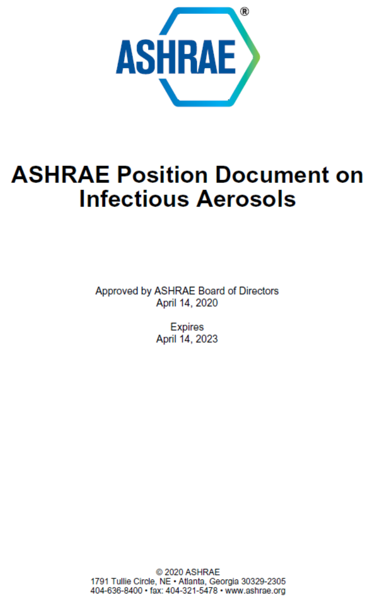
LG Air Solution
Based on ASHRAE/REHVA Guideline

ASHRAE Position Document on Infectious Aerosols(April 14, 2020)
REHVA COVID-19 Guidance Documents(April 3, 2020)


ASHRAE

ASHRAE Position Document on Infectious Aerosols

Approved by ASHRAE Board of Directors
April 14, 2020

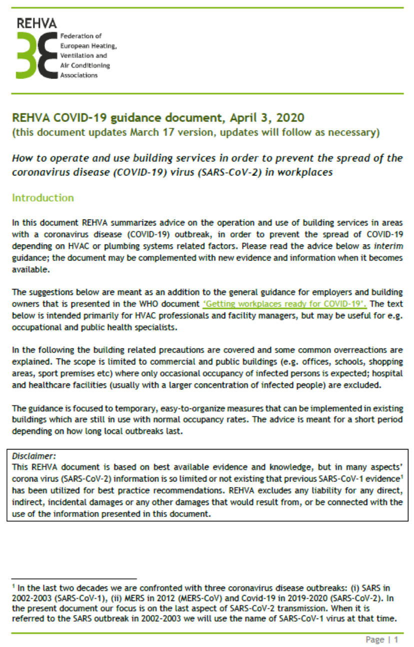
Expires
April 14, 2023

1791 Tullie Circle, NE • Atlanta, Georgia 30329-2305
404-636-8400 • fax: 404-321-5478 • www.ashrae.org

General

Healthcare Building

Non-Healthcare Building


REHVA
Federation of European Heating, Ventilation and Air Conditioning Associations

REHVA COVID-19 guidance document, April 3, 2020
(this document updates March 17 version, updates will follow as necessary)

How to operate and use building services in order to prevent the spread of the coronavirus disease (COVID-19) virus (SARS-CoV-2) in workplaces

Introduction

In this document REHVA summarizes advice on the operation and use of building services in areas with a coronavirus disease (COVID-19) outbreak, in order to prevent the spread of COVID-19 depending on HVAC or plumbing systems related factors. Please read the advice below as *interim* guidance; the document may be complemented with new evidence and information when it becomes available.

The suggestions below are meant as an addition to the general guidance for employers and building owners that is presented in the WHO document 'Getting workplaces ready for COVID-19'. The text below is intended primarily for HVAC professionals and facility managers, but may be useful for e.g. occupational and public health specialists.

In the following the building related precautions are covered and some common overreactions are explained. The scope is limited to commercial and public buildings (e.g. offices, schools, shopping areas, sport premises etc) where only occasional occupancy of infected persons is expected; hospital and healthcare facilities (usually with a larger concentration of infected people) are excluded.

The guidance is focused to temporary, easy-to-organize measures that can be implemented in existing buildings which are still in use with normal occupancy rates. The advice is meant for a short period depending on how long local outbreaks last.

Disclaimer:
This REHVA document is based on best available evidence and knowledge, but in many aspects' corona virus (SARS-CoV-2) information is so limited or not existing that previous SARS-CoV-1 evidence[1] has been utilized for best practice recommendations. REHVA excludes any liability for any direct, indirect, incidental damages or any other damages that would result from, or be connected with the use of the information presented in this document.

[1] In the last two decades we are confronted with three coronavirus disease outbreaks: (i) SARS in 2002-2003 (SARS-CoV-1), (ii) MERS in 2012 (MERS-CoV) and Covid-19 in 2019-2020 (SARS-CoV-2). In the present document our focus is on the last aspect of SARS-CoV-2 transmission. When it is referred to the SARS outbreak in 2002-2003 we will use the name of SARS-CoV-1 virus at that time.

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LG Life's Good

ASHRAE/REHVA Guideline

<Disclaimer>

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Original documents

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Original documents

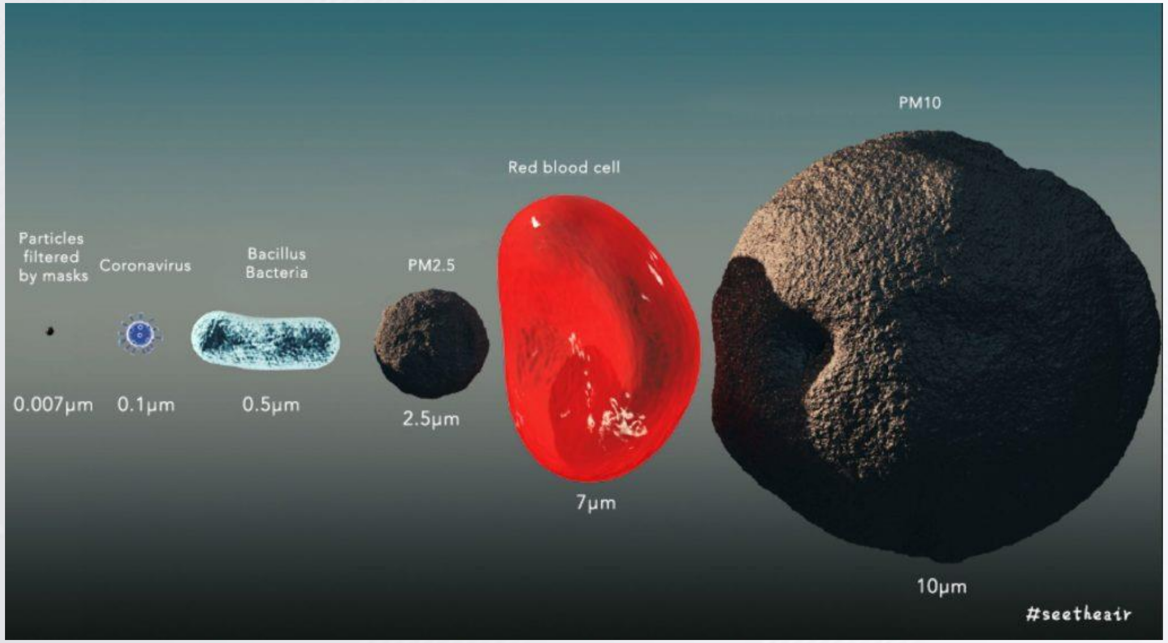
Airborne Dissemination [Source : ASHRAE.org]

Coughing, Sneezing, Shouting, Breathing and Talking
- Large Droplet 100㎛ → Dry out → 10 ㎛ and below → small aerosol can move by airflow

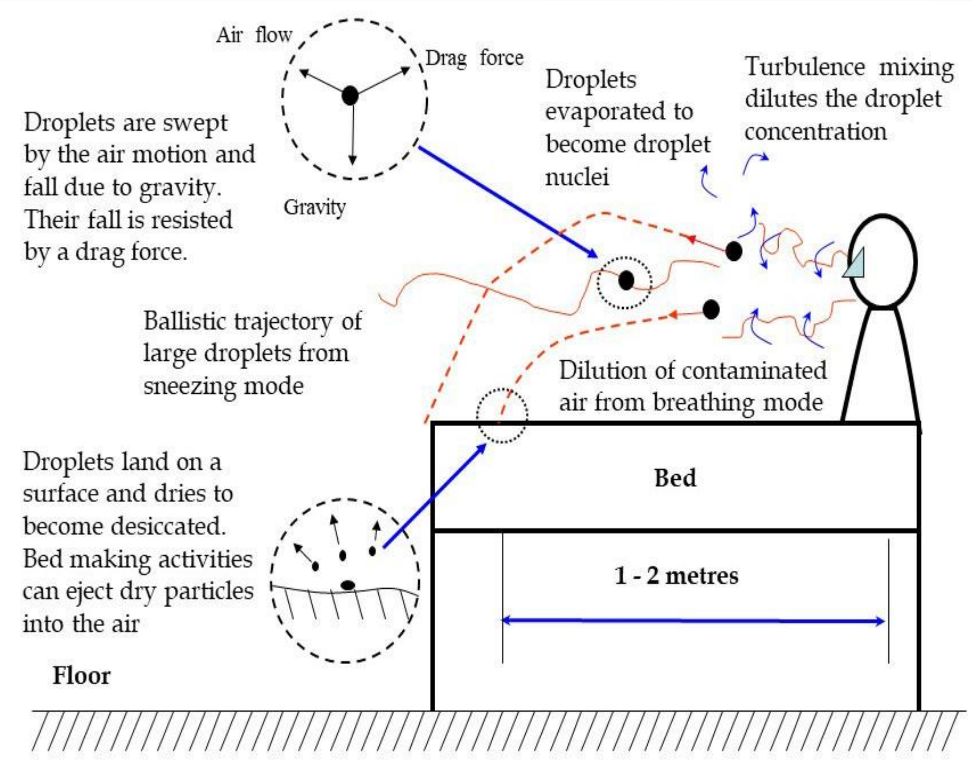
Air flow pattern and ventilation are very important factors to avoid infection by small airborne particles

[Comparative settling times by particle diameter in still air]

under 0.5 μm	0.5 μm	1 μm	3 μm	10 μm
over 41 hours	41 hours	12 hours	1.5 hours	8.2 minutes



[Theoretical aerobiology of transmission of droplets and small airborne particles produced by an infected patient]



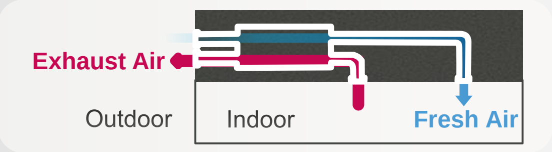
Practical Implication for BD Owner, Operators, Engineers

General Guidance

Ventilation

Personalized ventilation system
Provides local exhaust of infection source

100% Fresh Air / Avoid Recirculation
Provides highly filtered outdoor air to occupants



Personalized ventilation

100% Fresh Air AHU

Air Purification & Filtration

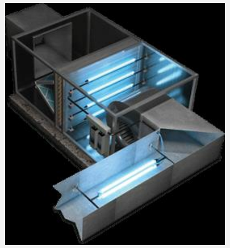
Highly efficient particle filtration in Centralized HVAC system
Provides local exhaust of infection source

Single-Space Particle filtration units(Ceiling Mount or Portable)
Can be highly effective in reducing/lowering concentrations of infectious aerosols in single space

HEPA Filter Application

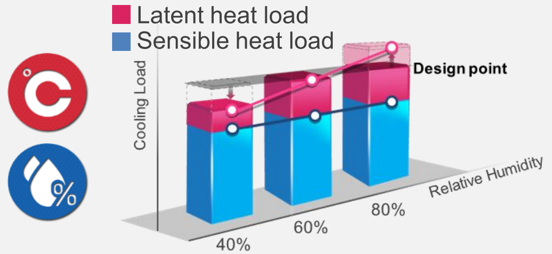
Sterilization

UVGI(Ultraviolet Germicidal Irradiation)
Can kill or inactivate microorganisms
US CDC has approved UVGI as an adjunct to filtration for reduction of tuberculous risk



Temperature & Humidity

Relative Humidity between 40% and 60%
Mousavi(2019) reports that microorganism unfavorably survive in RH 40 to 60%
Taylor and Tasi(2018) showed that RH below 40% increase infections



Non-healthcare Buildings

For General Occupants

System Running

Particular

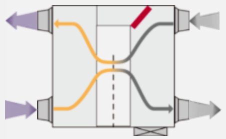
Keep systems running longer hours(24/7 if possible)

Start HVAC system running 2hrs before building usage time
Maintain system running 2hrs after building usage time(REHVA)

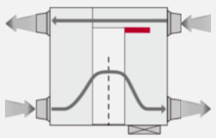
Ventilation

Increase outdoor air ventilation

Disable demand-controlled ventilation
Open outdoor air dampers to 100%



Normal Heat Recovery



Reduce infection Bypass

Individual energy recovery ventilation systems

Prevent potentially contaminated exhaust air leak back in to outdoor air supply(REHVA : 5% below)

Air Purification & Filtration

Improve Central air and other HVAC filtration to MERV-13(ASHRAE 2017b) or highest level achievable

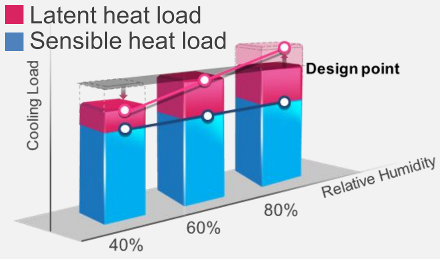
Add portable air cleaners with HEPA or high-MERV filters(AHAM 2015) *AHAM : Association of Home Appliance Manufacturers(US)

Medium Filter (MERV 13)

Air Purifier with HEPA Filter

Temperature & Humidity

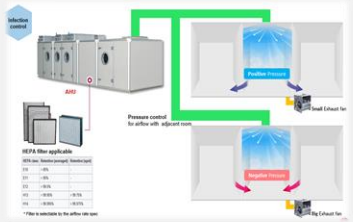
Relative Humidity between 40% and 60%

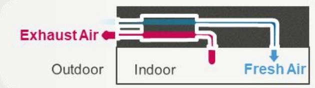


Healthcare Buildings

For Patients

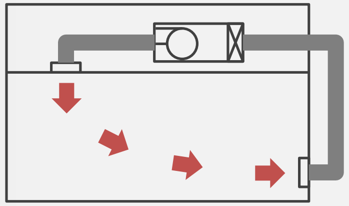
Particular **Pressure Control**	Maintain Negative pressure for ICU(Intensive Care Units)/Infectious patients rooms
Ventilation	100% Fresh Air / Avoid Recirculation 100% exhaust of patient rooms(toilet, bed) Increase outdoor air change rate from 2 to 6 times
Air Purification & Filtration	HEPA-grade filtration for local recirculation air
Sterilization	Use UVGI(Ultraviolet Germicidal Irradiation)



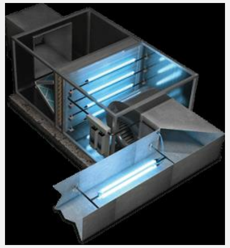


100% Fresh Air AHU

Indoor Unit with HEPA filter



HEPA Filter



Health care facilities are divided into the following categories*:

- *Hospital facilities*
- *Outpatient health care facilities*
- *Residential health care and support facilities*

* Reference : 2019 ASHRAE Handbook - HVAC Applications, Chapter 9 Health Care Facilities

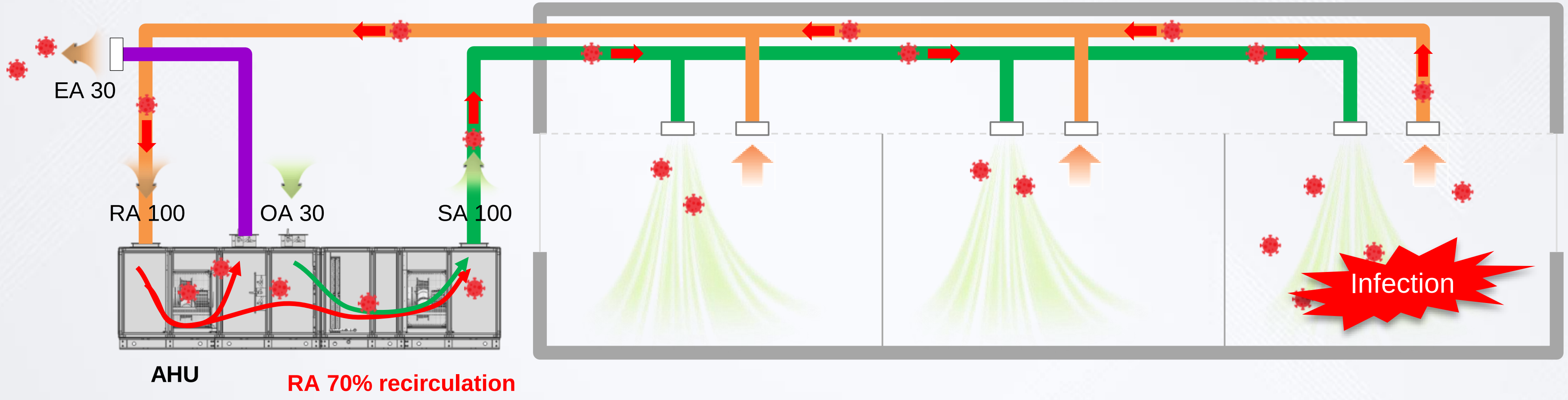
Risk of Centralized AHU System

Conventional

General AHU operated with RA recirculation, would increase the risk of infection.

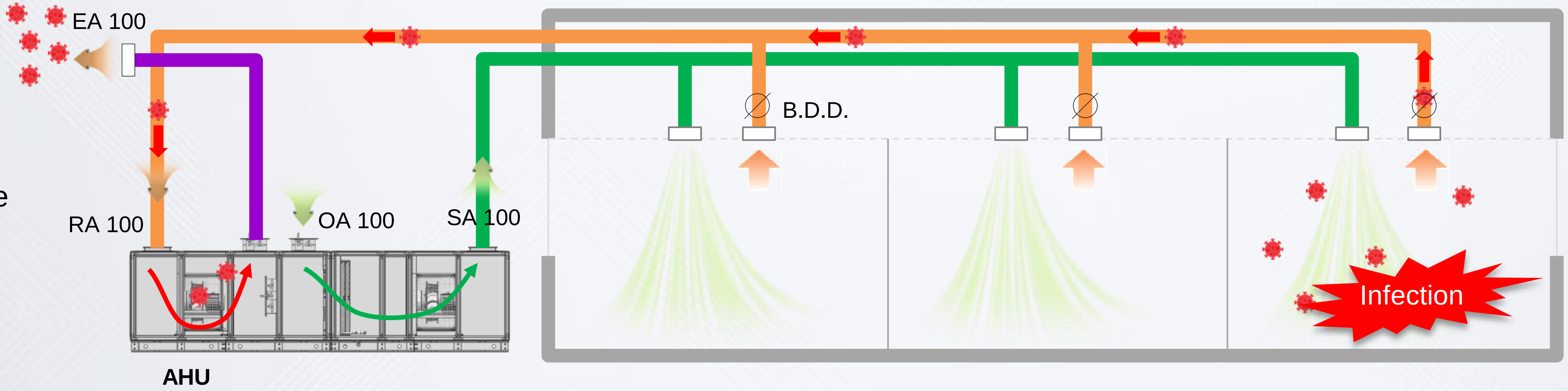
Recirculation type AHU system

- Infectious agent & pollutant will be disseminated to other zones by recirculation in AHU and common duct
- Not Recommendable



100% fresh air AHU system

- Infectious agent & pollutant will not be disseminated to other zone due to separate duct
- Full duct type AHU will consume excessive energy for cooling and heating due to large air volume
- Not Recommendable



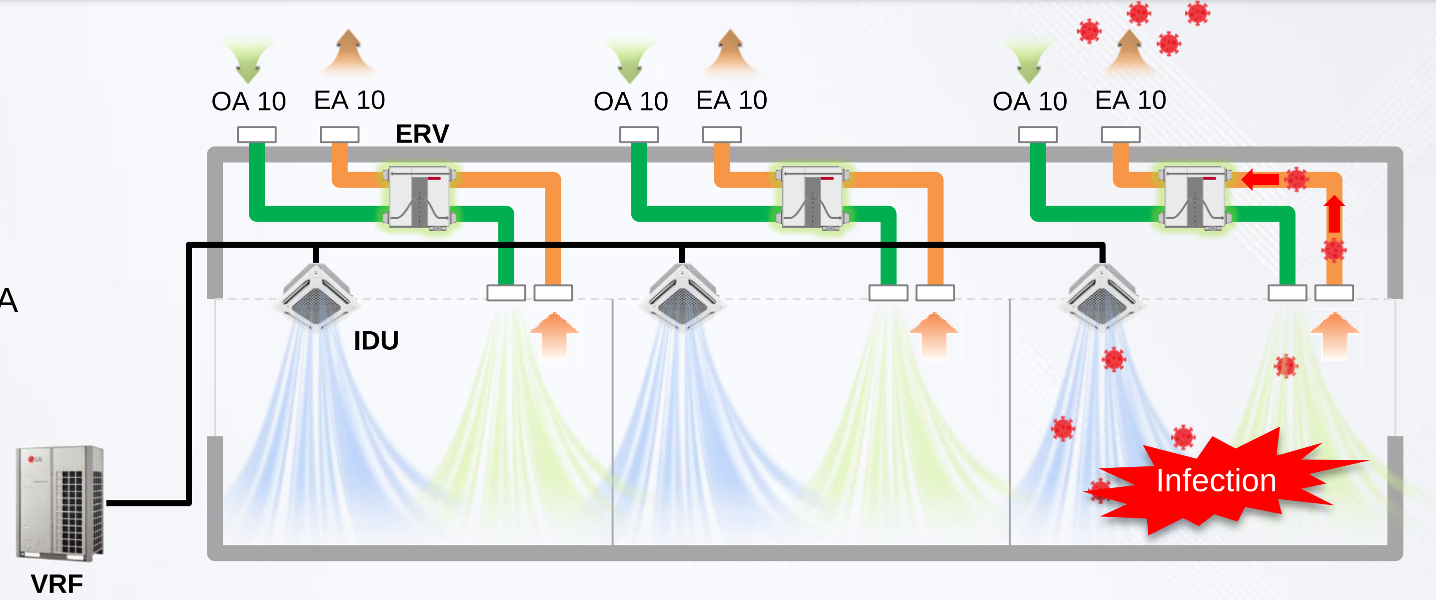
Individual Ventilation & DOAS system

Proposal

Individual ventilation & DOAS system is useful for preventing spread of infection to other spaces and saving energy.

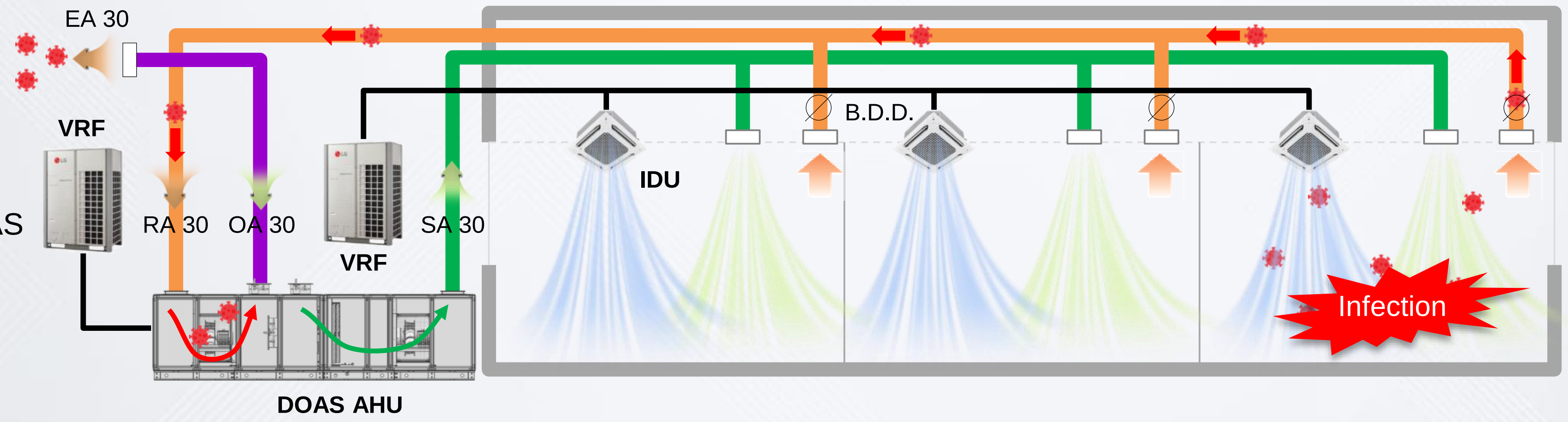
Individual ventilation + Indoor unit system

- No Infectious agent & pollutant transfer to other zones by individual energy recovery ventilation and individual cooling
- Indoor unit can match internal & partial cooling load from OA
- ERV and IDU can have air purification function
  - Electrostatic/ Medium/HEPA filter applicable
- Recommendable



DOAS AHU + Indoor unit system

- No Infectious agent & pollutant transfer to other zones due to DOAS AHU and individual cooling
- Only required ventilation and heat load by OA will be managed by DOAS
- IDU with Air purification manage individual cooling and air purification
- Reasonable Energy Consumption
- Recommendable

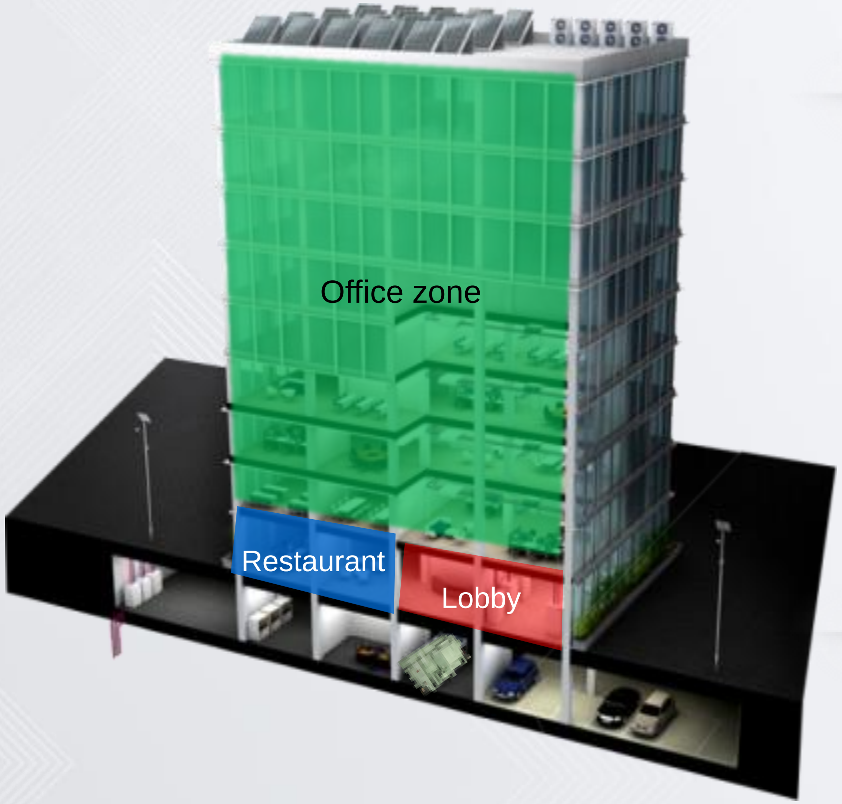


For Non-Healthcare Building

Non-Healthcare Building

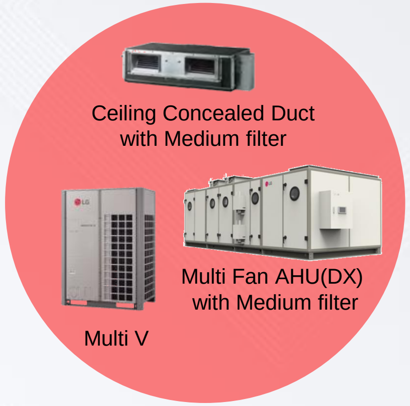
The proposed system according to the purpose of each space is like below.

System Running	Ventilation	Air Purification & Filtration	Temperature & Humidity



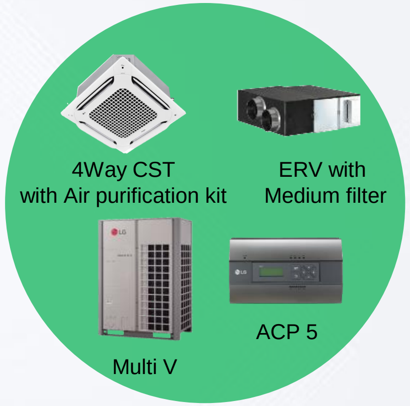
Lobby / Reception

- AHU with customized function (100% OA/sterilization)
- High static air pressure for high ceiling
- Comfort air conditioning with dual sensing control



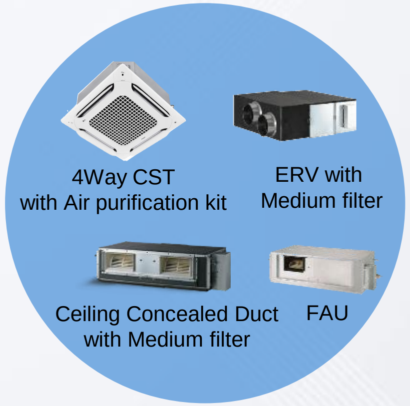
Office / Meeting Room

- Ventilation considering number of people
  - OA 100% intake and minimize RA recirculation
  - Air purification
  - CO_2 density is also be checked
- Individual(or zone) temperature control
  - Load of the equipment(TV, projector)
  - IDU with high grade filter to purifying air
  - Maintaining comfortable humidity by Dual sensing (temp. + humidity)
- Keep systems running longer hours



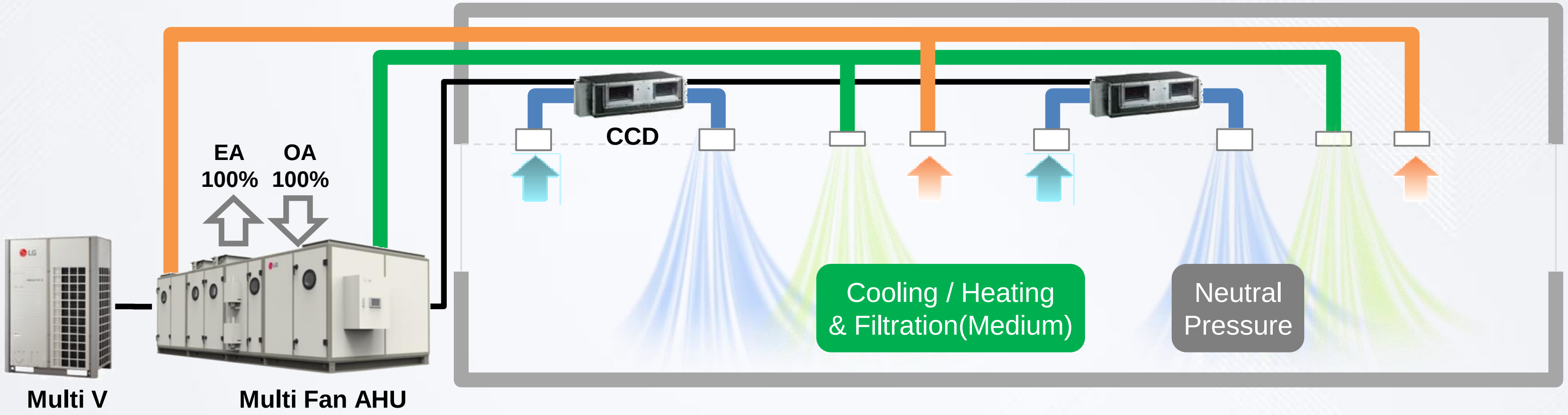
Cafeteria, Restaurant

- Negative pressure for prevent odor spread
- Air purification to provide a hygienic space
- Additional exhaust fan for kitchen.



Lobby / Reception

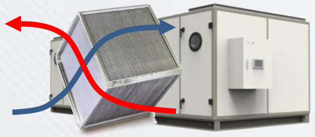
Recommend System : Multi V + Ceiling Concealed Duct + Multi Fan AHU(DX)



Ventilation & Filtration Solution : Multi Fan AHU

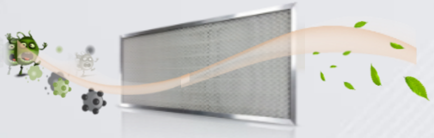
Heat Recovery with Plate HEX

- No contamination by air leakage
- Energy saving by heat recovery



Medium filter

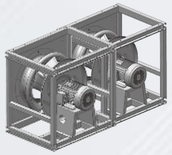
- Helps reduce particle and virus



Medium filter(over MERV 13)

Direct Fan(LG 3D Plug Fan)

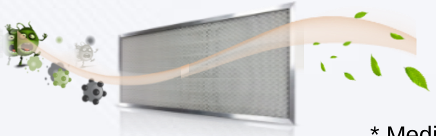
- No contamination by belt abrasion
- Stable fan operation with redundancy



Filtration & Humidity Solution : Ceiling Concealed Duct

Medium filter

- Helps reduce particle and virus
- Slot type filter : change filter by sliding



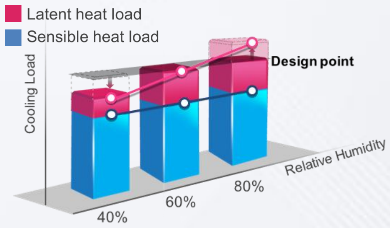
Medium filter(over MERV 13)

* Medium filter can be supplied by 3rd party

Maintaining comfortable humidity

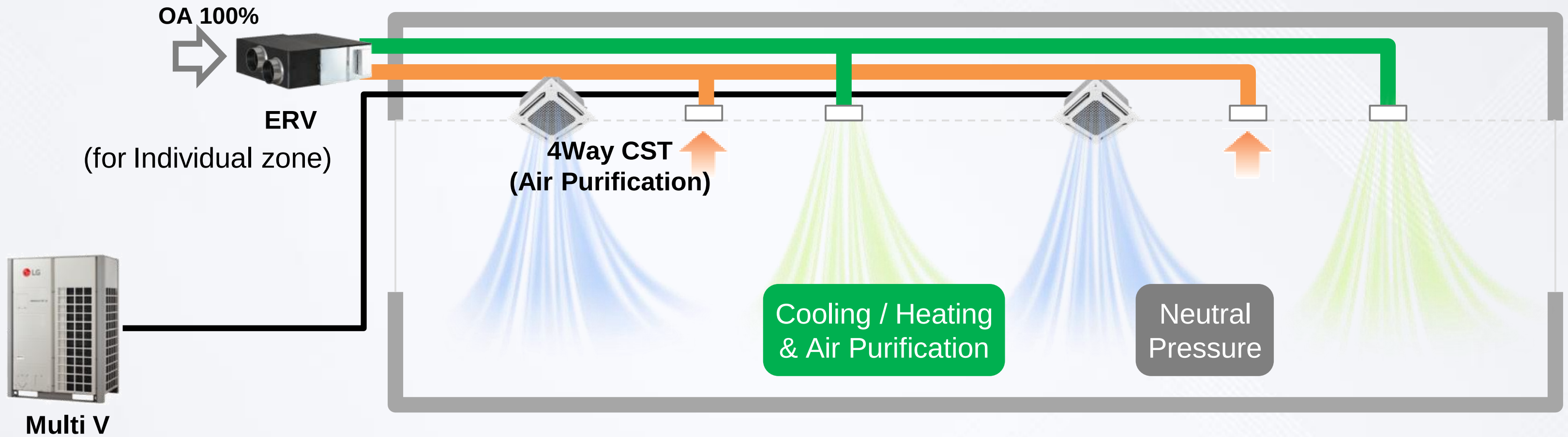
Temperature sensor + Humidity sensor

LG Multi V 5 : Dual Sensing
Other VRF : Single Sensing



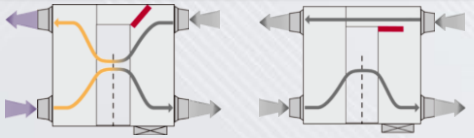
Office / Meeting Room

Recommend System : Multi V + 4 Way CST w/ Air Purification + ERV



Ventilation Solution & Air Purification Solution

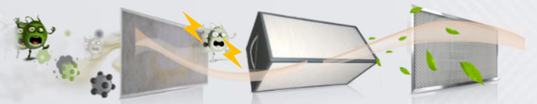
Heat Recovery & Bypass Ventilation



Normal Heat Recovery

Reduce infection Bypass

Medium Filter



Pre filter

Medium filter (over MERV 13)

* Medium filter is optional.

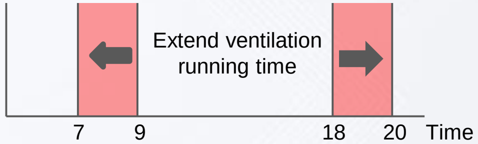
4 Phase Air Purification

- Captures fine dust
- Dust Electrification
- Captures micro fine dust
- Deodorizes

System Running Solution

Central Control Solution

- Auto schedule system running - flexible operation
- Interlocking 3rd party devices



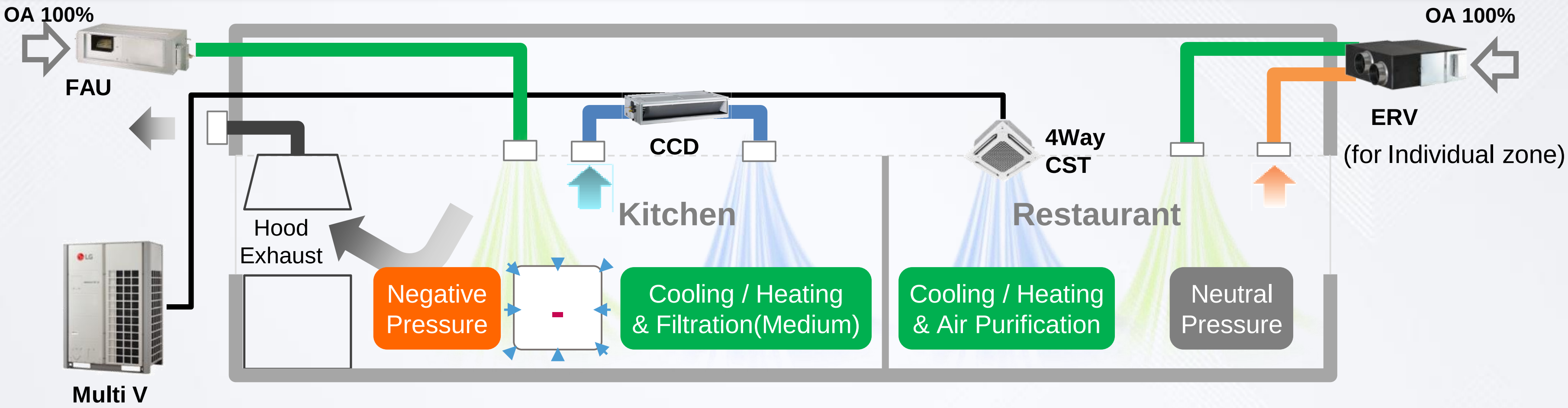
Schedule function

Energy Management

Operation Trending Report

Cafeteria, Restaurant

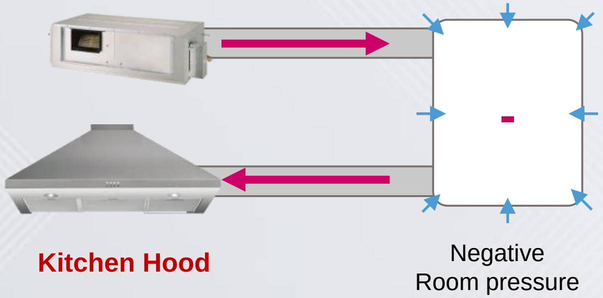
Recommend System : Multi V + Ceiling Concealed Duct + FAU / Multi V + 4 Way CST w/ Air Purification + ERV



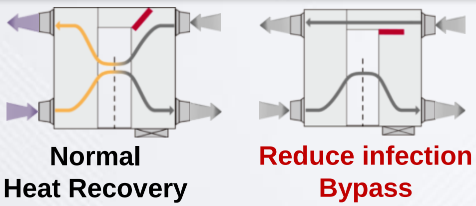
Ventilation Solution : FAU + Hood Exhaust / ERV

Pressure control

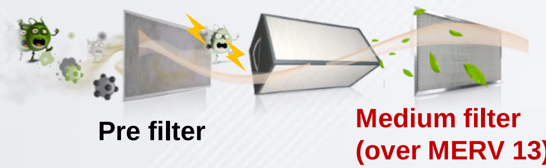
- Eliminates cooking odor
- Prevents spread of cooking odor



Heat Recovery & Bypass Ventilation



Medium Filter



* Medium filter is optional.

Air Purification Solution / Filtration Solution

Medium filter

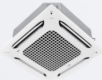
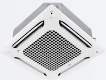
- Helps reduce particle and virus
- Slot type filter : change filter by sliding

* Medium filter can be supplied by 3rd party

4 Phase Air Purification

- Captures fine dust
- Dust Electrification
- Captures micro fine dust
- Deodorizes

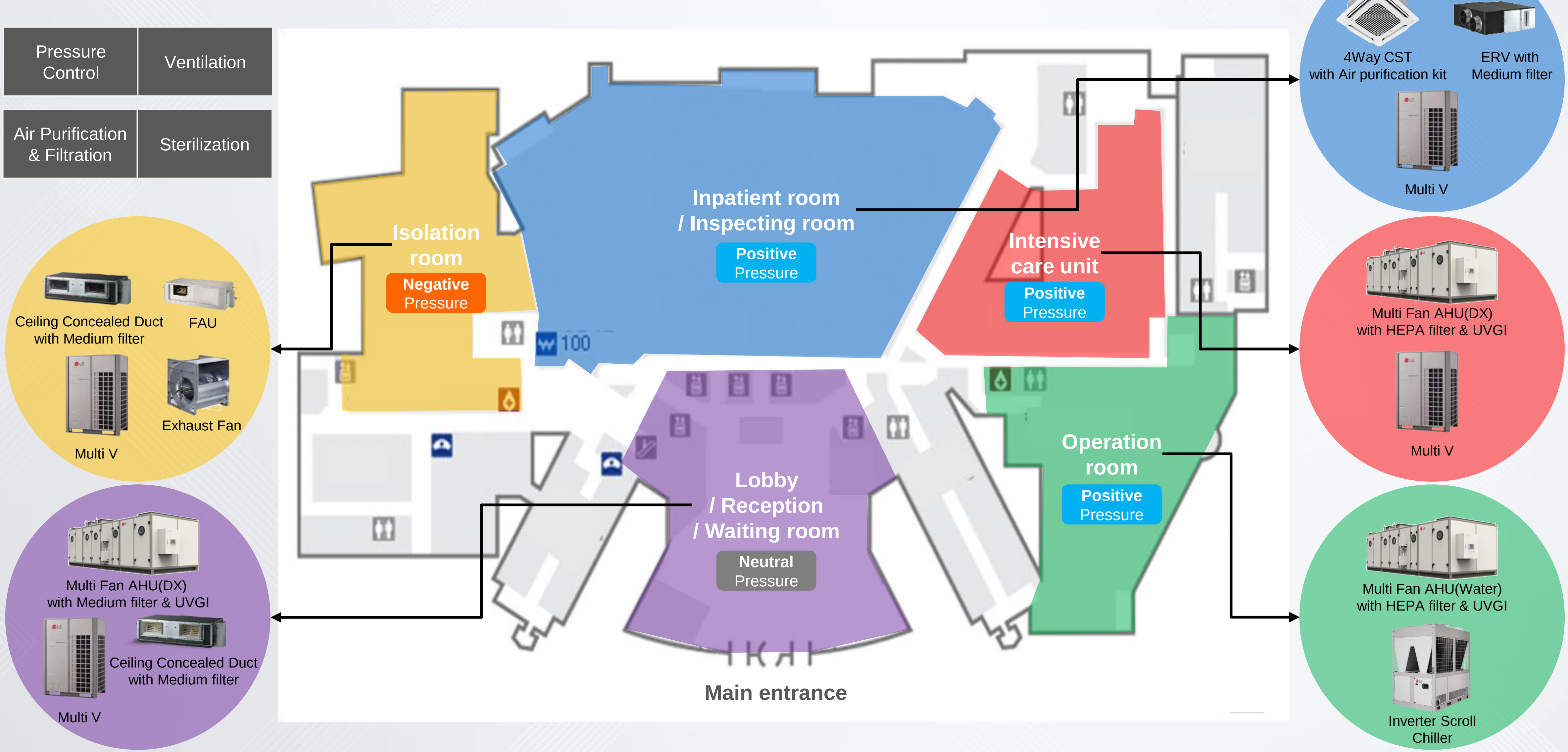
Non-Healthcare Building System Proposal

Room type	Recommended system	Cooling & Heating	Humidity	Air Purification & Filtration		Ventilation	System running
Lobby / Reception	 CCD with Medium filter  Multi V  Multi Fan AHU(DX) with Medium filter	● Multi V CCD	● Maintain Comfortable humidity		● Medium filter	● Medium filter	● ACP (Central Controller)
Office / Meeting room	 Multi V  4Way CST with Air purification kit  ERV with Medium filter	● Multi V CST	● Maintain Comfortable humidity	● Air Purification kit (Electro static)		● Medium filter	● ACP (Central Controller)
Cafeteria, Restaurant	**Kitchen**  CCD with Medium filter  FAU  Kitchen Hood  Multi V **Restaurant**  4Way CST with Air purification kit  ERV with Medium filter	● Multi V CCD	● Maintain Comfortable humidity	● Air Purification kit (Electro static)	● Medium filter	● Medium filter	● ACP (Central Controller)

For Healthcare Building

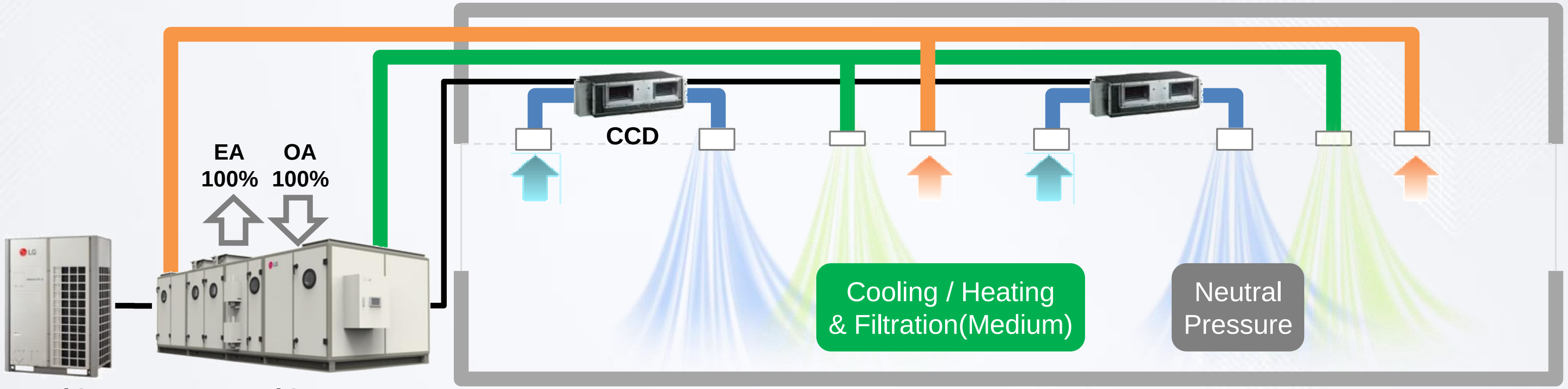
Healthcare Building(Hospital) Configuration

The proposed system according to the purpose of each space is like below.



Lobby / Reception

Recommend System : Multi V + Ceiling Concealed Duct + Multi Fan AHU(DX)



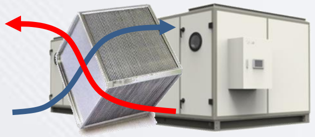
Multi V

Multi Fan AHU

Ventilation & Filtration Solution : Multi Fan AHU

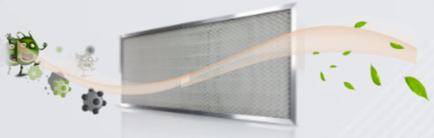
Heat Recovery with Plate HEX

- No contamination by air leakage
- Energy saving by heat recovery



Medium filter & UVGI

- Helps reduce particle and virus



Medium filter

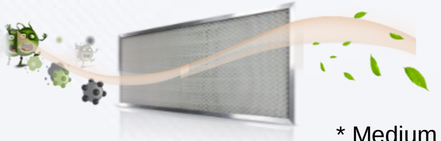
Direct Fan(LG 3D Plug Fan)

- No contamination by belt abrasion
- Stable fan operation with redundancy

Filtration & Humidity Solution : Ceiling Concealed Duct

Medium filter

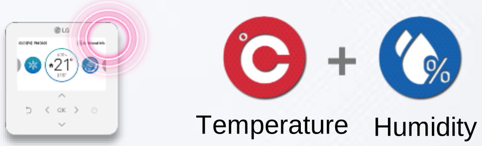
- Helps reduce particle and virus
- Slot type filter : change filter by sliding



Medium filter

* Medium filter can be supplied by 3rd party

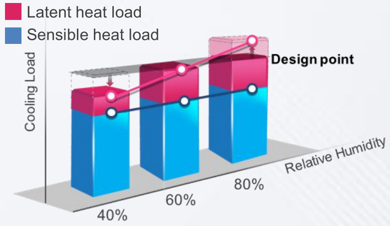
Maintaining comfortable humidity



Temperature sensor + Humidity sensor

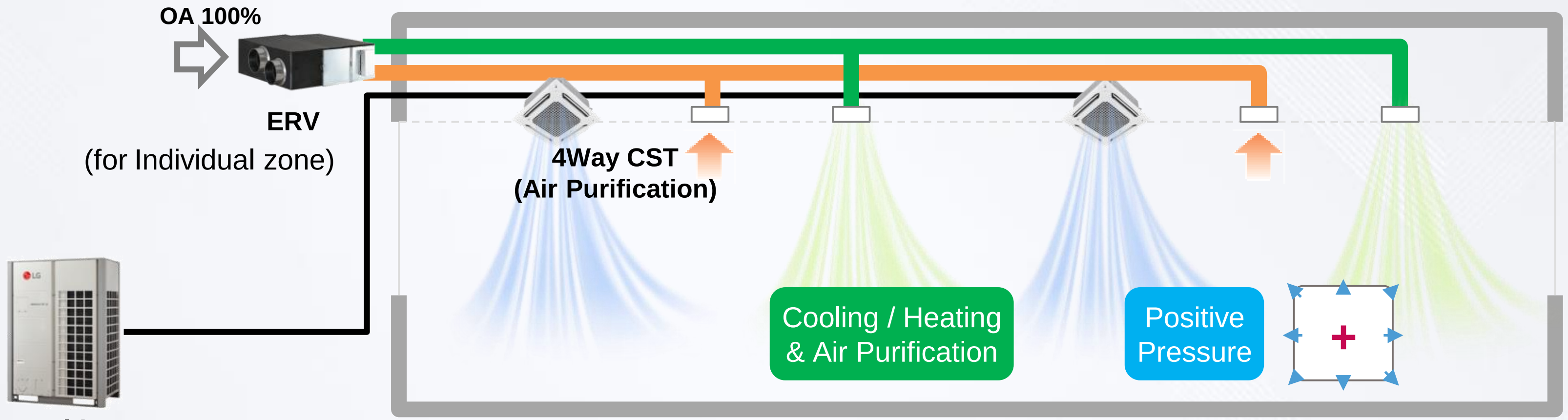
LG Multi V 5 : Dual Sensing

Other VRF : Single Sensing



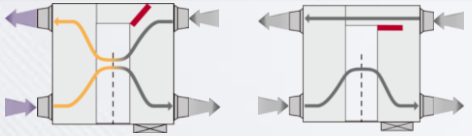
Inpatient Room / Inspecting Room

Recommend System : Multi V + 4 Way CST w/ Air Purification + ERV

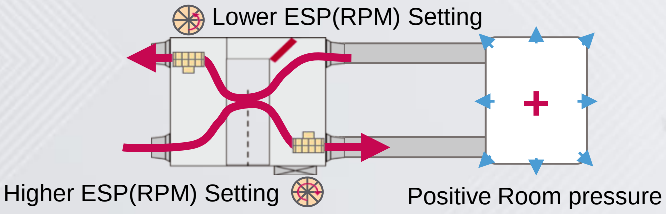


Ventilation Solution : ERV

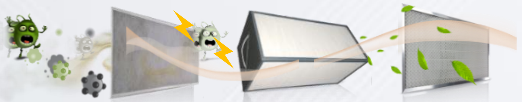
Heat Recovery & Bypass Ventilation



Positive pressure

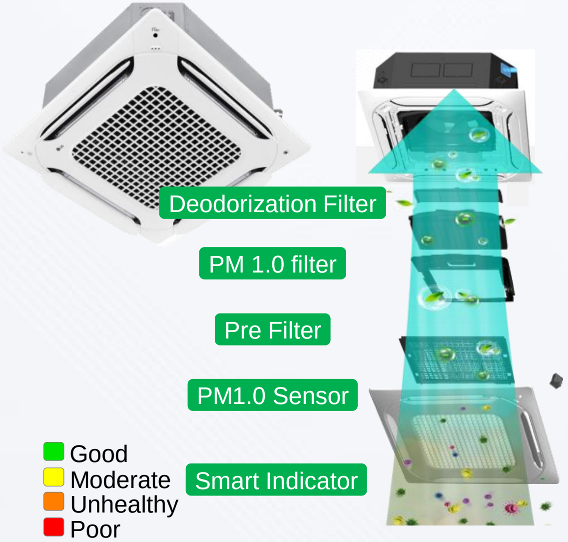


Medium Filter



* Medium filter is optional.

Air Purification Solution : Air Purification kit



4 Phase Air Purification

- Captures fine dust
- Dust Electrification
- Captures micro fine dust
- Deodorizes

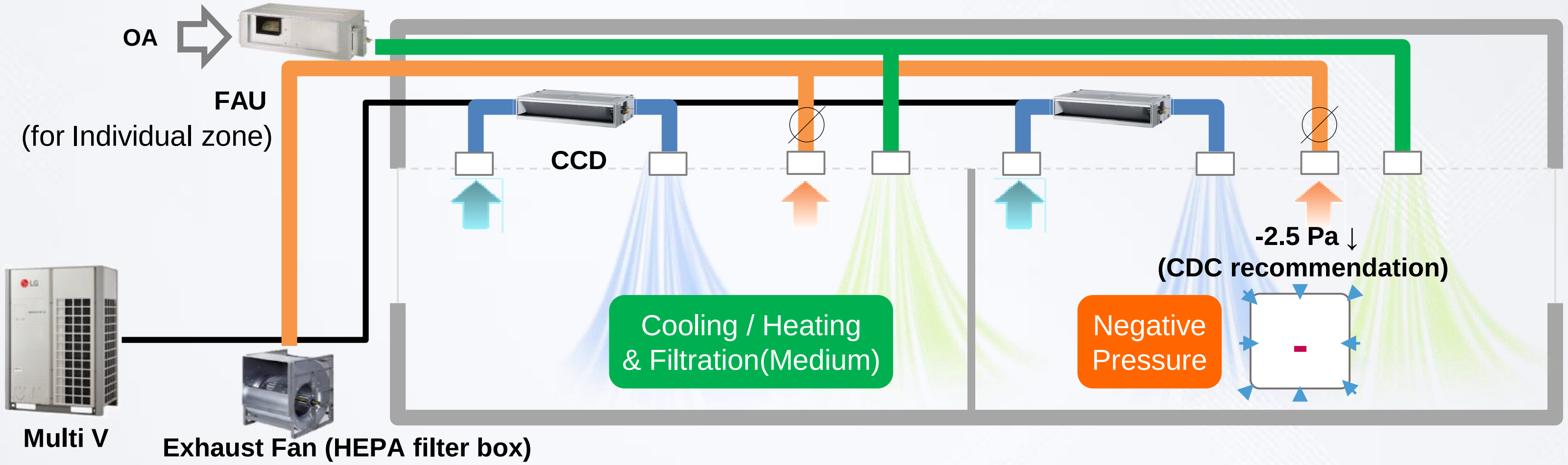
Easy Maintenance

- Pre filter : wash when polluted
- PM 1.0 filter : wash every 6 Month
- Deodorization filter : dry in sunlight every 6 Month

* Air Purification kit is optional.

Isolation Room / Intensive Care Unit (for Infectious Disease)

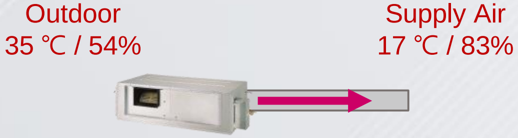
Recommend System : Multi V + Ceiling Concealed Duct + FAU



Ventilation Solution : FAU + Exhaust Fan

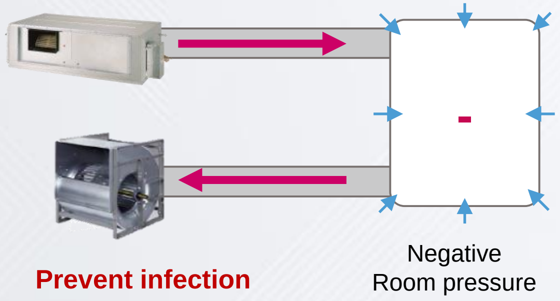
Pre cooling & Pre Heating

• Helps maintain indoor comfort



Pressure control

• Separated OA, EA path
• No cross contamination



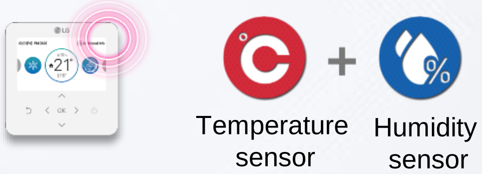
Filtration & Humidity Solution : Ceiling Concealed Duct

Medium filter

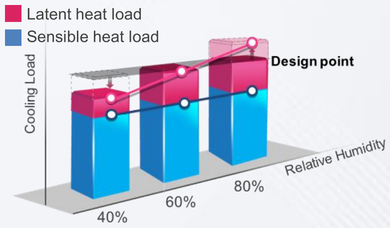
• Helps reduce particle and virus
• Slot type filter : change filter by sliding

* Medium filter can be supplied by 3rd party

Maintaining comfortable humidity

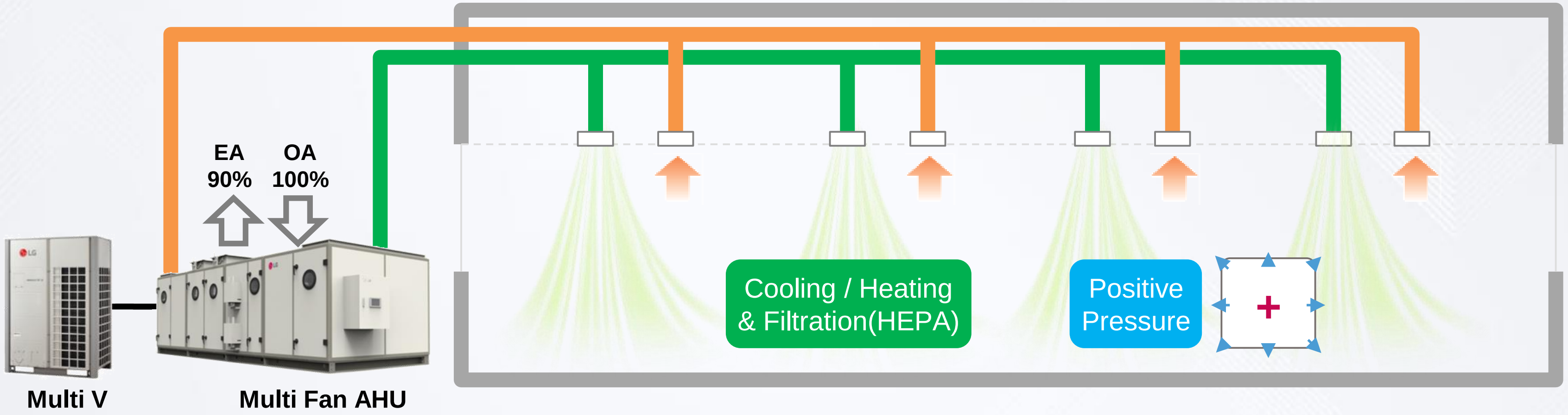


LG Multi V 5 : Dual Sensing
Other VRF : Single Sensing



Intensive Care Unit (for Normal Operation)

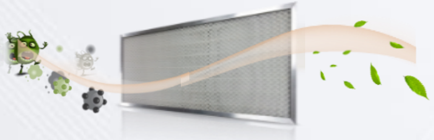
Recommend System : Multi V + Multi Fan AHU(DX)



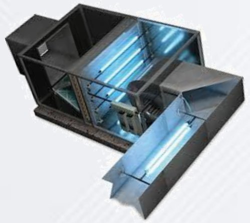
Ventilation & Filtration Solution : Multi Fan AHU

HEPA filter & UVGI

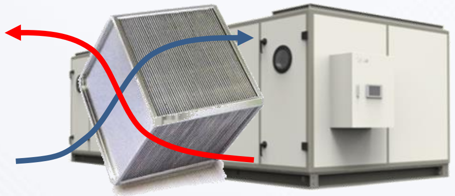
- Helps reduce particle and virus



HEPA filter(over MERV 17)

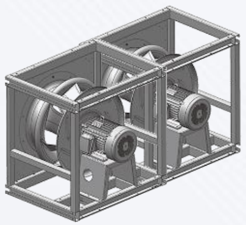


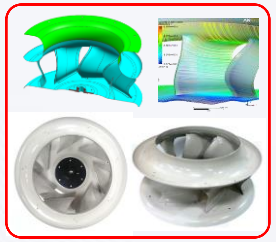
UVGI(Ultraviolet Germicidal Irradiation)



Heat Recovery with Plate HEX

- No contamination by air leakage
- 100% Fresh Air AHU with plate HEX
- Energy saving by heat recovery



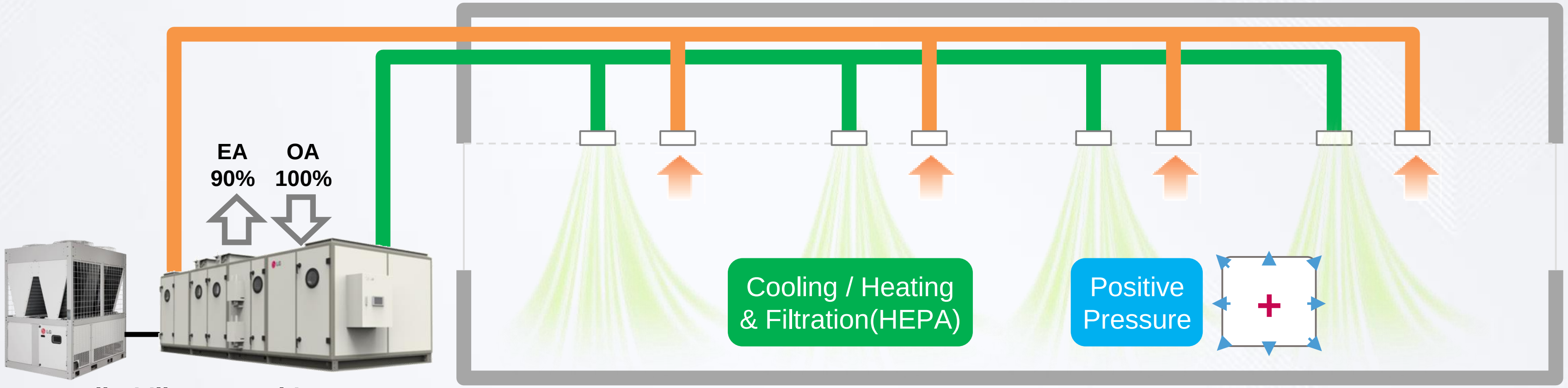


Direct Fan(LG 3D Plug Fan)

- Inverter Driver
  : High efficiency, precise control
- No contamination by belt abrasion
- Stable fan operation with multi plug fan

Operation Room

Recommend System : Inverter Scroll Chiller + Multi Fan AHU(water)

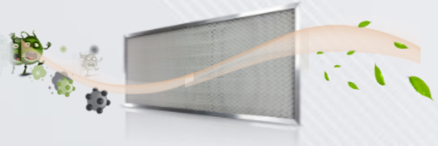


Inverter Scroll Chiller Multi Fan AHU

Ventilation & Filtration Solution : Multi Fan AHU

HEPA filter & UVGI

- Helps reduce particle and virus

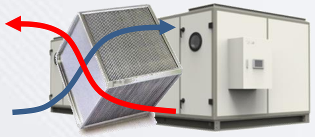


HEPA filter(over MERV 17)

UVGI(Ultraviolet Germicidal Irradiation)

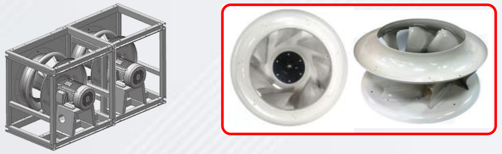
Heat Recovery with Plate HEX

- No contamination by air leakage
- Energy saving by heat recovery



Direct Fan(LG 3D Plug Fan)

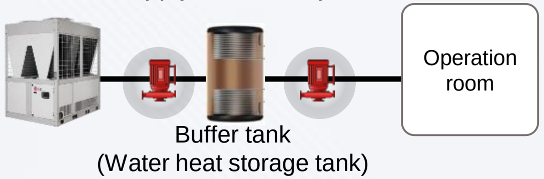
- No contamination by belt abrasion
- Stable fan operation with redundancy



Stable Heat Source Solution : Inverter Scroll Chiller

Stable cooling supply

- Constant supply water temperature



Back up Operation

- Continuous operation during malfunction

Healthcare Building System Proposal

Room type	Recommended system	Cooling & Heating	Humidity	Air Purification & Filtration		Ventilation	Sterilization	Pressure Control	System running
Lobby / Reception / Waiting room	 Ceiling Concealed Duct with Medium filter  Multi V  Multi Fan AHU(DX) with Medium filter	● Multi V CCD	● Maintaining Comfortable Humidity		● Medium filter	● Medium filter		Neutral	● ACP (Central Controller)
Inpatient room / Inspecting room	 Multi V  4Way CST with Air purification kit  ERV with Medium filter	● Multi V CST	● Maintaining Comfortable Humidity	● Air Purification kit (Electro static)		● Medium filter		● Positive	● ACP (Central Controller)
Isolation room	 Ceiling Concealed Duct with Medium filter  Multi V  FAU  Exhaust Fan	● Multi V CCD	● Maintaining Comfortable Humidity		● Medium filter	● Medium filter		● Negative	● ACP (Central Controller)
Intensive care unit	 Multi V  Multi Fan AHU(DX) with HEPA filter & UVGI	● Multi V AHU	● Humidifier		● HEPA filter	● HEPA filter	● UVGI	● Positive	● ACP (Central Controller)
Operation room	 Inverter Scroll Chiller  Multi Fan AHU(Water) with HEPA filter & UVGI	● Multi V AHU	● Humidifier		● HEPA filter	● HEPA filter	● UVGI	● Positive	● ACP (Central Controller)

Conclusion

- According to ASHRAE and REHVA Guideline for HVAC system to avoid infection, Ventilation, Air Purification(Filtration), Sterilization and Temperature/Humidity control are major factors

- For Non-Healthcare Building
  - More operation hours before and after working hour will be helpful to reduce infection and HVAC system central controller can support it
  - Individual ventilator(ERV) with Medium Filter can provide not only 100% fresh air, but also dust removal
  - 4Way cassette indoor unit with air purification kit will be helpful to reduce particle in the working space
  - VRF system with humidity sensor and control algorithm can help maintain the humidity level between 40~60%

- For Healthcare Building
  - Ventilation requires 100% Fresh Air Solution like Dedicated Outdoor Air System Also individual ventilation unit like energy recovery ventilator with medium filter is recommended
  - Air Purification and Filtration will need HEPA grade AHU filter and stand alone Air Purifier
  - UVGI will serve as a solution of Sterilization in AHU and Ducting.

- LG Electronics Air Solution will help customers to design and operate healthy and safe HVAC system.

LG

Life's Good

Innovation for a Better Life

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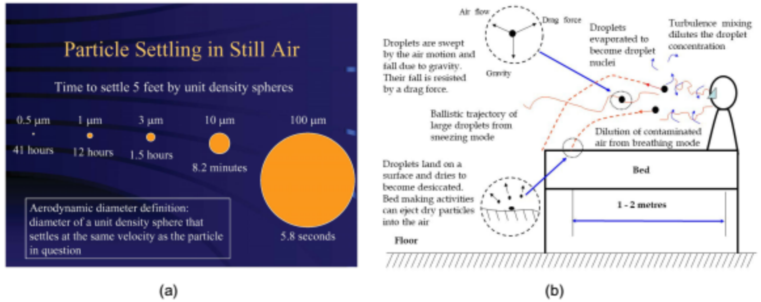

Figure 1 (a) Comparative settling times by particle diameter for particles settling in still air (Baron n.d.) and (b) theoretical aerobiology of transmission of droplets and small airborne particles produced by an infected patient with an acute infection (courtesy Yuguo Li).

ence short-range transmission. Conversely, dissemination of smaller infectious aerosols, including droplet nuclei resulting from desiccation, can be affected by airflow patterns in a space in general and airflow patterns surrounding the source in particular. Of special interest are small aerosols (<10 µm), which can stay airborne and infectious for extended periods (several minutes, hours, or days) and thus can travel longer distances and infect secondary hosts who had no contact with the primary host.

Many diseases are known to have high transmission rates via larger droplets when susceptible individuals are within close proximity, about 3–7 ft (1–2 m) (Nicas 2009; Li 2011). Depending on environmental factors, these large (100 µm diameter) droplets may shrink by evaporation before they settle, thus becoming an aerosol (approximately <10 µm). The term *droplet nuclei* has been used to describe such desiccation of droplets into aerosols (Siegel et al. 2007). While ventilation systems cannot interrupt the rapid settling of large droplets, they can influence the transmission of droplet nuclei infectious aerosols. Directional airflow can create clean-to-dirty flow patterns and move infectious aerosols to be captured or exhausted.

3. PRACTICAL IMPLICATIONS FOR BUILDING OWNERS, OPERATORS, AND ENGINEERS

Even the most robust HVAC system cannot control all airflows and completely prevent dissemination of an infectious aerosol or disease transmission by droplets or aerosols. An HVAC system's impact will depend on source location, strength of the source, distribution of the released aerosol, droplet size, air distribution, temperature, relative humidity, and filtration. Furthermore, there are multiple modes and circumstances under which disease transmission occurs. Thus, strategies for prevention and risk mitigation require collaboration among designers, owners, operators, industrial hygienists, and infection prevention specialists.

3.1 Varying Approaches for Facility Type

Healthcare facilities have criteria for ventilation design to mitigate airborne transmission of infectious diseases (ASHRAE 2013, 2017a, 2019a; FGI 2010); however, infections are also transmitted in ordinary occupancies in the community and not only in industrial or healthcare occupancies. ASHRAE provides general ventilation and air quality requirements in Standards 62.1, 62.2, and 170 (ASHRAE 2019a, 2019b, 2017a); ASHRAE does not provide specific requirements for infectious disease control in homes, schools, prisons, shelters, transportation, or other public facilities.

In healthcare facilities, most infection control interventions are geared at reducing direct or indirect contact transmission of pathogens. These interventions for limiting airborne transmission (Aliabadi et al. 2011) emphasize personnel education and surveillance of behaviors such as hand hygiene and compliance with checklist protocols and have largely been restricted to a relatively small list of diseases from pathogens that spread only through the air. Now that microbiologists understand that many pathogens can travel through both contact and airborne routes, the role of indoor air management has become critical to successful prevention efforts. In view of the broader understanding of flexible pathogen transmission modes, healthcare facilities now use multiple modalities simultaneously (measures that are referred to as *infection control bundles*) (Apisarnthanarak et al. 2009, 2010a, 2010b; Cheng et al. 2010). For example, in the cases of two diseases that clearly utilize airborne transmission, tuberculosis and measles, bundling includes administrative regulations, environmental controls, and personal protective equipment protocols in healthcare settings. This more comprehensive approach is needed to control pathogens, which can use both contact and airborne transmission pathways. Similar strategies may be appropriate for non-healthcare spaces, such as public transit and airplanes, schools, shelters, and prisons, that may also be subject to close contact of occupants.

Many buildings are fully or partially naturally ventilated. They may use operable windows and rely on intentional and unintentional openings in the building envelope. These strategies create different risks and benefits. Obviously, the airflow in these buildings is variable and unpredictable, as are the resulting air distribution patterns, so the ability to actively manage risk in such buildings is much reduced. However, naturally ventilated buildings can go beyond random opening of windows and be engineered intentionally to achieve ventilation strategies and thereby reduce risk from infectious aerosols. Generally speaking, designs that achieve higher ventilation rates will reduce risk. However, such buildings will be more affected by local outdoor air quality, including the level of allergens and pollutants within the outdoor air, varying temperature and humidity conditions, and flying insects. The World Health Organization has published guidelines for naturally ventilated buildings that should be consulted in such projects (Atkinson et al. 2009).

3.2 Ventilation and Air-Cleaning Strategies

The design and operation of HVAC systems can affect infectious aerosol transport, but they are only one part of an infection control bundle. The following HVAC strategies have the potential to reduce the risks of infectious aerosol dissemination: air distribution patterns, differential room pressurization, personalized ventilation, source capture ventilation, filtration (central or local), and controlling temperature and relative humidity. While UVGI is well researched and validated, many new technologies are not (ASHRAE 2018). (Evidence Level B)

Ventilation with effective airflow patterns (Pantelic and Tham 2013) is a primary infectious disease control strategy through dilution of room air around a source and removal of infectious

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Personalized ventilation systems, when coupled with localized or personalized exhaust devices, further enhance the overall ability to mitigate exposure in breathing zones, as seen from both experimental and computational fluid dynamics (CFD) studies in healthcare settings (Yang et al. 2013, 2014, 2015a, 2015b; Bolashikov et al. 2015; Bivolarova et al. 2016). However, there are no known epidemiological studies that demonstrate a reduction in infectious disease transmission. (Evidence Level B)

Advanced techniques such as computational fluid dynamics (CFD) analysis, if performed properly with adequate expertise, can predict airflow patterns and probable flow paths of airborne contaminants in a space. Such analyses can be employed as a guiding tool during the early stages of a design cycle (Khankari 2016, 2018a, 2018b, 2018c).

3.3 Temperature and Humidity

HVAC systems are typically designed to control temperature and humidity, which can in turn influence transmissibility of infectious agents. Although HVAC systems can be designed to control relative humidity (RH), there are practical challenges and potential negative effects of maintaining certain RH set points in all climate zones. However, while the weight of evidence at this time (Derby et al. 2016), including recent evidence using metagenomic analysis (Taylor and Tasi 2018), suggests that controlling RH reduces transmission of certain airborne infectious organisms, including some strains of influenza, this position document encourages designers to give careful consideration to temperature and RH.

In addition, immunobiologists have correlated mid-range humidity levels with improved mammalian immunity against respiratory infections (Taylor and Tasi 2018). Mousavi et al. (2019) report that the scientific literature generally reflects the most unfavorable survival for microorganisms when the RH is between 40% and 60% (Evidence Level B). Introduction of water vapor to the indoor environment to achieve the mid-range humidity levels associated with decreased infections requires proper selection, operation, and maintenance of humidification equipment. Cold winter climates require proper building insulation to prevent thermal bridges that can lead to condensation and mold growth (ASHRAE 2009). Other recent studies (Taylor and Tasi 2018) identified RH as a significant driver of patient infections. These studies showed that RH below 40% is associated with three factors that increase infections. First, as discussed previously, infectious aerosols emitted from a primary host shrink rapidly to become droplet nuclei, and these dormant yet infectious pathogens remain suspended in the air and are capable of traveling great distances. When they encounter a hydrated secondary host, they rehydrate and are able to propagate the infection. Second, many viruses and bacteria are anhydrous resistant (Goffau et al. 2009; Stone et al. 2016) and actually have increased viability in low-RH conditions. And finally, immunobiologists have now clarified the mechanisms through which ambient RH below 40% impairs mucus membrane barriers and other steps in immune system protection (Kudo et al. 2019). (Evidence Level B)

This position document does not make a definitive recommendation on indoor temperature and humidity set points for the purpose of controlling infectious aerosol transmission. Practitioners may use the information herein to make building design and operation decisions on a case-by-case basis.

3.4 Emerging Pathogens and Emergency Preparedness

Disease outbreaks (i.e., epidemics and pandemics) are increasing in frequency and reach. Pandemics of the past have had devastating effects on affected populations. Novel microor-

- Based on risk assessments, the use of specific HVAC strategies supported by the evidence-based literature should be considered, including the following:
  - Enhanced filtration (higher minimum efficiency reporting value [MERV] filters over code minimums in occupant-dense and/or higher-risk spaces) (Evidence Level A)
  - Upper-room UVGI (with possible in-room fans) as a supplement to supply airflow (Evidence Level A)
  - Local exhaust ventilation for source control (Evidence Level A)
  - Personalized ventilation systems for certain high-risk tasks (Evidence Level B)
  - Portable, free-standing high-efficiency particulate air (HEPA) filters (Evidence Level B)
  - Temperature and humidity control (Evidence Level B)
- Healthcare buildings[8] should consider design and operation to do the following:
  - Capture expiratory aerosols with headwall exhaust, tent or snorkel with exhaust, floor-to-ceiling partitions with door supply and patient exhaust, local air HEPA-grade filtration.
  - Exhaust toilets and bed pans (a must).
  - Maintain temperature and humidity as applicable to the infectious aerosol of concern.
  - Deliver clean air to caregivers.
  - Maintain negatively pressurized intensive care units (ICUs) where infectious aerosols may be present.
  - Maintain rooms with infectious aerosol concerns at negative pressure.
  - Provide 100% exhaust of patient rooms.
  - Use UVGI.
  - Increase the outdoor air change rate (e.g., increase patient rooms from 2 to 6 ach).
  - Establish HVAC contributions to a patient room turnover plan before reoccupancy.
- Non-healthcare buildings should have a plan for an emergency response. The following modifications to building HVAC system operation should be considered:
  - Increase outdoor air ventilation (disable demand-controlled ventilation and open outdoor air dampers to 100% as indoor and outdoor conditions permit).
  - Improve central air and other HVAC filtration to MERV-13 (ASHRAE 2017b) or the highest level achievable.
  - Keep systems running longer hours (24/7 if possible).
  - Add portable room air cleaners with HEPA or high-MERV filters with due consideration to the clean air delivery rate (AHAM 2015).
  - Add duct- or air-handling-unit-mounted, upper room, and/or portable UVGI devices in connection to in-room fans in high-density spaces such as waiting rooms, prisons, and shelters.
  - Maintain temperature and humidity as applicable to the infectious aerosol of concern.
  - Bypass energy recovery ventilation systems that leak potentially contaminated exhaust air back into the outdoor air supply.
- Design and build inherent capabilities to respond to emerging threats and plan and practice for them. (Evidence Level B)

[8] It is assumed that healthcare facilities already have emergency response plans.

◀ Back

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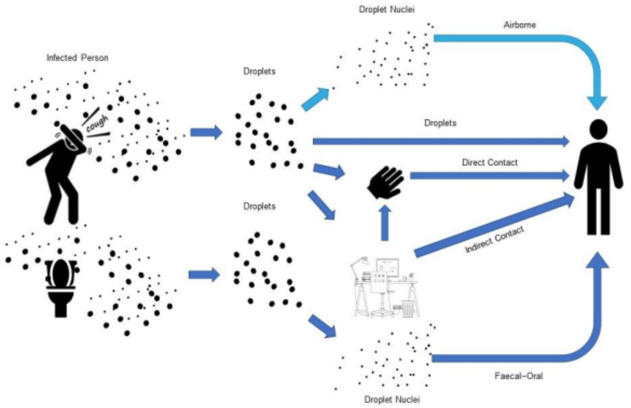

Figure 1. WHO reported exposure mechanisms of COVID-19 SARS-CoV-2 droplets (dark blue colour). Light blue colour: airborne mechanism that is known from SARS-CoV-1 and other flu, currently there is no reported evidence specifically for SARS-CoV-2 (figure: courtesy Francesco Franchimon).

With SARS-CoV-2 the airborne route - infection through exposure to droplet nuclei particles - has currently acknowledged by WHO for hospital procedures and indirectly through the guidance to increase ventilation[xv]. It may exist when certain conditions are met (i.e. opportunistic airborne) according to China national Health Commission (unpublished result). Airborne transmission can be possible according to Japanese authority under certain circumstances, such as when talking to many people at a short distance in an enclosed space, there is a risk of spreading the infection even without coughing or sneezing[xvi]. Latest study[xvii] concluded that aerosol transmission is plausible, as the virus can remain viable in aerosols for multiple hours. Another recent study[xviii] that analysed superspreading events showed that closed environments with minimal ventilation strongly contributed to a characteristically high number of secondary infections. The manuscript draft discussing airborne transmission concludes that evidence is emerging indicating that SARS-CoV-2 is also transmitted via airborne particles[xix].

Conclusion in relation to the airborne transmission route:
At this date we need all efforts to manage this pandemic from all fronts. Therefore REHVA proposes, especially in 'hot spot' areas to use the ALARA principle (As Low As Reasonably Achievable) and to take a set of measures that help to also control the airborne route in buildings (apart from standard hygiene measures as recommended by WHO, see the 'Getting workplaces ready for COVID-19' document).

Practical recommendations for building services operation

Increase air supply and exhaust ventilation
In buildings with mechanical ventilation systems extended operation times are recommended. Change the clock times of system timers to start ventilation at nominal speed at least 2 hours before the building usage time and switch to lower speed 2 hours after the building usage time. In demand-

controlled ventilation systems change CO_2 setpoint to lower, 400 ppm value, in order to assure the operation at nominal speed. Keep the ventilation on 24/7, with lowered (but not switched off) ventilation rates when people are absent. In buildings that have been vacated due to the pandemic (some offices or educational buildings) it is not recommended to switch ventilation off, but to operate continuously at reduced speed. Considering a springtime with small heating and cooling needs, the recommendations above have limited energy penalties, while they help to remove virus particles out of the building and to remove released virus particles from surfaces.
The general advice is to supply as much outside air as reasonably possible. The key aspect is the amount of fresh air supplied per person. If, due to smart working utilization, the number of employees is reduced, do not concentrate the remaining employees in smaller areas but maintain or enlarge the social distancing (min physical distance 2-3 m between persons) among them in order to foster the ventilation cleaning effect.
Exhaust ventilation systems of toilets should always be kept on 24/7, and make sure that under-pressure is created, especially to avoid the faecal-oral transmission.

Use more window airing
General recommendation is to stay away from crowded and poorly ventilated spaces. In buildings without mechanical ventilation systems it is recommended to actively use operable windows (much more than normally, even when this causes some thermal discomfort). Window airing then is the only way to boost air exchange rates. One could open windows for 15 min or so when entering the room (especially when the room was occupied by others beforehand). Also, in buildings with mechanical ventilation, window airing can be used to further boost ventilation.
Open windows in toilets with passive stack or mechanical exhaust systems may cause a contaminated airflow from the toilet to other rooms, implying that ventilation begins to work in reverse direction. Open toilet windows then should be avoided. If there is no adequate exhaust ventilation from toilets and window airing in toilets cannot be avoided, it is important to keep windows open also in other spaces in order to achieve cross flows throughout the building.

Humidification and air-conditioning have no practical effect
Relative humidity (RH) and temperature contribute to virus transmission indoors affecting virus viability, droplet nuclei forming and susceptibility of occupants' mucous membranes. Transmission of some viruses in buildings can be limited by changing air temperatures and humidity levels. In the case of COVID-19 this is unfortunately not an option as coronaviruses are quite resistant to environmental changes and are susceptible only for a very high relative humidity above 80% and a temperature above 30 ˚C[ix,x,xi], which are not attainable and acceptable in buildings for other reasons (e.g. thermal comfort and microbial growth). SARS-CoV-2 has been found highly stable for 14 days at 4 °C; 37 °C for one day and 56 °C for 30 minutes were needed to inactivate the virus[xx].
SARS-CoV-2 stability (viability) has been tested at typical indoor temperature of 21-23 °C and RH of 65% with very high virus stability at this RH[xxi]. Together with previous evidence on MERS-CoV it is well documented that humidification up to 65% may have very limited or no effect on stability of SARS-CoV-2 virus. Therefore, the evidence does not support that moderate humidity (RH 40-60%) will be beneficial in reducing viability of SARS-CoV-2, thus the humidification is NOT a method to reduce the viability of SARS-CoV-2.
Small droplets under interest (0.5 - 10 micron) will evaporate fast under any relative humidity (RH) level[xxii]. Nasal systems and mucous membranes are more sensitive to infections at very low RH of 10-20 %[xxiii,xxiv], and this is the reason for which some humidification in winter is sometimes suggested (to levels of 20-30%). This indirect need for humidification in winter in the COVID-19 case is not relevant however given the incoming climatic conditions (from March onwards we expect indoor RH higher than 30% in all European climates without humidification).
Thus, in buildings equipped with centralized humidification, there is no need to change humidification systems' setpoints (usually 25 or 30%[xxv]). Considering the springtime that is about to start, these systems should not be in operation anyhow. Heating and cooling systems can be operated

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normally as there are no direct implications on COVID-19 spread. Usually, any adjustment of setpoints for heating or cooling systems is not needed.

Safe use of heat recovery sections

Under certain conditions virus particles in extract air can re-enter the building. Heat recovery devices may carry over virus attached to particles from the exhaust air side to the supply air side via leaks. Regenerative air to air heat exchangers (i.e. rotors, called also enthalpy wheels) may be sensitive for considerable leaks in the case of poor design and maintenance. For properly operating rotary heat exchangers, fitted with purging sectors and correctly set up, leakage rates are about the same as that of plate heat exchangers being in the range of 1-2%. For existing systems, the leakage should be below 5%, and has to be compensated with increase of outdoor air ventilation according to EN 16798-3:2017. However, many rotary heat exchangers may not be properly installed. The most common fault is that the fans have been mounted in such a way that higher pressure on the exhaust air side is created. This will cause leakage from extract air into the supply air. The degree of uncontrolled transfer of polluted extract air can in these cases be of the order of 20%[xxvi], that is not acceptable.

It is shown that rotary heat exchangers, which are properly constructed, installed and maintained, have almost zero transfer of particle-bound pollutants (including air-borne bacteria, viruses and fungi), but the transfer is limited to gaseous pollutants such as tobacco smoke and other smells[xxvii]. Thus, there is no evidence that virus-bearing particles starting from 0.1 micron would be an object of carry over leakage. Because the leakage rate does not depend on the rotation speed of rotor, it is not needed to switch rotors off. Normal operation of rotors makes it easier to keep ventilation rates higher. It is known that the carry-over leakage is highest at low airflow, thus higher ventilation rates are recommended.

If leaks are suspected in the heat recovery sections, pressure adjustment or bypassing (some systems may be equipped with bypass) can be an option in order to avoid a situation where higher pressure on extract side will cause air leakages to supply side. Pressure differences can be corrected by dampers or by other reasonable arrangements. In conclusion, we recommend to inspect the heat recovery equipment including the pressure difference measurement. To be on the safe side, the maintenance personnel should follow standard safety procedures of dusty work, including wearing gloves and respiratory protection.

Virus particle transmission via heat recovery devices is not an issue when a HVAC system is equipped with a twin coil unit or another heat recovery device that guarantees 100% air separation between return and supply side[xxviii].

No use of recirculation

Virus particles in return ducts can also re-enter a building when centralized air handling units are equipped with recirculation sectors. It is recommended to avoid central recirculation during SARS-CoV-2 episodes: close the recirculation dampers (via the Building Management System or manually). In case this leads to problems with cooling or heating capacity, this has to be accepted because it is more important to prevent contamination and protect public health than to guarantee thermal comfort.

Sometimes air handling units and recirculation sections are equipped with return air filters. This should not be a reason to keep recirculation dampers open as these filters normally do not filter out particles with viruses effectively since they have standard efficiencies (G4/M5 or ISO coarse/ePM10 filter class)[xxix] and not HEPA efficiencies.

Some systems (fan coil and induction units) work with local (room level) circulation. If possible (no significant cooling need) these units are recommended to be turned off to avoid resuspension of virus particles at room level (esp. when rooms are used normally by more than one occupant). Fan coil units have coarse filters which practically do not filter small particles but still might collect particles. On the fan coil heat exchanger surface, it is possible to inactivate the virus by heating up fan coils to 60 °C during one hour or 40 °C during one day.

If fan coils cannot be switched off, it is recommended that their fans are operated continuously

because the virus can sediment in filters and resuspension boost can follow when the fan is turned on. In continuous circulation operation virus particles will be removed with exhaust ventilation.

Duct cleaning has no practical effect

There have been overreactive statements recommending to clean ventilation ducts in order to avoid SARS-CoV-2 transmission via ventilation systems. Duct cleaning is not effective against room-to-room infection because the ventilation system is not a contamination source if above guidance about heat recovery and recirculation is followed. Viruses attached to small particles will not deposit easily in ventilation ducts and normally will be carried out by the air flow anyhow[xxx]. Therefore, no changes are needed to normal duct cleaning and maintenance procedures. Much more important is to increase fresh air supply, avoid recirculation of air according to the recommendations above.

Change of outdoor air filters is not necessary

In COVID-19 context, it has been asked should the filters to be replaced and what is the protection effect in very rare occasions of outdoor virus contamination, for instance if air exhausts are close to air intakes. Modern ventilation systems (air handling units) are equipped with fine outdoor air filters right after the outdoor air intake (filter class F7 or F8[4] or ISO ePM2.5 or ePM1) which filtrate well particulate matter from outdoor air. The size of a naked coronavirus particle of 80-160 nm[viii] (PM0.1) is smaller than the capture area of F8 filters (capture efficiency 65-90% for PM1), but many of such small particles will settle on fibres of the filter by diffusion mechanism. SARS-CoV-2 particles also aggregate with larger particles which are already within the capture area of filters. This implies that in rare cases of virus contaminated outdoor air, standard fine outdoor air filters provide a reasonable protection for a low concentration and occasionally spread viruses in outdoor air.

Heat recovery and recirculation sections are equipped with less effective extract air filters (G4/M5 or ISO coarse/ePM10) which aim is to protect equipment from dust. These filters do not have to filter out small particles as virus particles will be ventilated out by exhaust air (see also the recommendation not to use recirculation under 'no use of recirculation').

From the filter replacement perspective, normal maintenance procedures can be used. Clogged filters are not a contamination source in this context, but they reduce supply airflow which has a negative effect on indoor contaminations itself. Thus, filters must be replaced according to normal procedure when pressure or time limits are exceeded, or according to scheduled maintenance. In conclusion, we do not recommend changing existing outdoor air filters and replace them with other type of filters nor do we recommend changing them sooner than normal.

HVAC maintenance personnel could be at risk when filters (especially extract air filters) are not changed in line with standard safety procedures. To be on the safe side, always assume that filters have active microbiological material on them, including viable viruses. This is particularly important in any building where there recently has been an infection. Filters should be changed with the system turned off, while wearing gloves, with respiratory protection, and disposed of in a sealed bag.

Room air cleaners can be useful in specific situations

Room air cleaners remove effectively particles from air which provides a similar effect compared to ventilation. To be effective, air cleaners need to have at least HEPA filter efficiency. Unfortunately, most of attractively priced room air cleaners are not effective enough. Devices that use electrostatic filtration principles (not the same as room ionizers!) often work quite well too. Because the airflow through air cleaners is limited, the floor area they can effectively serve is normally quite small, typically less than 10 m^2. If one decides to use an air cleaner (again: increasing regular ventilation often is much more efficient) it is recommended to locate the device close to the breathing zone. Special UV cleaning equipment to be installed for the supply air or room air treatment is also effective

[4] An outdated filter classification of EN779:2012 which is replaced by EN ISO 16890-1:2016, Air filters for general ventilation - Part 1: Technical specifications, requirements and classification system based upon particulate matter efficiency (ePM).

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ISO $_{e}PM_{1}$ 75% Filter Performance

ISO 16890-1:2016 Air Filter Test Results

VTT EXPERT SERVICES LTD — TEST REPORT No. S-03385-18 — Appendix 1 1 (3)

ISO 16890-1:2016 Air Filter Test Results

GENERAL

Test no.:	183808	Device receiving date:	18.5.2018
Test requested by:	LG Electronics Inc.	Date of test:	25.6.-26.6.2018
Device delivered by:	LG Electronics Inc.	Operator: VJ	Supervisor: TJ

DEVICE TESTED

Model	Manufacturer	Construction
AHFT035H0	LG Electronics Inc.	Panel

Type of medium	Net effective filtering area	Filter dimensions (width × height × depth)
Glass fibre	3.8 m²	600 mm x 600 mm x 25 mm

TEST DATA

Test air flow rate	Test air temperature	Test air relative humidity	Test aerosol	Loading dust
0.278 m³/s	23 - 24 °C	44 - 49 %	DEHS and KCl	-

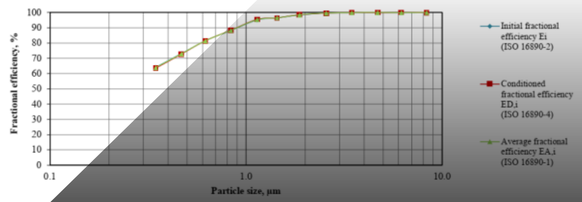
CONDITIONING ROOM

Time of conditioning	Room temperature	Room relative humidity	Barometric pressure	Evaporated IPA amount
24 h	21 - 22 °C	22 - 23 %	101.6 - 102.7 kPa	76 g

RESULTS

Initial pressure drop 83 Pa	Initial gravimetric arrestance -	$_{e}PM_{1, min}$ 75 %	$_{e}PM_{2.5, min}$ 82 %	$_{e}PM_{10, min}$ 94 %	ISO rating: ISO $_{e}PM_{1}$ 75 %
Final test pressure drop -	Test dust capacity -	$_{e}PM_{1}$ 75 %	$_{e}PM_{2.5}$ 82 %	$_{e}PM_{10}$ 94 %	

Remarks: -



$_{e}PM_{1, min}$	$_{e}PM_{2.5, min}$	$_{e}PM_{10, min}$	ISO rating
75 %	82 %	94 %	ISO $_{e}PM_{1}$ 75 %
$_{e}PM_{1}$ 75 %	$_{e}PM_{2.5}$ 82 %	$_{e}PM_{10}$ 94 %	

Air flow rate, m³/s

NOTE: The results of this test relate only to the test device in the condition stated herein. The performance results cannot be themselves be quantitatively applied to predict filtration performance in all "real life" environments.

The test results relate only to the sample tested

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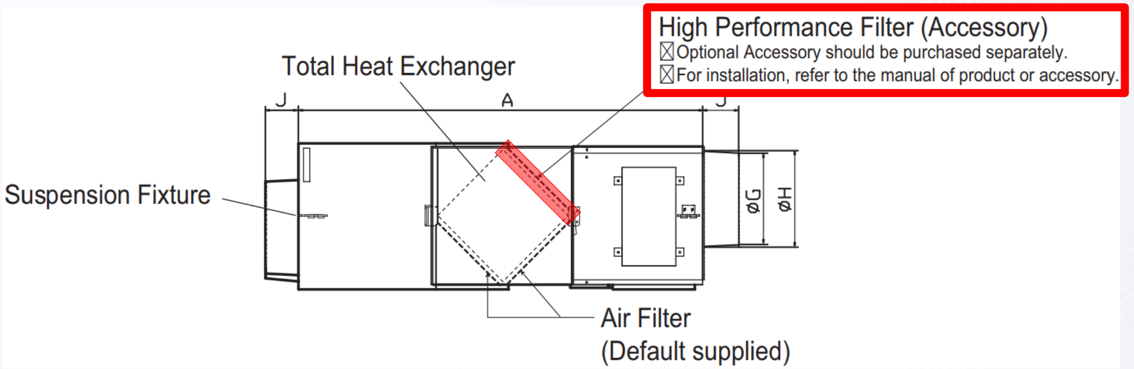
Test condition

- Test air flow rate
  : 0.278 m³/s
- Test air temperature
  : 23 - 24 °C
- Test air relative humidity
  : 44 ~ 49%
- Test aerosol
  : DEHS and KCl

* Efficiency can be differed by environmental condition.

➤ **Leakage amount in energy recovery mode is below 5 %**

➤ **How to install the filter**



➤ **Filter grade : same with MERV 14, F8**

ASHRAE Standard 52.2-1999				ASHRAE 52.1		EN	EN779:2012			EN 1822
Minimum Eff Reporting Value	Composite Average Particle Size Efficiency % in Size Range, µm			Average Arrestance	Average Dust Spot Efficiency	Filter Class	Av. Arrestance of Syn. Dust	Average Eff at 0.4 µm	Min. Eff at 0.4 µm	Average Eff at MPPS
11	n/a	E2≥65	E3≥85	97	60-65	M6		60≤Em≤80		
12	n/a	E2≥80	E3≥90	98	70-75					
13	n/a	E2≥90	E3≥90	98	80-85	F7		80≤Em≤90	35	
14	E1≥75	E2≥90	E3≥90	99	90-95	F8		90≤Em≤95	55	
15	E1≥85	E2≥90	E3≥90	99	95	F9		95≤Em	70	
16	E1≥95	E2≥95	E3≥95	100	99	E10				<85

* Source : Camfil Power Systems, www.camfil.com/ps

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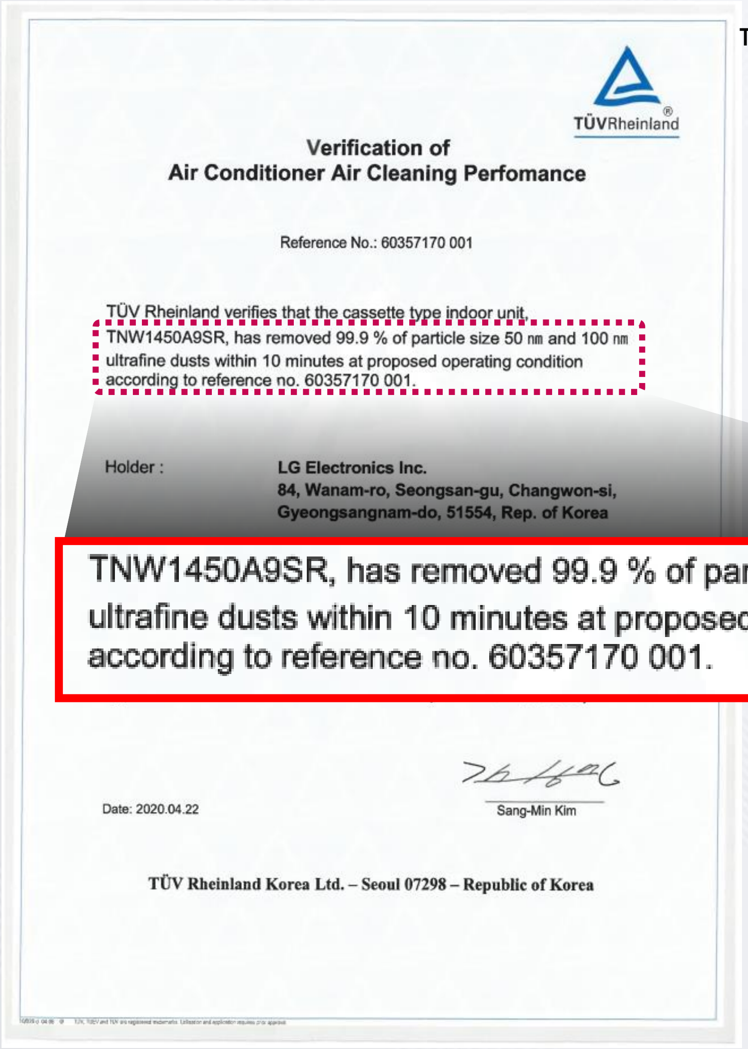
Air Purification Performance

Verification of Air Conditioner Air Cleaning Performance



TÜVRheinland

Verification of
Air Conditioner Air Cleaning Perfomance

Reference No.: 60357170 001

TÜV Rheinland verifies that the cassette type indoor unit,
TNW1450A9SR, has removed 99.9 % of particle size 50 nm and 100 nm ultrafine dusts within 10 minutes at proposed operating condition according to reference no. 60357170 001.

Holder : LG Electronics Inc.
84, Wanam-ro, Seongsan-gu, Changwon-si, Gyeongsangnam-do, 51554, Rep. of Korea

TNW1450A9SR, has removed 99.9 % of particle size 50 nm and 100 nm ultrafine dusts within 10 minutes at proposed operating condition according to reference no. 60357170 001.

Date: 2020.04.22

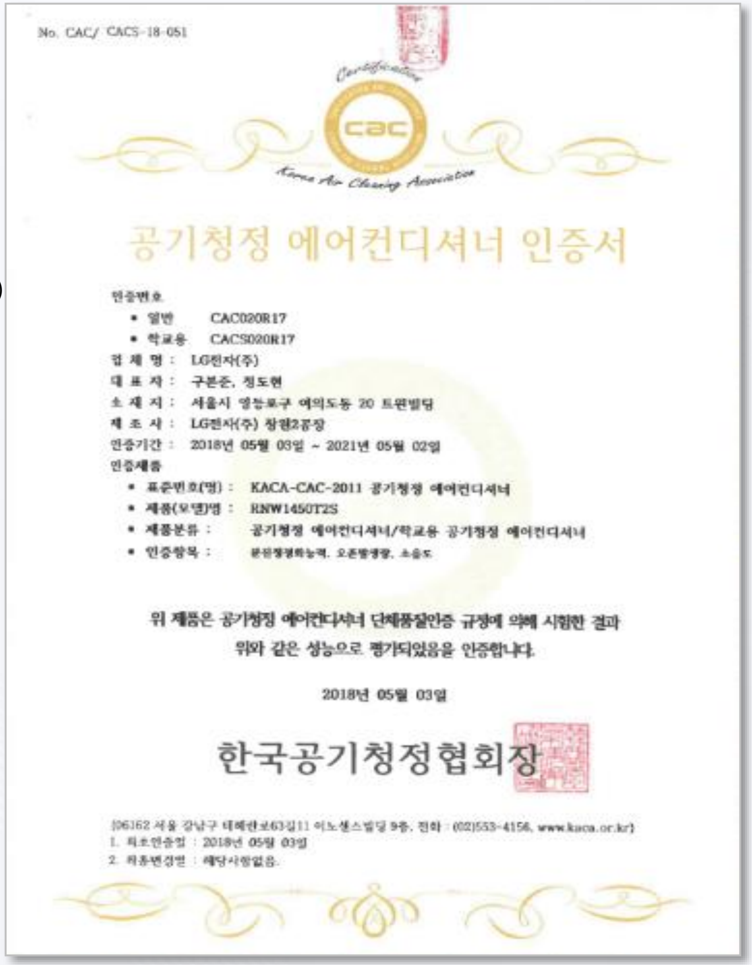
Sang-Min Kim

TÜV Rheinland Korea Ltd. – Seoul 07298 – Republic of Korea

Test Condition

- Test date : March, 2020
- Test place : LG electronics Inc.
- Test model : TNW1450A9SR
  (4-way Cassette, Max Air flow rate :32 CMM)
- Test Specification : SPS-KACA-002-132
  Test chamber size : 4m * 3m * 2.5m
  Test dust : Potassium chloride (50nm & 100nm)
  Initial particle concentration
  50nm : 100,000ea/cm^3
  100nm : 120,000ea/cm3

CAC* certification



No. CAC/ CACS-18-051

Certification

Korea Air Cleaning Association

공기청정 에어컨디셔너 인증서

인증번호
- 일반 CAC020R17
- 학교용 CACS020R17

업 체 명 : LG전자(주)
대 표 자 : 구본준, 정도현
소 재 지 : 서울시 영등포구 여의도동 20 트윈빌딩
제 조 사 : LG전자(주) 창원2공장
인증기간 : 2018년 05월 03일 ~ 2021년 05월 02일
인증제품
- 표준번호(명) : KACA-CAC-2011 공기청정 에어컨디셔너
- 제품(모델)명 : RNW1450T2S
- 제품분류 : 공기청정 에어컨디셔너/학교용 공기청정 에어컨디셔너
- 인증항목 : 분진청정화능력, 오존발생량, 소음도

위 제품은 공기청정 에어컨디셔너 단체품질인증 규정에 의해 시험한 결과
위와 같은 성능으로 평가되었음을 인증합니다.

2018년 05월 03일

한국공기청정협회장

CAC certification

The Korea Air Cleaning Association strictly tests the air purification function of air conditioner products and provides certification to the product which gives credibility to consumers.

CADR : 19.6 m^3/min
692.2 ft^3/min
Clean Area : 150.9 ㎡**

CADR
(Clean Air Delivery Rate)

CADR is a universal figure of merit that is cubic feet per minute (CFM) of air that has had all the particles of a given size distribution removed.

* Korean Air Cleaning Association Certification Standards (Jun, 2019)

** Clean Area is based on CAC standards(Korea).

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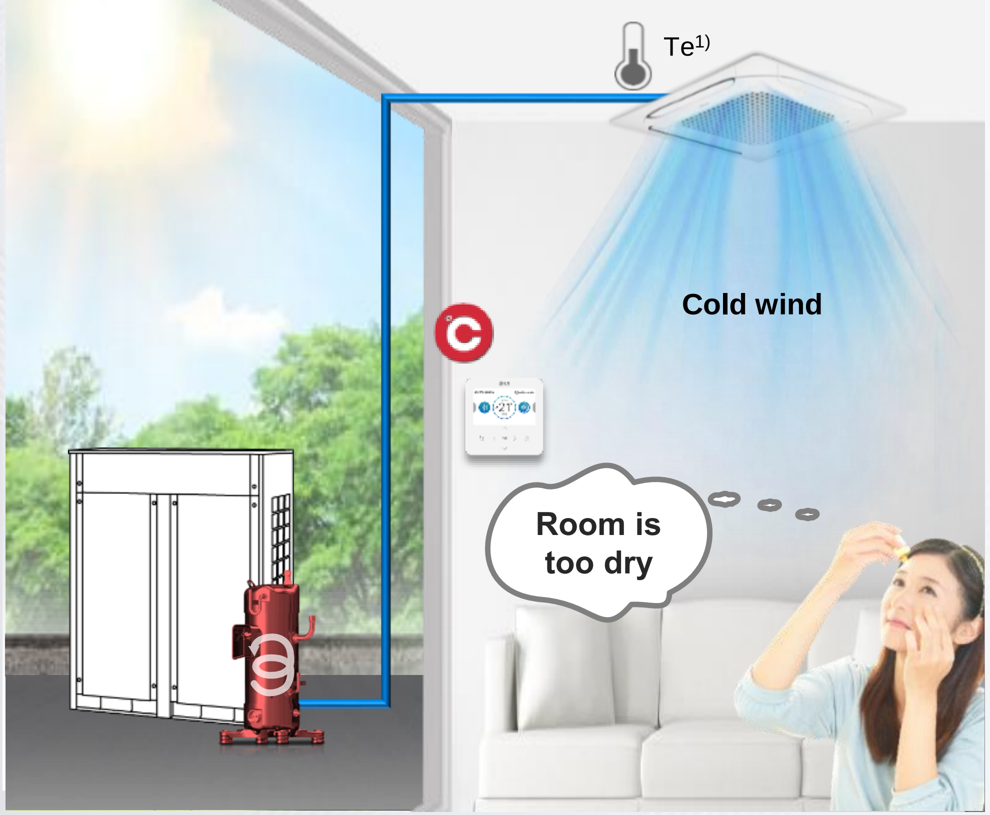
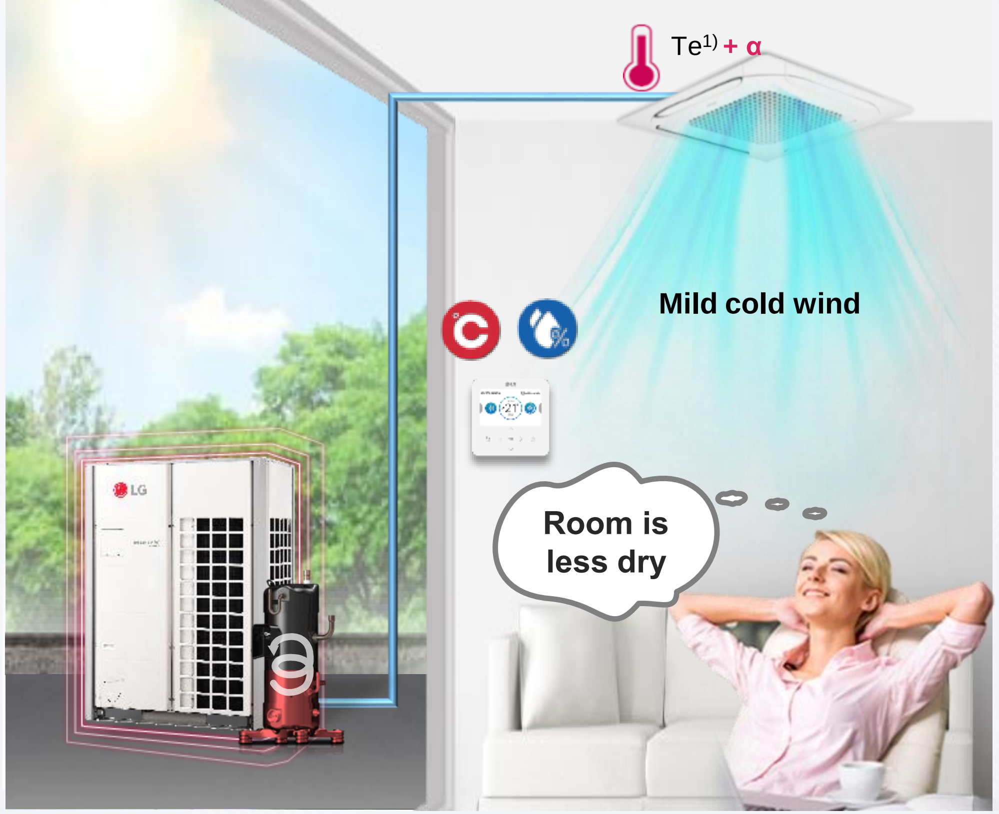
Maintaining Comfortable Humidity

General Cooling Operation	Maintaining Comfortable Humidity Cooling Operation
➢ Te[1] is controlled by Single sensing (Temperature only) ➢ Room become too dry ➢ Waste Energy to eliminate latent heat	➢ Te[1] is controlled by Dual sensing (Temperature and Humidity) ➢ Comfortable environment by making the room less dry ➢ Energy consumption is reduced.

1) Te : Evaporating Temperature



1) Te : Evaporating Temperature



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