ENERGY EFFICIENCY AND SMART SYSTEM FOR NEGATIVE PRESSURE ROOM IN HOSPITALS

Kafiuddin, MT

Government Affair Chair

Profile

Pendidikan :

- S2 Energy Conservation, **University of Indonesia** (1999-2001)
- S1/DIV Thermal System, **Universitaire de Technologie I Joseph Fourier, Grenoble France** (1991-1993)
- DIII Refrigeration & Air Conditioning, **Politeknik ITB Bandung** (1987-1990)
- SMA Xaverius Jambi (1983-1986)

Pengalaman Singkat :

- Professional Expert as Energy Efficiency, Mechanical System, & AC-Refrigeration Consultant, Trainer, and Contributor (2014-Present)
- PT. Cipta Andalan Persada (2016-Present), President Commissioner
- PT. Kresna Karya Parisudha (2016-Present), President Commissioner
- PT. Summarecon Agung, Engineering Development Manager (2008-2014)
- Cusson Technology Co. Ltd. (2004-2008) Project Manager (M&E)
- BPPT-LTMP (1993-2008), as Researcher

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Society Year 2019-20

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ASHRAE Overview

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Indonesia Chapter
108 members
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Celebrating 125 Years in 2020

7,400+
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10+
Regions
190+
Chapters
400+
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Industry Classification
Consulting Engineers
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1. Serve as pipeline for providing technical information to members, chapters, companies and government officials
2. Develop standards and technical guidelines to improve the built environment
3. Offer continuing education for industry professionals
4. Serve as networking tool for industry professionals

- 33 Standing Committees
- 130 Standards and Guidelines Committees
- 100+ Technical Committees
- 300+ Publications
- Seven Certification Programs
- 200+ Educational Courses
- Research
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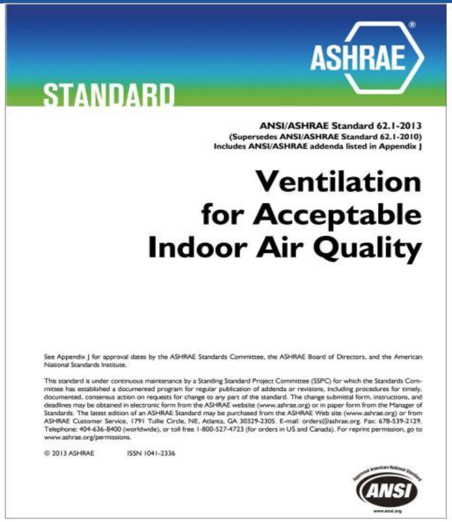
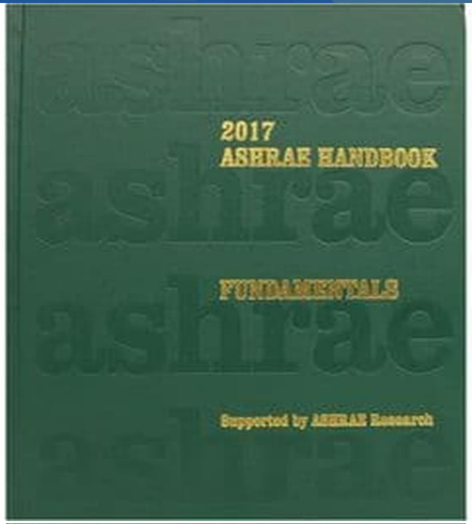
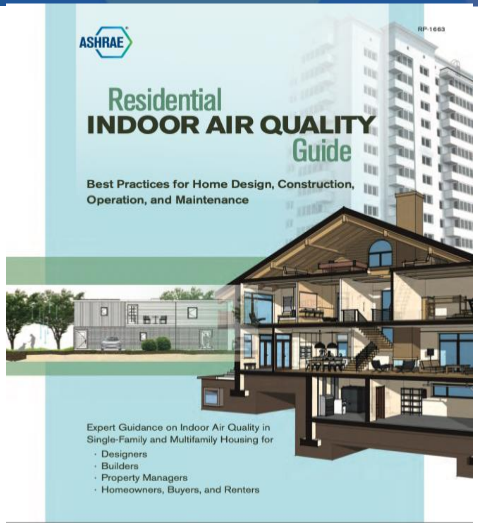
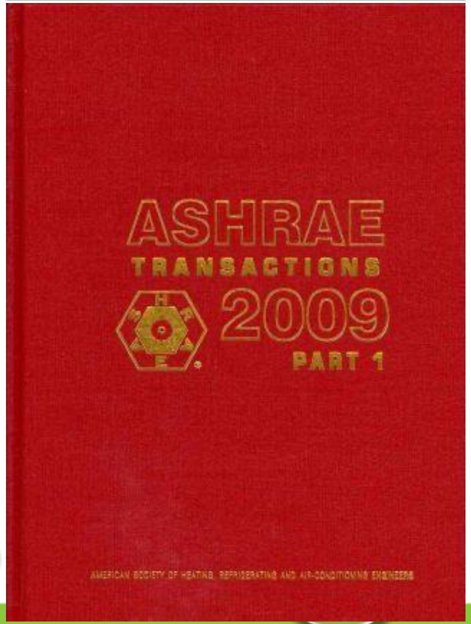
Technical Resource

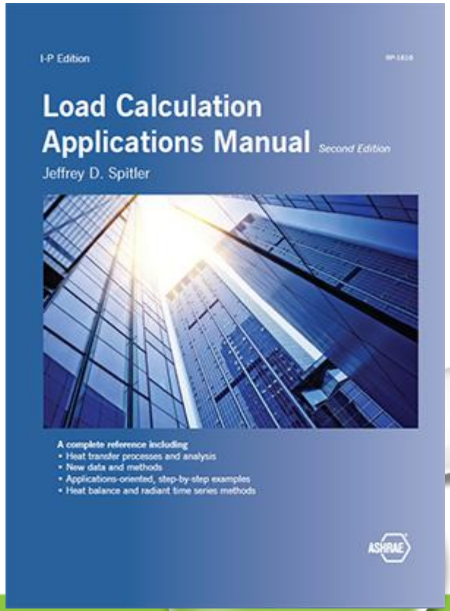
- ASHRAE Standard
- ASHRAE handbook
- Ashrae journal
- Ashrae Transactions
- Books.











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FINANCIAL CONFLICT

NO FINANCIAL CONFLICT TO REPORT

Daftar Isi

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Rumah Sakit Sebagai Sumber Penyakit

Rumah Sakit

✓Pusat dari orang sakit.

✓Sumber dari berbagai penyakit (Diantaranya adalah Penyakit menular – Covid19)

- Diperlukan perhatian khusus dan ketat agar penyebaran penyakit dari satu orang ke lainnya dibuat seminimum mungkin
- Diperlukan design khusus agar ruangan-ruangan yang ditempati tidak menjadi sumber penyakit baik untuk pasien maupun para medis/dokter, pengunjung dan sekitarnya.

Parameter Thermal Comfort udara di Rumah Sakit :

- Air temperature (°C),
- Radiant temperature (°C),
- Air velocity (m/s),
- Relative humidity (%),
- Air pressure (Pa),
- **Rate of metabolism (met)**
- **As well as clothing (clo) of the occupants.**

Permenkes Ruang operasi
keputusan Menteri Kesehatan RI Nomor 1204 /MENKES/SK/X/2004 :

- Indeks angka kuman: 10 CFU / m^3,
- Indek pencahayaan: 300 - 500 lux,
- Standar suhu: 19 - 24 ºC, kelembaban: 45 - 60%,
- Tekanan udara: Positif,
- Indeks suara 45 dBA

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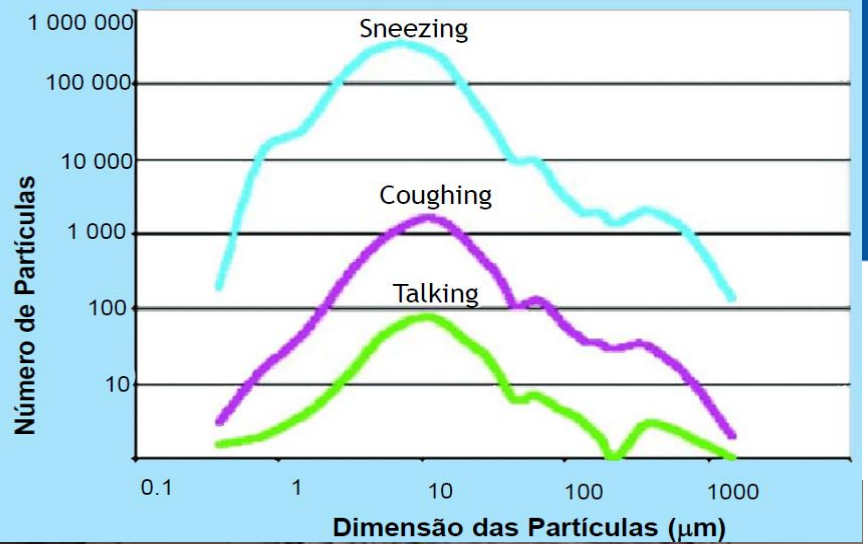
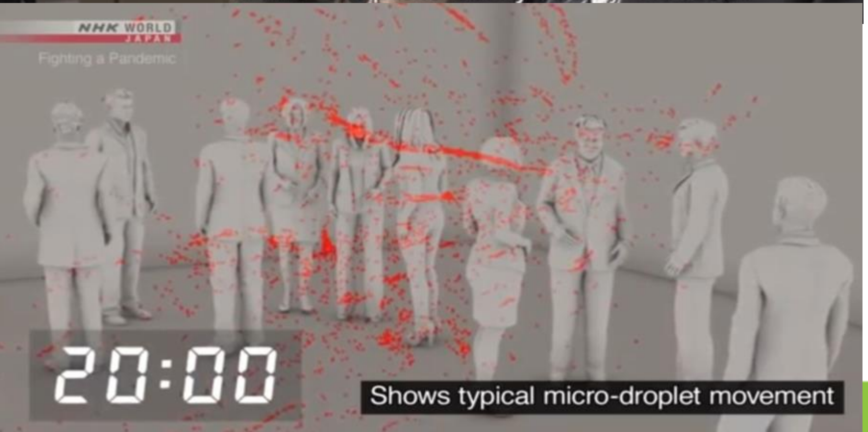
Covid 19 dalam Perspektif





Penularan Virus Covis19

- WHO menyebutkan bahwa proses penyebaran virus adalah dari manusia ke manusia melalui Droplet/Micro droplet/Aerosol dari penderita (OTG ataupun ODG) mengenai hidung, mulut atau mata sehingga menginfeksi saluran nafas dan paru-paru.
- Droplet/Micro droplet/Aerosol dikeluarkan saat orang bersin atau selagi berbicara.

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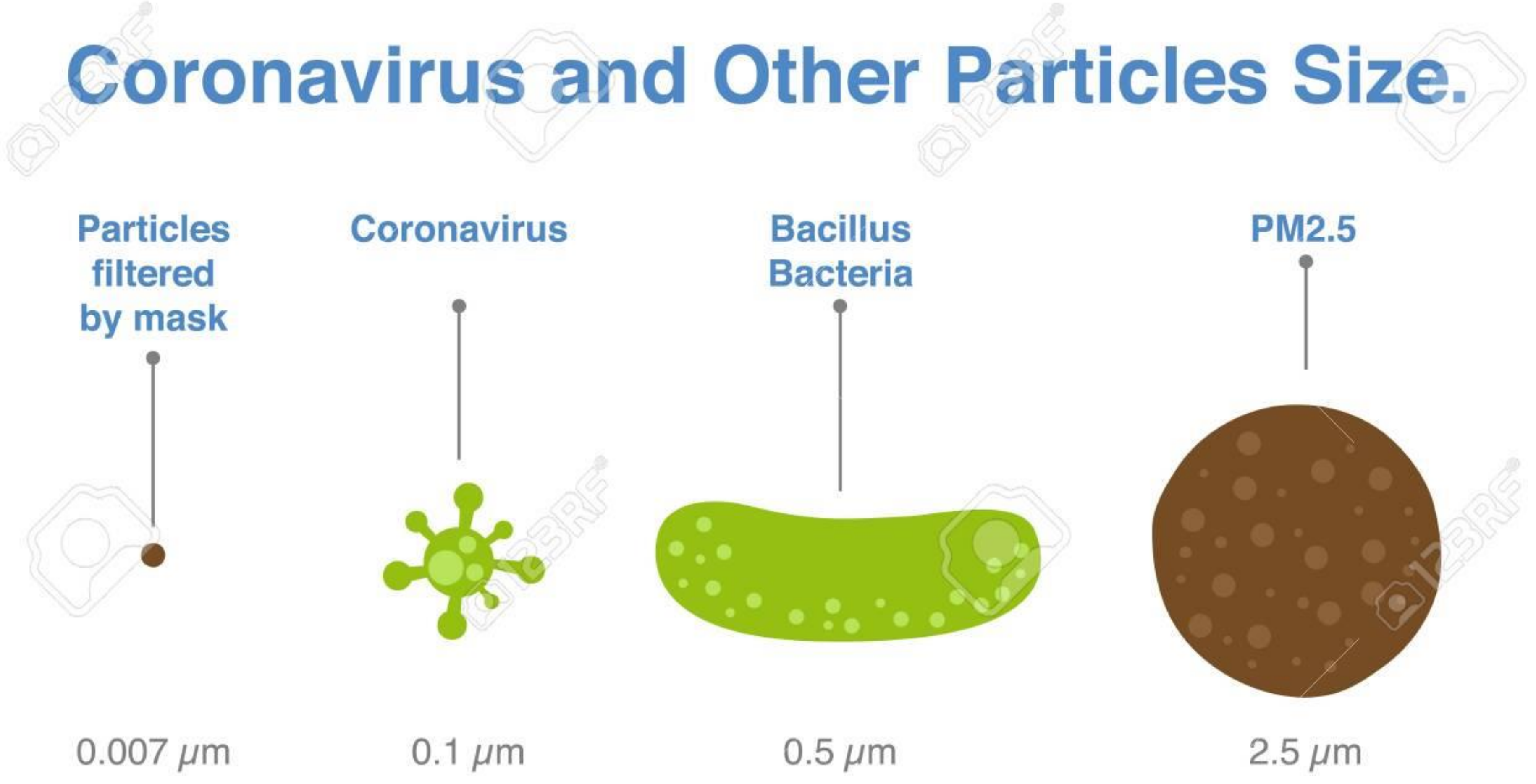
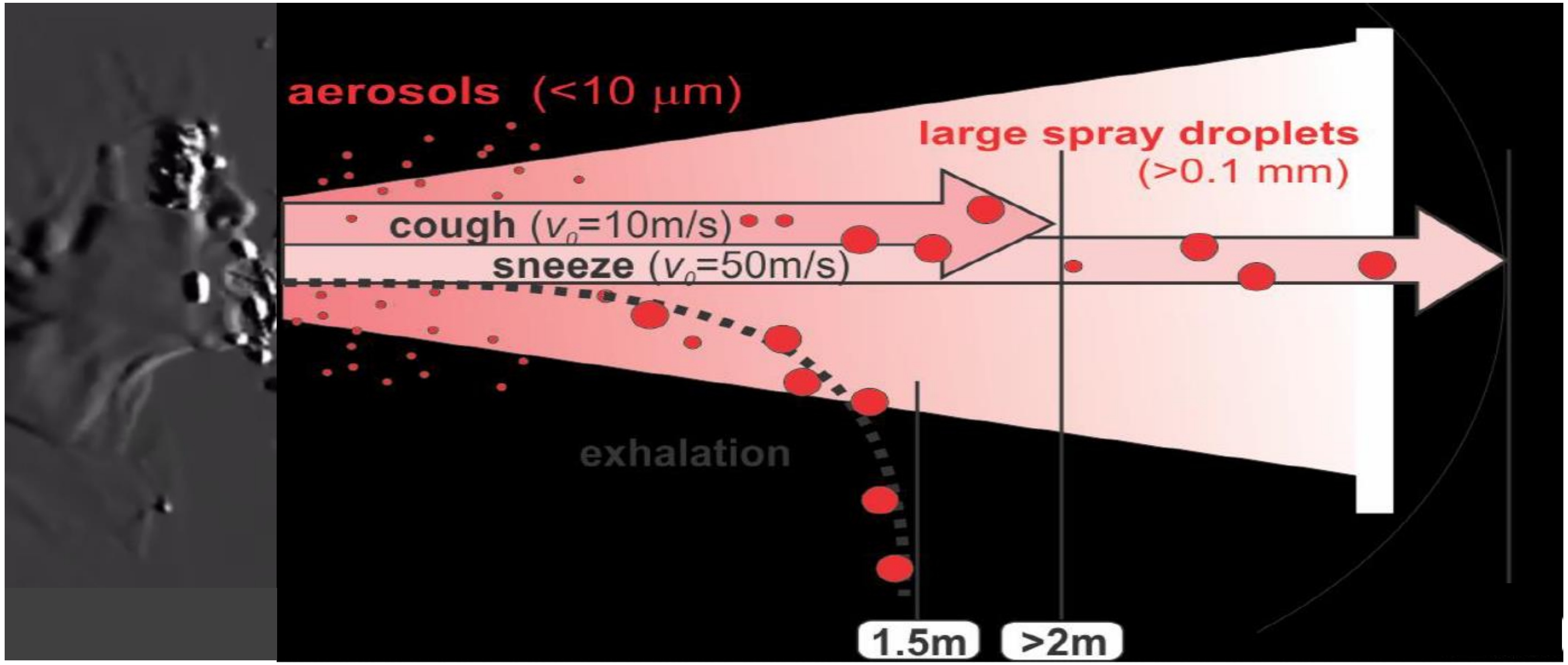
Source : Kyoto University

Ukuran virus



Ilustrasi Saat Bersin / Batuk



Microdroplet < 10 μm:
Bisa bertahan sekitar 3 jam di udara

Droplet > 10 μm:
Bisa menempel di seluruh permukaan benda dan bertahan sampai dengan 72 jam atau mengeringnya permukaan

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Source of Infectious Aerosols

- Humans – breathing, talking, singing, coughing, sneezing
- Plumbing – toilet flushing, splashing in sinks
- Medical procedures – dentistry, endotracheal intubation, and others

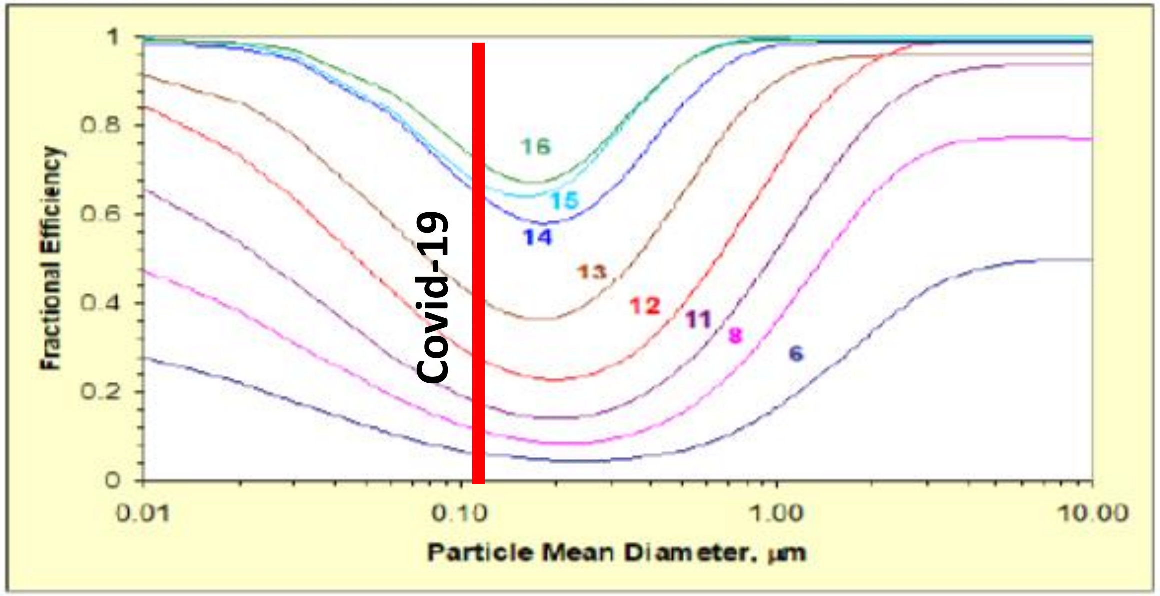
Performance								Application		
ANSI/ASHRAE Standard 52.2				ASHRAE Standard 52.1		IEST-RP-C001.3		Controlled particulate		
	Average minimum composite efficiency									
MERV	E_1 (0.3 µm to 1.0 µm)	E_2 (1.0 µm to 3.0 µm)	E_3 (3.0 µm to 10.0 µm)	Average arrestance	Average dust-spot efficiency	Type	Removal efficiency at particle size	Size	Examples	Typical application
6	–	–	35 to 50%	85 to 90%	< 20%	–	–	3.0 to 10.0 µm	Mold and spores; Cement dust; Hair spray; Powdered milk	Standard commercial buildings, industrial workplaces, paint-booth inlet air
7	–	–	50 to 70%	> 90%	25 to 30%	–	–			
8	–	–	> 70%	> 90%	30 to 35%	–	–			
9	–	< 50%	> 85%	> 90%	40 to 45%	–	–	1.0 to 3.0 µm	Legionella; Lead dust; Coal dust; Auto emissions	Better commercial buildings, hospital laboratories
10	–	50 to 65%	> 85%	> 95%	50 to 55%	–	–			
11	–	65 to 80%	> 85%	> 95%	60 to 65%	–	–			
12	–	> 80%	> 90%	> 95%	70 to 75%	–	–			
13	< 75%	> 90%	> 90%	> 98%	80 to 90%	–	–	0.3 to 1.0 µm	Bacteria; Most tobacco smoke; Cooking oil; Droplet nuclei (sneezes)	Superior commercial, general surgery, smoking lounges, hospital inpatient care
14	75 to 85%	> 90%	> 90%	–	90 to 95%	–	–			
15	85 to 95%	> 90%	> 90%	–	> 95%	–	–			
16	> 95%	> 95%	> 95%	–	–	–	–			
17	–	–	–	–	–	A	99.97% at 0.3 µm	< 0.3 µm	Virus (unattached); Sea salt; Radon progeny; Carbon dust	Cleanrooms, pharmaceutical manufacturing, radioactive materials, carcinogenic materials
18	–	–	–	–	–	C	99.99% at 0.3 µm			
19	–	–	–	–	–	D	99.999% at 0.3 µm			
20	–	–	–	–	–	F	99.999% 0.1 to 0.2 µm			

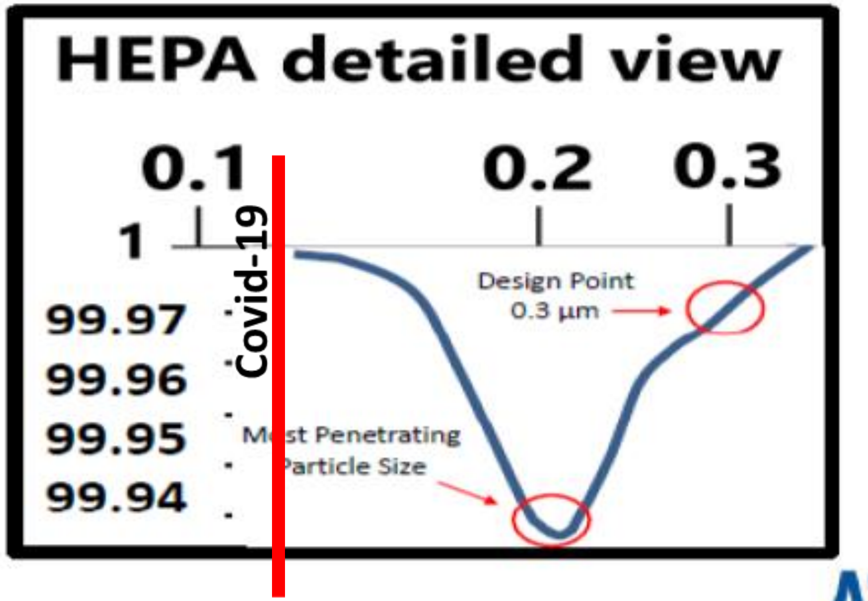
HEPA FILTER

High Efficiency Particulate Air (HEPA) Filters

- By definition, true HEPA filters are at least 99.97% efficient at filtering 0.3 µm mass median diameter (MMD) particles in standard tests.

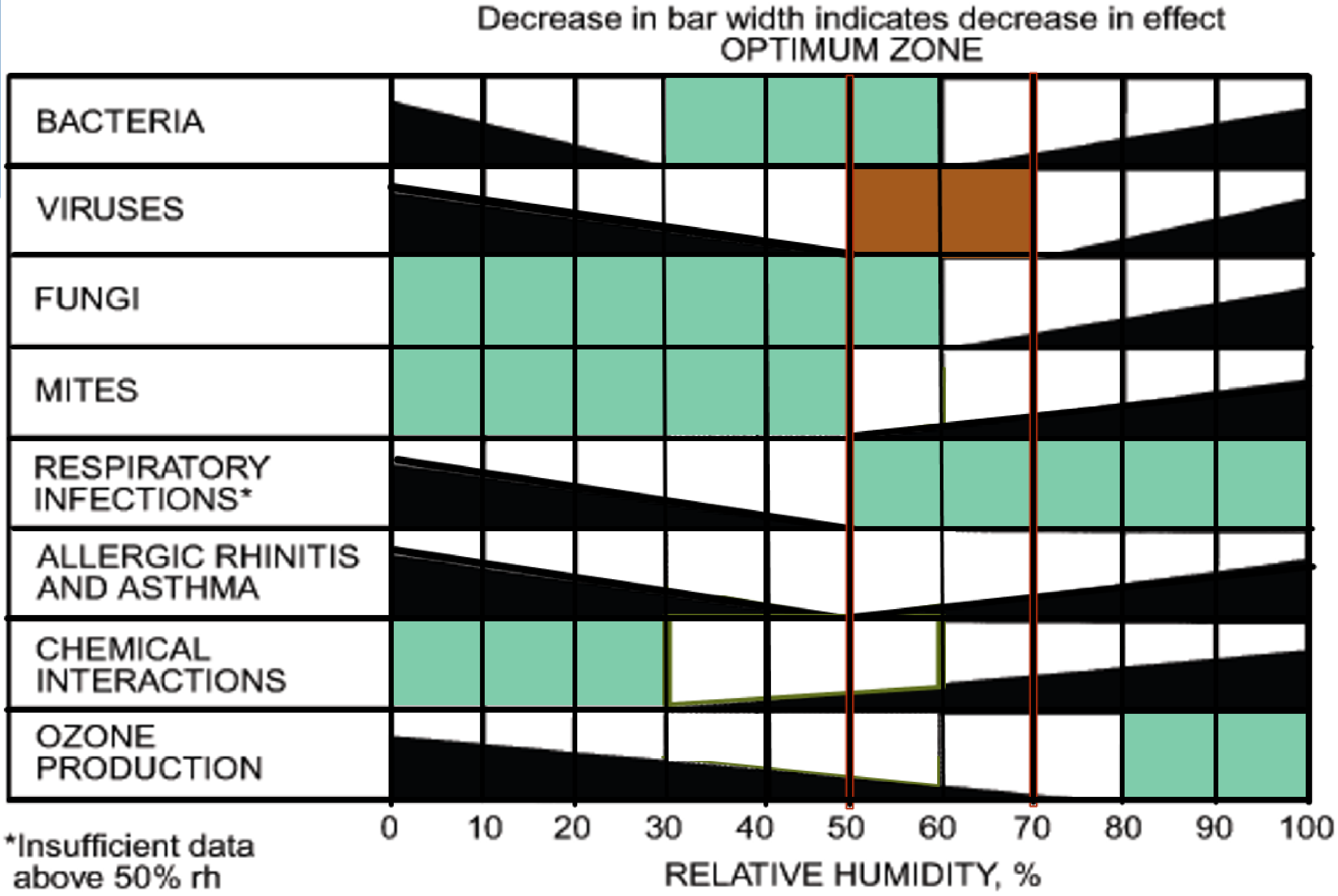
- Most penetrating particle size may be smaller than 0.3 µm, so filtration efficiency of most penetrating particles can be slightly lower.





Note: Numbers in graph represent MERV values.

The Effect of Relative Humidity to the Growth rate



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Tata Udara Ruang Isolasi

Acuan Standard

- **ANSI/ASHRAE/ASHE Addendum n to ANSI/ASHRAE/ASHE Standard 170-2017**

Approved by ASHRAE Standard Committee on January 20, 2018; by the ASHRAE Board of Directors on January 24, 2018; by the American Society for Healthcare Engineering on November 28, 2017; and by the American National Standards Institute on **March 3, 2020.**

Table 8.1 Design Parameters for Outpatient-Specific Spaces

Function of Space (f)	Pressure Relationship to Adjacent Areas (n)	Minimum Outdoor ach	Minimum Total ach	All Room Air Exhausted Directly to Outdoors (j)	Air Recirculated by Means of Room Units (a)	Minimum Filter Efficiencies (c)	Design Relative Humidity (k), %	Design Temperature (l), °F/°C
COMMON SPACES IN OUTPATIENT FACILITIES								
AII anteroom (i) (3.1–3.4.3)	(e)	NR	10	Yes	No	7/NR	NR	NR
AII room (i) (3.1–3.4.2)	Negative	2	12	Yes	No	7/NR	Max 60	70–75/21–24
Bronchoscopy, sputum collection, and pentamidine administration (n)	Negative	2	12	Yes	No	7/NR	NR	68-73/20-23
Clean supply storage (3.1–3.6.9)	Positive	2	4	NR	NR	7/NR	Max 60	72–78/22–26
Emergency waiting rooms	Negative	2	12	Yes (q)	NR	7/NR	Max. 65	70-75/21-24
Environmental services room (3.1–5.5.1)	Negative	NR	10	Yes	No	7/NR	NR	NR
General-purpose examination/observation room (3.1–3.2.2)	NR	2	4	NR	NR	7/NR	Max 60	70–75/21–24
Laboratory testing/work area if in a separate dedicated room (3.1–4.1.2)	Negative	2	6	Yes	NR	7/NR	NR	70–75/21–24
Medical waste holding spaces (3.1–5.4.1.3)	Negative	2	10	Yes	No	7/NR	NR	NR
Medication preparation room programmed to compound sterile preparations (b) (3.1–3.6.6.2)	Positive					(s)	NR	NR
Soiled holding room (3.1–3.6.10)	Negative						NR	72–78/22–26
Special-purpose examination room (3.1–3.2.3)	NR						Max 60	70–75/21–24

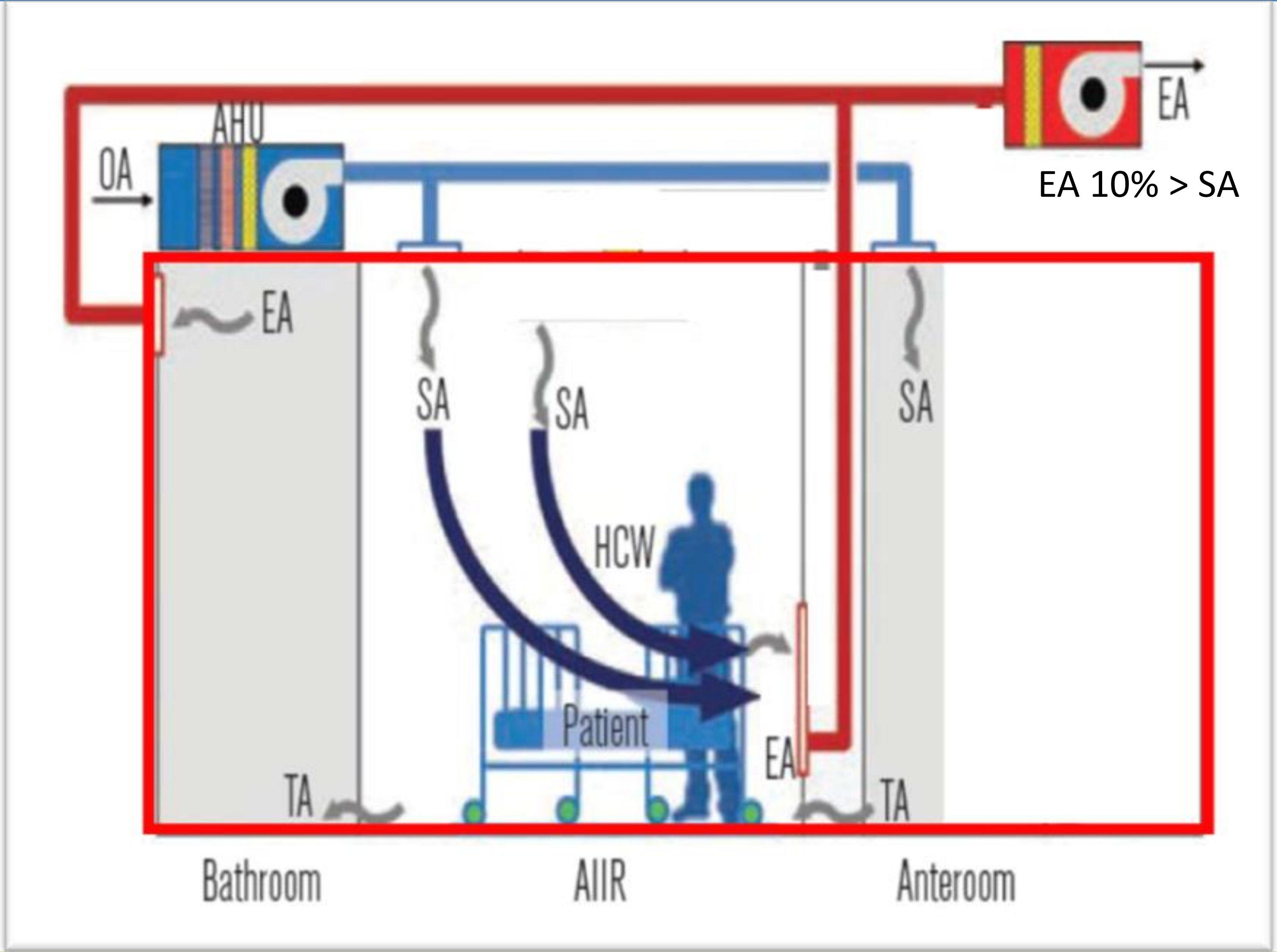
Standard Requirement Ruang Isolasi

Acuan Berbagai Negara (Perbandingan)

TABLE 1 Design standards for AIIR to prevent airborne contamination.[11]

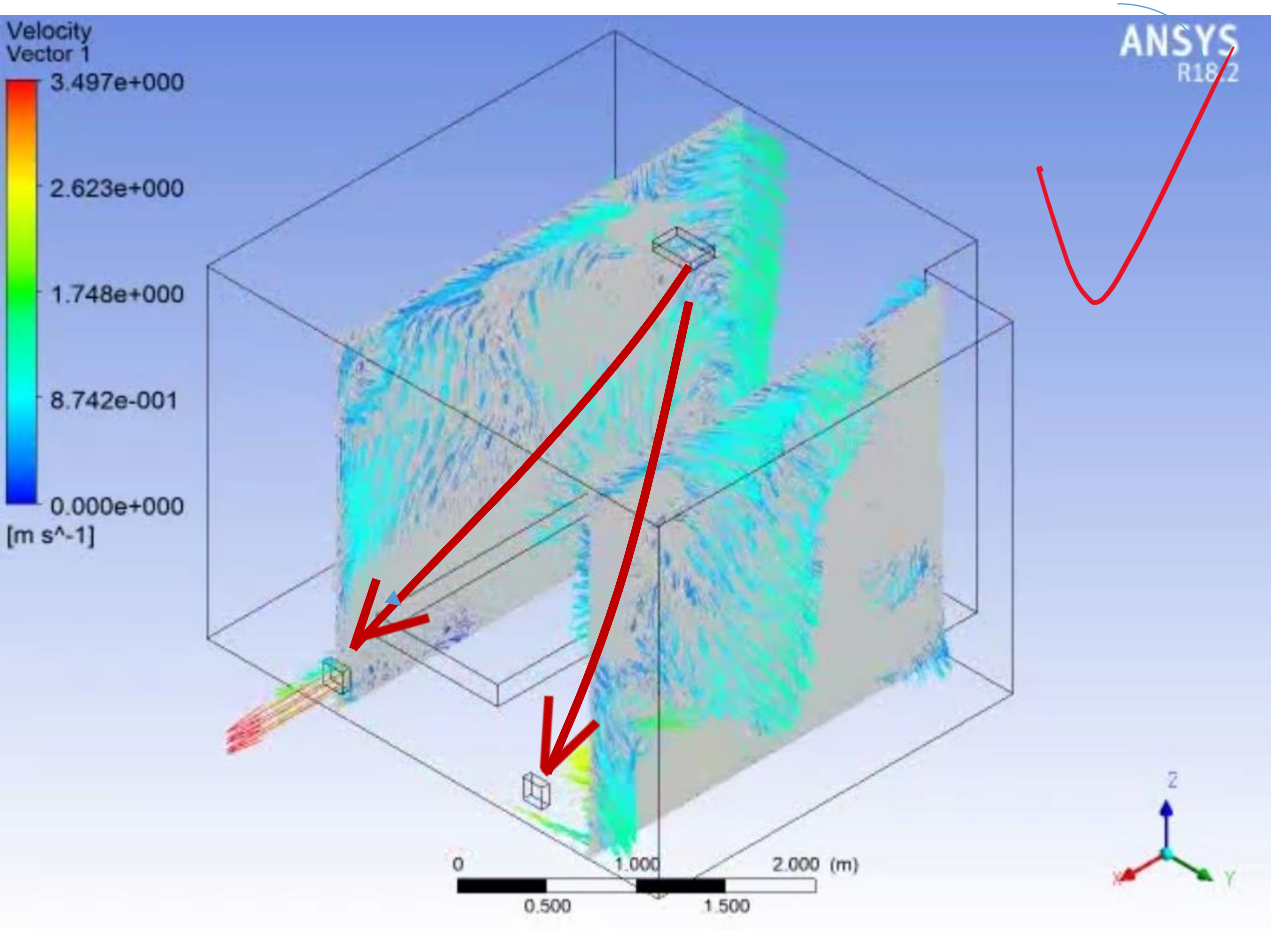
	ORGANIZATION	AIR CHANGE RATE (ACH)		PRESSURE DIFFERENTIAL	RECIRCULATION	ANTEROOM
USA	Centers for Disease Control and Prevention	Existing	New/Remodeling	More than 2.5 Pa	Yes (w/HEPA Filter)	Recommend
		More than 6	More than 12			
Canada	Public Health Agency of Canada	Existing	New/Remodeling	–	Yes (w/HEPA Filter)	Recommend
		More than 6	More than 9			
UK	Department of Health	More than 10		More than 5 Pa	No	Recommend
Norway	Folkenhelseinstitutt	More than 12		More than 5 Pa	No	Mandatory
Australia	Department of Health And Human Services	Mandatory	Recommend	More than 15 Pa	No	Mandatory
		More than 12	More than 15			
Hong Kong	Infection Control Committee Department of Health	Existing	New/Remodeling	More than 2.5 Pa	Yes (w/HEPA Filter)	–
		More than 6	More than 12			
South Korea	Centers for Disease Control and Prevention	Mandatory	Recommend	More than 2.5 Pa	Yes (w/HEPA Filter)	Mandatory
		More than 6	More than 12			

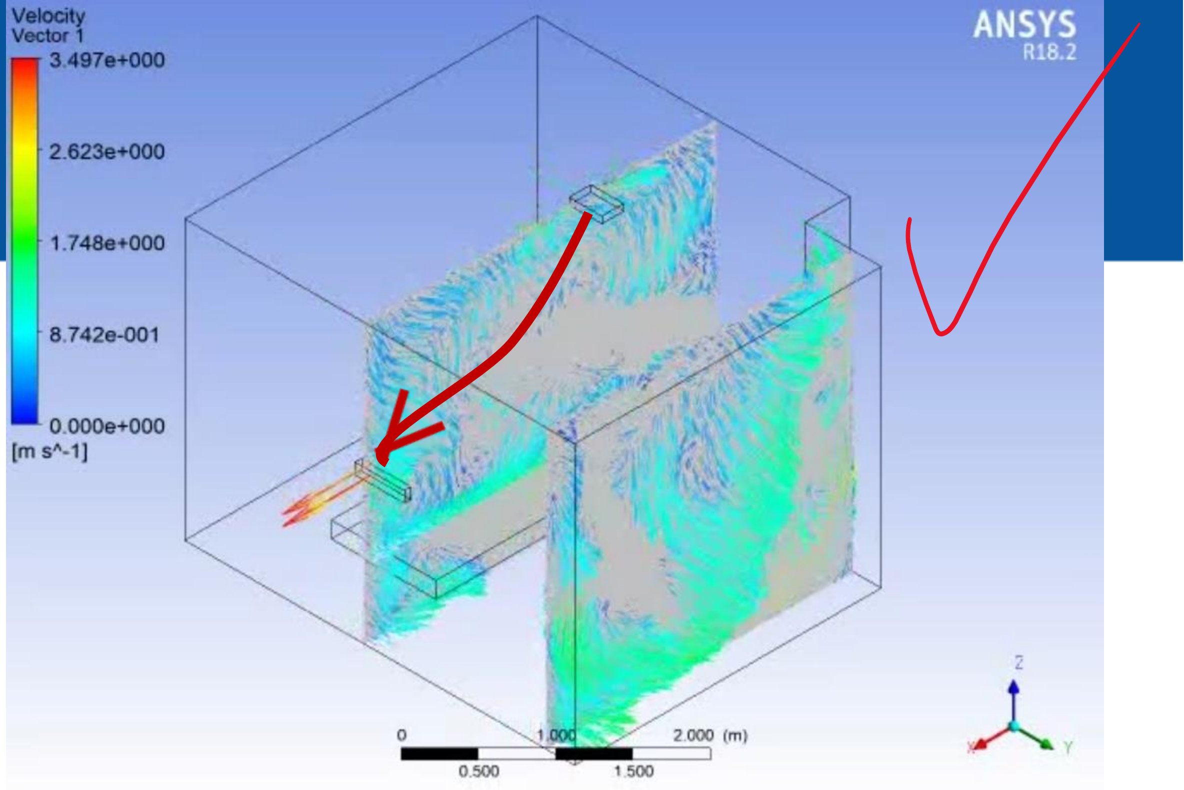
Schematic Design
AIIR (Airborne Infection Isolation Room)



EA 10% > SA

POSISI INTAKE EXHAUST





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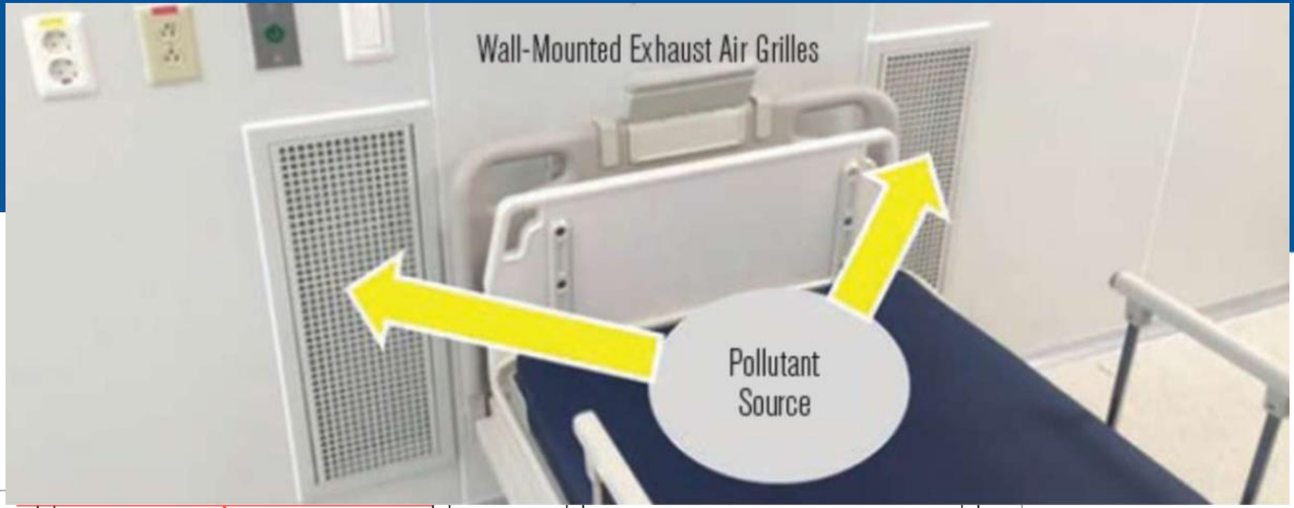
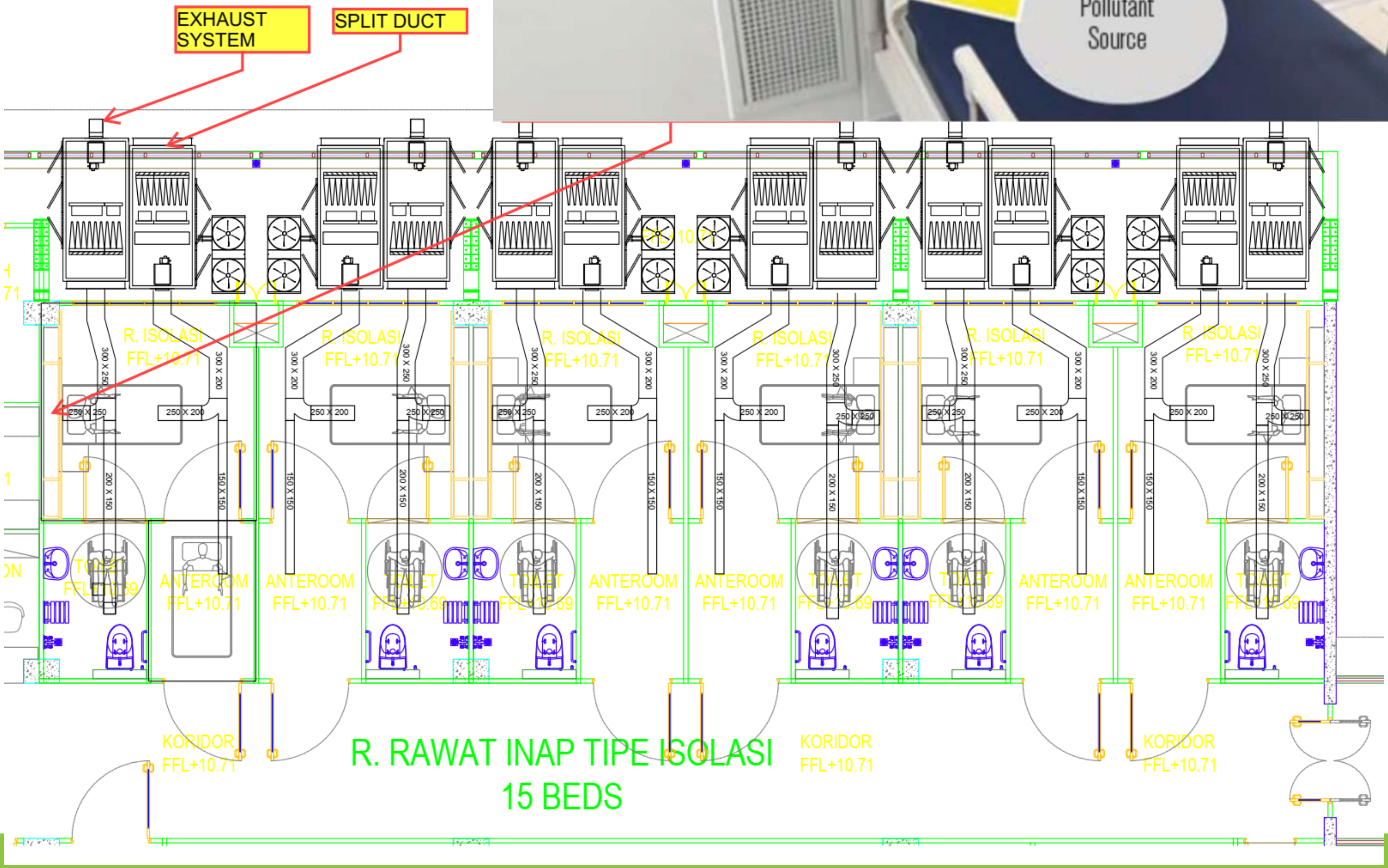
Instalasi Tata Udara

Ruang Isolasi





System Ducting Isolasi dilengkapi dengan :

1. Pre Filter → G3/G4 (25-35%) atau MERV 7
2. Medium Filter → F7/F8 (85-95%) atau MERV 14/15.
3. HEPA Filter di atas ruang operasi → H13/H14 (99.97% - 99.997%) atau MERV 17-20
4. Menggunakan Lampu UVc (Gelombang pendek) Germacidal Irradiation, 2 x 100Watt
5. Menggunakan pengatur putaran Variable Air Volume dari Exhaust fan dengan PLC

Fresh Air	**: Pre Filter saja**
Exhaust Air	**: Pre, Medium dan HEPA Filter**

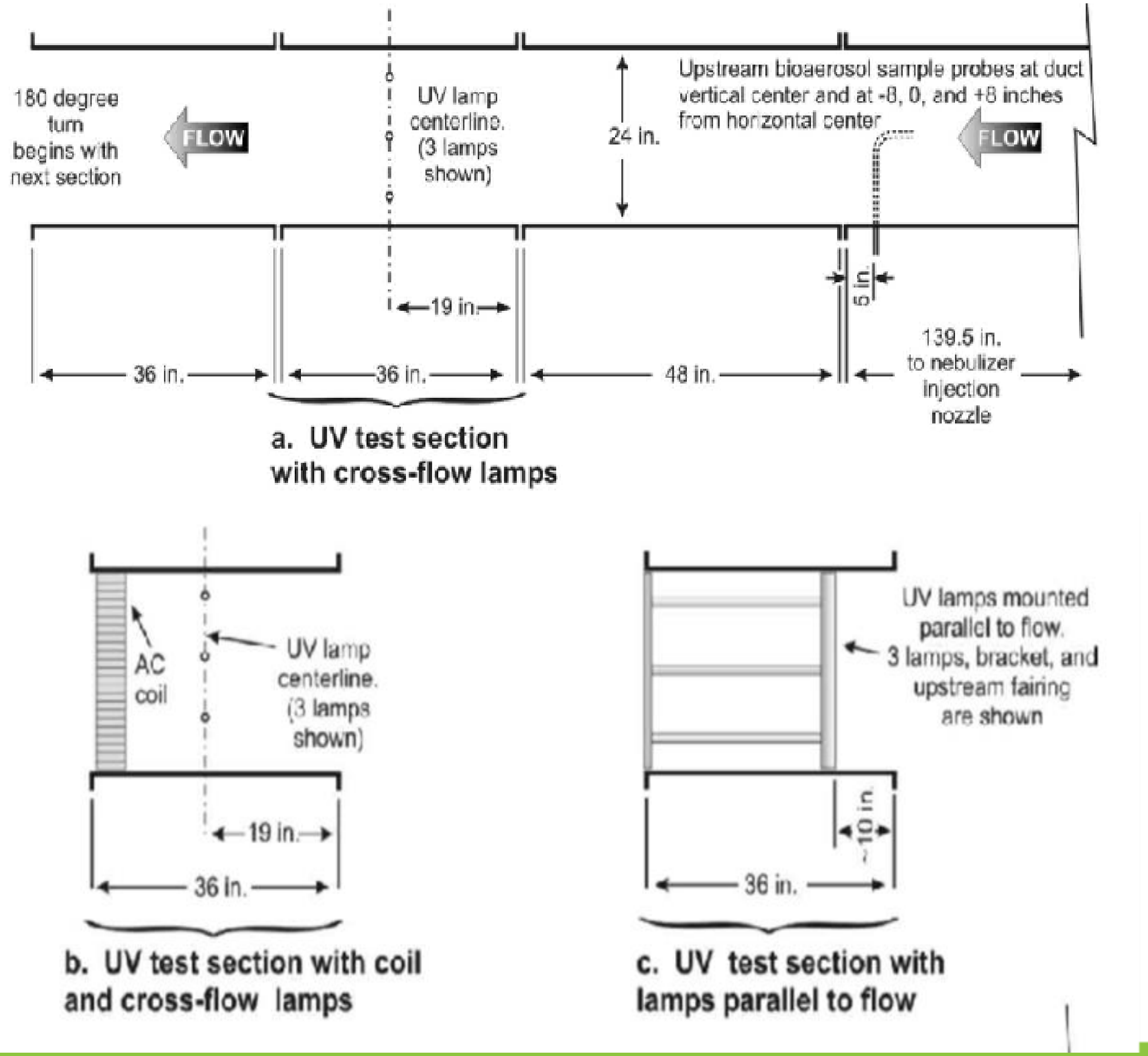
- *Kecepatan udara keluar dari HEPA filter (0.45 m/s ± 0.1 m/s).*

ACH & Waktu Contaminant Removal

- Follow CDC Air Change Clearance Rates:

Table B.1. Air changes/hour (ACH) and time required for airborne-contaminant removal by efficiency *		
ACH § ¶	Time (mins.) required for removal 99% efficiency	Time (mins.) required for removal 99.9% efficiency
2	138	207
4	69	104
6+	46	69
8	35	52
10+	28	41
12+	23	35
15+	18	28
20	14	21
50	6	8

Konfigurasi UVc Lamp



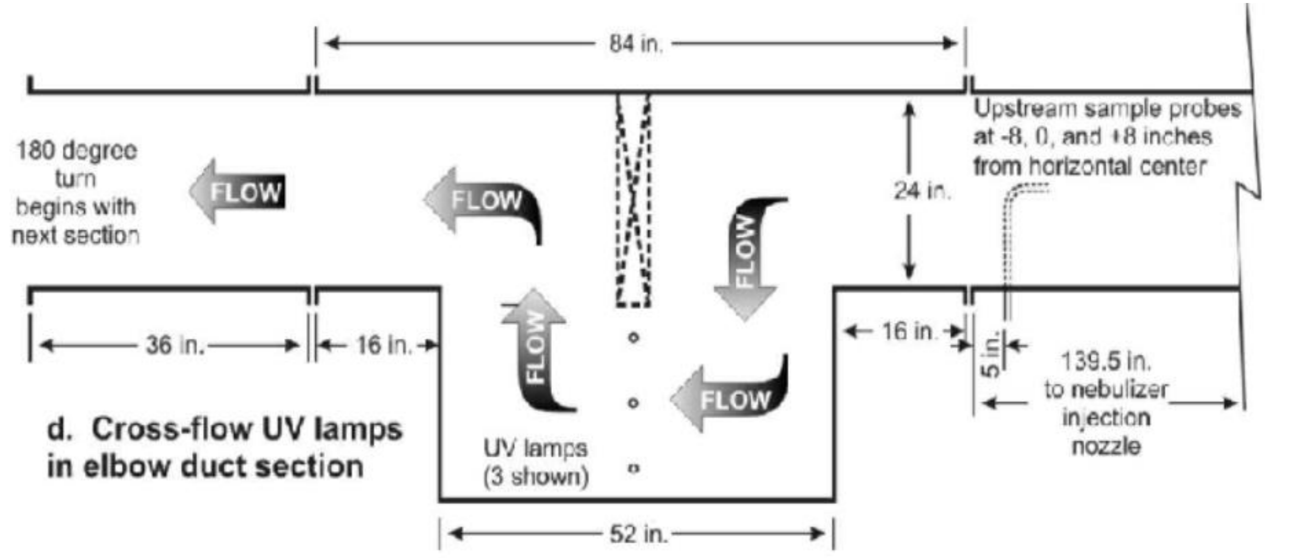


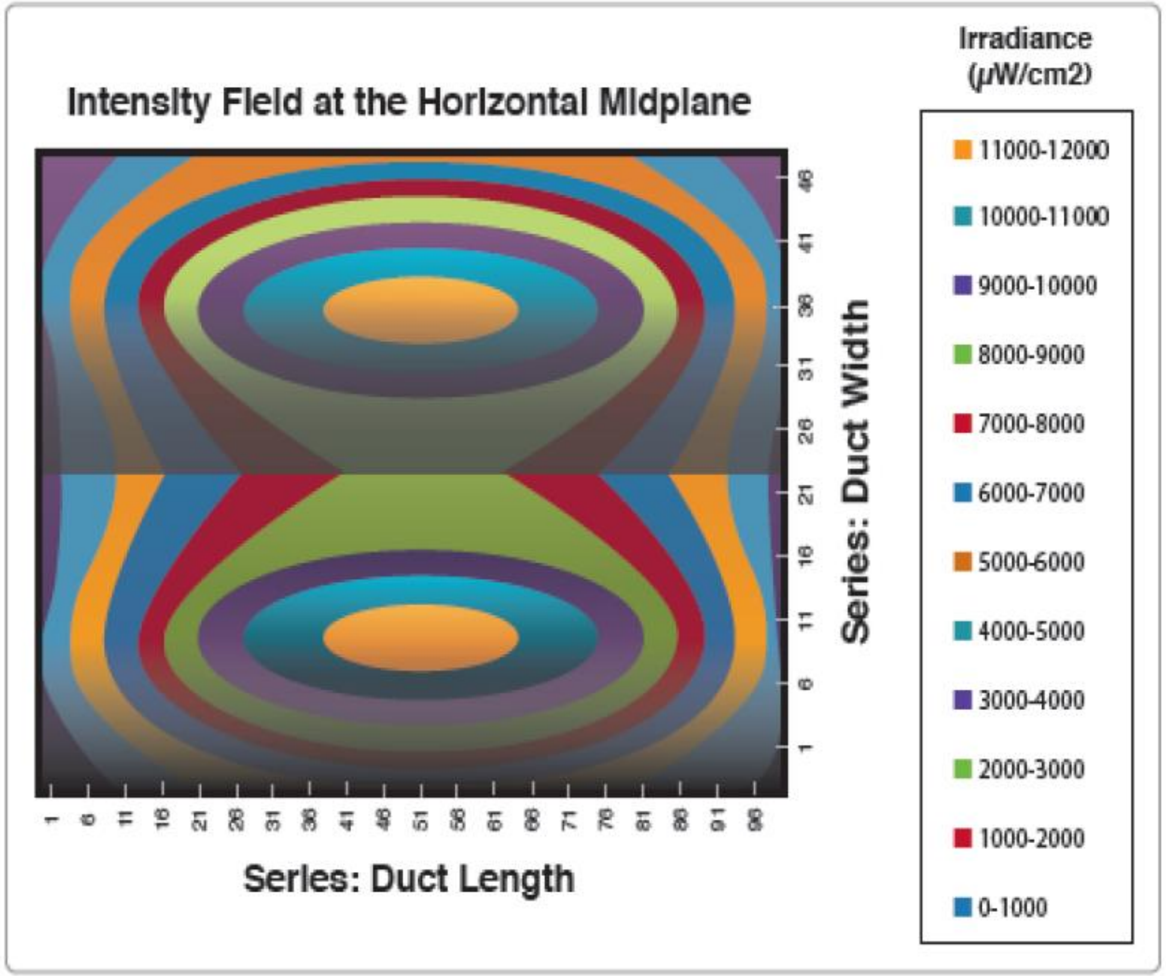
Figure 3. Lamp and test duct configurations

Efek susunan Lampu terhadap matinya bakteri

Table 3. Effect of Duct Configuration on Microbial Kill

Lamp Configuration	Number of Lamps	*Bacillis subtilis* % Kill	*Aspergillis versicolor* % Kill
Straight duct, crossflow lamps	6 3	99 76	56 20
Straight duct, parallel lamps	6 3	67 30	40 17
Straight duct, coil	6 3	92 55	43 23
Elbow duct	6 3	91 55	62 30

- How much Irradiance



Output Example of Engineering Modeling Software

Video

Efek irradiance UVc terhadap kecepatan udara dan suhu udara

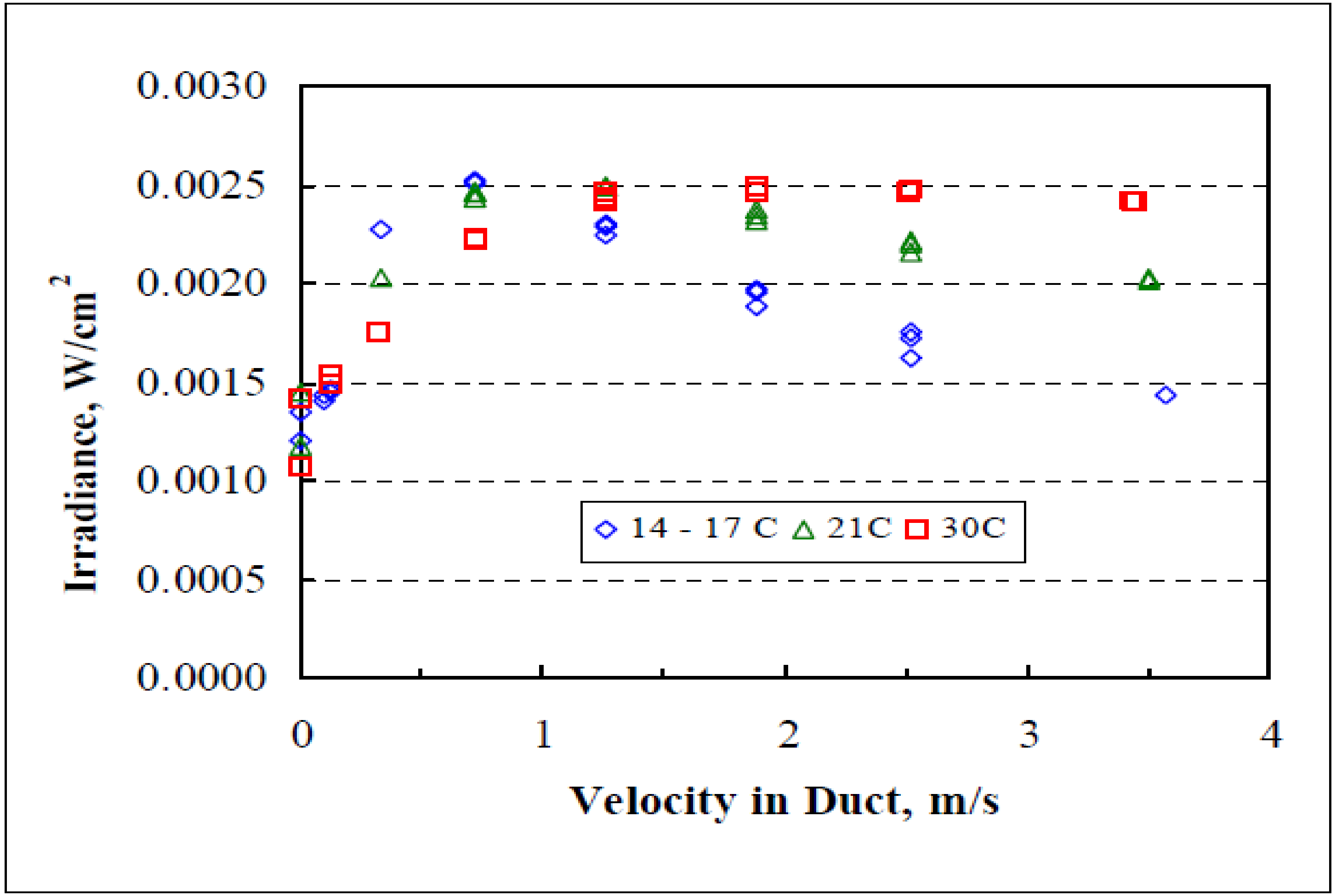


Figure 9. Effect of air velocity and temperature on 1-m irradiance for "high" output lamps.

Permasalahan & Optimasi Efisiensi Energy

Permasalahan Ruang Isolasi Saat ini

1. Kebutuhan darurat membuat design tidak maksimal
2. Konsumsi energi ruang isolasi SANGAT BESAR
3. Apakah RH ruang isolasi harus dikondisikan maksimal 60% seperti standard yang berlaku saat ini ???
4. Apakah luasan minimal ruang 16m2 ?
5. Keberadaan ruang isolasi (Existing) di Indonesia apakah memenuhi syarat untuk kasus Covid19 ? Apakah ada data akreditasi kelayakannya ?
6. Ruang penampungan isolasi pasien darurat apakah memenuhi syarat ?
7. Bagaimana sebaiknya bangsal atau Gedung dapat dialihfungsikan menjadi Ruang Isolasi yang aman bagi tenaga medis dan pasien ?
8. Bagaimana agar ruang operasi dapat difungsikan untuk tindakan operasi penderita Covid19 secara aman bagi tenaga medis ?
9. **Design AC ruang isolasi kebanyakan dilakukan secara Rule of Thumb**
10. **Design Sirkulasi udara tidak dilakukan justifikasi dengan Analisa CFD (Computerized Fluid Dynamic)**

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Telaah

Pedoman Teknis, Bangunan dan Prasarana Ruang Isolasi Penyakit Infeksi Emerging (PIE), Kemenkes, 13 April 2020

- **Disebutkan R.klinik menggunakan AC 6-8 HP dg flowrate 1445CMH (850 CFM), sebaiknya tidak disebutkan dan ini terlalu besar. Maka kebutuhan flow exhaust akan sangat besar (110% dari 1445 CMH)**

  AC cukup menyesuaikan kebutuhan flow yang lebih kecil 10% dari Exhaust flow (806,4 CMH flow Exhaust ruang 24m2). Kekurangan Cooling Capacity dapat dipenuhi dari AC precooling

- **WAJIB MENGGUNAKAN AC Split duct 0ne flow atau AHU dengan 100% Fresh Air (Bukan AC Split wall dengan return air), dan flow yang lebih kecil 10 % dari exhaust flow 806,4 CMH (Sesuai kebutuhan 12 ACH ruang 24 m2) berikut Toilet dan Anteroom.**
  - **Luas x Tinggi (24 x 2.8) = 67,2 m^3**
  - **ACH 12 minimal berarti, 806,4 CMH atau 474,6 CFM**

- Tekanan ruang isolasi disebutkan -15Pa jauh lebih kecil dari yg dipersyaratkan ASHRAE sebesar -2,5Pa. Hal ini boros energi
- Sebaiknya disebutkan agar exhaust fan dilengkapi dengan VSD (Variable Speed Driver) yang dapat diatur kebutuhan tekanan negative yang diinginkan
- **RH 60% (Sebaiknya tidak dipersyaratkan untuk Covid 19) dan temperature 24 ±2°C**

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Acuan Berbagai Negara (Perbandingan)

TABLE 1 Design standards for AIIR to prevent airborne contamination.[11]

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	ORGANIZATION	AIR CHANGE RATE (ACH)		PRESSURE DIFFERENTIAL	RECIRCULATION	ANTEROOM
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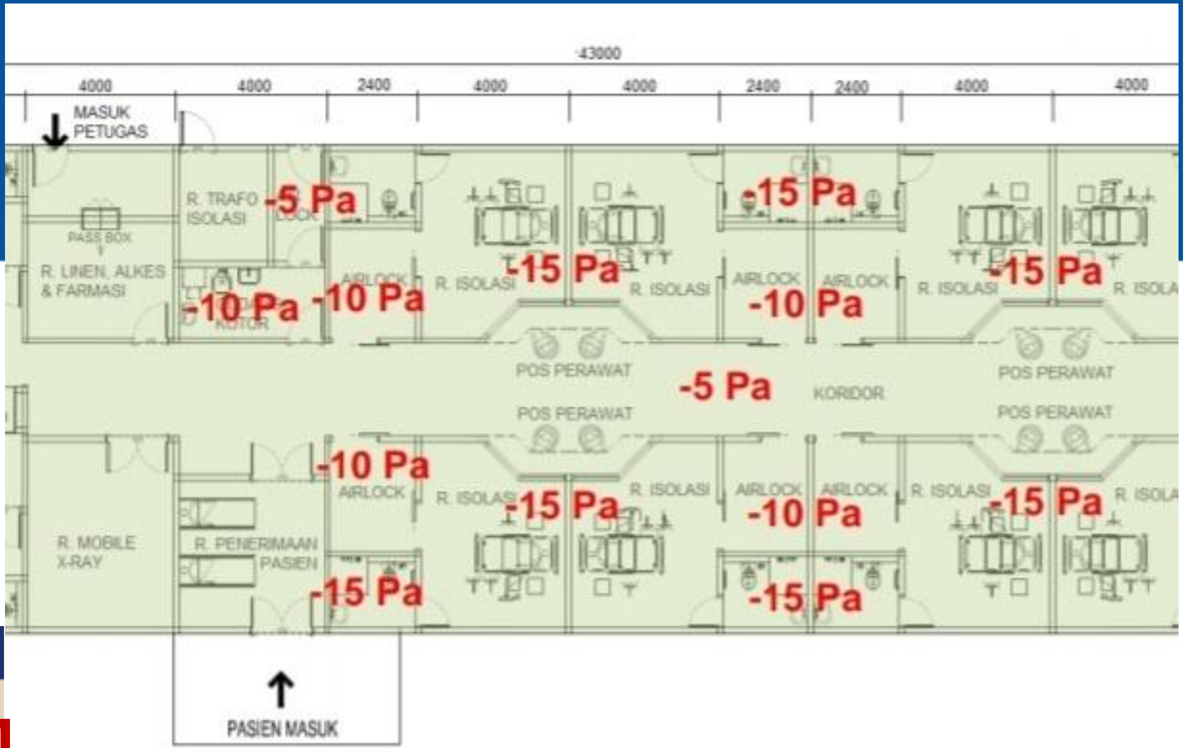
UK	Department of Health		More than 10	More than 5 Pa	No	Recommend
Norway	Folkenhelseinstitutt		More than 12	More than 5 Pa	No	Mandatory
Australia	Department of Health And Human Services	Mandatory More than 12	Recommend More than 15	More than 15 Pa	No	Mandatory
Hong Kong	Infection Control Committee Department of Health	Existing More than 6	New/Remodeling More than 12	More than 2.5 Pa	Yes (w/HEPA Filter)	-
South Korea	Centers for Disease Control and Prevention	Mandatory More than 6	Recommend More than 12	More than 2.5 Pa	Yes (w/HEPA Filter)	Mandatory



Gambar SistemTekanan Udara dalam komplek Ruang Isolasi

Indonesia

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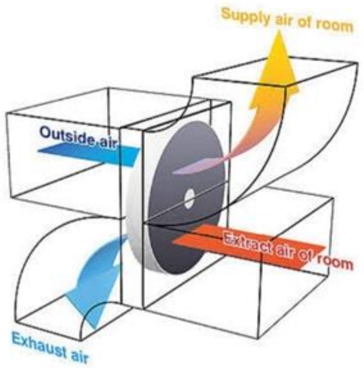
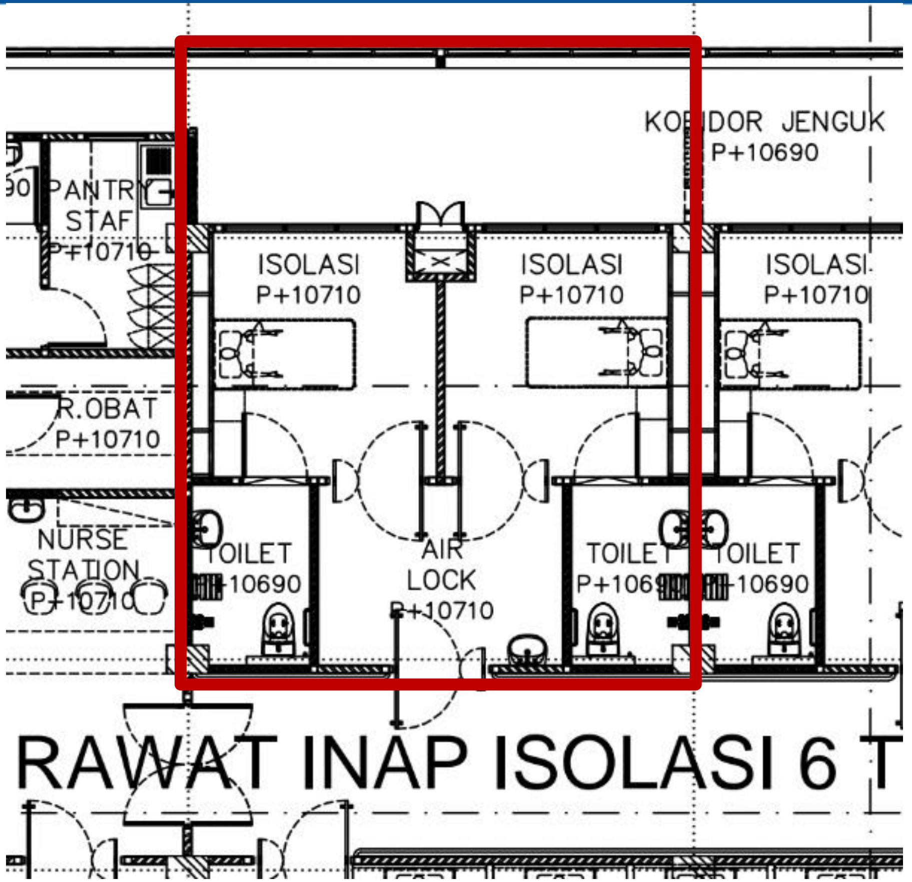
Potensi Energy Efficiency Ruang Isolasi

- Posisikan kondisi STEADY pada titik optimum -2,5Pa (ASHRAE Standard) dengan bantuan SMART CONTROL SYSTEM
- Tambahkan Air to Air Heat Exchanger antara Air Exhaust dan Fresh Air. Air Exhaust yang masih dalam kondisi dingin dikenakan untuk mendinginkan Fresh Air dari udara luar yang panas.



- Minimumkan Volume ruangan dan space sesuai kebutuhan. Perlu ditelaah luas dan tinggi minimum yang layak
- Anteroom couple design atau 2 ruang isolasi dengan 1 Anteroom adalah pilihan efisiensi space terbaik.



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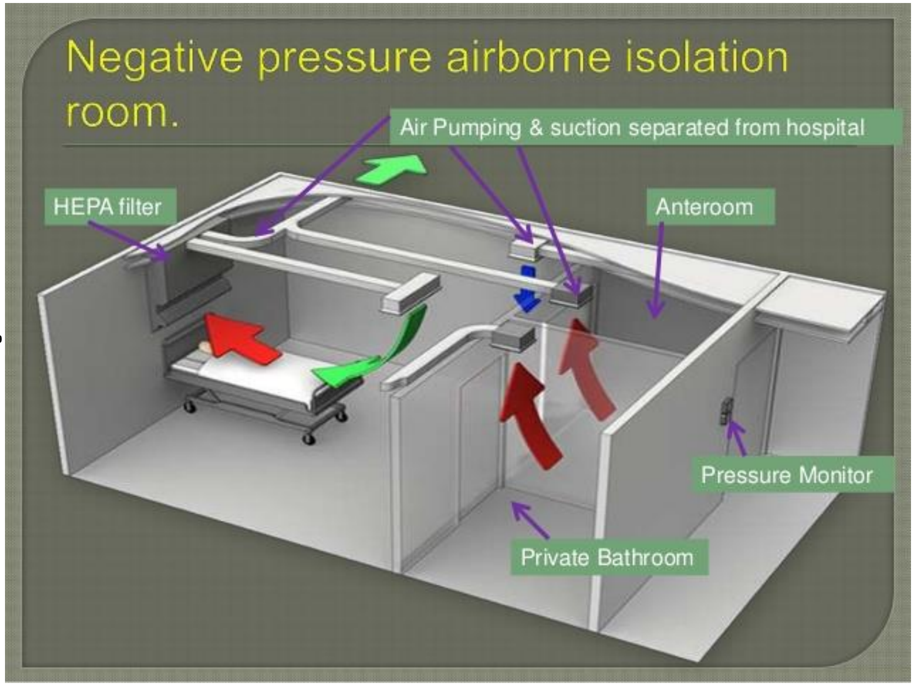
Potensi Energy Efficiency Ruang Isolasi

- Gunakan material dinding berbahan isolator baik dan pintu sealed yang benar-benar kedap.
- Volume ruang isolasi yang minimum
- Treatment kelembaban udara Fresh Air dengan Desiccant Wheel atau Heat Pipe sebelum didinginkan. (50%-70% RH)
- Menjaga pre filter tetap bersih dan secara optimum HEPA terkontrol kapan harus diganti melalui dP alert system.
- Control Monitoring 12 ACH ruang tetap diposisi minimum tercapai dengan mengukur flow udara exhaust.
- Return Air Possibility (Bila dipastikan bahwa return air system dan HEPA dapat 100% mencegah kuman kembali ke ruangan). **#Butuh reasearch tersendiri**



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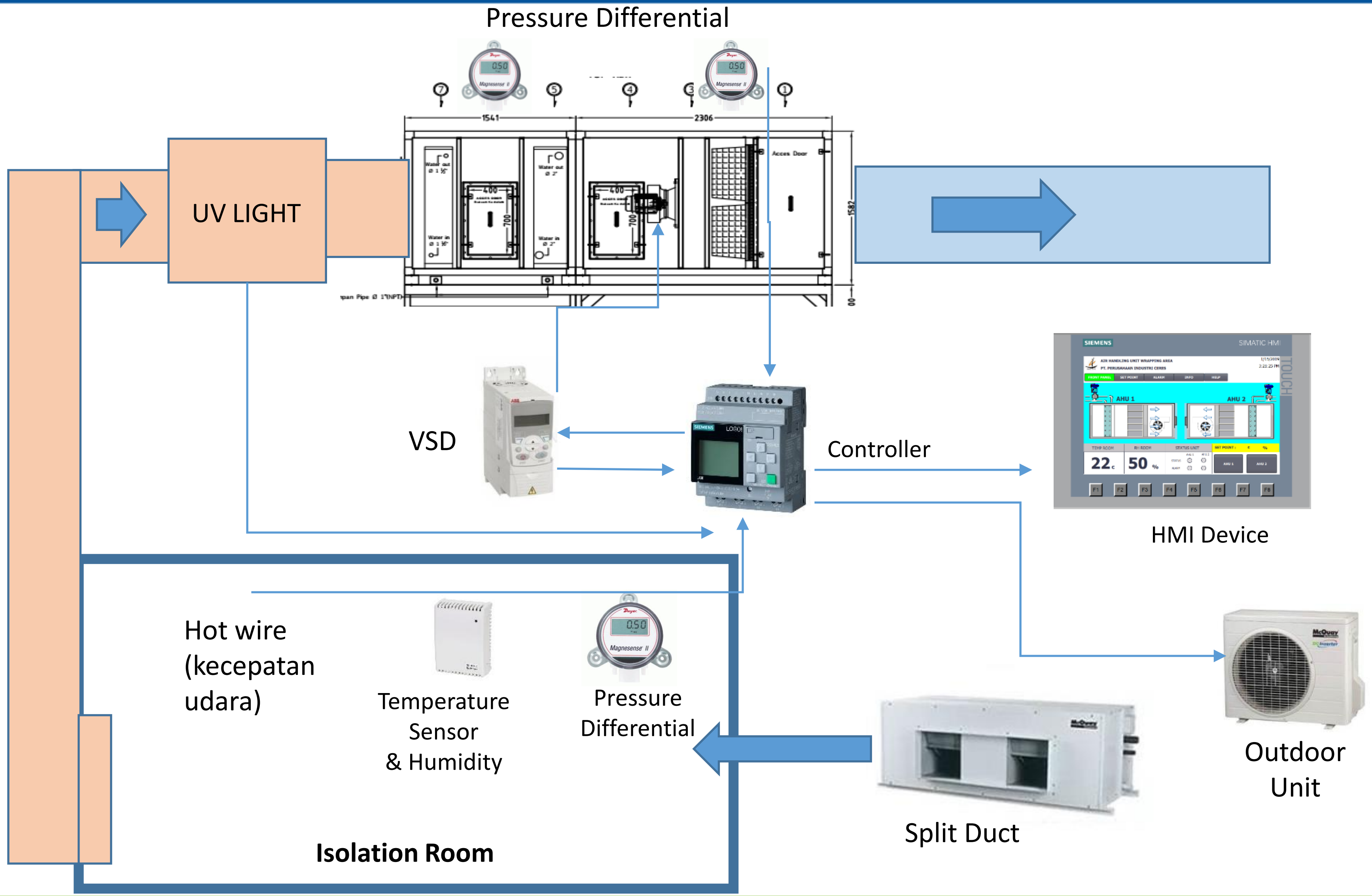
ISOLATION ROOM CONTROL & MONITORING

- NEGATIVE PRESSURE CONTROL & Monitoring
- FILTER MONITORING
- TEMPERATURE CONTROL & Monitoring
- ACH (Air Change per Hour) monitoring
- Humidity Monitoring

Digital Schematic Control
Negative Pressurization



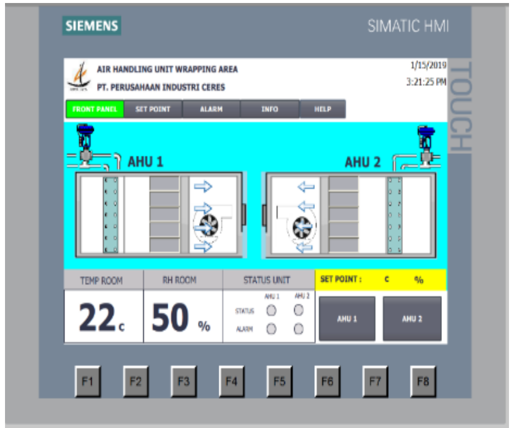
FILTER MONITORING SYSTEM

Pressure Differential HEPA FILTER

Pressure Differential Pre Medium FILTER

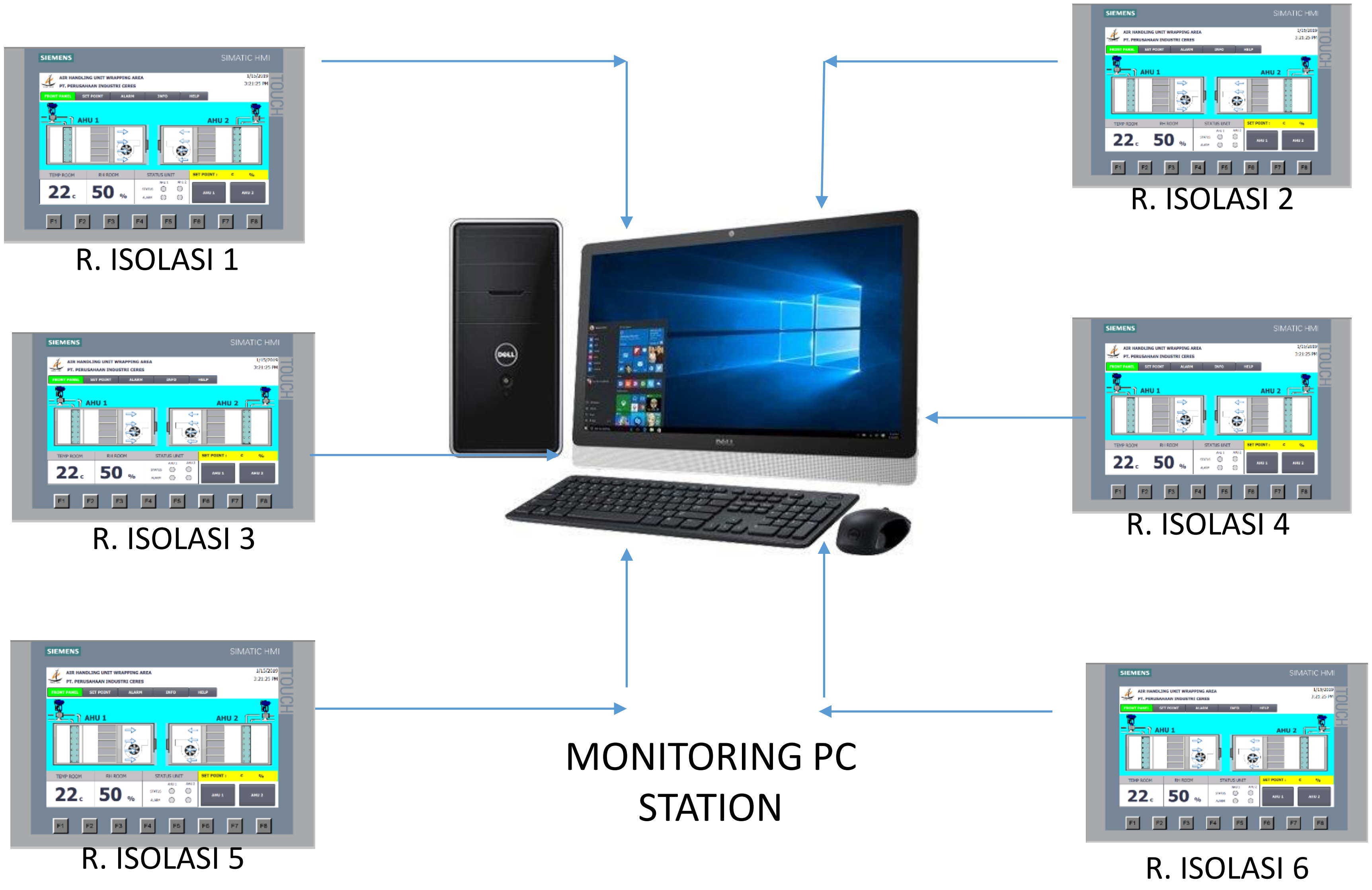
Pressure Differential Med. Filter AHU

Controller



HMI Device

Centralized Controller



GARDA • MEDICA

Membuat ruangan isolasi bertekanan negative dengan *Negative Pressure Room Generator* (NPRG)

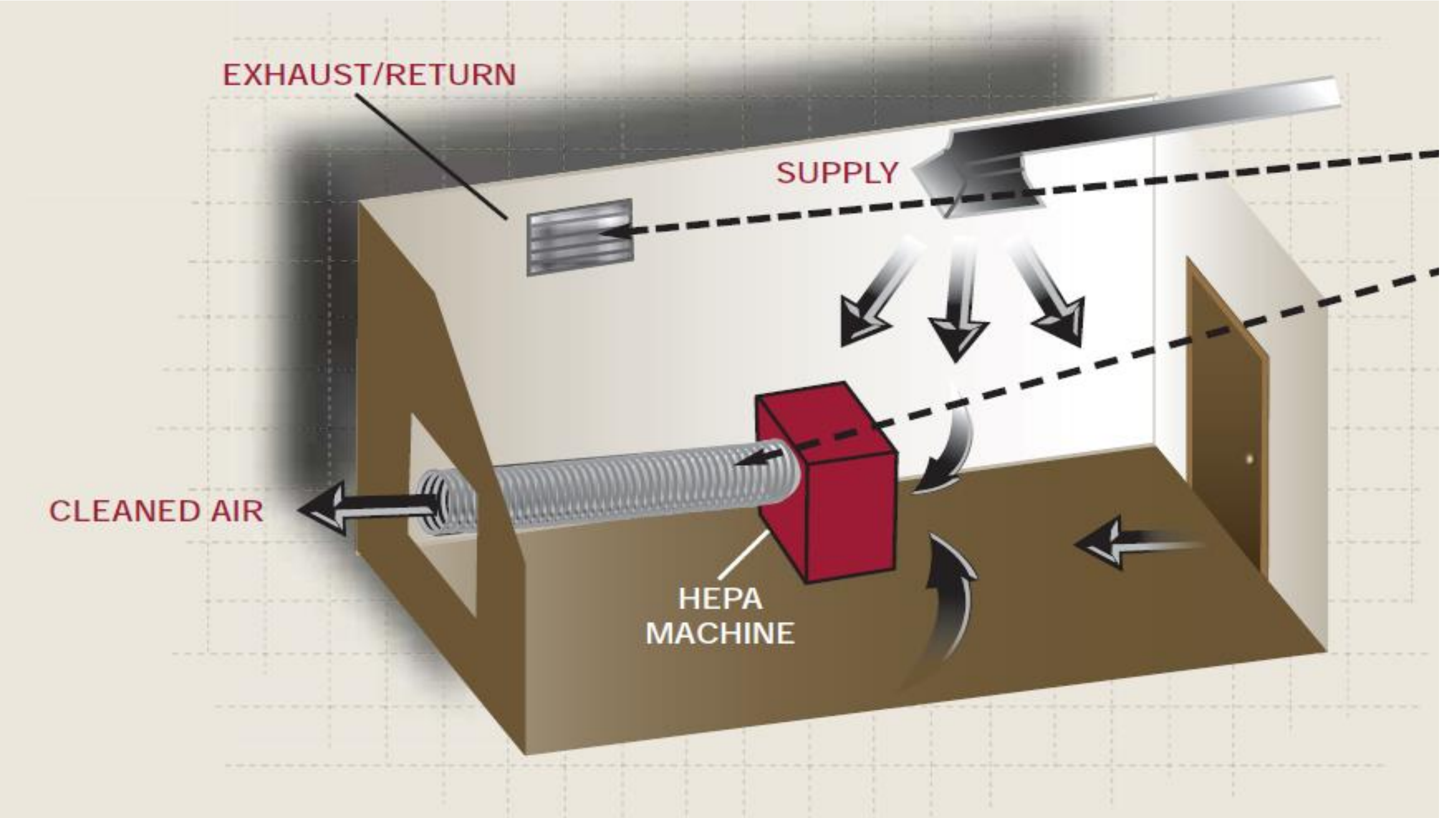


FIGURE 4

HEPA fan *exhausting clean air outside through the window.*

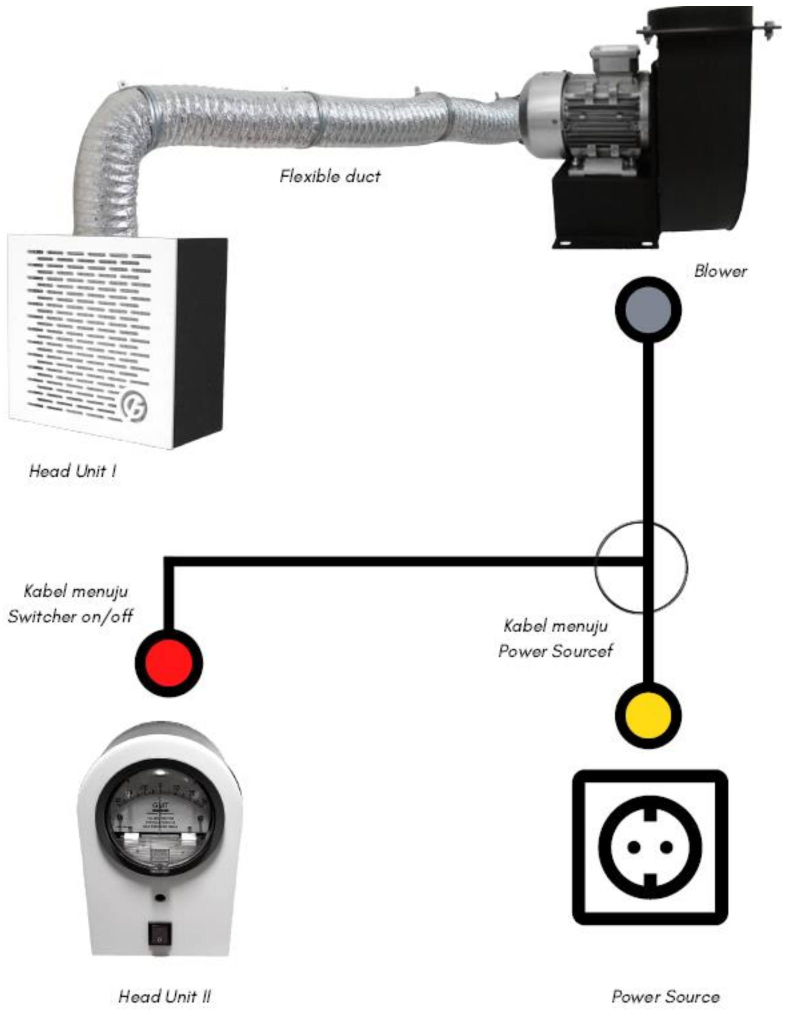
Untuk mencegah kebocoran udara, saluran udara harus ditutup rapat

Pengaturan HEPA machine and flex duct

Garda Medica mengadopsi dan memodifikasi metode dari Minnesota Department of Health dengan prinsip membuat ruangan bertekanan negative dengan cara mengalirkan udara keluar melalui saluran yang telah dilengkapi HEPA filter.

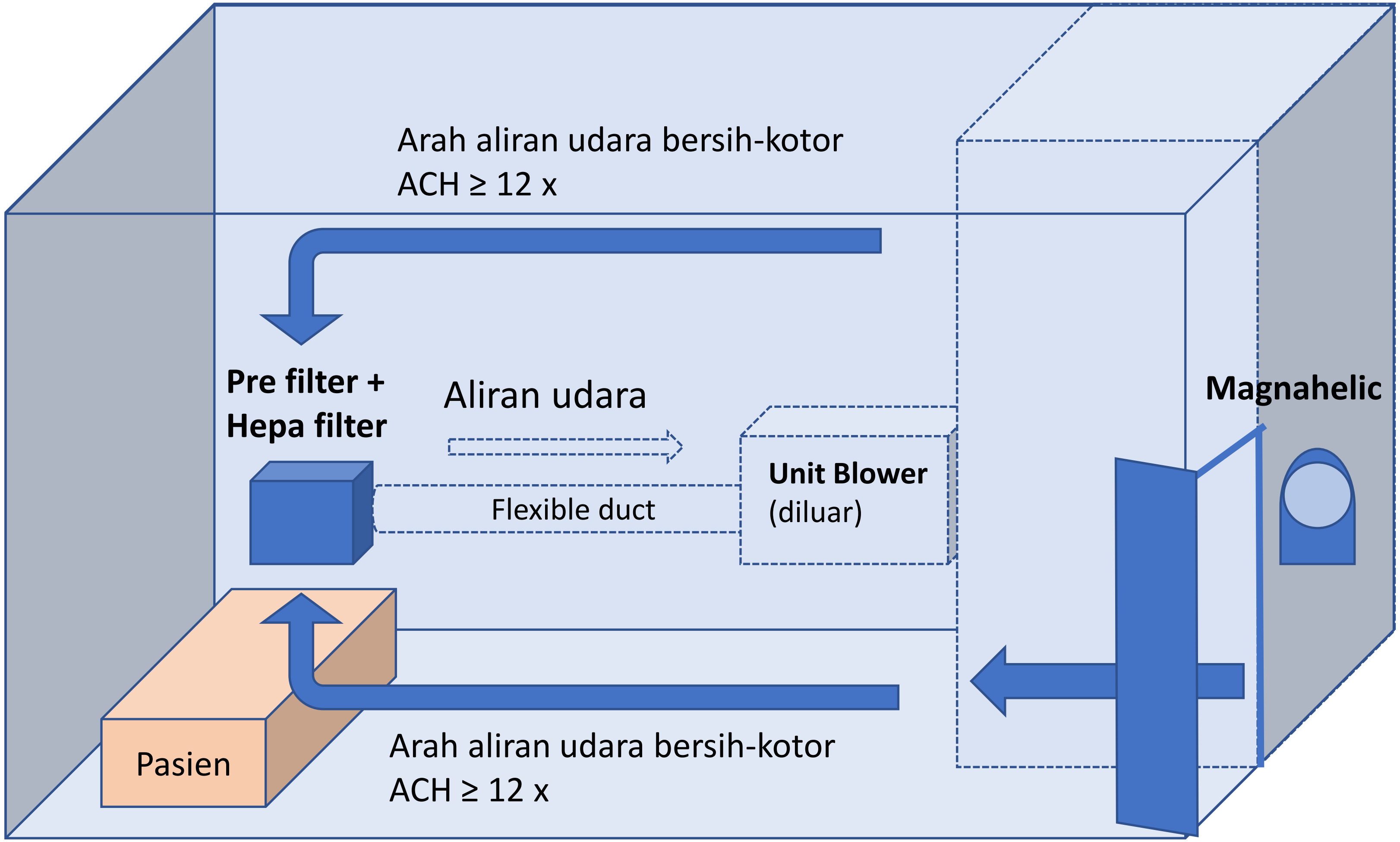
Minnesota Department of Health. Airborne Infectious Disease Management: Methods for Temporary Negative Pressure Isolation. Available from : https://www.health.state.mn.us/communities/ep/surge/infectious/airbornenegative.pdf

Negative Pressure Room Generator (NPRG)



- NPRG adalah sebuah sistem alat yang mengatur tekanan dalam ruangan dalam kondisi tekanan negatif, agar udara dalam ruangan dapat dialirkan keluar
- **NPRG memiliki 3 komponen dasar:**
  - Unit filtrasi
    - Media filtrasi yang berisi unit prefilter dan hepa filter, mampu memfiltrasi 99.97% partikel hingga ukuran 0.3 micron
  - Unit monitor
    - Alat untuk memantau tekanan di dalam ruangan secara *real-time*
  - Blower
    - Penghisap udara untuk dialirkan keluar ruangan

Skema ruangan isolasi dengan NPRG



- Menghasilkan tekanan negatif lebih dari -2,5 Pa untuk ruangan dengan volume 160 m3
- Menghasilkan lebih dari 12 kali pergantian udara ruangan dalam 1 jam
- Derajat kebisingan 50-60 dB sehingga tidak mengganggu pasien.
- Menggunakan double filter
- Monitor tekanan udara ruangan secara *real-time*

Kesimpulan

Kesimpulan

1. **Pola aliran udara** sangat penting disamping kondisi negative ruangan.
2. Sudah saatnya Design dilakukan secara proper dengan menggunakan **Design software** : perhitungan Cooling load secara detail dan simulasi sirkulasi udara dengan CFD, sehingga unit TIDAK OVER SIZE
3. Perlu andil para **konsultan professional (ASHRAE INDONESIAN CHAPTER)** dalam memberi masukan pada pembuat regulasi yang jelas sebagai panduan atas pendemi Covid19 ini.
4. Perlu dilakukan pengecekan atas kesesuaian ACH dan Negative pressure. Lebih baik bila terkontrol secara otomatis dengan PLC dengan **system ALERT**.
5. Penggunaan **energy ruang isolasi sangatlah besar**. Untuk itu perlu ada Langkah IMPROVEMENT agar system dapat bekerja lebih efisien.
6. Unit **Isolasi MINI untuk darurat** yang memenuhi persyaratan tata udara sangatlah dibutuhkan sebagai alternative darurat disaat sekarang.
7. AC untuk kebutuhan ruang isolasi adalah harus type **SPLIT DUCT AC**, bukan AC split Wall atau Cassette yang memiliki udara RETURN yang justru akan minimbulkan potensi infeksi dari Air borne lebih besar.
8. Kecepatan aliran hisap pada intake Exhaust adalah sangat penting ditetapkan pada kecepatan OPTIMUM yang tidak berisik **(3 m/s – 4m/s)** agar efek sedot dengan aliran tubulen ke area kontaminasi optimal.

Alternate Care Sites – Images


Pre-ED Screening Area

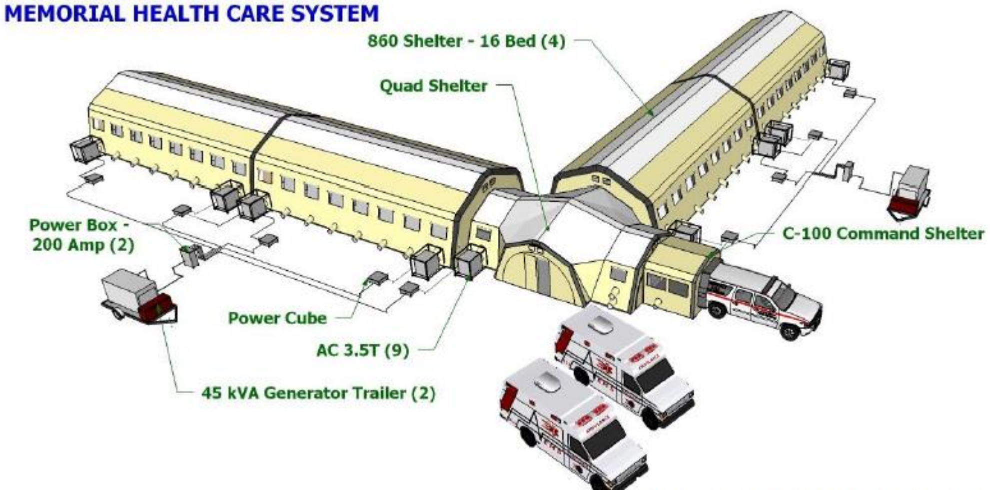


Image courtesy of Zumro


Limited Power per Bay


Vanderbilt MC Pre-ED screening, open air parking garage


Consider exhaust discharge locations – direct away from people and outside air intakes


Bottom opening exhausted to create front to back airflow across patient

ASHRAE CELEBRATING 125 YEARS


Thank You!