Air movements and dispersion of contaminants e.g., in front of steam autoclaves

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CONVECTIVE TRANSPORT

SOURCE

STREAMLINE
The theoretical velocity profile through a door opening with a temperature difference.
Through one-half of the opening, the discharge flow rate $Q$, (m³/s), in each direction can be calculated by:

$$Q = C_d \frac{WH^{3/2}}{3} (g \frac{\Delta \rho_o}{\rho_{om}})^{1/2}$$

- $C_d$ = discharge coefficient
- $W$ = opening width (m)
- $H$ = opening height (m)
- $g$ = gravitational acceleration (m/s²)
- $\Delta \rho_o$ = density difference (kg/m³)
- $\rho_{om}$ = mean density (kg/m³)
\[ c = \left\{ c_0 - \frac{S}{(Q_d + Q_m)} - \frac{(Q_d \cdot c_k)}{(Q_d + Q_m)} \right\} \cdot e^{-\frac{(Q_d + Q_m) \cdot t}{V}} + \frac{S}{(Q_d + Q_m)} + \frac{Q_d \cdot c_k}{(Q_d + Q_m)} \]
Equivalent door opening time with maximal door opening angle ($\pi/2, 90^\circ$)

\[ t_e = t_h + \frac{2}{\pi} (t_0 + t_s) \]

Opening time ($t_0$) = closing time ($t_s$) = 3 seconds

Open hold time ($t_h$) = 2 s, 5 s and 12 s give the following equivalent door opening times ($t_e$)

Fast: \[ t_e = 2 + 3,8 = 5,8 = 6 \text{ seconds} \]
Average: \[ t_e = 5 + 3,8 = 8,8 = 9 \text{ seconds} \]
Slow: \[ t_e = 12 + 3,8 = 15,8 = 16 \text{ seconds} \]
Concentration of bacteria-carrying particles as a function of time in an operating room with an air volume flow of 3.0 m$^3$/s when one door is opened at a time.

The concentration in the adjacent corridor is 180 CFU/m$^3$. 
Concentration of bacteria-carrying particles as a function of time in an operating room with an air volume flow of 3.0 m$^3$/s when one door is opened at a time.

The concentration in the adjacent corridor is 100 CFU/m$^3$. 
AUTOCLAVES

- are used for sterilization of equipment and supplies
- aseptic production
THEORY

Concentration of Airborne Contamination in a Chamber

\[
\frac{dc}{dt} + \frac{Q}{V} c = \frac{Q c_R}{V}
\]

\[
\begin{align*}
c &= \text{concentration in the chamber;} \\
   &= \text{particles (number/m}^3\text{); bacteria-carrying particles (CFU/m}^3\text{)}
\end{align*}
\]

\[
\begin{align*}
t &= \text{time (s)}
\end{align*}
\]

\[
\begin{align*}
Q &= \text{flow rate through door opening in each direction (m}^3\text{/s)}
\end{align*}
\]

\[
\begin{align*}
V &= \text{chamber volume (m}^3\text{)}
\end{align*}
\]

\[
\begin{align*}
c_R &= \text{constant concentration in the room (ambient area)}
\end{align*}
\]
The expression of the concentration in the chamber when the door is open becomes

\[ c = c_R \left( 1 - e^{-\frac{Q}{V} t} \right) \]
Air Velocities - Autoclave Opening

Results

At the beginning

After 30 minutes
## Air Temperatures - Autoclave Opening

### Result

<table>
<thead>
<tr>
<th>Time (Minutes)</th>
<th>Temp. outflowing air</th>
<th>Temp. air in chamber</th>
<th>Temp. inflowing air</th>
</tr>
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<tbody>
<tr>
<td>0</td>
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<td></td>
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<tr>
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<tr>
<td>120</td>
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</tr>
</tbody>
</table>

The graph shows the temperature changes over time for outflowing air, air in the chamber, and inflowing air.
Air Movements - Autoclave Opening - CFD

RESULTS - Case 1 - No HEPA-filter above the opening
RESULT - Case 1 - No HEPA-filter above the opening
Air Movements - Autoclave Opening - CFD

RESULT - Case 2 and 3
HEPA-filter above the opening
Air Temperatures - Autoclave Opening - CFD

RESULTS - Case 2 and 3

HEPA-filter above the opening

0.45m/s

+56°C

+62°C

+50°C

-45°C

+38°C

+27.5°C

0.90m/s

+45°C

+38°C

+27.5°C

+26°C

+20°C
Air Velocities - Autoclave Opening - CFD

RESULTS - Case 2 and 3
HEPA-filter above the opening
Air Movements - Autoclave Opening - CFD

RESULTS - Case 4 and 5
HEPA-filter at the side of the opening

0.45m/s 0.90m/s
Air Velocities - Autoclave Opening - CFD

RESULTS - Case 4 and 5

HEPA-filter at the side of the opening

0.45m/s

0.90m/s
Air Temperatures - Autoclave Opening - CFD

RESULTS - Case 4 and 5

HEPA-filter at the side of the opening

0.45m/s

0.90m/s
SUMMARY - CFD

Chamber openings with outflow in upper part are preferably protected by

- Horizontal airflow (0.45m/s or 0.9m/s)
- Vertical airflow with high air velocity (approx. 0.9m/s)
REFERENCES

