Design, Construction and Cost Estimate of Cleanroom for Pharmaceutical Industry

8 APRIL 2005

Presented by Usa Panpunuan
Design, Construction and Cost Estimate of Cleanroom for Pharmaceutical Industry

About the presenter: Usa Panpunuan

Professional Experience

- Experience in many aspects of mechanical engineering ranging from design of
  - HVAC System and Cleanroom
  - Sanitary System
  - Fire Protection System
  - Utility System (e.g. Compressed Air System, and Gas System, etc.)
- Experience in design of many industrial and commercial projects
  - For Pharmaceutical Industry: The Government Pharmaceutical Organization, Better Pharma, Capsulgel
  - For Electromechanical Industry: Canon, Toshiba, Hitachi, Pemstar, NEC
  - For Petrochemical Industry: Bayer, Starsoleil
  - For Eye glasses lens Industry: Hoya, Rodenstock
  - For Food and Beverage Industry: Pepsi, Ajinomoto
  - For Automobile Industry: Thai–Honda Manufacturing, NHK Spring, Tripetch Isuzu, Asian Auto Part
  - For Commercial Building & Hotel: MTRA underground train, All seasons place, Conrad hotel, Oriental hotel, many office buildings, many condominiums

Educational Background

- M. Eng. (Industrial Engineering), Chulalongkorn University
- B.Eng. (Mechanical Engineering), Kasetsart University

Objectives

- To outline the basic principles of Cleanroom
- To outline the basic principles of Cleanroom for Pharmaceutical Industry
- To review facilities for Pharmaceutical Plant
- To outline standards and guidelines that are the technical concern for Cleanroom
- To outline the concept of Design, Construction, and Cost Estimate for Cleanroom
Design, Construction and Cost Estimate of Cleanroom for Pharmaceutical Industry

Key points to be discussed

- What is Cleanroom?
- Design of Cleanroom and Facilities for Pharmaceutical Industry
- Cleanroom Construction In Pharmaceutical Industry
- Cost Estimate of Cleanroom In Pharmaceutical Industry

What is Cleanroom?

- Introduction to cleanroom
- Definition of Contamination
- Sources of Contamination
What is Cleanroom? : Introduction to cleanroom

- It is clear that a cleanroom is a room that is clean!!!
- A cleanroom now has a special meaning!!!
  - **Federal Standard 209 E**
    “A room in which the concentration of airborne particles is controlled and which contains one or more clean zones”
  - **ISO 14644-1**
    “A room in which the concentration of airborne particles is controlled, and which is constructed and used in a manner to minimize the introduction, generation, and retention of particle inside the room and in which other relevant parameters, e.g. temperature, humidity, and pressure, are controlled and necessary”

What is Cleanroom? : Definition of Contamination

- In cleanroom technology, contaminates are understood to be not only dust particles in the strict sense, but any disturbing effects of a solid, liquid, gaseous, thermal or electromagnetic nature capable of having a negative influence on the course of a process and the quality of a product.
- The size of particles is defined in microns (abbreviated µm) i.e. “small” in Greek. One micron is a millionth of a meter or a thousandth of a millimetre.
  As a comparison, one human hair has a diameter of about 60 - 80 microns; all particles from about 5 microns down are present in the air and are therefore called suspended particles.
What is Cleanroom? : Definition of Contamination

Particle Sizes and Distribution

- Smoke particle
- Silt in Read/Write Head
- Dust particle
- Fingerprint
- Human Hair

The read/write head travels at a speed of more than 200 kph across the magnetic plate, at a distance of less than 0.5 micron, which is smaller than the diameter of a human hair.

What is Cleanroom? : Sources of Contamination

Percentage Distribution of the Sources of Contamination

- People: 30 - 40%
- Equipment: 20 - 30%
- Process: 20 - 30%
- Media: 5 - 10%
- Air: 5 - 10%

It is important to take the contamination from people into account, which contributes considerable 30% of the total contamination in the cleanroom.
## What is Cleanroom? : Sources of Contamination

<table>
<thead>
<tr>
<th>External Impurities</th>
<th>Internal Impurities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction of contaminated outside air or circulating air *</td>
<td>Staff</td>
</tr>
<tr>
<td>Staff</td>
<td>Process</td>
</tr>
<tr>
<td>impure process media or raw materials</td>
<td>Production equipment, machines, tools etc.</td>
</tr>
<tr>
<td>Inadequately cleaned materials, tools etc.</td>
<td>Unsuitable building materials, work materials</td>
</tr>
<tr>
<td>* poor filter quality, none airtight filter seal surfaces, leakage in the ducting system, abrasion in air recirculation equipment and in the ducting system</td>
<td>Mechanical abrasion in the cleanroom</td>
</tr>
</tbody>
</table>

## Emission of Particles by People making various Movements without Cleanroom Clothing

<table>
<thead>
<tr>
<th>Particle Emission per Minute and Person</th>
<th>Type of Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 000</td>
<td>Standing and sitting without moving</td>
</tr>
<tr>
<td>500 000</td>
<td>Sitting with gentle movement of head, hand or lower arm</td>
</tr>
<tr>
<td>1 000 000</td>
<td>Sitting with moderate body and foot movement</td>
</tr>
<tr>
<td>2 500 000</td>
<td>Standing up with full body movement</td>
</tr>
<tr>
<td>5 000 000</td>
<td>Slow walking - approx. 3.5 km/h</td>
</tr>
<tr>
<td>7 500 000</td>
<td>Walking at about 6 km/h</td>
</tr>
<tr>
<td>10 000 000</td>
<td>Walking at about 9 km/h</td>
</tr>
<tr>
<td>15 - 30 000 000</td>
<td>Gymnastics and sports</td>
</tr>
</tbody>
</table>

Germ emission per minute (according to Botzenhart) 1 000 - 13 000 CFU depending on activity
Design of Cleanroom and Facilities for Pharmaceutical Industry:
Cleanroom and Facilities Design

Design step

1. Define User Requirements
2. What facilities are needed to be designed follow URS?
3. Review cleanroom technology for pharmaceutical industry
4. Basis of design
5. Conceptual design
6. Detail design

Key Point
• To understand the requirement to develop the project
  • Production purpose and process
  • Activity flow (human, materials, products, equipment and others)
• To discuss and confirm design conditions and utility which are required by the project

What is URS?
• URS = User Requirement Specification
• URS = Approved statements prepared by the user which define what is required by the project

Importance of URS
• URS should be sufficiently detailed to enable design specifications to be developed
Design, Construction and Cost Estimate of Cleanroom for Pharmaceutical Industry

Design of Cleanroom and Facilities for Pharmaceutical Industry: Cleanroom and Facilities Design

1. Define User Requirements

From URS, the design team will know / define in cleanroom design:

- **Process**
  - Process Equipment
  - Capacity and qualification for process equipment
  - Product segregation philosophy
  - Material Flow
  - Process Flow
  - Personnel flow
  - Process and product support facilities
  - Space for Manufacturing process equipment and storage

- **Utility**
  - Types of utilities
  - Qualification philosophy to determine Critical and Non-critical utilities
  - Capacity and qualification for utilities

2. What facilities are needed to be designed follow URS?

- **Process**
  - Process flow
  - Personnel flow
  - Material flow
  - Waste flow
  - Process equipment & Layout
  - Facilities to support process
    - WFI, Tap Water, Compressed Air
    - Purify Water, Drainage, Nitrogen Gas
    - DI Water, Process Steam, Vacuum

- **Building (Architectural, Civil & Structural works)**

- **HVAC & Cleanroom system**

- **Building facilities**
  - Electrical system
  - Fire protection system
  - Sanitary & Plumbing system
Design of Cleanroom and Facilities for Pharmaceutical Industry: Cleanroom and Facilities Design

2. What facilities are needed to be designed follow URS?

Process layout and activity flow

- Compressed Air
- Process steam
- Purify Water
- Vacuum
- Electrical
- DI Water
- Tap Water
- Drainage
- Fire Protection
3. Review Cleanroom Technology for Pharmaceutical Industry

- Classification of Cleanroom
- Guidelines and standards for the design of cleanroom and facilities
- Pharmaceutical Cleanroom Classification
- Pharmaceutical Cleanroom Structure
- How to keep room clean?

### 1 Federal Standard 209 E

<table>
<thead>
<tr>
<th>Class</th>
<th>Particles / ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≥ 0.1 µm</td>
</tr>
<tr>
<td>1</td>
<td>35</td>
</tr>
<tr>
<td>10</td>
<td>350</td>
</tr>
<tr>
<td>100</td>
<td>NA</td>
</tr>
<tr>
<td>1,000</td>
<td>NA</td>
</tr>
<tr>
<td>10,000</td>
<td>NA</td>
</tr>
<tr>
<td>100,000</td>
<td>NA</td>
</tr>
</tbody>
</table>
Review Cleanroom Technology for Pharmaceutical Industry: Classification of cleanroom

2 ISO Standards

Table 2: Selected ISO 14644-1 airborne particulate cleanliness classes for cleanrooms and clean zones

<table>
<thead>
<tr>
<th>ISO Classification number</th>
<th>≤ 0.1µm</th>
<th>&gt; 0.1µm</th>
<th>&gt; 0.2µm</th>
<th>&gt; 0.3µm</th>
<th>&gt; 0.5µm</th>
<th>&gt; 1µm</th>
<th>&gt; 5.0µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO Class 1</td>
<td>10</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISO Class 2</td>
<td>100</td>
<td>24</td>
<td>10</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISO Class 3</td>
<td>1 000</td>
<td>237</td>
<td>102</td>
<td>35</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISO Class 4</td>
<td>10 000</td>
<td>2 370</td>
<td>1 020</td>
<td>352</td>
<td>83</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>ISO Class 5</td>
<td>100 000</td>
<td>23 700</td>
<td>10 200</td>
<td>3 520</td>
<td>832</td>
<td>293</td>
<td></td>
</tr>
<tr>
<td>ISO Class 6</td>
<td>1 000 000</td>
<td>237 000</td>
<td>102 000</td>
<td>35 200</td>
<td>8 320</td>
<td>2 930</td>
<td></td>
</tr>
<tr>
<td>ISO Class 7</td>
<td></td>
<td></td>
<td></td>
<td>352 000</td>
<td>8 320</td>
<td>2 930</td>
<td></td>
</tr>
<tr>
<td>ISO Class 8</td>
<td></td>
<td></td>
<td></td>
<td>3 520 000</td>
<td>8 320 000</td>
<td>29 300</td>
<td></td>
</tr>
<tr>
<td>ISO Class 9</td>
<td></td>
<td></td>
<td></td>
<td>35 200 000</td>
<td>8 320 000</td>
<td>293 000</td>
<td></td>
</tr>
</tbody>
</table>

Maximum concentration limits (particles/m³ of air) for particles equal to and larger than the considered sizes shown below

ISO Classification number

Comparison between FS 209 and ISO 14644-1

Table 3: Comparison between selected equivalent classes of FS 209 and ISO 14644-1

<table>
<thead>
<tr>
<th>ISO 14644-1 Classes</th>
<th>Class 3</th>
<th>Class 4</th>
<th>Class 5</th>
<th>Class 6</th>
<th>Class 7</th>
<th>Class 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS 209 Classes</td>
<td>Class 1</td>
<td>Class 10</td>
<td>Class 100</td>
<td>Class 1000</td>
<td>Class 10 000</td>
<td>Class 100 000</td>
</tr>
</tbody>
</table>
Review Cleanroom Technology for Pharmaceutical Industry:
Guidelines and standards for the design of cleanroom and facilities

A. Guidelines for design of cleanroom and pharmaceutical

- **GMP**: Good Manufacturing Practice
- **ISPE**: International Society of Pharmaceutical Engineering

The most used GMP guides for cleanroom

- **PIC**: GMP and Guidelines
  - Valid in European countries outside the EU and Australia
- **FDA cGMP**: Valid for the United States
- **EU GGMP**: Valid for the EU area

B. Standards for design of cleanroom and facilities

- **ASHRAE**: American Society of Heating, Refrigerating, and Air Conditioning Engineers
- **ARI**: Air Conditioning Refrigeration Institute
- **SMACNA**: Sheet Metal and Air Conditioning Contractor’s National Association Inc.
- **ASME**: American Society of Mechanical Engineers
- **ASTM**: American Society of Testing and Materials
- **ANSI**: American National Standard Institute
- **IEC**: International Electromechanical Commissions
- **NEC**: National Electrical Code
- **NFPA**: National Fire Protection Association
- **NPC**: National Plumbing Code
- **ISO**: International Organization for Standardization
- **TIS**: Thai Industrial Standard
- **EIT**: The Engineering Institute of Thailand
Design, Construction and Cost Estimate of Cleanroom for Pharmaceutical Industry

Review Cleanroom Technology for Pharmaceutical Industry:
Pharmaceutical Cleanroom Classification

European Union Guide to Good Manufacturing Practice

Table a: Airborne classification in the EU GGMP

<table>
<thead>
<tr>
<th>Grade</th>
<th>Maximum permitted number of particles/m³ equal to or above</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>at rest</td>
</tr>
<tr>
<td>A</td>
<td>3 500</td>
</tr>
<tr>
<td>B</td>
<td>3 500</td>
</tr>
<tr>
<td>C</td>
<td>350 000</td>
</tr>
<tr>
<td>D</td>
<td>3 500 000</td>
</tr>
</tbody>
</table>

• Larminar flow type cleanroom

• Turbulent flow type cleanroom
**Laminar Flow Type Cleanroom**

- Ceiling with integrated HEPA Filter
- Cleanroom Class 100 (A/B) with laminar airflow

**Advantages:**
- easy operator access
- flexible layout

**Disadvantages:**
- high investment and operation costs

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**Turbulent Flow Type Cleanroom**

- HEPA Filter installed in filterbox
- Cleanroom Class 10 000 (C/D) with turbulent airflow
- Clean Cabin Class 100 (A/B) with laminar airflow

**Advantages:**
- Low investment and operation cost

**Disadvantages:**
- Limited flexibility and operator access
Review Cleanroom Technology for Pharmaceutical Industry: How to keep room clean?

- Do not allow the dust to flow into or bring into the room
- To minimize the dust generating source
- Do not accumulate and redisperse the dust
- To remove the generated dust before it spread

Air filtration
Make up clean air
Clean up system
  - Air lock room
  - Air shower
  - Pass box
To minimize the dust generating source
e.g. dress code

Dress step
1. Prior to entering
2. Blue overshoes over your own shoes
3. Headcover: make sure all hair is inside, tighten if possible
4. Coverall: hold in sleeves and waist, step in as high as possible, tighten if possible
5. Cleanroom boots: tighten under knees and over shoes
6. Gloves: do not touch outside of fingertips with bare hands
Note: Taking off: the other way around

Do not accumulate and redisperse the dust
- Clean up system for room and equipments
- Exhaust system

To remove the generated dust before it spread
e.g. Staff working instruction

Do
- Wear hair under head cover
- Shave regularly
- Change gloves whenever dirty or torn
- Use a fresh pair of gloves whenever handling wafers
- Wipe down wafer handling areas with isopropanol
- Use cleanroom paper and dust-free ballpoint pens
- Remove used items
- Clean spills immediately

Don't
- Touch your face or skin with gloves
- Touch building hardware, oily machinery, or wafer loading areas
- Lean on equipment
- Wear cosmetics, powders or colognes
- Wear anything on fingers: remove all rings and bracelets
- Use paper, pencil or markers that leave dust or lint
Design, Construction and Cost Estimate of Cleanroom for Pharmaceutical Industry

Design of Cleanroom and Facilities for Pharmaceutical Industry:
Cleanroom and Facilities Design

4. Basis of Design

Key Point

- To outline the following concept to develop the project
  - The site (Area Size and Location)
  - Production requirements
  - Room layouts and operation
  - Process & plant utilities

- To establish budget to develop the project (with contingency ± 20%)

Example of basis of design of utilities

* Chilled Water
  Chiller plant will provide water in the range of 5°C to 11°C to the AHU systems cooling coils. Process chilled water for vessel cooling may be required but will be determined during the design development.

* Instrument Air
  Instrument air will be provided as a separate system. The plant will include oil-free compressors, receivers, air dryer and pressure control equipment. The air must be oil-free and should conform to the requirements of ISO. 8573 Quality Class 2.

* Plant Steam
  The usage for plant steam will be minimal and may be used for the generation of hot water for domestic or process use. The provision of a small electrode type boiler may be sufficient.
5. Conceptual Design

Key Point

- To outline description of process, building, facility and utilities which are required to develop the project
- To outline system description for process, building, facility and utilities
- To outline criteria for process, building, facility and utilities
- To calculate capacity of utilities (e.g. cooling load calculation)
- To summarize machine, equipment, and material for process, building, facility and utilities
- To provide equipment schedule of main equipment for process, building, facility and utilities
- To prepare building layout
- To prepare equipment layout
- To provide schematic of process, facility and utilities
- To establish budget to develop the project (with contingency ± 15%)

HVAC System design consideration

- Proper design consideration
- Design cleanroom complying guidelines and standards (e.g. GMP, ASHRAE, FS 209 E)
- Separation and local treatment of heat, generation and contamination materials
- Operation ratio and demand factor
- Minimize high grade area (e.g. cleanroom class 100A)
- Partial load operation
- Flexibility for production layout change
- Backup system and trouble shooting
- Environmental issue
- Safety
- Energy conservation
Design of Cleanroom and Facilities for Pharmaceutical Industry: Cleanroom and Facilities Design

5. Conceptual Design

Construction Material and Surface Finishes for Cleanroom

Material design consideration

- Non-dust generation from surface
- Easy to clean
- Air tight
- Conductivity
- Out-gas
- Chemical resistance
- Fire safe

• Architectural works
  - Wall
  - Ceiling
  - Floor
  - Door
  - Window

Utility Columns  Cleanroom Solutions  Cleanroom Partitions
GMP-conform ceilings for the Pharmaceutical Industry  Cleanroom ceilings with dry and fluid seals
Design, Construction and Cost Estimate of Cleanroom for Pharmaceutical Industry

Design of Cleanroom and Facilities for Pharmaceutical Industry:
Cleanroom and Facilities Design

Construction Material and Surface Finishes for Cleanroom

- **Accessories for cleanroom**
  - Air shower
  - Pass-box
  - Cross-over bench
  - Cabinet

- **HVAC system for cleanroom**
  - Air handling unit
  - Air filter
  - Fan filter unit (Laminar flow)
  - Air grille
  - Relief damper

Thai FDA Presentation by Usa Panpunuan
Design, Construction and Cost Estimate of Cleanroom for Pharmaceutical Industry

Design of Cleanroom and Facilities for Pharmaceutical Industry:
Cleanroom and Facilities Design

Construction Material and Surface Finishes for Cleanroom

- Other facilities for cleanroom
  - Lighting fixture
  - Automatic control system
5. Conceptual Design

Example of conceptual design of HVAC system

System description for HVAC system

The HVAC system provided for medicinal product buildings shall be the centralized chilled water system served by water-cooled chillers.

HVAC system for Clean Room Class 100,000 will conform to the ISO standard 14644 and Federal Standard No. 290E of U.S.A. Air Conditioning System shall be the conventional clean room system (Turbulent Flow).

Air handling units shall be double skin module type.

Criteria for HVAC system

1. Cleanliness
2. Temperature
3. Humidity
4. Air flow pattern
5. Noise level
6. Vibration
7. Room air pressure
8. Electro static charge
9. Chemical gas
10. Odor
11. Lighting
Design of Cleanroom and Facilities for Pharmaceutical Industry: Cleanroom and Facilities Design

5. Conceptual Design

Example of heat source in cleanroom for design of HVAC system

Criteria for HVAC system

<table>
<thead>
<tr>
<th>Condition</th>
<th>Temp (°C)</th>
<th>Rel. Humidity (% RH)</th>
<th>Pressure (Pa)</th>
<th>Cleanliness (Class)</th>
<th>Air flow pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean corridor</td>
<td>22 +/- 2</td>
<td>50 +/- 10</td>
<td>+</td>
<td>100K</td>
<td>at rest</td>
</tr>
<tr>
<td>Sterile gowning</td>
<td>21 +/- 2</td>
<td>50 +/- 10</td>
<td>+++</td>
<td>100B</td>
<td>at rest</td>
</tr>
<tr>
<td>De-gowning</td>
<td>22 +/- 2</td>
<td>50 +/- 10</td>
<td>++</td>
<td>10K</td>
<td>at rest</td>
</tr>
<tr>
<td>Mixing room</td>
<td>21 +/- 2</td>
<td>50 +/- 10</td>
<td>++++</td>
<td>100A</td>
<td>at rest</td>
</tr>
<tr>
<td>Preparation room</td>
<td>22 +/- 2</td>
<td>50 +/- 10</td>
<td>++</td>
<td>10K</td>
<td>at rest</td>
</tr>
</tbody>
</table>
5. Conceptual Design

Example of conceptual design of HVAC system

Room layout (plan)
Design of Cleanroom and Facilities for Pharmaceutical Industry:
Cleanroom and Facilities Design

5. Conceptual Design
Example of conceptual design of HVAC system
Schematic of HVAC system

6. Detail Design
Key Point
- To develop drawing follows conceptual design for construction and installation work
- To prepare technical specification of equipment and material for construction and installation work
- To establish budget to develop the project (with contingency ± 15%)
Design, Construction and Cost Estimate of Cleanroom for Pharmaceutical Industry

Design of Cleanroom and Facilities for Pharmaceutical Industry:
Cleanroom and Facilities Design

6. Detail Design
   Example of detail design of HVAC system
   Room layout (Plan)

Design, Construction and Cost Estimate of Cleanroom for Pharmaceutical Industry:
Cleanroom and Facilities Design

6. Detail Design
   Example of detail design of HVAC system
   Room layout (Section)
Design, Construction and Cost Estimate of Cleanroom for Pharmaceutical Industry

Construction of Cleanroom and Facilities for Pharmaceutical Industry

■ Facilities needed to be constructed

- Building (Architectural, Civil & Structural)
- HVAC & Cleanroom system
- Building facilities
  - Electrical system
  - Fire protection system
  - Sanitary & Plumbing system
- Process facilities
  - WFI
  - Purify Water
  - DI Water
  - Tap Water
  - Drainage
  - Process Steam
  - Compressed Air
  - Nitrogen Gas
  - Vacuum

Clean Construction Protocol

■ Stages of Construction Cleanliness:
  - Normal Clean
  - Very Clean
  - Ultra Clean

■ Quality Assurance:
  - Clean Working Protocol
    - Use lint-free paper & cleanroom-approved pens
    - Visitors should not enter the cleanroom, if not necessary
    - No eating, drinking or smoking, cosmetic
    - Do not allow both doors of the cleanroom and of the smock area to be opened at the same time
    - No hydrocarbon lubricants
  - Gowning
    - Garmrnts: wear a head cover, facemask, jumpsuit, and shoe cover
    - Use properly fitting vinyl or rubber disposable gloves
Design, Construction and Cost Estimate of Cleanroom for Pharmaceutical Industry

Project Management and Construction
- Project Planning
- Construction Analysis
- Projects Scheduling
- Cost Maintain
- Construction Management & Supervision Quality Management

Procurement Services & Materials Management
- Field Engineering
- Safety Management
- Commissioning & Start-Up

Cost Estimate of Cleanroom and Facilities for Pharmaceutical Industry

Cost estimate step

<table>
<thead>
<tr>
<th>Period</th>
<th>Contingency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feasibility study</td>
<td>+/- 30 %</td>
</tr>
<tr>
<td>Basis of design</td>
<td>+/- 20 %</td>
</tr>
<tr>
<td>Conceptual design</td>
<td>+/- 15 %</td>
</tr>
<tr>
<td>Detail design</td>
<td>+/- 15 %</td>
</tr>
</tbody>
</table>
Design, Construction and Cost Estimate of Cleanroom for Pharmaceutical Industry

Cost Estimate of Cleanroom and Facilities for Pharmaceutical Industry

- Facilities needed to be estimated
  - Architectural
  - Civil & Structural
  - HVAC & Cleanroom system
  - Building facilities
    - Electrical system
    - Fire protection system
    - Sanitary & Plumbing system
  - Process facilities
    - WFI
    - Purify Water
    - DI Water
    - Tap Water
    - Drainage
    - Process Steam
    - Compressed Air
    - Nitrogen Gas
    - Vacuum