Economical Approaches to Clean Space

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ABSTRACT

For nanotech research facilities, whether new construction or retrofit, clean space commonly becomes one of the expensive, hard-to-to-integrate imbedded-space program elements.

- How to cut the cost?
- How to incorporate it into the total building envelope?

Recent case studies illustrate key nanotech research program activities requiring clean space and address the big question: "Imbedded clean spaces – Where to put them, and why?"

Keywords: hazardous production materials (HPM's), clean class, occupancy rating

1 COST DRIVERS

The most expensive components of a clean space are typically driven by the environment requirements. These characteristics of a space are generally captured on a room conditions or room data sheets. Common characteristics include the clean classification, temperature, humidity, vibration and EMI requirements. These requirements are primarily driven by the process equipment and/or the process being performed within the clean space.

Some other costly features of a clean space that are not normally realized are items such as: the use of HPM's, raised floor or subfab, and even the height of the cleanroom. In many, if not all, cases these common and not so common cost drivers affect each other, either in performance or cost. Understanding how these characteristics affect each other plays a key role in controlling the escalating costs of your clean space.

1.1 Clean Classification

The clean classification of a cleanroom is primarily driven by the process being performed within the clean environment. Clean class is a measurement of particle size per cubic meter using the ISO 14644 standard, previously Federal Standard 209E. Table 1 below shows the relationship between particle counts and clean classification.

ISO 14644-1 Class	FED-STD 209E Class	0.5µ Particles Per/m^3	0.5µ Particles Per/ft^3
8	100,000	350,000	100,000
7	10,000	35,0000	10,000
6	1,000	35,000	1,000
5	100	3500	100
4	10	350	10
3	1	35	1

Table 1: Clean classification particle counts.

When planning for a clean space the above table can be very helpful. However, in many cases the deciding factor on what clean class to design to is driven by the geometries that are planned for the process. In many cases you may be able to reduce your clean classification requirements in most of the cleanroom; while the Photo/Lithography area maintains the best possible clean class for your process. This type of approach has a large ripple affect on costs particularly related to HVAC.

The clean classification will be the most costly decision that has to be made. This decision has direct impact on the following items that can greatly affect cost.

Key points to remember:

- Air Changes and Treatment
- Quantity Filters
- Quality of Filters (ULPA vs. HEPA)
- Types of Construction Materials
- Cost of Ownership
- Understanding the Process and Geometries will help in selecting the appropriate clean class.

1.2 Height

The height of a cleanroom is commonly missed as a cost driver for the cleanroom. Adding height to the cleanroom adds overall volume to the space. When we look at the requirements of the clean classification selected; not only is particles a factor, but each clean classification also has an air changes requirement. This is measurement of air changes per hour. The better the clean class the more air

changes are required. For example an ISO Class 5 requires a minimum of 240 air changes per hour, where an ISO Class 6 requires a minimum of 150 air changes/hour. These differences in themselves have an impact on HVAC, but when you add height to the equation the overall amount of air to be changed can have a large impact. Let's say we have a single bay of a cleanroom at an ISO Class 5 and is 24'x14' at a height of 10'. The volume of our clean space is 3,360 ft^3; that means we would have to change 3,360ft^3 of air 240 times per hour; that's 806,400 CFH. If we had the same space, but the height is only 9', just one foot less in height the difference is 80,640 CFH. This could make a significant difference in the size of the air handlers required.

Key points to remember:

- Height affects volume of clean space
- Keeping ceiling heights to a minimum can be a cost savings

1.3 Use of Hazardous Production Materials

In these types of clean environments the use of HPM's is fairly common. The major differences between facilities are the quantities of the HPM's in use and on hand. The quantities of particular HPM's directly affect the occupancy rating of a clean space. The typical rating categories are "H" for hazardous and "B" for business. The quantities allowed for a "B" occupancy facility are much less than what is allowed for an "H" rated facility.

Typically the procedure for determining what rating is acceptable for a particular facility, is to understand what HPM's are planned and the quantities. Aggregating the quantities by type of hazard and compare these totals to the maximum allowable quantities per the local codes. Such hazards to be aggregated are; toxic, highly toxic, flammable, pyrophoric, corrosive, oxidizer, etc.. These types of hazards when compared to the maximum allowable quantities will then determine what type of occupancy the clean space will need to be rated. Some differences to be aware of are whether or not the HPM is considered to be in an open or closed situation and whether or not the HPM is in use or in storage. This makes a difference on the overall totals and where the quantities are applied. For example if the HPM's are totaled correctly it may be possible to rate the HPM storage area as an "H" occupancy while the actual processing environment is a "B" rating.

The differences between and "H" and a "B" occupancy area will greatly affect the cost of the facility. Costs are increased for the construction of an "H" rated facility. The construction materials, space requirements, air handling, egress and HPM delivery all needs to be taken into consideration when an "H" rated facility is being constructed. A "B" rated facility does not have many of the same requirements as an "H" rated facility, but industry best practices are usually recommended for some systems.

Key points to remember:

- Quantities of HPM's will affect the occupancy rating of a facility.
- The occupancy rating of a facility will affect the overall cost of the facility.
- Understanding the usage and storage of HPM's and keeping to a minimum may reduce the cost of the facility.

1.4 Humidity Control

The humidity levels in a cleanroom environment can directly impact the process taking place, it can even affect the equipment. Process materials, for example photoresist, can be sensitive to humidity conditions in a cleanroom. Equipment such as specialized metrology or imaging equipment can be greatly affected by humidity that can impact the performance of the equipment and provide in accurate results. To understand what chemicals or equipment is affected by humidity the manufacture specifications and installation guides are typically referenced for the humidity requirements of a space.

The humidity of a clean space is typically controlled at the make-up air handler. However, depending on the humidity requirements the method of chilling can be extremely costly. The lower the humidity requirements the more expensive the HVAC systems will be; a glycol chiller may be required to bring the humidity levels down to the specified requirements. If the humidity requirements are not extremely critical, one item to consider is the geographical location of the facility. In some cases if the climate generally maintains same throughout the year with very little humidity fluctuations it may not be required to provide humidity control; as long it is acceptable to have a certain percentage of spec deviation throughout the year. These types of deviations are normally acceptable for research facilities.

Key points to remember:

- Understand the humidity requirements for the equipment and production materials.
- Does the climate warrant humidity control?

1.5 Raised Floor/Subfabs

In designing new clean space, raised floors and subfabs are often considered. Both raised floors and subfabs are very costly to construct and in the case of a subfab, operating costs must also be considered. Depending on the type of facility to be constructed; is either absolutely necessary? In the case of a Manufacturing facility to produce extreme volumes of product, a subfab and even raised floor may be required. Having a subfab and raised floor in a manufacturing facility will allow for more production equipment to occupy the clean space making better use of the facility. However, in the case of a research

and even small scale production facility neither of these may be warranted. Typically a subfab is used as a location to place the support equipment for the process tools and in some cases the building support systems. Raised floors are primarily used as a location for the distribution of facilities. In a bay and chase cleanroom environment it is common to locate support equipment for process tools in the adjacent chases, eliminating the need for a costly subfab. With proper planning the chase can also be used as the location for the distribution of utilities, removing the need for a raised floor. These methods work very well for research and small production facilities and can reduce costs.

Key points to remember:

- Can process support equipment be located in chases?
- Can distribution of utilities be located in chases?
- Is a subfab or raised floor absolutely necessary?

2 HVAC METHODS

HVAC is going to be the most costly portion of any new clean space. However, there are many methods of HVAC systems for cleanroom environments. These methods can range widely in cost and functionality. Because these systems vary it is critical to understand the requirements for clean class, temperature and humidity.

2.1 Fan Filter Units

Probably the most cost effective HVAC method is the Fan Filter Unit (FFU's). The use of FFU's has pros and cons, which makes it critical to understand the room conditions required for a particular process and tool set.

Below is a list of capabilities (pro's) of the FFU.

- Can fit in a reduced access ceiling space
- Can be individually controlled and monitored.
- If one unit fails the clean space can still operate.
- Each unit can be replaced individually
- Can be very flexible for modular wall modifications.

Below is a list of limitations (con's) of the FFU.

- No reconditioning of recirculated air
- No local control for temperature and humidity
- All conditioning of air occurs at make-up air unit
- Tend to generate noise at level above requirements for sensitive process equipment.
- Fan motors add heat to the room.

3 PHYSICAL CONSTRAINTS

With new construction physical constraints can be items such as structural columns, dedicated pathways requirements. The same constraints are true for retrofits, but retrofits have additional constraints due to the existing structure and adjacent spaces.

3.1 Columns

Columns are simply barriers and can cause major interference with layout of process equipment when planning for a new clean space. During new construction there are some options to consider relating to columns. One option is "Clear Span". In a clear span design there will be no columns located within the envelope of the clean space. Although this gives maximum flexibility for wall positioning and process equipment placement, it is very costly. To save costs columns can be located in the cleanroom envelope. To avoid extreme interference with columns it is best practice to locate columns in chases, away from the filtered area.

3.2 Pathways

Pathways can occupy a large amount of useful square footage that could be potentially instead be used for clean space. Typical pathways for these types of facilities are as follows:

- Tool Move-In
- Pedestrian/Viewing Corridor
- HPM Delivery
- Emergency Egress

A cost effective approach would be to double the use of a particular pathway. For example using the Pedestrian/Viewing corridor as Tool Move-In pathway eliminates the need for a dedicated tool path. It may also be possible to use the same corridor as the emergency egress.

Viewing corridors are very desirable especially in research and academic facilities. Again, depending on the rating of the facility the materials of construction can have a cost impact to the construction of the clean space. Viewing aisles generally require a large amount of glass. In a clean environment rated as "H" occupancy a 2 hour rated fire wall is generally required between rated spaces. In this case it may be required to reduce the amount of glass in the rated wall or upgrade the glass to a specific fire rating dictated by the fire and building code.

The HPM delivery pathway will most likely be dependent upon the occupancy rating of the clean space. In a "B" rated occupancy area a dedicated HPM corridor may not be required. However, in an "H" rated facility a dedicated pathway for HPM delivery is required and cannot be used as a pedestrian or egress pathway.

4 CLEANROOM UTILITY PATH

Depending on the configuration of the cleanroom space there may be some cost savings on how the utilities are distributed. There are two typical approaches to

configuring the layout of a cleanroom, center aisle and offset aisle.

4.1 Center Aisle

The Figure below shows a typical center aisle configuration of a cleanroom. With this configuration there are many small bays and chases allowing for more isolated spaces for different applications or users. However, this layout tends to require a duplication of utility runs as shown in the Figure 1. This may also require additional doors at the end of each bay and chase to accommodate all the code and egress requirements.

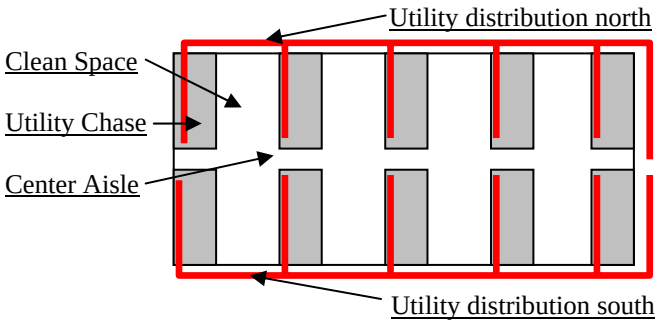

Figure 1: Center Aisle Configuration

4.2 Offset Aisle

Figure 2 below shows a typical offset aisle cleanroom configuration. With this type of layout there are fewer bays, but the bays a longer with more continuous linear wall space. This also allows for all utilities to be distributed on one side of the cleanroom, this is very helpful for continual maintenance of the space. This configuration will also reduce the amount of doors that will be required for egress depending on the local code requirements. In many cases the configuration shown in Figure 2 is often less expensive configuration architecturally and mechanically.

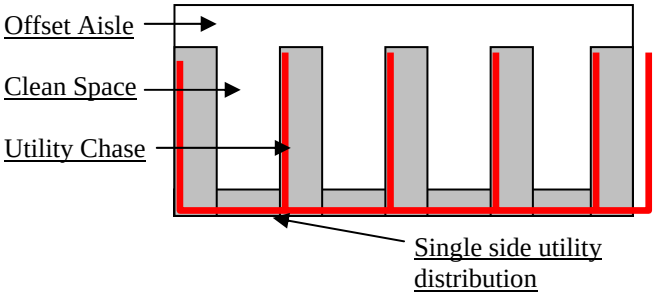

Figure 2: Offset Aisle Configuration

5 CODE RESTRICTIONS

Code will play a huge role in the design of any new or retrofit of a cleanroom. Having an understanding of what the impacts the code will help reduce the costs associated with the code requirements.

5.1 Gas and Chemical Quantities

As mentioned previously, exceeding the maximum allowable quantities of hazardous production materials may force certain code requirements to be incorporated into the facility. For example code may dictate that the following items are required based on the amount of HPM's on hand.

- Dedicated HPM delivery corridor
- Dedicated ventilation
- Special abatement/scrubbing systems
- 24 hour manned monitoring service
- Rated walls

These are a sample of some of the more costly items either during construction or on going operating costs. Knowing how much HPM's are needed and how often can possibly eliminate the need for these types of requirements.

5.2 Consider Alternate Options

One method for minimizing the requirements outlined above is to research alternate options. When determining what HPM's are needed and how much; it is critical to understand how often they must be replenished. Many times operational procedures can be used to reduce the amount of chemicals and gases that are needed to be on hand at any given time. For example when considering a delivery method of gases and chemicals look at a "Just in time" delivery practice. This will eliminate the need to keep any chemicals or gases in storage, thus reducing the amount of HPM's on hand. This works very well for research and academic facilities.

Another option may be to minimize the number of locations where the HPM's are kept. If a central storage and distribution area can be used; the amount of hazardous space can be kept to a minimum. This is primarily done by focusing the "H" rated area at the distribution and storage areas.

REFERENCES

[1] ISO 14644-1 Cleanroom Classifications
[2] Federal Standard 209E Cleanroom Classification