)	6372 (716)	6282 (1255)	6329 (1213)	6186 (396)
20-21	0 (0)	5837 (11)	6132 (12)	5812 (3)	0 (0)	6106 (2)	5920 (18)	0 (0)

Mid-MERV: Total Capacity [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	6871 (29)	6814 (58)	6735 (363)	6673 (185)	6576 (147)	6574 (96)	6603 (894)	6480 (482)
18-19	6700 (327)	6632 (460)	6608 (445)	6578 (401)	6474 (251)	6390 (636)	6422 (1013)	6352 (208)
19-20	6770 (1)	6619 (39)	6788 (39)	6616 (54)	6527 (25)	6047 (10)	5852 (22)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	5843 (1)	0 (0)	0 (0)	0 (0)	0 (0)

High-MERV: Total Capacity [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	6748 (237)	6762 (353)	6772 (443)	6280 (574)	6662 (709)	6552 (421)	6447 (133)	0 (0)
18-19	6614 (205)	6466 (377)	6429 (449)	6363 (250)	6303 (457)	6351 (910)	6363 (298)	6180 (4)
19-20	0 (0)	6315 (21)	6196 (40)	6161 (67)	6023 (77)	6186 (61)	0 (0)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table 215. TH Downflow System: Total Capacity (W)

Low-MERV: Total Capacity [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	6087 (30)	5627 (73)	0 (0)
18-19	6477 (94)	6317 (58)	6337 (24)	6294 (69)	5725 (227)	5880 (683)	5553 (1081)	5437 (658)
19-20	6024 (567)	5870 (890)	5847 (1148)	5735 (1168)	5718 (1533)	5706 (1950)	5448 (2039)	5517 (1575)
20-21	5868 (362)	5803 (468)	5766 (579)	5654 (632)	5600 (794)	5495 (1438)	5460 (2211)	5461 (440)

Mid-MERV: Total Capacity [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	5393 (24)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
18-19	6534 (45)	6434 (17)	5605 (19)	5379 (35)	5346 (143)	5727 (265)	5436 (361)	5428 (528)
19-20	5563 (110)	5583 (256)	5508 (434)	5415 (397)	5296 (434)	5229 (526)	5057 (438)	5010 (237)
20-21	5164 (4)	5108 (1)	0 (0)	5266 (22)	5084 (96)	5070 (283)	4985 (191)	5006 (135)

High-MERV: Total Capacity [W] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	6164 (133)	6149 (216)	6073 (385)	5989 (675)	5978 (609)	5779 (140)	5949 (19)	0 (0)
18-19	5998 (68)	5940 (241)	5938 (431)	5764 (506)	5824 (670)	5653 (392)	5594 (27)	0 (0)
19-20	5656 (87)	5610 (218)	5613 (265)	5569 (432)	5499 (512)	5374 (565)	5332 (492)	0 (0)
20-21	0 (0)	5565 (59)	0 (0)	0 (0)	5275 (14)	5277 (161)	5225 (126)	0 (0)

Table 216. TH Upflow System: System Efficiency (-)

Low-MERV: System Efficiency [-] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	5.34 (51)	4.82 (95)	4.6 (239)	4.38 (111)	4.17 (415)	3.98 (659)	3.74 (823)	3.62 (1263)
18-19	4.92 (603)	4.72 (1204)	4.39 (1071)	4.17 (1242)	4.01 (1207)	3.82 (2289)	3.64 (2925)	3.51 (1305)
19-20	4.78 (564)	4.51 (1036)	4.28 (829)	4.07 (536)	3.94 (716)	3.69 (1255)	3.58 (1213)	3.32 (396)
20-21	0 (0)	4.58 (11)	4.01 (12)	3.35 (3)	0 (0)	3.39 (2)	3.71 (18)	0 (0)

Mid-MERV: System Efficiency [-] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	5.02 (29)	4.54 (58)	4.36 (363)	4.24 (185)	3.95 (147)	3.86 (96)	3.71 (894)	3.51 (482)
18-19	4.89 (327)	4.61 (460)	4.34 (445)	4.12 (401)	3.87 (251)	3.69 (636)	3.58 (1013)	3.48 (208)
19-20	5.37 (1)	4.51 (39)	4.31 (39)	4.35 (54)	3.92 (25)	3.8 (10)	3.48 (22)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	4.06 (1)	0 (0)	0 (0)	0 (0)	0 (0)

High-MERV: System Efficiency [-] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	4.98 (237)	4.69 (353)	4.57 (443)	4.14 (574)	4.19 (709)	3.93 (421)	3.76 (133)	0 (0)
18-19	4.92 (205)	4.54 (377)	4.23 (449)	4.08 (250)	3.88 (457)	3.71 (910)	3.68 (298)	3.45 (4)
19-20	0 (0)	4.15 (21)	3.96 (40)	3.75 (67)	3.6 (77)	3.75 (61)	0 (0)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table 217. TH Downflow System: System Efficiency (-)

Low-MERV: System Efficiency [-] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2.79 (30)	2.49 (73)	0 (0)
18-19	3.66 (94)	3.44 (58)	3.64 (24)	3.31 (69)	2.9 (227)	2.74 (683)	2.49 (1081)	2.4 (658)
19-20	3.46 (567)	3.18 (890)	3.09 (1148)	2.9 (1168)	2.75 (1533)	2.68 (1950)	2.49 (2039)	2.43 (1575)
20-21	3.28 (362)	3.13 (468)	2.99 (579)	2.82 (632)	2.69 (794)	2.58 (1438)	2.49 (2211)	2.47 (440)

Mid-MERV: System Efficiency [-] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	2.8 (24)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
18-19	3.6 (45)	3.29 (17)	2.81 (19)	2.65 (35)	2.59 (143)	2.65 (265)	2.45 (361)	2.39 (528)
19-20	3.04 (110)	2.93 (256)	2.8 (434)	2.71 (397)	2.53 (434)	2.44 (526)	2.3 (438)	2.28 (237)
20-21	2.82 (4)	2.84 (1)	0 (0)	2.56 (22)	2.56 (96)	2.42 (283)	2.32 (191)	2.29 (135)

High-MERV: System Efficiency [-] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	3.41 (133)	3.37 (216)	3.27 (385)	3.02 (675)	2.97 (609)	2.71 (140)	2.71 (19)	0 (0)
18-19	3.24 (68)	3.19 (241)	3.09 (431)	2.89 (506)	2.92 (670)	2.74 (392)	2.81 (27)	0 (0)
19-20	3.19 (87)	3.03 (218)	2.91 (265)	2.83 (432)	2.68 (512)	2.53 (565)	2.48 (492)	0 (0)
20-21	0 (0)	2.89 (59)	0 (0)	0 (0)	2.43 (14)	2.44 (161)	2.39 (126)	0 (0)

Table 218. TH Upflow System: System Airflow Rate (CFM)

Low-MERV: System Airflow Rate [CFM] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	981 (51)	977 (95)	978 (239)	979 (111)	977 (415)	979 (659)	977 (823)	978 (1263)
18-19	977 (603)	978 (1204)	977 (1071)	978 (1242)	980 (1207)	977 (2289)	976 (2925)	977 (1305)
19-20	974 (564)	976 (1036)	976 (829)	976 (536)	976 (716)	975 (1255)	974 (1213)	979 (396)
20-21	0 (0)	981 (11)	983 (12)	986 (3)	0 (0)	986 (2)	976 (18)	0 (0)

Mid-MERV: System Airflow Rate [CFM] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	933 (29)	946 (58)	938 (363)	941 (185)	946 (147)	940 (96)	947 (894)	950 (482)
18-19	953 (327)	950 (460)	954 (445)	943 (401)	952 (251)	934 (636)	949 (1013)	953 (208)
19-20	974 (1)	951 (39)	972 (39)	954 (54)	972 (25)	938 (10)	947 (22)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	931 (1)	0 (0)	0 (0)	0 (0)	0 (0)

High-MERV: System Airflow Rate [CFM] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	913 (237)	913 (353)	913 (443)	913 (574)	914 (709)	912 (421)	909 (133)	0 (0)
18-19	909 (205)	910 (377)	910 (449)	908 (250)	910 (457)	910 (910)	910 (298)	912 (4)
19-20	0 (0)	915 (21)	908 (40)	909 (67)	907 (77)	911 (61)	0 (0)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table 219. TH Downflow System: System Airflow Rate (CFM)

Low-MERV: System Airflow Rate [CFM] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1032 (30)	1021 (73)	0 (0)
18-19	1028 (94)	1006 (58)	1019 (24)	1022 (69)	996 (227)	1013 (683)	987 (1081)	991 (658)
19-20	1016 (567)	1000 (890)	1006 (1148)	1004 (1168)	1016 (1533)	1020 (1950)	997 (2039)	1015 (1575)
20-21	1021 (362)	1026 (468)	1021 (579)	1012 (632)	1015 (794)	1018 (1438)	1021 (2211)	1027 (440)

Mid-MERV: System Airflow Rate [CFM] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	890 (24)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
18-19	803 (45)	795 (17)	873 (19)	934 (35)	919 (143)	917 (265)	951 (361)	958 (528)
19-20	943 (110)	947 (256)	938 (434)	936 (397)	918 (434)	901 (526)	927 (438)	929 (237)
20-21	883 (4)	878 (1)	0 (0)	934 (22)	931 (96)	932 (283)	927 (191)	932 (135)

High-MERV: System Airflow Rate [CFM] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	900 (133)	901 (216)	902 (385)	905 (675)	900 (609)	901 (140)	896 (19)	0 (0)
18-19	902 (68)	901 (241)	904 (431)	903 (506)	901 (670)	904 (392)	908 (27)	0 (0)
19-20	900 (87)	903 (218)	904 (265)	905 (432)	905 (512)	903 (565)	902 (492)	0 (0)
20-21	0 (0)	905 (59)	0 (0)	0 (0)	898 (14)	903 (161)	903 (126)	0 (0)

Table 220. TH Upflow System: Supply Leakage Airflow Rate (CFM)

Low-MERV: Supply Airflow Leakage Rate [CFM] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	22 (51)	22 (95)	22 (239)	22 (111)	22 (415)	22 (659)	22 (823)	22 (1263)
18-19	22 (603)	22 (1204)	22 (1071)	22 (1242)	22 (1207)	22 (2289)	22 (2925)	22 (1305)
19-20	22 (564)	22 (1036)	22 (829)	22 (536)	22 (716)	22 (1255)	22 (1213)	22 (396)
20-21	0 (0)	22 (11)	22 (12)	22 (3)	0 (0)	22 (2)	22 (18)	0 (0)

Mid-MERV: Supply Airflow Leakage Rate [CFM] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	21 (29)	21 (58)	21 (363)	21 (185)	21 (147)	21 (96)	21 (894)	21 (482)
18-19	21 (327)	21 (460)	21 (445)	21 (401)	21 (251)	21 (636)	21 (1013)	21 (208)
19-20	22 (1)	22 (39)	22 (39)	21 (54)	22 (25)	21 (10)	21 (22)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	21 (1)	0 (0)	0 (0)	0 (0)	0 (0)

High-MERV: Supply Airflow Leakage Rate [CFM] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	20 (164)	20 (212)	20 (158)	20 (304)	20 (552)	20 (380)	20 (133)	0 (0)
18-19	20 (113)	20 (358)	20 (449)	20 (143)	20 (341)	20 (891)	20 (298)	20 (4)
19-20	0 (0)	20 (21)	20 (40)	20 (67)	20 (77)	20 (61)	0 (0)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table 221. TH Downflow System: Supply Leakage Airflow Rate (CFM)

Low-MERV: Supply Airflow Leakage Rate [CFM] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	117 (30)	116 (73)	0 (0)
18-19	117 (94)	115 (58)	116 (24)	116 (69)	114 (227)	116 (683)	113 (1081)	113 (658)
19-20	116 (567)	114 (890)	115 (1148)	115 (1168)	116 (1533)	116 (1950)	114 (2039)	116 (1575)
20-21	116 (362)	117 (468)	116 (579)	116 (632)	116 (794)	116 (1438)	116 (2211)	117 (440)

Mid-MERV: Supply Airflow Leakage Rate [CFM] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	105 (24)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
18-19	97 (45)	96 (17)	103 (19)	108 (35)	107 (143)	107 (265)	110 (361)	110 (528)
19-20	109 (110)	109 (256)	109 (434)	108 (397)	107 (434)	105 (526)	107 (438)	107 (237)
20-21	105 (4)	104 (1)	0 (0)	108 (22)	109 (96)	109 (283)	108 (191)	108 (135)

High-MERV: Supply Airflow Leakage Rate [CFM] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	105 (45)	104 (125)	104 (250)	105 (415)	104 (531)	105 (140)	104 (19)	0 (0)
18-19	105 (19)	105 (140)	105 (155)	105 (223)	105 (510)	105 (259)	105 (27)	0 (0)
19-20	105 (15)	105 (112)	105 (207)	105 (406)	105 (512)	105 (565)	105 (492)	0 (0)
20-21	0 (0)	105 (58)	0 (0)	0 (0)	104 (14)	105 (161)	105 (126)	0 (0)

Table 222. TH Upflow System: Temperature Difference Across Coil (°C)

Low-MERV: Temperature Difference Across Coil [°C] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	10.1 (51)	10.2 (95)	10 (239)	10 (111)	9.9 (415)	10.1 (659)	10.1 (823)	10.2 (1263)
18-19	9.4 (603)	9.4 (1204)	9.4 (1071)	9.4 (1242)	9.4 (1207)	9.5 (2289)	9.5 (2925)	9.4 (1305)
19-20	8.8 (564)	8.9 (1036)	8.9 (829)	8.8 (536)	8.7 (716)	8.8 (1255)	9 (1213)	8.8 (396)
20-21	0 (0)	7.4 (11)	7.7 (12)	7.5 (3)	0 (0)	8.2 (2)	7.9 (18)	0 (0)

Mid-MERV: Temperature Difference Across Coil [°C] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	10.1 (29)	10.1 (58)	10.1 (363)	10.1 (185)	10 (147)	10.1 (96)	10.2 (894)	10 (482)
18-19	9.5 (327)	9.4 (460)	9.5 (445)	9.6 (401)	9.5 (251)	9.6 (636)	9.5 (1013)	9.4 (208)
19-20	9 (1)	8.9 (39)	9.1 (39)	9 (54)	9 (25)	8.7 (10)	8.4 (22)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	7.7 (1)	0 (0)	0 (0)	0 (0)	0 (0)

High-MERV: Temperature Difference Across Coil [°C] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	10.8 (237)	10.9 (353)	11 (443)	10.2 (574)	10.9 (709)	10.8 (421)	10.3 (133)	0 (0)
18-19	9.9 (205)	9.7 (377)	9.7 (449)	9.7 (250)	9.7 (457)	9.8 (910)	9.9 (298)	9.6 (4)
19-20	0 (0)	9.1 (21)	9 (40)	9 (67)	8.8 (77)	9.3 (61)	0 (0)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table 223. TH Downflow System: Temperature Difference Across Coil (°C)

Low-MERV: Temperature Difference Across Coil [°C] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	9 (30)	8.2 (73)	0 (0)
18-19	8.8 (94)	8.8 (58)	8.8 (24)	8.8 (69)	8.2 (227)	8.4 (683)	8.3 (1081)	8.1 (658)
19-20	7.9 (567)	7.9 (890)	7.9 (1148)	7.8 (1168)	7.8 (1533)	7.8 (1950)	7.7 (2039)	7.8 (1575)
20-21	7.3 (362)	7.2 (468)	7.3 (579)	7.3 (632)	7.3 (794)	7.2 (1438)	7.2 (2211)	7.2 (440)

Mid-MERV: Temperature Difference Across Coil [°C] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	8.6 (24)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
18-19	10.7 (45)	10.7 (17)	8.7 (19)	8 (35)	8.2 (143)	8.8 (265)	8.3 (361)	8.4 (528)
19-20	7.7 (110)	7.8 (256)	7.9 (434)	7.9 (397)	7.9 (434)	8 (526)	7.5 (438)	7.6 (237)
20-21	7.5 (4)	7.5 (1)	0 (0)	7.4 (22)	7.1 (96)	7.1 (283)	7.1 (191)	7.2 (135)

High-MERV: Temperature Difference Across Coil [°C] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	10 (133)	10.1 (216)	10 (385)	9.9 (675)	10 (609)	9.6 (140)	10.3 (19)	0 (0)
18-19	9.4 (68)	9.3 (241)	9.4 (431)	9.2 (506)	9.4 (670)	9 (392)	8.7 (27)	0 (0)
19-20	8.2 (87)	8.2 (218)	8.4 (265)	8.3 (432)	8.3 (512)	8.2 (565)	8.2 (492)	0 (0)
20-21	0 (0)	7.8 (59)	0 (0)	0 (0)	7.9 (14)	7.7 (161)	7.8 (126)	0 (0)

Table 224. TH Upflow System: Humidity Ratio Difference Across Coil (kg/kg)

Low-MERV: Humidity Ratio Difference Across Coil [kg/kg] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0.0017 (51)	0.0016 (95)	0.0016 (239)	0.0016 (111)	0.0015 (415)	0.0014 (659)	0.0014 (823)	0.0013 (1263)
18-19	0.002 (603)	0.002 (1204)	0.0019 (1071)	0.0018 (1242)	0.0017 (1207)	0.0016 (2289)	0.0016 (2925)	0.0015 (1305)
19-20	0.0023 (564)	0.0022 (1036)	0.0021 (829)	0.0021 (536)	0.002 (716)	0.0019 (1255)	0.0018 (1213)	0.0017 (396)
20-21	0 (0)	0.0023 (11)	0.0024 (12)	0.0021 (3)	0 (0)	0.002 (2)	0.0021 (18)	0 (0)

Mid-MERV: Humidity Ratio Difference Across Coil [kg/kg] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0.0021 (29)	0.0019 (58)	0.0018 (363)	0.0017 (185)	0.0016 (147)	0.0016 (96)	0.0015 (894)	0.0014 (482)
18-19	0.0021 (327)	0.0021 (460)	0.002 (445)	0.002 (401)	0.0018 (251)	0.0018 (636)	0.0018 (1013)	0.0017 (208)
19-20	0.0024 (1)	0.0025 (39)	0.0023 (39)	0.0024 (54)	0.0021 (25)	0.002 (10)	0.0018 (22)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	0.0025 (1)	0 (0)	0 (0)	0 (0)	0 (0)

High-MERV: Humidity Ratio Difference Across Coil [kg/kg] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0.0016 (237)	0.0015 (353)	0.0015 (443)	0.0014 (574)	0.0013 (709)	0.0013 (421)	0.0016 (133)	0 (0)
18-19	0.0021 (205)	0.0021 (377)	0.002 (449)	0.0019 (250)	0.0018 (457)	0.0018 (910)	0.0017 (298)	0.0017 (4)
19-20	0 (0)	0.0022 (21)	0.0022 (40)	0.0021 (67)	0.0021 (77)	0.0019 (61)	0 (0)	0 (0)
20-21	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table 225. TH Downflow System: Humidity Ratio Difference Across Coil (kg/kg)

Low-MERV: Humidity Ratio Difference Across Coil [kg/kg] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.001 (30)	0.0011 (73)	0 (0)
18-19	0.0017 (94)	0.0017 (58)	0.0015 (24)	0.0015 (69)	0.0014 (227)	0.0013 (683)	0.0012 (1081)	0.0012 (658)
19-20	0.0019 (567)	0.0018 (890)	0.0017 (1148)	0.0017 (1168)	0.0016 (1533)	0.0015 (1950)	0.0014 (2039)	0.0013 (1575)
20-21	0.0021 (362)	0.002 (468)	0.0019 (579)	0.0018 (632)	0.0017 (794)	0.0017 (1438)	0.0016 (2211)	0.0016 (440)

Mid-MERV: Humidity Ratio Difference Across Coil [kg/kg] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0 (0)	0 (0)	0.0015 (24)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
18-19	0.0027 (45)	0.0026 (17)	0.002 (19)	0.0016 (35)	0.0015 (143)	0.0017 (265)	0.0012 (361)	0.0012 (528)
19-20	0.0019 (110)	0.0019 (256)	0.0018 (434)	0.0017 (397)	0.0017 (434)	0.0017 (526)	0.0015 (438)	0.0014 (237)
20-21	0.0021 (4)	0.002 (1)	0 (0)	0.0019 (22)	0.0019 (96)	0.0018 (283)	0.0018 (191)	0.0017 (135)

High-MERV: Humidity Ratio Difference Across Coil [kg/kg] (Number of observations)								
	Outdoor Dry Bulb (°C)							
Entering Wet Bulb (°C)	23-25	25-27	27-29	29-31	31-33	33-35	35-37	37-39
17-18	0.0015 (133)	0.0014 (216)	0.0014 (385)	0.0013 (675)	0.0012 (609)	0.0012 (140)	0.001 (19)	0 (0)
18-19	0.0017 (68)	0.0017 (241)	0.0016 (431)	0.0014 (506)	0.0014 (670)	0.0015 (392)	0.0016 (27)	0 (0)
19-20	0.0021 (87)	0.002 (218)	0.0019 (265)	0.0018 (432)	0.0017 (512)	0.0017 (565)	0.0016 (492)	0 (0)
20-21	0 (0)	0.0022 (59)	0 (0)	0 (0)	0.0018 (14)	0.0019 (161)	0.0018 (126)	0 (0)