Numerical simulation of the air flow distribution in the air shower area of a clean room

Mahmoud Fouad* and Taher Halawa**

* Professor  ** Lecturer

Mechanical Power Engineering
Faculty of Engineering
Cairo University
Introduction
Airborne Particles

- People in the work space generate particles in the form of skin flakes, lint, cosmetics, and respiratory emissions.
- A human hair is about 75-100 microns in diameter. A particle 200 times smaller (0.5 micron) than the human hair can cause major disaster in a clean room.
Particles Sources

External Sources

- Infiltration through doors, windows and wall and ceiling penetrations.
- Outside makeup air entering through the air conditioning.
- Controlled primarily by air filtration, room pressurization and sealing of space penetrations.

Internal Sources

- People, clean room surface shedding, process equipment and the manufacturing process itself.
- Controlled with new clean room garments, proper gowning procedures and airflow designed to continually shower the workers with clean air.
Particle generation rate for persons

People are the major source of contamination in the clean room released from skin flakes and oil, hair, spittle, cosmetics & perfume, clothing debris.

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>PARTICLES</th>
<th>DESCRIPTION OF ACTIVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100,000</td>
<td>MOTIONLESS IN EITHER SITTING OR STANDING POSITION</td>
</tr>
<tr>
<td></td>
<td>500,000</td>
<td>HANDS, FOREARMS, NECK AND HEAD MOTION</td>
</tr>
<tr>
<td></td>
<td>1,000,000</td>
<td>HANDS, ARMS, TRUNK, NECK, HEAD MOTION AND SOME LOWER BODY MOTION</td>
</tr>
<tr>
<td></td>
<td>2,500,000</td>
<td>SITTING TO STANDING OR VICE VERSA</td>
</tr>
<tr>
<td></td>
<td>5,000,000</td>
<td>WALKING AT 2.0 MPH</td>
</tr>
<tr>
<td></td>
<td>7,500,000</td>
<td>WALKING AT 3.5 MPH</td>
</tr>
<tr>
<td></td>
<td>10,000,000</td>
<td>WALKING AT 5.0 MPH</td>
</tr>
</tbody>
</table>

Source: -(Austin and Timmerman 1965).
Objectives

- Making an unsteady CFD simulation of the air showering process in the air shower room.

- Studying the effect of changing airflow direction on the particles distribution.
Description of the Clean Room Existing Design
Existing design of the clean room
Gowning Room

Gowning board

Door

Door
Main Room

- 21 lamps
- 10 inlet grilles
- 9 exhaust grilles
Numerical Modeling
CFD Modeling

Standing human model
Boundary Conditions

Boundary Conditions of Occupant's bodies and faces (heat source and H₂O source)

• The mass flow or expired air from the occupants is calculated as $2 \times 10^{-4}$ kg/s per occupant based on 20 times per minute, Schottelius (1978), during normal activity.

• The volume of the H₂O gas in the expired air from occupant is 6.2% of the total volume of the expired air.

• The occupant's bodies as obstacles, having a temperature of 37 °C, Guyton (1986), and heat generation rate based on occupant's activity.
# Airborne particles generation from persons

<table>
<thead>
<tr>
<th>Activity</th>
<th>Underpants (particles/min)</th>
<th>Cleanroom garment (particles/min)</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting still</td>
<td>40,000</td>
<td>40,000</td>
<td>1.0</td>
</tr>
<tr>
<td>Sitting: arm movements</td>
<td>90,000</td>
<td>70,000</td>
<td>1.3</td>
</tr>
<tr>
<td>Standing: rotation torso</td>
<td>140,000</td>
<td>60,000</td>
<td>2.0</td>
</tr>
<tr>
<td>Walking on the spot</td>
<td>400,000</td>
<td>180,000</td>
<td>2.2</td>
</tr>
</tbody>
</table>

**Particle strength from person (particles /minute)**

![Graph showing particle number concentration vs. aerodynamic particle diameter](image)

Source: Ramstorp et al. (2005)
Existing design versus proposed design for the air shower room
Existing design

Proposed design
Results
[Existing Design]
Path lines of air during air shower for the existing design
Particles concentration (µg/m³) at different time frames during air shower process.

- t= 5 sec
- t= 10 sec
- t= 15 sec
- t= 20 sec
- t= 25 sec
- t= 30 sec
- t= 35 sec
- t= 40 sec
Results

[Proposed Design]
Path lines of air during air shower for the proposed design

At the beginning of the 1st stage of the air shower process

At the beginning of the 2nd stage of the air shower process
Particles concentration ($\mu$g/m$^3$) at different time frames during air shower process

t= 30 sec  t= 35 sec  t= 40 sec  t= 45 sec

t= 50 sec  t= 55 sec  t= 60 sec
Conclusions

- The air shower room is very important because it helps to minimize the number of airborne particles which exist on the human body and on the clothes specially when the outdoor air is highly contaminated.

- The air showering process should get rid of air borne particles and pushes them away from the human body, and this can be achieved by using unidirectional air shower which forces particles to leave the human body and go downward. Also the unidirectional air flow prevents turbulence and circulation of air.

- Using air jets at the side walls is essential because the turbulence generated can create a momentum to move particles from the human body but the downward air flow can help to control the path of particles motion so, it is recommended to make an integrated system that will combine these two effects.