A typical jet fan in a car park (note the low height of the fan)

Considerations in Car Park Ventilation System Design

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Introduction

Car parking areas in buildings are fully enclosed or partially open. Fully enclosed areas are often underground and require mechanical ventilation. A combination of natural and mechanical ventilation is normally recommended for partially open car parks.

Ventilation of car parking areas requires the designer to take care of CO emission from automobiles, and oil and petrol that may cause headaches and nausea. Additionally, smoke haze and NOx from diesel engines also need to be considered. However, the ventilation rate required to dilute CO to acceptable levels is usually enough to control the level of all the other contaminants, except when the percentage of diesel cars exceeds petrol cars.

Ventilation of car parking areas requires careful study by the designer, and should require the fire officer's approval for large buildings and multi-level car parking.

The M&E contractor would expect that the car park ventilation system would be studied by the contractor, consultant and client's engineer along with a specialist contractor prior to the tender. In addition, at the time of detailed design by the contractor, the design parameters must be cleared by the consultant and, where possible, by the fire officer.

Scope of Work

The consultant has the responsibility for the design of car park ventilation including system design and equipment capacity. The contractor is responsible for the correctness of entire system operation, including equipment and controls, that he has offered as per tender specifications. Therefore, as a specialist, the contractor would have the overall responsibility for selection, sizing and rating of the equipment, control and installation as a whole. It is necessary that the feasibility of the installation be checked by the contactor. Any discrepancy in design, which would affect the system, must be pointed out to the consultant and cleared by him prior to quoting, ordering of equipment and detailed design. It is imperative that the contractor should verify and ensure, in his

About the Author

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own contractual interest, acceptability to the fire officer before commencement of procurement and execution.

The following is intended to provide an outline of the design of a car park ventilation system, aspects of contamination caused by vehicular exhaust from the parking facility, control of CO level as well as exhaust from diesel cars.

References

- Reference should be made to National Building Code, Part 4; *Fire and Life Safety*, Part 8, Section 3 – for provisions of car parking in buildings. The local fire officer normally goes by the recommendations of NBC 2005 and its subsequent revisions, and they are binding on the MEP contractor. All fire officers are conversant with National Fire Prevention Association (NFPA – USA) codes and standards as well as NBC; therefore it is recommended that the contractor should be aware of the latest NFPA provisions applicable to the project as well as NBC 2005, as per contract specifications.
- ASHRAE Application Handbook should be referred for detailed information on car park ventilation systems, and for monitoring and control of vehicular exhaust emissions.
- ASHRAE standards should be read in conjunction with the applicable NBC standards.

If the project specifications are less stringent than NBC standards, the design or installation engineer should bring this to the consultant's notice so that the building is not built with less than the mandatory provisions for life and safety measures. A suitable claim should be made to the client/consultant if contract specifications in the tender documents do not ask for the minimum mandatory provisions.

Design Requirements

Ventilation required for a car park depends mainly on the following factors:

Minimum Ventilation Rates and CO_2 Concentration

Oxygen is consumed in the enclosed parking space by the occupants, and the CO_2 level goes on increasing. Ventilation is required to limit the CO_2 concentration. This shortfall is met by increasing the oxygen level through fresh air introduced in the car parking bays. Usually 6 air changes per hour (0.007 $m^3/m^2.s$) are specified in ASHRAE 62.1. A car parking facility with CO monitoring would require less ventilation, and 0.00025 $m^3/(m^2.s)$ can be permitted with a CO monitoring system that restores full ventilation when CO levels exceeding 25 ppm are detected. This is as allowed by *International Mechanical Code* published by the International Code Council (ICC 2012). However, unless insisted upon by the consultant, the minimum ventilation air rates should not be reduced below ASHRAE Standard 62.1.

Maximum Acceptable Level of Harmful Contaminants in Car Parking Areas

Maximum acceptable levels of CO as per ASHRAE/ICC 2012 and NBC are:

25 ppm for 8 hour exposure

35 ppm for 1 hour exposure

The designer (consultant) is expected to provide the accepted level of CO ppm for the parking facility. If tender or project specifications do not provide this information, the contractor should ask for it by raising a tender query prior to submitting the bid.

Number of Cars in Operation During Peak Time

The number of cars working (with the engines running) would vary with the type of parking facility. For distributed use such as residential building or shopping area, generally 5% of the total capacity is considered adequate. However, in residential buildings the number of cars leaving and entering the parking area will be substantially higher in the mornings (office opening time) and evenings (when people return from work); and shopping malls will be crowded at closing time, Sundays and holidays. For such areas and other places of assembly, 15 to 25% capacity is considered to be in operation. The designer's advice and confirmation must be taken for design values.

Length of Travel and Operating Time for Cars

The length of time that a car remains in operation in the parking facility depends on the car size and parking layout. More the levels of parking, more is the running time of the car within the parking area. The average time a car engine works during parking varies from 35 to 100 seconds. Again, the consultant's advice must be obtained in such cases.

System Design and Control Philosophy

Parking area ventilation must meet applicable codes, ensure adequate supply of oxygen and maintain contaminant levels below specified limits. If permitted by the local fire officer and the designer, ventilation air flows should be varied according to CO levels to conserve fan energy. If permitted by codes, multiple fans with single or multiple speed motors or with variable pitch blades may be used.

Equipment Operation for Building Car Parks

There are several ways to operate a car park ventilation system:

- Constant volume ventilation system, where fans are kept ON all the time to enable oxygen feed through fresh air. Centrifugal fans draw fresh outside air into the parking space. Large car parks may have multiple centrifugal fan rooms located in different areas, together with separate zones.

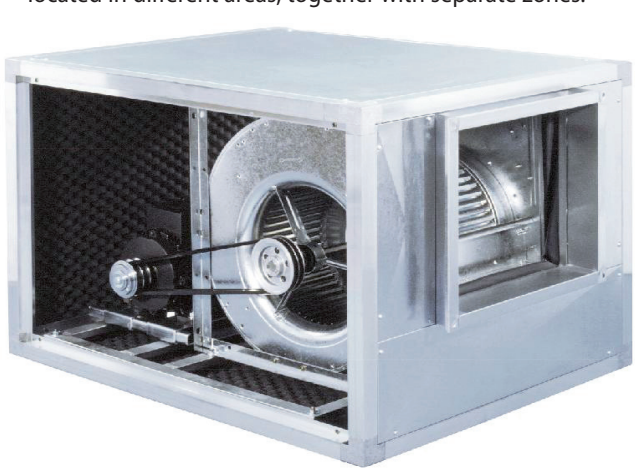

Figure 1: Centrifugal fan used in a car park

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Figure 2: Jet fan used for car park ventilation

- For large basements where high volumes of air are required and duct work cannot be accommodated, large centrifugal fans are placed in a fan room and a number of small diameter jet fans are placed in the parking space to achieve uniform air movement. The jet fans are grouped in convenient and logical zones to ventilate different parts of the car park.
- The control and monitoring system will operate and sequence the jet fans and avoid build up of CO_2 levels due to the operation of cars by increasing outside air intake. Normal ventilation as well as ventilation in fire conditions is achieved by increasing the fan speed through VFD or multiple pole motors. Either method may be used to control the speed of jet fans and centrifugal fans. Variable air volume control is achieved using two-speed axial fans or variable pitch blade fans, based on input from CO sensors.
- Large capacity smoke extract fans are located in the zones to remove the smoke from the floor as required by the control philosophy. The smoke fans are capable of handling hot smoke laden air and to run continuously until stopped by the fire officer. The entire fan assembly (including the starters, cabling and casing) is fire rated to run at 300°C for 120 minutes. The fans and associated electrics is certified by NFPA and approved by the fire officer or his approved adviser agency.

Figure 3: Smoke extract fan

Smoke extract fans are used to remove smoke from the building. Fire department personnel should have quick access to fire so that it can be extinguished and the trapped occupants can be safely moved from the area under fire. Smoke from the fire zone must be removed and replaced with fresh air from outside.

When dealing with multilevel car parking spaces, it is important to allow for safe exit of the occupants and a clear way for heavy and dense smoke in the escape routes. Smoke and exhaust dampers along with fresh air inlet dampers are required to direct fresh air to the fire floor, clear the smoke from the affected space by displacing it, and clear the way for the exit of occupants.

The architect or the consultant must be consulted if the specifications are not clear about the escape and evacuation strategy. The contractor's engineer must obtain the fire policy and escape strategy from the architect or the consultant prior to bidding for the tender. During the execution stage, the fire officer's approval for the proposal should be obtained by the architect/ consultant.

Arrangement of a large number of jet fans operating together with large capacity centrifugal/ axial fans drawing outside air is preferred over the conventional car park exhaust system having a single large capacity centrifugal fan with stand-by and ductwork, for the following reasons:

- Jet fans require small head-room as compared to large size ducts, and circulate large air flows to improve air movement. This can allow the building height to be reduced.
- It is easy to achieve better air movement with jet fans and establish logical zoning for fan power saving.
- With zone control it is possible to have an interface with fire alarm and CO monitoring systems, which is desirable for public safety. Control of fan speed of a large number of smaller fans from to Hi to Lo would result in power saving.

The initial cost of jet fans in such a system could be higher compared to the cost of duct work; however, the overall cost of fans and cabling (together with ease and feasibility of ventilation system control) should be considered.

A careful flow study of the area must be carried out, and air flow patterns of the exhaust air and fresh air replenishment must be taken into consideration. The fans are grouped and placed within the building to allow extraction from each zone/floor. Car park fans, both centrifugal and jet, as well as electrical switchgear and cabling work must have fire department approval. Normally all the fans, electrical cables and switchgear for fire duty must be listed for fire duty.

Control Strategy for Car Park Ventilation

A building car park must cater to mandatory provisions and allow safe use of the facility in line with the strategy approved by

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the fire officer. NBC and ASHRAE give guidelines for design and installation of life safety system for car parking in buildings. While NBC standards give mandatory requirements, ASHRAE provides guidelines for application.

The main ventilation fans should be selected to provide the minimum fresh air quantity. Fans must be sized for ventilation of parking garages in different situations (see *Table 1*).

Table 1: Norms for car park ventilation in different situations

Situation	Ventilation Norm	Reference
Normal ventilation of car parking garages	6 air changes per hour (0.0075m^3/ ($s.m^2$)	NBC Part 8, p33 Table 5, ASHRAE Standard 62.1
Smoke ventilation for car parking	• 12 air changes per hr • 30 – 60m^3/($h.m^2$) (0.008 – 0.016)m^3/($s.m^2$)	NBC Part 4, p24 NBC Part 8, p33
CO demand control ventilation for car parking	• 0.007 to 0.00025m^3 / ($s.m^2$) • CO level between 29 and 137 mg/m^3	ASHRAE A-13.18 (2007) NBC Part 8, p33

Jet fans circulate ventilation air in the various floors and zones of the car park to achieve uniform air distribution. The control system, with CO sensors placed in various zones, allows local air movement depending upon the need for smoke movement, the direction in which smoke should be driven, to allow safe exit of the trapped occupants, and to allow access to personnel fighting the fire.

Speed control of main exhaust fans and jet fans is programmed as per the logic in *Table 2*.

Table 2: Logic of operation of fans to control CO

Condition	Logic of Operation	Reference
Main constant volume outside air fans where ventilation system is kept ON during entire occupancy period	Main fans are started and stopped during the entire period by real time clock	NBC Part 4, p24
CO levels exceeding 25 ppm for 8 hour duration (or exceeding 40 ppm for 1 hour duration): NBC allows fans to maintain CO levels between 29 and 137 mg/m^3 using fan controls	Fans are stopped and started based on input from CO sensors in the zone	NBC Part 8, p33
CO level exceeding 25(+15) ppm: fan speed is regulated, or stepped by using two-speed fans	Jet fans run at high or low speed in different zones as necessary, based on the need of smoke control logic as approved by the CFO	NBC Part 8, p33

All fans for handling smoke should be supplied with central emergency power source.

Fans, Attenuators and Related Accessories

Fans used in a car park ventilation system must be selected to perform the specified duty:

Figure 4: Fire rated centrifugal fan (typically rated for 300°C, for 2 hours)

Figure 5: Fire rated axial fan (typically rated for 300°C, for 2 hours)

- Fans should be rated to the selected duty to handle air volume and pressure.
- The class of construction of fans must be suitable for the applicable duty.
- Fans should be able to perform at ambient temperatures, and should be suitably fire rated as specified by the consultant. Normally, centrifugal and jet fans for car park ventilation are fire rated for 300^{0}C, typically for 2 hours, unless otherwise specified in the contract. Fans must be approved by the fire officer.
- Fresh air entry to the car parking space should be built with fire rated ductwork, and the entire exhaust from the space must also be constructed using fire rated ductwork.
- Sound attenuators and anti-vibration mounts must be installed with the fans to restrict noise and vibration due to fan operation. Care must be taken to maintain the fan and the associated electrical services, and adequate maintenance space should be provided.
- Jet fans in a car park should be provided with inlet and outlet sound attenuators and weather

Figure 6: Jet fan with inlet and outlet silencers

Figure 7: Tunnel fans for exit-entry points of underground car park

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proof junction boxes for cable termination. Adequacy of motors for the specified duty should be verified.

Related Services

- Cables for the fans must meet the specified rating applicable for the duty. Fan cabling should be suitably fire rated (Mineral Insulated Copper Cable – MICC); fire codes generally recommend use of Low Smoke Fire Rated (LSFR) cables. Control cables for operation of main fire fans and jet fans are also often specified as MICC type, since operational signals for starting or stopping the equipment related to fire and logistics controlled by the fire officer should be fail-safe in conditions of fire.
- CFD analysis is necessary and helps positioning of the fans in large car parks. Please bear in mind that the cost of performing CFD analysis is substantial, and the contractor's engineer must make sure that it is payable as per the contract. The engineer must discuss the matter with the client, consultant, fire specialist contractor and (where possible) the fire department head before costing of the tender, as the cost of all special material and specialty services like CFD analyses would be high.
- Operation and logistics of AC and exhaust air equipment in the building should be subject to the fire officer's approval, and must be explained to the client's operating staff/ management agency.
- Generally, before handing over the services for use by the client, it is recommended that all agencies be explained the operation and function of the building services related to life safety of the facility users.

Conclusion

Properly ventilated car parks are mandatory for all areas where cars are parked in a building. If the parking area is above ground, norms are prescribed in NBC to ensure enough openings for ventilation by natural movement of air. The entire car park facility should be fully sprinkled and fire cabinets with fire fighting equipment must be provided. When space is allowed for cars in underground spaces by building laws, the parking areas must allow ventilation so that:

- Enough ventilation is provided for people using the car park to neutralise the depletion of oxygen consumed by the occupants.
- Enough fresh air is injected into the space to combat the rise in CO content due to car engine exhaust. This is achived by CO sensors in the car park, and enough ventilation is provided if there is a fire in the car park or an unattended car catches fire during night hours, by an automatic fire suppression system.
- To allow safe exit of the people using the car pak in case of fire, it is equipped with NBC/NFPA/ASHRAE/Chief Fire Officer (CFO) approved smoke management equipment and ventilation.
- There should be a direct telephonic link from the building fire panel to the fire station and the CFO.