Air Conditioning and Ventilation for Fast Food Restaurants

Serving counter in a McDonalds restaurant

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Introduction

On a long road trip or during lunch time on the move between two meetings, have you sometimes felt the need to look around for a place to 'grab a bite'? While small eateries have mushroomed all over the place, a hygienically safe place for a quick bite is what you really need on such occasions. A few operators in the food industry have recognised this need as a business opportunity. This in turn has brought the discipline of HVAC into the food industry.

The advent of McDonalds in India about 20 year ago brought in the concept of western style fast food restaurants. These restaurants have provision of central air conditioning in the seating area as well as the kitchen. Currently there are about 250 such restaurants operating in Indian cities. The strategy used in popularizing such restaurants is to serve standard menus in clean, hygienic and comfortable environment at a price considered reasonable even by Indian standards. Hence these restaurants are very popular with the youth of modern India. To maintain low meal prices, the owners must use technology inputs to reduce the operating costs of the air conditioning and ventilation system, and these are described later.

Basics of HVAC System for a Cooking Zone

The function of any HVAC system, as we know, is to

- control temperature and humidity,
- provide clean filtered air,
- ensure proper air movement, and
- induct fresh air into the space.

In addition to these, the HVAC system for a kitchen needs to

- extract heat,
- extract smoke and effluents generated during cooking, and
- contain odour and prevent it from spreading to the dining and other areas.

This enables mass production of fast food in a controlled and hygienic environment. However, all this is easier said than done. This article aims to provide an overview of the guidelines and trends that are currently being followed. It will also highlight a few difficulties in design, installation, operation and maintenance of the appropriate HVAC system for this application.

About the Author

In her career spanning over two decades in the field of HVAC, **Sangita Jhangiani** has designed HVAC systems for varied applications. These include laboratories, data centres, switch centres, mixed use buildings, retail outlets, residential complexes and corporate offices. She is working with McDonalds India as a consultant. Being a LEED Accredited Professional, she is committed to build in green concepts in her work. She can be contacted at *sangita@enova.co.in*

At this juncture, it is important to note that it is not necessary to air condition the kitchen, but provision of ventilation is a must. Air conditioning addresses the issue of human comfort which in turn enhances hygiene levels in the cooking process. Ventilation addresses effective removal of smoke and heat which is absolutely essential for the safety of the people working in that environment. Non removal of smoke can cause breathing difficulties and can even be fatal.

The effluents (smoke, oil vapours etc.) which are generated during cooking are removed by placing kitchen ventilation hoods over the cooking equipment. The air which is exhausted has to be made up. Without the make-up air provision, the ventilation process would be rendered ineffective. In addition to this, the cooking process may also use up the oxygen present in the air. Hence air replenishment is a must.

Kitchen Appliances

Heat in the kitchen is generated mainly by the cooking equipment and process. Some of the equipment used for cooking could be

- Gas fired or electric burners
- Ovens
- Fryers
- Clamshell grills

Heat generated from the equipment is transferred to the ingredients used in cooking. The cooking process generates a "plume", comprising of a mass of hot air. The plume, being hot, tends to rise up. The kitchen hood is designed to capture the plume.

The three modes of heat transfer that we know are by means of conduction, convection and radiation. The heat of conduction and convection is removed by capturing the plume and exhausting it to the outside. The heat from equipment due to radiation cannot be captured by the hood and is transmitted into the kitchen space.

ASHRAE Handbook – Fundamentals, Chapter 18, Tables 5a, 5b and 5c provide a comprehensive list of kitchen equipments, along with details of heat dissipated from hooded and non hooded equipments. The HVAC designer can use this data to compute the heat gain from equipments.

In addition to the above, there are other electrical equipments used in a kitchen like grinders, pulverisers, slicers, steamers, dough mixers – to name a few. At times there could be a heated preparation table used for assembly, or a table with a refrigerated cabinet below. Other refrigerated equipments like ice cream makers, cold beverage dispensers and plug in refrigerators are small equipments with built in condensers that dissipate heat.

It may be noted that all the above equipments are not operated simultaneously. Hence it is advisable to prepare a list of all the connected equipment and their rated capacity. A diversity factor should be applied to the load. Usage could be discussed with the end users to arrive at a mutually agreed diversity factor, which could range between 10 and 30 %.

For an air conditioned kitchen, heat gain from building materials (walls, partitions, floor, roof, ceiling, fenestration etc.), lighting and occupants should also be taken into account.

Kitchen Heat Gain

Heat gain in the kitchen is on account of

- Cooking equipments and appliances
- Outdoor air
- Occupants
- Lighting
- Building envelope (walls, floor, fenestration etc.)

The major contributors are the outdoor air and the heat gain from appliances. It is important to note that hood design is critical. If the hood is unable to capture the plume, it would cause a spill over and the HVAC equipment would not be able to work effectively.

Make-up Air Requirement and Pressurisation

The cooking process generates odours. It is therefore necessary to maintain a negative pressure in the kitchen compared to the dining area. A pressure balance diagram should be prepared to estimate the outdoor air that should be supplied to the air handling unit. The pressure balance diagram should take into account extraction through hood, miscellaneous exhaust (e.g. toilets, janitor areas etc.) and dining area pressurisation.

At this juncture, the outdoor air requirement for the dining area must also be computed. The outdoor air requirement for the dining area would be much larger than that of a fine dining restaurant, because the number of meals served per hour and

A kitchen grill

Inside the kitchen

An assembly line for burgers

the number of occupants in a fast food restaurant is substantially higher, considering the nature of its business. In addition to the number of seats, there are occupants at the serving counters in a queue rail. This should also be factored in appropriately.

The outdoor air requirement should be based on the higher of the two computations.

Kitchen Hood Extract

As mentioned earlier, the kitchen hood is meant to extract the plume. Hence make-up air has to be provided for its effective functioning. For an air conditioned kitchen, the make-up air is the largest contributor in sizing the HVAC equipment. It is, therefore, important and critical to compute the hood extract correctly. Chapter A33 of *AHSRAE 2011 Handbook – Applications* on Kitchen Ventilation provides details of extract hood flow rates based on the type of hood and its duty, that is, temperature range of the equipments.

Vats in a kitchen with hood

The hoods are provided with filters to trap grease. The use of UV lamps in hoods can be evaluated. UV lamps convert the grease into inert substance and ozone. UV lamps are effective for odour control. However, it is essential to ensure that the UV lamps are on only when the extract fan is operational.

Use of volume control dampers is not permitted in exhaust ducts as per *NFPA 96*. This makes it difficult to balance the extract through multiple hoods with a common extract fan. Use of air balancing baffles is effective in ensuring proper air balancing. Ducts should be sized to ensure that all the hoods have equal static pressure at their design exhaust flow.

The extract air from the hoods is ducted and connected to an extract air fan. The extract air for a fast food restaurant would normally be located close to other dwellings, and is a nuisance to neighbouring buildings. Hence it is essential to remove odour and grease from the extract air before it is discharged into the atmosphere. A grease collector box should to be provided in the extract air duct prior to discharge. Wet scrubbers or electrostatic precipitators (also known as dry scrubbers) may also be used for grease and odour removal prior to discharge.

To reduce the make-up air quantity, compensatory type hoods, i.e. hoods with an air curtain in the front, which allows fresh air to be directly injected into the hood, are sometimes used. However, injecting air in front of the hood has been found to scatter the plume and to render capture of the plume by the hood ineffective. Better and effective alternate hoods are being developed by some manufactures, and the food industry would soon be able to reduce its energy consumption with this improved technology.

Energy Conservation – the Need of the Hour

In a fine dining restaurant, the duration of each meal served is much longer compared to a fast food restaurant. Hence the temperature in the dining area of a fast food restaurant can be maintained at a relatively higher temperature – say, at 25 +/- 2°C. This would help to reduce the power bill.

For restaurants that require hot water, cooling units with heat recovery systems can be used. This is achieved by adding a desuperheater in the compressor discharge line to recover heat and generate free hot water for the kitchen. This in turn reduces the condensing temperature which further helps in lowering the power consumed. Thus the HVAC equipment provides cooling and hot water as well, without expense of extra energy.

Some Food for Thought for Engineers

For air cooled units, it is generally not possible to locate the outdoor units in a small size stand-alone store at an ideal location. Hence often the air circulation around the machines is inappropriate, and hot air from the condenser is bypassed to condenser inlet. This raises the condensing temperature and energy consumption. Apart from this, units located in hot and dry parts of the country also have to operate at a high ambient.

The air entering the condenser coil for an air cooled system can be pre cooled adiabatically. This would reduce the condensing temperature and build efficiency into the system by lowering the power consumption. Use of water from the condensate drain pan of the evaporator unit can be evaluated for this.

Since the kitchen hoods extract a large quantity of air, almost an equal volume (or slightly less than equal) of ambient air has to be cooled and brought into a kitchen which is air conditioned. The cooling capacity of the kitchen AHU is therefore high. To reduce the energy consumption, it is necessary to control air outflow and inflow.

This is successfully done in laboratories where the use of fume hoods is predominant. The fume hood typically has a controller, which tracks the linear movement of the sash position. This is converted to a percentage of sash opening, which changes the extract air quantity. This is achieved by varying the speed of the extract air fan motor using a variable frequency drive.

The same logic can be applied to a kitchen extract. However, the control here would be operated by sensing the temperature differential of the extract air. For example, during peak hours, when cooking is being done, the temperature of the plume would be higher. During non peak hours the temperature of the plume would be lower. The temperature differential could be used to modulate the extract air quantity. But this would create an imbalance between the supply and extract air. As mentioned earlier, the kitchen area is designed to operate under negative pressure. Hence it is necessary to modulate the outdoor air quantity in the same proportion. This is possible with a chilled water treated fresh air unit, but not advisable on a unit with a direct expansion cooling coil as it may lead to ice formation on the coil. With the onset of the variable refrigerant volume systems,

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Challenges for HVAC Design of a Fast Food Restaurant

- The location of a fast food restaurant in India typically, as compared to the West, is in a dense congested location, in proximity of other buildings.
- The footprint of a fast food restaurant is small, and the footfall and number of meals served are high.
- Fast food restaurants, in most cases, are located in buildings which do not have centralised cooling equipment. Hence HVAC equipment selection narrows down to ducted units. Identifying a suitable location for outdoor units is always a challenge. Routing of refrigerant piping, space for maintenance around the unit, and circulation space for free air movement around the outdoor unit are associated problems. Damage of piping insulation by rodents is a common maintenance issue.
- A yet bigger challenge is to identify the locations of extraction and make-up air points. The make-up air opening should be sized correctly. It should be located close to the indoor unit or else the air will not be inducted through the duct. The HVAC engineer may need to evaluate the use of a fan. While the use of a fan should be avoided, sometimes there is no alternative. The make-up air should be located away from extract points, including toilet and janitor room extracts. In a recent project, the make-up air provision was planned for and executed correctly, only to find it being blocked subsequently by the store signage!
- Frequent door openings allow outside air to enter the conditioned space. This leads to condensation on air outlets, affecting thermal comfort in the conditioned space. Power consumption of HVAC equipment increases as the compressor operates continuously to provide the desired cooling. Large openings at take-away counters add to the infiltration. Doors in the kitchen meant for material entry by the kitchen personnel are left open due to lack of training and discipline, further jeopardising the functioning of the HVAC system. Though the space is meant to be operated as a pressurised zone, lack of provision for adequate and effective suction of make-up air by HVAC equipment nullifies the intent, leading to a host of problems.
- Ingress of warm humid air into the conditioned space could affect food items. Dampness on walls and other surfaces allows fungus and bacteria to grow. Microbial growth in ducts has adverse effects on human health.

Busy time in a fast food outlet

- Air distribution scheme for a fast food restaurant is also a challenge. This is a function of the type of building the outlet is in. In most places the true ceiling height and bottom of beams are found to be low. Duct sizing to attain a working ceiling height requires working back and forth with the project architect.
- Air outlet location is also critical in a kitchen. Air outlets should be located in aisles or work space of kitchen personnel. Laminar air flow with help of perforated diffusers is recommended. This prevents air draft on the cooking equipment. Air draft over the cooking process would tend to lower its temperature. This is undesirable. The air draft could also affect the plume causing spillage into the cooking zone and ineffective capture of plume by the kitchen hood.
- Size of the AHU for the kitchen area, if it is air conditioned, is large. To fit it in and to ensure clearances required for maintenance demands thought and attention.
- Adequate care should be taken during execution. Leaky ducts and damaged insulation could cause recurring problems.
- The HVAC system must be commissioned properly before it is handed over to the operations team. This includes proper air balancing to ensure that there is no or minimum ingress of outdoor air into the space through doors and openings. Proper documentation complete with as-built drawings, equipment serial numbers, location of all serviceable units, sequence of operation, escalation matrix etc. must be provided to the end user. The maintenance team needs to be trained to service the units regularly, to clean and replace the filters, and to clean the air ducts periodically.

it is worthwhile to try and achieve a variable air volume AHU by controlling the refrigerant flow through the DX cooling coil. This would help in saving a substantial amount of energy because fresh air is the major contributor to the tonnage of the kitchen cooling unit. This concept could lead to energy saving in most other HVAC applications.

Conclusion

The concepts of basic requirements of HVAC and other services need to be imparted to all stake holders. To start with, this includes the outlet leasing team as they need to tie up the outdoor location for HVAC, refrigeration units, extract air fans along with other electrical and plumbing service requirements prior to signing up for a property. The criticality of space requirement for HVAC equipment and the location of fresh air intake, extract air duct and fan need to be understood by the architect and interior designer. In its absence the HVAC system, which comes at a cost and consumes a considerable amount of energy, cannot function the way it is intended to. ❖

Note: All photographs in this article are courtesy Hardcastle Restaurants Pvt. Ltd., the franchise for McDonalds.