5.3.12 Number of Viable Particles Varying with Time (UV3)

UV3: UVGI output power 40W, located on the near bed wall, 7.5' from the floor.

Note that the number of vented out number varying with time remains the same as in 5.3.1, (10W output) since increase of the UVGI power output does not influence the airflow field.

Figures 5.100 to 5.108 show the number of viable particles varying with time. The number of viable particles of winter cases dropped under 500 after 2 minute when the flow rate is high. For summer cases with peak T, this number is lower than 1500 after 2 minutes regardless the flow rate. For summer case with peak Q, viable particles are less than 1000 after 2 minutes. At the end of the 5 minutes there is only around 100 viable particles left in the room as seen in Figure 5.102.

Figures 5.103 and 5.104 tell us that high exhaust location results in less viable particles when the flow rate is low. For summer cases and winter cases with high flow rate, the number of viable particles is not sensitive to the exhaust location.

Figure 5.105 indicates that baseboard heating results in lower number of viable particles when the exhausts are low. Figure 5.106 compares the high and low exhausts with baseboard heating used, which shows that exhaust location makes some different in the number of viable particle, and the low location seems to slightly over-perform the high one in UV particle killing.

Figure 5.107 shows that the effects of increased pressurization on the number of viable particles are different from case to case. For summer cases, the particle killing is not sensitive to the pressurization of the room as seen in Figure 5.108.

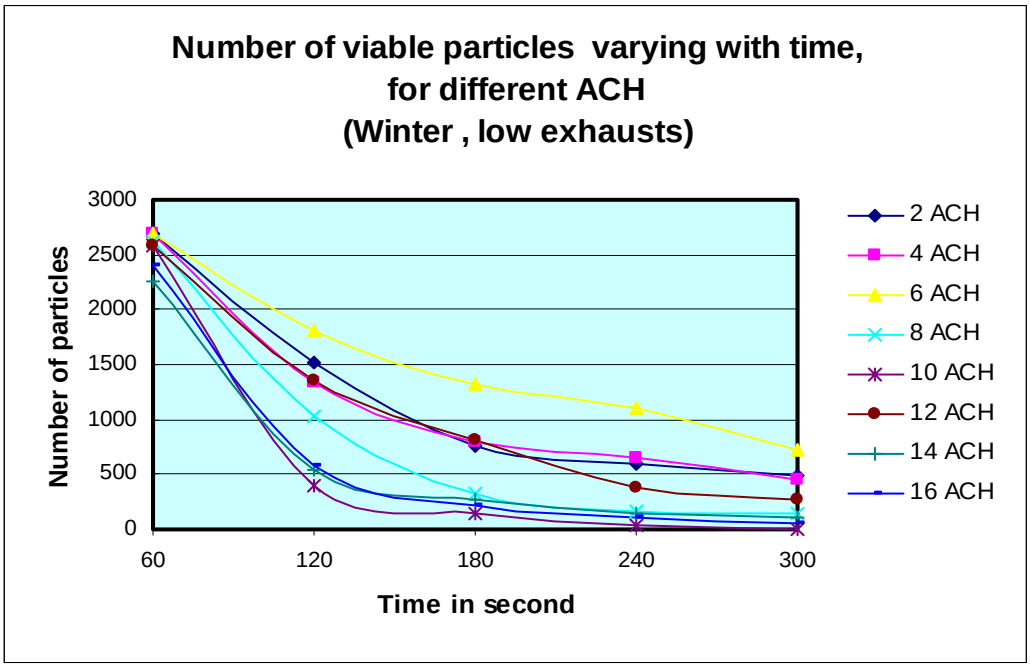

Figure 5.100. *Number of viable particles with ACH change (Winter)*

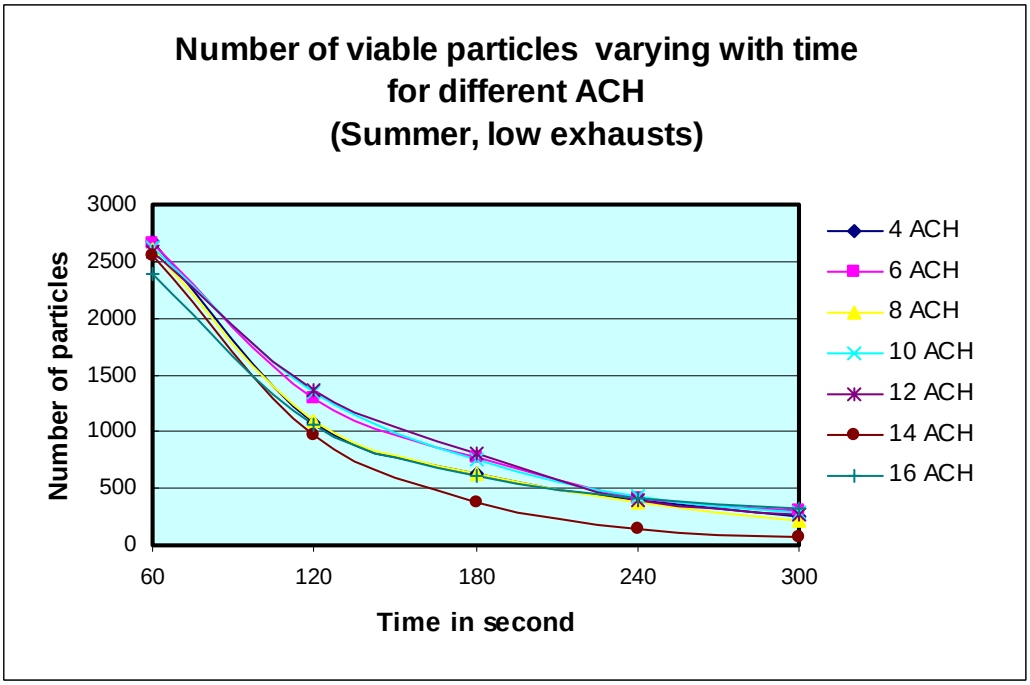

Figure 5.101. *Number of viable particles with ACH change (Summer).*

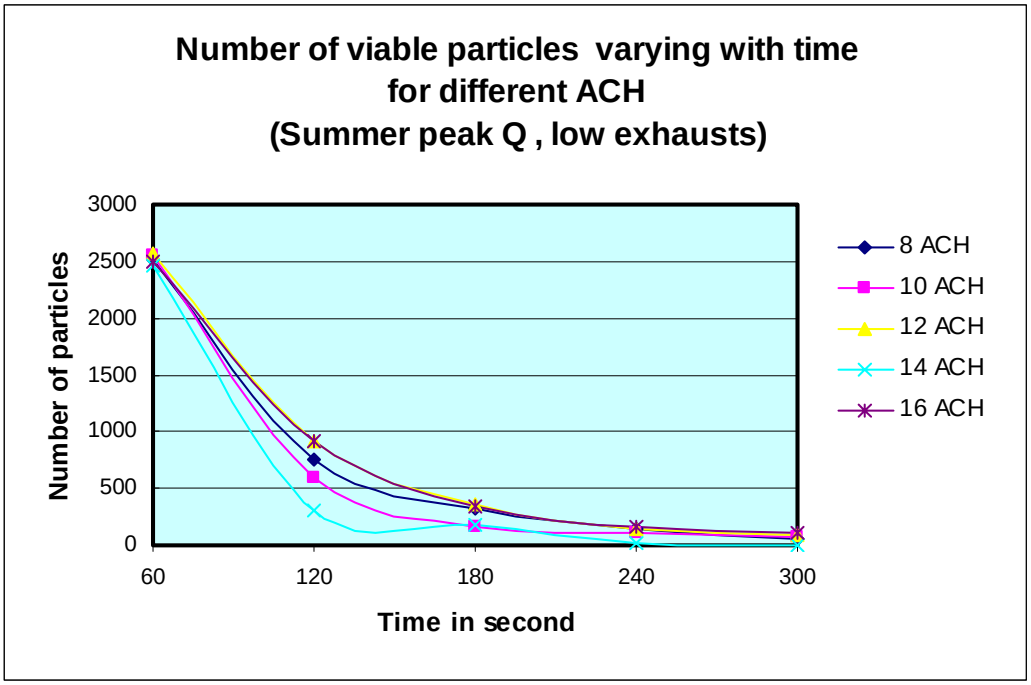

Figure 5.102. *Number of viable particles with ACH change (Summer peak Q).*

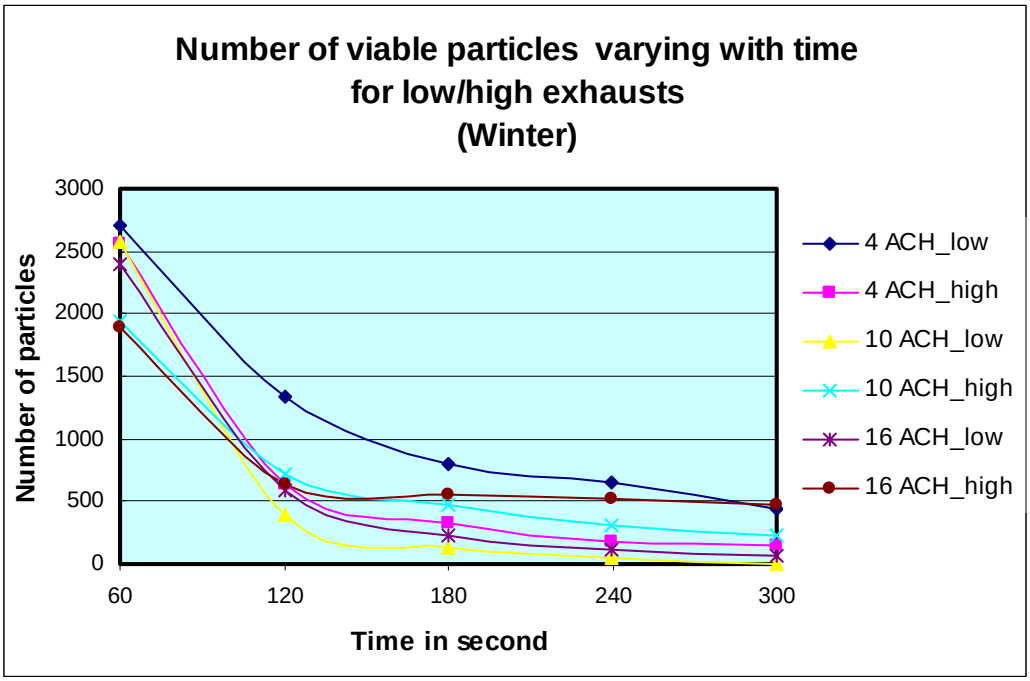

Figure 5.103. *Number of viable particles with exhaust location change (Winter).*

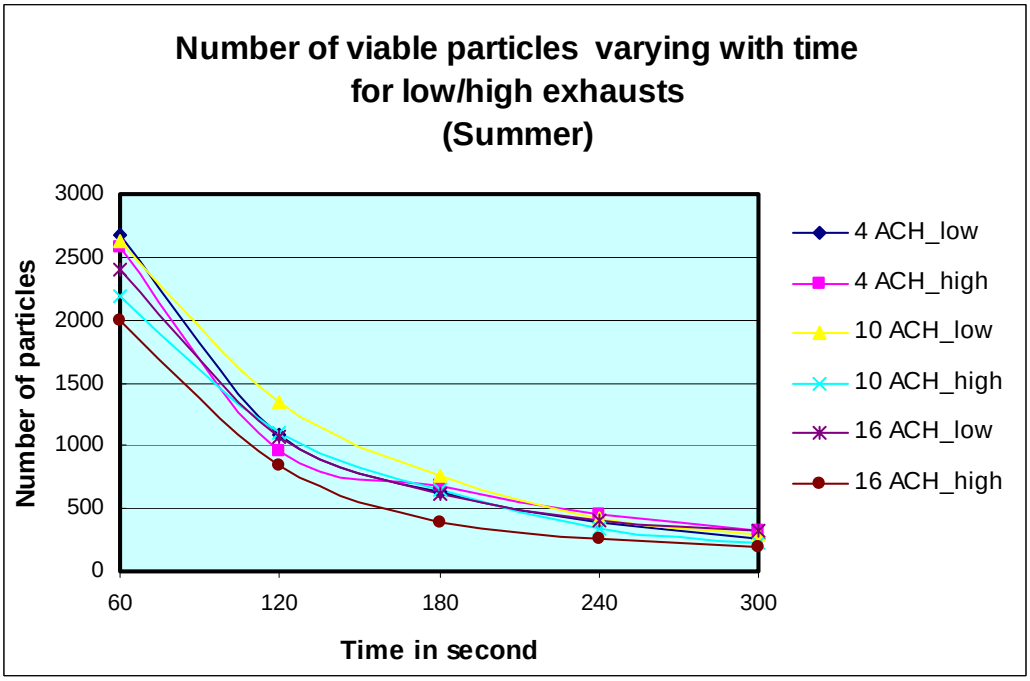

Figure 5.104. *Number of viable particles with exhaust location change (Summer).*

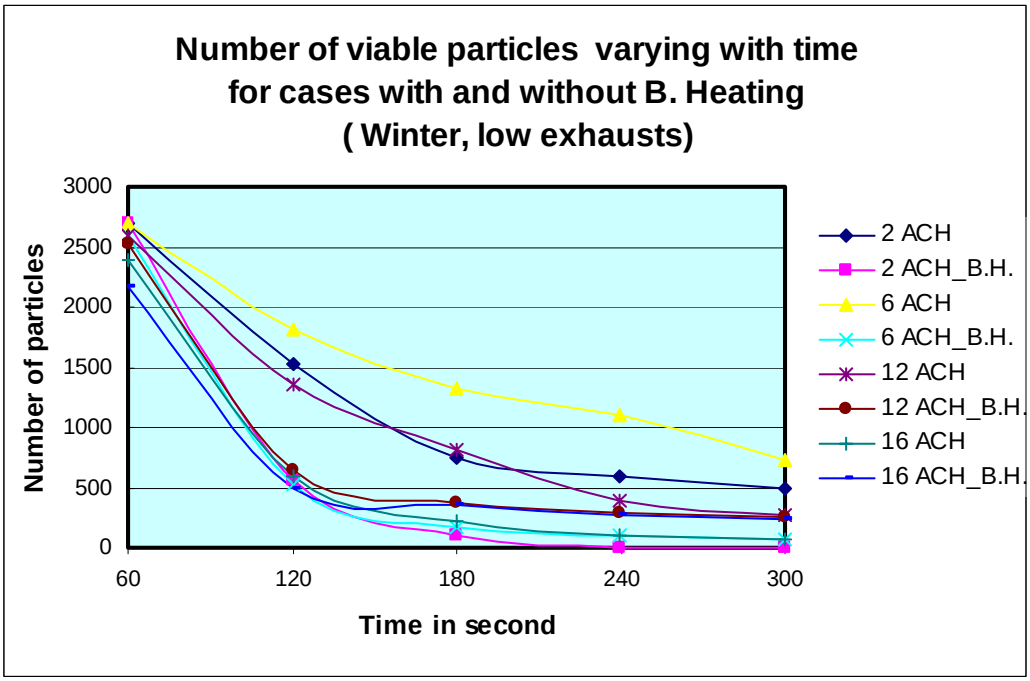

Figure 5.105. *Number of viable particles for cases with/ without Baseboard Heating.*

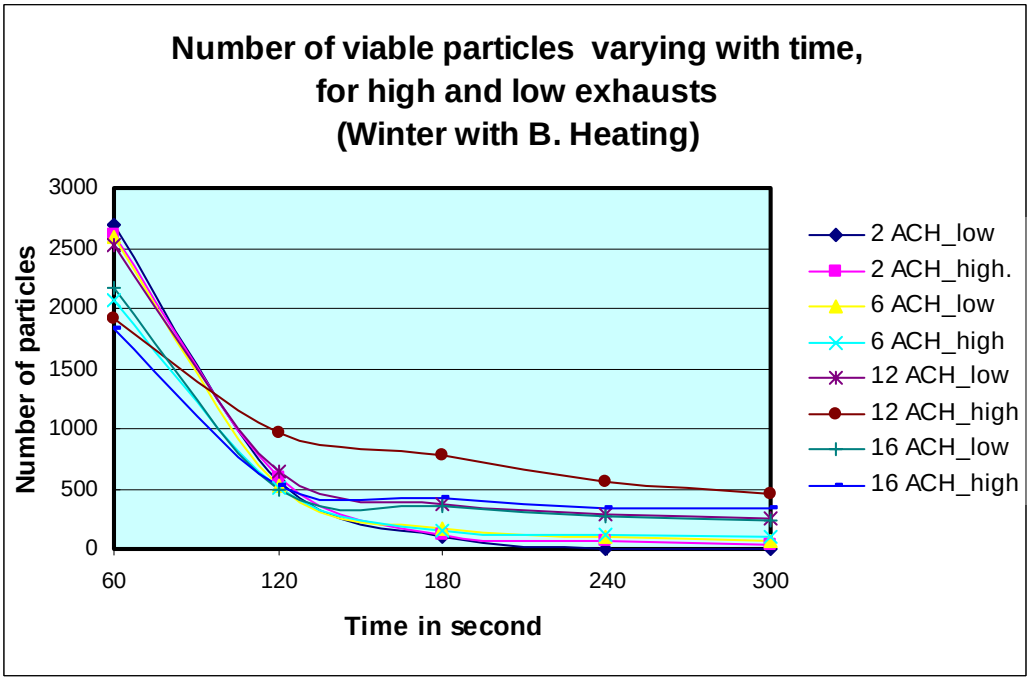

Figure 5.106. *Number of viable particles for exhaust location change when baseboard heating is applied*

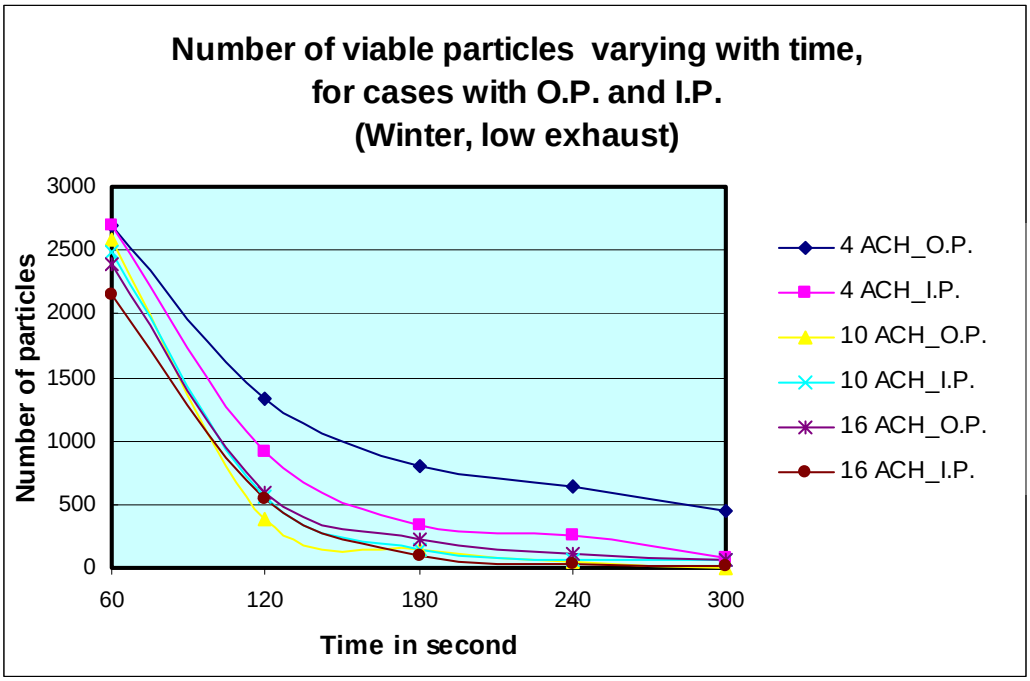

Figure 5.107. *Number of viable particles for cases with original/ increased pressurization (Winter)*

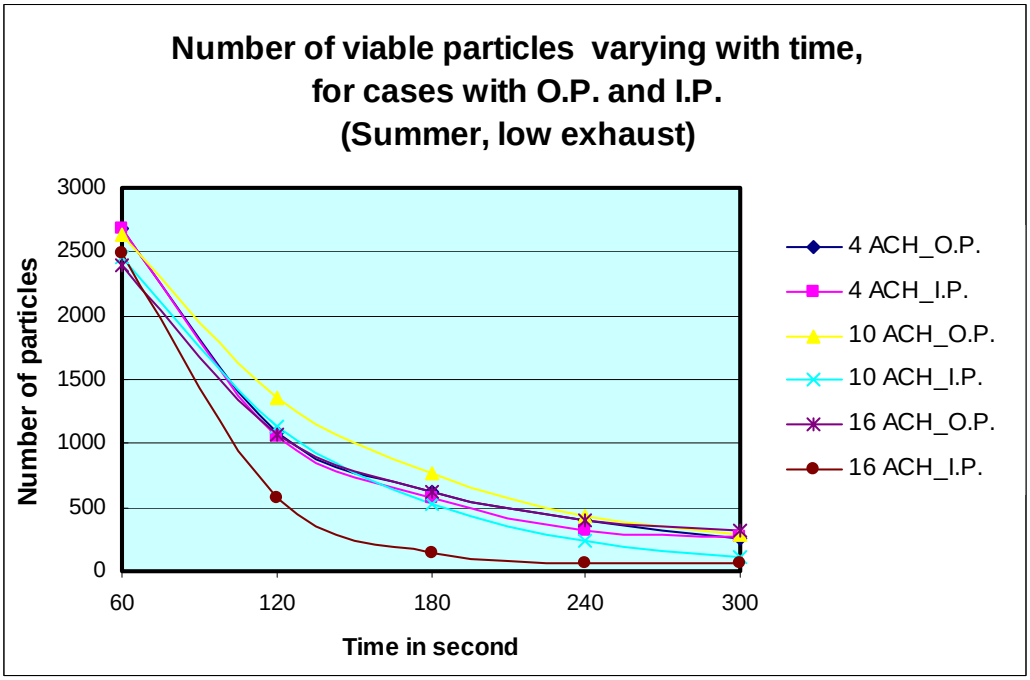

Figure 5.108. *Number of viable particles for cases with original/ increased pressurization (Summer)*

5.3.13 Number of Viable Particles – Individual Counting - Varying with Time (UV3)

UV3: UVGI output power 40W, located on the near bed wall, 7.5’ from the floor.

The conclusions drawn in 5.3.12 can be generally applied to this section. However, when UV output increases to 40W, the non-uniformity of the UV field becomes severe. Although the average dose of the particles is increased, some particles receive very high dose while some other particles have no dose at all. As a result, the number of killed particles in individual counting is not increased as significantly as in group counting method. Therefore, the viable number of particles calculated from individual counting method is remarkably higher than that from group counting method.

Figures 5.109 to 5.117 show the number of viable particles varying with time. Figures 5.109 to 5.111 show that in winter condition, increase of ventilation flow rate has much strong impact on the number of viable particles than in summer condition.

It is observed from Figures 5.112 and 5.113 that high exhaust location generally results in less viable particles when the flow rate is low. Figure 5.114 indicates that baseboard heating results in lower number of viable particles when the exhausts are low. Figure 5.115 compares the high and low exhausts with baseboard heating used, which shows that exhaust location makes little different in the number of viable particle.

Figures 5.116 and 5.117 show that the number of viable particles is not sensitive to the increased pressurization of the room.

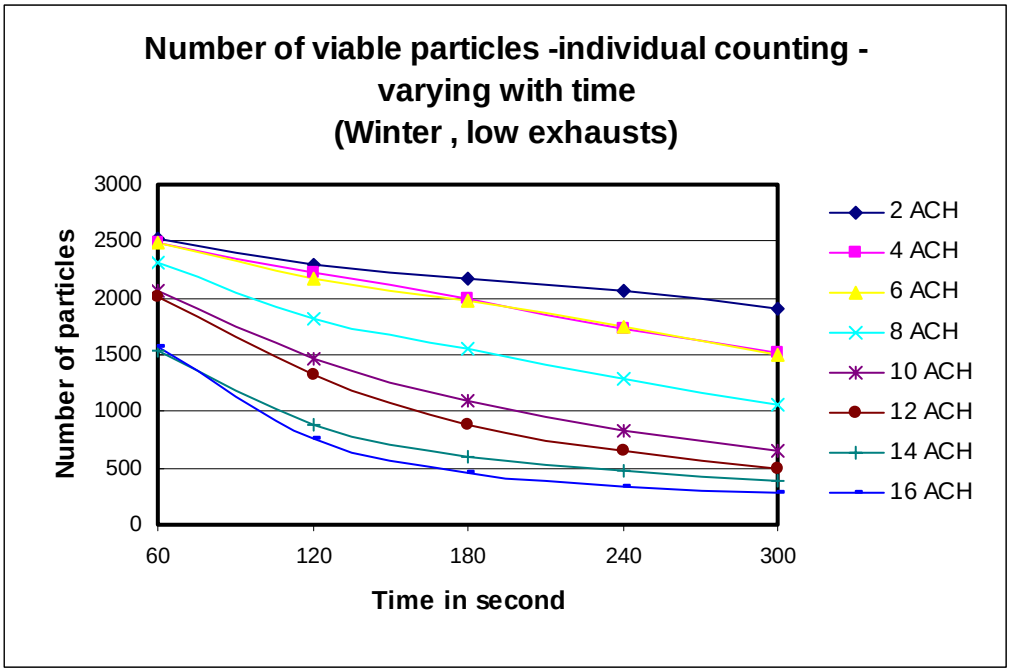

Figure 5.109. *Number of viable particles with ACH change (Winter)*

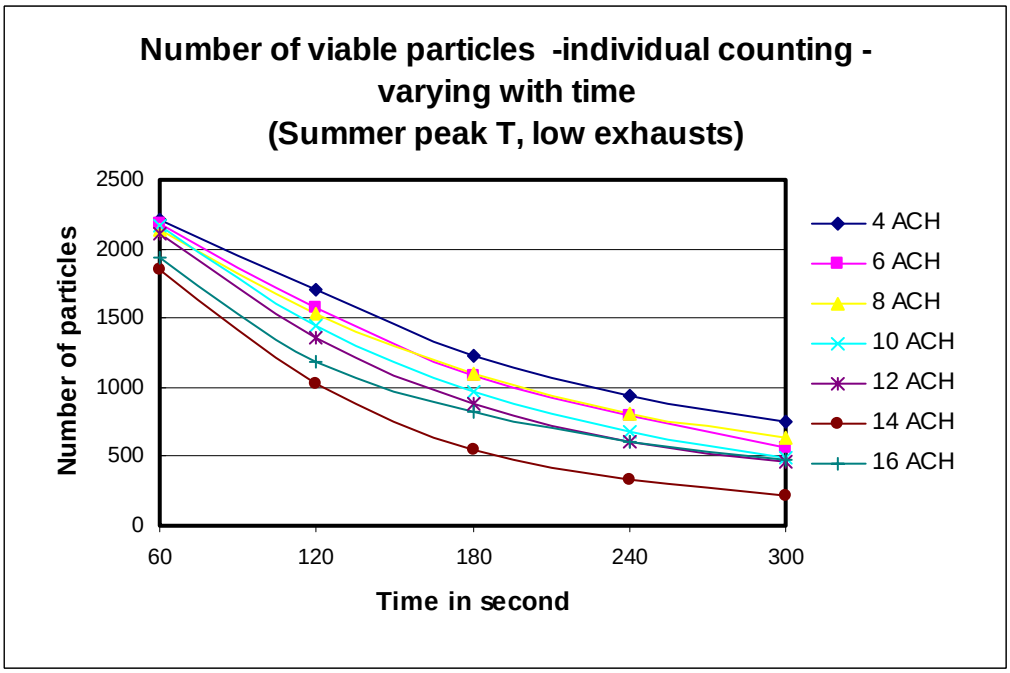

Figure 5.110. *Number of viable particles with ACH change (Summer).*

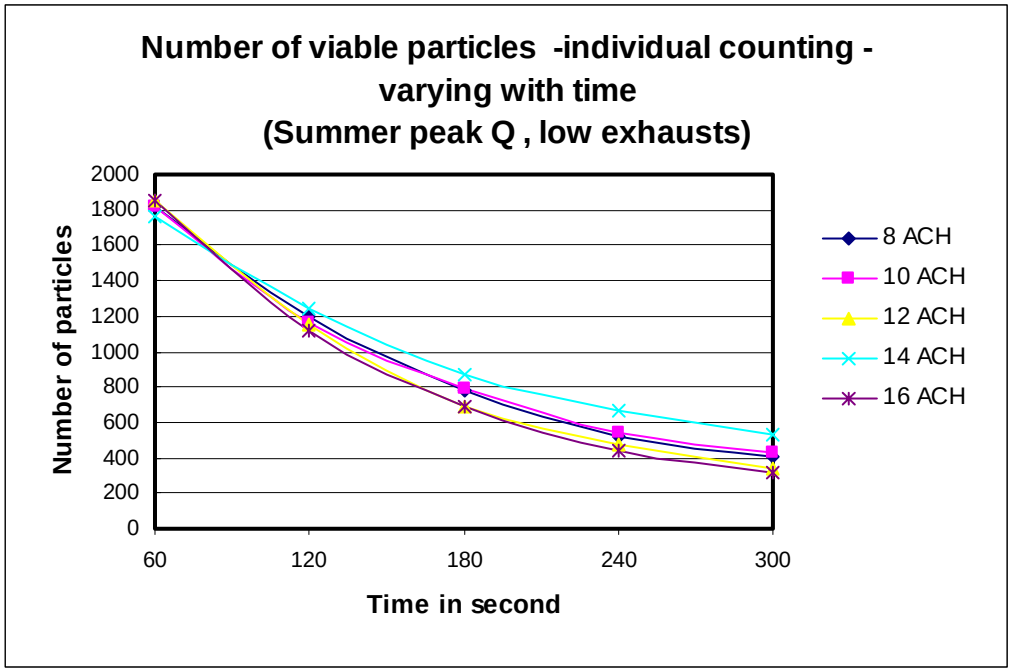

Figure 5.111. *Number of viable particles with ACH change (Summer peak Q).*

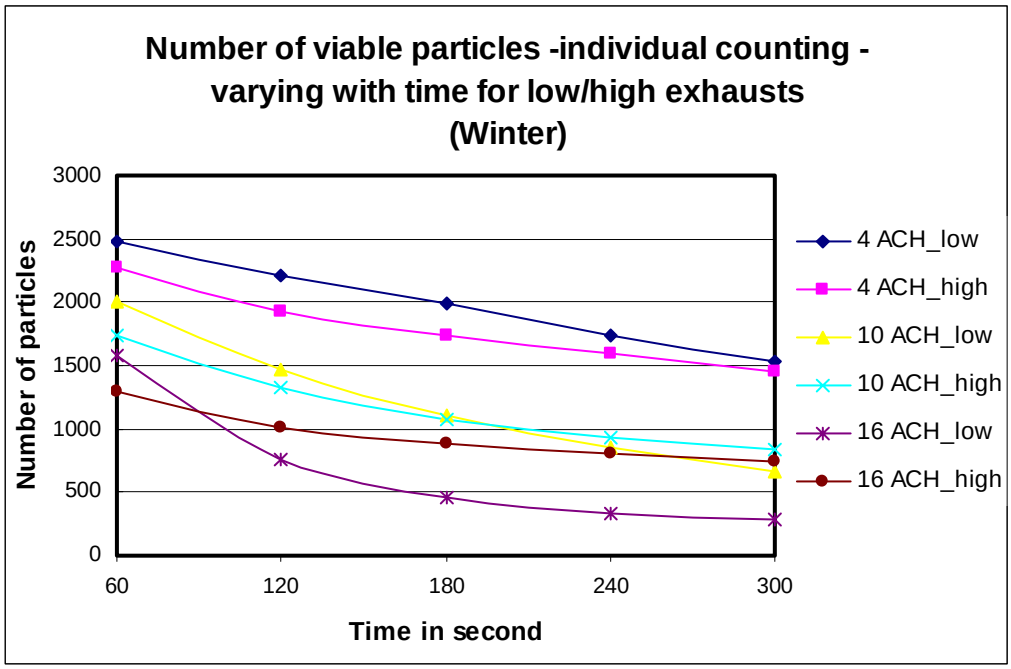

Figure 5.112. *Number of viable particles with exhaust location change (Winter).*

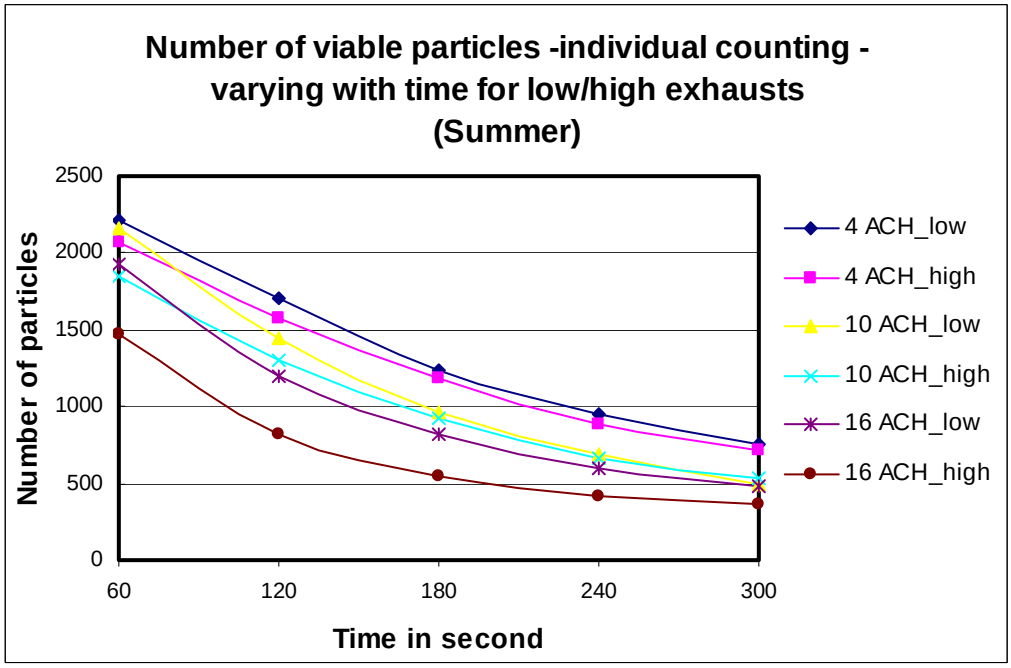

Figure 5.113. *Number of viable particles with exhaust location change (Summer).*

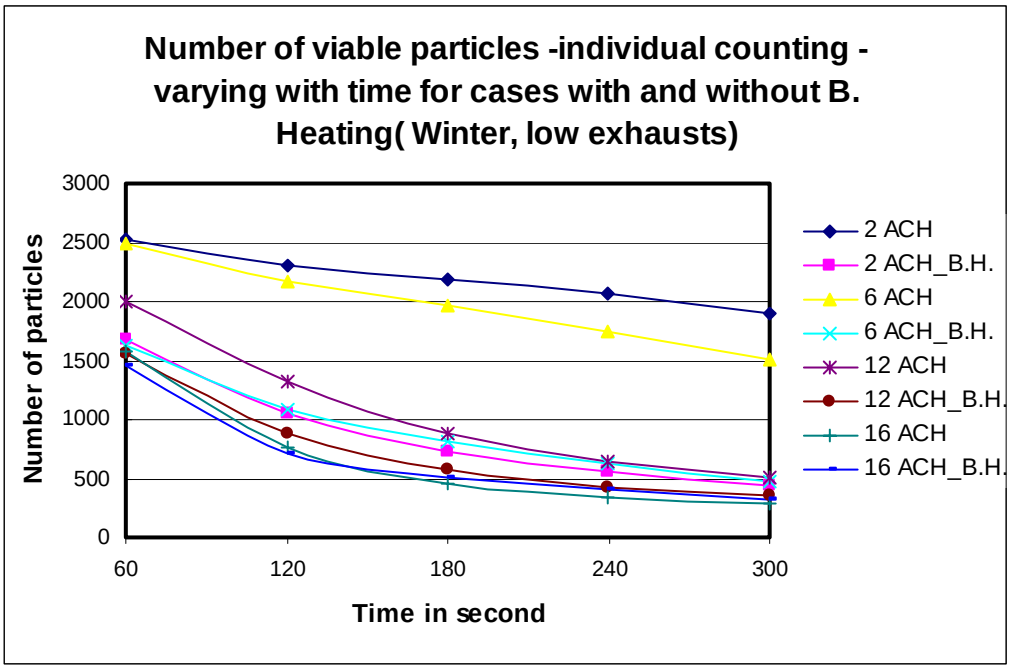

Figure 5.114. *Number of viable particles for cases with/ without Baseboard Heating.*

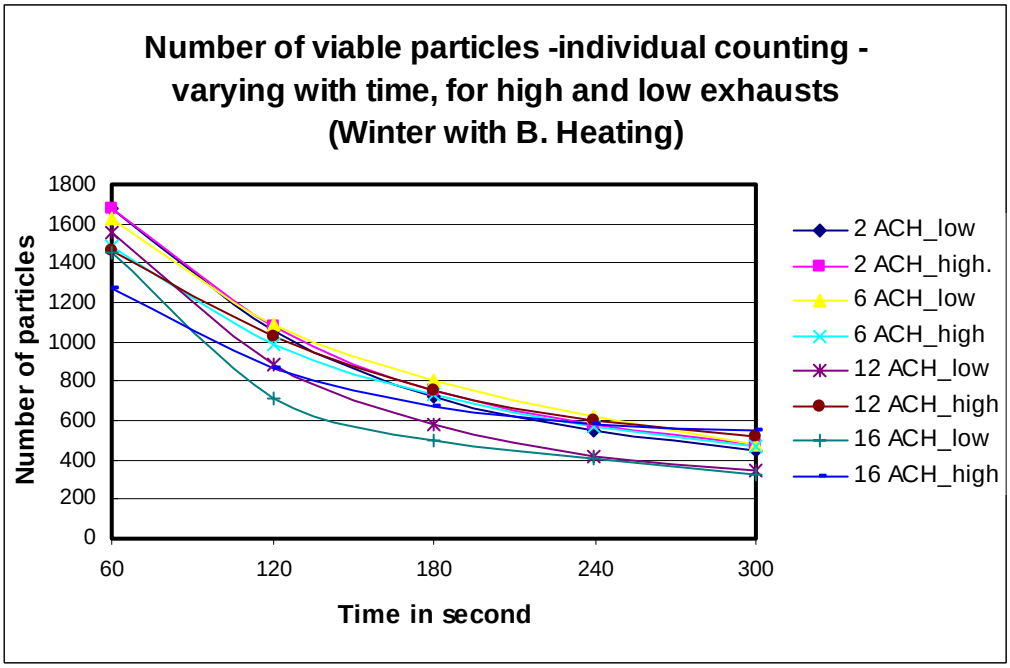

Figure 5.115*. Number of viable particles for exhaust location change when baseboard heating is applied*

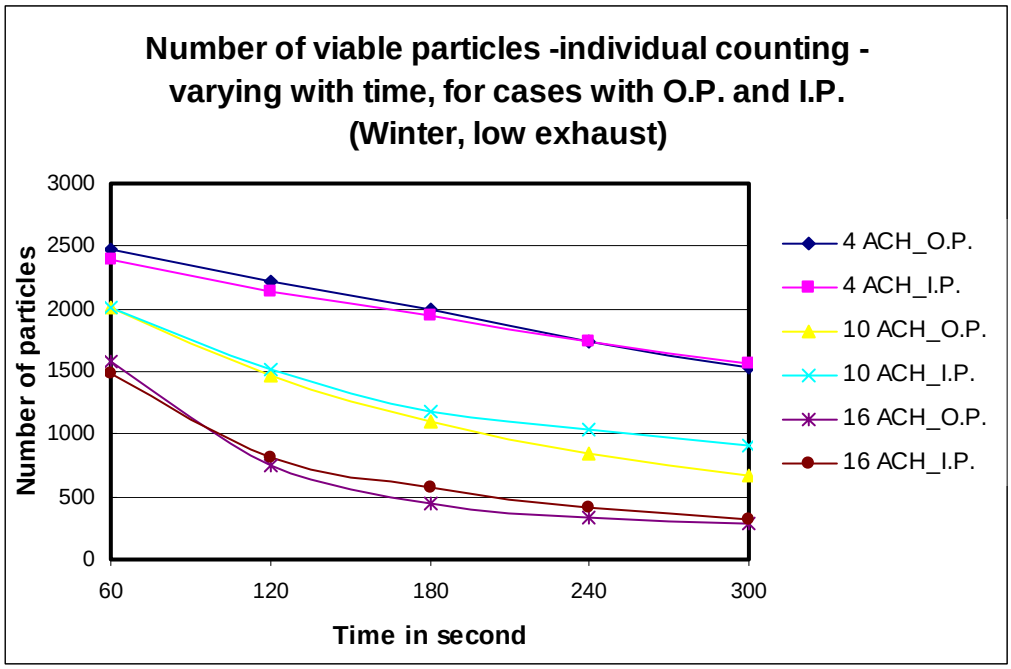

Figure 5.116. *Number of viable particles for cases with original/ increased pressurization (Winter)*

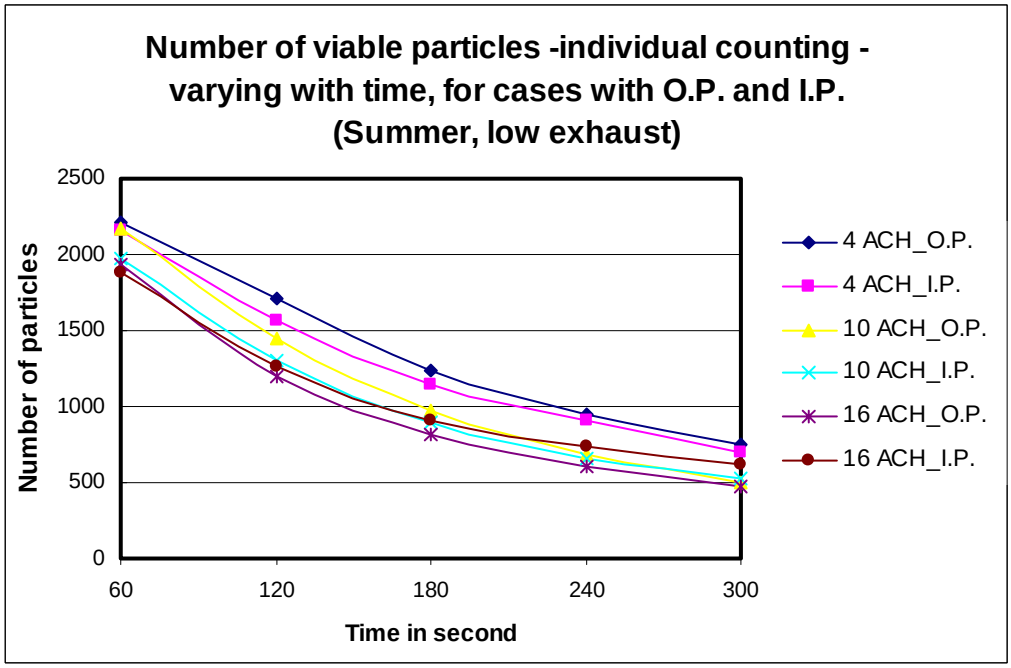

Figure 5.117. *Number of viable particles for cases with original/ increased pressurization (Summer)*

5.3.14 Number of Killed Particles - Group Counting - Varying with Time (UV3)

UV3: UVGI output power 40W, located on the near bed wall, 7.5' from the floor.

Figure 5.118 shows that 10 ACH gives highest number of killed particles. Further increase of the ventilation does not necessary result in higher number of particles killing. In summer cases, the number of killed particles decreases when flow rate increases as indicated in Figures 5.119 and 5.120.

Figure 5.121 indicates for winter cases, the high exhausts location gives higher number of killed particle. But in summer cases, it is opposite as seen in Figure 5.122.

Figure 5.123 shows, with baseboard heating, the number of killed particles is actually increased.

Figure 5.124 compares the high and low exhausts with baseboard heating used, which shows that low exhausts result in higher number of killed particles by UVGI.

For both winter and summer cases, pressurizing the room gives further slightly higher number of killed particles as shown in Figures 5.125 and 5.126.

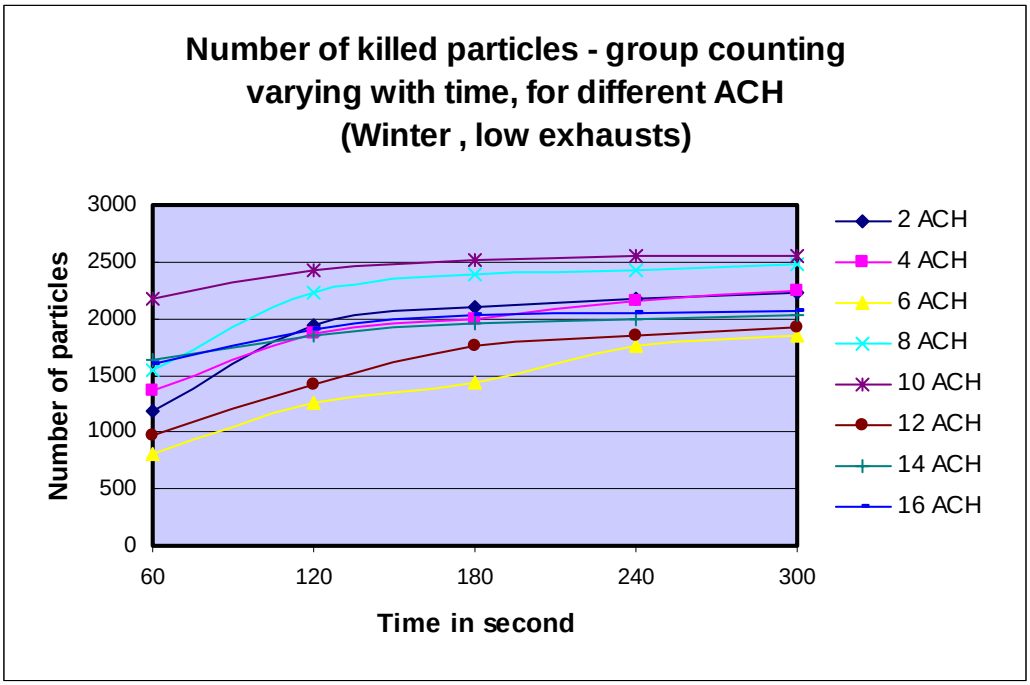

Figure 5.118. *Number of killed particles with ACH change (Winter)*

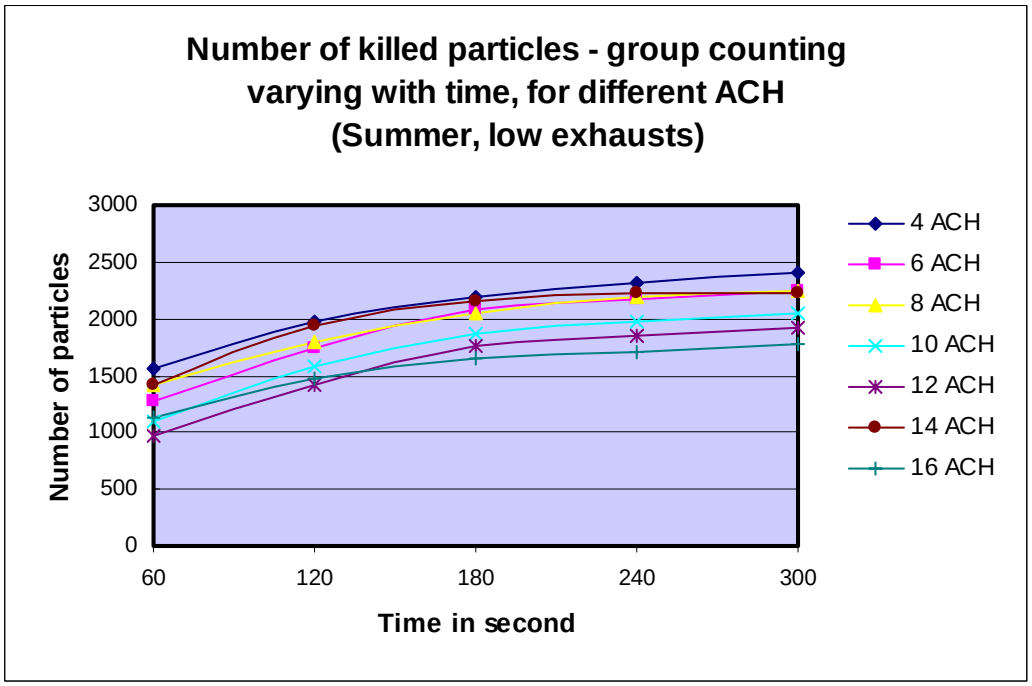

Figure 5.119. *Number of killed particles with ACH change (Summer)*

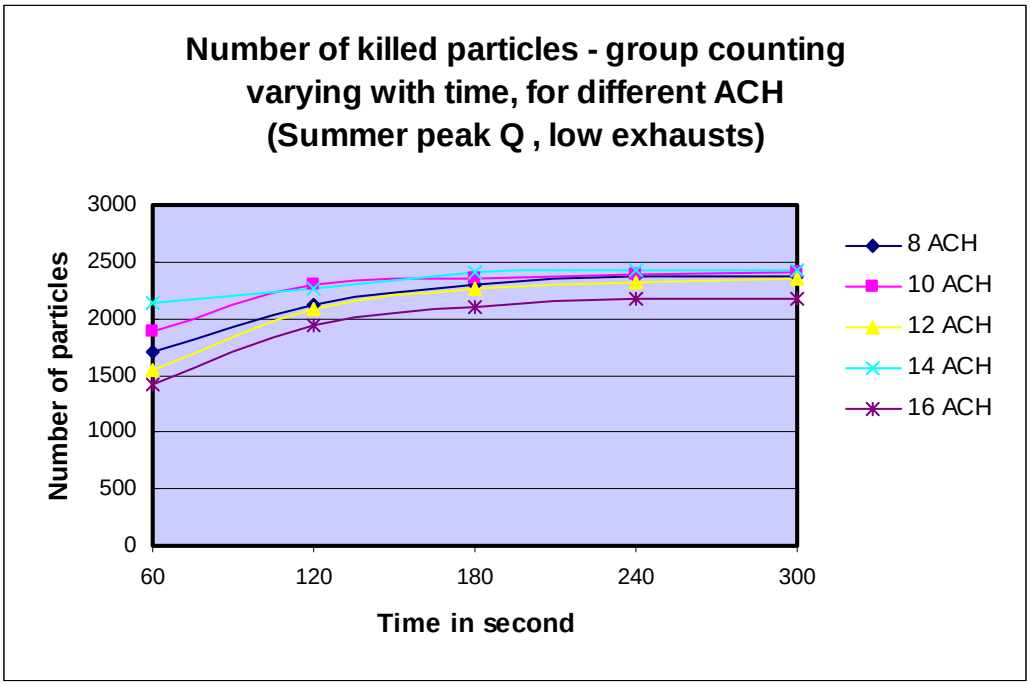

Figure 5.120. *Number of killed particles with ACH change (Summer peak Q)*

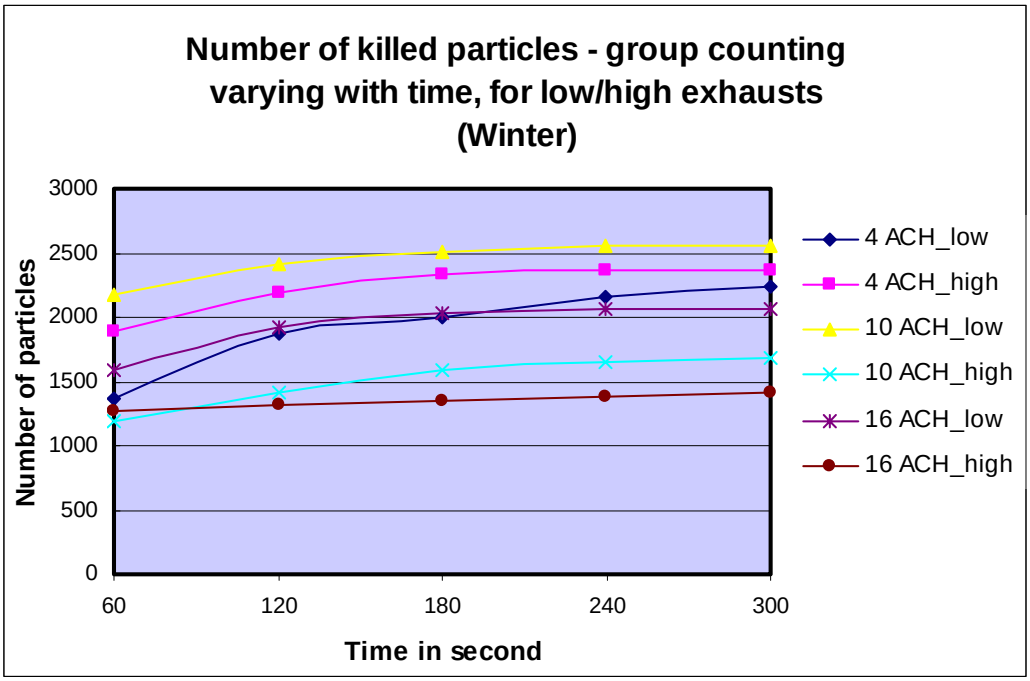

Figure 5.121. *Number of killed particles with exhaust location change (Winter)*

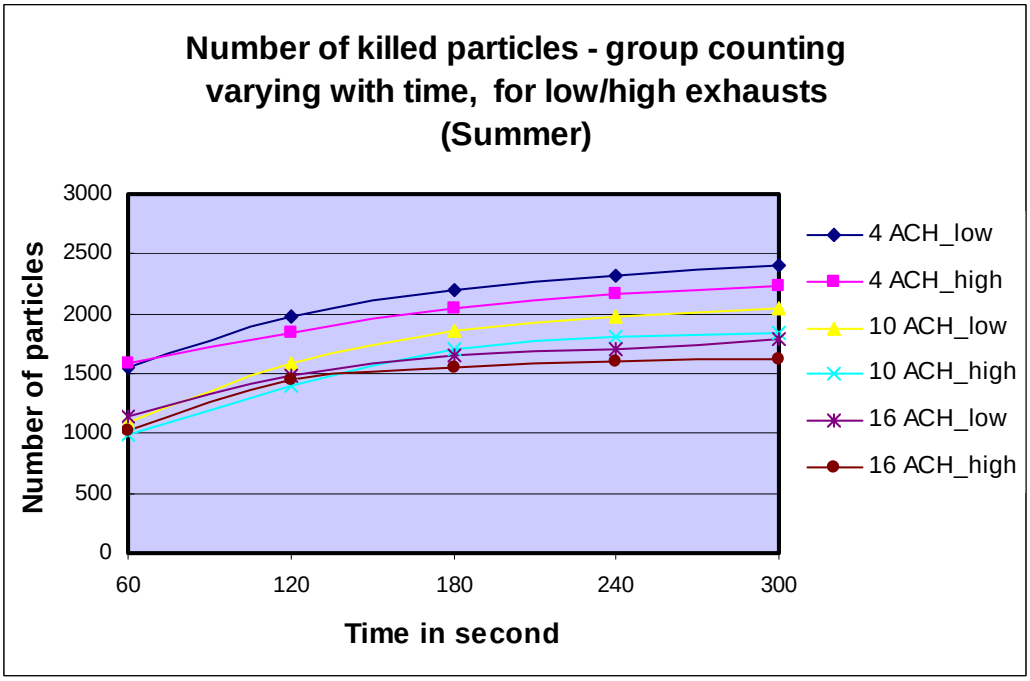

Figure 5.122. *Number of killed particles with exhaust location change (Summer)*

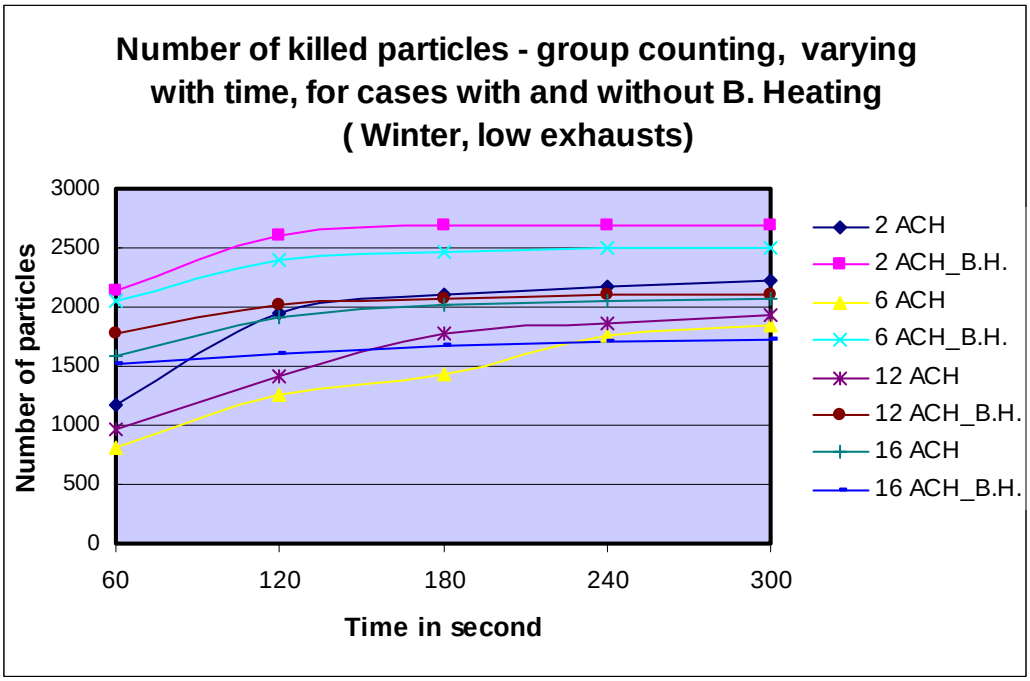

Figure 5.123. *Number of killed particles for cases with/without Baseboard Heating*

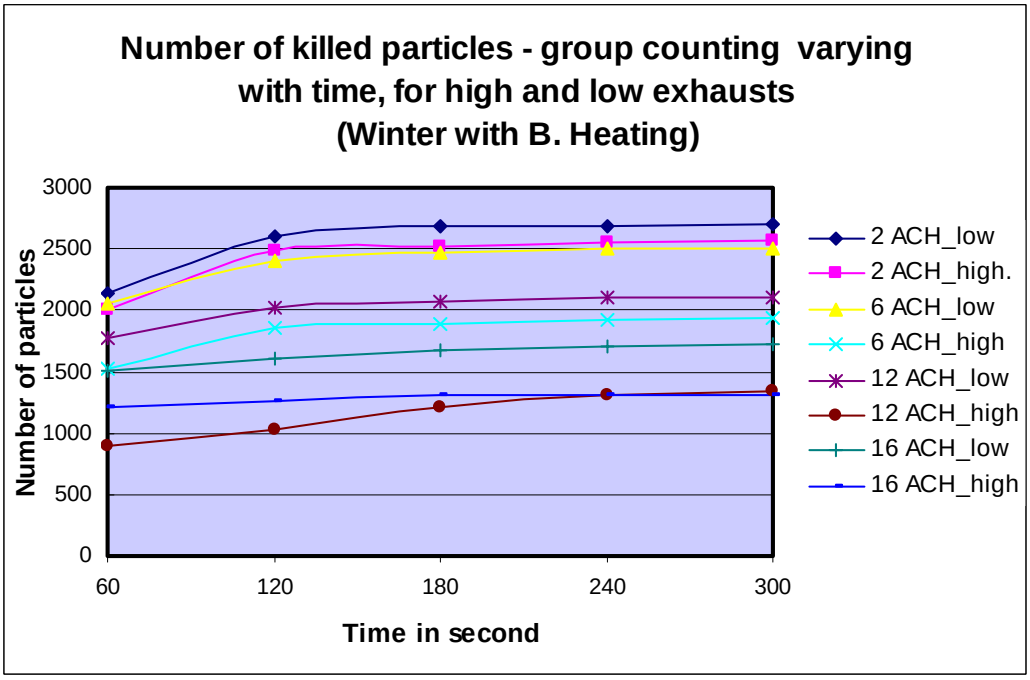

Figure 5.124. *Number of killed particles for exhaust location change when baseboard heating is applied*

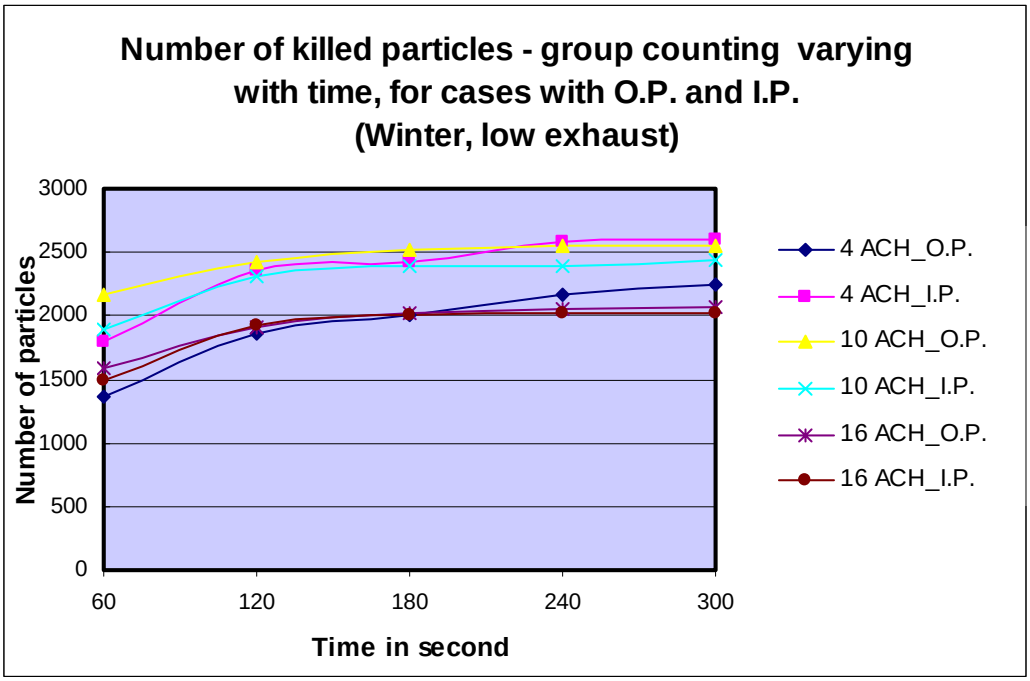

Figure 5.125. *Number of killed particles for cases with original/ increased pressurization (Winter)*

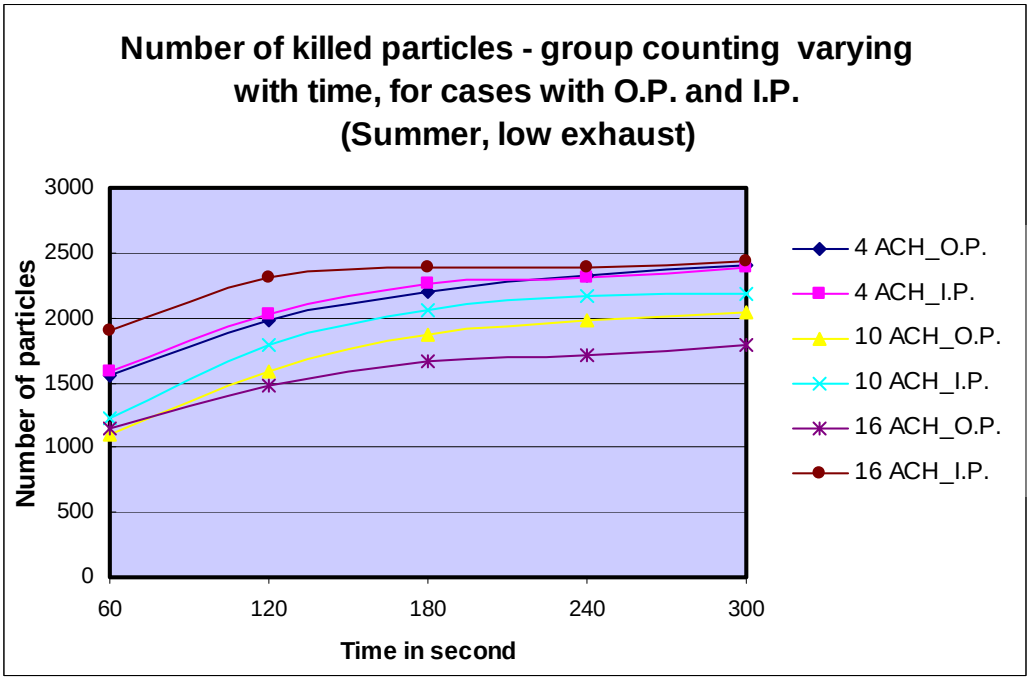

Figure 5.126. *Number of killed particles for cases with original/ increased pressurization (Summer)*

5.3.15 Number of Killed Particles - Individual Counting - Varying with Time (UV3)

UV3: UVGI output power 40W, located on the near bed wall, 7.5' from the floor.

Figure 5.127 shows that 10 ACH gives highest number of killed particles. Further increase of the ventilation does not necessary result in higher number of particles killing. This tendency is not so obvious in summer cases as presented in Figures 5.128 and 5.129.

Figures 5.130 and 5.131 show no obvious tendency as to which exhaust location does better in UV killing

Figure 5.132 indicates that baseboard heating significantly increases the number of killed particles when the flow rate is low. Figure 5.133 compares the high and low exhausts with baseboard heating used, which shows that low exhausts greatly increase the number of killed particles by UVGI.

For both winter and summer cases, increased pressurization of the room slightly increases number of killed particles, except for winter case with 10 ACH as illustrated in Figures 5.134 and 5.135.

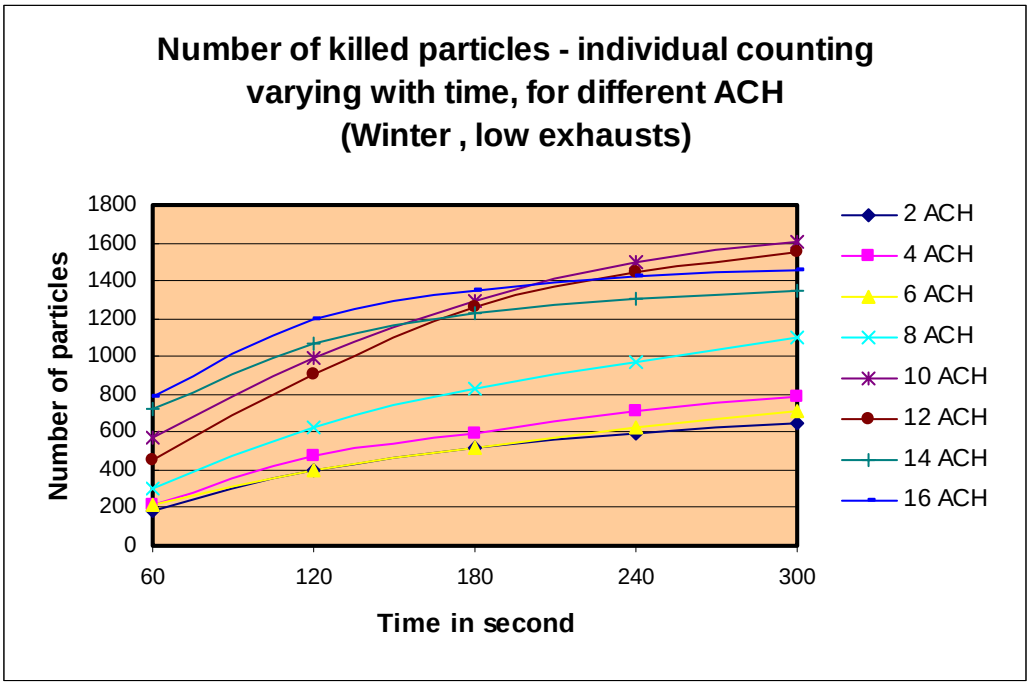

Figure 5.127. *Number of killed particles - individual counting - with ACH change (Winter)*

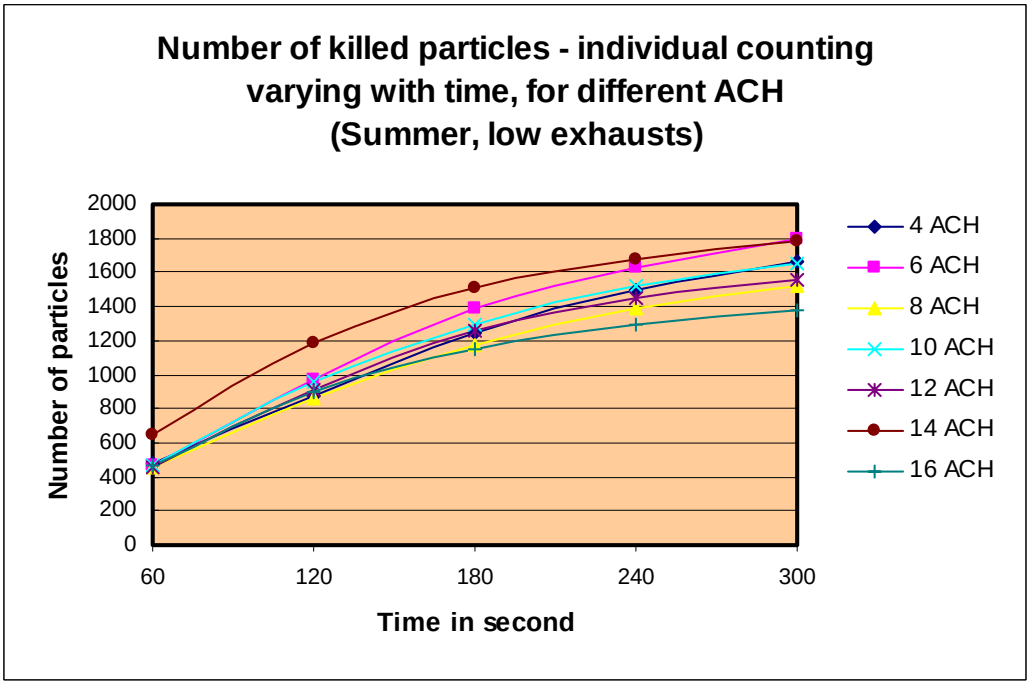

Figure 5.128. *Number of killed particles - individual counting - with ACH change (Summer)*

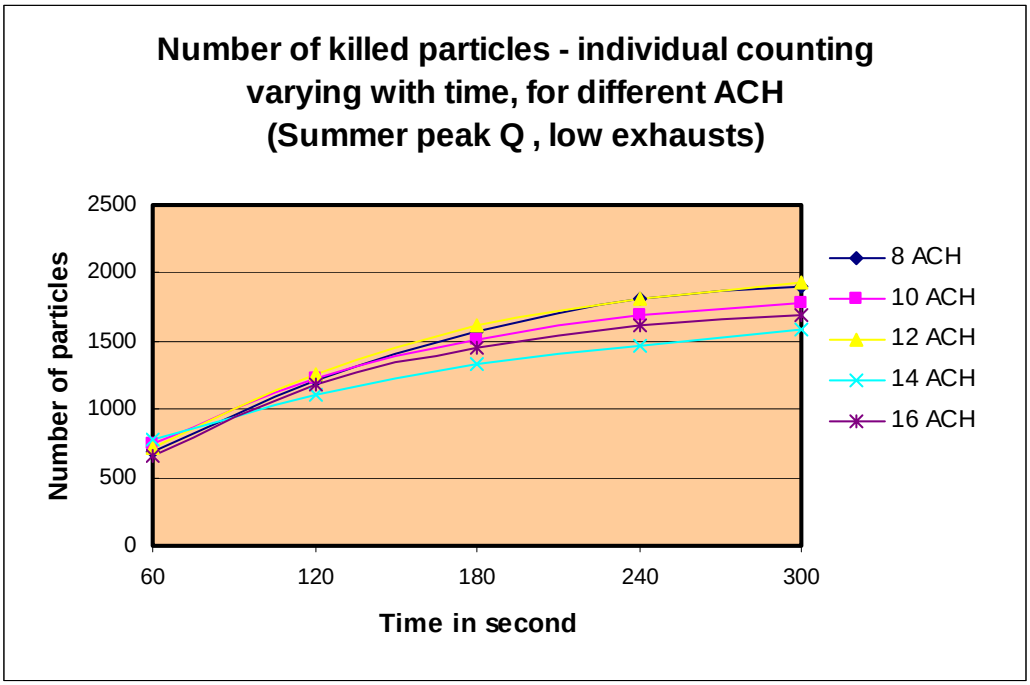

Figure 5.129. *Number of killed particles - individual counting - with ACH change (Summer peak Q)*

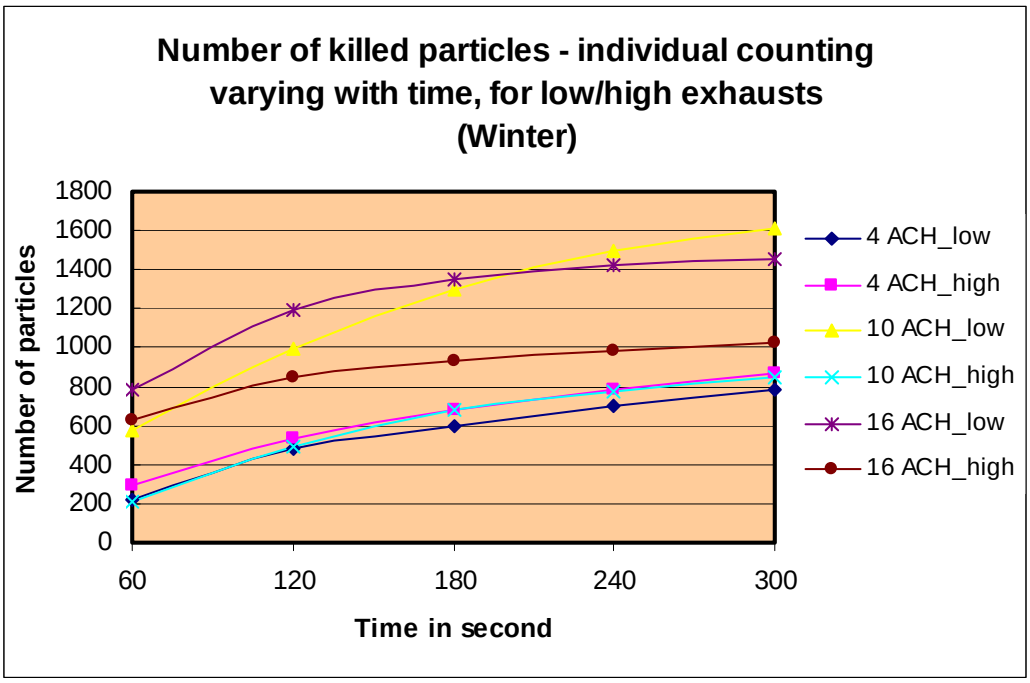

Figure 5.130. *Number of killed particles - individual counting - with exhaust location change (Winter)*

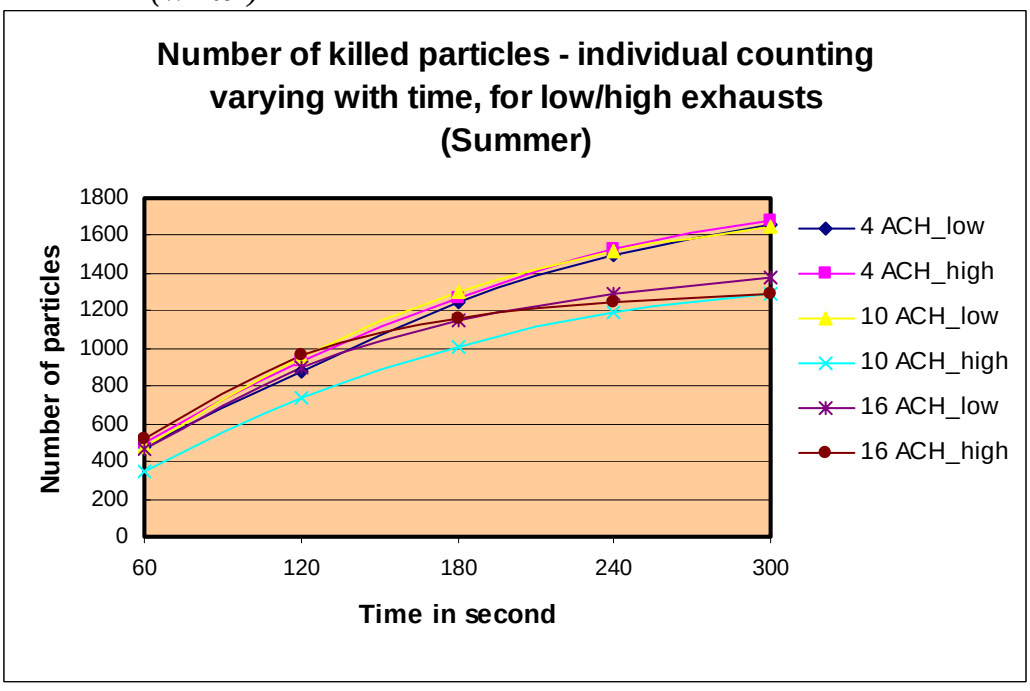

Figure 5.131. *Number of killed particles - individual counting - with exhaust location change (Summer)*

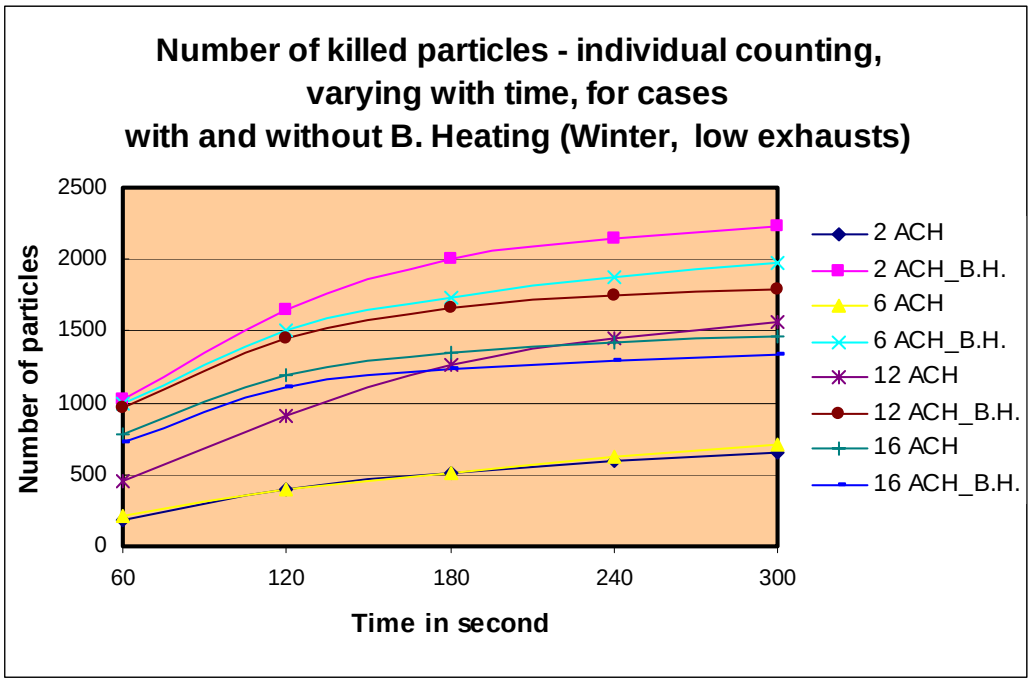

Figure 5.132. *Number of killed particles - individual counting - for cases with/without Baseboard Heating*

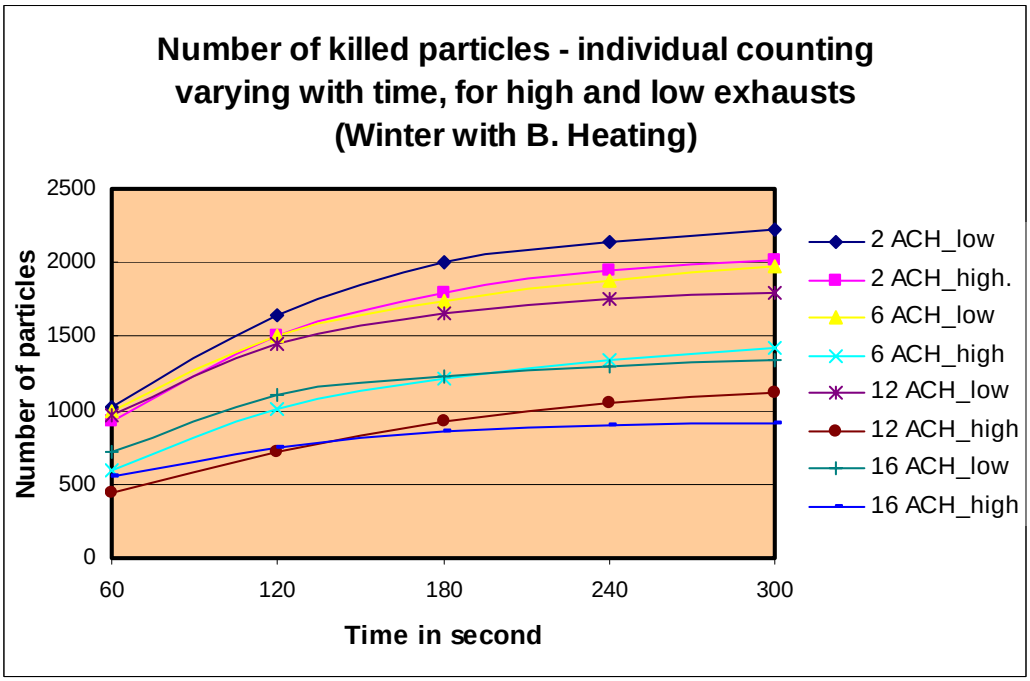

Figure 5.133. *Number of killed particles - individual counting - for exhaust location change when baseboard heating is applied*

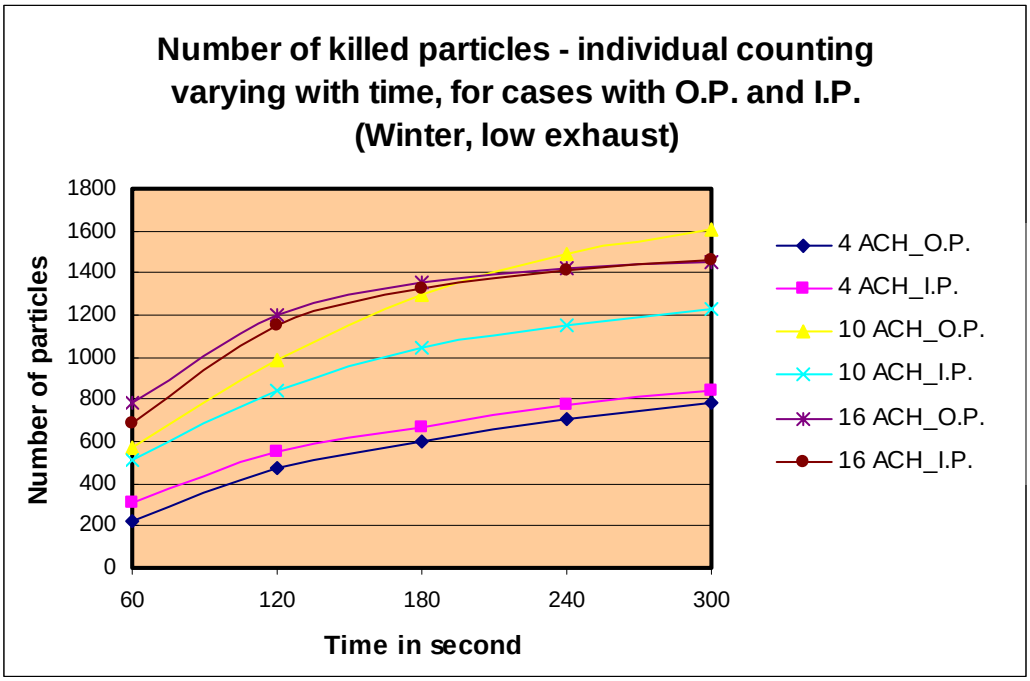

Figure 5.134. *Number of killed particles - individual counting - for cases with original/ increased pressurization (Winter)*

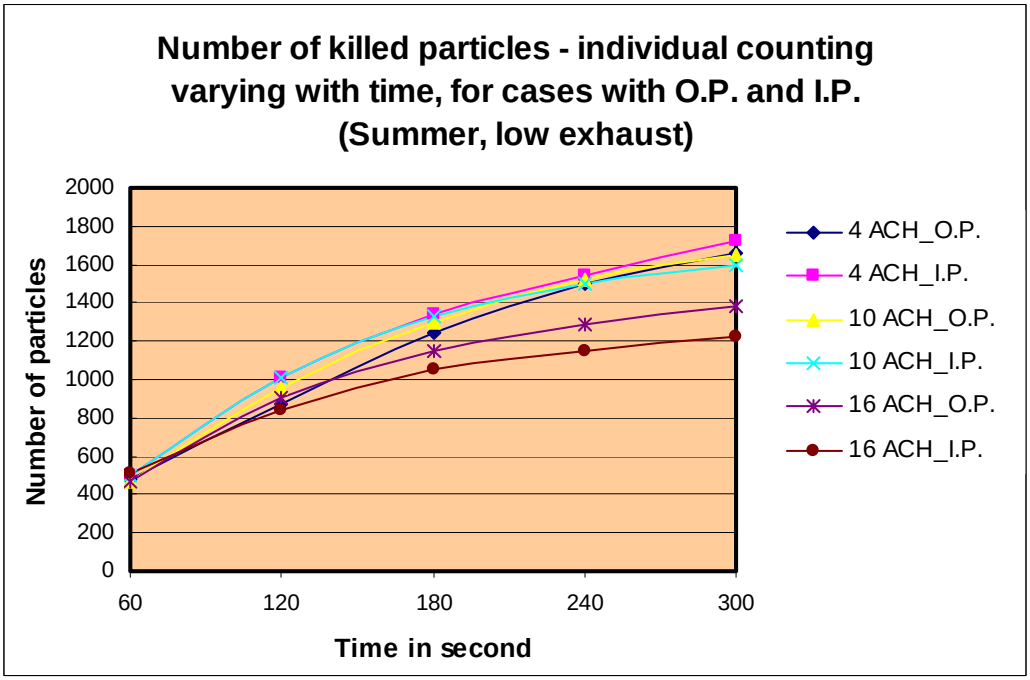

Figure 5.135. *Number of killed particles - individual counting - for cases with original/ increased pressurization (Summer)*

5.3.16 The Survival Fraction of Particles Varying with Time (UV3)

UV3: UVGI output power 40W, located on the near bed wall, 7.5' from the floor.

For winter cases, the survival fraction with 10 ACH become 100% at the end of 300s. This is because all the particles left in the room are with zero dose. The surviving fractions with other flow rates are between 65-90% (See Figure 5.136). For summer cases with peak Q, the survival fraction has a great change from case to case as shown in Figure 5.138.

For high and low exhausts, no conclusion can be draw for winter cases as to which location gives higher surviving fractions (See Figure 5.139). Under summer condition, the low exhausts seem to give consistently lower surviving fractions. As shown in Figure 5.140.

The baseboard heating seems to give significant impact to the surviving fractions. But it is not clear whether it will increase the surviving fractions.

Figure 5.142 compares the high and low exhausts with baseboard heating used. The effects of increased pressurization of the room on surviving fraction for winter and summer conditions are presented in Figures 5.143 and 5.144, respectively. Nothing remarkable is observed.

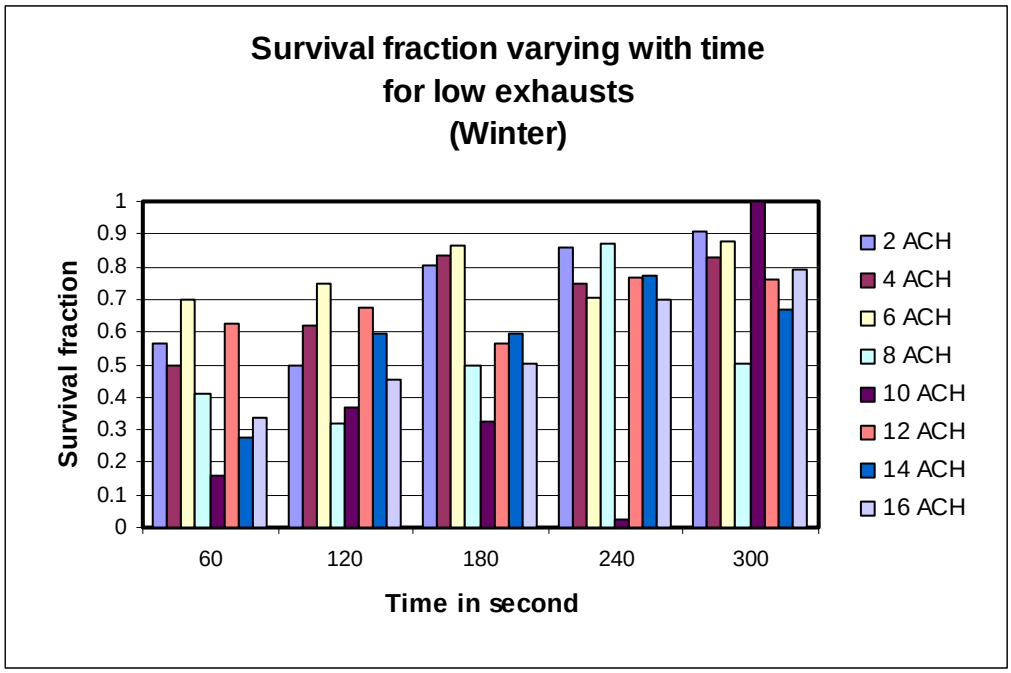

Figure 5.136. *Survival fraction with ACH change (Winter)*

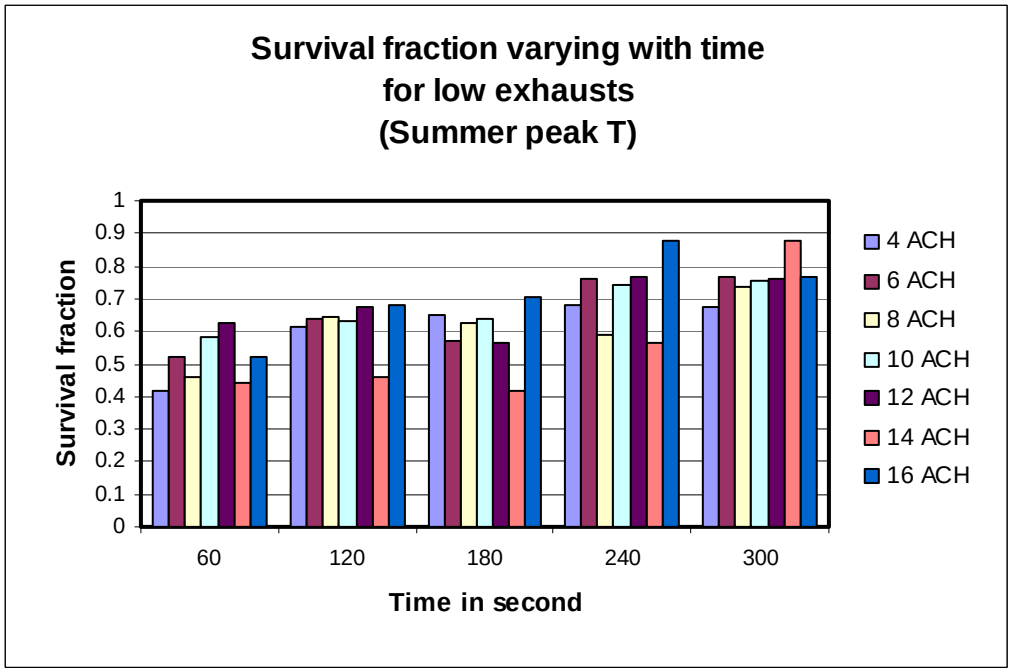

Figure 5.137. *Survival fraction with ACH change (Summer)*

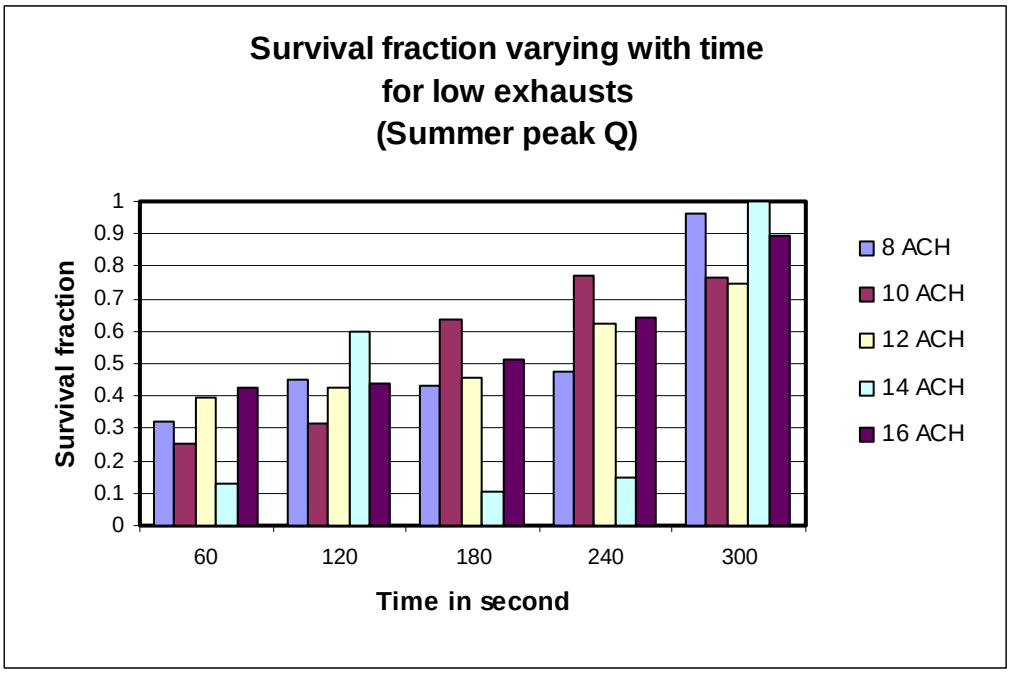

Figure 5.138. *Survival fraction with ACH change (Summer peak Q)*

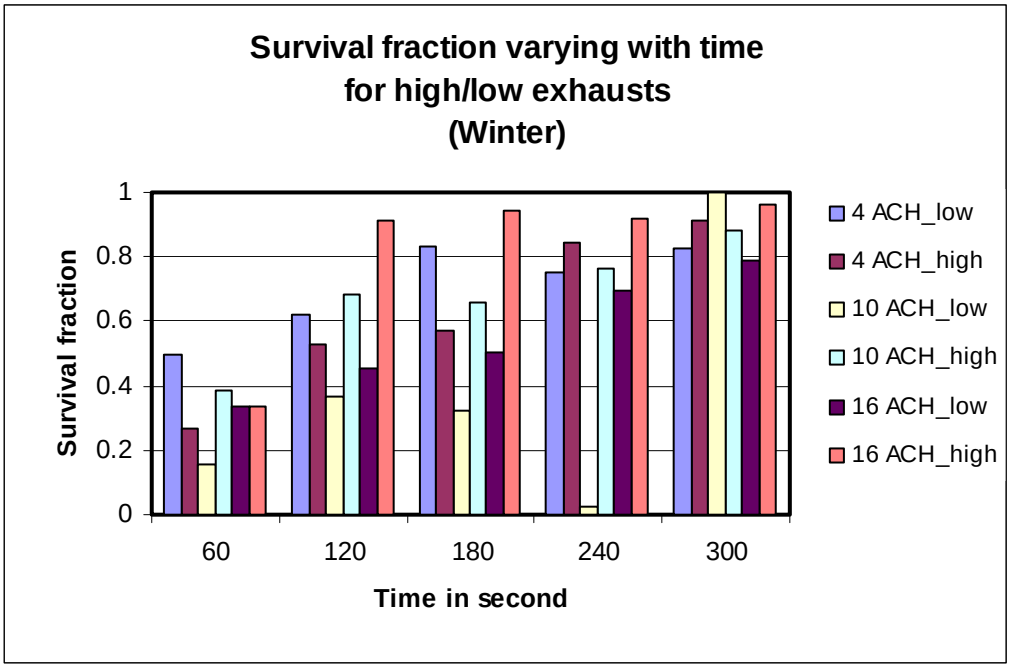

Figure 5.139*. Survival fraction with exhaust location change (Winter)*

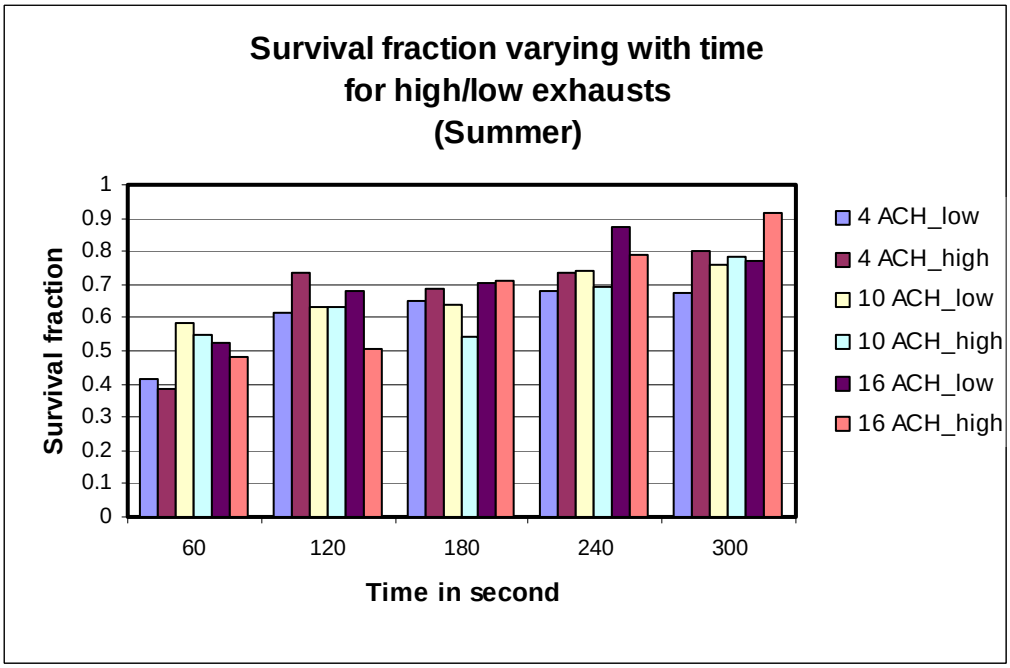

Figure 5.140. *Survival fraction with exhaust location change (Summer)*

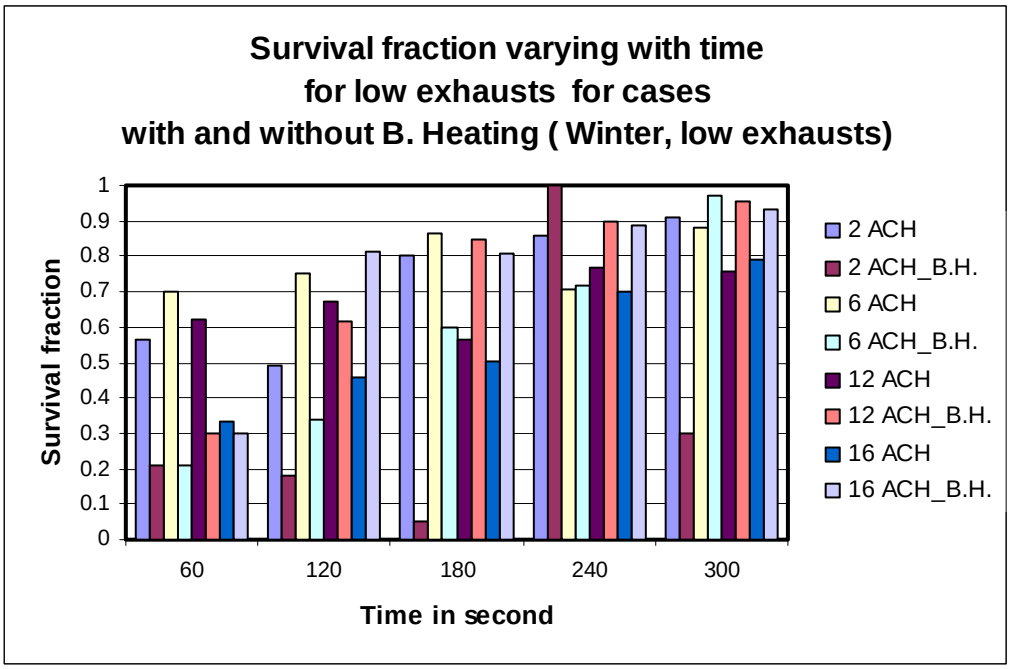

Figure 5.141. *Survival fraction for cases with /without Baseboard Heating*

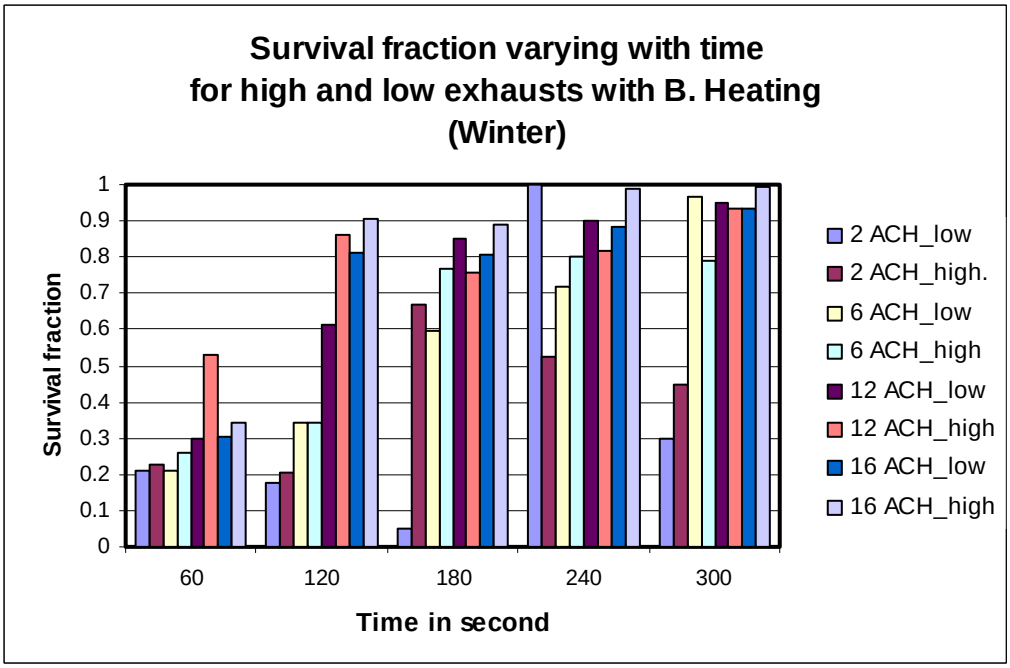

Figure 5.142. *Survival fraction for exhaust location change when baseboard heating is applied*

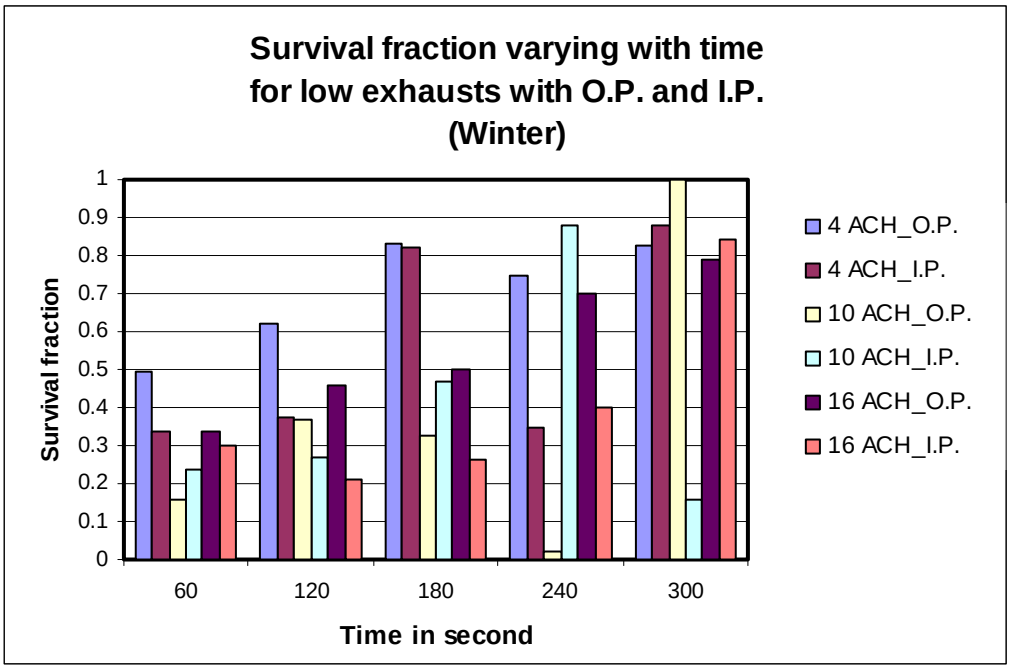

Figure 5.143. *Survival fraction for cases with original/ increased pressurization (Winter)*

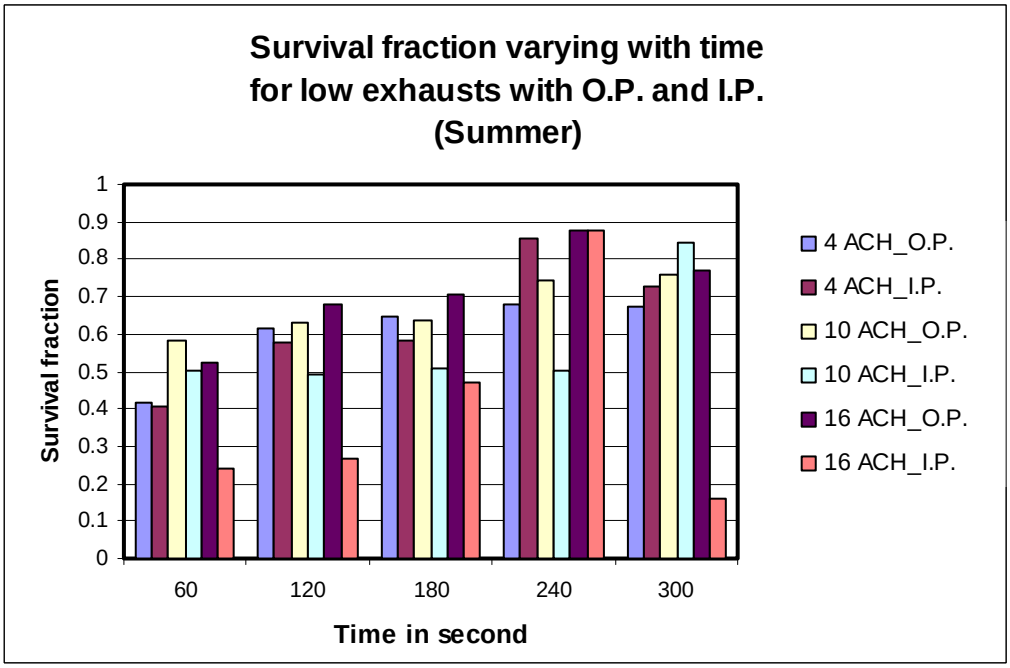

Figure 5.144. *Survival fraction for cases with original/ increased pressurization (Summer)*

5.3.17 Comparison of Performances of UVGI And Ventilation for Different ACH

The group-counting approach is used in the comparison.

Figures 5.145 to 5.146 compare number of particles that are removed by the two mechanisms: ventilation and UVGI under winter and summer weather conditions, respectively. The UVGI generally removes more particles than the ventilation system except the winter cases with high ventilation flow rate (14 ACH). The results for summer case (Figure5.146) indicate that the lower the ventilation rate is, the more pronounced the UVGI effectiveness over the ventilation.

Figures 5.147 and 5.148C present the same comparison in percentage at the end of 300s tracking time.

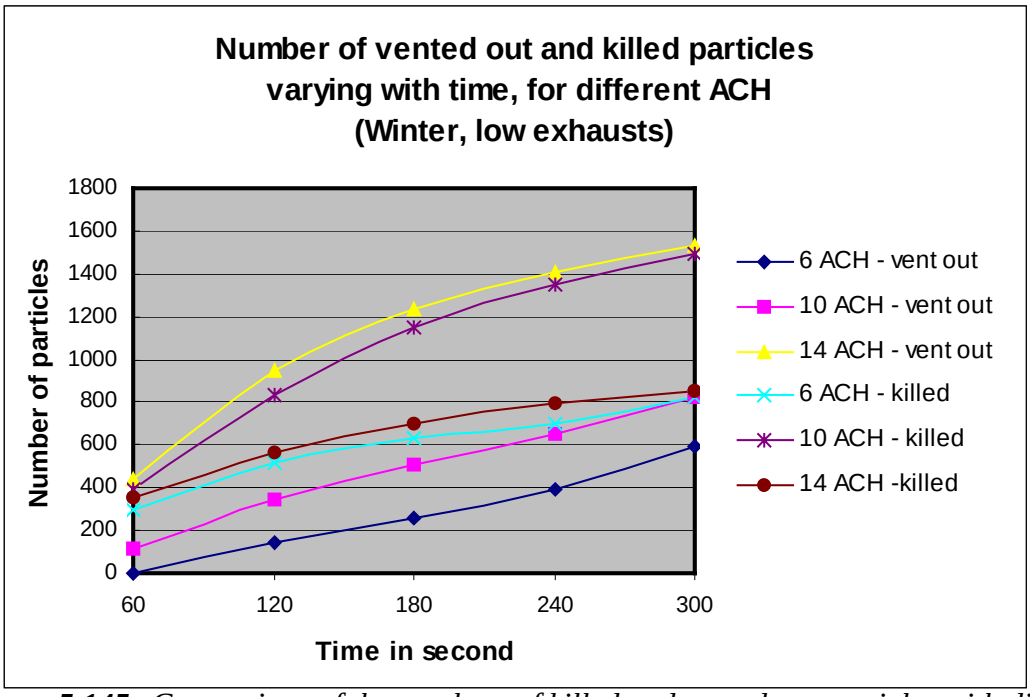

Figure 5.145*. Comparison of the numbers of killed and vented out particles with different ACH (Winter cases).*

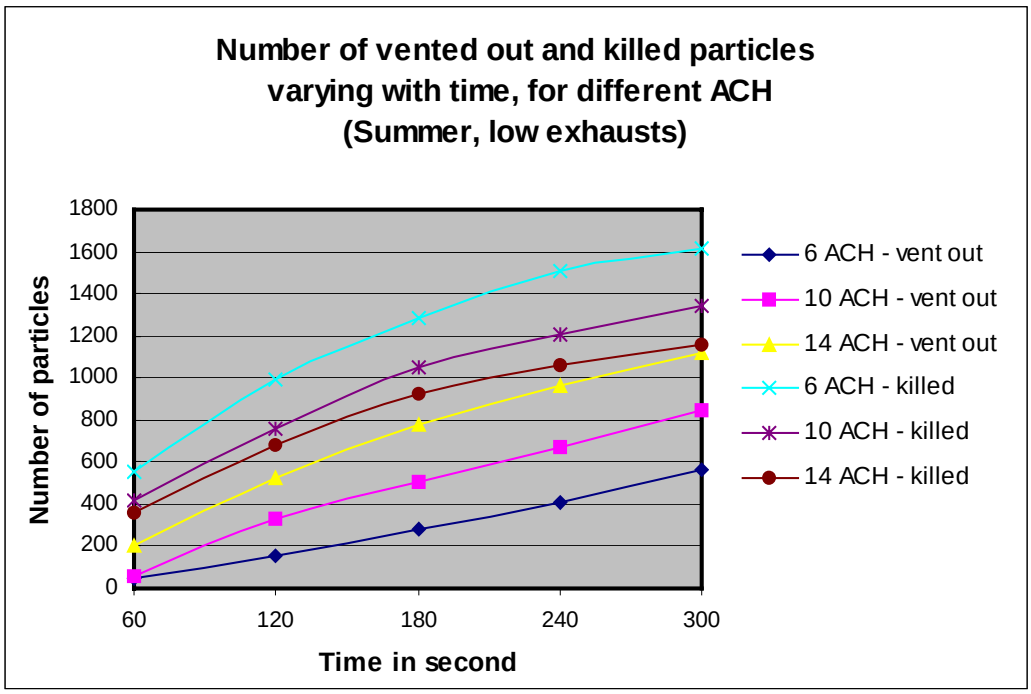

Figure 5.146. *Comparison of the numbers of killed and vented out particles with different ACH (Summer cases).*

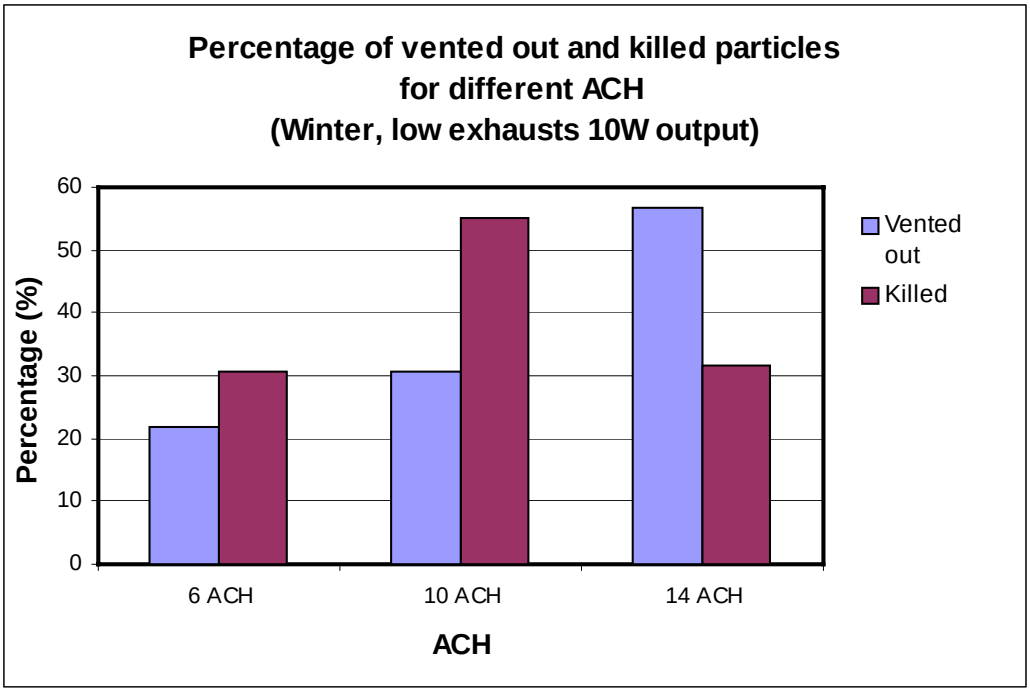

Figure 5.147*. Comparison of percentage of killed and vented out particles at the end of 300S (Winter cases).*

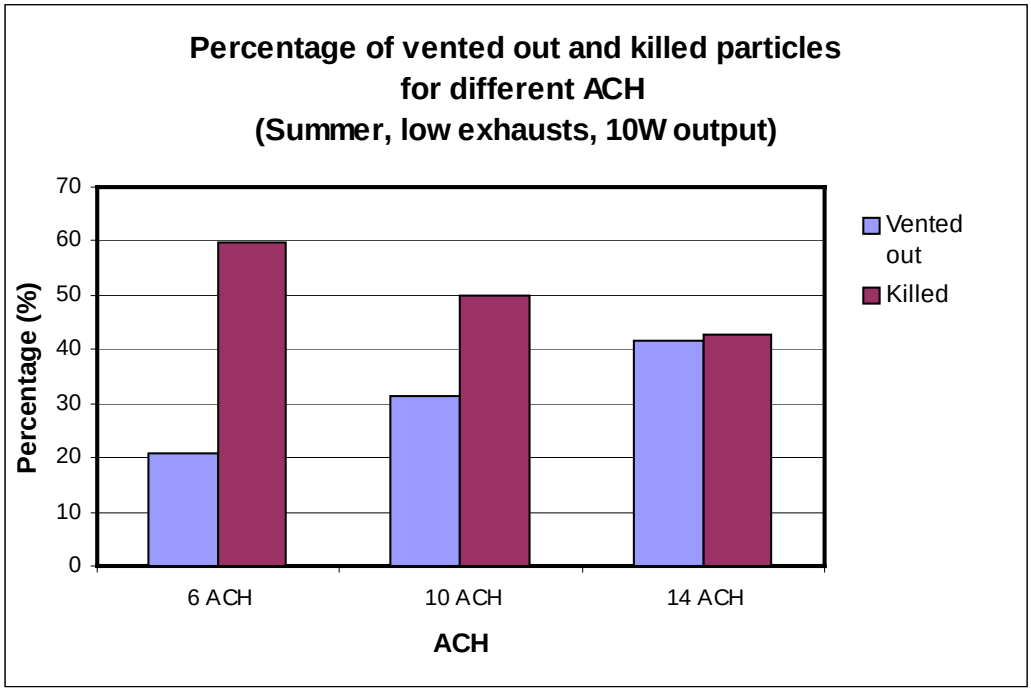

Figure 5.148. *Comparison of percentage of killed and vented out particles at the end of 300S (Summer cases).*

5.3.18 Comparison of Performances of UVGI And Ventilation for Different UV Power Output

In this comparison, the removal capability of 3 UV power outputs, 10W, 20W and 40W, are compared for the same UVGI location (on the wall near the bed, 7.5' from the floor).

It is shown that higher power output gives remarkably higher killing percentage in the first minute. In the winter case, for example, the percentages of killed particles at the first minute are 35%, 60% and 80% for 10W, 20W and 40W, respectively (see figures 5.149, 5.151 and 5.153). After 5 minutes, increasing the output power from 10W to 20W results in the increase of percentage of killed particles from 65% to 90%. Further increase of the output from 20W to 40W only gives 4% more of particle killing. For the summer case, the increase of the output power consistently gives about 15% more particle killing. This may be due the higher mixing in the summer condition that prevents the particles from spending longer time in the upper room where the UV intensity is higher.

With 10 ACH, the UVGI is about 20-30% more effective under winter condition than under summer condition.

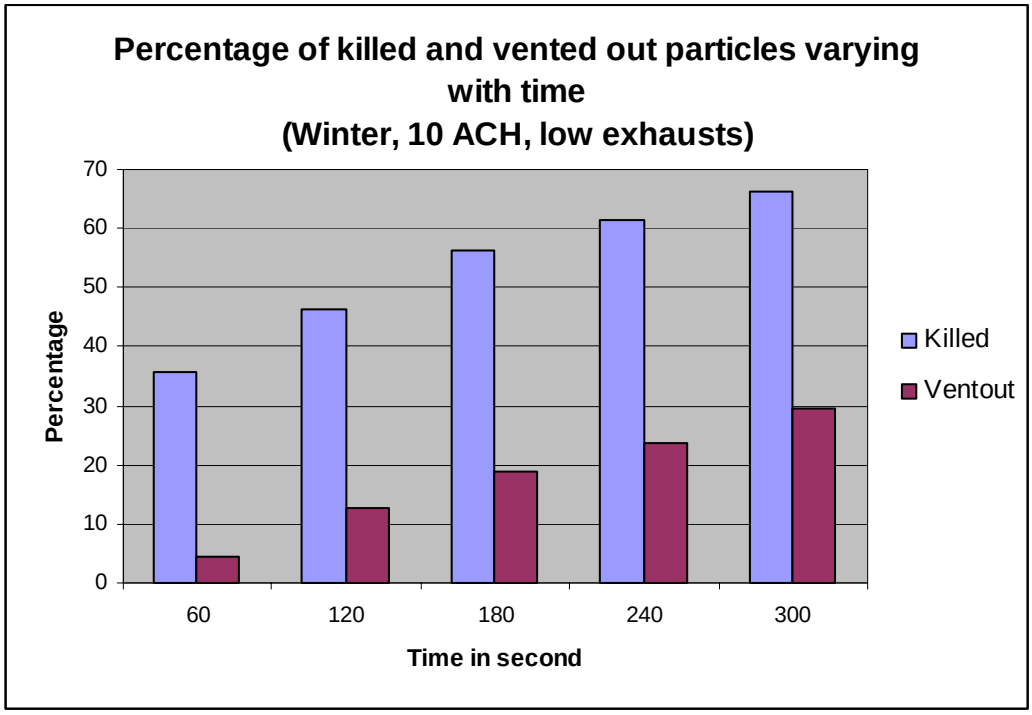

Figure 5.149 *10 W UV output power (Winter)*

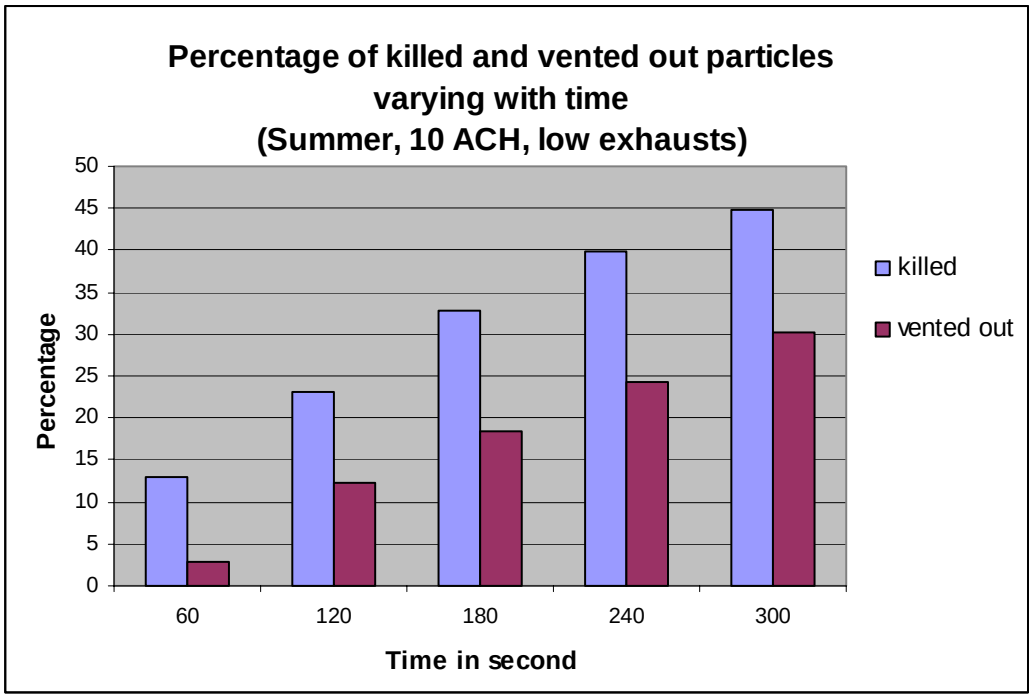

Figure 5.150. *10 W UV output power (Summer Peak T)*

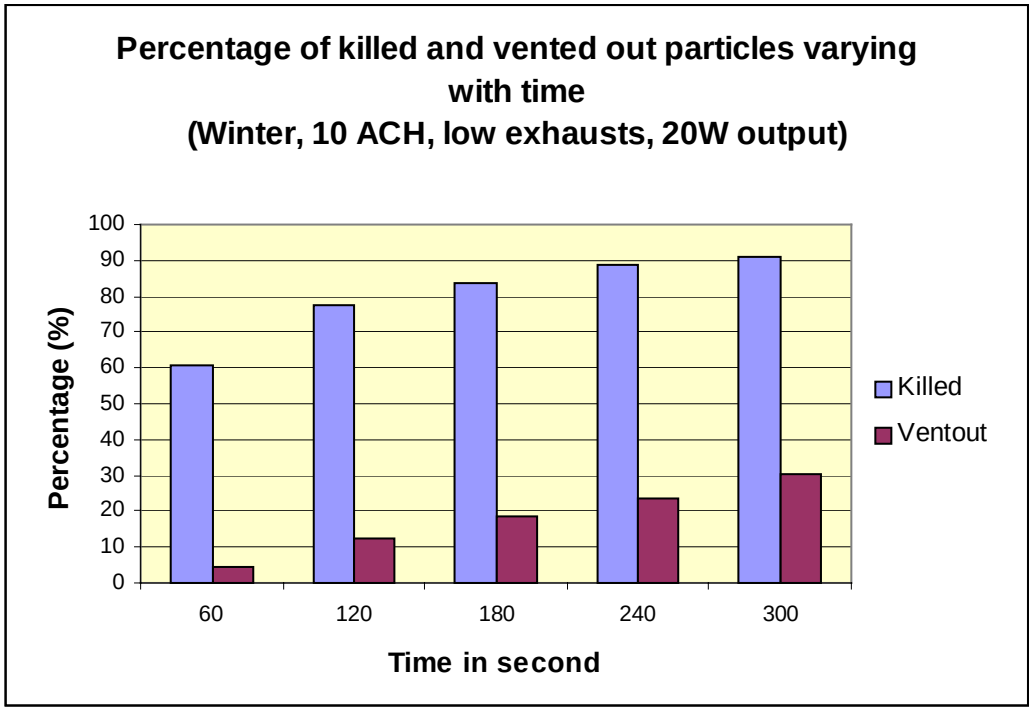

Figure 5.151. *20 W UV output power (Winter)*

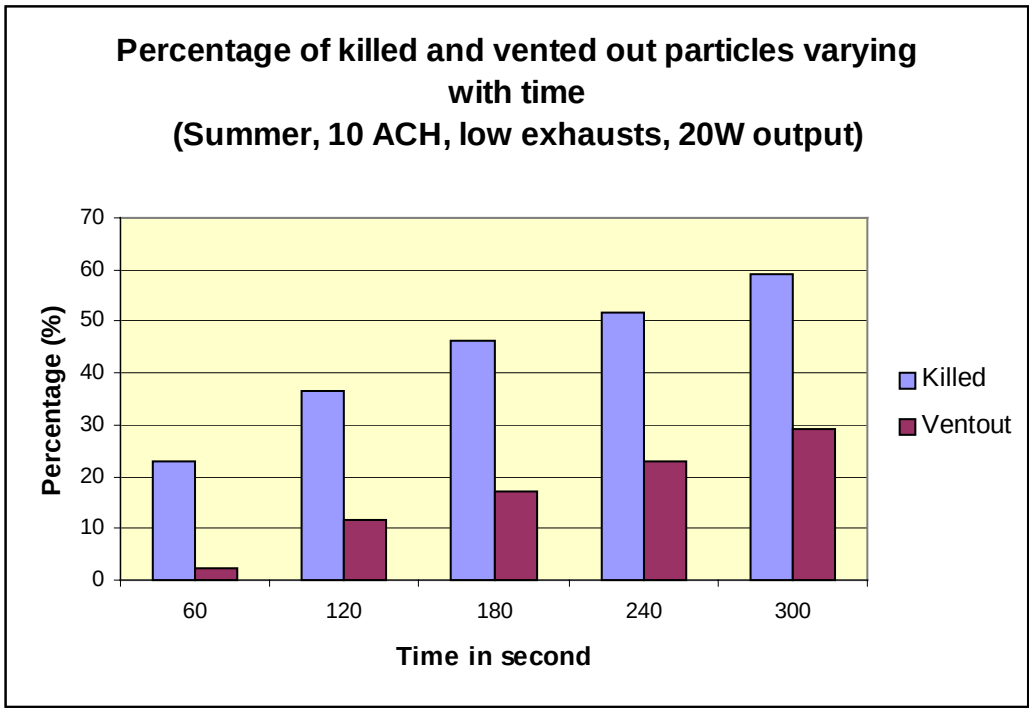

Figure 5.152. *20 W UV output power (Summer)*

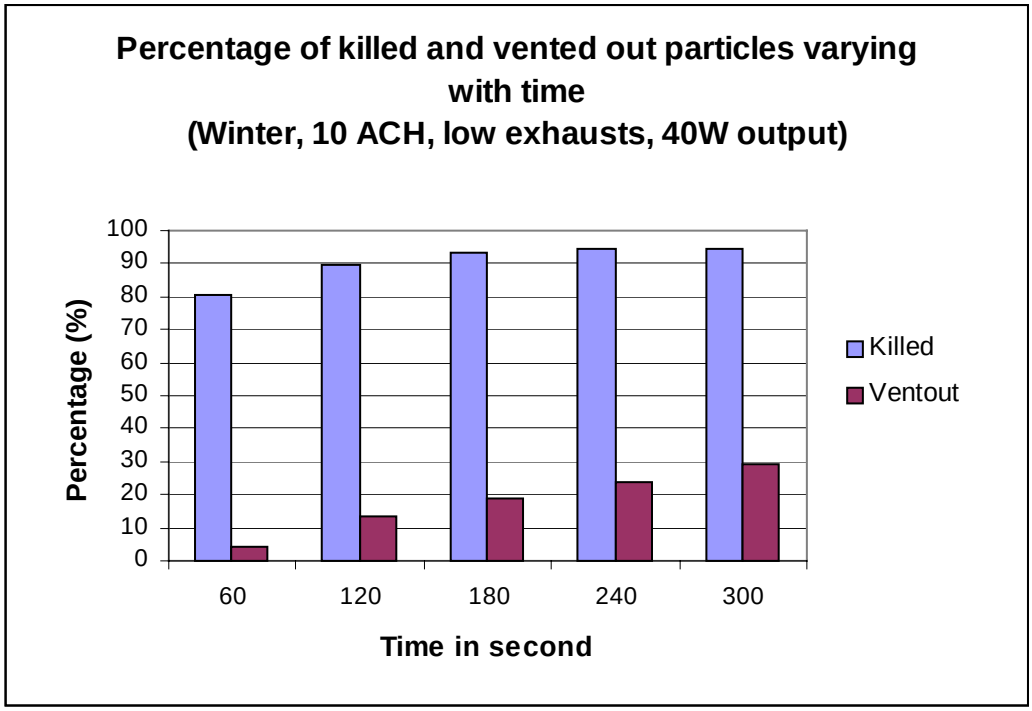

Figure 5.153. *40 W UV output power (Winter)*

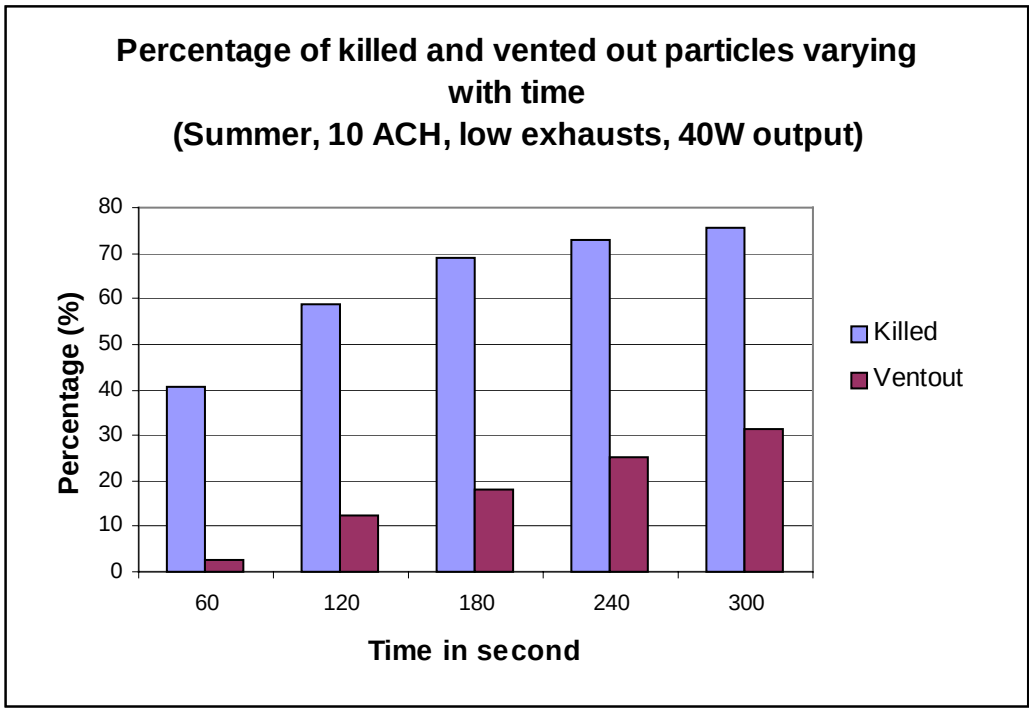

Figure 5.154. *40 W UV output power (Summer)*