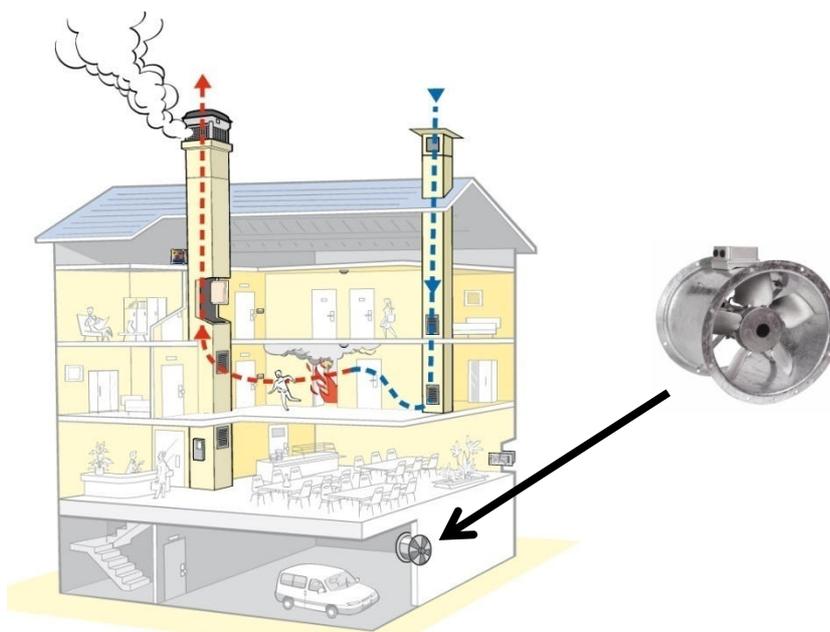


How to design easily a smoke management system?

Mechanical smoke extraction for enclosed car park

Car park: specificity of the smoke extraction system

Car parks are nowadays integrated directly inside buildings to gain space outside. These enclosed car parks are usually **underground at basement level**, and thus pose a particular fire hazard due to the amount of **motor vehicles** and the resulting potential for fire spread. Smoke caused by such an underground car park fire represents the major killer (smoke inhalation), and consequently **smoke has to be exhausted outside to let the people escape safely**.



Smoke Management System - Underground car park smoke extraction

A **car park smoke extraction system** is following the same principles and goals as a *corridor smoke extraction system*, ie "to manage the extraction of smoke, fumes and hot gases inside a compartment under fire to let the people escape safely the car park during the early stage of the fire". The role of the car park smoke extraction system is also **to create a smoke free layer** above the floor by removing smoke, and thus improve the conditions of safe escape and/or rescue of people with a **better visibility** and **reduced temperature**.

Furthermore, the car park smoke extraction system shall give assistance to the fire brigade to **restrict the expansion of smoke** to other areas, **locate the fire** in all its stages and fight it (part of the smoke control), and to **clear the car park for smoke** after the fire is extinguished (smoke clearance).

Whereas ventilation systems and smoke management systems are usually totally different systems with notably different ductwork, **a car park smoke extraction system is also used as a car park ventilation system** (same ductwork, same fans...) which is designed to remove exhaust gases produced by motor vehicles and ensure a **healthy environment** with **acceptable indoor air quality** based on the **CO level**. Although the users are present during a short-time in the car park (mostly 1-10 minutes), the risk of breathing polluted air can be really hazardous due to potential high concentrations of toxic gases (CO, NO₂, C₆H₆, BaP, SO₂, Ozone...).

Consequently, the design of a car park extraction system has to integrate both constraints for **effective pollutants removal** (CO, NO_x...) and **safe smoke removal at high temperature**.

Car park categories & general requirements

Two main types of car parks with different requirements are generally considered internationally: open car parks & enclosed car parks.

→ Open car parks or “well-ventilated car parks”

- Open car parks or “well-ventilated car parks” are usually above ground level with permanent wall openings on each level to provide cross natural ventilation. These openings are considered to provide sufficient **natural ventilation** for clearance of both smoke and vehicles exhaust fumes, and there is **no need for automatic sprinkler system**. An open car park has to comply with the following UAE Fire Code requirements which are relatively common amongst international standards:

- ✓ 50% of the car park perimeter shall be having permanent natural ventilation opening
- ✓ At least $\frac{3}{4}$ of the car park shall be within 30m of a permanent natural ventilation opening
- ✓ Any part of the car park shall be within 30m of a permanent natural ventilation opening
- ✓ The car park area shall not be more than 2230m²
- ✓ Such car parks cannot be more than 3 levels of parking

→ Enclosed car parks

- Enclosed car parks are usually underground, but comprise basically all the car parks which don't meet the requirements for open car parks. The different levels of an enclosed car park can be divided into **compartments** of 3000m² maximum (3600m² maximum for an entire level) or 6000m² if the compartment is equipped with an automatic sprinkler system. These car parks should have a **mechanical ventilation** to ensure an acceptable indoor air quality based on a maximum threshold limit of carbon monoxide CO, and this mechanical ventilation should perform also the **smoke extraction for each compartment/zone**. The smoke extraction system shall be **activated automatically by the fire alarm control panel** with a **remote manual start-stop switch** located at fire command centre or at main fire alarm control panel on 1st storey in case here is no emergency command centre in the building. Air intake shall not be less than 5m from any exhaust discharge openings.



Enclosed car park – Smoke exhaust axial fan & smoke exhaust duct

Note: In case the car park has permanent **openings on each level, equal to 2.5% of the floor area**, natural air supply will be considered sufficient for the smoke extraction system. The openings shall be evenly distributed over the car park areas.

For mechanical air supply, the supply airflow should be equal to 75% of the extract airflow with 10% tolerance.

Enclosed car park & mechanical ventilation requirements

→ Key criterion for IAQ: CO air pollutant level (toxic gas)

As already mentioned, car parks have to be designed to ensure an acceptable indoor air quality based mainly on a maximum threshold limit of **CO air pollutant**. CO is a toxic gas easily absorbed by hemoglobin in human blood which inhibits oxygen delivery to the y causing adverse health effects varying from headache to death.

The recommendations for the CO exposure limit are not consistent between various regulations in different countries, but a limit of **25 ppm for long-term CO exposure (1h)** would meet almost every code and standards in USA (IMC) and Europe. (cf "ASHRAE 2007 HVAC Applications – Enclosed Vehicular Facilities").

In the UAE, **ESTIDAMA** has a specific credit requirement for "**Car Park Air Quality Management**" following the WHO Guidelines 2000 Air Quality Guidelines for Europe, 2nd Edition: "The guideline values for CO are 100 mg/m³ (90ppm) for 15 minutes, 60 mg/m³ (50ppm) for 30 minutes, 30 mg/m³ (25ppm) for 1 hour, and 10 mg/m³ (10ppm) for 8 hours." The credit requirement from ESTIDAMA does not consider only CO level, but also NO₂ level and PM₁₀ level.

LBi-4: Car Park Air Quality Management

Intent	To facilitate the provision of adequate air quality within enclosed car parks.		
Credit Requirements	GENERAL		
	Demonstrate that the ventilation design meets or exceeds requirements for pollutant concentrations in car parks. This will be achieved via continuous measurement of the following pollutants:		
	Air Pollutant	Averaging Time	Maximum concentration
	Carbon Monoxide (CO)	15 minutes	100 mg / m ³
	Nitrogen Dioxide (NO ₂)	1 hour	200 µg/m ³
	Particular Matter PM ₁₀	24 hours	50 µg/m ³

→ Minimum extract ventilation rates for CO removal & smoke removal

The recommendations for the minimum extract ventilation rates are not consistent as well between various regulations in different countries (prescriptive methods):

- **France:** 900m³/h per vehicle & per compartment or 600m³/h per vehicle & per compartment if the compartment is equipped with an automatic sprinkler system
- **UK:** 6 air changes per hour (ACH) for comfort extraction (CO removal) & 10 ACH in case of fire (Smoke removal)
- **USA:** ASHRAE & IMC requires 1.5cfm/ft² whereas NFPA 88A recommends a minimum of 1.0 cfm/ft²

According to the UAE Fire Code, the requirement is fixed at **9 ACH in the UAE** for enclosed car park with total floor exceeding 2000m².

→ Demand-control ventilation rates for day to day CO removal

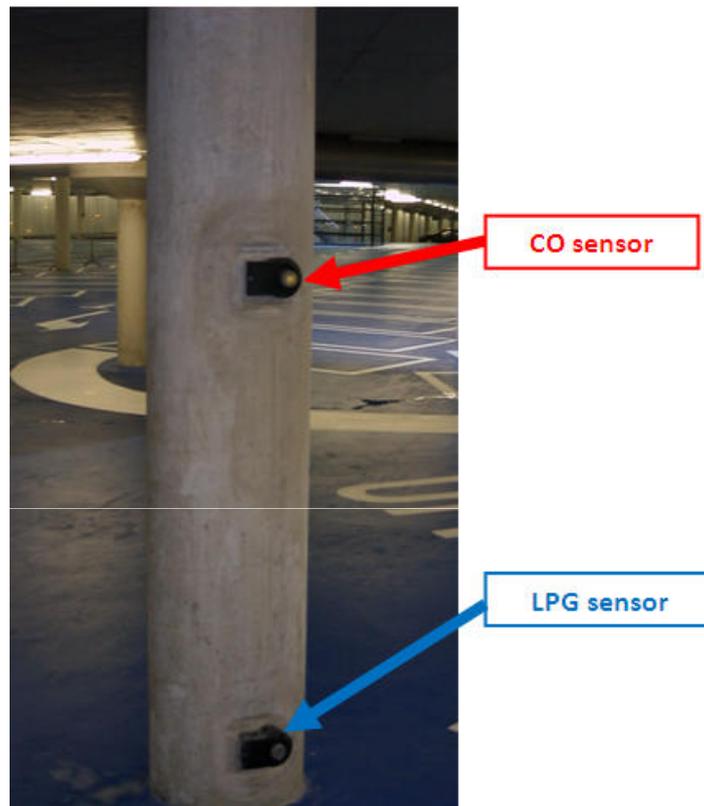
The simplest (but rarely used) option is to run the system at a constant speed, providing the minimum extract ventilation rates throughout the car park. To **reduce energy costs**, a permanent **CO detection system** shall be used to allow the system to run at a reduced ventilation rate in periods when vehicle movements are low.

By using a single output detector, a two-stage control (ex: On/Off) can be provided typically switching before the maximum threshold limit of CO. By using variable output detectors, the system can even modulate to match the ventilation rate to the car park usage. A **variable air volume (VAV)** control using **two-speed fans** (half speed & full speed) based on input from **CO sensors** can be used as an efficient way to increase **energy saving**.

→ **CO detection system**

CO sensors are placed usually at **1.5m above floor level** and may guard a maximum **area of 200-400m²**. The height of 1.5m is regarded as the breathing zone and therefore the height to measure the concentration especially considering that density of CO is similar to Air.

Note: In case of LPG detection, the **LPG sensors** should be placed at **150mm above floor level** as LPG is much heavier than air and therefore measured just above the floor.



Enclosed car park & smoke extraction requirements

The minimum extract ventilation rates for smoke extraction in the UAE has been fixed at **9 ACH in the UAE** for enclosed car park with total floor exceeding 2000m².

→ **Smoke detection system**

An **early detection** of smoke is fundamental to warn occupants and let them escape safely the car park. The detection will also give a signal to the ventilation / smoke extraction system to work on the highest exhaust airflow. As well, the fire brigade can automatically be informed and start faster the fire fighting. Smoke detectors should be located at **ceiling height** as hot buoyant smoke will rise naturally.

In case of use of a **sprinkler system** and if activated by the fire alarm control panel, the sprinkler system activation should be **delayed** after the correct activation of the smoke extraction system to allow the people to escape safely the car park. Indeed, the **cooling effect** of the sprinkler system on the smoke will make it fall down and then cause a **loss of visibility** to the occupants. Moreover, the shock caused by the sudden onset of cold water might increase the anxiety of the occupants (panic). The sprinkler system could be activated by **heat sensing** which would provide an automatic delay. This delay has also to be reasonably short to make the sprinkler system efficient enough to fight the growing fire.

➔ **Smoke exhaust fans**

The purpose of the smoke exhaust fan is to overcome the pressure loss of the ductwork and ensure the correct minimum extract airflow rate at high temperature in case of fire. **Smoke exhaust axial fans**, duct or wall mounted, are mostly used as they are well adapted for low pressure and high airflows

- **Each compartment/zone** should have its **own exhaust fan system**. The system should have at **least 2 exhaust fans, each providing 50% of the extract**, with a **secondary power supply** to operate in the event of a main power failure.
- Exhaust fans shall be capable of operating effectively at **400°C for 2 hours** (F400 – 120 as per EN 13501-3 classification).
- Exhaust fans should be spaced **at least 3 meters away from any parked vehicle** to avoid any failure due to the direct effect of fire. Where this distance cannot be respected, the installation of a protection enclosure should be made of incombustible material with fire resistance equal to the fire resistance of the upper slab (max. 1 hour).

Smoke Exhaust Axial Fan for Car Park

Type Model		Axial Fan HELIONE
Standards		EN 12101-3 (CE)
Key Features	Fire Resistance	200°C or 400°C - 2h
	Speeds	1 or 2 (2 speeds recommended)
	Direct/Belt driven	direct driven
	Max Airflow	72000 m3/h

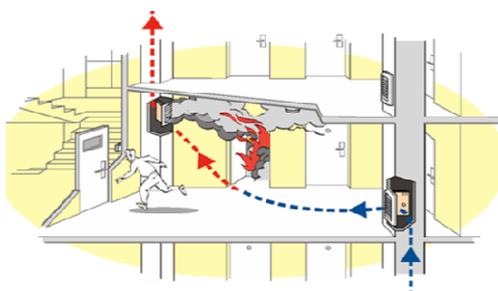


➔ **Smoke exhaust ducts**

Smoke exhaust ducts shall be manufactured from heavy gauge steel (**1.2mm thick**).

➔ **Supply & extract grilles location**

Concerning the location of supply air inlet and extraction air outlet, the key principle is to have a **satisfactory sweeping** with **expected air flow rate** from supply air inlet to extraction air outlet to ensure an efficient smoke extraction. This is the same principle as for corridor smoke extraction where the “**cold**” fresh air has to help and push the hot buoyant smoke through the extract duct:



Sweeping method & smoke free layer – Supply & extract grilles (GFA 007 & AC 121)

Consequently, for a good performance of the smoke extraction system, **supply air inlet shall be located at the bottom of the compartment** (openings in facade or duct) when the **extract air outlet shall be installed on the upper part of the compartment**. They shall not be installed in vehicle entrance / exit ramps.

These requirements are really important to ensure a correct smoke extraction, and thus a safe evacuation of the occupants. The system will ensure correct comfort ventilation as well as the fresh air will be supplied from down and will replace the polluted air which will be extracted from the top (natural movement).

Note: As per the French prescriptive method for natural air supply, the air supply duct section should be at least equal to the free area of the air inlets and there should be a maximum ratio Height/Length or Length/Height of 2. The air inlets should be 9dm² for extraction airflow of 900m³/h per vehicle and per compartment or 6dm² for extraction airflow of 600m³/h per vehicle and per compartment.

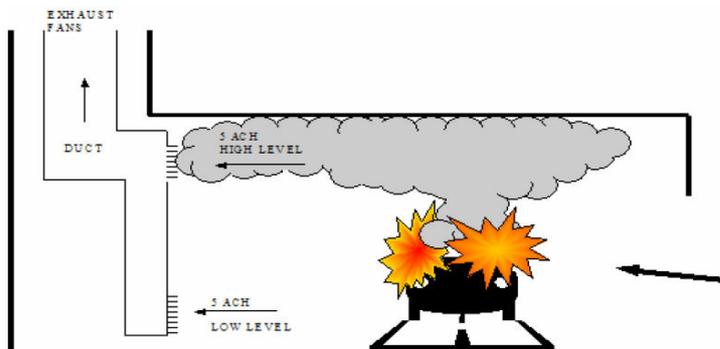
Note: A common requirement from UK is to have extract grilles – 50% at high level and 50% at low level with supply / replacement air from natural ventilation or mechanical air supply ductwork at high level if necessary.



Smoke exhaust duct

- High level extract grille
- Low level extract grille

This system using a **distribution by air mixing** can be correct for comfort ventilation (CO removal), but this system will have **bad performances for smoke extraction as only 50% of the grilles (high level ones) will basically extract the smoke** which will be then diluted in the ductwork with replacement air coming from the 50% grilles on the bottom part.



This system should be avoided and replaced by a system with extract grilles on the top and supply grilles on the bottom to ensure the **safe escape of the people inside the car park**. This is the **1st priority of a smoke extraction system**.

As already described, here are the 2 main priorities of a smoke extraction system:

1. **Safe escape of the occupants with smoke free layer, better visibility, reduced temperature & expansion restriction**
2. **Help fire fighters to locate the fire and fight it, and then clear the smoke**

➔ **Maintenance & regular checking**

Although the ventilation system will function on a daily basis, the maintenance and servicing of the car park smoke extraction system is essential and should be made mandatory.

- ✓ A **regular checking** should be performed every month to check any potential defective equipment.
- ✓ A **preventive maintenance** should be scheduled every 6 month or every year to check all moving parts with potential mechanical and corrosion damage, overheated parts...
- ✓ A **full functional test** should be performed every year to check the full system operation in case of fire.



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These conventional methods and requirements described here above are **prescriptive**. They present an **easy way** to achieve a **correct and forecasted level of safety** for occupants to escape an enclosed car park, and they should work basically for any common type of enclosed car parks.

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