

EE-527: MicroFabrication

Clean Rooms

How Big of a Particle is Tolerable?

- Example: 0.5 μm CMOS technology
 - Lateral Features:
 - pattern size = 0.5 μm
 - pattern tolerance = 0.15 μm
 - level-level registration = 0.15 μm
 - Vertical Features:
 - gate oxide thickness = 10 nm
 - field oxide thickness = 20 nm
 - film thicknesses = 250-500 nm
 - junction depths = 50-150 nm

Filtration Media

- Fibers
 - “depth” filters
 - many randomly oriented intertangled strands laid into a mat
 - Fourdrinier process, usually submicron glass fibers
 - void volume is typically about 85 - 90 %
- Membranes
 - “surface” filters
 - homogeneous sheet material with holes punched into it
 - 1. cellulose nitrate; void volume is about 70 - 85 %
 - holes formed by solvent evaporation, irradiation, or stretching
 - 2. polycarbonate sheets; void volume is about 10 - 20 %
 - 3. PTFE sheets; biaxially stretched
 - 4. sintered silver particles

Clean Room Air Filters

- High Efficiency Particulate Air (HEPA) Filters
 - most common type of clean room air filter
 - high efficiency, low pressure drop, good loading characteristics
 - uses glass fibers in a paper-like medium
 - are rated by their particle retention:
 - A true HEPA-rated filter will retain 99.97 % of incident particles of 0.3 μm or larger. (DEFINITION)

HEPA History

- developed during WWII atomic bomb research for containment of radioactive aerosols
- called “superimpingement” or “superinterception” filters; later referred to as “absolute” filters
- first prototype filters used esparto grass as the filter medium
- in 1950s glass fibers were introduced into the paper
- in 1960s specifications were standardized and called HEPA filters
- in 1970s asbestos was removed
- in 1960 the first laminar flow bench was invented at Sandia National Laboratory
- HEPAs have now been developed by the semiconductor industry to far outstrip their original specifications

HEPA Filter Types

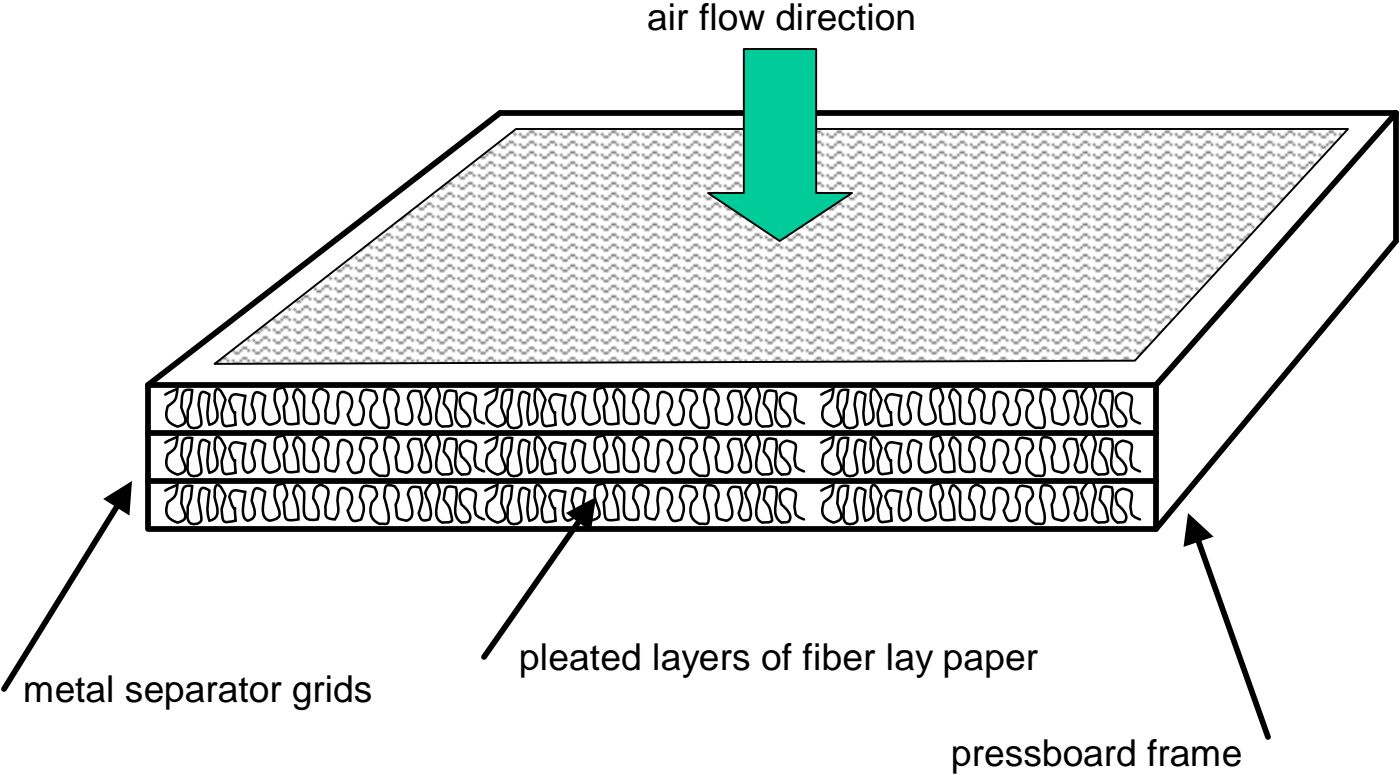
<u>Type</u>	<u>Application</u>	<u>Performance</u>
A	industrial, noncritical	> 99.97 % @ 0.3 μm (MIL-STD-282)
B	nuclear containment	> 99.97 % @ 0.3 μm (certified by DOE)
C	laminar flow	> 99.97 % @ 0.3 μm (MIL-STD-282)
D	ultra-low penetration air (ULPA)	> 99.9995 % @ 0.12 μm
E	toxic, nuclear, and biohazard containment	MIL-F-51477 MIL-F-51068 (classified performance)

Grade 1 = fire resistant
Grade 2 = semicomcombustible

HEPA / ULPA Characteristics

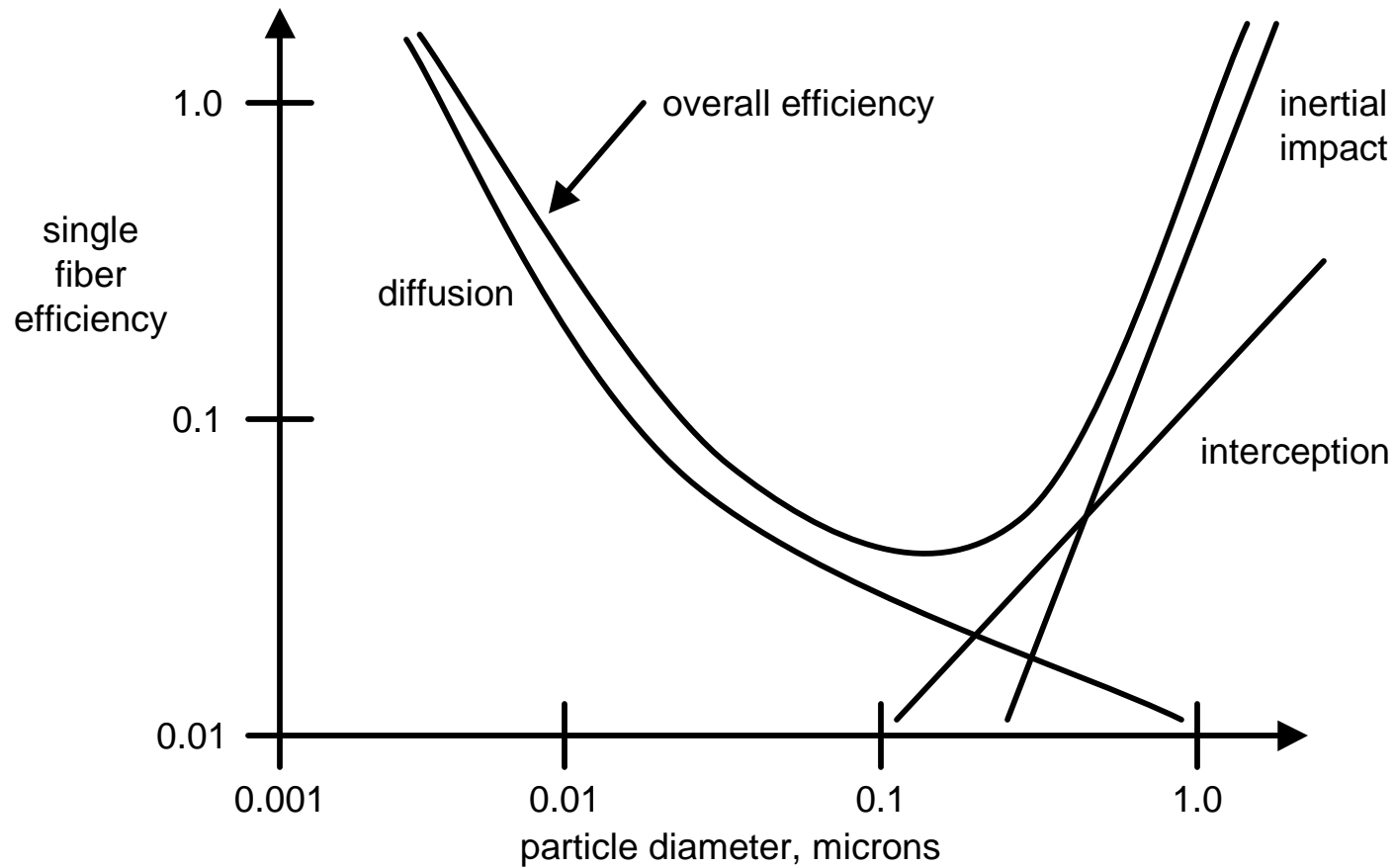
- Most submicron fabrication lines use Type-D ULPA filters as an improvement over traditional HEPA's for Class-1 and Class-10 environments.
- Usual size is 3 ft. x 6 ft. x 5.875 in. frame.
- When new, maximum pressure drop is 1 in of H₂O = 0.036 psi
- Each ft² of opening corresponds to about 50 ft² of paper area.
- Designed for 90 lfm air velocity, or 45.7 cm/sec.
- Designed for entraining 500 - 1000 grams of dust per 1000 cfm
- Are sealed into the ceiling using gel-sealed T-bars
- Typical lifespan is several years if air is properly prefiltered

HEPA Filter Construction



Physics of Fiber Filtration

conditions: 1.0 μm fiber radius;
0.1 packing density; 10 cm/s air velocity



Advanced Air Filtration Methods

- Particles around the 0.1 μm size range are most difficult to filter.
- Reducing air velocity decreases the fractional penetration.
- New trend is to use electrostatic methods in series with HEPA's and ULPA's
 - Obtain a factor of 10 improvement from corona precharging
 - Obtain another factor of 10 improvement from corona precharging followed by collector electrification

Fractional Penetration of 0.1 μm Particles

HEPA @ 7 cm/s	10^{-3}
HEPA @ 3.5 cm/s	10^{-4}
ULPA @ 7 cm/s	10^{-4}
ULPA @ 3.5 cm/s	10^{-5}
ULPA @ 1.25 cm/s	10^{-6}

Clean Room Class Ratings

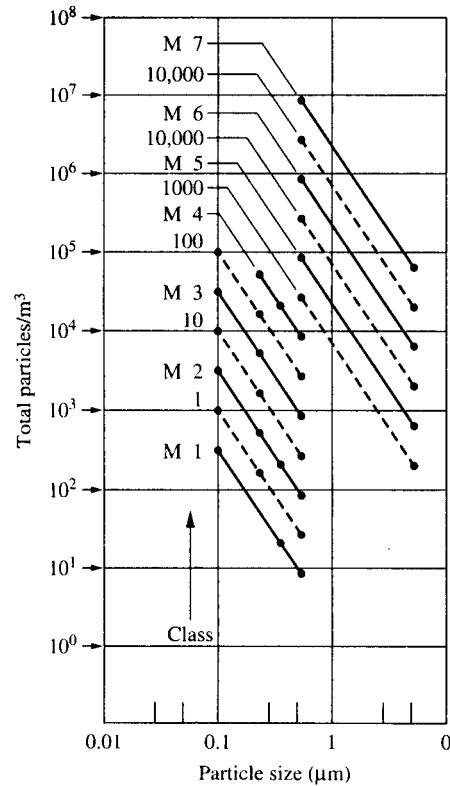


FIGURE 1
Air cleanliness according to U.S. Fed. Std. 209E.

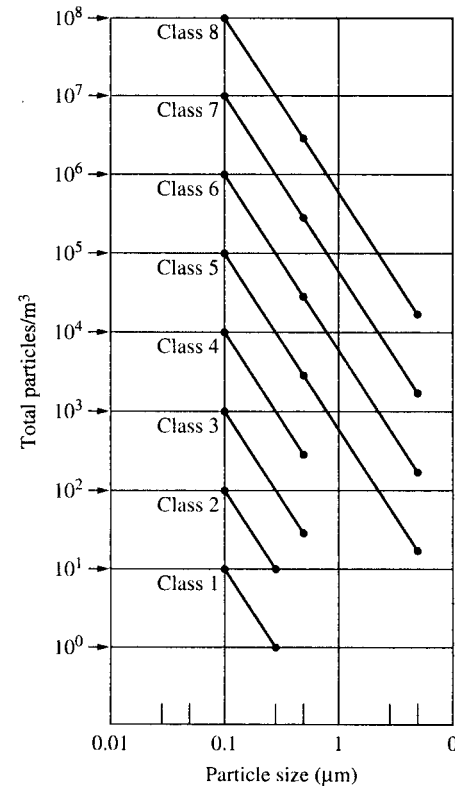


FIGURE 2
Air cleanliness according to Japanese Std. B9920 rev.

from *ULSI Technology* by Chang and Sze

Clean Room Class Ratings

Class	# 0.5 μm particles per ft^3	# 5.0 μm particles per ft^3	air changes per hour	ceiling filter coverage (%)	air velocity (fpm)	max. vibration ($\mu\text{in/s}$)	temp. tolerance	RH tolerance	approx. capital cost per ft^2
office			12-18						\$10
100,000	100,000	650	18-30	10					\$50
10,000	10,000	65	40-60	30	10		$\pm 3.0^\circ\text{F}$	$\pm 5\%$	\$200-250
1,000	1,000	6.5	150-300	50	30-50		$\pm 2.0^\circ\text{F}$	$\pm 5\%$	\$350-400
100	100	0.65	400-540	80-100	75-90	500	$\pm 1.0^\circ\text{F}$	$\pm 5\%$	~\$1200
10	10	0.065	400-540	100	75-90	250	$\pm 0.5^\circ\text{F}$	$\pm 3\%$	~\$3500
1	1	0.0065	540-600	100	90-100	250	$\pm 0.3^\circ\text{F}$	$\pm 2\%$	~\$10,000+
.5	.5	0.0033	540-600	100	100-110	125	$\pm 0.1^\circ\text{F}$	$\pm 1\%$	~\$25,000+

Types of Cleanrooms - 1

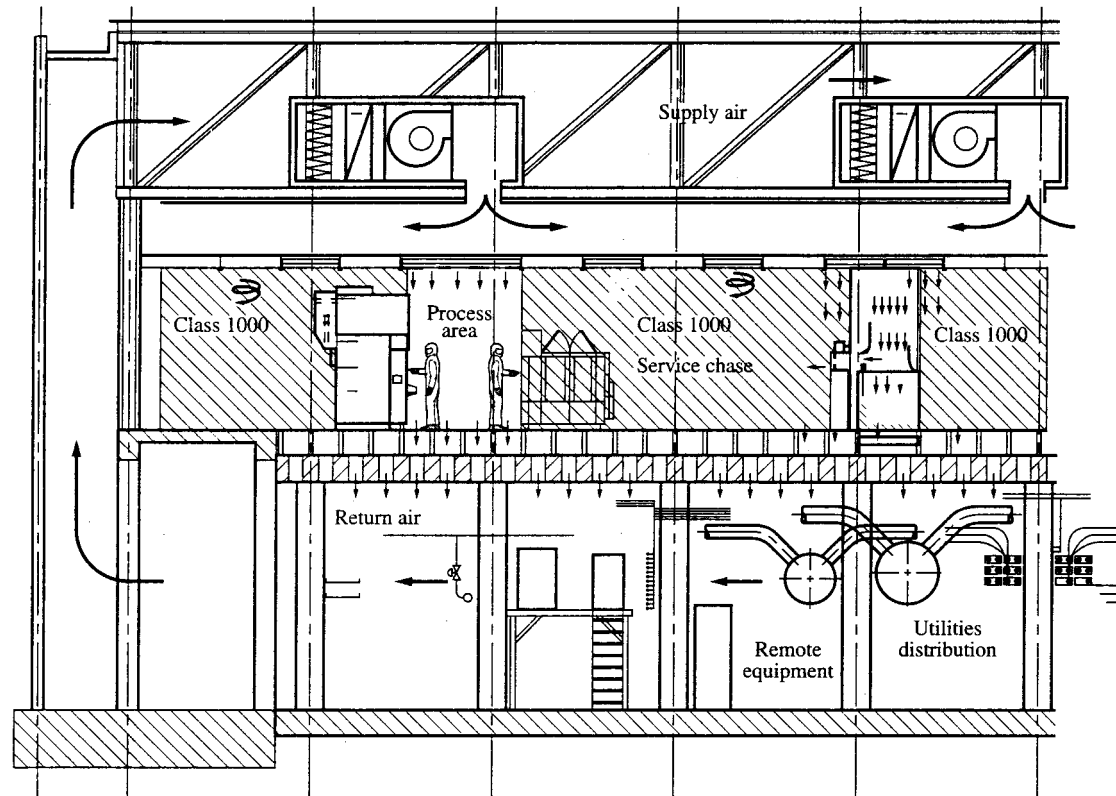


FIGURE 7
Cleanroom with centrifugal fan units installed on top of process level.

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Types of Cleanrooms - 2

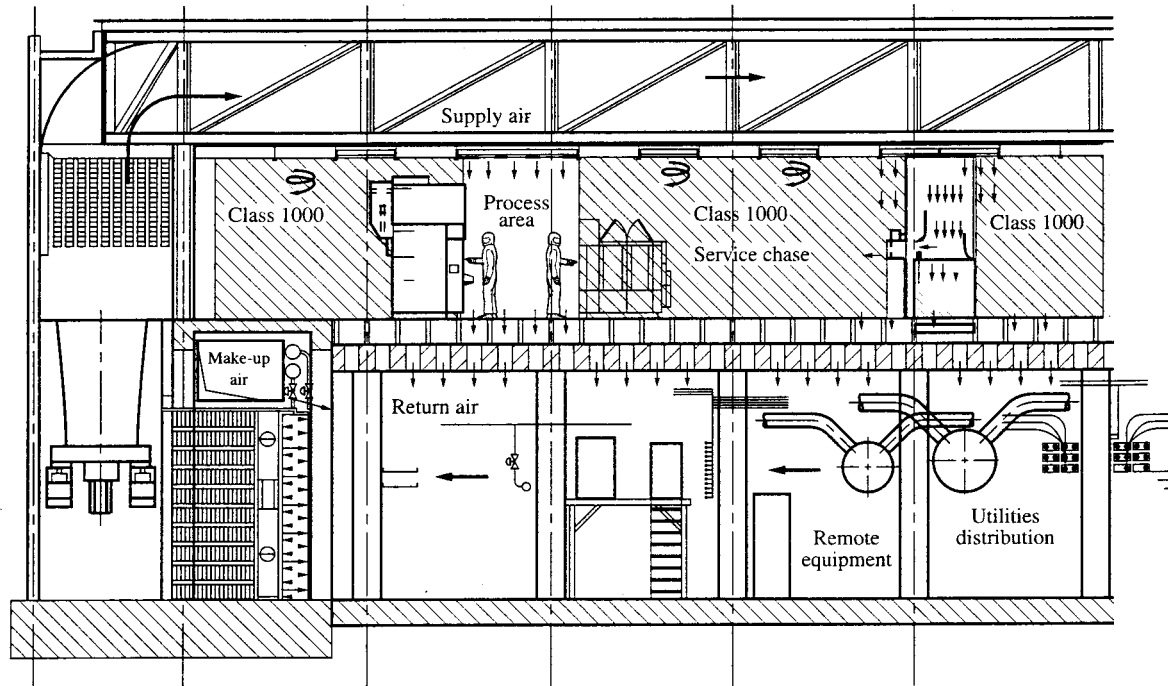


FIGURE 8
Cleanroom with axial fan units installed sideways connecting the air-supply plenum at the top and the air-return plenum at the bottom.

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Types of Cleanrooms - 3

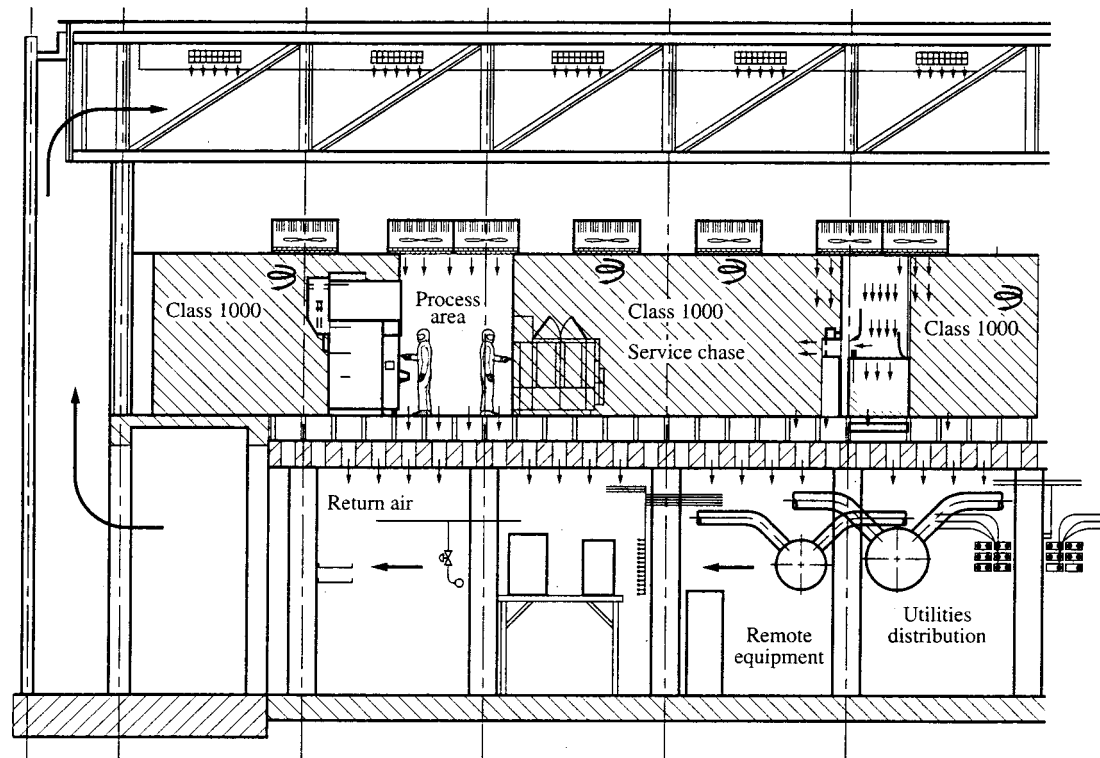


FIGURE 9
Cleanroom with filter fan units installed on the top of process area.

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Types of Cleanrooms - 4

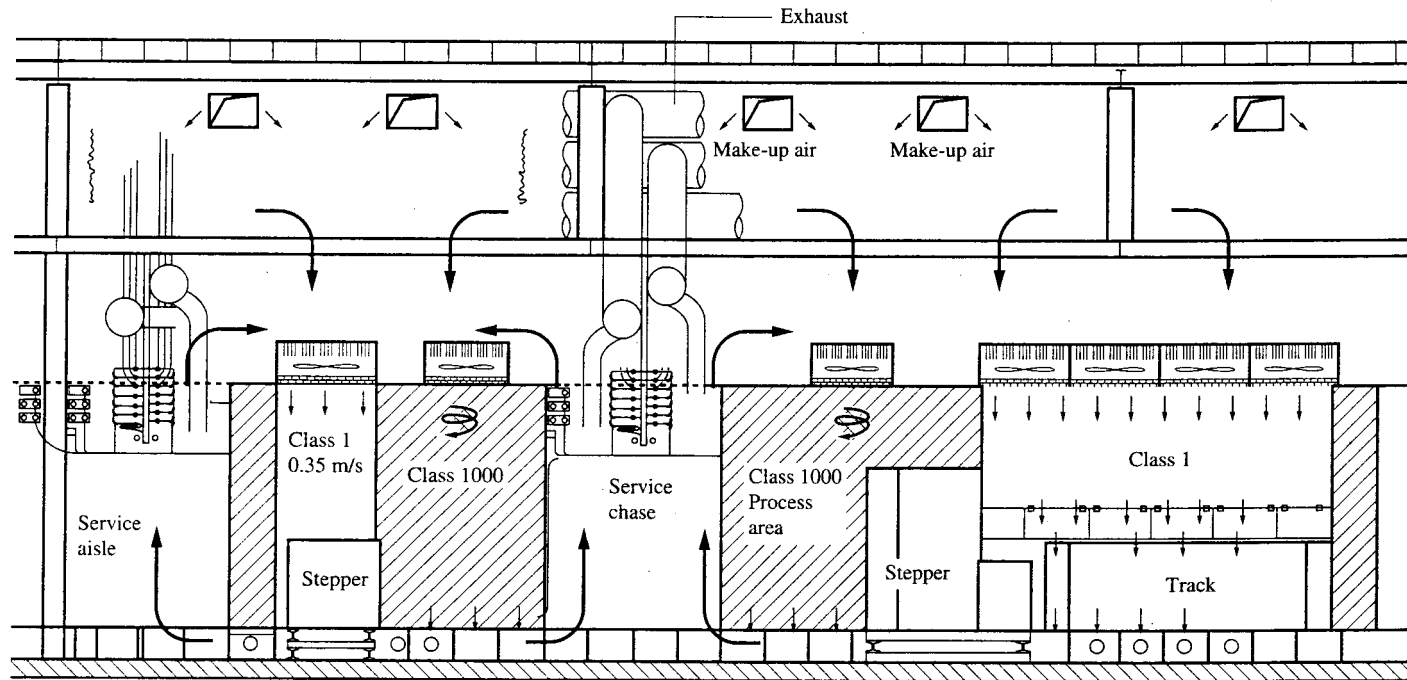


FIGURE 6
Ballroom-type cleanroom with process and service areas located on the same floor.

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R. B. Darling / EE-527

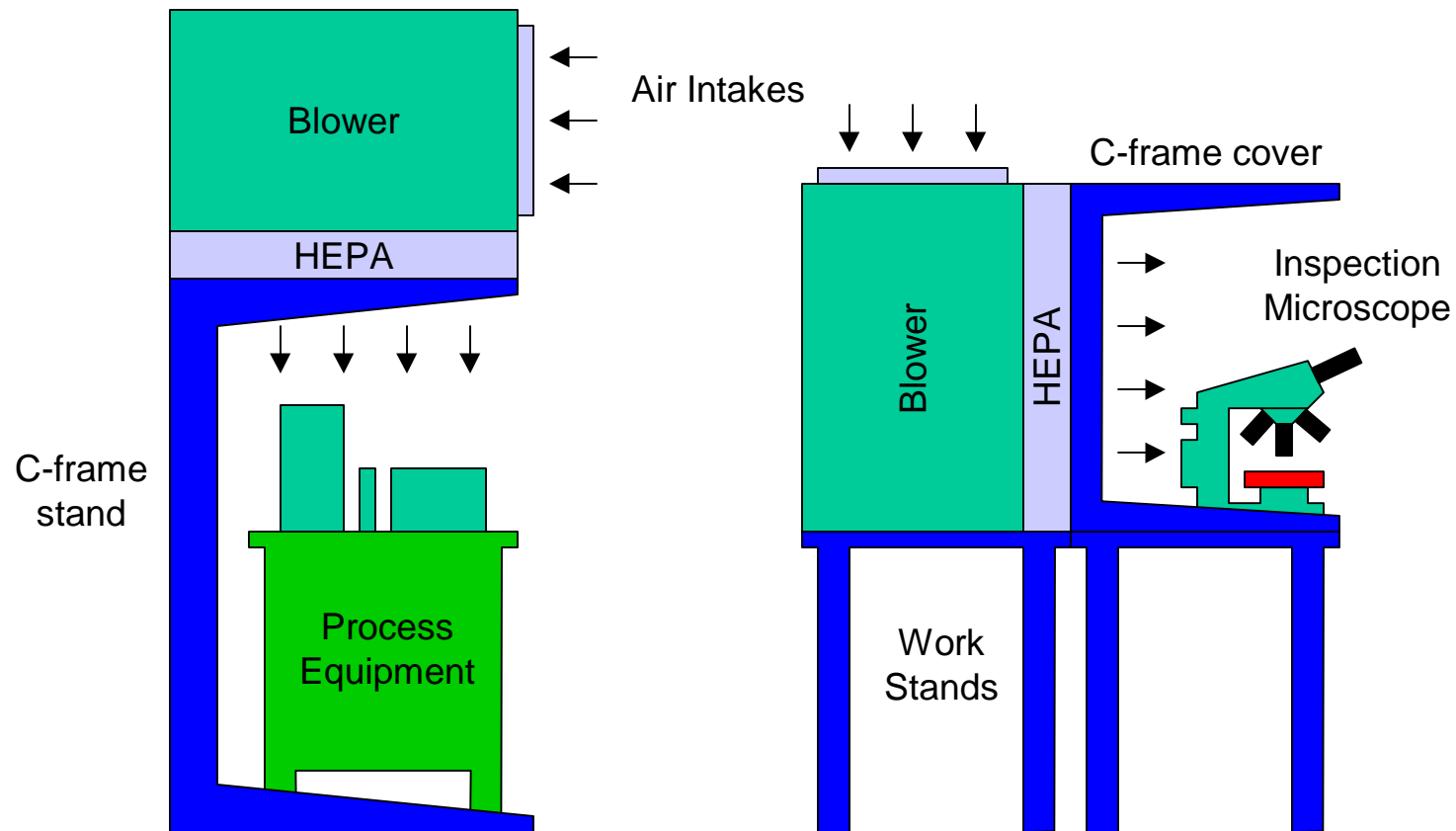
Characteristics of Clean Rooms

- Air is recirculated through HEPA filters with about 20 % make up.
 - Vapors are entrained, so contamination potential is very high
 - Extensive gas detection and alarm systems are installed
- Temperature is controlled to 68 - 72 °F.
- Humidity is controlled to 40 - 46 % RH.
- Room is held at positive pressure
 - Typically 0.1 in of H₂O for Class 100, Class 1000, and Class 10,000
 - Typically 0.3 - 0.4 in of H₂O for Class 1 and Class 10
 - Positive pressure constantly blows dust OUT
 - (Biohazard rooms operate at negative pressure to keep bugs IN)
 - Doors open inward, so room pressure closes them shut
 - 0.1 in H₂O = 3.6×10^{-3} psi = 0.52 lb/ft²
 - This produces 9.1 lbs. force on a 7' x 30" door

Laminar Flow Benches

- A HEPA filter used to provide local clean air conditions
 - Can usually drop the class rating by 2 decades within a local area
 - Example: Class 100 local environment within a Class 10,000 room
- Designed to minimize turbulence which creates dust and dirt collection pockets
- Vertical style used above free standing equipment and load zones
- Horizontal style used behind microscope and inspection benches
- Benches usually have built-in air diffusers, lights, and occasionally shutters to close off the workspace from the outside

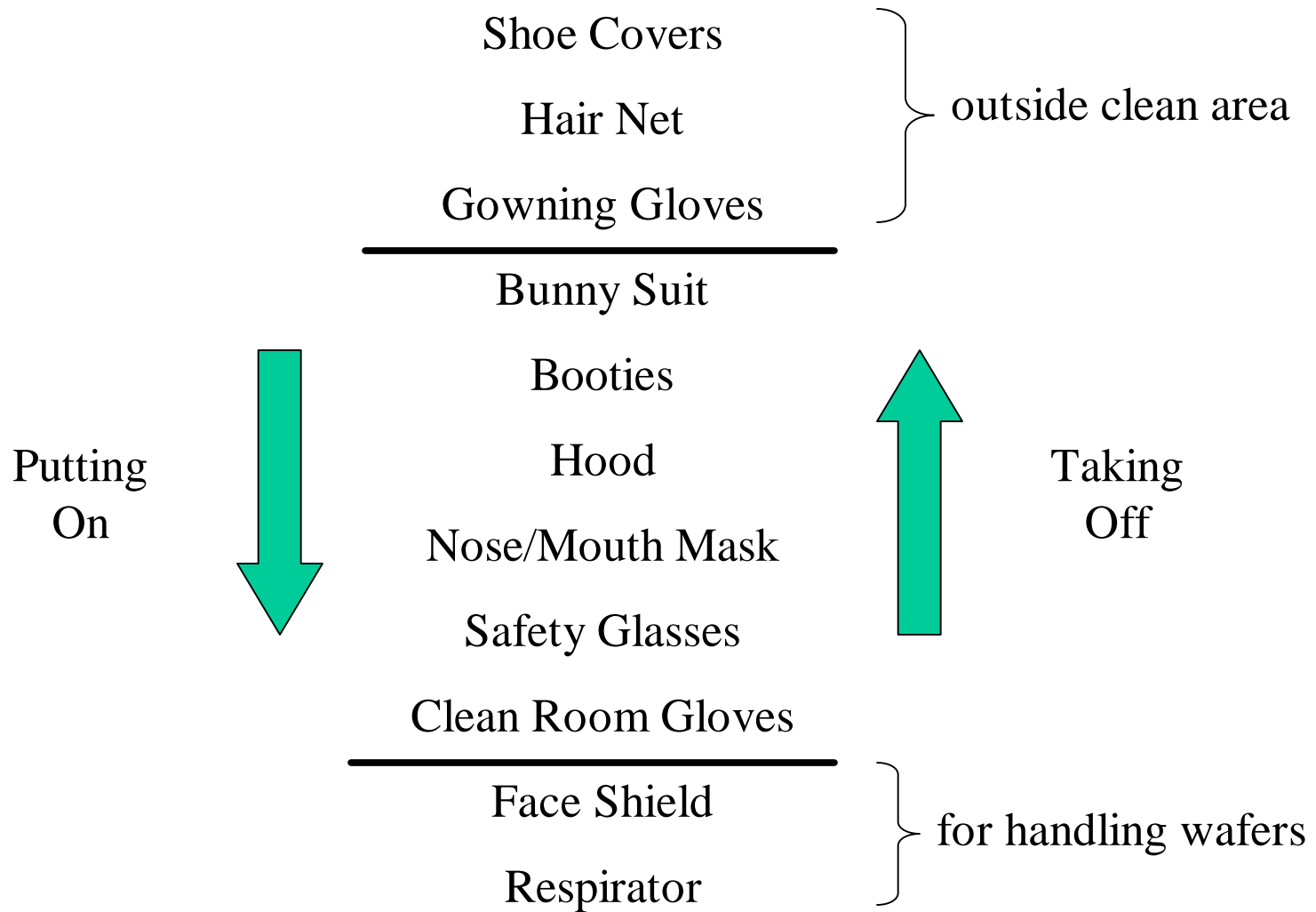
Vertical and Horizontal Laminar Benches



Gowning - Class 10,000



Gowning - Class 100



Clean Room Dos and Don'ts

- 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, pencils or markers that leave dust or lint
- Do:
 - change gloves whenever they get dirty or torn
 - use a fresh pair of gloves whenever handling wafers
 - wipe down wafer handling areas with isopropanol
 - use clean room paper and dust-free ball point pens

Bringing Items In and Out

- Everything should be double bagged
 - Use zip-lock bags or aluminum foil or plastic wrap
- Once cleaned and sealed inside a clean room, items should not be opened unit inside another clean room
- Standard clean and degrease is required for all new items entering the clean room