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9. SMOKE EXTRACTION GARAGES

The dynamic development of motorization causes inadequate parking places in the city centers as well as in their outskirts. The emergence of new residential buildings and public utilities results in the need to create new parking spaces. Due to the problem of limited development space as well as the high cost of building plots, investors decide to create one or multi-storey closed garages (Gładyszewska-Fiedoruk & Nieciecki, 2012 a, b). The area of these garages often reaches several tens of thousands of square meters. For these new parking spaces, an adequate and effective ventilation system should be provided, which at the same time functions as a residential ventilation system, and has a fire ventilation function as a means of protecting escape routes and rescue teams during a fire.

Ventilation consists in maintaining proper air quality in a ventilated room or part thereof. Contamination and exhausted air are thrown outwards, and then the outside air is introduced with the proper parameters. By smoke ventilation we mean a fire ventilation system that removes smoke and hot fire gases directly from the ceiling of the area of smoke extraction, ensuring that smoke is kept in a strictly defined area above the heads of evacuees. On the other hand, fire ventilation is a ventilation system designed to remove smoke and hot gases which may result from a fire and provide compensating air of the requisite quantity (Węgrzyński & Krajewski, 2019).

9.1. Ventilation systems in garages

The residential ventilation system provides suitable conditions for the short-term residence of people, by keeping the concentration of gaseous pollutants at a safe level. Harmful substances and gases in the air such as propane butane or carbon monoxide are eliminated by the appropriate ventilation system. The design of the installation must meet the requirements of technical and building regulations. Mechanical ventilation, which is mandatory, controls the unacceptable concentration of carbon monoxide. To determine the amount of supplied and discharged air, the following aspects are taken into account: the number of parking spaces, engines' idle time, distance to the exit gate, types of engines of vehicles in running order, parking occupancy rate, daily distribution of parking space (hot and cold engine operation). The amount of ventilation air for garages of varying cubic capacity may vary from 1.5 to 6 air changes per hour. In a closed garage of average height, the volume of clean air supply is approximately 27 m^3/h per square meter of floor area (Gładyszewska-Fiedoruk & Nieciecki, 2012 a, b). Correct calculations are the basis for the selection of ventilation fans supplying the ventilation system (WEB-1). Based on the Regulation of the Minister of Infrastructure of 2002, with subsequent changes and additions on the technical conditions to be met by the buildings and their location, the ventilation conditions to be met in the garages were determined. In closed garages, ventilation should meet the following requirements (Gładyszewska-Fiedoruk & Nieciecki, 2012 a, b; Systemair, 2014):

- At least natural ventilation, the ventilation holes placed in the opposite or side walls, or in garage doors, with total net area of ventilation holes of not less than 0.04 m^2 for each parking stall separated from others by partitions, – in unheated overground parking lots or built inside other buildings.
- Providing at least 1.5 air changes per hour – in heated overground or partially sunken garages with no more than 10 parking spaces.
- Mechanical ventilation, controlled by sensors for carbon dioxide concentration – in other garages not mentioned above and in inspection channels for professional car maintenance and repair or in multi-station parking.
- Mechanical ventilation, controlled by sensors for propane-butane gas concentration – in garages where propane-powered cars are parked and in the ones built below the ground level.

In open garages, however, natural ventilation should be provided to meet the following requirements (Systemair, 2014):

- The total size of uncovered openings in the outer walls on each storey should be less than 35% of the total wall area, allowing the use of permanent shutters therein, without limiting the openings.
- The distance between the pair of opposite walls and the unopened holes should not be greater than 100 m.

9.2. Fire ventilation system for multi-location garages

9.2.1. Division of fire ventilation systems

Depending on the type of equipment, fire ventilation systems can be divided as follows (Węgrzyński et al., 2014a):

- Smoke and Heat Exhaust Ventilation System (SHEVS) – designed to provide smoke removal from the layer stored under the ceiling and to maintain a smoke-free space through which people can evacuate;

- Smoke and heat control system – designed to keep smoke in the area between the source of fire and the place where it is disposed so as to ensure that rescue teams have easy access to the source of fire.
- Smoke clearance dilution – a system that is designed to remove smoke and mix it with infiltrating compensation air to reduce its temperature and toxicity.

Schematically, the division of ventilation systems together with the most frequently used system and devices is shown in Fig. 9.1 below.

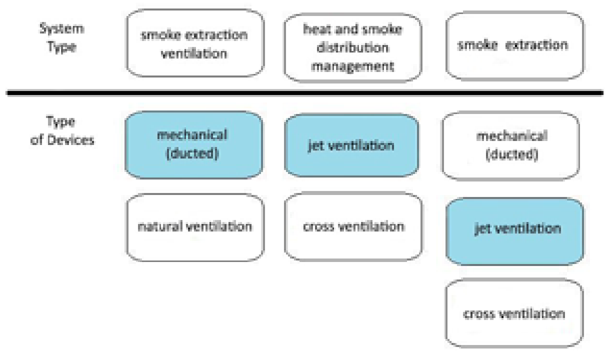

Fig. 9.1. Division of fire ventilation systems due to their type and type of equipment used, with the most commonly used systems in closed garages (Source: ALNOR, 2017; Gładyszewska-Fiedoruk & Nieciecki, 2012 a, b; Węgrzyński et al., 2014a)

Evaluation of fire ventilation systems can be made using the criteria listed in Table 9.1 (Węgrzyński et al., 2014 b; Sztarbała, 2013).

Table 9.1. Criteria for assessing fire ventilation systems (Source: own elaboration based on data from Sztarbała, 2013; Węgrzyński et al., 2014B)

Criterion	Smoke exhaust ventilation	Smoke and heat control	Smoke removal
During the evacuation			
Temperature	Under the ceiling – 200°C		
Smokiness	At the height up to 1.8 m – 60°C		
Radiation	Smoke under the ceiling of the storey at the height up to 1.8 m – 0.105 g/m^3 (Range of visibility of evacuation signs glowing with their own light – 10 m)		
During rescue and firefighting operations			
Temperature	At a height of 1.5 m, less than 120°C, in the distance of above 15 m from the source		

Criterion	Smoke exhaust ventilation	Smoke and heat control	Smoke removal
Smokiness	At a height of 1.5 m, less than 0.105 g/m^3 (visibility of evacuation signs glowing with their own light – better than 10m), at a distance of over 15 m from the source of fire	At a height of 1.5 m, less than 0.105 g/m^3 (visibility of evacuation signs glowing with their own light – better than 10m), at a distance of over 15 m from the source of fire	Zone may be smoky
Radiation	To 15 kW/m^3 at a distance of 15 m from the source of fire, 2.5 kW/m^3 in the other area	To 15 kW/m^3 at a distance of 15 m from the source of fire to the fire, 2.5 kW/m^3 in the other area	To 15 kW/m^3 at a distance of 15 m from the source of fire, 2.5 kW/m^3 in the other area
Access to the source of fire	Smoke in two layers – the source of fire is visible and access is facilitated	Possible access to the fire source at a distance up to 15 m from its location using a smoke free way	The whole area of the smoke zone – the fire area should be small enough to quickly locate the fire

9.2.2. The purpose of applying fire ventilation in garages

Fire-extinguishing systems are used to separate smoke-free zones and hot combustion products in areas of firefighting. In the event of fire, they allow for lowering the temperature and bringing air from the outside into the space. Fire-extinguishing systems can also be used as ventilation under normal building operating conditions. Depending on the type of product, they have a fire resistance of 60 to 120 minutes.

The basic purpose of using fire ventilation in garage enclosures is to provide appropriate evacuation conditions, enable effective operation for rescue teams and protect building structures. It is also important to safeguard evacuation routes against the smoke, by using appropriate smoke suppressors in the fire zone and preventing the spread of smoke to the rest of the garage (REG-2).

Basic ways of reducing hazards caused by smoke and hot fire gases include (Skaźnik, 2013):

- the use of physical barriers – doors, gates and other closures of openings for which fire resistance or smoke tightness is required, in appliances providing automatic closing of the opening in case of fire;
- ensuring a stable separation of the smoke layer from the smoke-free zone;
- smoke control by providing overpressure in protected spaces (differential pressure);
- smoke removal from the place of fire to the withdrawal point.

The choice of how to reduce hazards is strictly dependent on the conditions that must be maintained during the evacuation and rescue operation. It is assumed that for rooms with the height of up to 1.8 m from the floor, the minimum visibility without smoke should be up to 10 m, and the temperature should not exceed 60°C. For garages higher than 2.5 m above the floor, the temperature should not exceed 200°C in the floor area. Smoke extraction should ensure a safe escape of the rescue crews, 15 minutes after the outbreak of fire at a distance of 10 m from the source of fire. Due to specialist firefighters' equipment, it is acceptable to carry out firefighting for a period of 30 minutes at temperature not exceeding 100°C. This is illustrated in Fig. 9.2.

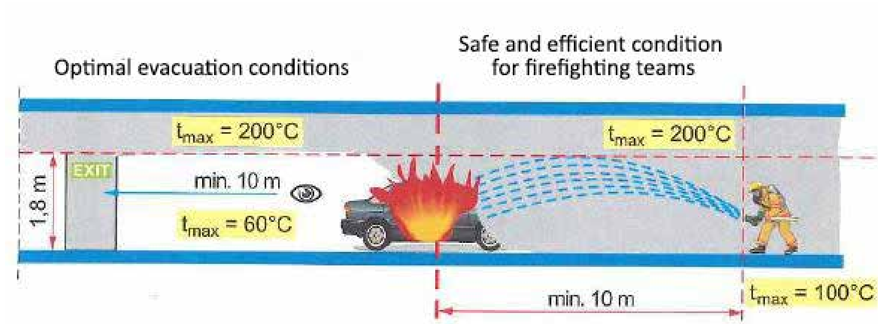

Fig. 9.2. Acceptable conditions for firefighting in a garage depending on the purpose of system operation (Source: based on data from ALNOR, 2017; Mizieliński & Kubicki, 2012)

9.2.3. Basic legal requirements for smoke removal from garages

The necessity to use automatic mechanical smoke exhaust systems for passenger cars is a result of technical and construction regulations. These regulations require the mechanical removal of smoke for garages with more than 10 parking spaces and obligatory for underground garages with the total area exceeding 1500 m^2 (REG-1).

Division of the area of the fire zone in the closed garage:
- overground garage – max. 5000 m^2,
- underground garage – max. 2500 m^2.

It is necessary to increase the fire zone by 100% if:
- fixed automatic fire extinguishers are used,
- walls separating up to two parking places were built with fire resistance class of the minimum EI30, from the floor to the ground with clearance under the ceiling of 0.1 to 0.5 m in height.

On each floor of the garage with a total area exceeding 1500 m^2, there should be at least two escape routes (Fig. 9.3) and the distance to the nearest emergency exit should be:
- in a closed garage – maximum 40 m,
- in an open garage – maximum 60 m.

The distance to the nearest exit can be increased only if there is:
- fixed fire extinguishing equipment – by 50%,
- automatic smoke extraction system operated by smoke detectors – by 50%.

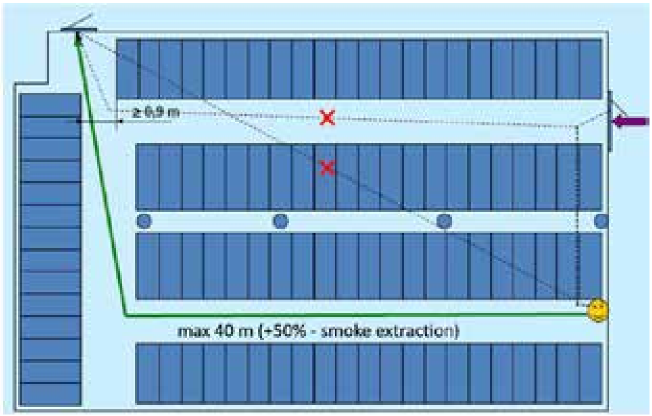

Fig. 9.3. Required distances to escape routes (Source: based on data from ALNOR, 2017; Zaforymska, 2017)

9.2.4. Main requirements for installation of smoke extraction system

Smoke extraction requirements (REG-1):

The smoke extraction installation should remove the smoke with an intensity that ensures there is no smoke or high temperature during the evacuation of people in protected passageways and evacuation routes.

There should be maintained constant supply of outdoor air to the enclosed garage, thus supplementing the exhaust air with the smoke.

Requirements for smoke extraction ducts, due to fire integrity and smoke tightness criteria (REG-1):
- Cables serving one fire zone should have at least a fire resistance class E600S, that is at least the same as the fire resistance class of the ceiling. It is acceptable to use a lower smoke class E300S, provided that the calculated smoke temperature does not exceed 300°C.
- Cables serving more than one fire zone should have at least the EIS fire resistance class, which means at least as high as the class of the ceiling.

Requirements for shut-off flaps in smoke extraction ducts, due to fire integrity and smoke-tightness criteria (REG-1):
- Shut-off flaps serving one fire zone should be started automatically and have at least the same fire resistance class – E600S AA – as the ceiling. It is acceptable to

use a lower smoke class E300S, provided that the calculated smoke temperature produced during the fire does not exceed 300°C.
- Shut-off flaps serving more than one fire zone should have at least a fire resistance class EIS AA, such as the class of the ceiling.

Requirements for smoke extraction fans (REG-1):
- smoke extraction fans F_{600} 60 – if the predicted smoke temperature exceeds 400°C;
- smoke extraction fans F_{400}120 – in other cases, unless the analysis of smoke temperature calculations and the safety of rescue teams is possible.

Requirements for smoke flaps in gravitational smoke extraction (REG-1):
- class B_{300} 30 – for flaps opened automatically,
- class B_{600} 30 – for flaps that are only opened manually.

All the above smoke extraction components should meet the standard PN-EN 1351 – 4:2008 Fire classification of construction products and building elements, Part 4: Classification based on the results of fire resistance testing of smoke diffusion control systems.

Fire-fighting devices in the facility should be constructed in accordance with the fire protection design agreed upon by a fire protection expert and shall only be approved for use on condition of carrying out appropriate testing and fire conditions can be increased only if there isappropriate testing and validation for the equipment in question (PN-EN 1351-4:2008).

9.3. Division of garage smoke systems

Due to the practical and economic aspects, ventilation systems are commonly used to combine two functions – life saving and fire protection. Please note that in this situation, the fire protection conditions should be a priority in designing a two-way system. In the case of closed garages, only mechanical ventilation systems (Fig. 9.4 and 9.5) should be used. Until recently, the garage ventilation system was often used as a duct system that served as both the ventilation and the smoke extraction system in the event of fire. At present, more and more often the jet fan ventilation system is used, flow fans are installed directing the flow of smoke or the flow of clean air throughout the garage space or the underground car park.

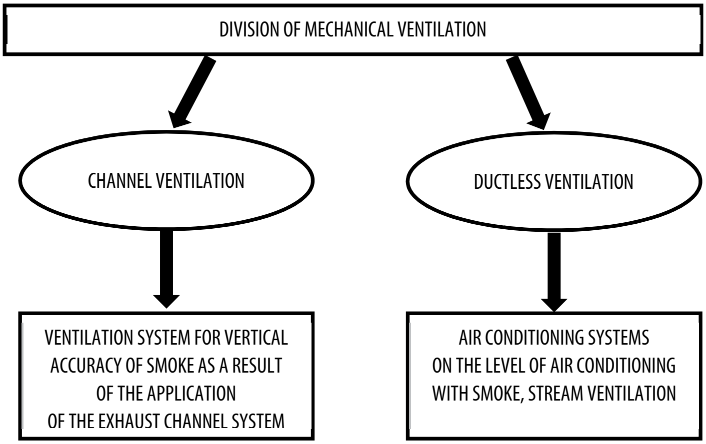

Fig. 9.4. Fire protection systems used in closed garages (Source: own elaboration based on data from Mizieliński & Kubicki, 2012)

The operation of both installation systems will be discussed in more detail below.

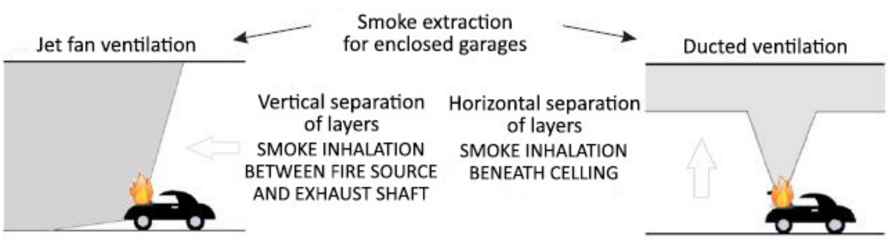

Fig. 9.5. Division of the garage fire protection ventilation system (Source: based on data from ALNOR, 2017)

In order to ensure the correct operation and efficiency of smoke extraction systems, technical inspections and maintenance work are required to be performed at periods established by the manufacturer, but not less than once a year.

9.3.1. Construction and principle of operation of fire ventilation systems

Traditional duct fire ventilation system consists of the following components:

- ventilation ducts,
- ventilation grilles,
- exhaust fans,
- fire dampers.

All these components must meet the operational requirements in the event of fire.

In order to ensure proper operation of the duct system (Fig. 9.6), the garage must be divided into smoke zones using smoke curtains (pos.1). Their aim is to stop the spread of smoke to the rest of the garage. In case of fire, smoke is removed through the grating on the ducts (pos. 2). There is a clear division into the hot smoke layer under the ceiling and the smoke-free layer (pos. 3). Compensatory air is supplied in such a way that it does not cause smoke to fall (pos. 4).

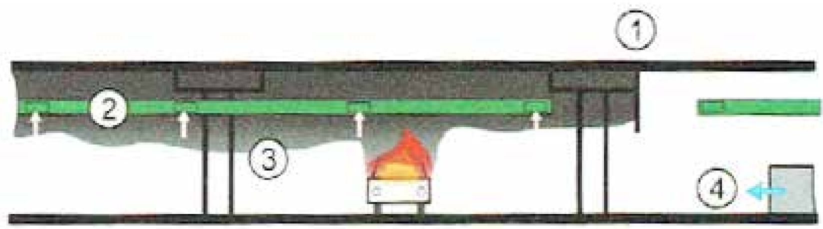

Fig. 9.6. Principles of operation of the smoke ventilation duct system (Source: based on data from Węgrzyński & Krajewski, 2015)

The following conditions must be met in order for the installation to meet fire safety requirements (Mizieliński & Kubicki, 2012):

- two-speed or inverter-controlled fans (variable speed) need to be installed,
- adequate amounts of exhaust air under normal and fire conditions must be ensured.

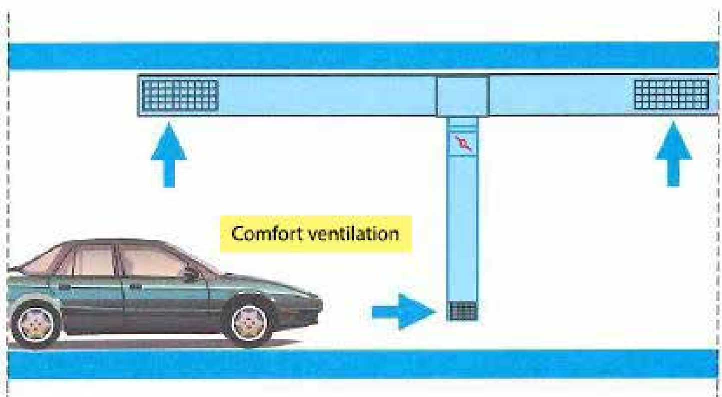

Fig. 9.7. Operation of the duct ventilation system in normal conditions (Source: based on data from ALNOR, 2017; WEB-1)

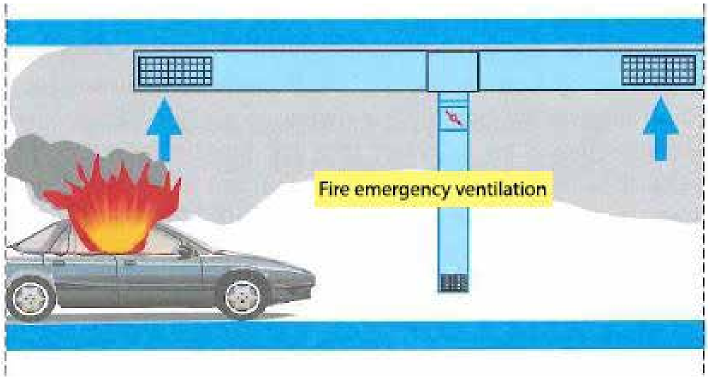

Fig. 9.8. Operation of duct ventilation system in fire conditions (Source: based on data from ALNOR, 2017; WEB-1)

Exhaust grates should be located at two heights above the floor level (Figs. 9.7, 9.8):

- at a height above 1.8 m – removing lighter fractions of impurities,
- at less than 0.8 m above the level of the floor – removing impurities heavier than the air.

During normal operation of the installation, about 60% of the air is removed from the ceiling space, while the remaining 40% from the floor level. In the event of fire, the lower extractor is cut off and 100% of the fire output of the air is drawn through the upper grilles. A typical flow diagram of the duct system for smoke extraction is illustrated in Fig. 9.9.

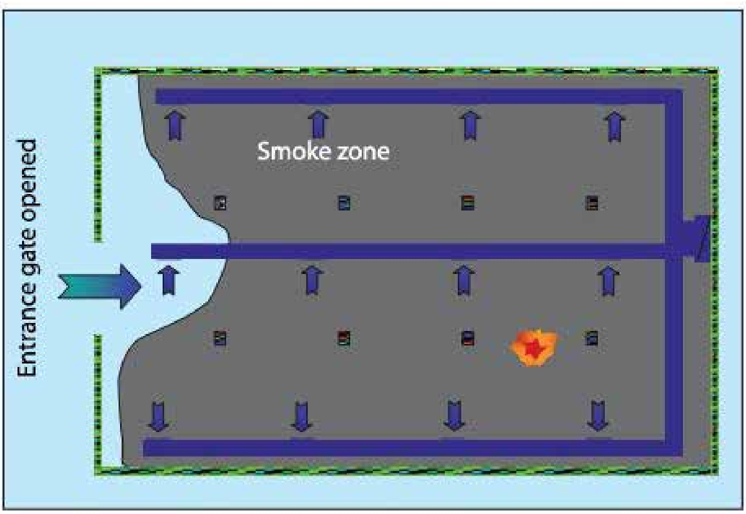

Fig. 9.9. Duct system in smoke function (Source: based on data from ALNOR, 2017; WEB-1)

Conditions for proper ventilation of the ventilation duct (NBN S 21-208-2):
- required garage space:
  - required area of the smoke zone: 2600 m^2,
  - maximum length of the smoke zone: 60 m;
- minimum required height of the garage:
  - with the use of sprinkler system: 2.8 m,
  - without sprinklers: 3.8 m;
- required height of the smoke-free layer:
  - with the use of sprinkler system sprinklers: 2.5 m,
  - without sprinklers: 3.5 m;
- the smoke layer should remain at least 0.3 m below the lowest element of the ceiling;
- requirements for system components:
  - smoke exhaust fans with sprinkler system: 200°C/1h,
  - smoke exhaust fans without sprinklers: 300°C/1h,
  - exhaust channels: 200°C/1h.

Such high demands are to ensure the free movement of people, both evacuees and rescue workers. Garages that do not meet the above requirements should be covered by ductless ventilation system.

9.3.2. Construction and principles of operation of ductless fire ventilation systems

The fire ventilation system is based on the use of parallel axial flow fans (jet fans). Most commonly used devices are those of circular cross-section and diameters from 315 to 450 mm. The fans are equipped with silencers on both sides, i.e. on the inlet and outlet side. The installation site of these units is the upper part of the garage space and in the human habitation zone. Jet fans process relatively small amounts of air, but with considerable speed. In this way, the air flow is of up to 40 m.

The jet fan ventilation system consists of the following elements:
- fet fans;
- air intake system at the time of smoke extraction: mechanical ventilation with air supply fans (aeration) or air supply through the ventilation openings or entry gates due to negative pressure caused by the exhaust fans;
- main exhaust fans;
- air supply and exhaust shafts fitted with grilles that function as an air intake and exhaust system;
- jet fans, other than the ones used during smoke exhaust operation.

The role of jet fans in normal conditions is to force the orderly flow of air masses in the whole volume of the garage, from the supply air holes to the air extraction points. (Fig. 9.10). The performance of the ventilation system is adjusted by the automation system to the momentary demand for fresh air. The signal to change the operating parameters of the equipment is the concentration of carbon monoxide (CO) or LPG in the garage, measured by appropriate sensors. This solution gives a lot of flexibility to the system and allows for its optimal operation, in terms of both economics and efficiency of air exchange in the facility (Król, 2014).

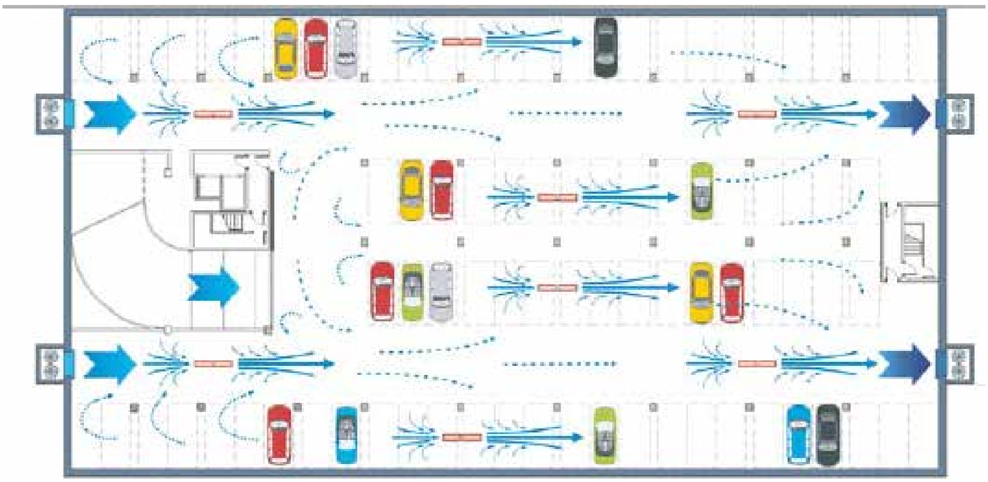

Fig. 9.10. Operation of jet fans for garage ventilation (Source: based on data from Król, 2014)

Proper operation of the CO and LPG detectors depends on their proper location in the garage. Detectors should be arranged according to the following rules:

- on walls, supports, pillars at the height of not less than 180 cm from the floor;
- away from the supply openings;
- near the exhaust holes;
- in places not exposed to direct external air supply, water vapor, water, car exhaust, dust, etc.

All system components used in ductless ventilation must meet the requirements imposed on ducted fire ventilation.

The primary role of the system under fire conditions is to limit the spread of smoke within the garage and to turn it as quickly as possible to the exhaust points, whereby the contaminants are removed to the outside of the building (Fig. 9.11). In the event of a fire alarm, the system automatically switches to fire mode. The installation at this point achieves the highest possible performance. At the same time, the entrance gate to the garage is opened, through which the external air is let in, compensating air flows due to the negative pressure caused by the exhaust fans. Due to the use of jet fans operating in the reverse system, the direction of the air flow in the garage can be adjusted to the location of fire. Achieving full flexibility of the system also requires the use of variable flow fans in the exhaust and supply system. At the same time, ensuring adequate airflow in the event of fire, may undoubtedly require additional fans. Additional fans will only be used in fire conditions, otherwise they will remain in working order.

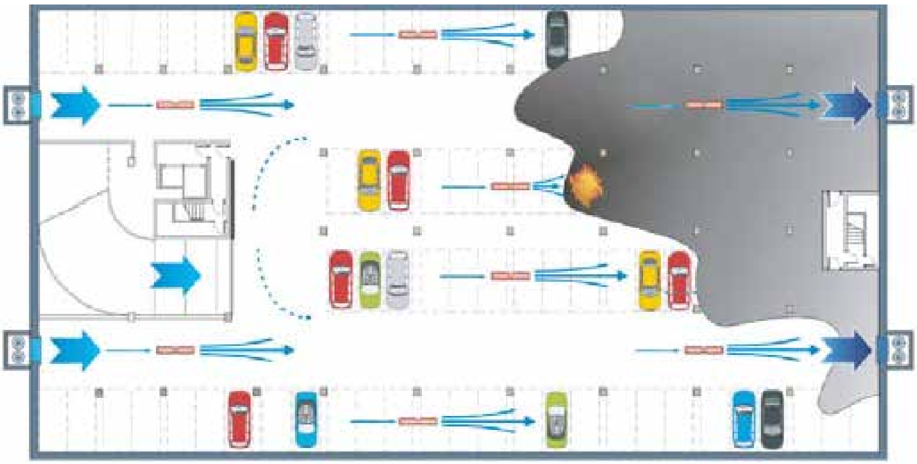

Fig. 9.11. Operation of jet fans for the needs of fire ventilation (Source: based on data from Król, 2014)

A general diagram showing the operation of the system using jet fans is presented in Fig. 9.12.

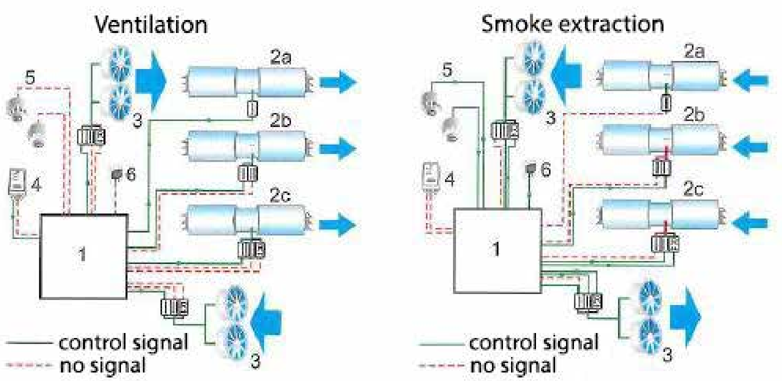

Fig. 9.12. Control of the ventilation system in home and fire ventilation (Source: based on data from ALNOR 2017, Król 2014)

After performing all necessary calculations and preliminary selection of system components, it is advisable to perform the appropriate simulations using CFD programs to verify the correctness and effectiveness of the adopted system. Numerical analysis allows verification of the correct distribution of supply and exhaust openings and jet fans in the garage space. Computer simulations will also allow you to correctly set the system start-up time to optimize the protection of escape routes. The complete design of the ductless system should consist of the following components (Fig. 9.13):

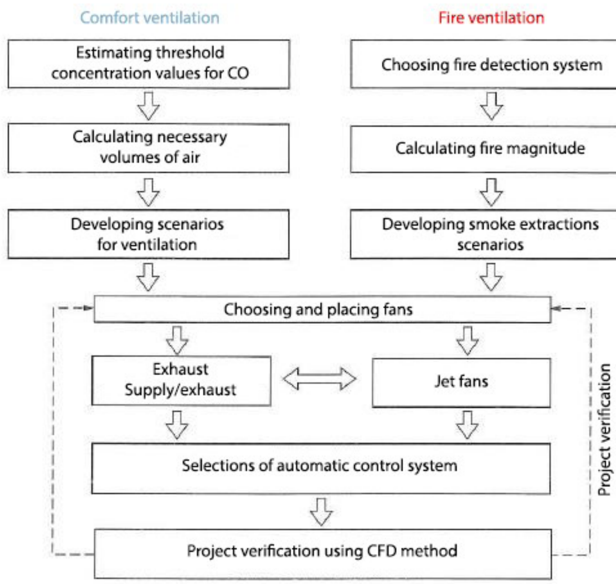

Fig. 9.13. Design procedure for ductless system (Source: based on data from ALNOR, 2017; Mizieliński & Kubicki, 2012)

During the work on selection and placement of fans, the following aspects should be taken into account (WEB-2):

- jet fans should be positioned so that the flow is directed towards the exhaust points;
- the aggregate capacity of the jet fans cannot exceed the total amount of air supplied to the garage;
- jet fan should be positioned so that the air velocity at the contact points of the individual planes is not less than 1 m/s;
- for the modelling of the fan system in a parking area, only the airflow generated on the discharge side is taken into account; the suction side is not considered;
- smoke should be directed in such a way as to allow the rescue crew to move freely;
- smoke during the spread must not occupy a surface greater than the permissible area of the smoke zone (the allowable area of the smoke zone is 2600 m^2);

- the minimum efficiency of the BS-7346-7: 2006 smoke system is 10 ACH/h;
- jet fans should be switched on with a delay, only after evacuation. The delay time is based on the RET (Required Evacuation Time). This time is calculated taking into account the appropriate evacuation time, fire detection time, alarm time, event recognition time and event response time.

9.3.3. Compensating air supply

A very important element of a garage fire ventilation is the need to provide a sufficient amount of complementary air flow through the entry ramps, garage doors (open during fire) or other openings dedicated to this purpose. This is a condition for its normal and undisturbed functioning. Taking into account the effectiveness of the fire ventilation system, it is desirable that the compensating air grates are located in the lower part of the space so that when the smoke is exhausted, clean air from the outside pushes the smoke layer up to the ceiling area (Smardz & Paliszek-Saładyga, 2011).

One of the most common causes that lead to too fast a drop of smoke is the induction of air from the garage space to the supply air with too high a velocity of the compensation air (Fig. 9.14). This induction depends on the supply air velocity and the distance from the upper edge of the supply point to the base of the smoke layer (WEB-3).

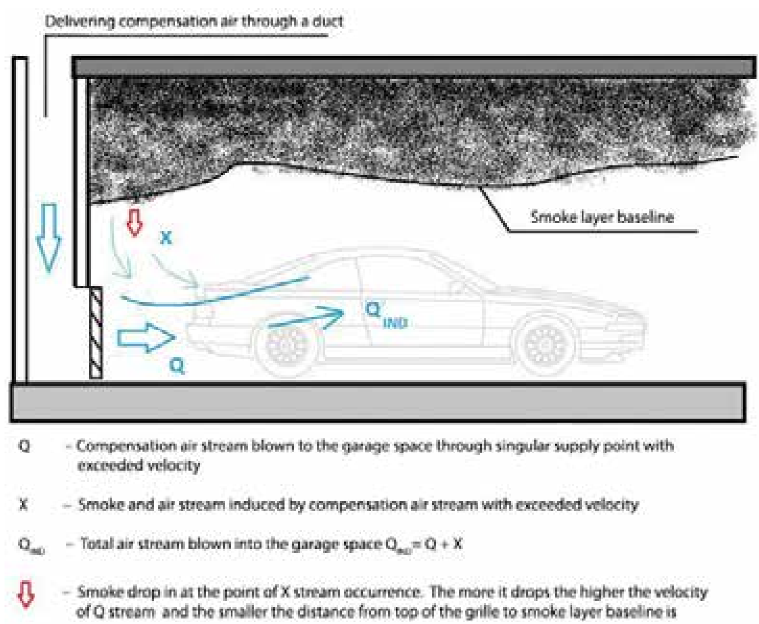

Fig. 9.14. Sketch showing the principle of inducing air and smoke through the supply point causing the smoke to fall during the operation of smoke extracting through a duct (based on data from ALNOR 2017; WEB-3)

The TR 12101-5 standard and associated with it BS 7346-4 standard indicate that the distance from the upper edge of the supply point to the base of the smoke layer should be no less than 1m unless the compensation air velocity is less than 1 m/s. This case is very common in typical garage projects with a smoke exhaust system because it involves the use of the gate as a compensating hole (Fig. 9.15) (BS 7346-4:2003; CEN/TR 12101-5; Gładyszewska-Fiedoruk & Nieciecki, 2016).

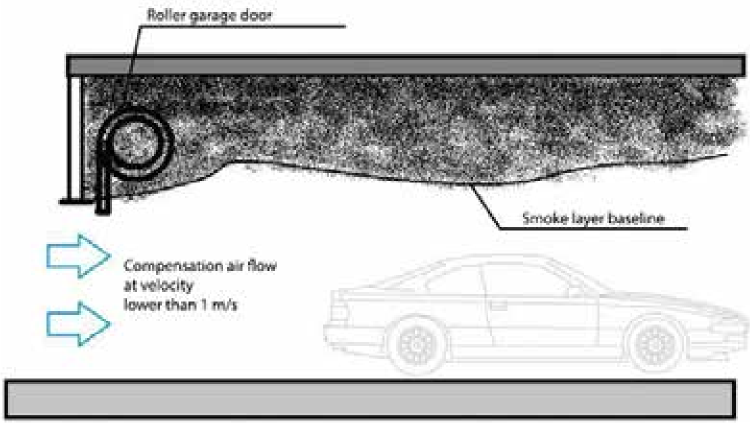

Fig. 9.15. Using the entrance gate as a compensation hole (based on data from ALNOR, 2017; WEB-3)

The compensation air velocity of 1 m/s also appears in the NFPA 92 standard. This value is given for the compensation air stream during contact with the smoke or smoke convection column in the smoke collector. For the sake of simplicity in terms of such records, it can be assumed from the standards that the local limit of air velocity for which a laminar flow (without induction) ends and a turbulent one starts, is about 2 m/s. The speed in the compensation hole will always be different at every point of the hole. For safety reasons, this speed should not exceed 2 m/s. For design purposes it is therefore recommended to adopt an average design speed of 1 m/s (NFPA 92).

Bearing in mind the above guidelines, it is best to locate the place of supply of compensating air as far away from the smoke as the adjacent smoke zone. From the point of view of ensuring the proper efficiency of the installation and the means needed to achieve the intended purpose, this is definitely the best solution. The air velocity in the evacuation zone, i.e. at passages and crossings, should not exceed 5 m/s.

However, it should be borne in mind that the resulting air movement and induction method should not significantly affect the smoke zone in which the fire has been detected.

Another alternative is to feed the compensating air through smoke channels in the neighbouring smoke zone by reversing the activation of the smoke extraction fans. Although the grilles on the ducts are located under the ceiling, the air effectively loses its velocity and flows under the smoke curtain adjacent to the smoke zone thus protecting the zone against the inflow of smoke. In order to comply with the above guidelines, always apply compensation air from two opposite sides of the garage (Gładyszewska-Fiedoruk & Nieciecki, 2016).

9.3.4. Simplified scenario for the operation of a fire system

In order to guarantee proper operation of a fire ventilation system one should (Węgrzyński & Krajewski, 2015):

1. stop the functioning ventilation system,
2. isolate fire zones (doors, fire gates) including automatic lowering of smoke curtains,
3. control fire dampers included in the fire ventilation system,
4. open gravity compensating air sources (external gates, dampers on gravity aeration channels,
5. turn on the exhaust fans with full or limited capacity,
6. in case of jet ventilation, after the evacuation time ends, activate full-flow and exhaust fans.

It is very important that the fire alarm system performs a fire scenario only for the first detected fire location. Turning-on the exhaust or supply fans should always follow the clearing of shut-off or fire flaps. When smoke is detected, the smoke exhaust system is activated in the fire zone.

Improper operation of the system by not blocking the fire scenario for the first smoke zone may cause the system shutdown for this zone. Small amounts of smoke entering the neighbouring smoke zone can trigger the system in this zone and stop it for the fire zone.

9.3.5. Commissioning of fire ventilation systems

It is a condition for the use of fire-fighting equipment to carry out appropriate tests that confirm the correct operation of the fire-fighting equipment. During these tests, hot air and smoke are used instead of fire in the building without causing damage to the structure, installation or interior trim. Smoke spreading under the ceiling activates the fire detection system which instantaneously sends signal to the fire safety system, following the fire scenario set up for the facility.

During the hot smoke test, first and foremost, the following aspects are assessed: the length of time of maintaining the two separate layers of smoke, the ability of the system to locate the source of fire and confine the smoke to a single smoke zone. The test also checks the start-up time, performance of all the system components, as well as its cooperation with other security systems located in the building. The test fire power used in the hot smoke test should not be less than 300 kW for garages equipped with fixed water fire extinguishers and not less than 450 kW in other garages. When the garage height exceeds 3.2 m, it is advisable to increase the fire power to reach a higher temperature of the smoke layer under the ceiling (AS 4391-1999). If there is a sprinkler system in the garage, it should be adequately protected from uncontrolled water discharge.

Hot smoke tests also verify:

- the effectiveness of maintaining smoke in the under-floor layer for the evacuation of people;
- not mixing of smoke and compensating air;
- the limitation of smoke ingress outside the smoke zone in which the test is being conducted, and the correctness of the implementation of solid or active excrements (smoke curtains);
- the correctness of operation of the fire detection and alarm system;
- the impact of location, size and number of supply points on the quality of the smoke extraction system;
- the correctness of the designed and manufactured smoke extraction system – visual assessment;
- in case of smoke and heat spread control systems, the assessment of whether or not a source of fire is available at a distance of no more than 15 m.

Hot smoke tests provide the possibility of detecting beforehand defects and failures in fire protection system implementation that cannot be detected through simplified tests or by setting off individual detectors. Warm smoke test is currently the most realistic method for verifying the functioning of smoke and other fire safety systems, such as: detection, alarm and control automation systems.

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