CODE NOTES

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BUILDING TECHNOLOGIES PROGRAM

ANSI/ASHRAE/IES Standard 90.1-2010

Kitchen Exhaust

Kitchen and dining facilities use a large amount of energy per floor area. Kitchen exhaust hoods contribute greatly to that energy use. Energy is used both to operate fans and to heat and cool makeup air that is then exhausted.

ANSI/ASHRAE/IES Standard 90.1-2010 sets energy efficiency requirements for kitchen exhaust hoods. Energy can be saved by using transfer air—conditioned air from adjacent spaces—as much as possible for replacement air, minimizing the need for conditioned makeup air. In larger kitchens, fan energy is saved by reducing airflow when cooking activity is low.

Two mandatory requirements apply to all kitchens: (1) makeup air is limited to maximize transfer air, and (2) short-circuit hoods are not allowed. Short-circuit hoods inject more than 10% of unconditioned makeup air directly into the hood rather than into the space. Recent research has found that these hoods require higher airflows to effectively contain smoke, increasing overall energy use.

In larger kitchen facilities, ASHRAE Standard 90.1-2010 limits the volume of air for kitchen exhaust to an appropriate but not excessive level. Larger kitchens must also meet one of three energy efficiency requirements: (1) use 50% transfer air, (2) use variable speed hood fans, or (3) use exhaust heat recovery.

The variable speed fan option or demand ventilation system (DVS) includes controls that sense temperature and smoke under the hood and vary the speed to maintain safe and effective kitchen exhaust. The DVS must be applied to 75% of total hood flow, must be able to reduce exhaust flow to half, and must modulate makeup airflow. Controls maintain hood airflow at the levels needed to capture and contain smoke, effluent, and combustion products. Performance testing verifies proper operation of the DVS.

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Heat recovery options usually include coils or a heat exchanger that extracts heat from kitchen exhaust and uses the heat to preheat ventilation air or preheat service hot water. A heat recovery system for a hood with greasy exhaust air requires a wash-down system to automatically clean the coil, which continually consumes detergent. Heat recovery systems are less expensive for oven and other hoods where grease cleaning is not necessary. To qualify, the heat recovery device must be listed with a heat recovery effectiveness of 40%. In most cases, a DVS is preferred over heat recovery units because of initial cost and ongoing maintenance costs.

Definitions[1]

Demand ventilation system (DVS): A system that includes controls that sense temperature and smoke under the hood and vary the exhaust and makeup fan speeds to maintain safe and effective kitchen exhaust both in idle and full cooking conditions.

Demand control ventilation (DCV): A ventilation system capability that provides for the automatic reduction of outdoor air intake below design rates when the actual occupancy of spaces served by the system is less than design occupancy.

Makeup air (dedicated replacement air): Outdoor air deliberately brought into the building from the outside and supplied to the vicinity of an exhaust hood to replace air, vapor, and contaminants being exhausted. Makeup air is generally filtered and fan-forced, and it may be heated or cooled depending on the requirements of the application. Makeup air may be delivered through outlets integral to the exhaust hood or through outlets in the same room.

Replacement air: Outdoor air that is used to replace air removed from a building through an exhaust system. Replacement air may be derived from one or more of the following: makeup air, supply air, transfer air, and infiltration. However, the ultimate source of all replacement air is outdoor air. When replacement air exceeds exhaust, the result is exfiltration.

Transfer air: Air transferred from one room to another through openings in the room envelope, whether it is transferred intentionally or not. The driving force for transfer air is generally a small pressure differential between the rooms, although one or more fans may be used.

1 Demand control ventilation, makeup air, replacement air, and transfer air definitions from ASHRAE Standard 90.1-2010.

ASHRAE Standard 90.1-2010 Requirements

The first two requirements apply in all kitchens. The third and fourth apply in larger facilities where total hood exhaust airflow exceeds 5,000 cfm.

1. (6.5.7.1.1) "Short-circuit" airflow does not exceed 10% of exhaust rate.
2. (6.5.7.1.2) Conditioned makeup airflow to the kitchen is limited.
3. (6.5.7.1.3) A kitchen/dining facility with total kitchen exhaust airflow greater than 5000 cfm must limit each hood's exhaust flow rate.
4. (6.5.7.1.4) A kitchen/dining facility with total kitchen exhaust airflow greater than 5000 cfm must meet one of the following energy saving requirements:
   (a) at least 50% of all replacement air is transfer air,
   (b) at least 75% of the exhaust air is controlled by a DVS to reduce exhaust and replacement air system airflow rates up to 50%, or
   (c) at least 50% of the total exhaust airflow has energy recovery devices.

Plan Review

Plan review requires the following four steps. An instruction set with blank tables is attached to assist with determining compliance.

1. Verify that short-circuit air delivery limits are not exceeded.
2. Determine transfer air percentage used as replacement air.
3. Verify maximum individual hood airflow is not exceeded where limited.
4. Determine efficiency requirements of 6.5.7.1.4 are met where required using one of the three prescribed methods.

Inspection

1. Verify that hood airflow installed in field matches the schedule(s) in specifications or on plans.
2. If energy efficiency devices are required, verify presence of DVS controls and interface with the makeup airflow control or energy recovery devices.
3. When DVSs are installed, review documentation of performance testing, including low flow performance testing.

Transfer Air Scheduling

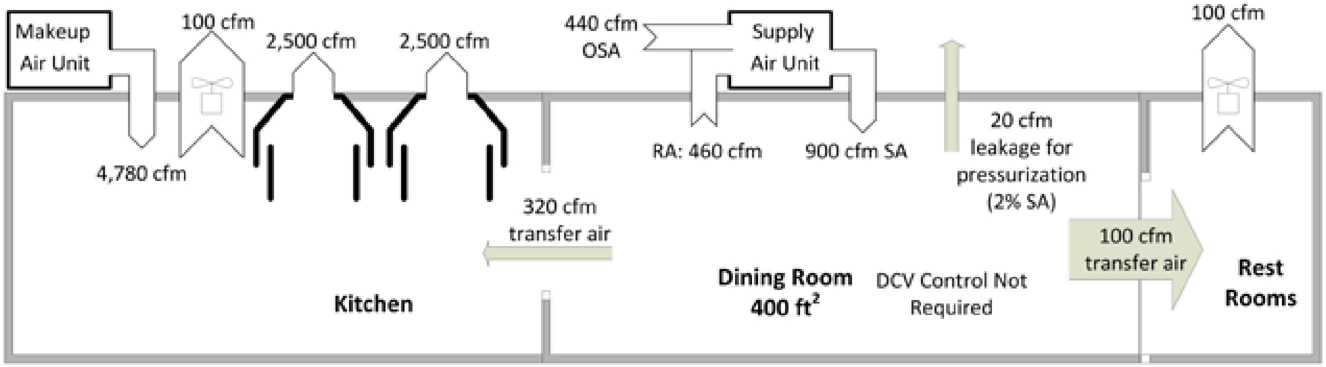
For transfer air options to be valid, the HVAC systems in adjacent spaces should operate on a similar schedule to the kitchen exhaust hoods. If schedules are not similar, it is not reasonable to use the "more than 50% transfer air" option to avoid installation of DVS(s) or energy recovery devices. In situations with DVS(s) and some overlap in scheduling, it is beneficial to use transfer air as much as possible to reduce makeup air; however, this is not a current code requirement and requires advanced controls to integrate airflows of the DVS, the makeup air unit, and the supply air unit for the adjacent spaces.

Examples

Several examples are included to illustrate the range of conditions that might trigger different code requirements. For all the examples, the code requires that the makeup air unit airflow is limited to the kitchen exhaust less available transfer air from adjacent spaces, and that short-circuit hoods not be used. The examples are intended to illustrate different transfer

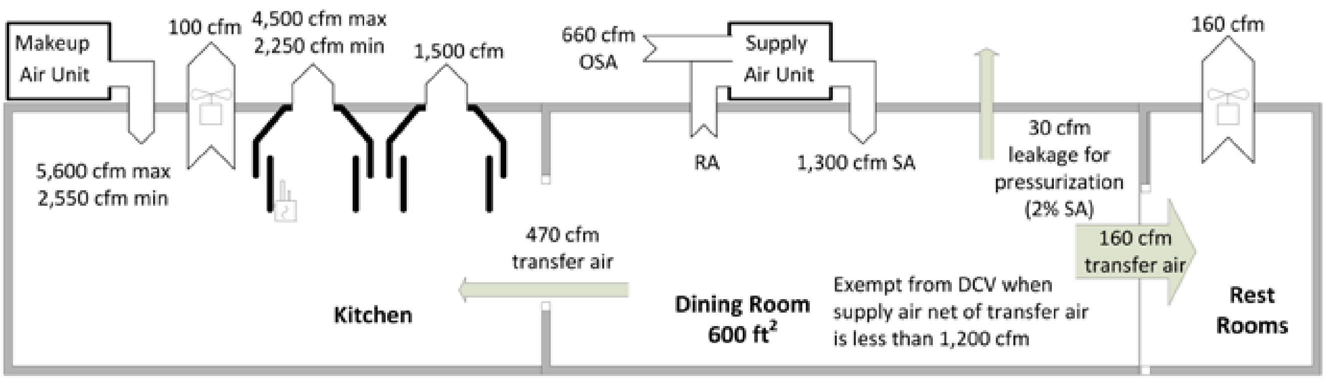
Kitchen Exhaust *(Continued)*

air conditions and when DVS(s) or energy recovery devices are required. Example A shows a kitchen that does not have more than 5,000 cfm of hood exhaust. This situation only requires that the makeup air unit airflow is limited to the kitchen exhaust less available transfer air from adjacent spaces, and that short-circuit hoods not be used.



Example A. Kitchen hoods 5,000 cfm total or smaller; kitchen exhaust demand ventilation system not required. Kitchen makeup is limited.

Example B shows a kitchen with more than 5,000 cfm of hood exhaust. In addition to a limitation on makeup air, this kitchen requires an energy saving option. There is not enough transfer air to meet the 50% replacement air requirement, so a DVS is used. The makeup air unit also requires variable airflow control, interfaced to the exhaust hood with the DVS. In this example, only one of the two exhaust fans needs a DVS to control 75% of the exhaust airflow.

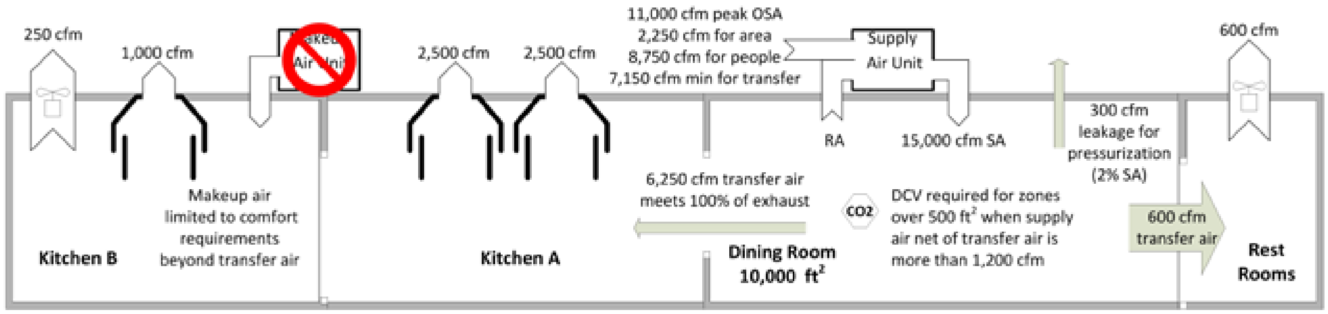


Example B. Kitchen hoods cfm total more than 5,000 cfm; demand ventilation system required on 75% of total kitchen exhaust air.

In both Examples C and D, there are two kitchens and different design approaches are taken. Each kitchen has 5,000 cfm of hoods or less; however, because the entire kitchen/dining facility has more than 5,000 cfm of exhaust hoods, the requirements for the larger system apply—individual exhaust hood airflows must be checked against the maximum airflow table and one of the three energy saving methods must be met.

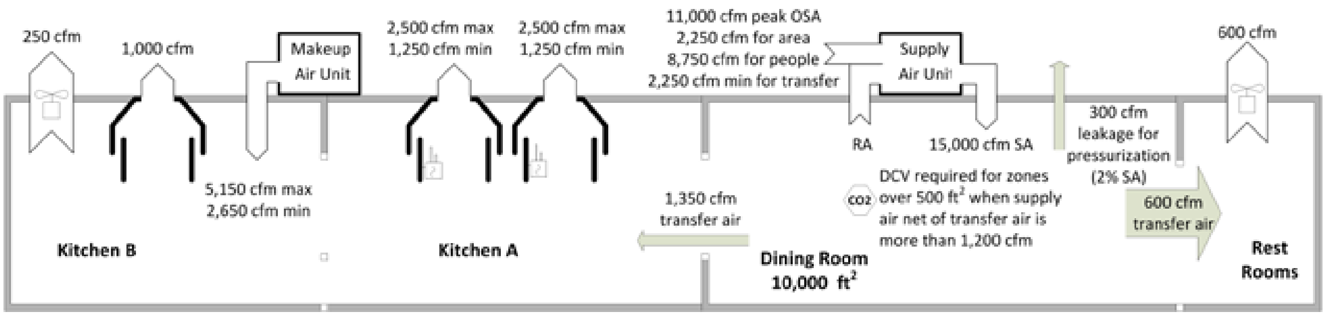
Kitchen Exhaust *(Continued)*

In Example C, the designer has chosen to supply more than 50% of replacement air with transfer air, and can meet the entire replacement air requirement with transfer air, eliminating the need for a kitchen makeup air unit. A lower minimum outside airflow could be selected for the dining room, and a makeup air unit would be needed in the kitchen. Meeting at least 50% of the kitchen exhaust replacement requirement with transfer air means that a DVS is not required.



Example C. Kitchen hoods total more than 5,000 cfm; more than 50% transfer air; kitchen exhaust demand ventilation system not required. In this example, the designer could choose to have the dining room supply minimum lower, but as long as available transfer air is more than 50% of kitchen exhaust, a kitchen exhaust demand ventilation system would not be required.

In Example D for the same kitchen and adjacent space situation, the designer has reduced the minimum dining outside air and chosen to include a makeup air unit and DVSs on two of the hoods. Based on the current language and definition of DCV, either approach would comply with both Section 6.4.3.9 (see separate Demand Controlled Ventilation Code Note[2]) and Section 6.5.7.1 of ASHRAE Standard 90.1-2010 Note that the DCV is a mandatory requirement, and some reduction of ventilation air in the dining spaces must be included, while the kitchen ventilation requirement is prescriptive and the savings generated can be traded off with another energy saving strategy using the performance approach in Section 11 of ASHRAE Standard 90.1-2010.



Example D. Kitchen hoods total more than 5,000 cfm. In this example, the designer could choose to have the dining room supply minimum at 2,500 cfm, and then transfer air would be less than 50% of kitchen exhaust and a demand ventilation system would be required.

2 U.S. Department of Energy, Building Energy Codes Program. 2012. "Demand Controlled Ventilation – Code Notes," Building Energy Codes Resource Center, Article ????. U.S. Department of Energy, Washington, D.C. Available online at: www.energycodes.gov/help/notes.stm

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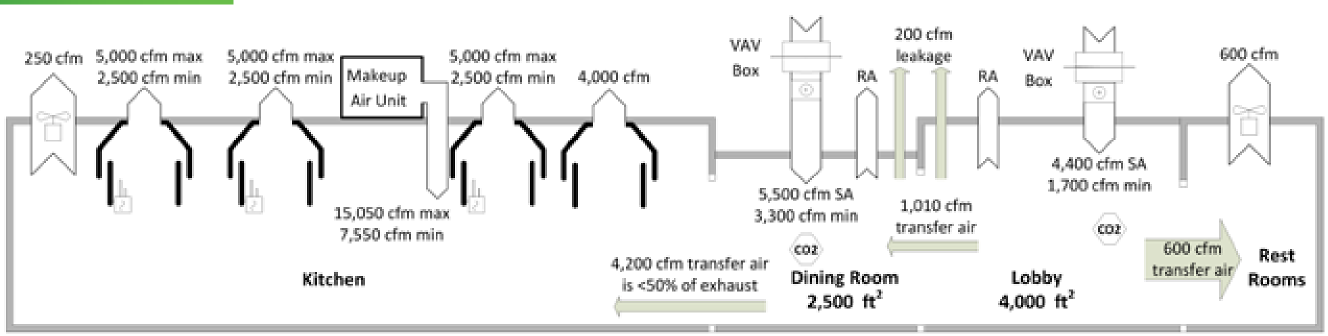
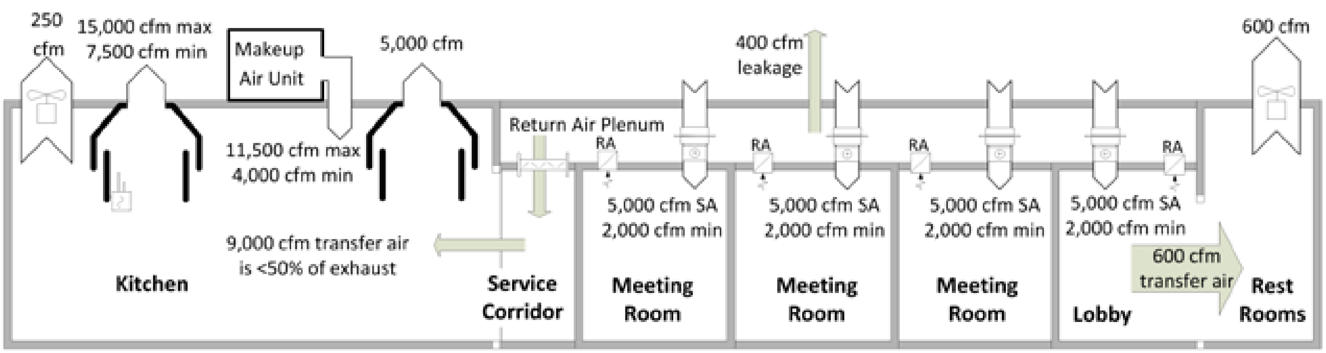
Example E shows the case when adjacent spaces are served by variable air volume (VAV) reheat systems. In this case, increasing the zone minimum airflow above that required for ventilation will likely require more use of reheat; so, unlike Example C, providing more transfer air is inefficient and inappropriate. An appropriate interpretation when transfer air is coming from VAV reheat systems would be to require no more "available transfer air" be considered for makeup air unit sizing than the lowest airflow setpoint on the VAV boxes under DCV control. This means that less than 50% of replacement air is coming from transfer air, resulting in a requirement for DVSs or heat recovery. For the hoods, DVSs will likely be installed because they are less expensive than heat recovery options, especially in hoods that have greasy exhaust air. To properly control kitchen pressure relationships to adjacent spaces, it is best to maintain a constant minimum VAV box and transfer airflow so that kitchen exhaust can be properly balanced dynamically with the makeup air unit. More advanced control strategies may use pressure controls to adapt the makeup air unit airflow to variable transfer air as dining and lobby airflows adjust based on DCV and comfort requirements.



Example E. Kitchen hoods total more than 5,000 cfm; less than 50% transfer air so kitchen exhaust demand ventilation system is required.

Kitchen Exhaust *(Continued)*

Example F explores some interpretation around what is “available” transfer air. With a VAV system, this time with no DCV requirement, the box minimum air can be transferred via the return plenum or ducted return, even if sound attenuation ductwork or a fire damper is required. There is some interpretation required here, but all spaces that are adjacent to the kitchen or kitchen service corridor can make transfer air available, and spaces with easy return access to the kitchen could be considered sources of available transfer air. When exhaust hoods have total airflow greater than 5,000 cfm and the available transfer air is less than 50% of the hood exhaust, either heat recovery or a DVS for exhaust hoods will be required.



Example F. Kitchen hoods total more than 5,000 cfm; less than 50% transfer air so kitchen exhaust demand ventilation system would be required.

Code Citations:

ASHRAE Standard 90.1-2010*

6.5.7.1 Kitchen Exhaust Systems

6.5.7.1.1 Replacement air introduced directly into the hood cavity of kitchen exhaust hoods shall not exceed 10% of the hood exhaust airflow rate.

6.5.7.1.2 Conditioned supply air delivered to any space with a kitchen hood shall not exceed the greater of:

a. the supply flow required to meet the space heating or cooling load
b. the hood exhaust flow minus the available transfer air from adjacent spaces. Available transfer air is that portion of outdoor ventilation air not required to satisfy other exhaust needs, such as restrooms, and not required to maintain pressurization of adjacent spaces.

6.5.7.1.3 If a kitchen/dining facility has a total kitchen hood exhaust airflow rate greater than 5000 cfm then each hood shall have an exhaust rate that complies with Table 6.5.7.1.3. If a single hood, or hood section, is installed over appliances with different duty ratings, then the maximum allowable flow rate for the hood or hood section shall not exceed the Table 6.5.7.1.3 values for the highest appliance duty rating under the hood or hood section. Refer to ASHRAE Standard 154 for definitions of hood type, appliance duty, and net exhaust flow rate.

ANSI/ASHRAE/IES Standard 90.1-2010

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Exception: At least 75% of all the replacement air is transfer air that would otherwise be exhausted.

6.5.7.1.4 If a kitchen/dining facility has a total kitchen hood exhaust airflow rate greater than 5000 cfm then it shall have one of the following:

a. At least 50% of all replacement air is transfer air that would otherwise be exhausted.
b. Demand ventilation system(s) on at least 75% of the exhaust air. Such systems shall be capable of at least 50% reduction in exhaust and replacement air system airflow rates, including controls necessary to modulate airflow in response to appliance operation and to maintain full capture and containment of smoke, effluent and combustion products during cooking and idle.
c. Listed energy recovery devices with a sensible heat recovery effectiveness of not less than 40% on at least 50% of the total exhaust airflow.

6.5.7.1.5 Performance Testing: An approved field test method shall be used to evaluate design airflow rates and demonstrate proper capture and containment performance of installed commercial kitchen exhaust systems. Where demand ventilation systems are utilized to meet 6.5.7.1.4, additional performance testing shall be required to demonstrate proper capture and containment at minimum airflow.

Table 6.5.7.1.3 Maximum Net Exhaust Flow Rate, CFM per Linear Foot of Hood Length

Type of Hood	Light Duty Equipment	Medium Duty Equipment	Heavy Duty Equipment	Extra Heavy Duty Equipment
Wall mounted canopy	140	210	280	385
Single island	280	350	420	490
Double island (per side)	175	210	280	385
Eyebrow	175	175	Not allowed	Not allowed
Backshelf/Pass-over	210	210	280	Not allowed

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ASHRAE Standard 90.1-2007**

6.5.7.1 Kitchen Hoods

Individual kitchen exhaust hoods larger than 5000 cfm shall be provided with makeup air sized for at least 50% of exhaust air volume that is

a. unheated or heated to no more than 60°F and
b. uncooled or cooled without the use of mechanical cooling.

Exceptions:

a. Where hoods are used to exhaust ventilation air that would otherwise exfiltrate or be exhausted by other fan systems.
b. Certified grease extractor hoods that require a face velocity no greater than 60 ft/s.

International Energy Conservation Code***

There are no specific requirements for kitchen exhaust systems in the 2009 or 2012 International Energy Conservation Code.

References

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EERE Information Center
1-877-EERE-INFO (1-877-337-3463)
eere.energy.gov/informationcenter

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Building Energy Codes
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Plan Review Calculations

For this complex set of requirements, plan review is organized with a set of tables that can be used to verify compliance. In the tables, reference is made to the plan check steps. Once the instructions and tables are laid out, several examples are reviewed to cover some of the different situations that can occur. For plan review efficiency, the requirements are approached in a different order than outlined in the standard.

1. **Verify that short-circuit air delivery limits are not exceeded.**
   a. Tabulate the hood IDs and their airflows from the mechanical plans or specifications.
   b. Indicate any short-circuit airflow (makeup air introduced inside the hood). If no hoods have makeup air introduced directly inside the hood, then the requirements of 6.5.7.1.1 are met (skip to Step 2).
   c. Calculate the percentage of (short-circuit) air introduced inside each hood.
      [Short-circuit airflow] / [Maximum airflow]
   d. Verify all hoods are below 10% directly introduced makeup air.

2. **Determine transfer air percentage.**
   a. Total all exhaust hood airflows.
   b. Total all other kitchen exhaust airflows in cfm, such as dishwasher or general exhaust fans.
   c. Find kitchen replacement air.
      [2a: Hood exhaust cfm] +
      [2b: Other kitchen exhaust cfm]
   d. Find kitchen makeup air unit airflow from plans (total if more than one unit).
   e. Find imputed transfer airflow, cfm.
      [2c: Kitchen replacement airflow cfm] –
      [2d: Kitchen makeup unit total cfm]
   f. Calculate imputed transfer air percentage.
      [2e: Imputed transfer airflow cfm] /
      [2c: Kitchen replacement airflow cfm]

   g. Find available transfer air.
      i. Locate areas adjacent to kitchen. If there multiple separated kitchens, then complete the calculation separately for each one.
      ii. Note design supply airflow from mechanical schedules.
      iii. Note available transfer air. (a) For single zone units this will be ventilation air as shown on plan schedules. Note that ventilation air is usually in the range of 10% to 30% of supply air.
      For VAV boxes serving additional areas, it will be **the lesser of** (b) individual zone box minimum air or (c) total VAV fan ventilation air. For a VAV system serving only areas adjacent to the kitchen, it will be VAV system ventilation air at maximum ventilation efficiency (Ev).
      iv. Total the adjacent space gross transfer air based on applicable airflows from 2g.iii.
      v. Total exhaust air from non-kitchen areas near adjacent spaces, such as restrooms.
      vi. Total envelope leakage to maintain adjacent space pressurization. If a calculated amount is not presented, this can be estimated between 2% of supply air for new, tight construction to 10% for an alteration of older loose construction.
      vii. Available net transfer air in cfm is:
      [2g.iv: Gross transfer air] –
      [2g.v: Non-kitchen exhaust] –
      [2g.vi: Leakage].

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h. Determine actual transfer percentage.
   [2g.vii: Available transfer airflow cfm] /
   [2c: Kitchen replacement airflow cfm]

i. Determine allowed makeup air. (Note: if the imputed percentage is greater than the actual percentage, this indicates either the makeup air limit is exceeded or there is a need for more air to meet comfort conditions.)
   [2c: Kitchen replacement airflow cfm] -
   [2g.vii: Available transfer airflow cfm]

j. If the makeup air [2d] is greater than allowed makeup air [2i], it may be justified to meet the cooling load in the kitchen; justification can be requested from applicant, or the cooling requirement can be calculated based on the sensible cooling load, cooling setpoint, and supply air temperature. The needed airflow can be approximated.
   [Sensible cooling load, Btu/hr] / { 1.085 x
   ([Setpoint, °F] - [Supply air temperature, °F])}

k. Determine if the kitchen makeup air meets code requirements. It does if the scheduled makeup air [2d] is no more than the greater of the allowed makeup air [2i] or the makeup air required for cooling [2j].

3. **Verify maximum hood airflow is not exceeded.**
   a. If total hood airflow (step 2a) is less than 5,000 cfm this kitchen facility is exempted from this requirement; skip to step 4.
   b. If actual transfer air percentage determined in Step 2h is greater than 75%, this kitchen facility is exempted from this requirement; skip to step 4.
   c. For each hood, list equipment duty.
   d. Note allowed cubic feet per minute per foot of hood from table 6.5.7.1.3.
   e. Note length of hood from plans.
   f. Calculate allowed airflow for each hood.
      [3d] x [3e]
   g. Verify each hood airflow is no more than the maximum allowed hood airflow in cfm.

4. **Determine efficiency requirements of 6.5.7.1.4 are met.**
   a. If total hood airflow of all kitchens in the kitchen dining facility is 5,000 cfm or less, there are no further efficiency requirements.
   b. If actual transfer air percentage is 50% or more, there are no further efficiency requirements.
   c. Meet efficiency requirement with DVS.
      i. Total maximum airflow of all hoods equipped with DVSs that reduce airflow by 50%.
      ii. Determine percentage of the kitchen exhaust air served by such systems:
         [4c.i: Hood airflow with DVS cfm] /
         [2c: Kitchen replacement airflow cfm]
      iii. Determine if percentage airflow with DVS [4c.ii] is greater than 75%.
   d. If requirements are not met through 4a, 4b, or 4c, then heat recovery must be provided.
      i. Total maximum airflow of all hoods equipped with energy recovery devices that have a sensible heat recovery effectiveness of 40% or more.
      ii. Determine percentage of the kitchen exhaust air served by such systems:
         [4d.i: Hood airflow with heat recovery] /
         [2c: Total kitchen replacement air]
      iii. Determine if percentage airflow with heat recovery [4d.ii] is at least 50%.

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Kitchen Hood Working Table

1a Hood ID	1a Maximum Airflow (cfm)	1b Short-Circuit Airflow (cfm)	1c Percent Short Circuit	1d Meets Req'mt (< 10%)	3c Hood Duty (L,M,H, XH)	3d Allowed cfm per foot of Hood	3e Hood Length	3f Allowed Airflow (cfm)
2a:		Total exhaust all hoods in facility, cfm						
2b:		Total non-hood kitchen exhaust						
2c:		Total kitchen replacement air						

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Transfer Air and Makeup Air Validation

2c		Total kitchen replacement air, cfm		
2d:		Total kitchen makeup airflow (max) cfm		
2e:		Imputed transfer airflow ([2c] - [2d])		
2f:		Imputed transfer percentage ([2e] / [2c])		
2g:		**Find Available Transfer Air**		
2g.i	**2g.ii**	**2g.iii(a)**	**2g.iii(b)**	**2g.iii(c)**
Adjacent space unit or box ID	**Supply airflow, cfm**	**Adjacent space single zone <u>ventilation</u> cfm**	**Adjacent space VAV box minimum cfm**	**VAV main system ventilation cfm at maximum Ev**
Total Above				
2g.iv		Available gross transfer air, cfm ([2g.iii(a)] + min([2g.iii(b)] + [2g.iii(c)]))		
2g.v		Non-kitchen adjacent space exhaust air, cfm		
2g.vi		Estimated envelope leakage to maintain pressurization of adjacent spaces (2% to 10% of supply air)		
2g.vii		Net available transfer air, cfm ([2g.iv] - [2g.v] - [2g.vi])		
2h		Actual transfer percentage ([2g] / [2c])		
2i		Allowed makeup air based on available transfer air ([2c] - [2g.vii])		
2j		Allowed makeup air based on required comfort cooling		
2k.		Determine if the kitchen makeup air meets code requirements		

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Verify Maximum Hood Airflow is Not Exceeded

Step	Reference	Criteria	Determination (Y/N)
3a	2a:	If total hood airflow [2a] does not exceed 5,000 cfm, hood airflow limits are met.	
3b	2h:	If actual transfer percentage [2h] is at least 75%, hood airflow limits are met.	
3c-3f	If either of the above is true, skip to step 4. If neither of the above is true, then return to the "Kitchen Hood Working Table" and complete steps 3c through 3f.		
3g	[1a] ≤ [3f]	Check that each hood's airflow [1a] on the the "Kitchen Hood Working Table" does not exceed maximum allowed airflow [3f].	

Kitchen Exhaust Energy Efficiency Determination

Step	Reference	Criteria	Determination (Y/N)
4a	2a:	If total hood airflow (2a) does not exceed 5,000 cfm, efficiency requirements are met.	
4b	2h:	If actual transfer percentage (2h) is 50% or more, efficiency requirements are met.	
If one of the above is not true, then one of the following (4c or 4d) must be met:			
4c.i		Total hood airflow with demand ventilation systems that reduce airflow by 50%	
4c.ii		Percentage airflow with DVS ([4c.i] / [2c])	
4c.iii	If 4c.ii is greater than 75%, efficiency requirements are met.		
4d.i		Total hood airflow with energy recovery systems with a sensible heat recovery effectiveness of 40% or more	
4d.ii		Percentage airflow with heat recovery ([4d.i] / [2c])	
4d.iii	If 4d.ii is at least 50%, efficiency requirements are met.		

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