2022 SHASE Kinki Chapter & SAREK Busan-Ulsan-Kyungnam Chapter

HVAC System in Post-COVID19

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SAREK The Society of Air-Conditioning and Refrigerating Engineers of Korea

公益社団法人空気調和・衛生工学会
The Society of Heating,Air-Conditioning and Sanitary Engineers of Japan

Topic: HVAC System in Post-COVID19

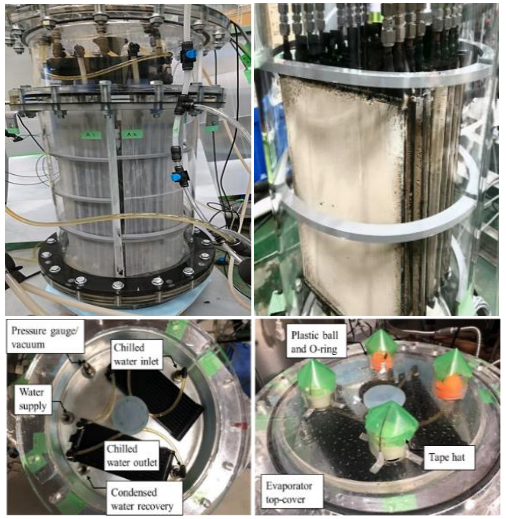
Introduction

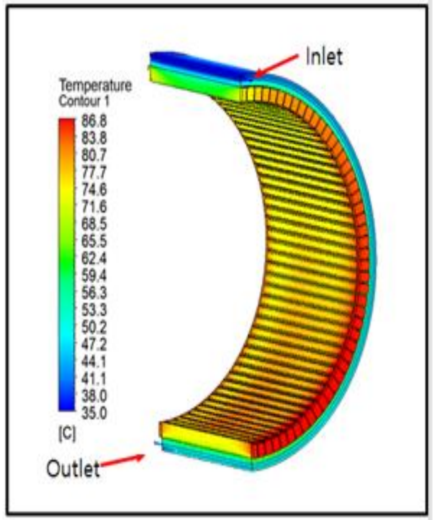
1 Education Background

Degree	Period	Department	Details
Bachelor	2007. 03 ~ 2015. 02	Refrigeration and Air-conditioning Engineering, PKNU	-
Master	2015. 03 ~ 2017. 02	Refrigeration and Air-conditioning Engineering, PKNU	Research Topic: Ocean Thermal Energy
Doctor	2017. 10 ~ 2020. 09	Human Environmental Systems Department of Engineering, Hokkaido University	Research Topic: Adsorption Heat Pump System
Doctoral Thesis	Study on Adsorption Heat Pump Using Composite Natural Mesoporous Material as Low-carbon Air Conditioning (Hokkaido University, Supervisor: Katsunori Nagano)		

2 Research Field

- Low carbon air-conditioning using adsorption heat pump **(흡착식 냉동기를 이용한 저탄소 공조)**
- Brine chiller for semi-conductor manufacturing process **(반도체 공정용 브라인 칠러 개발)**
- Development of seawater cooling, ice making system **(해수 냉각, 제빙 시스템 개발)**
- Heat transfer CFD **(열전달 수치해석)**

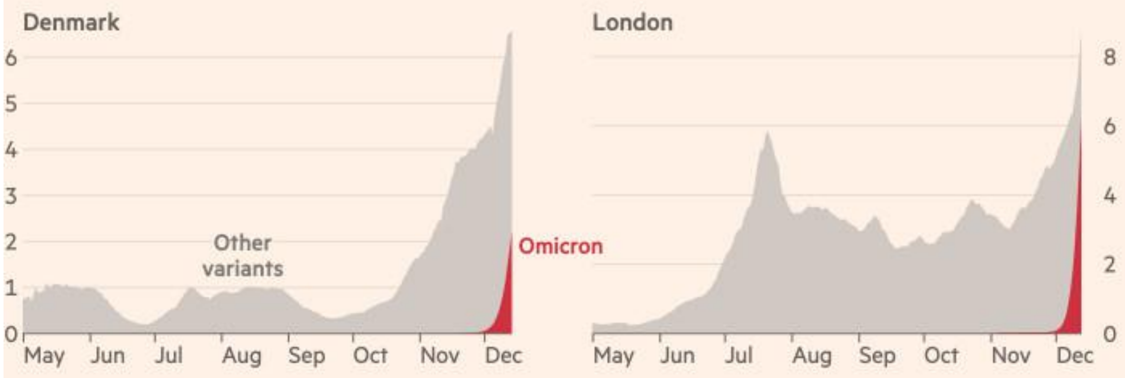




COVID-19 and OMICRON (코로나19와 Omicron 변이)

The Omicron variant is on the brink of dominance in Denmark and London, and has sent cases soaring in both locations

Daily cases in each country/region (in thousands), by variant



Source: FT analysis of data from UKHSA and the Statens Serum Institut
FT graphic by John Burn-Murdoch / @jburnmurdoch
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B Bloomberg.com

Omicron's Spread Across Hotel Hall Highlights Transmission ...

The omicron variant spread among two fully vaccinated travelers across the hallway of a Hong Kong quarantine hotel, underscoring why the...

1주 전

Deseret News

Is the omicron variant more contagious? Is omicron airborne?

The omicron variant of the novel coronavirus has dominated news ... Some cases were found in Hong Kong among travelers from South Africa.

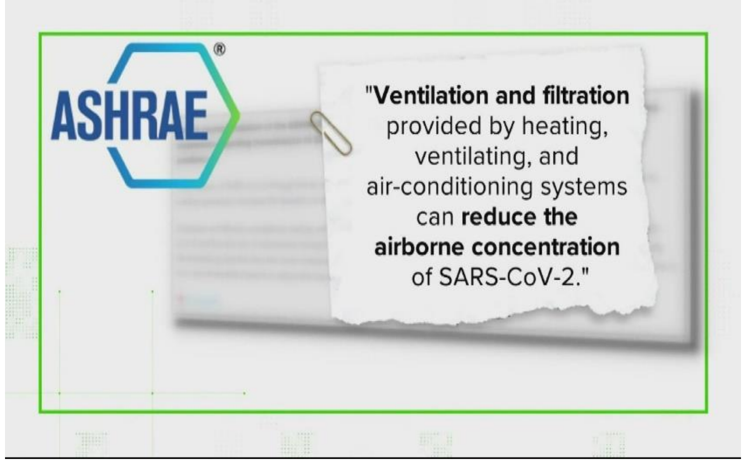
2주 전

Characteristics of spread of COVID19 (코로나19 바이러스의 전파 특성)

※ Figure out spread root first, then prevent and respond properly.

- Still unclear main spread root of COVID19 and Omicron (여전히 불분명한 오미크론 및 코로나19 바이러스의 전파 경로)
- Airborne infection through particles smaller than 5 microns → Assignment of HVAC system (5 미크론 이하 크기의 입자의 공기중 전파가 HVAC 시스템에서 다루어야 할 과제)

HVAC for COVID19 (코로나19 대응 HVAC)



HVAC Systems of COVID19-era (코로나19 시대의 HVAC 설비)

Topic (Report) HVAC of COVID19-era

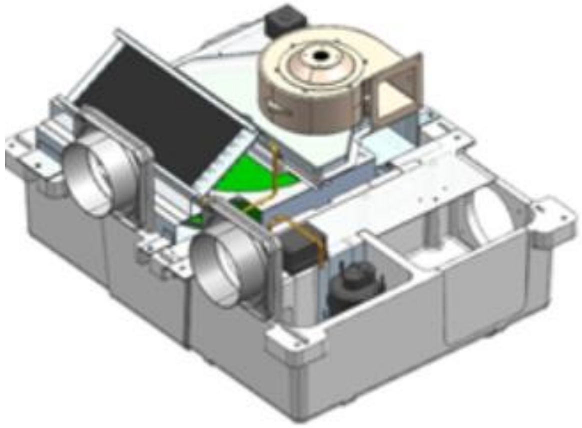
'복합환기' 트렌드, HVAC 최대시장 견인하나

"Combination ventilation" trend. HVAC is leading the market.

Prospects of integrated HVAC unit (통합 HVAC 유닛의 전망)

- Development of All-in-one device having the function of ventilation, heat recovery, dehumidification, cooling and heating, sterilization. (환기, 열회수, 제습, 냉난방, 살균 기능을 갖춘 올인원 HVAC 장치의 개발)
- Obstacle for development of All-in-one unit and compact design: Latent heat (올인원 장치 소형화의 장애물: 증가된 제습 부하)
- Development high efficiency latent heat recovery element. (고성능 잠열 회수 엘러먼트의 개발)
- Integration of All-in-one unit with desiccant dehumidification rotor. (건식 제습 로터와의 결합)

Ventilation + heat/cooling

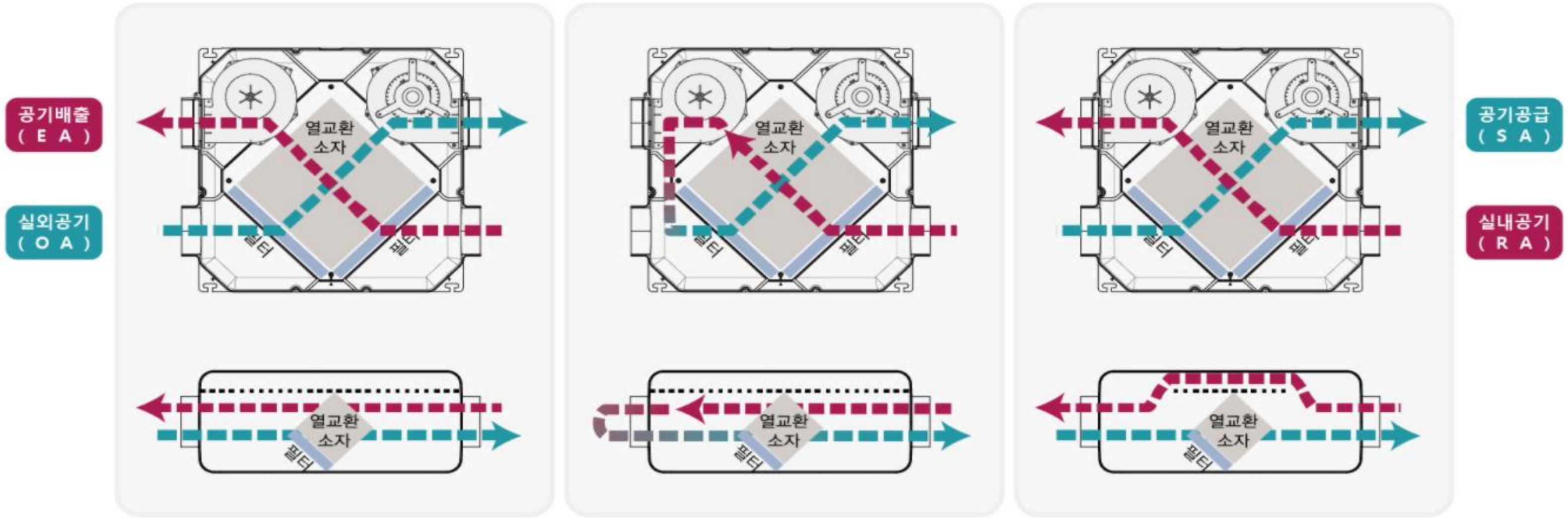


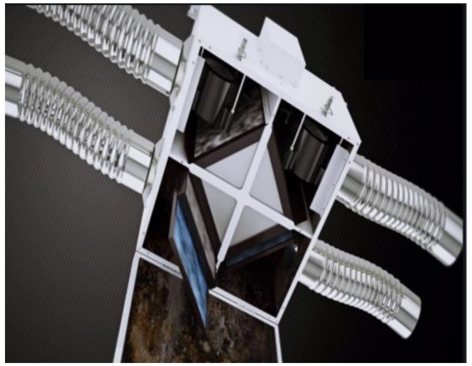
Ventilation+heat/cooling+dehumidification

Ventilation system (환기 시스템)

Topic Operation Modes of Ventilation Systems with Heat Recovery

Ventilation mode | Filtering mode | Bypass mode





Diamond type Hexagon type Square type

Heat recovery devices (열회수 장치)

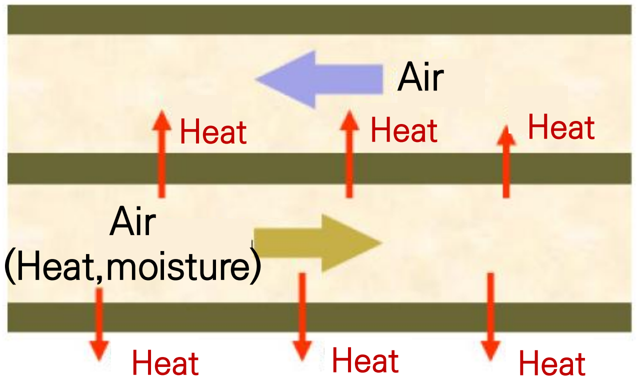
Prospects of ventilation system (환기 시스템의 전망)

- Problem: Latent heat recovery rate is much lower than that of sensible heat. (문제점: 잠열 회수 비율이 현열 회수 비율보다 매우 낮음)
- Total heat recovery in summer (45%) and winter (70%). (여름철 전열 효율이 45% 수준인데 반해 겨울철은 전열회수 효율은 70%)
- Enhancement of latent heat recovery is essential. (향후 전열 회수 성능 향상 관련 연구 필요)

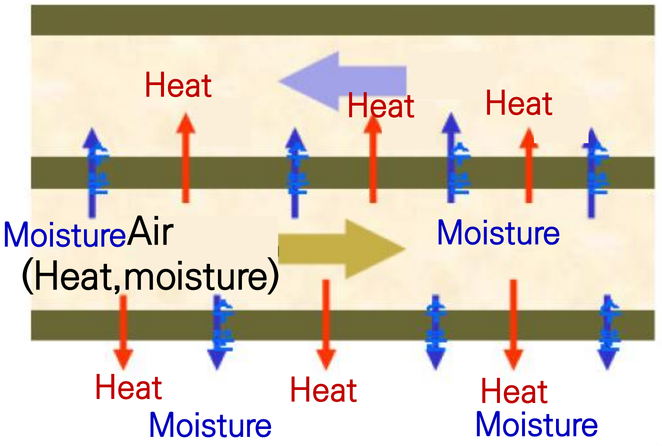
Heat recovery device (열회수 장치)

Topic Installation of ventilation unit

Sensible heat exchange (현열 교환) (Temperature)



Total heat exchange (잠열교환) (Temperature + Humidity)



Dew in heat recovery device
열회수 장치의 결로 발생

Air purification with air filters (에어필터를 통한 공기 정화)

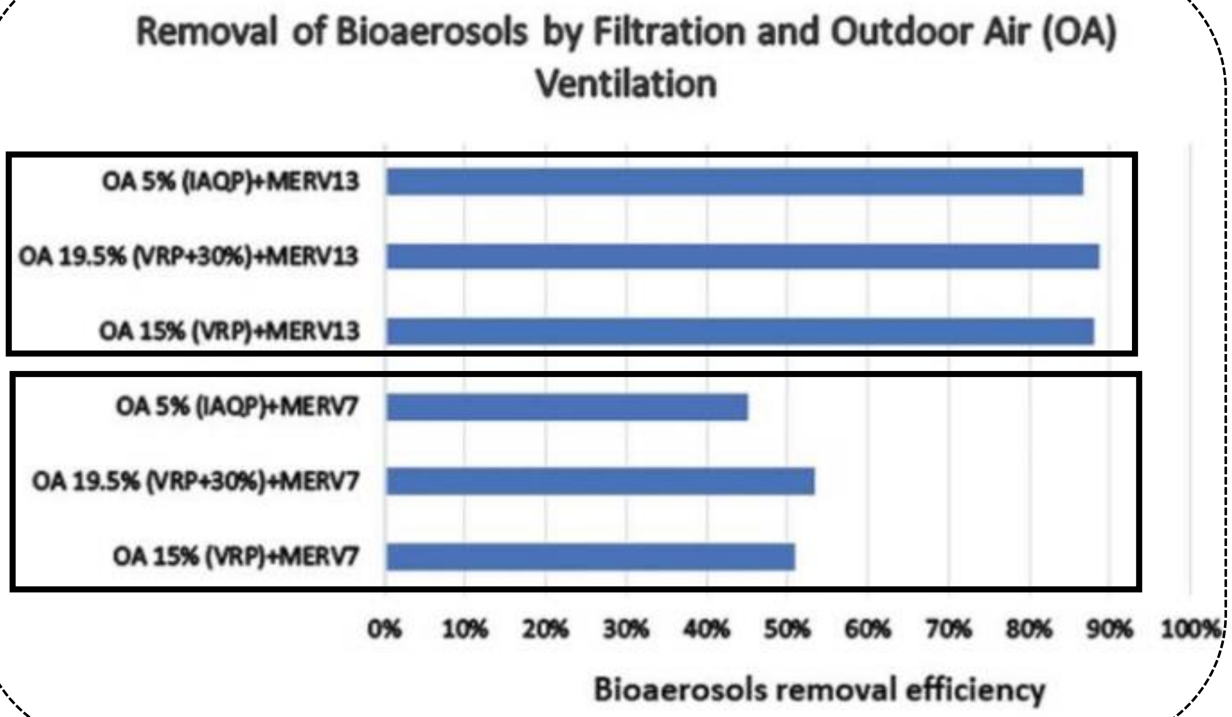
Topic Air filter

- Usually air filters with MERV 17 above is classified as HEPA filters. (일반적으로 MERV 17등급 이상의 필터는 HEPA 필터로 분류)
- Most of AHU adopts MERV 7~9 filters (medium) which shows bioaerosol removal rate of 40%. If the higher grade air filter (ex, MERV 13) is applied, bioaerosol removal rate rises up to 85%. (대부분의 AHU에는 바이오에어로졸 제거율 40% 수준의 MERV 7~9의 미디움필터가 사용됨. 이를 MERV13 급의 고성능 필터로 교체할 경우 제거율은 85% 까지 증가함.)

- Careless application of higher grade air filter may results in lack of air flow rate and collection capacity. Thereby careful consideration is needed. (무분별한 고성능 필터의 사용은 송풍량 감소와 포집용량 감소로 이어질 수 있으므로 주의)

Rating of air filters (에어필터의 등급)

MERV (Minimum efficiency reporting value): ASHRAE classifies air filters into 1~20 grades (the higher number represents the higher performance)



* Source: I. Biran and A. Goel, HVAC design in commercial building to mitigate COVID-19, 2020

Impact of flow direction (유동 방향의 영향)

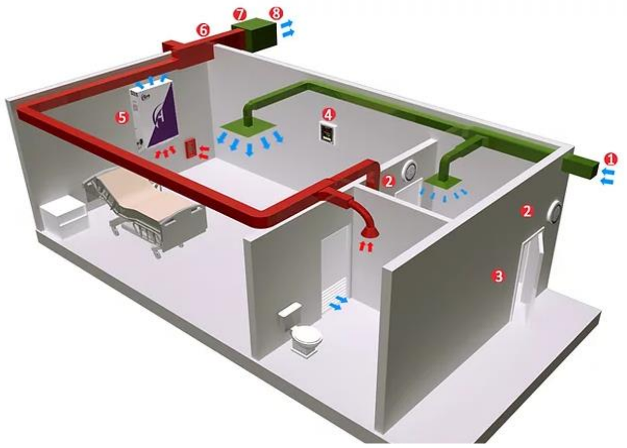
Topic Negative pressure ward

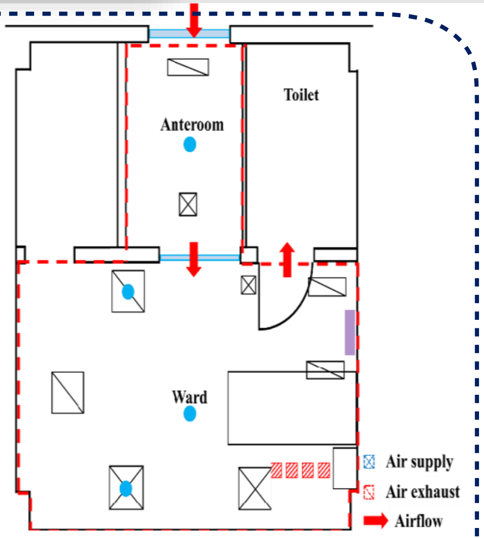
- Direction of flow should be different: ① **To prevent the virus transmitting between rooms (−)**, ② To resist the entry of surrounding contaminated air (+). **(공기 유동 방향이 달라야 함: ① 다른 공간으로 바이러스가 전파되는 것을 막기 위해서는 음압, ② 오염된 공기가 공간으로 침입하는 것을 방지하기 위해서는 양압)**
- The negative pressure is only maintained when doors and windows are fully closed → Anteroom is required to separate the ward and corridor. **(음압은 오로지 창문과 문이 닫겨 있을 때만 형성됨 → 병실과 복도 사이에 전실 이라는 개념이 필요)**
- The pressure difference ranges from 2.5 Pa to 15 Pa. **(공간간 압력의 차이는 2.5 Pa과 15Pa 사이 수준)**

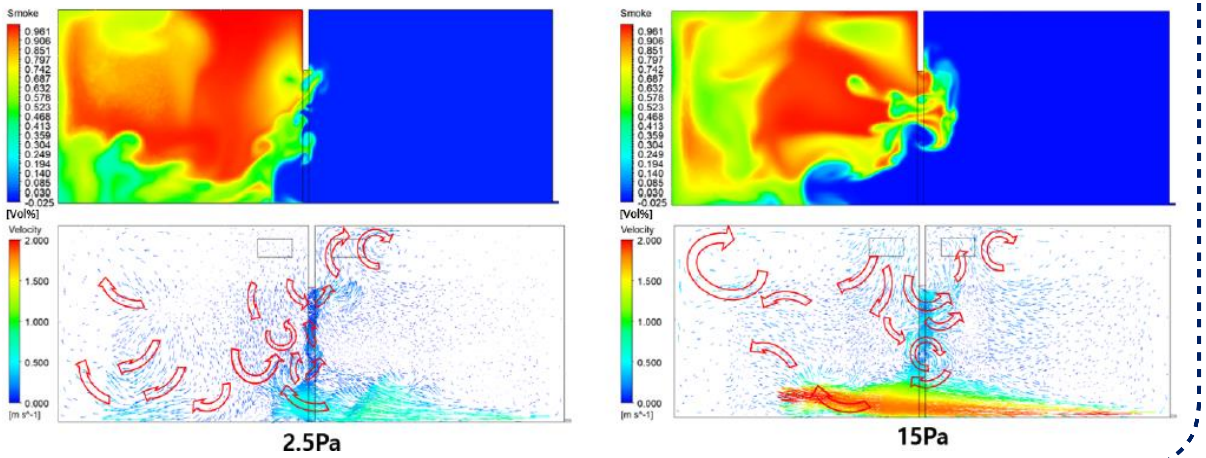
Intensive care unit (ICU)
(중환자실)

Negative pressure ward
(음압병실)

Negative pressure ward
(음압병실)







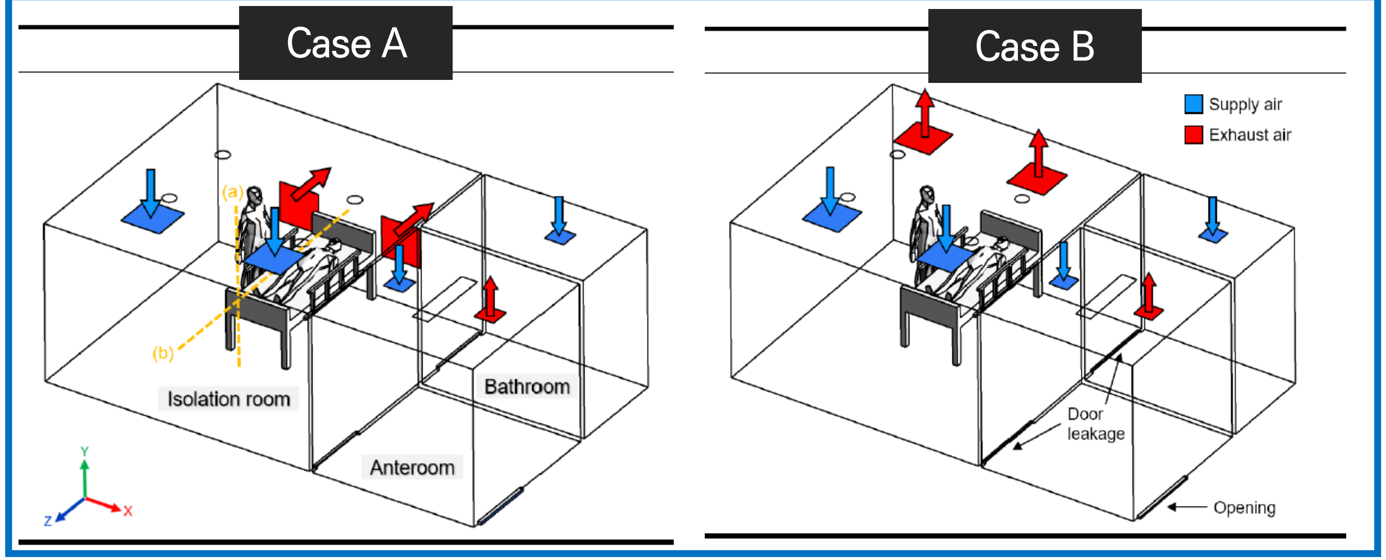
* Source: J. Y. Kim, J.K. Hong, A numerical analysis on contaminant air leakage according to pressure difference and exhaust location of negative pressure isolation room, SAREK, 2020

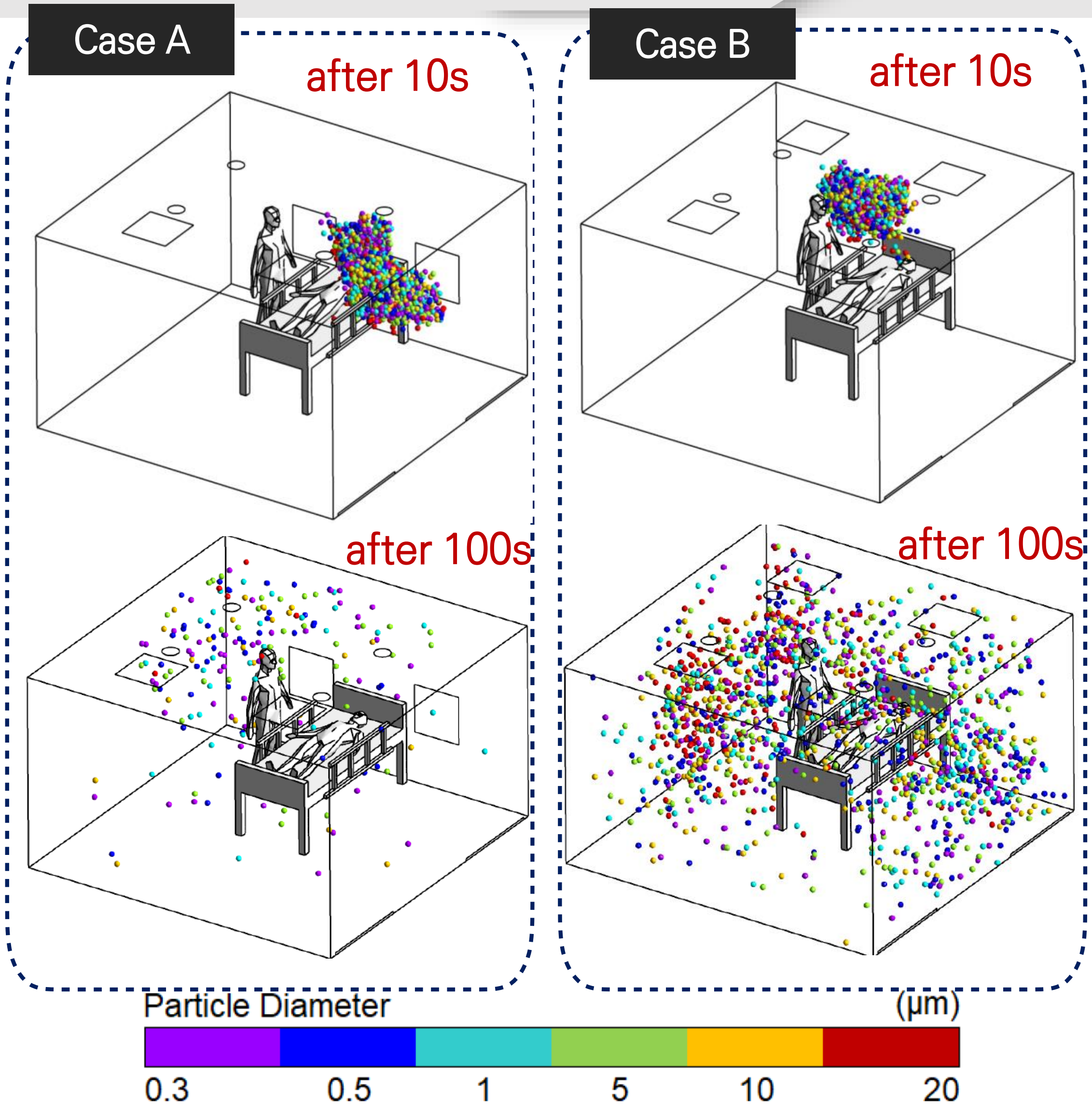
Impact of flow direction (유동 방향의 영향)

Topic Effect of exhaust location

- Aside from ventilation amount, ventilation efficiency is dependent on number and location of diffusers → Ex) Ceiling exhaust and Wall exhaust. **(환기량 이외에도 환기의 효율은 급배기구의 숫자와 설치 위치에 영향을 받음)**
- Cough produces 3,000 particles of droplets, and their size ranges from 0.6~15 ㎛, Exhaust and deposit characteristics are affected by the droplet particle size. **(기침은 0.6~15 ㎛의 3000개의 비말 입자를 발생시키며 배출과 퇴적은 입자 크기의 영향을 받음)**

Topic Two different exhaust condition (Case A, Case B)





* Source: M.J. Jung, J. K. Hong, A numerical study on cough particle dispersion and deposition according to the location of exhaust air diffuser in airborne infection, SAREK, 2019

Impact of flow direction (유동 방향의 영향)

Topic Shortage of Negative Pressure ward

- Li et al. measured the ventilation performance of 38 SARS wards after 18month of establishment, and 60% of toilet ↔ ward were operated under wrong airflow direction. (38개의 SARS병동의 환기 성능을 최초 설립으로 부터 18개월 후에 재측정 결과 60%의 화장실↔병실 공기유동 방향이 잘못됨)
- Nondurability results in shortage of NPW in the case of emergency (SARS, COVID19 etc). (NPW의 내구성의 문제로 SARS나 COVID19의 상황에서 병실의 부족을 야기함)
- In case of emergency, temporary negative pressure cubicles can be a good option. (비상 상황에서는 임시 음압병실의 사용이 훌륭한 옵션일 수 있음)

Factors for failed pressure control (압력 조절 실패 요인)

- Inadequate reliability of pressure monitoring and controlling devices. (압력 모니터링, 조절 장치의 부실)
- Strong diffuser flow directed at the door, and interaction with other exhaust ventilation system. (문측에서의 강한 기류, 다른 배기 시스템과의 상호작용)
- Poor air tightness of suspended false ceiling. (가천장의 부적절한 기밀성)

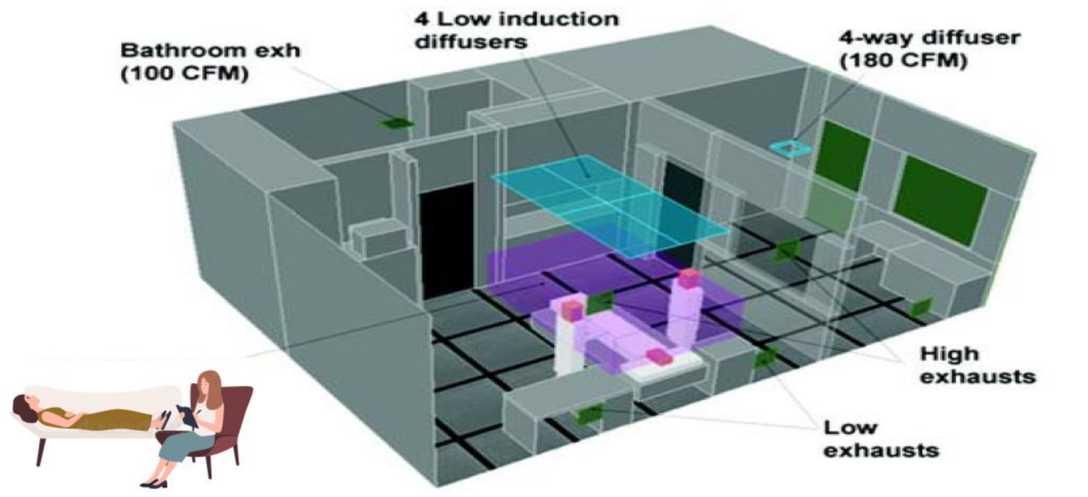
Temporary cubicle (임시 음압 병실)

Impact of air flow pattern (기류 패턴의 영향)

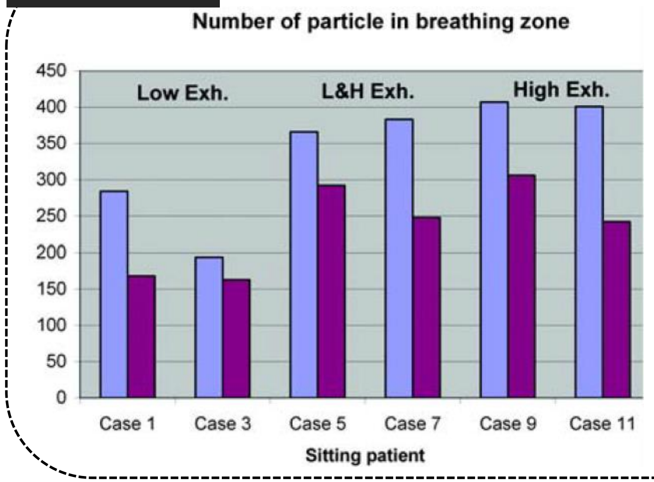
Topic Effect of exhaust location

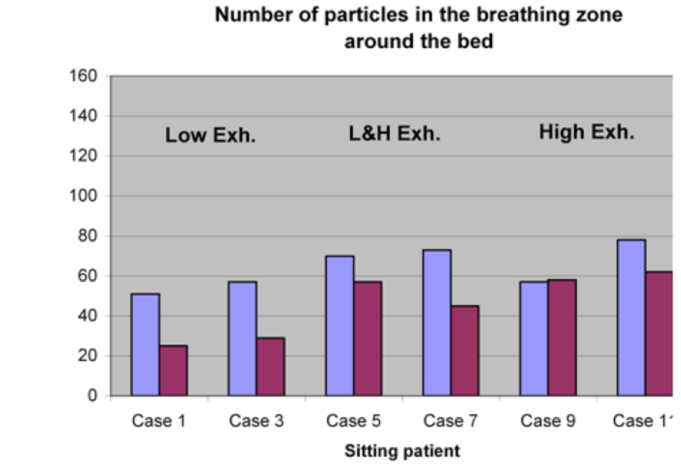
- Exhaust location (high exhaust, low exhaust and both) greatly affect ventilation performance. (배기구의 위치 (상부, 하부, 양측)에 따라 환기 성능이 크게 좌우됨)
- Relation between direction of cough jet (sitting, lying) and air flow is important. (sometimes 12 ACH removes particle better than 16ACH) (기침의 방향 (앉아있는 혹은 누워있는)과 공기유동의 관계가 중요함 → 12ACH 풍량으로도 16ACH 환기량 대비 높은 입자 제거율을 보인 사례가 있음)

Topic Ventilation system in isolation suite



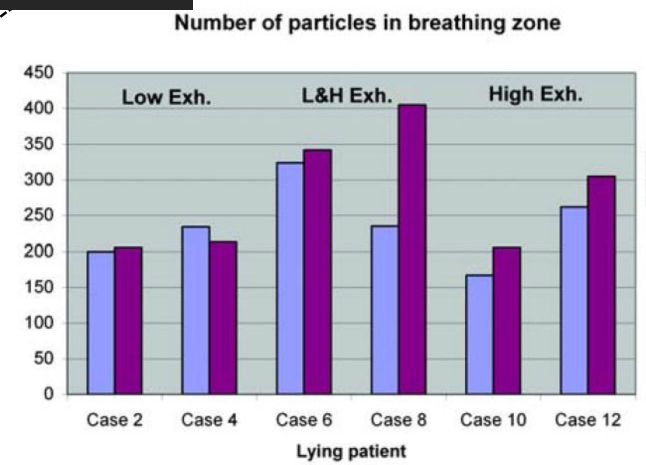
Sitting

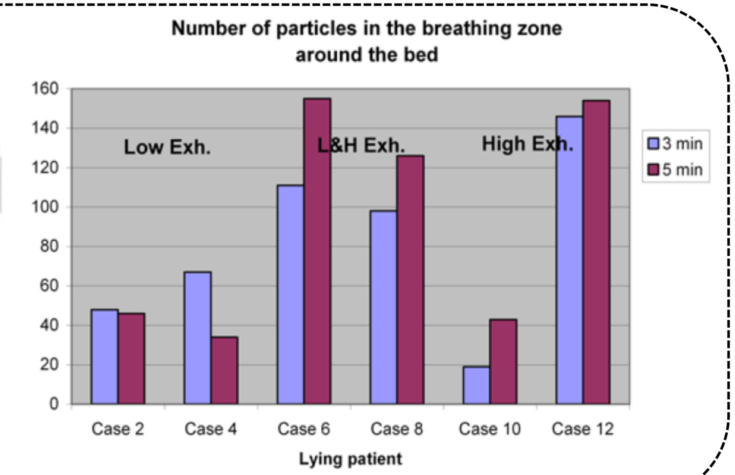




* Source: F. Memarzadeh, Improved strategy to control aerosol transmitted infections in a hospital suite, ASHRAE, 2011

Lying



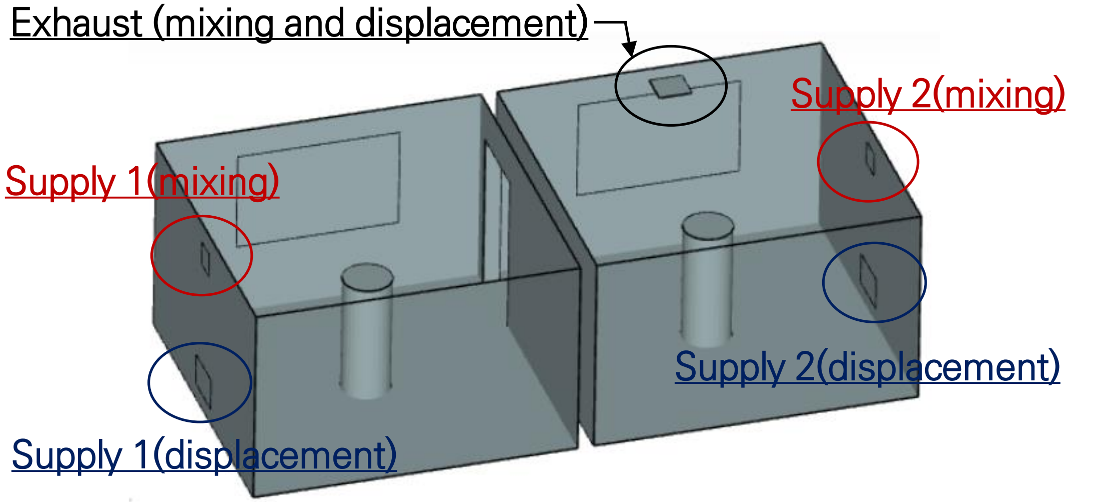


Impact of air flow pattern (기류 패턴의 영향)

Topic Displacement ventilation

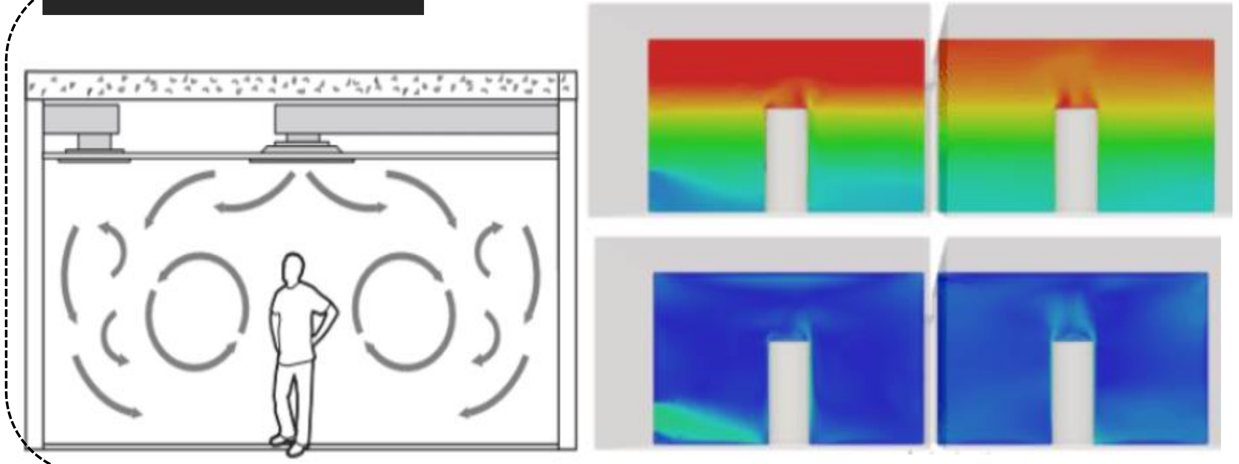
- DV is air-distribution strategy that introduces conditioned outdoor air at a low velocity for supply diffuser usually located near floor level. (DV 방식은 처리된 외기를 보통 바닥면에 설치된 취출구를 통해 저속으로 공급함)
- The cool air, pooling near the floor level, accelerates because of the buoyancy force, and is then carried up into the thermal plumes formed by heat source (occupants, electric appliances). (바닥 레벨에 쌓인 차가운 공기는 부력에 의해 가속되고 열원(거주자, 기기)에 의해 형성되는 Thermal Plume에 의해 상승)

Topic Location of supply and exhaust

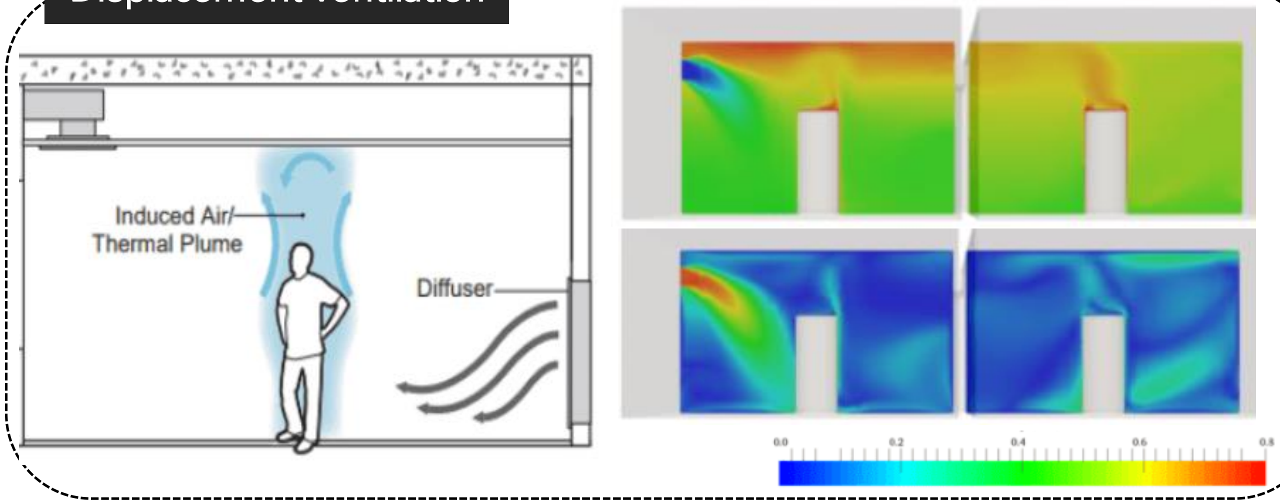


* Source: A. Churazova, How to optimize displacement ventilation design with CFD, SIMCSALE, 2020

Mixing ventilation

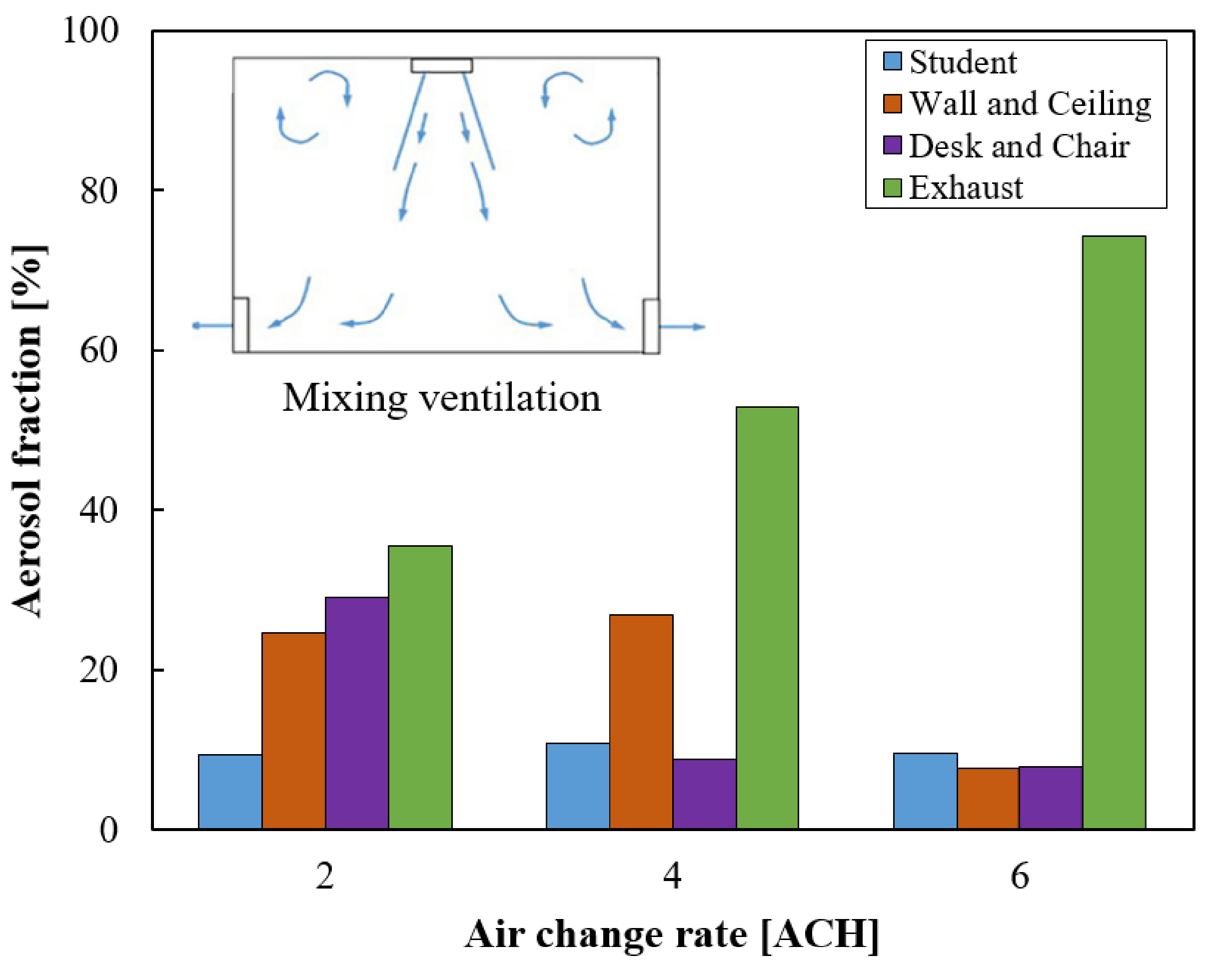


Displacement ventilation

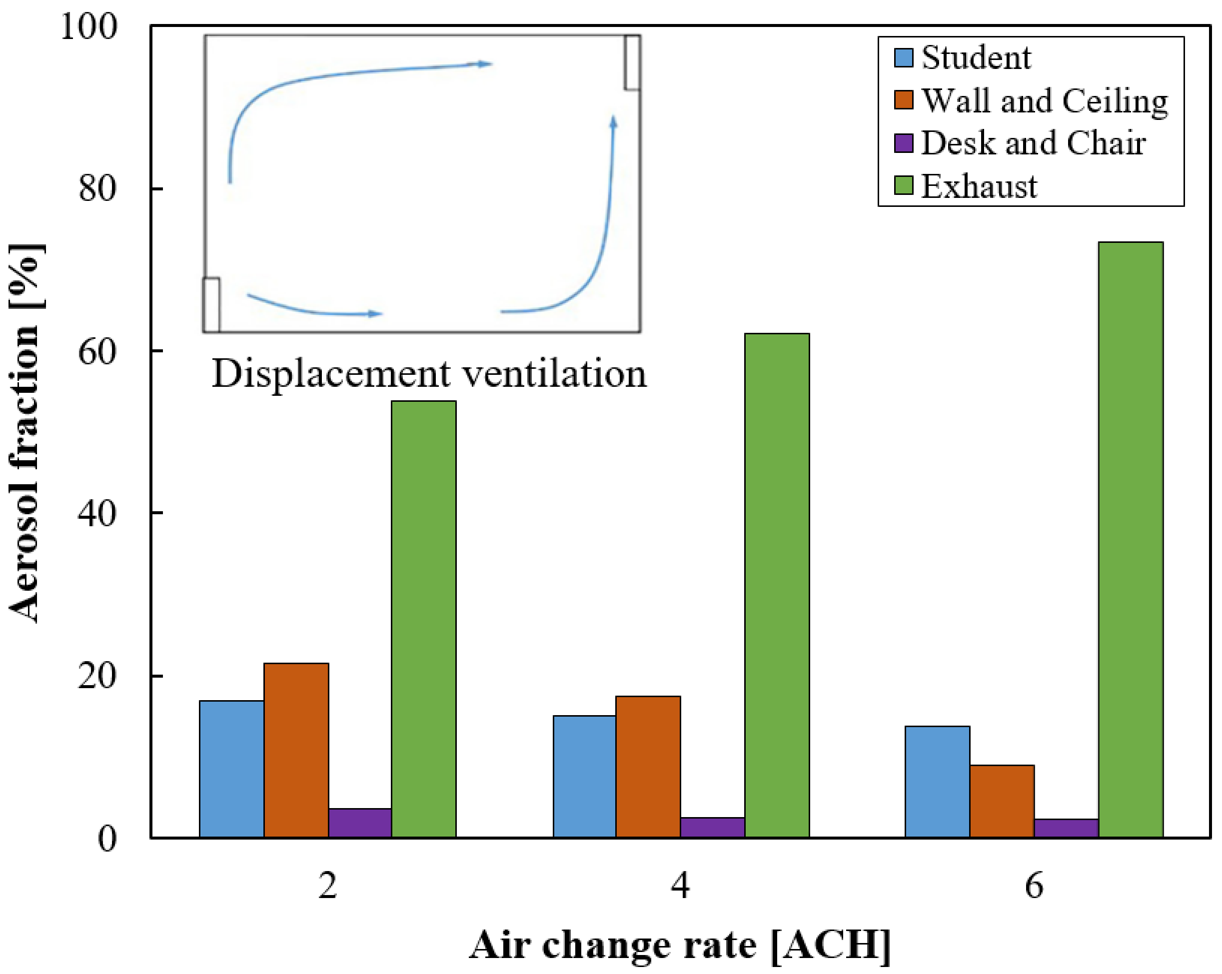


Impact of air flow pattern (기류 패턴의 영향)

Topic Effect of ACH in Mixing ventilation



Topic Effect of ACH in Displacement ventilation

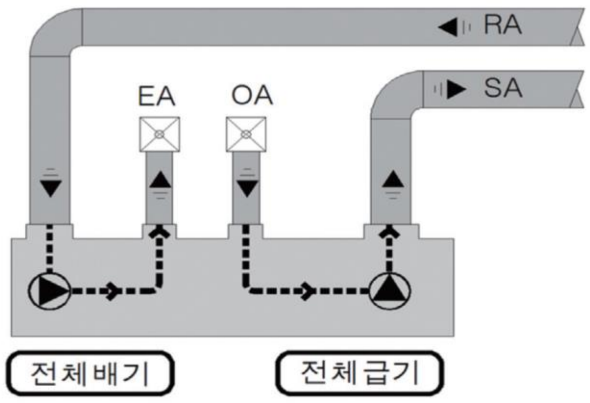


* Source: Y.L. Vong, Y. A. Abakr, Numerical study of the impact of ventilation system on the spread of infectious aerosol transport in a classroom, Nottingham, 2020

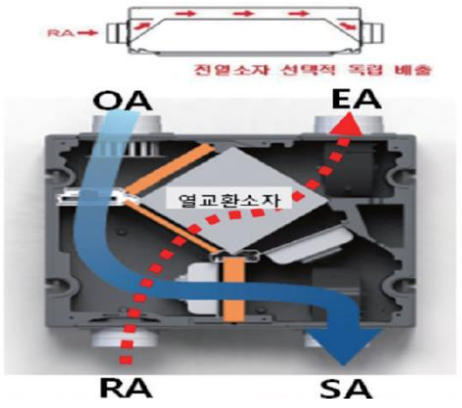
HVAC in COVID-19 Area (코로나19 시대의 HVAC)

Source: Applied and Environmental Microbiology, L. Casanova et al., 2010

Topic 1: Proper ventilation



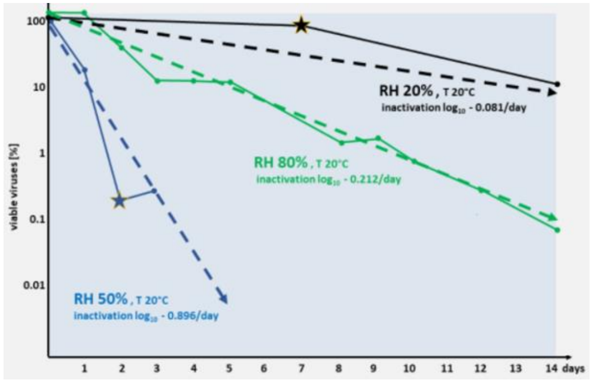
100% OA Induction



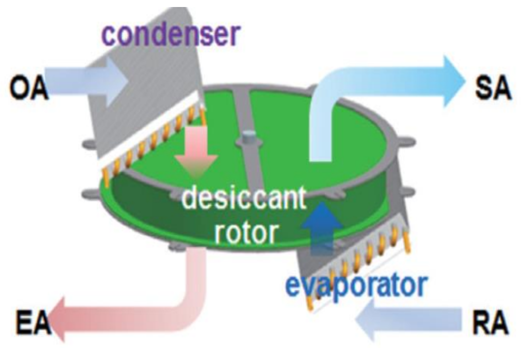
Ventilation unit

- Refrain recirculation of indoor air, utilization of Ventilation unit (실내공기의 재순환을 지양, 환기 유닛 적극 활용)
  - Ways to relieve increase of energy cost coming from increasing ventilation rate. (환기량 증가에 따른 에너지 비용 증가 완화 방안)
  - Heat recovery device: Ensuring high moisture transport, air tightness (rotor type, plate type). (열회수 장치: 수분회수 효율 향상, 기밀성 향상)
  - In case recirculation is inevitable, consider use of high-level air filters, UVGI etc to manage air pollution. (재순환이 불가피한 경우 고성능 에어필터와 UVGI 살균의 적용 고려)

Topic 2: Humidity control



SARS survival vs Humidity

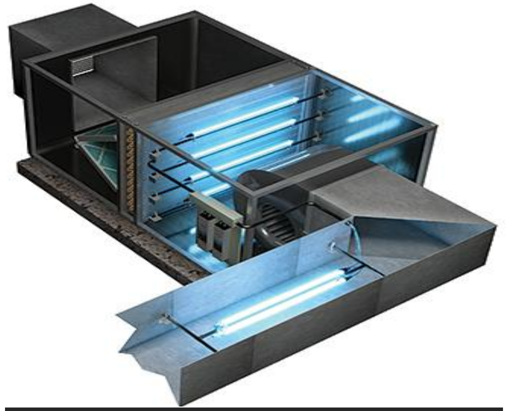


Hybrid desiccant rotor

- Maintain indoor relative humidity between 40~60% to prevent airborne transmission of COVID-19) (코로나19의 공기중 전파 방지를 위해 40~60%의 실내 상대습도 유지)
  - If relative humidity is too low, (상대습도가 너무 낮은 경우)
    1) Moisture evaporates from droplet (비말에서 수분 증발) → Smaller droplet (비말크기감소) → Stay longer in air (공기중 체류 증가)
  - 2) Moisture evaporates from droplet (비말에서 수분 증발) → NaCl in droplet extracted (비말 중 NaCl 석출) → Activation of virus (바이러스활성)
  - 3) Dry throat (건조한 목) → Lower immunity (면역력 감소)

HVAC in COVID-19 Area (코로나19 시대의 HVAC)

Topic 3: UVGI (Ultraviolet Germicidal Irradiation)

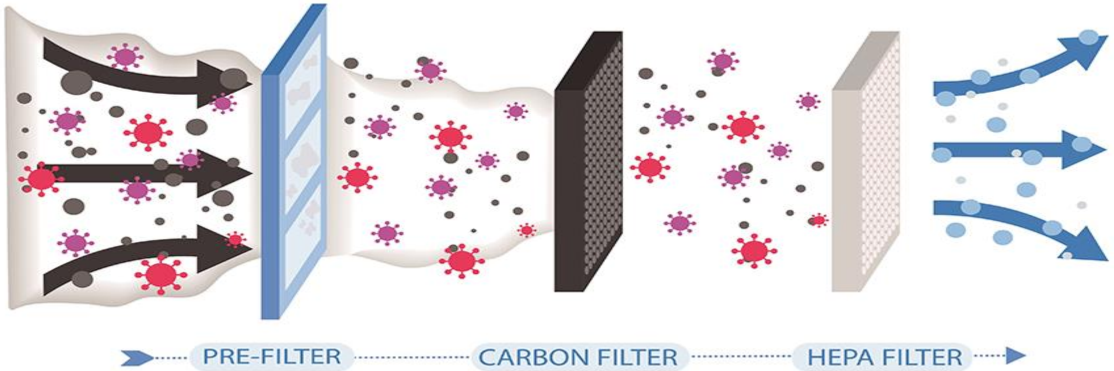


Application of UVGI in ducts

UVGI unit indoor

- Air sterilization with UV-C Irradiation (UV-C를 통한 공기 살균)
  - UV-C makes the DNA structure of virus transformed into harmless microorganism. (UV-C는 미생물의 DNA구조를 변형시켜 무해한 미생물로 변화)
  - Irradiation time may be too short to ensure the effect. On the other hand, cooling and heating coils, filters and duct itself may have sterilization effect. (덕트 내 설치 UV-C는 짧은 시간 내 자외선을 충분히 조사하기 어려움, 냉각코일 및 덕트의 살균 효과가 기대)
  - Indoor UVGI unit can be utilized partly when the space is not occupied. (실내 상부 UV-C는 재실자에 영향을 미칠 가능성으로 취급에 주의)

Topic 4: High-grade air filter (HEPA)



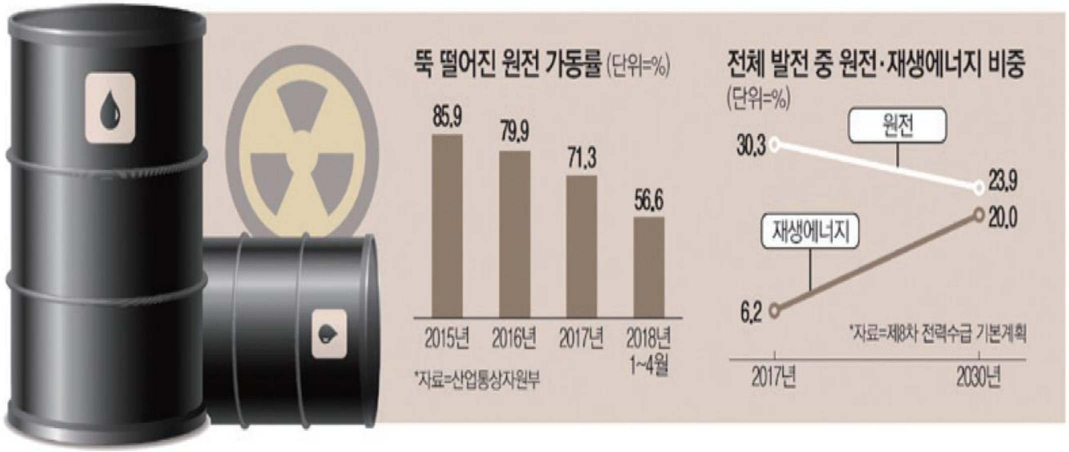
HEPA virus collection

- Filtration of COVID-19 virus with High-grade air filters (고성능 필터의 적용을 통한 COVID 바이러스의 여과)
  - In some case, filtration can be more effective then ventilation regarding dilution of COVID-19 virus. (경우에 따라 환기보다 여과에 의한 바이러스 정화가 효율적일 수 있음)
  - Increase of ventilation amount will result in latent load, energy cost. (외기 도입량을 증가시키는 것은 건물 냉난방 부하를 증가시키므로 비용 및 에너지 소비 상승의 우려가 큼)
  - If simply increase ventilation amount with current HVAC system, possibility of failure of temperature and humidity control. (단순히 환기량을 늘리기 위해 외기의 도입을 늘릴 경우 습도제어에 실패할 수 있음)

Topic: HVAC System in Post-COVID19

Necessity of HVAC Energy Management (에너지 관리의 필요성)

Topic Energy Management Regarding Nuclear Plants

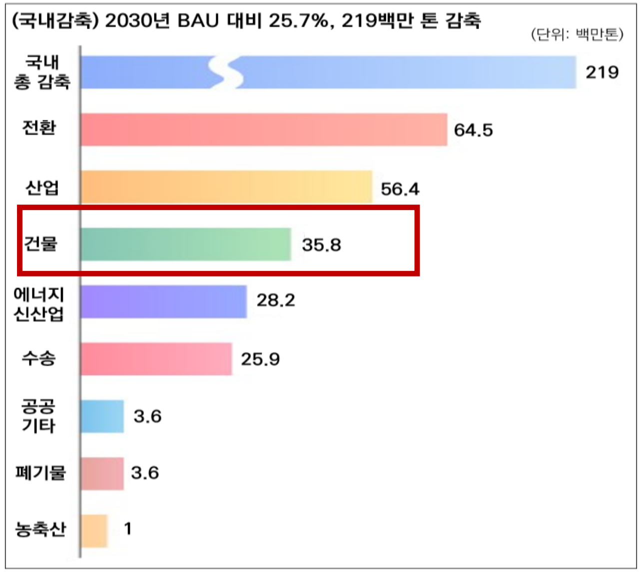


- Necessity of HVAC Energy Management (효율적인 전력 관리의 필요성)
  - Electricity cost is expected to rise as the portion of NG and renewable energy power generation increases, instead of relatively cheap nuclear power generation. (정부의 에너지 전환 정책에 따라 원전 가동률이 감소하고 있고 값싼 원전 대신 비싼 LNG 발전, 신재생에너지 발전의 비중이 늘면서 전력생산비가 증가할 것으로 전망)
  - Cooling energy demand takes approximately 23% of the maximum electricity load in summer. (여름철 최대 전력 부하의 약 23%는 냉방에 의한 전력 수요에 의한 것)

Topic Policy on Reduction of Global Warming Gas

Post 2020 National CO_2 Emission Reduction Targets
from United Nations Framework Convention on Climate Change

Country	Reduction target
U.S.A	By 2025 reduce 26 ~ 28 % compared to 2005
China	By 2030 *carbon intensity of its GDP* reduce 60 ~ 65 % compared to 2005
EU	By 2030 reduce 40 % compared to 2005
Japan	By 2030 reduce 26 % compared to 2013
Russia	By 2030 reduce 70 ~ 75% compared to 1990
Korea	By 2030 reduce 37 % compared to BAU
India	By 2030 *carbon intensity of its GDP* reduce 33 ~ 35% compared to 2005

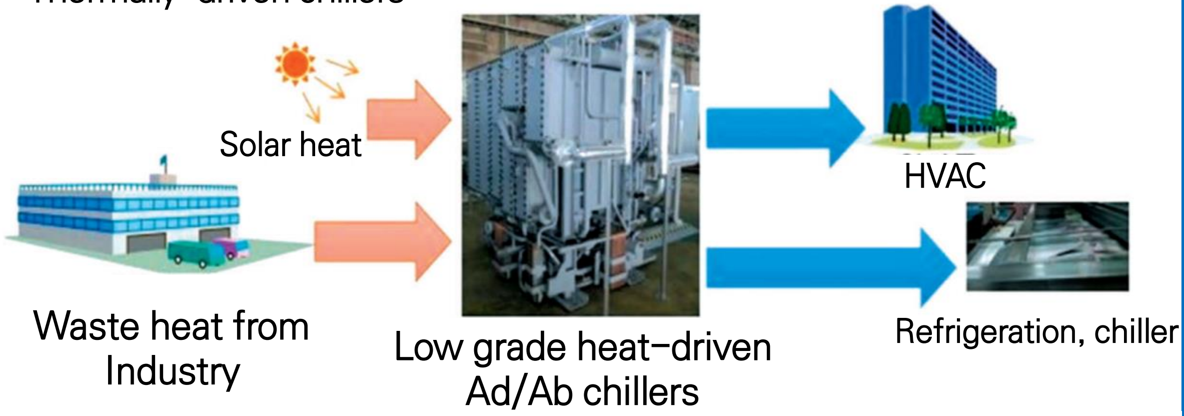


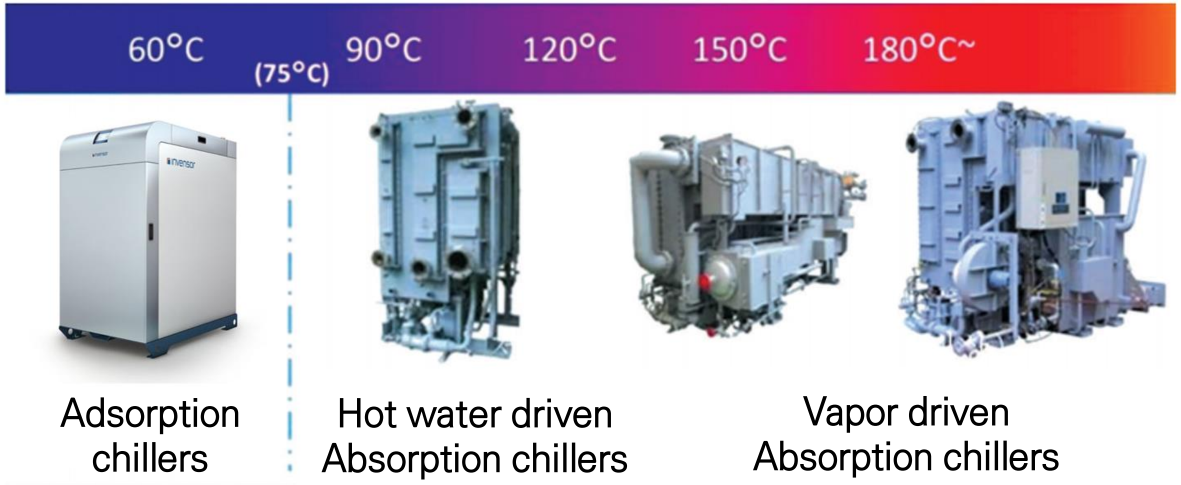
- World's Trend on Global Warming Gas Emission (온실가스 배출량 감소의 세계적인 흐름)
  - 'Building' sector takes as much as 16% of entire domestic target of the reduction. (국내 감축목표량에서 '건물' 부문에서의 감축목표량은 전체의 16% 수준으로 상당히 높음)
  - Efficient utilization of HVAC energy which covers pretty large portion of 'Building' sector should be accompanied. (건물에너지의 큰 부분을 차지하는 공조부문에서의 에너지의 효율적인 이용이 요구되는 실정)

Various heat sources (다양한 열원 설비)

Topic HVAC cooling heat source

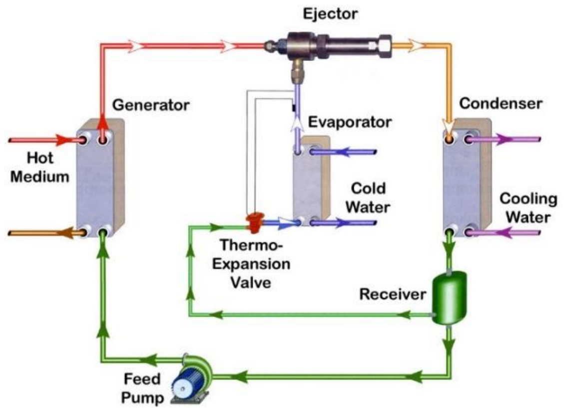
- Thermally-driven chillers

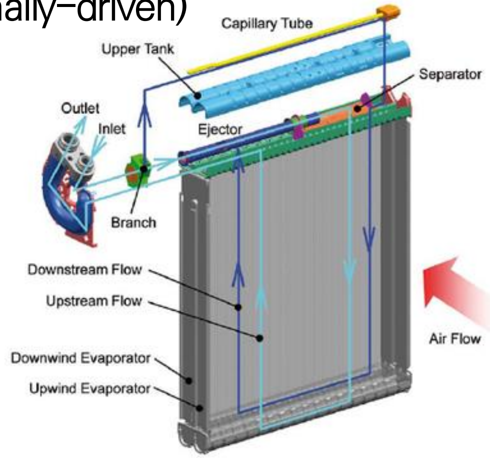




Topic Efficiency enhancement (Ejector refrigeration)

- Ejector refrigeration system (Thermally-driven)



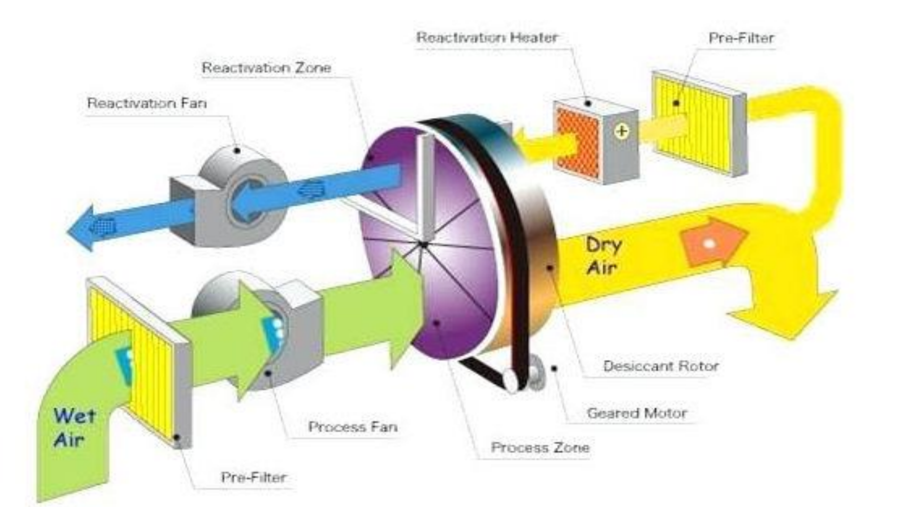


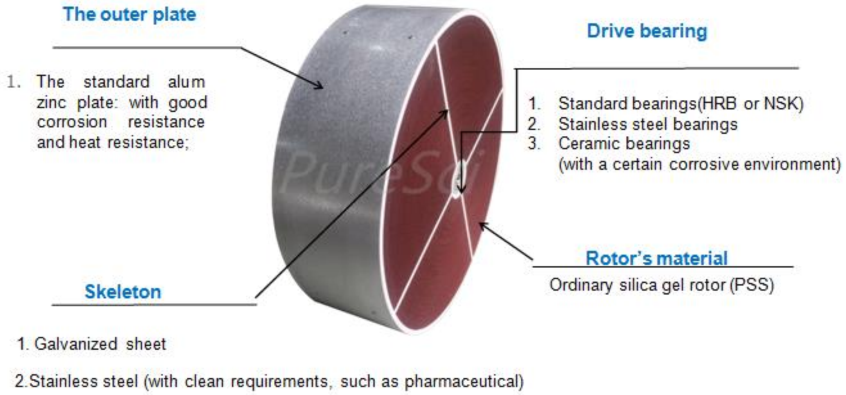
Topic Vapor compression refrigeration system

- Application of HFO refrigerant

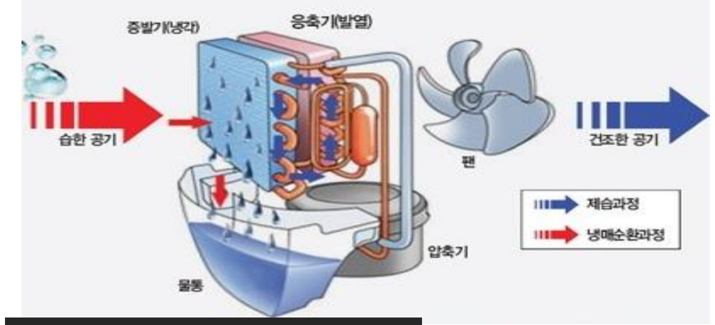
Desiccant Dehumidification (건식 제습설비)

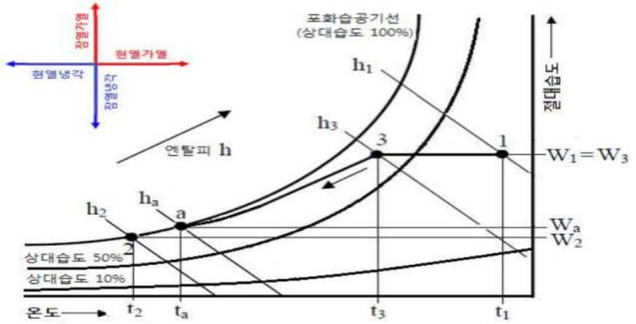
Topic Dehumidification using desiccant rotor





Topic Typical dehumidification method





More charming when !

- Outdoor humidity is greatly high (i.e. rainy season) (외기의 상대습도가 유난히 높은 조건: 장마철 등)
- Space requires greatly low relative humidity (semi-conductor storage) (대단히 낮은 상대습도를 필요로 하는 환경: 반도체라인, 2차전지 공정 등)

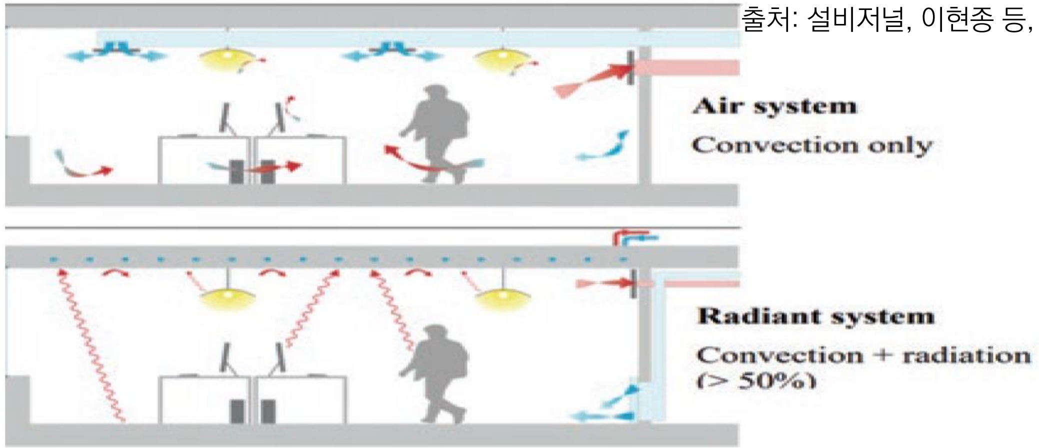
Prospects of desiccant rotor system (건식제습 시스템의 전망)

- Outdoor air supply tends to increase due to current issues on pandemic (실내 환기에 대한 이슈가 많아지며 외기도입량이 증가)→ Dehumidification loads increases (하절기 제습부하의 증가)→This system can be one of the options to handle increased latent heat load. (에너지 효율적인 대처 측면에서 부각)
- Utilization of low-level thermal energy and wasted heat source. (저온열원과 폐열의 활용)

Radiation cooling, DOAS system (복사냉난방 시스템과 DOAS)

Topic Radiation cooling system

출처: 설비저널, 이현종 등, 2017



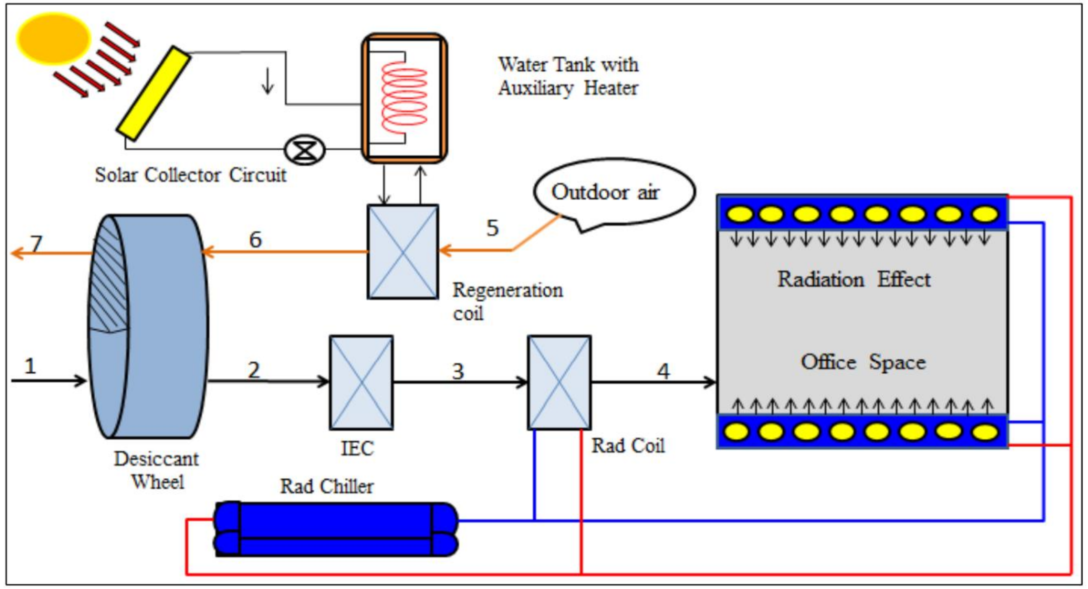
- Utilization of radiation cooling system (복사냉난방 시스템)
  - Cooling/heating method utilizing natural convection resulted from thermal layers and radiation heat transfer. (천장, 벽, 바닥에 설치된 복사패널을 이용한 복사열과 이로 인한 자연대류 효과를 이용하는 냉난방 방식)
  - ASHRAE defines radiation cooling as "Radiation heat transfer occupies 50% above from the entire heat transfer".(ASHRAE에서는 "공간과의 열교환 중 복사의 비율이 50% 이상인 냉난방 방식"으로 정의)
  - U.S. DOE(Department of Energy) defined radiation cooling has great potential for energy saving. (미국의 DOE(Department of Energy)은 천장 복사냉방이 에너지 저감 잠재력이 높은 기술로 분류)

Advantage of radiation cooling 복사 냉방시스템의 장점

- Good thermal comfort due to radiation and natural convection. (복사 열전달에 의한 냉온열감이 우수하여 열쾌적성이 우수)
- Air flow in the space is moderate, meaning less partial discomfort by high velocity air flow (공간 내 공기의 유속을 눈에 띄게 변화시키지 않음) → All air system tends to supply excessive air flow. (전공기 방식에서 발생할 수 있는 과도한 송풍으로 인한 불쾌감을 완화)
- Indoor temperature may be maintained 1~2℃ higher(cooling) or lower(heating) → Energy consumption of source system 8~10 % reduced. (전공기 방식 시스템보다 실내온도를 1~2℃ 높거나(냉방) 낮게(난방) 운전: 열원시스템 에너지 8~10 % 정도의 절감)
- Conveyance energy is greatly reduced as water (high thermal capacity) carries the thermal energy instead of air (low thermal capacity). (에너지 반송을 공기보다 열전달 효율이 월등히 높은 물을 이용하므로 전공기 방식 대비 열 반송 동력을 크게 절감)
- Radiation cooling system handles only sensible heat load. Thus, independent system which handles the latent load is necessary: DOAS (Dedicated outdoor air system) (복사 냉난방에서 복사패널을 통해 현열부하만을 대응할 수 있으므로 잠열 부하를 담당할 별도의 "독립된" 시스템이 필요: DOAS)

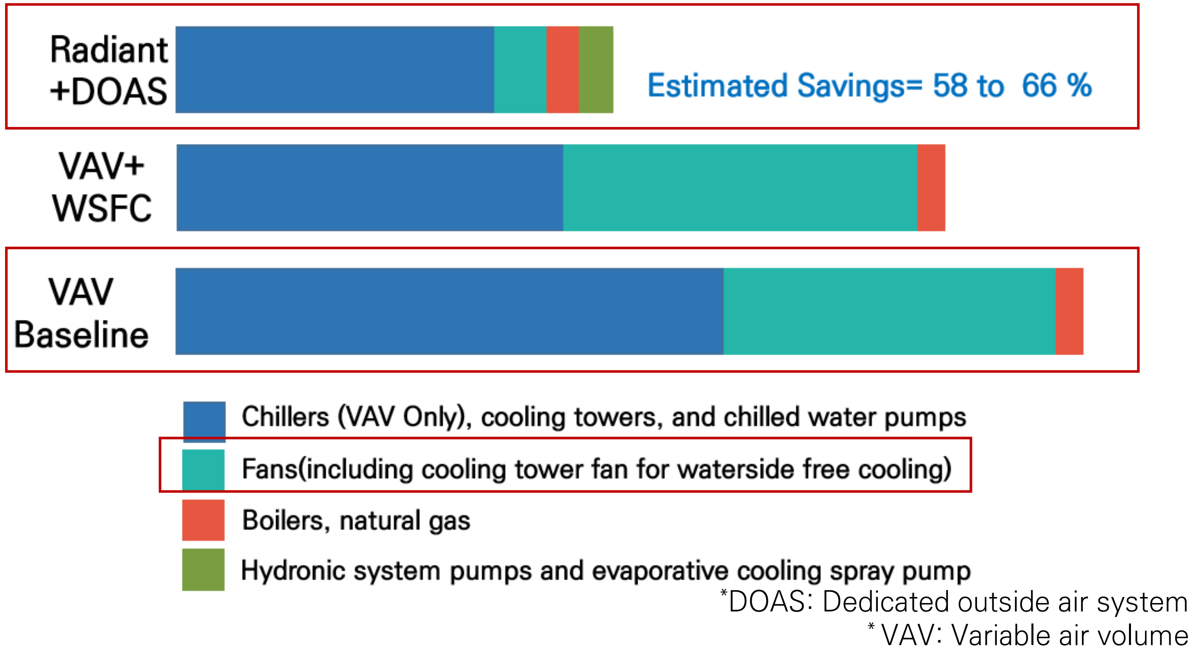
Radiation cooling, DOAS system (복사냉난방 시스템과 DOAS)

Topic Sensible and latent heat load



- Air-water cooling system (공기-수 냉각 방식)
  - Radiation cooling system is integrated with DOAS system. (복사냉방 시스템에 외기전담공조시스템(DOAS) 을 결합한 형태)
  - Cooling(sensible) and ventilation(latent) are separated, thereby ventilation can be supplied only as required amount and to required place. (건물의 냉난방 시스템을 환기 및 제습시스템과 분리함으로써 건물 내 필요한 곳에 필요한 만큼의 환기가 효과적으로 이루어 질 수 있음)

Topic Comparison energy consumption of HVAC components



- Effect of separation of sensible and latent heat (현열/잠열부하의 분담의 효과)
  - Fan energy reduction due to reduced air flow. (송풍량 절감으로 인한 Fan 부하의 현저한 감소)
  - Chiller energy reduction due to relatively higher chilled water supply temperature. (상대적으로 높은 냉수 공급 온도에 따른 칠러 소비 에너지 절감 효과)

* Source: Yasin Khan et al., Performance Assessment of Radiant Cooling System Integrated with Desiccant Assisted DOAS with Solar Regeneration, Applied Thermal Engineering, 2017

Sum up