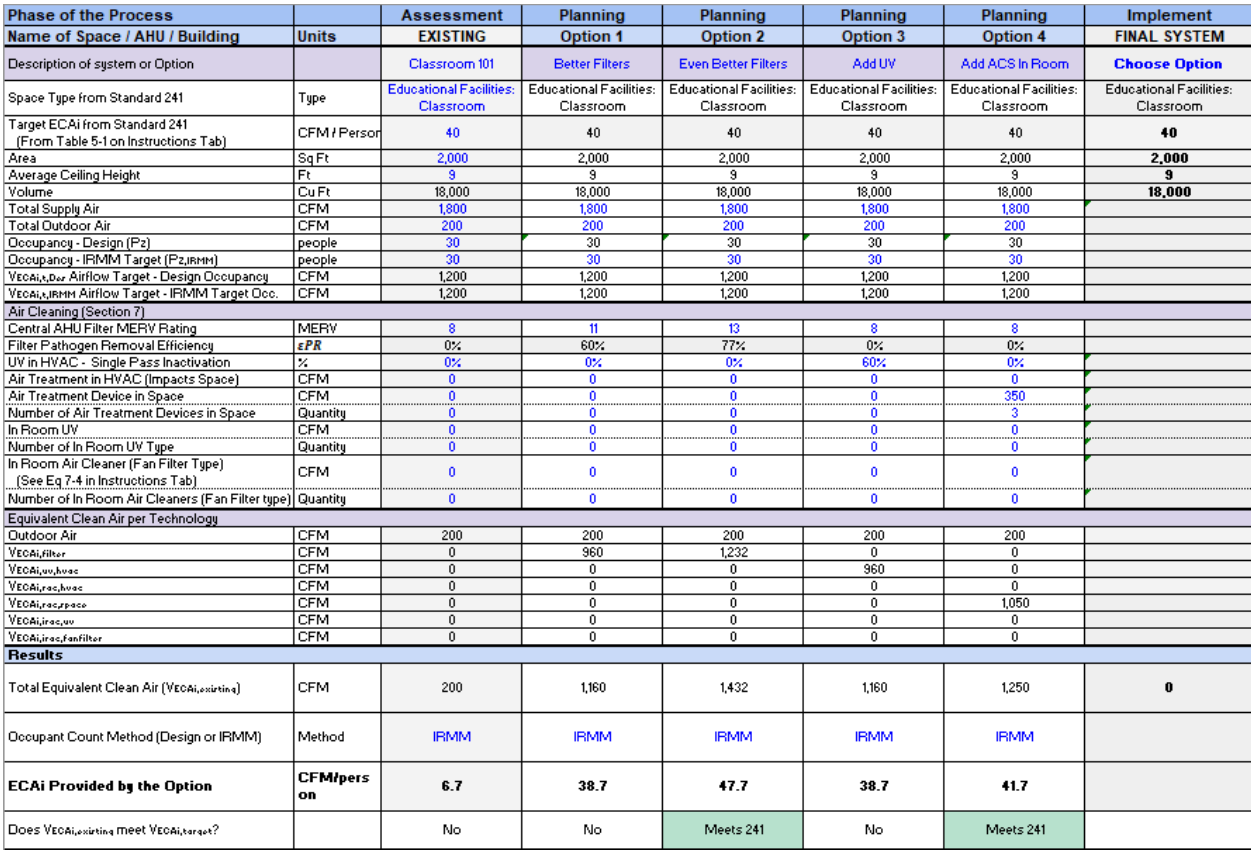
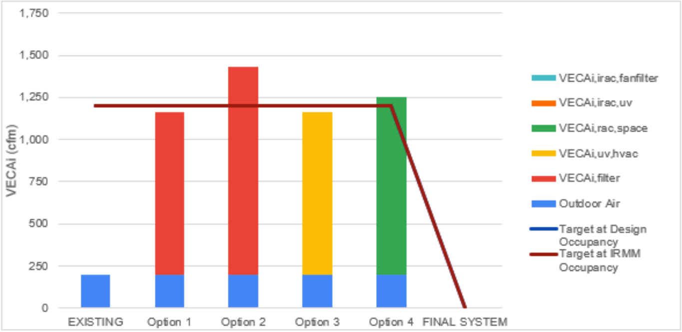
April 2024 ASHRAE Journal

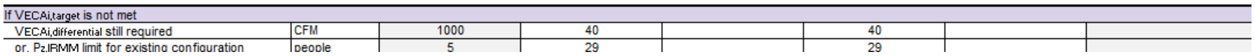
The following pages contain supplementary information for these articles in the April 2024 issue of ASHRAE Journal

From “Operating and Maintaining Building Systems: Reducing Risk With ASHRAE Standard 241,” by Meghan K. McNulty, P.E., Member ASHRAE, and Wade H. Conlan, P.E., BCxP, Member ASHRAE



Phase of the Process		Assessment	Planning	Planning	Planning	Planning	Implement
Name of Space / AHU / Building	**Units**	**EXISTING**	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**FINAL SYSTEM**
Description of system or Option		Classroom 101	Better Filters	Even Better Filters	Add UV	Add ACS In Room	**Choose Option**
Space Type from Standard 241	Type	Educational Facilities: Classroom	Educational Facilities: Classroom	Educational Facilities: Classroom	Educational Facilities: Classroom	Educational Facilities: Classroom	Educational Facilities: Classroom
Target ECAi from Standard 241 (From Table 5-1 on Instructions Tab)	CFM / Person	40	40	40	40	40	**40**
Area	Sq Ft	2,000	2,000	2,000	2,000	2,000	**2,000**
Average Ceiling Height	Ft	9	9	9	9	9	**9**
Volume	Cu Ft	18,000	18,000	18,000	18,000	18,000	**18,000**
Total Supply Air	CFM	1,800	1,800	1,800	1,800	1,800	
Total Outdoor Air	CFM	200	200	200	200	200	
Occupancy - Design (Pz)	people	30	30	30	30	30	
Occupancy - IRMM Target ($P_{z,IRMM}$)	people	30	30	30	30	30	
$V_{ECAi,t,Des}$ Airflow Target - Design Occupancy	CFM	1,200	1,200	1,200	1,200	1,200	
$V_{ECAi,t,IRMM}$ Airflow Target - IRMM Target Occ.	CFM	1,200	1,200	1,200	1,200	1,200	
Air Cleaning (Section 7)							
Central AHU Filter MERV Rating	MERV	8	11	13	8	8	
Filter Pathogen Removal Efficiency	εPR	0%	60%	77%	0%	0%	
UV in HVAC - Single Pass Inactivation	%	0%	0%	0%	60%	0%	
Air Treatment in HVAC (Impacts Space)	CFM	0	0	0	0	0	
Air Treatment Device in Space	CFM	0	0	0	0	350	
Number of Air Treatment Devices in Space	Quantity	0	0	0	0	3	
In Room UV	CFM	0	0	0	0	0	
Number of In Room UV Type	Quantity	0	0	0	0	0	
In Room Air Cleaner (Fan Filter Type) (See Eq 7-4 in Instructions Tab)	CFM	0	0	0	0	0	
Number of In Room Air Cleaners (Fan Filter type)	Quantity	0	0	0	0	0	
Equivalent Clean Air per Technology							
Outdoor Air	CFM	200	200	200	200	200	
$V_{ECAi,filter}$	CFM	0	960	1,232	0	0	
$V_{ECAi,uv,hvac}$	CFM	0	0	0	960	0	
$V_{ECAi,rac,hvac}$	CFM	0	0	0	0	0	
$V_{ECAi,rac,space}$	CFM	0	0	0	0	1,050	
$V_{ECAi,irac,uv}$	CFM	0	0	0	0	0	
$V_{ECAi,irac,fanfilter}$	CFM	0	0	0	0	0	
Results							
Total Equivalent Clean Air ($V_{ECAi,existing}$)	CFM	200	1,160	1,432	1,160	1,250	**0**
Occupant Count Method (Design or IRMM)	Method	IRMM	IRMM	IRMM	IRMM	IRMM	
ECAi Provided by the Option	**CFM/person**	**6.7**	**38.7**	**47.7**	**38.7**	**41.7**	
Does $V_{ECAi,existing}$ meet $V_{ECAi,target}$?		No	No	Meets 241	No	Meets 241	





If $V_{ECAi,target}$ is not met							
$V_{ECAi,differential}$ still required	CFM	1000	40		40		
or, $P_{z,IRMM}$ limit for existing configuration	people	5	29		29		

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From “Analysis of a Building in Turkey: How Much Condensation Occurs With Various Insulation Thicknesses?” by Gökhan Kahraman, Erdem Isik

The equation for temporal one-dimensional heat conduction in a multilayer wall can be written as follows:

$$k_j * \frac{\partial^2 T_j}{\partial x^2} = \rho_j * c_j * \frac{\partial T_j}{\partial t}, \qquad J = 1,2, \dots\dots.., M \tag{1}$$

In *Equation 1*, *x* and *t* are space and time coordinates, respectively. T_j is the temperature of the *j*th layer, while ρ_j, c_j, and k_j are the density, specific heat, and thermal conductivity of the *j*th layer, respectively. To solve *Equation 1*, it is necessary to specify an initial condition and two boundary conditions. As an initial condition, a random uniform heat zone can be assumed. Boundary conditions for the external and internal wall surfaces are defined in *Equations 2* and *3*, respectively:

$$-k_1 * \left(\frac{\partial T}{\partial x}\right)_{x=0} = h_e * (T_e(t) - T_{x=0}) \tag{2}$$

$$-k_M * \left(\frac{\partial T}{\partial x}\right)_{x=L} = h_i * (T_{x=L} - T_i) \tag{3}$$

In *Equation 2*, h_e is the combined heat transfer coefficient on both sides, T_e is the external temperature, and $T_{x=0}$ is the temperature at point 0 of the x coordinate of the building component. In *Equation 3*, h_i is the combined internal heat transfer coefficient, T_i is the internal temperature, and $T_{x=L}$ is the temperature value at point *L* of the x coordinate of the building component.

For the provinces of Antalya, Istanbul, Elazıg, and Erzurum, the internal temperature of the building was taken as 19°C (66°F). Average external temperatures by month are shown in Table 3.[20]

As a result of solving *Equation 1*, the heat flux formula to be used for the condensation calculation was obtained, as shown in *Equation 4*:

$$q = U * \Delta T \qquad \text{(W/m2)} \tag{4}$$

In *Equation 5*, the formula for the total heat permeability coefficient of the building component is shown:

$$\frac{1}{U} = \frac{1}{\propto_i} + \frac{1}{R_e} + \frac{1}{\propto_e} \tag{5}$$

In *Equation 5*, $\frac{1}{\propto_i}$ is defined as the surface convection resistance of the inner surface ($m^2K{\cdot}W$), $\frac{1}{R_e}$ as the total thermal conductivity resistance ($m^2K{\cdot}W$), and #$\frac{1}{\propto_e}$ shows the surface convection resistance of the outer surface ($m^2K{\cdot}W$).

After calculating the heat flux via Equation 4, the calculation method for the temperature values for each surface of the building component shown in Equation 6 was applied:

$$T_j = T_{j-1} - R_{j-1} * q \qquad \text{(°C)} \tag{6}$$

With *Equation 6*, after the temperature differences were found for each surface of the building component, the water vapor pressures (Pa) corresponding to each temperature were determined. The relative humidity ratios were then determined for internal and external conditions and multiplied by the water vapor pressures corresponding to the internal and external temperatures. In this case, the resulting graph line forms the boundary line for the occurrence of condensation. If the relative humidity graph line created for the surfaces coincides with the boundary line, we can say that condensation will start at the point of overlap.

To calculate the amount of condensate on the walls of heated buildings, one-dimensional steady-state conditions are accepted. Air movements through the building elements are not considered. It is assumed that the moisture transfer is only through water vapor diffusion. The formula for calculating the amount of condensation is shown in *Equation 7*.[20]

$$g_{sw} = \delta * \left(\frac{P_i - P_{sw}}{S_{dT} - S_{dsw}} - \frac{P_{sw} - P_d}{S_{dsw}}\right) \quad (\mathrm{kg/m^2}) \tag{7}$$

In *Equation 7*, g_{sw} denotes the water condensed in one second. δ is the water vapor diffusion resistance that shows minimal changes depending on temperature and barometric pressure. In this calculation, the effects of these variables were neglected and taken as $\delta = 2 \times 10^{-10}$ (kg/m.s.Pa). P_i and P_d represent partial water vapor pressure, while P_{sw} represents saturated water vapor pressure. S_{dT} is defined as the thickness of the total air layer showing the resistance equivalent to the resistance of a building element layer to the passage of water vapor. S_{dsw} is defined as the thickness of the still air layer and shows the resistance equivalent to the resistance of a structural element layer to the passage of water vapor, as calculated with Equation 8:

$$S_{dw} = \mu * d \tag{8}$$

In *Equation 8*, µ represents the water vapor diffusion resistance coefficient and is a physical property of the building material. *d* refers to the thickness of the building material in meters.