Energy Efficient Cleanroom Air Recirculation Systems

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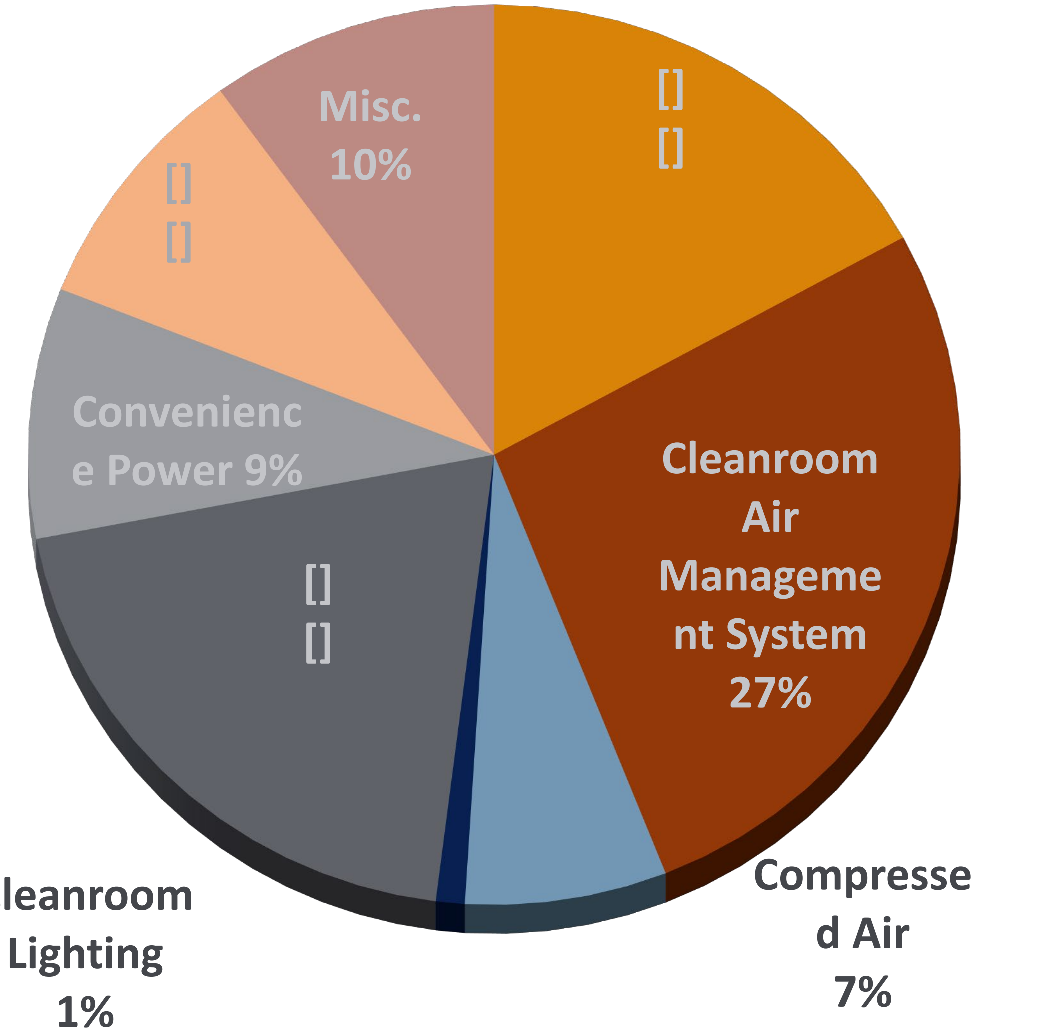
June 25, 2018

Enegry Efficient Design Goals

- Provide a functional clean environment that is transparent to the activities carried out on the space
- Provide an environment that is conducive to research
- Optimize capital and construction costs
- Design an application specific system
- Resist “canned” designed systems

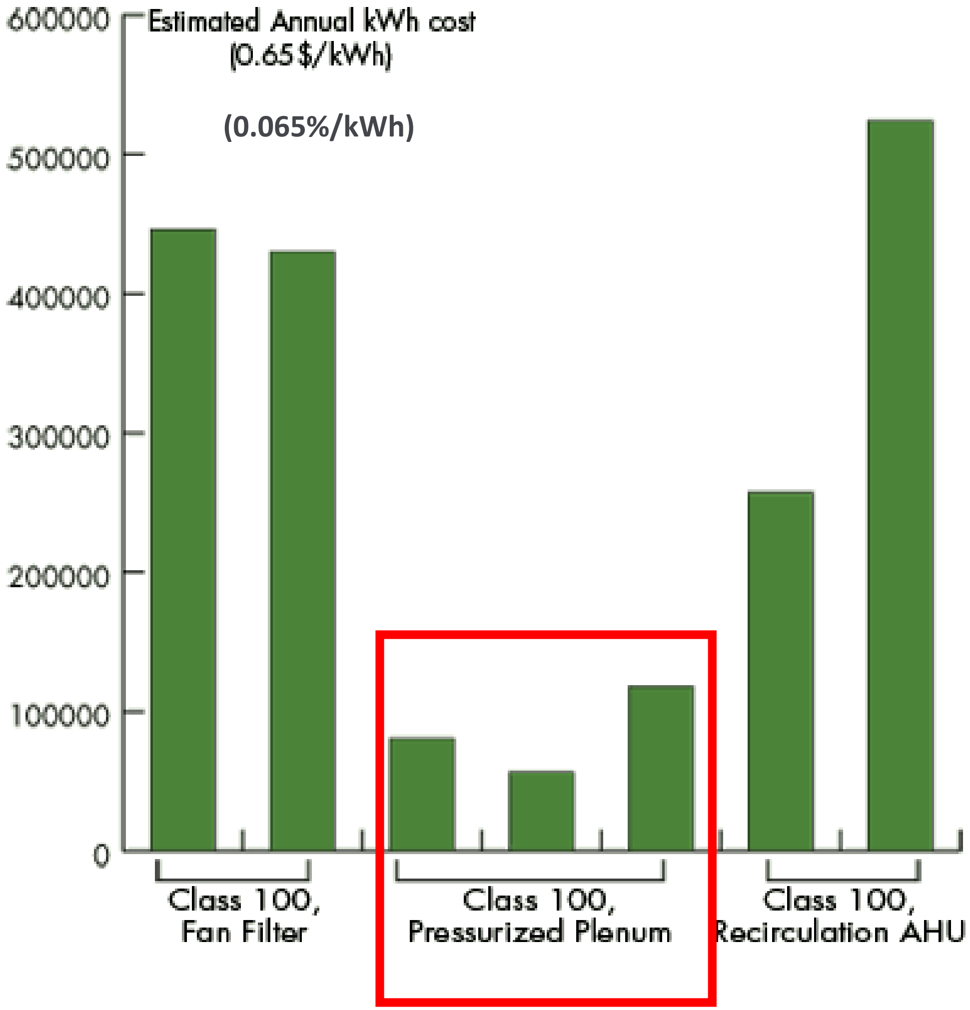
Cleanroom Energy Use



20%+ overall cleanroom energy reduction is achievable

Source: LBNL Cleanroom Energy Benchmarking Study
http://ateam.lbl.gov/cleanroom/benchmarking/Results.htm

Air Management System Type Efficiency



Estimated annual kWh cost for a 1,000,000 cfm, class 100 re-circulation system based upon actual measured efficiencies.

Source: LBNL Environmental Energy Technology Division, http://eetd.lbl.gov/newsletter/nl09/eetd-nl09-4-cleanroom.html

Energy Use Metrics

Table 1. Performance Metrics of Cleanroom Air Systems and Process Load

Metrics	Definition	Unit
Re-circulation Air Handler Unit Efficiency	Recirculated airflow rate per kW of electricity used by all re-circulation air fans	Cfm/kW
Power Intensity for Re-circulation Air Handler Unit	Total fan power of re-circulation air handler unit per unit of primary cleanroom floor area	W/ft^2
Re-circulation Air Change Rate	Re-circulation airflow rate divided by primary cleanroom volume	1/hr
Average Cleanroom Air Velocity	Re-circulation airflow rate divided by primary cleanroom floor area	fpm
Make-up Air Handler Unit Efficiency	Make-up airflow rate per kW of electricity used by make-up air fans	Cfm/kW
Process Load Intensity	Process load per unit of primary cleanroom floor area	W/ft^2

Source: **Energy Performance of Cleanroom Environmental Systems**
,Tengfang Xu, and William Tschudi
Ernest Orlando Lawrence Berkeley National Laboratory
November 2001

Fan Energy (KW)

$$KW = \frac{(CFM * SP * 0.00011712}{FAN\ \acute{\eta} * MOTOR\ \acute{\eta} * DRIV}$$

$CFM = Cubic\ Feet\ per\ Minute\ of\ Air$

$SP = Fan\ Static\ Pressure\ Differential$

$\acute{\eta} = Component\ Efficiency$

Design Decisions Impact these Elements!

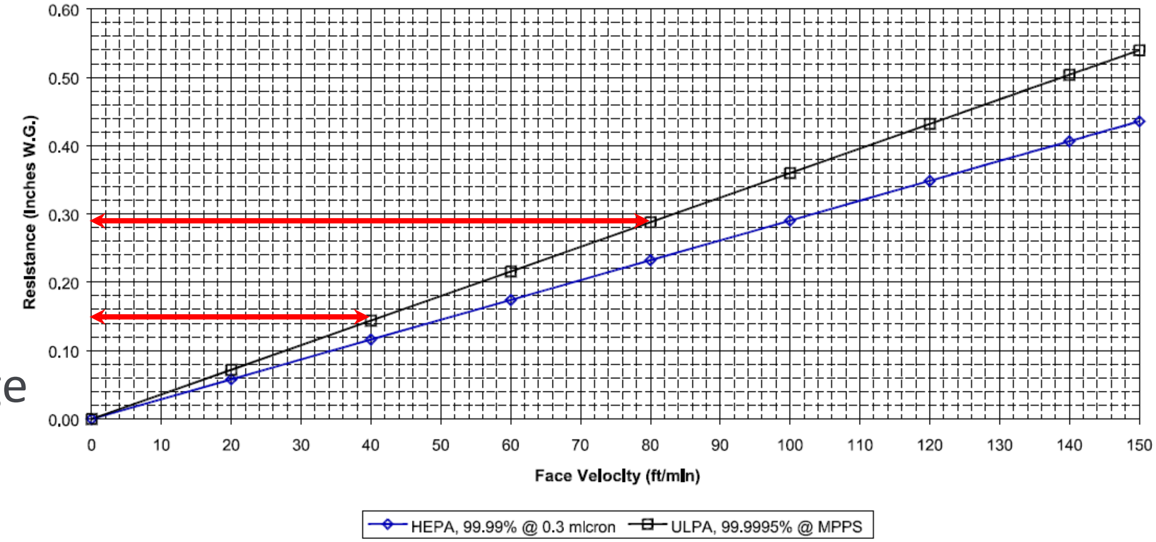
Reduce Static Pressure

- Use Actual Filter Resistance Curve Data
- Dirty Filter Load = 2X Clean Filter Resistance

Static Reduction
~.15 – .2”wg

40FPM 50% Coverage
0.29”wg

40FPM 100% Coverage
0.14”wg

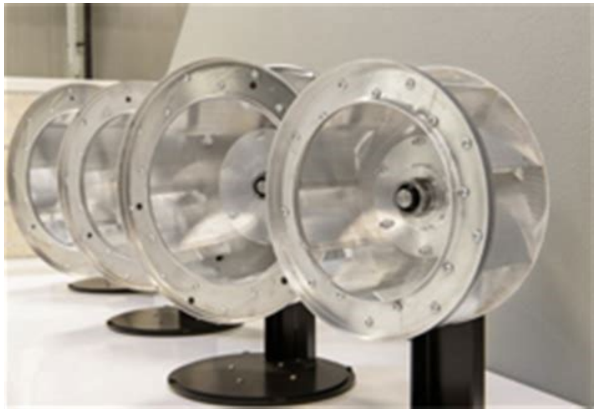


Static Pressure

- Decrease AHU component face velocity
- Minimize / eliminate sound attenuators
- Use appropriate room air flow for required cleanliness class and function

Efficiency ή

- Optimize recirculation unit capacity
- Consider combined motor / wheel efficiency
- RPM matters
- Sound power impacts efficiency and BHp.



Fan / Motor Selection

Validate Selection at:

- Selection Point - 125% of loaded filter static
  - Confirm acceptable operation at
    - N+1 operating point with clean and dirty filters
    - N operating point with clean and dirty filters
- Use IE-4 super premium efficiency motors
- Estimate CFM / Kw metric at normal and N+1 operating point

Operating Cleanroom Example

Carnegie Mellon University - Scott Hall

Claire and John Bertucci Nanotechnology Laboratory

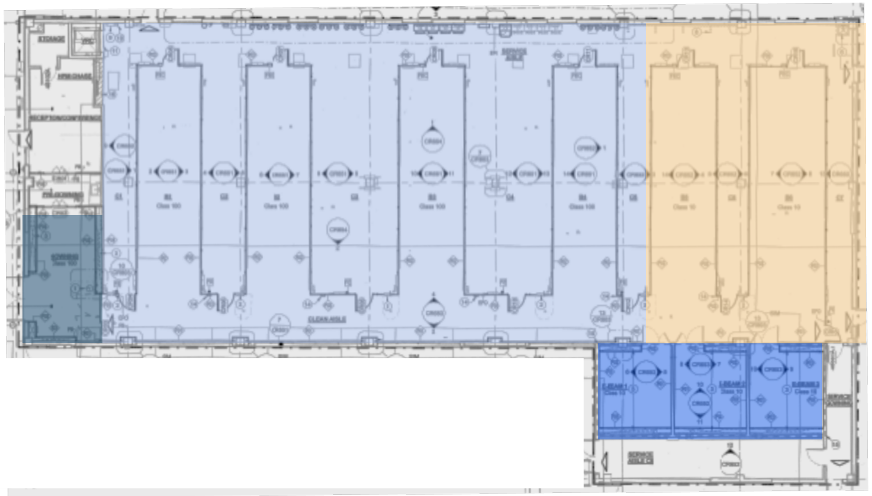
- 8500GSF slab on grade cleanroom suite
- Class 10 (ISO Cl 4)
- Class 100 (ISO Cl 5)
- Class 1000 (ISO Cl 6)

Operating Cleanroom Example

Carnegie Mellon University

- Cl 10 - 100% filter coverage @ 40FPM
- Cl 10 e-Beam - 100% filter coverage @ 30FPM

- Cl 100 - 100% filter coverage @ 30FPM
- Cl 1000 - 80% filter coverage @ 17.5FPM -



Recirculation System Efficiencies

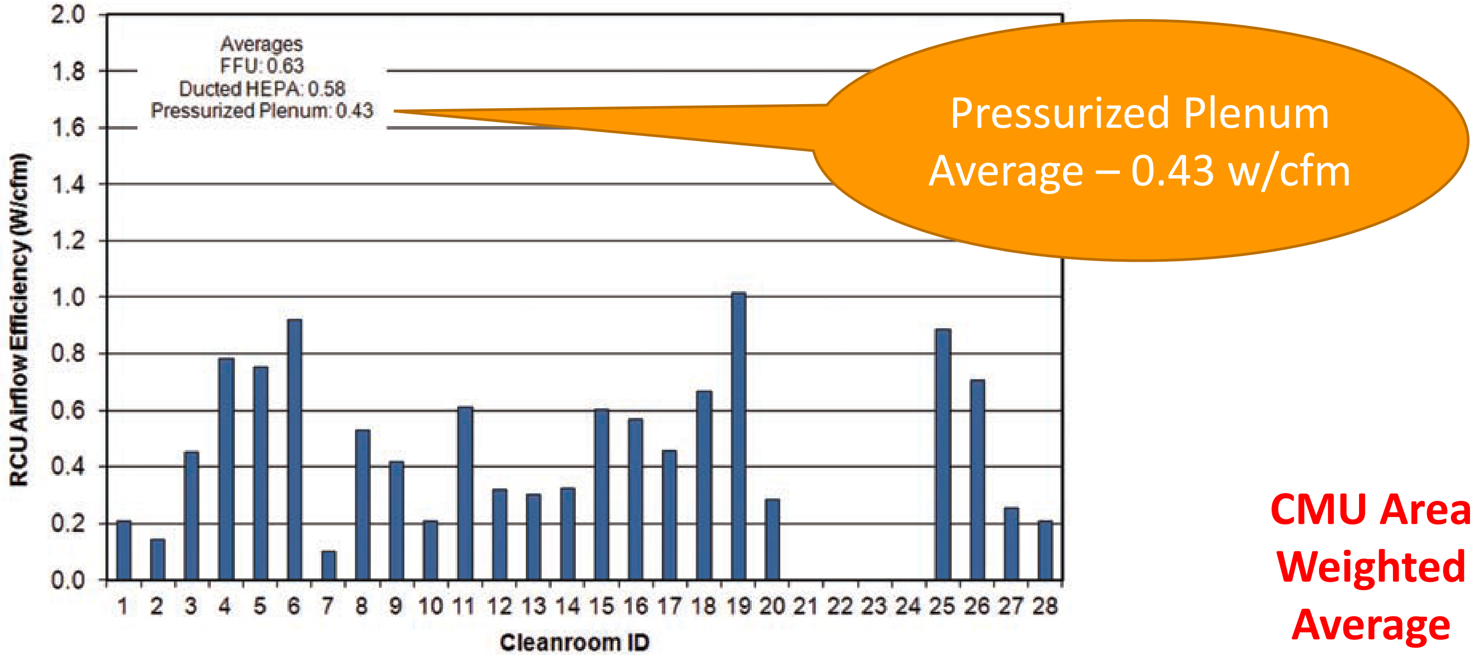


Figure 5: Recirculation units (RCU) airflow efficiency in the LBNL database.

Source: *Cleanroom Energy Efficiency*, ASHRAE Journal, October 2010, Paul A. Mathew, Ph.D., Member ASHRAE; William Tschudi, P.E., Member ASHRAE; Dale Sartor, P.E.; James Beasley

CMU Area Weighted Average 0.0993 w/cfm

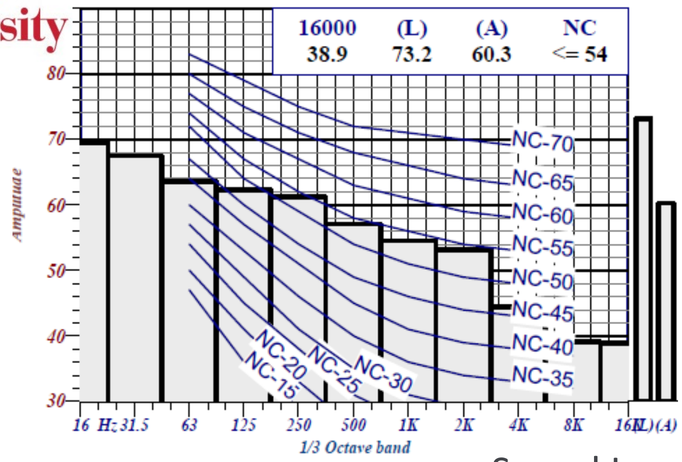
77% reduction from 2010 average energy use

Operating Cleanroom Example

Carnegie Mellon University

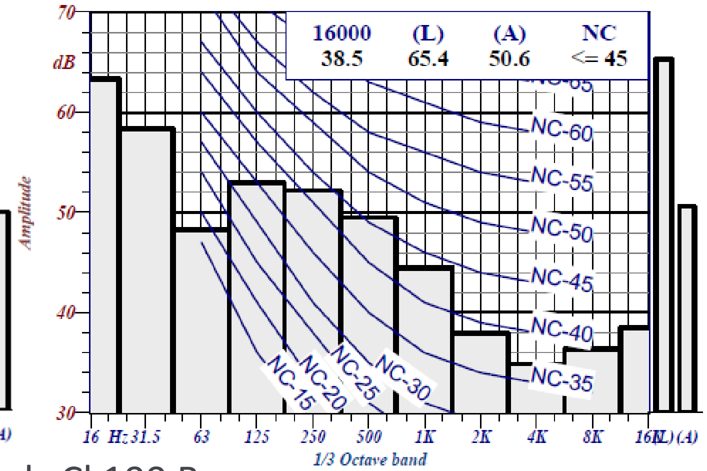
Sound Levels Cl 10 Bay

(No attenuation)



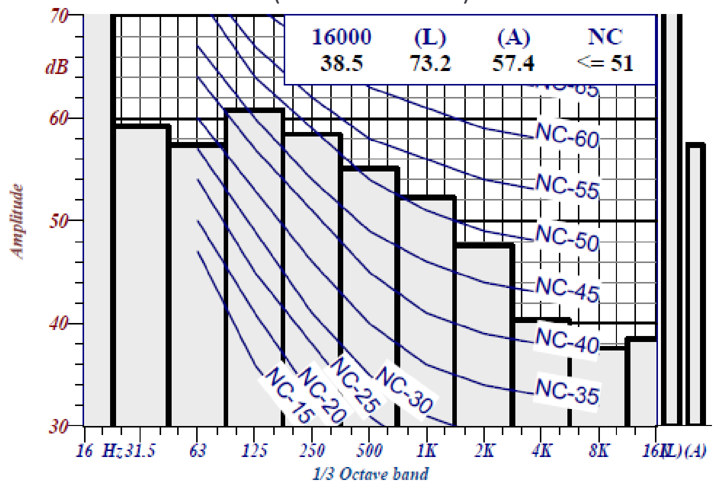
Sound Level Cl 10 e-Beam Room

(with attenuation)



Sound Levels Cl 100 Bay

(No attenuation)



Typical values for each type of space

Cl 10 ≤ NC 54
Cl 10 ≤ NC 45 e-beam
Cl 100 ≤ NC 51

Operating Cleanroom Example

Carnegie Mellon University

Particle Counts

AREA	ISO CLASS	PARTICLE SIZE	AVERAGE PARTICLE/FT3	TOTAL LOC	PASS/ FAIL
Gowning 4S104	6	0.5	0	9	Pass
Clean Aisle	5	0.5	0	19	Pass
Bay 1	5	0.5	0	13	Pass
Bay 2	5	0.5	0	13	Pass
Bay 3	5	0.5	0	13	Pass
Bay 4	5	0.5	0	13	Pass
Bay 5	4	0.5	0	13	Pass
Bay 6	4	0.5	0	14	Pass
E-BEAM 1	4	0.5	0	9	Pass
E-BEAM 2	4	0.5	0	9	Pass
E-BEAM 3	4	0.5	0	9	Pass

Space activity during particle counts– Tool Installation

General Design Guidance

- Engineer the design of the system
- Use real numbers
- Avoid rules of thumb
- Focus on metrics
- Consider first cost vs ROI

Carnegie Mellon University

Special Thanks

Matt Moneck

Max Dorosa

Questions

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