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Indian Society of Heating Refrigerating & Air Conditioning Engineers

ISHRAE
Delhi Chapter

I-SHARE

By Delhi Chapter of ISHRAE

Vol. XVII, Issue 3, Society Year 2025-26, Editor : Dr. Arunendra K. Tiwari, Co-editor : Tapas Kushwaha

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Dear ISHRAE Members,

Greetings from Delhi Chapter of ISHRAE (DCI),

It gives me immense joy to connect with you again thru the **Third Edition of I- SHARE** and I am grateful to all the ISHRAE members of Delhi chapter for their wholehearted dedication and support.

In the third quarter of this society year starting October, DCI aggressively worked with focused approach on **making new members and renewals** and **surpassed the target of 200 new membership** given by HQ for the society year 2025-2026 getting special recognition and appreciation by national leadership at **second SBOG -Colombo (Sri Lanka) (14-16 November)**.

We have now 213 New members and 135 renewals as of today as I write it, taking total memberships at DCI to 1903 making DCI distinguishing itself as largest chapters in all of 61 chapters in India and abroad. This could be achieved due to overwhelming support and enthusiasm of participants in our programs, workshops, IKTs and Seminars by Contractors, manufacturers, Consultants, Academia, builders, PMCs, OEMs etc.

We have **achieved 100% of the chapter programs targets**, be it Distinguished Lectures, Full day workshops, Half day workshops, ITDs, IKTs, IECs, Refrigeration programs and national programs.

We have also already installed **six student chapters with active student strength of 200** so far this year and aggressively doing student engagement and internship programs which are being carried out at each of these colleges. On K-12 front We have done several programs on education, cleanliness &Energy saving.

I would specially like to mention day long "**Climate Summit**" program done on 4th of October at the Le-Meridian Hotel New Delhi on the theme "A movement of accelerating Climate Action for a Net Zero Future" attended by 300 experts from industry & bringing in focus climate responsive design and actions by all stakeholders to contain the rising temperatures, melting of glaciers, biodiversity losses, extreme weather, Pollution, flash floods, greenhouse gases etc. **We also had the distinction of achieving carbon neutrality for this Event** in accordance with PAS 2060-2014 marking it as the first carbon neutral event done by any ISHRAE chapter this society year.

The much-awaited **DCI cricket cup tournament 2025** in its **5th Edition** was also organized at Wisteria Cricket grounds on 1st and 2nd November with 16 top teams from our Industry playing passionately to get the **Trophy and BMW bike** that was to be won in final match. This year **GRUNDFOS** team played exceptionally well and won final match in a nail-biting day night final. These matches were attended by 1000+ spectators of the industry including members (and families) of ISHRAE, OEMs, System Integrators and Service Provider, Prominent Consultants & Architects and senior project officials and management of end clients (Real estate developers and business groups). DCI cup has become a big Mela for 2-3 days every year for fun, sun, food, sports and networking opportunities for our Industry.

I also would like to share that we are working in close coordination with our sub-chapters for their development. Meerut has been a subchapter for last 16 years but with our efforts **Meerut sub-chapter has been made a full ISHRAE chapter this society year**. Now our focus is to make Lucknow sub chapter also a full ISHRAE chapter. This is important for expanding our communities into further sub-chapters for these chapters and reaching out to a larger geographical area for the benefit of young Engineers, Supervisors, Technicians among other workforces.

This edition of I-Share is special edition for **Pharma Connect 2025** on theme of "**Powering the future of Pharma thru the Excellence in HVAC & R**" as we host Pharma Connect on 13th of December 2025 at Hyatt Place-Haridwar, Haridwar is surrounded by major Pharma Industries in Roorkee, Dehradun, Paonta Sahib & Baddi. It is expected that 200+ experts from Pharma industry shall attend this high-powered conference. Pharma Connect is a national program aimed at connecting the Pharma Industry and HVAC & R Industry and sharing knowledge and working on solutions as required by Pharmaceutical Industries.

I Would like to extend my heartfelt gratitude to all our Partners of Pharma Connect i.e VTS, KPT Pipes, Prince Pipes and Fittings, Humdin Casilica, Perfect Air, HIRA, Camfil India, Carrier, Fusion Industries Limited, HITACHI, Fläkt Group India Pvt. Ltd & Aerofoam.

I am thankful to all our Annual Partners, ALP Aeroflex, Advance Valves, The Refrigeration House, Belimo, Zeco, Bosch, K-Fflex, Avantec, Truestar & Greenoz for extended their support.

I shall be more than happy to get your suggestions, feedback and thoughts at my personal e-mail ID wsiddiqui21@yahoo.com or at my whatsApp number 9810450857.

Best Regards

Waliullah Siddiqui
President
Delhi Chapter of ISHRAE

Sustainable Pharma HVAC - Engineering a Greener Future

by **Samta Bajaj**

INTRODUCTION

The pharmaceutical industry plays a unique role in today's world. On one hand, it is essential for human health, creating medicines that save lives, improve quality of life, and control diseases. On the other hand, its operations have a significant impact on the environment through high energy use, resource consumption, and waste generation.

With climate change becoming more urgent and environmental pressures increasing, the pharmaceutical sector must rethink how it operates. Sustainability can no longer be treated as an optional or separate effort. Today, it is a core business requirement, a regulatory responsibility, and a competitive advantage.

Following the basic idea of sustainability—using resources in a way that does not harm future generations—the pharmaceutical industry must redesign its systems, infrastructure, and processes. This includes adopting Net-Zero Carbon goals, reducing waste, improving energy efficiency, and supporting a circular economy. All these improvements must be made while still meeting strict Good Manufacturing Practices (GMP), safety requirements, and regulatory standards.

In simple terms, the future of pharmaceuticals depends on balancing life-saving innovation with responsible, environmentally conscious operations.

HVAC-Pharma's Core Control System

The pharmaceutical industry utilizes many types of Heating, Ventilating and Air Conditioning (HVAC) systems for applications ranging from research & development to bulk and finished product manufacturing. In every facility the HVAC system plays an important role in ensuring that the environment is suitable for personnel comfort and safety and product integrity.

The pharmaceutical facilities are closely supervised by the U.S. food and drug administration (FDA) which requires manufacturing companies to conform to CGMP (Current Good Manufacturing Practices).

What is GMP ?

GMP refers to the Good Manufacturing Practice regulations which have the force of Law and require that manufacturing, processes and packagers of drugs, medical devices are to take proactive steps to ensure that their products are safe, pure and effective.

The GMP for HVAC services embraces number of issues

starting with fine selection of building materials and furnishes, flow of equipment, personnel and products, determination of key parameter like temperature, humidity, pressures ,filtration, airflow parameters and classification of cleanrooms. It also governs the level of control of various parameters for quality assurance, regulating the acceptance criteria, validation of the facilities. Failure of firms to comply with GMP regulations can result in various serious consequences including recall, seizure, fines and jail time.

So efficiency has been a lower part in design by necessity and there is a tendency on part of designer to re-use proven designs regardless of their efficiency which still results in needless inefficient designs.

We all know that HVAC has the highest contribution to the overall energy spent in a building. In a standard pharmaceutical facility, it can consist of upto 60% of the consumed energy.

Optimizing the energy management in HVAC can provide substantial savings in terms of operating costs and can also reduce GHG emissions into the atmosphere. In this article we are trying to discuss few steps on energy saving in pharmaceutical HVAC design and how to

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reduce energy consumption. The challenge is double because we should not compromise GMP regulations or safety requirement.

Before we dive further into the subject, it is imperative for us to recap some basic fundamentals of clean rooms.

Clean Room Classifications

- Cleanroom classifications are established by measurement of number of particles 0.5 micron and larger that are contained in 1 ft³ of sampled air.
- Cleanrooms are classified in the United states by Federal Standard 209 E and by the European Economic Community (EEC) published Guidelines.

US Federal Standard 209E

Table 1.01:
Cleanroom class cleanliness levels

Source: <http://en.wikipedia.org/wiki/Cleanroom>

ISO Class	Maximum Number of Particles / m³						FED STD 209E Equivalent
	≥ 0.1 µm	≥ 0.2 µm	≥ 0.3 µm	≥ 0.5 µm	≥ 1 µm	≥ 5 µm	
ISO 1	10	2					
ISO 2	100	24	10	4			
ISO 3	1,000	237	102	35	8		Class 1
ISO 4	10,000	2,370	1,020	352	83		Class 10
ISO 5	100,000	23,700	10,200	3,520	832	29	Class 100
ISO 6	1,000,000	237,000	102,000	35,200	8,320	293	Class 1,000
ISO 7				352,000	83,200	2,930	Class 10,000
ISO 8				3,520,000	832,000	29,300	Class 100,000
ISO 9				35,200,000	8,320,000	293,000	Room air

ISO 14644 equivalent levels are shown on the right and were discontinued Nov 29, 2001; however, they continue to be used in the industry.

European Community defines cleanroom in Grade A, B, C, D.

Comparison of US Federal standard 209 E vs EEC

Clas100	is equivalent to	(Grades A and B)
Clas10,000	is equivalent to	(Grade C)
Clas100,000	is equivalent to	(Grade D)

STEPS TO REDUCE ENERGY CONSUMPTION IN PHARMACEUTICAL FACILITIES

STEP -1 CERTIFICATIONS GUIDING THE SUSTAINABLE PHARMA TRANSITION

There are several ways in which an organisation can plan sustainability for their new facilities and HVAC energy optimization plays an important role in them: Sustainability certification systems such as LEED, BREEAM, and Net Zero Energy Building (NZEB) frameworks are now shaping how pharmaceutical facilities are designed, validated, and operated. These frameworks evaluate not only GMP compliance but broader environmental impacts, including energy consumption, water intensity, refrigerant leakage, waste diversion performance, and lifecycle carbon emissions. As sustainability becomes central to regulatory and operational strategy, these certifications are evolving into key drivers of performance and accountability. The facilities shall be extremely energy efficient. (Fig.1 & 2)

Fig.1 Net zero energy buildings

Fig.2 LEED and BEEAM tools for sustainable pharmas

STEP-2 EVOLVING TOWARDS ZONED AND MULTILOOP HVAC ARCHITECTURE

Modern pharmaceutical cleanrooms are moving away from single oversized air-handling units toward multi-loop or zoned HVAC architectures. In these systems, primary loops condition outdoor air while secondary and tertiary loops recirculate conditioned indoor air. This layered approach reduces reheating loads, improves humidity stability, and aligns system performance with real operational needs. As a result, energy use becomes more efficient and more predictable across different rooms and cleanroom classes.

STEP-3 OPTIMIZE AIR CHANGE RATE

Each clean classification has an air change rate. Fig 3 shows the normally followed air change rates for different grades of clean rooms. There is an industry standard that established a relationship between GMP classification and air changes However cleanroom air change rate should take anticipated activity with the clean room into account. A class 1,00,000 (ISO 8) cleanroom having a Low occupancy rate, Low particle generation process and positive space pressurization in relation to adjacent dirtier cleanroom spaces might use 15 acph, while the same cleanroom having high occupancy, frequent in /out traffic, high particle generation process or neutral space pressurization will probable need 30 acph.

Class ISO 146144 – 1	FED STD 209E	Avg. Air Velocity (m/s)	No. of ACPH
ISO 8	Class 100,000	0.005 – 0.041	5 – 48
ISO 7	Class 10,000	0.051 – 0.076	60 – 90
ISO 6	Class 1,000	0.127 – 0.203	150 – 240
ISO 5	Class 100	0.203 – 0.406	240 – 480
ISO 4	Class 10	0.254 – 0.457	300 – 540
ISO 3	Class 1	0.305 – 0.457	360 – 540

Fig.3 Recommended air change rates for different grades of clean rooms

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Also many air change rate recommendations were developed decades ago. The recommended design ranges for ISO class 5 (clean 100) cleanroom ranges from 250-480 air change per hour.(Fig.3) But benchmarking studies have also verified that the actual operating ACRs documented for ten ISO Class-5 cleanrooms was between 94 and 276 air changes per hour.. Please note that energy consumption increases as per ACH increase. Optimal ACH depends on particle generation velocity and by increasing ACH rates you can only achieve the classification fast and reduce the recovery time.

3In the Fig.4 you can observe the dependence of particle concentration in a clean room with the air change rate. We can observe for the normal particle generation rates between 1000-10000 particles / (min X m^3), ACH increasing affects only how fast we achieve the classification It is a wrong assumption that by increasing the air change rates, you will get a better quality of air. This is only partially true.

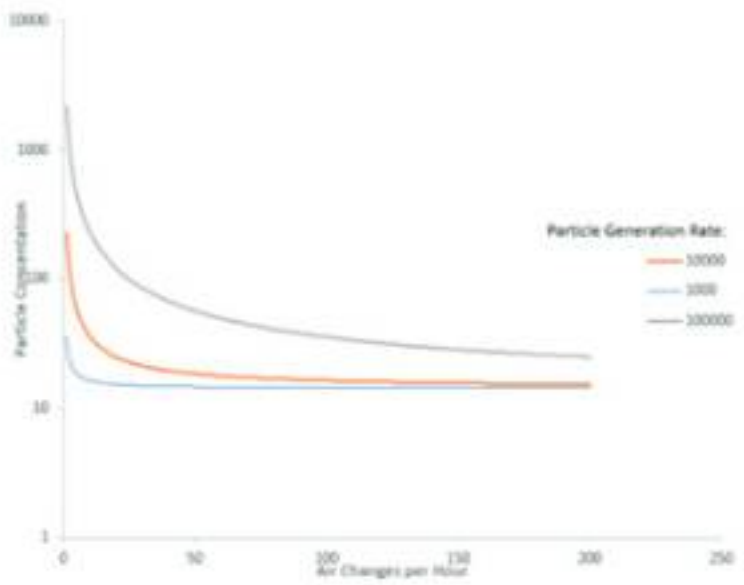

Fig.4 Particle concentration as a function of air changes per hour for different particle generation rates.

PRINCIPLES

- Lower air change rates result in smaller fans which reduce both the initial investment and construction cost.
- Fan power is proportional to the cube of air change rates or airflow. A reduction in the air change rates by 30% result in power reduction by approximately 66%.
- Lower air flow may improve actual cleanliness by minimizing turbulence.
- A 20 percent decrease in ACR will enable close to a 50 percent reduction in fan size.
- ACR reductions are also possible when pharma cleanrooms are unoccupied for a long time. Human occupants are the primary source of contamination. So once cleanroom is vacated, lower air changes per hour are possible allowing for setback of the air handling system.
- Set back of the air handling system fan can be achieved by manual setback, timed setback, Use of occupancy sensor or by monitoring particle counts and controlling air flow based upon actual cleanliness levels.
- Best practice for ACRs is to design new facilities at the lower end of the recommended ACR range. Once the facility is built, monitoring and controlling based upon particle counts can be used to further reduce ACRs.
- Variable speed drives should be used on all recirculation air system for air flow adjustment to optimize air flow or account for filter loading.

STEP 4 - DEMAND CONTROLLED FILTRATION

- Reducing air flow by use of variable speed fans which are normally a feature of recirculation system is an energy efficiency measure that can save a lot of energy. Every small reduction in airflow can save significant amount of energy due to the approximately cubic relationship between air flow and fan energy.

PRINCIPLES

- Optimize air flow for best contamination control by real time particles monitoring and automatic control of the recirculation system.
- Recirculation air flow can be controlled in various ways:

APPROACH

- Use of timer or scheduling software to lower air flow at times when the clean room is unoccupied and with minimum process activity.
- Use of occupants sensors to lower air flow when people are not present in the cleanroom
- Use of particle counters to control air flow in the room based on real time cleanliness.

However system pressurization is an important factor implementing air flow reduction strategy. It is important to note that make up air system and exhaust system will continue to operate at their normal levels.

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Axial Flow Check Valve Flanged	DN 25 - 1600 NPS 2 - 64	ASME CL 150 - 1500	ASME B16.34, API 6D	All Services including Cryogenic & Fire Safe, -196°C (-321°F) to 750°C (1382°F)
Butterfly Valve - Triple Offset Metal Seated Wafer, Lugged, Flanged	DN 80 - 3000 NPS 3 - 120	ASME CL 150 - 1500	API 609 Category B, API 607, API 641 ISO 5752, ISO 15848, BS 6364, ISO 28921, ISO 10497, SIL 3	All Services including Cryogenic & Fire Safe, -196°C (-321°F) to 750°C (1382°F)
Butterfly Valve - Double Offset High Performance Wafer, Lugged, Flanged	DN 80 - 3000 NPS 3 - 120	PN 10 - 25 ASME CL 150 - 300	API 609 Category B, BS EN 593, ISO 5752, IS 13095, AWWA C504/516	Water, Chemicals, Air, Oil, Gases up-to 200°C (392°F), Vacuum
Butterfly Valve - Concentric Integrally Molded Liner	DN 50 - 1200 NPS 2 - 48	PN 10 - 20 ASME CL 150	API 609 Category A, BS EN 593, IS 13095, UL 1091	Water, Chemicals, Air, Oil, Gases up-to 200°C (392°F), Vacuum
Butterfly Valve - Concentric Low Torque Replaceable Liner	DN 50 - 300 NPS 2 - 12	PN 10	API 609 Category A, BS EN 593 IS 13095	Water, Chemicals, Air, Oil, Gases -20°C to 120°C
Actuated Butterfly On-Off / Modulating	DN 50 - 3000 NPS 2 - 120	PN 10 - 16 ASME CL 150 - 1500	API 609 Category A & B, SIL 3	Electric, Pneumatic, Electro-Hydraulic Hydraulic, Controls & Accessories
Balancing Valve	DN 25 - 1200 NPS 1 - 48	PN 10 - 25	DIN 3202, BS 7350, BS EN 593 Face to Face - ISO 5752 Table 8	Water, Glycol, Brine Solution

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STEP-5 DUAL TEMPERATURE CHILLED WATER LOOPS

Fig.5 Typical centrifugal chiller unit

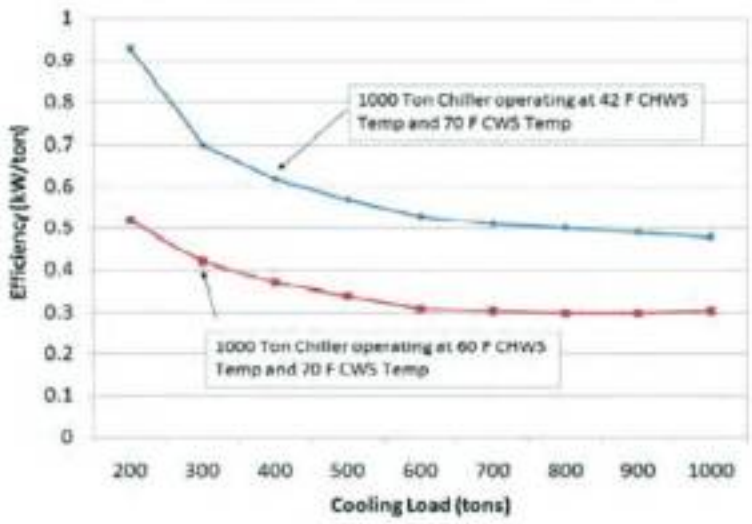

Fig. 6 Comparison of low temperature & Medium temperature water cooled chillers

- Chiller energy can account for 10 to 20% of total cleanroom energy use. The majority of annual chilled water goes to medium temperature chilled water requirements 55° F for sensible cooling and 60 to 70° F for process cooling loads. Standard cleanroom chiller plant design provides chilled water at temperature of 39 to 42° F. While this temperature is needed for dehumidification, low set point imposes efficiency penalty on chiller.(Fig 6) Typically heat exchangers and / or mixing loops are used to convert the low temperature, energy intensive chilled water into warmer chilled water temperature for sensible or process cooling loads .By dedicating a chiller in a dual chiller plant to provide chilled water at 55° F , 20 to 40% of chiller energy can be saved when compared to both chillers operating at 42°F

PRINCIPLES

- If chilled water temperatures are raised and / or condenser water temperatures are lowered chiller work is reduced.

- The majorly of cleanroom chilled water requirements are best served by medium temperature 55 to 70° F chilled water.

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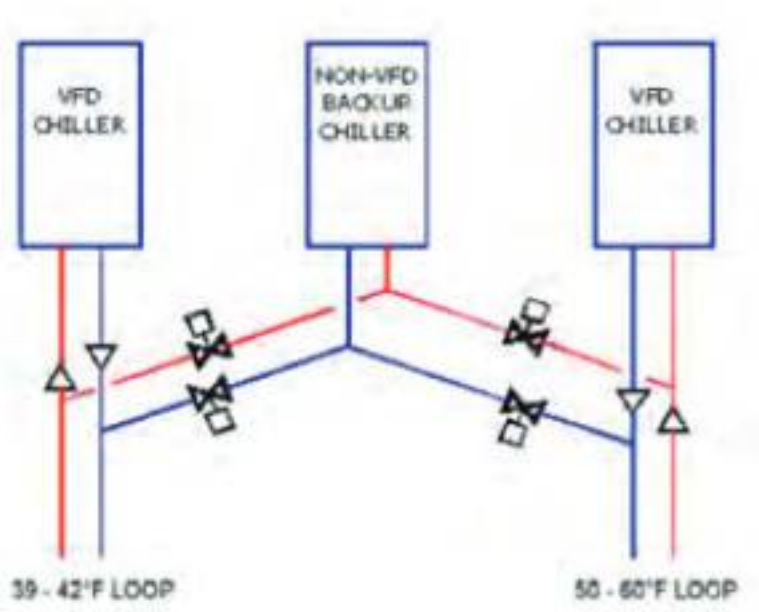

Fig 7 Configuration of chillers for dual temperature chilled water loop system

Fig. 8 Exhaust Optimisation

- Clean room facilities need low temperature water only to handle peak outside air loads which occur only 2 to 5 % of the time in an year.
- Cleanroom facilities have a number of medium temperature loops required by the industrial processes which use heat exchangers to create water between 60 and 70° F
- Energy savings can be realized by a careful plant layout by creating medium temperature water directly without wasting energy intensive low temperature water
- The redundant or back up chiller can be sized to provide either low temperature or medium temperature water as required. The chiller without a variable frequency (VFD) drive can help to lower the initial lost based on anticipated runtime of the chiller. (Fig. 7)

STEP-6 EXHAUST OPTIMISATION

Often manufacturers recommendations for exhaust air flow rates are significantly overstated and / or based on crude face velocity approach to estimate exhaust rates required for containment.(Fig.8)

PRINCIPLES

- All air exhaust from a cleanroom has to be replaced by filtered make up air.
- For a cleanroom facility operating 24 hours a day, costs for exhaust air range is substantial.

APPROACH

- Good practice suggests using direct measurements of containment to set exhaust rate
- Methods such on tracer gas testing variety and document safe operating condition.
- Proper optimization of exhaust flow rates results in substantial energy savings in addition to safety benefits.

STEP- 7 OPTIMISE THE OUTDOOR AIR FLOW

- A rule of thumb for concept design stage is to set outdoor air flow requirement about 10-20% of the total air supply flow. In reality may require less than 10%. So accurate analysis of required airflow and later balancing the system can reduce substantially the energy consumed by make-up air.

STEP- 8 FAN FILTER UNITS

The HVAC system in pharma cleanrooms may consume 50 percent or more of the total cleanroom energy and fan energy contributes over 50% of HVAC energy. (Fig. 9)

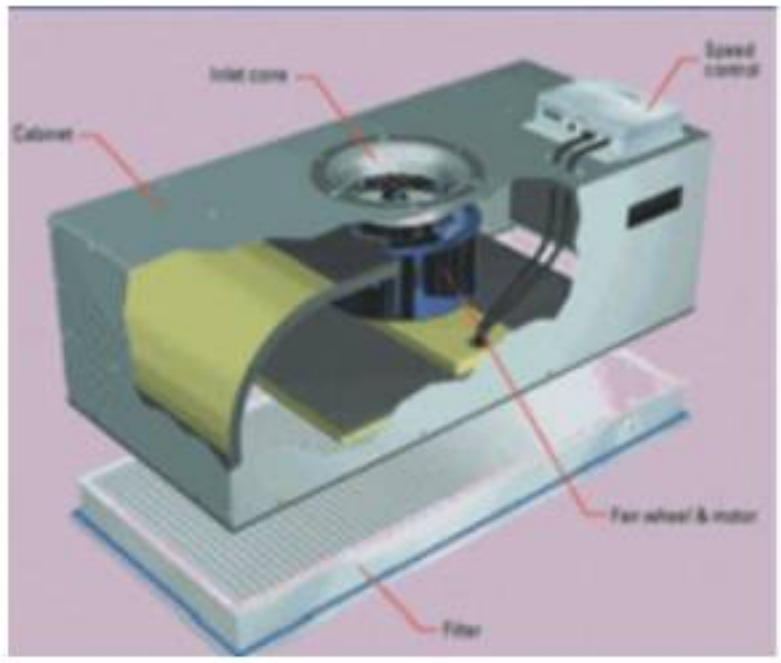

Fig.9 A fan filter unit (FFU)

The use of FFUs in an air handling system is becoming more and more popular since there are modular, portable, easier to install, controlled and monitored to maintain filtration. However efficiency of these units is lower than their counter parts.

PRINCIPLES

A FFU usually consists of small fans with controller and a HEPA / ULPA filter enclosed in a box which fits into common cleanroom ceiling

APPROACH

- Fan power is proportional to the cube of the airflow rate or air flow speed .A reduction in air change rate by 20% may result in power reduction of approximately 27%.
- Selective FFUs with flexibility of speed control and high energy efficiency is critical for energy efficiency of the system.

STEP- 9 USE OF HIGH EFFICIENCY FANS

Fig.10 Plug fan

Fig.11 EC fan array

- Fans should be provided with a variable frequency drive (VSDs) as a minimum. A flow transmitter should be provided to control the required flow as the filters get closed. Minimum IE 4 efficiency of motor should be selected. (Fig. 10)

- Another option is to use EC (electronically commutated) fans arrays. An EC fan has a brushless permanent magnet DC motor with inbuilt electronics for controlling a fan rotor. The efficiency class is higher IE 5.Only problem is that a single fan cannot provide the high static pressure required in pharmaceutical application.(Fig. 11)

However solution is providing a fan array in parallel which also gives redundancy in cases of failure of one of these fans.

STEP-10 USE OF ADSORPTION CHILLERS

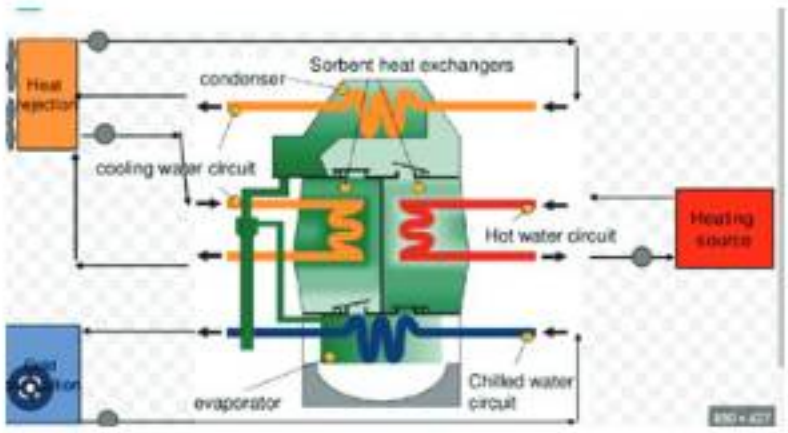

Fig. 12 Adsorption chiller

Adsorption chillers use green technology (Silica gel-water pair) to help cut cooling costs upto 99% .It harnesses the waste/ solar energy available in abundance across varied process industries and solar plants for low cost process cooling and air conditioning. (Fig. 12)

STEP-11 LOW PRESSURE DROP SYSTEMS

Fan energy accounts for 20 to 40% of total cleanroom energy used. Fan energy use is directly proportional to includes lowering the pressure drop that the fan is pushing air through. Strategies for lowering the pressure drop includes lower face velocity air handling units , low pressure drop filters, optimized design of ducting and air pattern including open plenum and centralized air handling type of configuration. Other benefits of low pressure drop system are less noise, more effective dehumidification and better filter effectiveness.

PRINCIPLES

- Air handler system power consumption can be estimated by the equation below:-

- $$\text{Fan Power (kw)} = \frac{\text{Air Flow (CFM) x pressure Drop (in wg)}}{\text{6345 x efficiency (\%)}}$$

- Pressure drop in a duct or air handler is approximately fan proportional to the face velocity squared.

- The pressure drop in duct work is inversely proportional to the fifth power of the duct diameter for example substituting a 16" duct for 12" duct reduce the pressure Drop by about 75%

$$\text{Duct } \Delta P \text{ (in wg)} \ \alpha \ \text{(1/ Duct dia in)}$$

APPROACH

- To reduce the pressure drop, specify face velocity of 250 to 450 FPM range.

- Lower face velocity reduces the pressure across the filter and the chances of unfiltered air leaking past poor filter rack seals or tears in the media

STEP-12 OPTIMAL OUTDOOR TEMPERATURE DESIGN

Oversized outdoor conditions lead to oversizing of heating / cooling equipment but with the warranty than the indoor design condition will always be within limits while undersized conditions will require less power but indoor condition may suffer during hottest / coolest days of the year

Outside conditions in the data books are indicated us 0.4 % percentile, 1% percentile which gives an idea of the number of hours during an year that the temperature is higher than that temperature.

So we should take into consideration if it is really necessary to increase the cooling capacity just to cover a few hours per year of unusually higher temperature.

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STEP 13 MINI ENVIRONMENTS

Mini environment is a localized environment by an enclosure to isolate a product or process from surrounding environment. The advantages in using mini environments are following:-

- Mini Environments may create better contamination control and process integration.
- Mini Environments maintain better contamination control by better control of pressure or through use of unidirectional air flows.
- Mini Environments may potentially reduce energy costs.(Fig. 14)
- Use of fan filter modules (FFUs) is common , but increase the power density in the clean rooms

Fig. 14 Mini Environments

Fig. 15 Airtightness of Clean rooms

APPROACH

- Determine the cleanliness requirement of mini environment and the surrounding cleanroom
- Use computation fluid dynamics (CFD) modelling to assist in design process.
- Determine air flow velocity and optimal air change rates
- Improve efficiency of the mini environment system and design including using energy efficient fan and better controls.
- Optimize air flow rates of the surrounding clean room areas and where possible reduce air flow rate.

STEP-14 AIR TIGHTNESS OF HVAC CLEAN ROOM IS IMPORTANT

Clean rooms are usually designed with positive differential pressure which is maintained by a makeup air flow which is expensive including humidification or dehumidification. So we should decrease the leakage through our system (Fig. 15)

APPROACH

- Provide and test good airtight ductwork construction
- Provide good air tight cleanroom construction
- Avoid unnecessary high differential pressures between rooms; 5-10 pa between the same classification room and about 15 pa between adjacent classification room are normally accepted.

STEP-15 RECIRCULATION AIR SYSTEM TYPES

Recirculate air handle fan energy accounts for 10 to 30% of total cleanroom energy use. There are three basic recirculatory systems. 1.Fan Filter Unit (FFU) 2. Ducted Hepa 3. Pressurized plenum.

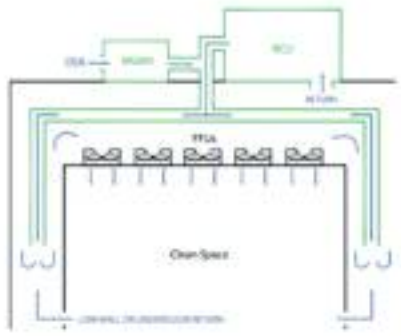

Fig. 16 Fan Filter Units

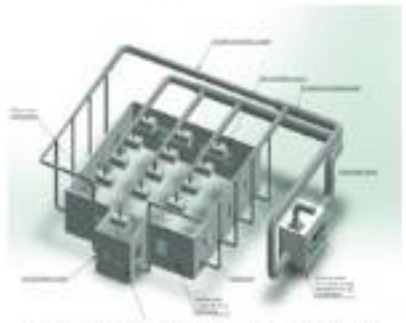

Fig. 17 Ducted Hepa System

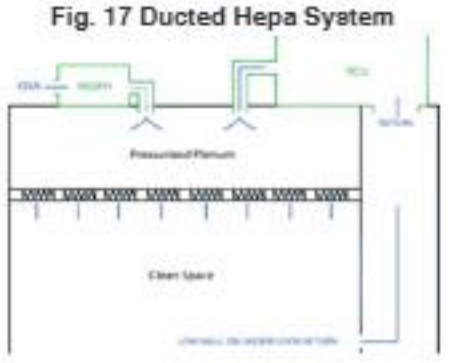

Fig. 18 Preasurised Plenum System

PRINCIPLES

- The recirculation system efficiency equation is

$$\text{CFM/ Kw} = \frac{\text{Total cooling Air Flow (CFM)}}{\text{Recirculate Fan Kw + sensible cooling fan Kw}}$$

- Low fan power consumption is influenced by low pressure system
- Fan and motor efficiency becomes important when we consider small fans and motors such as used in 2' x 4' FFU modules(Fig. 16,17,18)

APPROACH

- Deeper filter with lower pressure drop result in energy savings and can down size the fan sizes
- Utilizing plenum return at lower velocities cause lower pressure drops
- Very low face velocity can reduce the system pressure drop
- The use of larger FFU modules such as 4' x 4' can allow use of more efficiency fans.

STEP-16 MODIFY TEMPERATURE AND HUMIDITY SETPOINTS

- The cooling capacity required by raising up the set point temperature from 20 to 22° C reduce by about 8%
- Likewise by changing the humidity set point from 50% to 60%, dehumidification requirement is less and the cooling duty decreases by about 30%

STEP-17 WIDEN TEMPERATURE DEADBANDS

- Setting the widest possible dead bands as the temperature and humidity set points within the limit of the zone requirement will reduce the building energy consumption.
- A temperature range of 18 - 24° C is more energetically friendly than 20 - 22° C (Fig.18)

STEP-18 WATER SIDE FREE COOLING

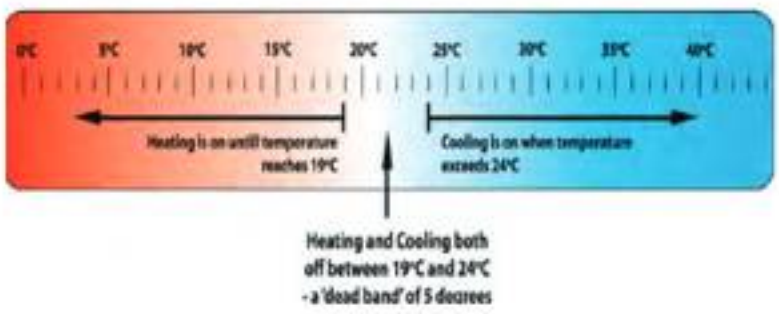

Fig. 19 Widen temperature dead bands

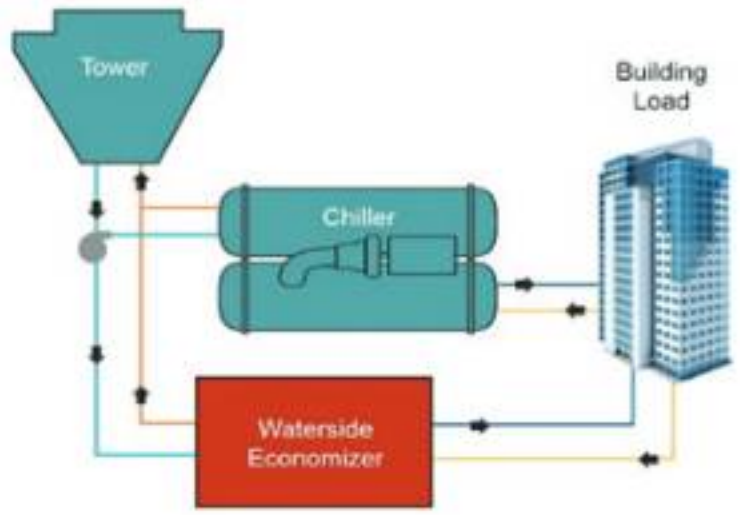

Fig. 20 Water side free cooling

Free cooling uses the evaporative cooling capacity of a cooling tower to indirectly produce chilled water for use in medium temperature loops such as process cooling loops and sensible cooling loops. (Fig. 20)

PRINCIPLE

- Chilled water systems use chiller which typically operate at 0.5 to 0.7 kw/ TR in a particle load regime whereas free cooling systems typically operate at 0.05 to 0.15 Kw / TR.
- A plate heat exchanger is used to isolate the chilled water loop from open tower condenser water loop
- The low approach cooling tower is critical to achieve the highest energy savings
- A traditional chiller is used to provide cooling during hot period and as an always available emergency back up.

STEP-19 PROCESS CHALLENGES

Bigger a cleanroom is, more is the energy required independently of its classification. So we should challenge the process constraints like

Fig. 21 Closed Process

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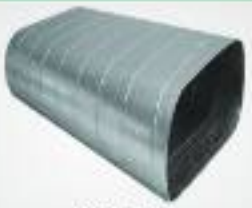
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Fig. 22 RABS/ Isolator technology

- If closed process can be used since they usually require less classification level. (Fig. 20)
- It is feasible to use RABS / Isolator technology. If so, the surrounding area could be designed in lower classification(Fig 21)
- Try to install large heat generating equipment outside the clean room .This will reduce the need for cooling and we will need only good ventilation.

STEP-20 FILTER SELECTION AND MAINTENANCE

Filter Class EN1822	Width (mm)	Height (mm)	Depth (mm)	Airflow (m3/h) @ 0,45m/s	Pressure drop (Pa) @ 0,45 m/s
Show all	1220	620	Show all	Show all	Show all
H14	1223	610	66	1206	90
H14	1223	610	90	1206	65

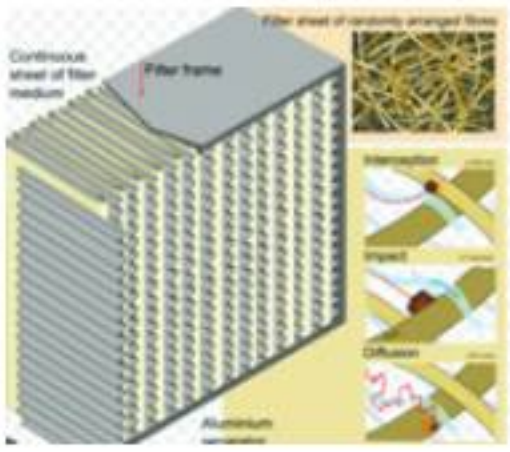

Fig. 23 Hepa Filter selection

Most of the pharmaceutical facilities require HEPA filter which have a large pressure drop So it is essential to pay attention to filter selection to save an important amount of fan energy to compensate for the filter pressure drop. Fig. 23 shows a selection when maximum deep filter (90mm) has a pressure drop of 65Pa while 66mm deep filter has a pressure drop of 90 Pa (38% more)

STEP-21 VARIABLE PRIMARY PUMPING DISTRIBUTION SYSTEM

Presently, chilled water (CHW) system designs are based on a variable primary configuration, which offers many operational and cost advantages. A variable primary system reduces first cost by eliminating the need for separate secondary pumps and related piping, resulting in a simpler and more compact mechanical layout. Pumping energy is also reduced because the primary pumps operate with variable-speed drives that modulate flow directly to the load. With proper controls, the system can maintain higher delta-T, improve chiller part-load efficiency, and require less maintenance due to fewer components. Compared to traditional primary–secondary systems, variable primary requires more sophisticated control logic to ensure minimum chiller flow and stable operation, but it avoids the hydraulic mixing losses and additional pump energy inherent in primary–secondary designs.

STEP-22 SELECTION OF THE MORE EFFICIENT COOLING / HEATING TECHNOLOGY FOR YOUR PROCESS

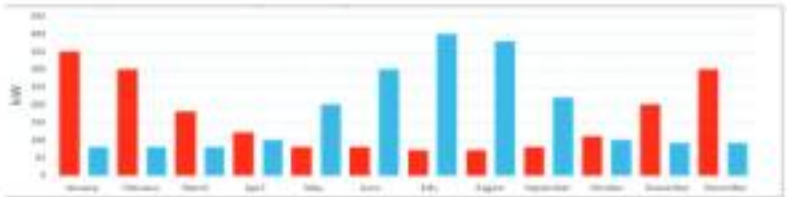

Fig.24 Determine cooling/ heating demand across the year

By simulation we can decide the cooling and heating demand across the year. Based on this most adequate system can be designed (fig. 24)

1) Chiller + boiler : Chilled and hot water are generated independently
2) Reversible Heat pump (2 pipes): This system provides chilled water or hot water. Simultaneously heating and cooling are not possible. It can be used for seasonal comfort cooling or heating with scheduled changeover
3) 4 pipe heat pumps: A single system providing cooling and heating on two separate loops all the year
4) Heat recovery chiller: This system offers possibility to recover energy when there is simultaneously request for cooling and heating.

According to our cooling and heating need we can select most efficient technology or combination of a few of them.

STEP-23 USE HEAT RECOVERY SYSTEM

- Fan system with 100% fresh air or other significant amount of fresh air and exhaust is required we should consider heat recovery system.
- Traditional cross flow plate heat exchangers and rotary heat exchangers are not recommended in pharmaceutical applications due to possible cross contamination.(Fig 25)
- The run around coil (Fig. 26) is the most suitable system where supply and exhaust flow rates are completely segregated. It comprises two heat exchangers hydraulically connected and circulating by means of pumps .The heat transfer fluid is usually a mix of water and glycol

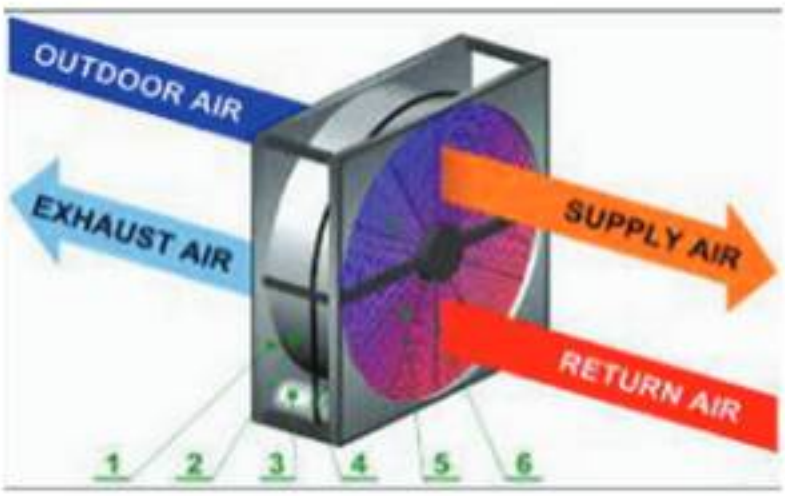

Fig. 25 Cross flow heat exchanger

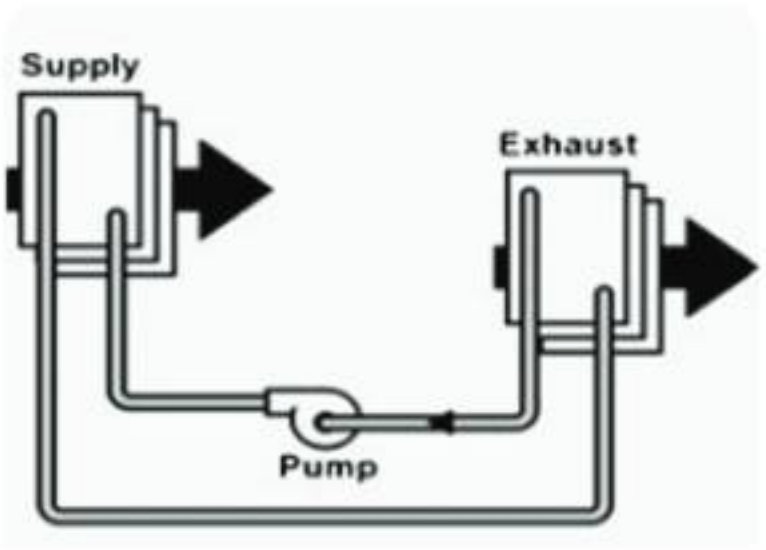

Fig. 26 Runaround loop coil system

STEP-24 VACUUM PUMP OPTIMIZATION

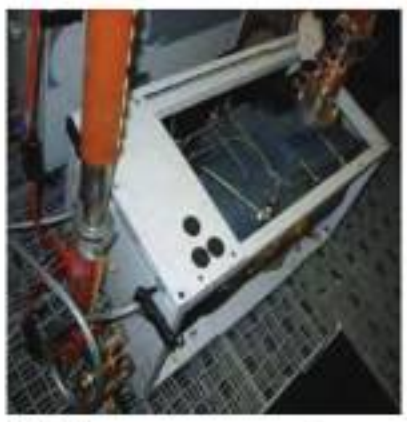

Fig. 27 Rotary vacuum pump in operation

- Rotary vane vacuum pumps are highly used in pharmaceutical facilities and account for 5 to 10 percent of facilities consumption. However recent advances in vacuum pumps technology have improved efficiency of vacuum pump by 50-60 percent and thus can reduce pump energy by 50%-90 %.(Fig. 27)

APPROACH

- Use of high efficiency pumps will not only reduce operating costs but also yield savings by down sizing of central plant equipment and electrical infrastructure since all power used is removed through the central cooling system as waste heat.

STEP-25 DIGITALISATION, THE CATALYST FOR SUSTAINABLE HVAC

Digital transformation plays a key enabling role in this transition. With IoT sensors, machine learning, artificial intelligence, and advanced building or energy management platforms, HVAC systems can dynamically adjust filtration intensity, airflow, pressurization, temperature, and humidity based on risk rather than fixed setpoints. Predictive analytics and optimization algorithms alone can deliver 8–12% annual energy savings with no major hardware modifications. Digital twins are further enhancing system intelligence by enabling continuous simulation and performance optimization throughout the full asset lifecycle—from design to decommissioning

Fig 28 Digital transformation in pharmas

Fig. 29 Decarbonization of Pharmaceutical industry

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STEP-26 HOLISTIC APPROACH TO DECARBONIZING PHARMA FACILITIES

Long-term sustainability in pharmaceutical manufacturing requires a full-system approach. The first priority is reducing energy demand using measures such as airtight building envelopes, ultra-low-leakage ductwork, high-efficiency motors and fans, and VFD-controlled equipment. Even small adjustments—such as increasing temperature setpoints by 2°C—can reduce cooling loads by roughly 8%, while wider humidity tolerances may lower latent loads by nearly 30%. The next phase focuses on recovering wasted energy through heat pipes, run-around coils, condensate reuse systems, and combined heat and power (CHP) or trigeneration plants. Finally, facilities must reduce fossil fuel dependence by integrating low-GWP refrigerants, electrified heating, solar PV, solar-thermal regeneration, and emerging green hydrogen solutions.

CONCLUSION

Reducing energy consumption in a pharmaceutical HVAC system is a challenge due to GMP constraints and or biological containment of the facility. However there are a number of design approaches as mentioned above have been shown to meet all the requirements of a clean room facility while minimizing power consumption and cost. Now things have changed and it is proven that GMP and sustainability are not contradicting and on occasions go beautifully hand in hand.

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HVAC Design for Pharmaceutical Facilities - Managing Low Humidity (Moisture), Pressurization & CVRH (Terminal)

By **Niladri Mukherjee, niladri.hvac@gmail.com**

Introduction

In Pharmaceutical manufacturing, how space conditions impact the product being made is of primary importance. The pharmaceutical facilities are closely supervised by the US food and drug administration (FDA) , which requires manufacturing companies to confirm cGMP. These regulations, which have the force of law, require that manufacturers, processors and packagers of drugs take protective steps to ensure that their products are safe, pure and effective. GMP regulations require a quality approach to manufacturing, enabling companies to minimize or eliminate instances of combination, mix ups and errors.

The GMP for HVAC services embraces number issues starting with the selection of building materials and finishes, the flow of equipment, personnel and products, determination of key parameters like temperature, humidity, particles, pressures, filtration, airflow parameters and classification of cleanrooms. It also governs the level of control of various parameters for quality assurance, regulating the acceptance criteria, validation of the facility and documentation for operation and maintenance.

Various countries have formulated their own GMP. In the United States, it is regulated by several documents such as Federal Standard 209, code of Federal regulations CFR 210 & 211 etc, which are revised and updated from time to time. The European Community has a " Guide to Good Manufacturing Practice for Medical Products "and in the United Kingdom it is BS 5295. The WHO version of GMP is used by pharmaceutical regulators and the pharmaceutical industry in over one hundred countries worldwide, primarily in the developing world. All GMP's have one common theme -CLEANLINESS, CLEANLINESS and CLEANLINESS.

Challenges of Pharmaceutical Manufacturing

Climate

- Low humidity (Moisture) Control
- Pressurization - Control of Contamination of Pharmaceutical

Manufacturing Zone

Climate for Pharmaceutical Manufacturing unit

Climate is extremely crucial for selecting a Pharmaceutical Manufacturing Site. Fresh air supply is one of the Critical design factors for any pharmaceutical manufacturing facilities. It is always advice to select a site where ambient air quality is extremely good and carbon free. But sometimes high humidity becomes a hindering factor. My experience of handling a proposed Pharmaceutical Manufacturing unit near to Shillong on behalf of a Pharma client, where high moisture, day - night temperature swing came as a challenge in HVAC design and the high energy usages. But Shillong is absolutely friendly for using outside air.

We found in July the RH of the proposed site between 85% to 90% and average humidity (RH) is above 70 %. Further there is a temperature swing between day and night. As our manufacturing room design temperature was 24C (75.2F), there would be a requirement of heating & cooling within 24 hours along with a high moisture load. Tablets are one of the main products of any Pharma manufacturing unit and the granulation process is extremely critical as it helps to give a solid formation from the powdery raw materials. Most of these raw materials are hygroscopic in nature. The hygroscopicity (K) of the raw materials indicates the design R

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Low humidity (Moisture) control for the Pharmaceutical Manufacturing unit

How moisture affects pharmaceutical manufacturing?

- Encourage in hygroscopicity of the Pharma products
- Allows formation of different types of fungus in the manufacturing units
- Moisture negatively affects electric insulation by decreasing its dielectric strength and increasing its conductivity, which can lead to insulation failure, short circuit, even fires
- Failure of electronic control equipment's

Most of the Pharma raw materials are hygroscopic in nature and their hygroscopicity (k) is normally very high. Mainly for tablet manufacturing, most of the cases RH is maintained between 35% to 40 %. Now through vapor compression technology and fresh air induction there would be a constant moisture load in the room. It would further enhance if the location - climate holds excessive moisture. It would be extremely difficult to bring down the room moisture level or RH at 35% where ambiance RH is about 70% or more. Fresh air with high moisture, any coil size can't support the condensation desired moisture to maintain a manufacturing room's RH at 35%. In this situation Desiccant Dehumidifier can be installed in a returned line. Rotor size of the Desiccant Dehumidifier would depend on the CFM handling. Desiccant Dehumidifier works on moisture absorption technology and absorbed moisture is removed by a heating coil. Moisture would be controlled as per design data via RH sensor in combination of condensation at coil and Desiccant Dehumidifier.

AHU design is extremely Critical for Pharmaceutical Manufacturing units, from filter selection to coil size design. Fungus also can develop at the condensation collection. Therefore, it is technically advised when designing a large size cooling coil for the pharmaceutical manufacturing unit, it's essential to consider the impact of the condensation collection on the coil's performance. As the lower portion of the coil collects condensate from above, the air velocity in the upper portion can become excessively high, increasing the risk of water blow - off from the coil's fan. To mitigate this issue, following design guidelines can be considered.

Incorporate an intermediate condensate drain pan for a large coil. Fin spacing is advised 12 fins per inch or greater. Air velocity is recommended below 400 fpm for coils exceeding 3.2 ft (1000 mm) in height. A suitable solution may be to split the coil horizontally into two units, each with the drain pan.

Condensate water may come to the room along with the air movement and it can develop Fungi like Aspergillus, Penicillium, Cladosporium. These fungi are extremely harmful for the Pharma products. Microbiological research says the growth rate of fungi associated with HVAC systems, particularly downstream of cooling coil Pharma AHU, can be significant and potentially overwhelming if neglected.

- Aspergillus Ruber - 1 mm / day (100 mm in 100 days) at 12C and 85% RH
- Penicillium Cyclopium - 0.1 mm / day (10 mm in 100 days) at 12C and 85% RH
- Stachybotrys Chartarum - 0.1 mm / day (10 mm in 100 days) at 12C and 95% RH

Pressurization - Pharmaceutical Manufacturing Units

Pressurization prevents the infiltration from adjacent spaces. Pressurization of clean areas (Aseptic Room in Pharmaceutical) is required to keep the products from being contaminated by particles and / or to protect people from contact with harmful substances by physical means or inhalation. This can be easily accomplished by supplying more air than the cumulative of what is returned, exhausted or leaked from the Aseptic room.

Standard 209E Specifies that the minimum positive pressure between the Aseptic room and any adjacent area with lower cleanliness requirements should be 0.05 in. w.g with all entryways closed. During facility operation as doors are opened, the design differential pressure is generally reduced, but air must continue to flow from the higher to lower pressure space, even though a reduced flow rate. To maintain a differential of 0.05 in water, a velocity approximately 900 ft/min (4.7 m/s) should be maintained through all the openings or leaks in the Aseptic room, such as cracks around the door opening.

The amount of air being returned has a bearing on room pressurization and well depends on the process taking place within the Aseptic place (Clean Space). For a space requiring positive pressurization, the returned air volume is typically 15% less than the total supply air volume. While calculating supply air quantities for various rooms, allowance should be made for process equipment like tunnels that cross room pressure boundaries and open doors.

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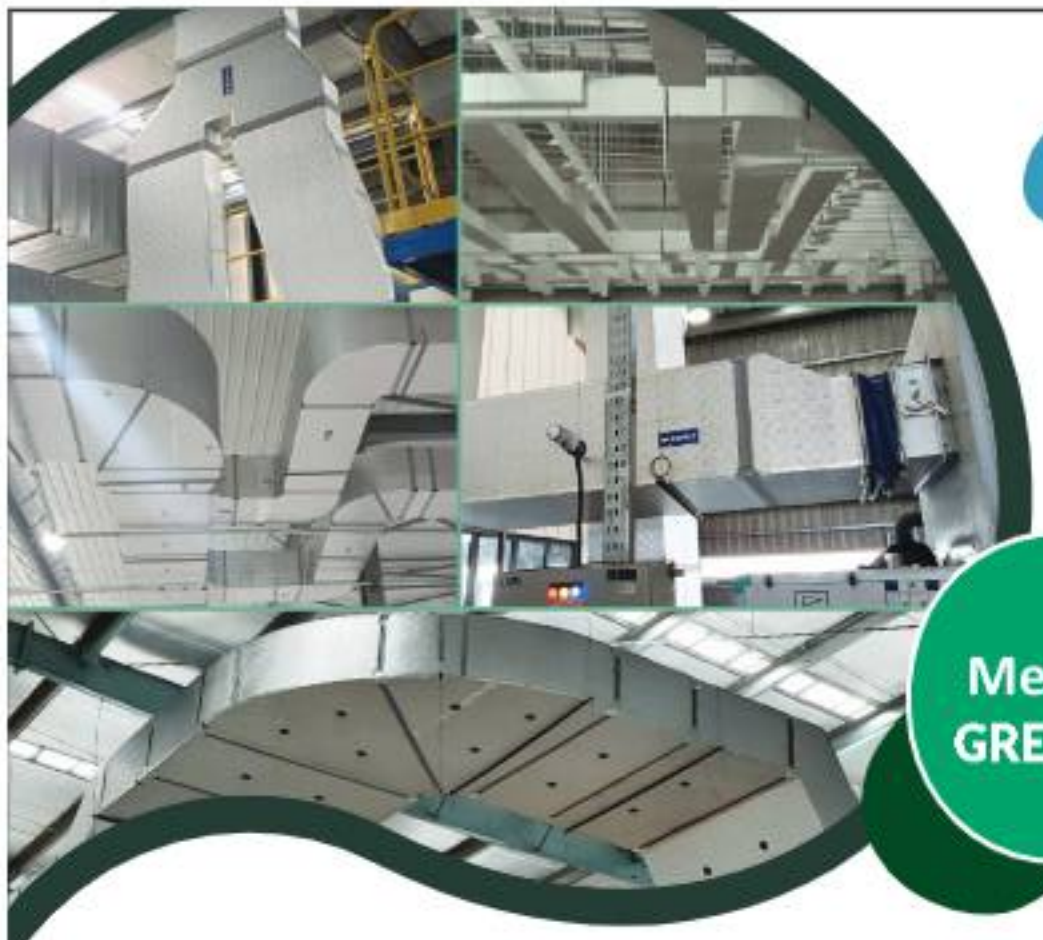

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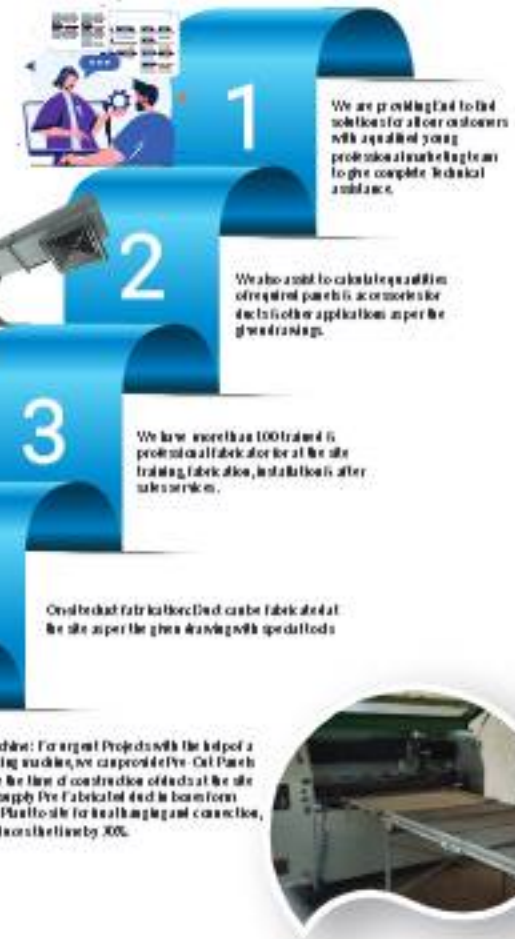

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Aseptic areas – Pressure Gradient

Cooling corridors	- 45Pa
Access corridors	- 35Pa
Manufacture laboratory	- 55Pa
Filling Rooms	- 55Pa
Change Rooms	- 25Pa

CVRH (Terminal)

Constant Volume Reheating - Terminal is the most reliable system for pharmaceutical manufacturing areas. This is because ensuring constant pressure gradient between the adjacent areas is of prime importance.

In the terminal reheat system the air leaving the cooling coil is set at a fixed temperature, and the terminal reheat responds to a space thermostat, turning on heat to satisfy the load. Yes, this can waste energy, since air is cooled and then reheated. Ideally where close control of temperature and humidity is required for process areas the energy conservation requirement is waived. The advantage of re heating systems is that humidity is always controlled. Another advantage of CVRH systems is that airflow is constant, which makes balancing and pressurization easier to maintain.

AUTHOR

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- Expert in Hospital HVAC Design with projects across India, Bangladesh & Gulf countries.
- Advises hospitals on cost-effective, infection-controlled HVAC solutions.
- Contributed to OR & IVF/ART cleanroom standards for South Asia.

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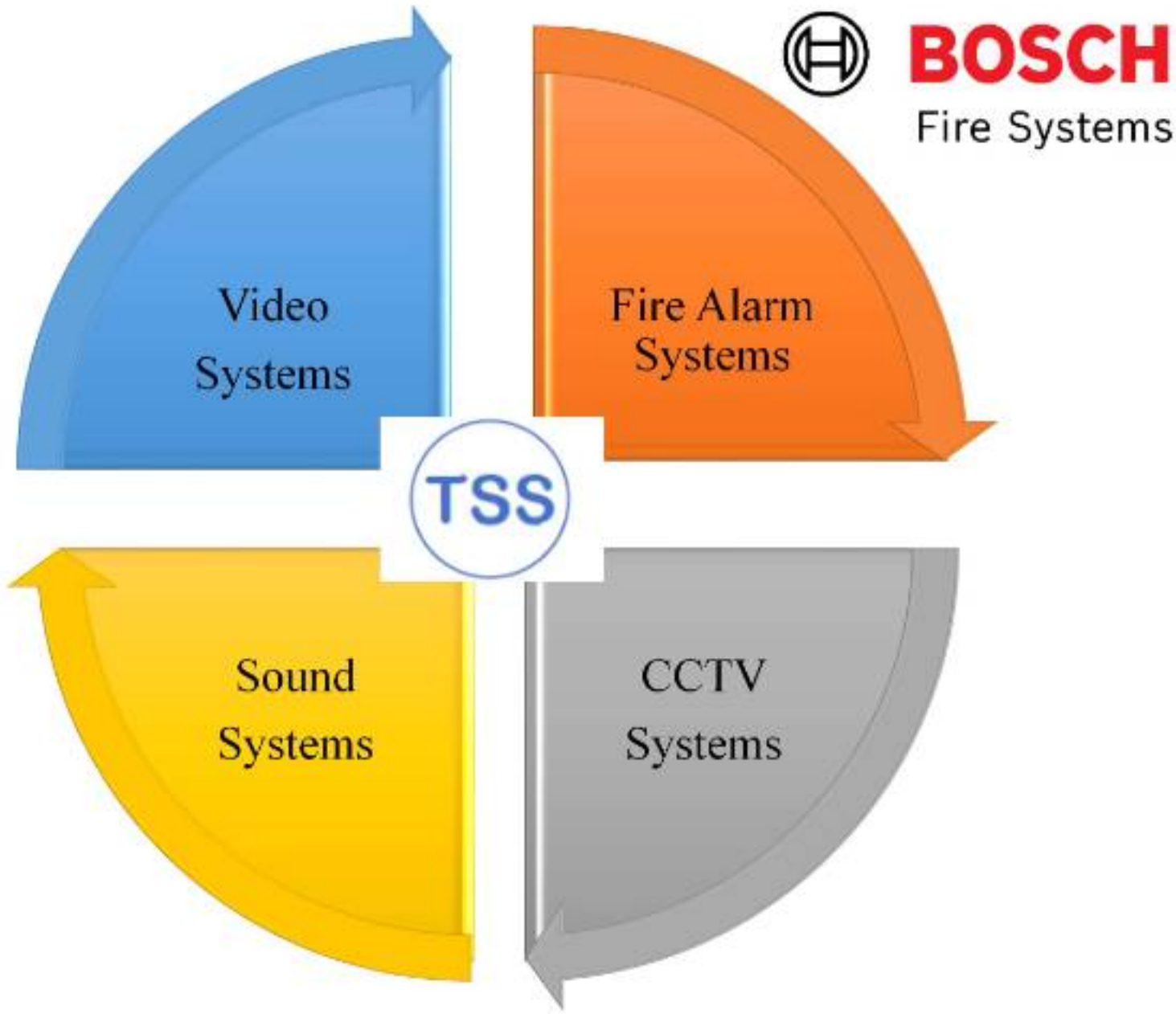

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Smart & Sustainable Cleanroom Strategies for Next-Generation Pharmaceutical Facilities

By Narender Pal Singh, Vice President & Site Head – Plant Operations Panacea Biotec Ltd.

Cleanrooms exist for a single non-negotiable reason: to protect patients by controlling contamination risk.

That purpose is unchanged. What has changed is the context in which cleanrooms must deliver. In pharmaceuticals, the cleanroom is more than a controlled space—it is the last physical barrier between a patient and contamination risk.

Across India and globally, cleanrooms are now expected to perform under pressures that did not exist a decade ago: energy volatility, water stress, carbon accountability, supply-chain fragility, and significant talent constraints in skilled operations and maintenance. At the same time, regulatory expectations are shifting from "periodic proof of compliance" toward lifecycle evidence of control through a robust **Contamination Control Strategy (CCS).**

The outcome is clear. Future pharmaceutical cleanrooms must remain fully GMP-compliant while becoming dramatically lighter on energy, water, and total lifecycle cost. From the chair of operations, I see sustainability not as an extra program, but as a plant-reliability necessity. A system that is oversized and wasteful is also harder to stabilize, more likely to drift, and more prone to deviations. In contrast, a cleanroom that is right sized by risk and kept within control through continuous data verification is easier to run, easier to defend in audits, and far more resilient.

This article outlines practical strategies to build and operate smart, sustainable cleanrooms, and it shares typical industry transformations that Indian pharma facilities can adopt without compromising sterility assurance.

What Do We Mean by "Smart" and "Sustainable"?

A next-generation cleanroom is not defined merely by higher background grades or newer equipment. It is defined by the intelligence of its risk-to-resource alignment.

Smart Cleanrooms

A smart cleanroom has four operational qualities:

- Measured: its critical environmental parameters are monitored with dependable sensors.
- Connected: systems are integrated—BMS, EMS, utilities, alarms, and maintenance platforms share the same truth.
- Responsive: control is dynamic, not static; airflow and utilities respond to occupancy and process reality.
- Continuously verified: health is demonstrated daily by trends, not only during qualification windows.

Sustainable Cleanrooms

A sustainable cleanroom is built and run so that:

- **Air, energy, and water are used only to the extent risk demands.**
- **Lifecycle emissions and maintenance burden are minimized at design stage.**
- **Waste from consumables and maintenance is reduced without affecting control.**

The sharpest facilities will treat smart capabilities as the **method** and sustainability as the **result**. Smart without sustainability becomes an expensive toy. Sustainability without smart verification becomes fragile under audit pressure.

Why Cleanrooms Must Evolve Now

1) Utilities dominate the site footprint

In sterile, biological, and high-containment blocks, HVAC energy is often one of the largest energy consumers at the facility level. And within HVAC, air movement is the main cost driver. Every extra ACPH adds fan power continuously. It is not a one-time CAPEX decision; it is a 10–15-year OPEX and carbon commitment.

2) CCS pushes risk-based performance

Modern regulatory thinking emphasizes CCS as a living framework. This naturally discourages blind inheritance of old URS numbers and encourages performance-based, risk-justified control.

3) Resilience is a compliance factor

Power variability, utility interruptions, and manpower scarcity are realities for many sites. Oversized systems with multiple competing control loops are harder to manage and therefore more deviation prone. Efficiency and controllability are now compliance enablers.

Strategy 1: Right Grade, Right Zone, Right Air

The most powerful sustainability lever is the same lever that strengthens GMP control: do not over-grade or over-ventilate by habit.

A. Address grade inflation

Grade inflation is common in long-running plants. A corridor is upgraded "just in case." A change room is ventilated as if it were a compounding bay because of a decade-old URS. Support areas retain critical-area specs even after the product or process moved out.

The result is predictable: high energy draw, unstable cascades, and an EMS that alarms too easily.

B. Zone by CCS risk questions

Zoning must begin with risk, not with tradition. Three questions should drive grade selection:

1. Product risk: sterile vs non-sterile, potent vs conventional, biotech vs small molecules.
2. Process risk: open handling, duration of exposure, manual intervention intensity.
3. Environmental risk: flows of people and materials, gowning level, and personnel density.

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When these questions are answered honestly, grades become defensible and resource use becomes rational.

C. Replace fixed ACPH with validated performance bands

ACPH is a means, not an outcome. Outcomes are particle levels, recovery times, and airflow stability. A best-practice path is to validate a **safe operating range** of ACPH through:

- steady-state particle mapping,
- recovery testing after interventions,
- airflow visualization to confirm directionality and mixing,
- stability checks during worst-case operation.

Once a control envelope is validated and documented in CCS, dynamic operation inside that envelope is GMP-sound and energy-efficient.

D. Protect the risk point, not the whole room

Localized protection is often superior to room-wide escalation:

- UDAF at critical exposure zones
- RABS or isolators for aseptic steps
- point-of-use HEPAs
- barrier-based layouts to reduce background grade dependency

This decreases HVAC burden while improving sterility assurance.

Strategy 2: HVAC Engineered for Minimum Safe Energy

Once grades and airflow are right-sized, HVAC must deliver control at the lowest possible pressure and energy.

A. Fan power reduction first

Fan energy is the base load that never sleeps. Key levers:

- high-efficiency fans and EC motors
- low-pressure duct design and smooth routing
- correct duct velocities and sizing
- low initial ΔP filter selection
- elimination of unnecessary bends and restrictions

Tiny decreases in resistance translate to massive lifetime savings.

B. Heat recovery on high fresh-air systems

Sterile blocks and containment facilities often require high outdoor air fractions. This makes them ideal for recovery solutions that avoid cross contamination:

- segregated plate exchangers,
- run-around coils,
- chilled-water or hot-water reset strategies.

Apart from energy reduction, recovery improves temperature control stability.

C. Humidity control without energy wastage

Humidity systems frequently waste energy by over-dehumidifying then reheating. Improvements include:

- seasonal dewpoint reset based on real risk needs,
- avoiding unnecessarily tight RH bands where product allows,
- desiccant or hybrid systems where monsoon conditions demand,
- setpoint strategies that prevent simultaneous heat-cool loops.

D. Validated VFD dynamic control

Dynamic control provides reliable savings when validated:

- low-occupancy modes
- night setbacks
- process-dependent ACPH reduction
- adaptive pressure balancing between supply and exhaust

A simple compliance reminder helps teams align:

Regulators do not object to energy saving. They object to unvalidated change.

If dynamic operation is qualified and built into CCS, it is not only acceptable—it is preferable.

Strategy 3: Smart Cleanrooms and Continuous Verification

Traditional cleanrooms are qualified periodically. Smart cleanrooms are verified continuously.

A. Build a cleanroom health index

Instead of separate alarm streams, combine core indicators into a health view:

- particle trend and excursions
- pressure differential stability
- airflow balance
- temperature/RH drift patterns
- door-event frequency and duration
- filter ΔP trends
- recurrence of micro-alarms

This gives QA and operations a shared language of control.

B. Predictive, condition-based maintenance

Filters and fans provide early warnings through data. Condition-based replacement:

- extends filter life safely
- reduces unplanned shutdowns
- lowers disposal and replacement waste
- prevents EMS excursions rooted in utility drift

C. Digital evidence for qualification

Automated trending and secure data trails allow:

- EMS/BMS logs to become PQ evidence
- faster RCA with timestamps across systems
- audit readiness without last-minute data hunting
- requalification based on actual performance history

Smartness strengthens GMP because it removes uncertainty between qualification events.

Strategy 4: Water, Cleaning, and Waste Optimization

Energy dominates HVAC impact. Water and consumables dominate operational waste.

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A. Validated low-water cleaning

By validating lower-volume cleaning where risk permits, facilities can reduce both water and chemical burden. Foam/spray methods and risk-based frequency help most in support zones.

B. CIP/SIP cycle tuning

Many cycles still run on historical conservatism rather than endpoints. Optimizations include:

- validated rinse-endpoint monitoring (conductivity, TOC)
- eliminating excess rinse overruns
- recovering heat from hot effluent streams
- condensate recovery in safe, validated loops

C. Gowning decisions by lifecycle

Reusable vs disposable gowns should be evaluated on:

- contamination risk profile
- washing energy vs disposal load
- grade-dependent consumption
- smart issue/return tracking to reduce over-use

Illustrative Pharma Transformations

Case 1: ACPH rationalization in support rooms

A sterile block had Grade C/D support zones ventilated at legacy fixed ACPH derived from an old URS. Recovery studies and particle mapping verified safe performance at lower values. A validated ACPH band was introduced with VFD control.

Outcome: meaningful fan-energy reduction, better pressure stability, and fewer nuisance EMS alarms.

Lesson: a validated envelope is safer than inherited fixed numbers.

Case 2: Heat recovery on a high-OA sterile block

High fresh-air systems in Indian summers carry steep cooling loads. Recovery via segregated run-around coils followed by chilled-water reset reduced load without any cross-mixing risk.

Outcome: noticeable cooling energy cut, fewer temperature drift alerts, and quick payback.

Lesson: recovery is most profitable where fresh air is highest.

Case 3: Barrier technology reducing background demand

Some aseptic operations need high sterility assurance only at limited exposure points. RABS/isolator solutions combined with localized UDAF allowed background grades to be adjusted through CCS while improving sterility assurance.

Outcome: large HVAC savings and reduced gowning burden with better control.

Lesson: protect the exposure, not the address.

The Maturity Ladder for Future Facilities

Facilities can frame their journey simply:

1. **Compliant baseline:** fixed specs, periodic qualification.
2. **Efficiency optimized:** grades and utilities right sized by risk.
3. **Smart verified:** continuous monitoring, predictive maintenance, digital PQ.
4. **Autonomous:** analytics-driven self-correction and AI control.

Most Indian sites already sit between Levels 1 and 2. Moving to Level 3 depends less on equipment availability and more on **validation confidence and cultural readiness**.

Five Rules to Guide Every New Project or Retrofit

1. Risk drives Cleanroom grade, not tradition.
2. Performance is validated; numbers are justified.
3. Air is the costliest utility you manufacture.
4. Continuous verification makes sustainability audit safe.
5. Lifecycle thinking outperforms CAPEX fear.

The cleanroom of the future will not be the one with the highest background grade or the largest air handling units. It will be the one that is right graded by risk, engineered for minimum safe resource use, and proven in control every day through data.

That is how we protect patients, sustain compliance, and serve responsibly in a resource-constrained world.

AUTHOR

Narender Pal Singh is Vice President and Site Head – Operations & Projects at Panacea Biotec Ltd., bringing 25+ years across pharmaceutical engineering, utilities, projects, sterile/biotech facility management, cleanrooms, and EHS. He has led multiple greenfield and brownfield transformations focused on contamination control strategy (CCS), operational reliability, and lifecycle GMP compliance. His work integrates risk-based cleanroom design, energy-efficient HVAC and predictive maintenance. A regular speaker at industry forums and universities, he recently conducted a "Factory Fit Assessment" training for the DCVMN, with delegates from across the globe. Training materials are hosted on the TTT5 Post-Training Resource Hub on the DCVMN Moodle e-Learning Platform.

Program & Events

ITD Celebrating World De-Carbonisation Day @IIMT College of Engineering

The event was held on 5th September 2025. 20 Attendees & 20 Members participated.

Full Day Workshop @Bharat Mandapam, New Delhi

The event was held on 18th September 2025. 24 Attendees & 24 Members participated.

ISHRAE KNOWLEDGE TALK @Bharat Mandapam

The event was held on 19th September 2025. 24 Attendees & 24 Members participated.

Refcold @Bharat Mandapam, New Delhi

The event was held from 18th-20th September 2025. 1000+ Attendees, 800+ Member & 200+ Non-Member participated.

ISHRAE KNOWLEDGE TALK @DCI Office, Saket

The event was held on 26th September 2025. 20 Attendees, 5 Members & 15 Non-Members participated.

Annual General Meeting @India Habitat Centre

AGM was held on 27th September 2025. 37 Attendees & 37 Members participated.

Full Day Workshop @Le Meriden, New Delhi

The event was held on 4th October 2025. 270 Attendees, 253 Members & 17 Non-Members participated.

DCI CUP 2025 @Wisteria Sports Club, Baliawas, Gurugram

The event was held on 1st November 2025.
650 Attendees and 650 Members participated.

Half Day Workshop @Medanta Hospital, Gurugram

The event was held on 7th November 2025. 14 Attendees & 14 Non-Members participated.

IEC @DCI Office, Saket

The event was held on 8th November 2025.
13 Attendees,
12 Members & 1 Non-Member participated.

ICP @DCI Office, Saket

The event was held on 13th-14th November 2025. 26 Attendees, 12 Members & 14 Non-Members participated.

Distinguished Lecture @IIMT College of Engineering

The lecture was held in 21st November 2025. 18 Attendees, 15 Members & 3 Non-Members participated.

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Advocacy Program @IIMT College of Engineering

The program was held on 21st November 2025. 100 Attendees, 8 Members & 92 Non-Members participated.

Product Presentation @Honeywell,Gurugram

The event was held on 4th December 2025. 22 Attendees, 20 Members & 2 Non-Members participated.

Full Day Workshop @Honeywell,Gurugram

The workshop was held on 4th December 2025. 14 Attendees, 12 Members & 2 Non-Members participated.

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