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

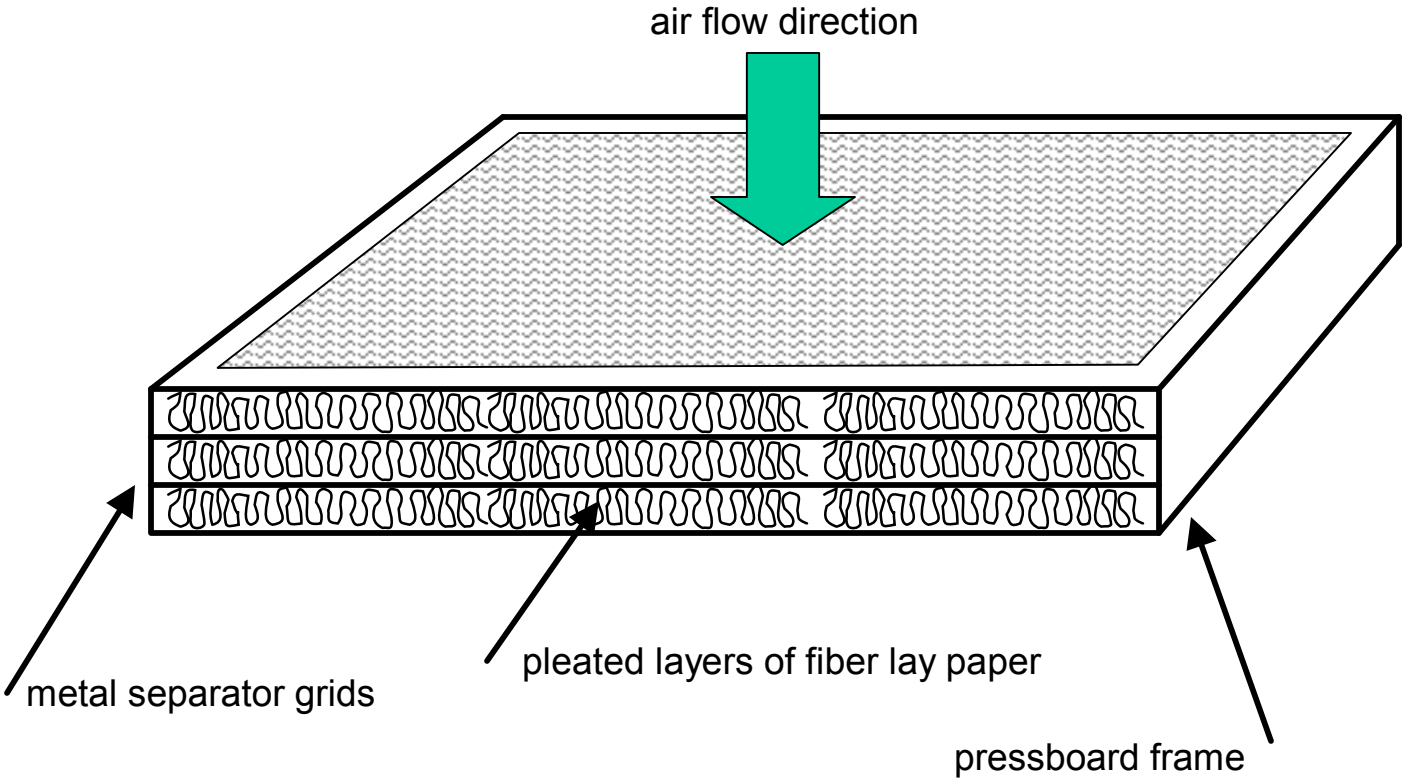
Type	Application	Performance
A	industrial, noncritical	> 99.97 % @ 0.3 μm (MIL-STD-282)
B	nuclear containment	> 99.97 % @ 0.3 μm (certified by DOE)
C	laminar flow	> 99.97 % @ 0.3 μm (MIL-STD-282)
D	ultra-low penetration air (ULPA)	> 99.9995 % @ 0.12 μm
E	toxic, nuclear, and biohazard containment	MIL-F-51477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

Grade 1 = fire resistant
Grade 2 = semicombustible

HEPA / ULPA Characteristics

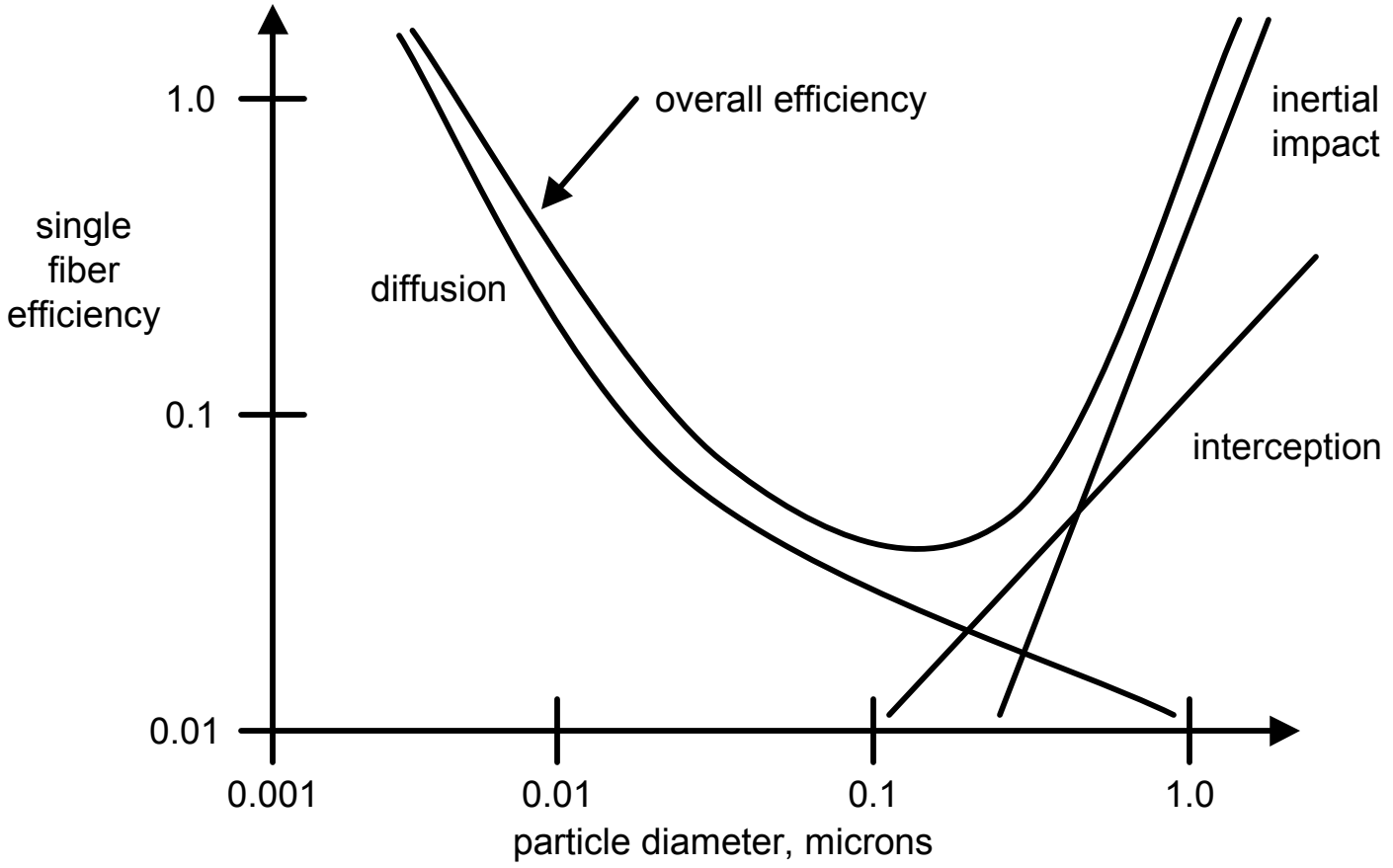
- Most submicron fabrication lines use Type-D ULPA filters as an improvement over traditional HEPAs for Class-1 and Class-10 environments.
- Usual size is 3 ft. x 6 ft. x 5.875 in. frame.
- When new, maximum pressure drop is 1 in of H_2O = 0.036 psi
- Each ft^2 of opening corresponds to about 50 ft^2 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 HEPAs and ULPAs
  - 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

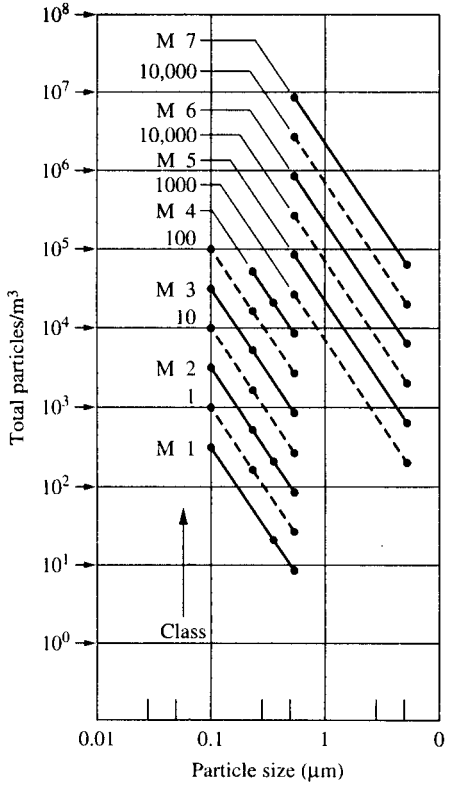


FIGURE 1
Air cleanliness according to U.S. Fed. Std. 209E.

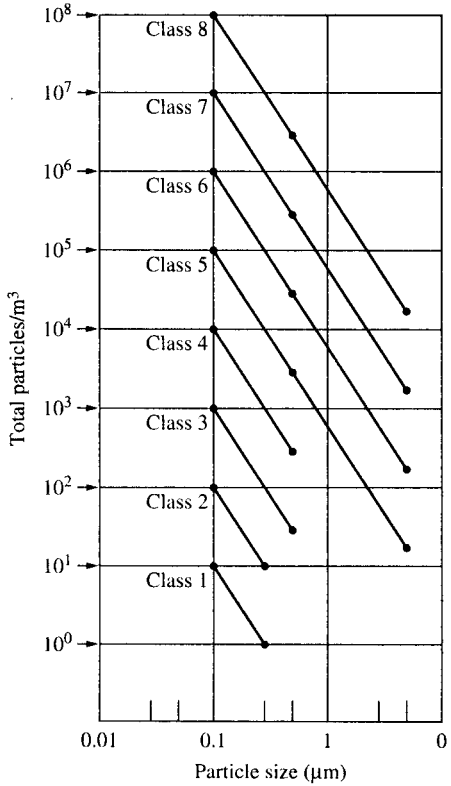


FIGURE 2
Air cleanliness according to Japanese Std. B9920 rev.

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 (μin/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		±3.0°F	±5%	$200-250
1,000	1,000	6.5	150-300	50	30-50		±2.0°F	±5%	$350-400
100	100	0.65	400-540	80-100	75-90	500	±1.0°F	±5%	~$1200
10	10	0.065	400-540	100	75-90	250	±0.5°F	±3%	~$3500
1	1	0.0065	540-600	100	90-100	250	±0.3°F	±2%	~$10,000+
.5	.5	0.0033	540-600	100	100-110	125	±0.1°F	±1%	~$25,000+

Types of Cleanrooms - 1

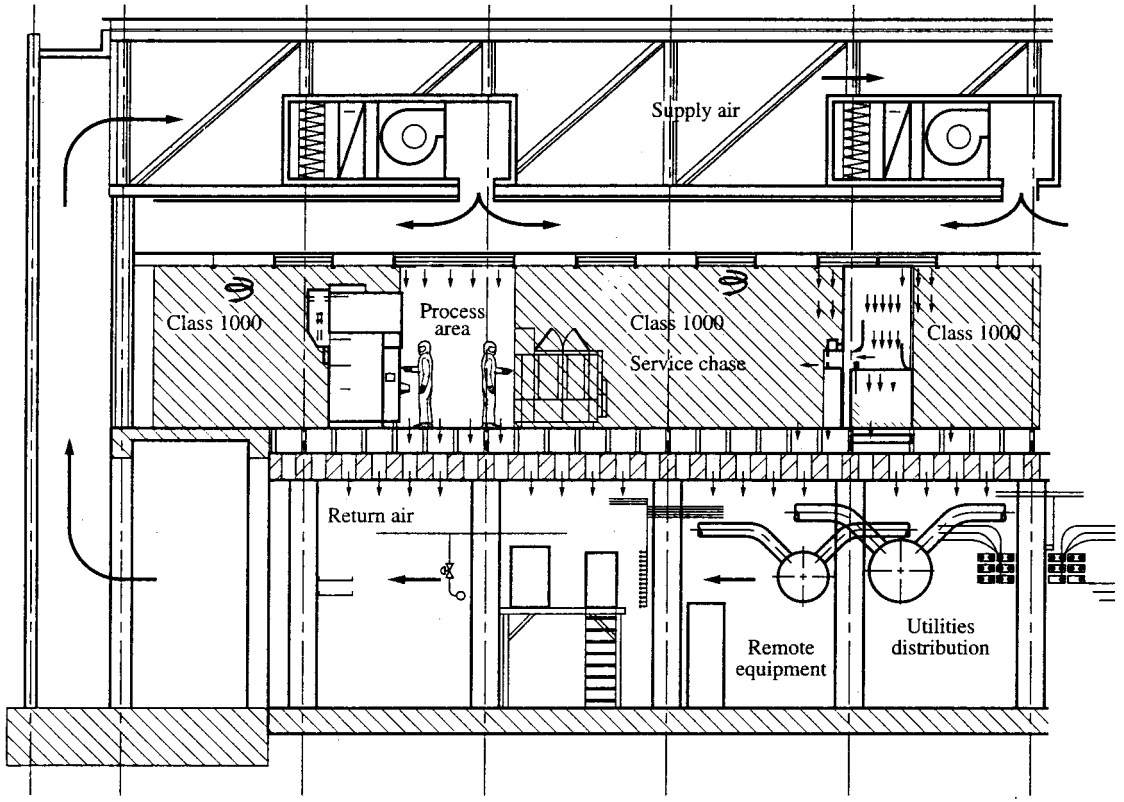


FIGURE 7
Cleanroom with centrifugal fan units installed on top of process level.

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Types of Cleanrooms - 2

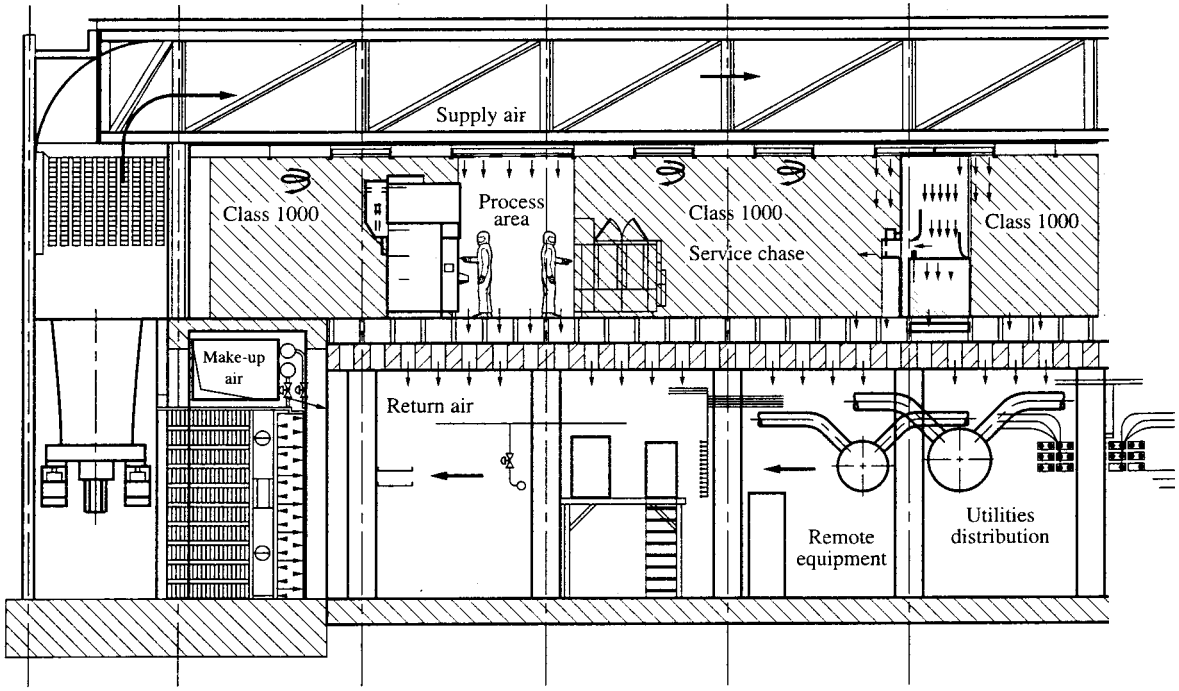

FIGURE 8
Cleanroom with axial fan units installed sideways connecting the air-supply plenum at the top and the air-return plenum at the bottom.

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Types of Cleanrooms - 3

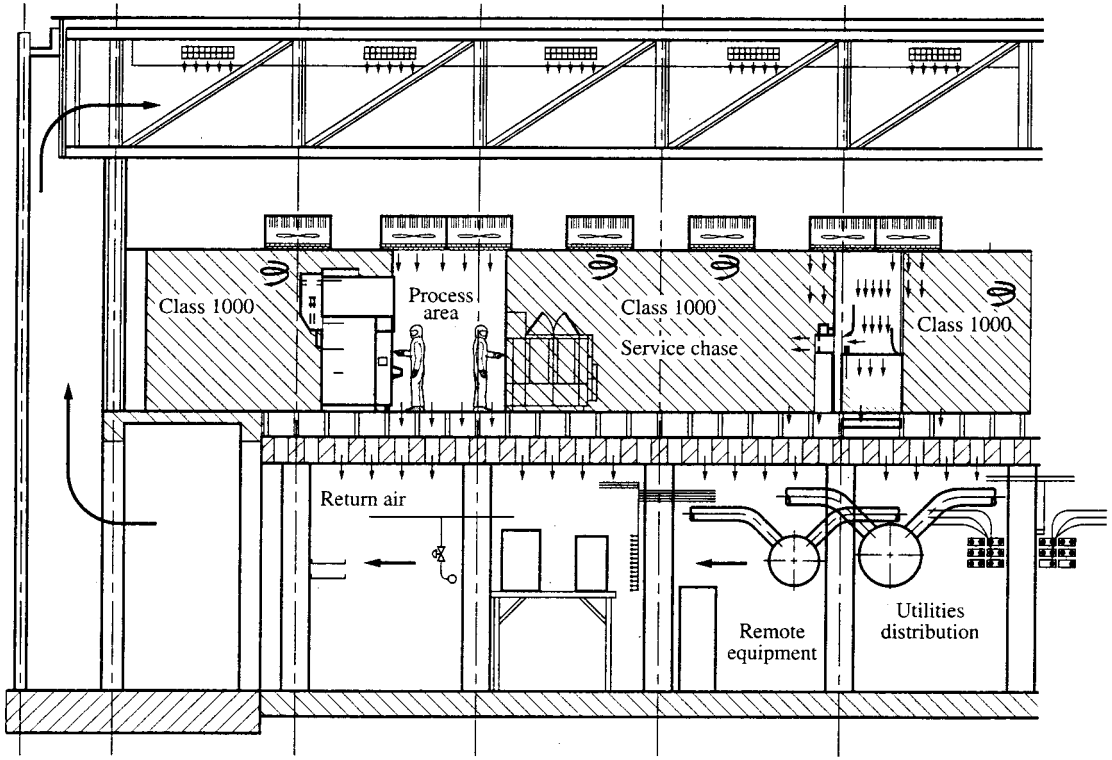

FIGURE 9
Cleanroom with filter fan units installed on the top of process area.

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Types of Cleanrooms - 4

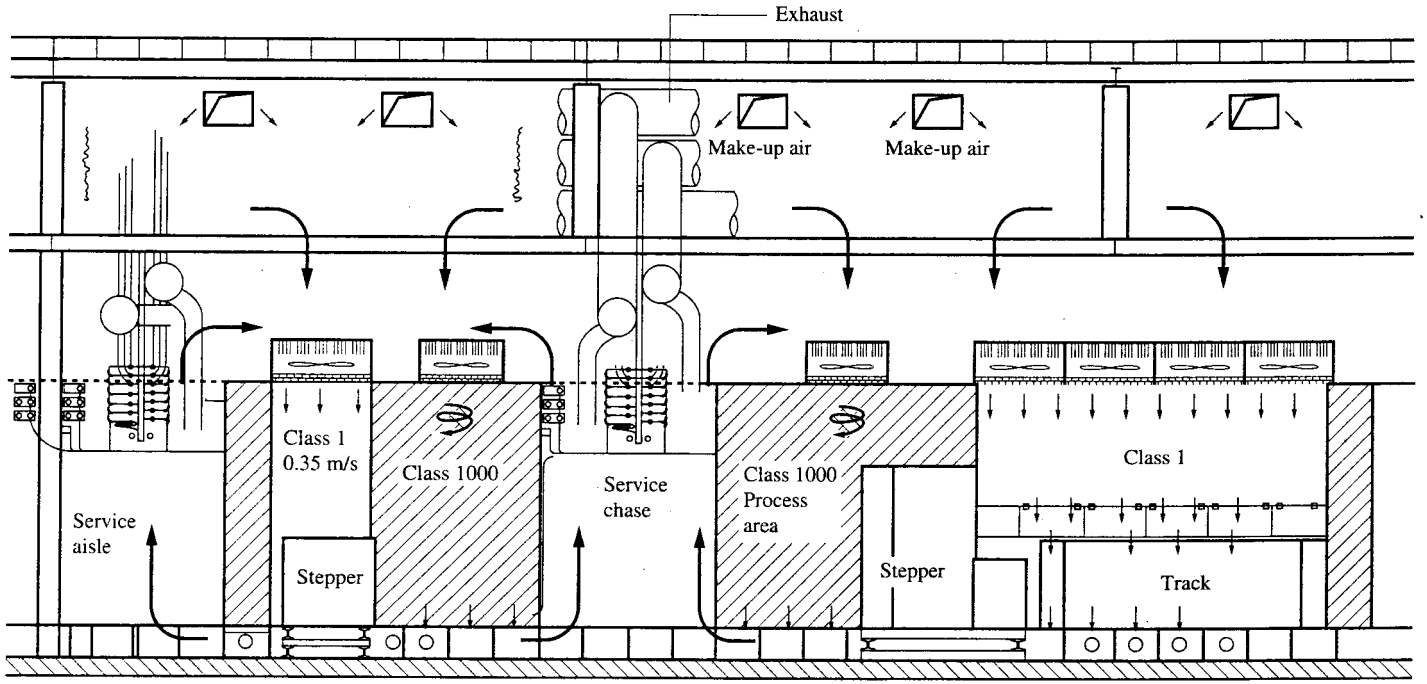

FIGURE 6
Ballroom-type cleanroom with process and service areas located on the same floor.

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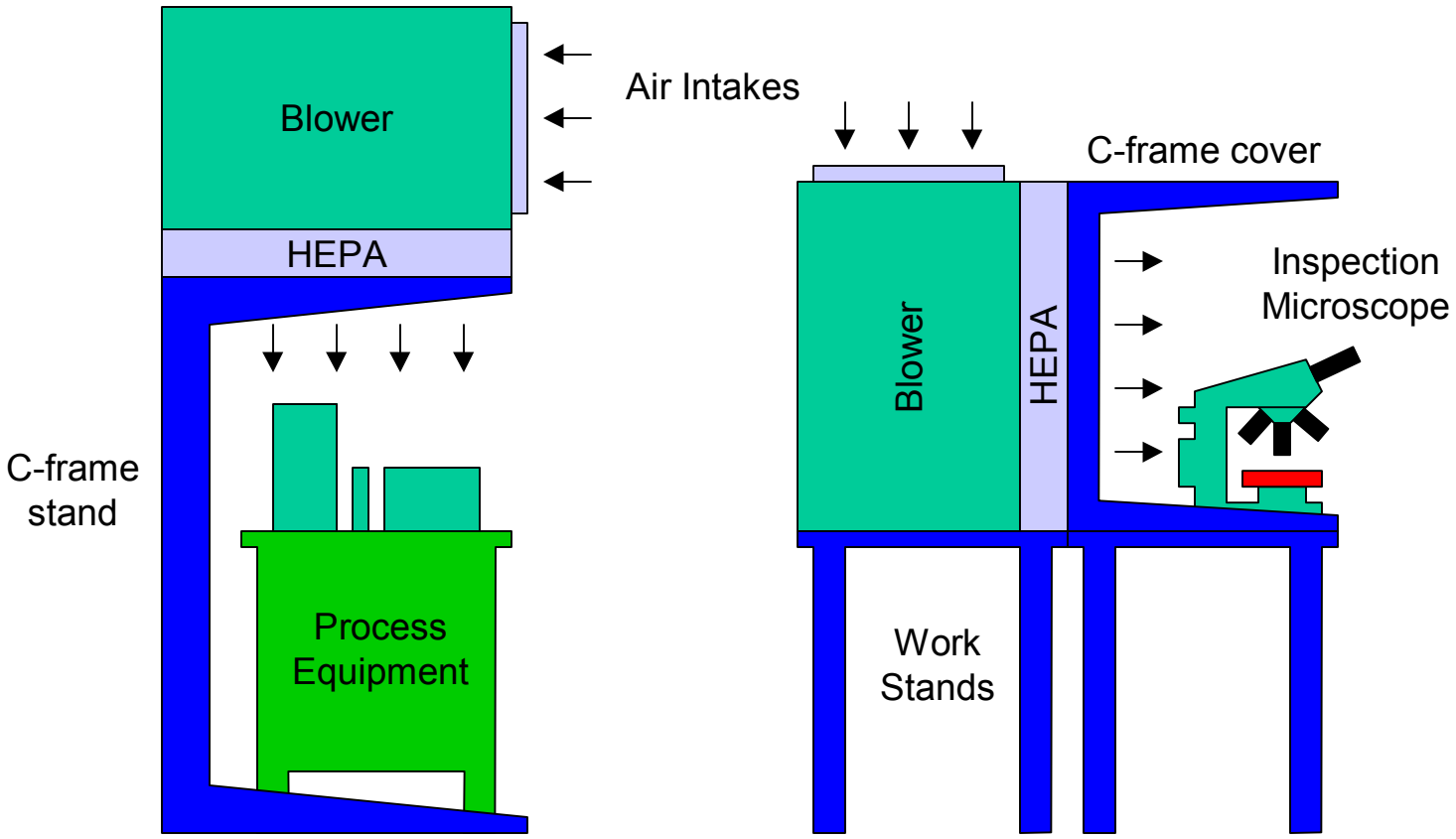
Characteristics of Clean Rooms

- 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 H_2O for Class 100, Class 1000, and Class 10,000
  - Typically 0.3 - 0.4 in of H_2O 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 H_2O = 3.6 x 10^{-3} psi = 0.52 lb/ft^2
  - This produces 9.1 lbs. force on a 7’ x 30” door

Laminar Flow Benches

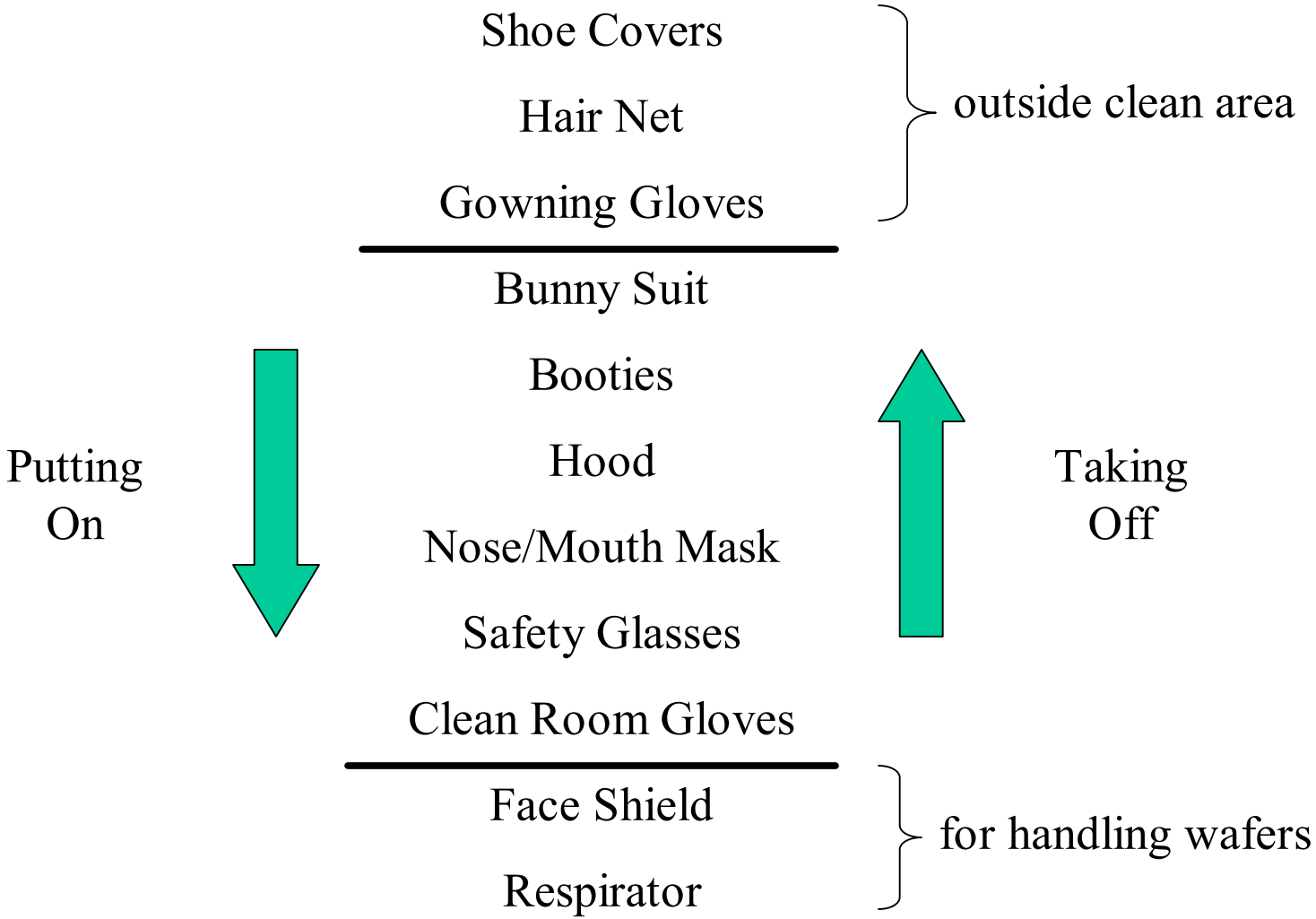
- A HEPA filter used to provide local clean air conditions
  - Can usually drop the class rating by 2 decades within a local area
  - Example: Class 100 local environment within a Class 10,000 room
- Designed to minimize turbulence which creates dust and dirt collection pockets
- Vertical style used 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