FIRE SAFETY AND SHELTER DEPARTMENT
SINGAPORE CIVIL DEFENCE FORCE

FIRE SAFETY REQUIREMENTS FOR DUCTLESS JET FANS SYSTEM IN CAR PARKS

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DUCTLESS JET FANS SYSTEM IN CAR PARKS

1. OBJECTIVES

1.1 The objectives of the ductless jet fans system are as follow:

a) To relief heat and smoke from the car park in the event of fire.

b) To assist fire-fighters in locating and attacking the fire safely.

2. SCOPE

2.1 This set of requirements is only applicable to conventional car parks where passenger cars/light weight vehicles are parked alongside each other with common driveways and is not intended for mechanized car park system or other forms of car parking systems.

3. DESIGN CONSIDERATIONS

3.1 Provision of sprinkler system in car park

3.1.1 The basement car park shall be sprinkler protected in accordance with the SS CP 52.

3.1.2 The arrangement of the sprinkler heads and the jet fans shall be such that, upon the operation of the jet fans, the effect on the spray pattern of the sprinklers is minimized.

3.2 Zoning of car park

3.2.1 The car park space shall be divided into smoke control zones with each zone not larger than 2000m^2 (excluding plant rooms and circulation spaces) for purpose of smoke containment and faster location of fire. As the zones are virtual smoke zones, it has to be demonstrated that smoke can be contained within the zone boundaries and channeled to the extract fans. Demonstration is to be carried out using hot smoke test as part of the commissioning test.

3.2.2 Each smoke control zone shall have its own jet fans system (fresh air fans, exhaust air fans and jet fans) to purge smoke from the affected zone. The ducts shall be fabricated from heavy steel gauge steel of 1.2mm thick. Alternatively, sharing of the fresh air and exhaust air fans is permitted provided the fans, wiring and control panel are protected with at least 1-hr fire resistance rating. The exhaust fan system shall also be designed to run in at least two parts, such that the total exhaust capacity does not fall below 100% of the required rate of extract for the zones affected in the event of failure of any one part. This requirement is also applicable for mechanized supply fan system, if it is used.

3.3 Jet fans system

3.3.1 The jet fans system shall be activated by the sprinkler system serving the basement car park level and any other areas located within the same level. The activation of the jet fans system shall at least be confined to the smoke control zone on fire and all its adjacent zones. A fireman cut off and activation (override) switch shall be provided at the Fire Command Centre. As an alternative form of fans activation, the use of smoke detectors to activate the jet fans system is allowed based on the following conditions:

(i) The detectors are positioned at the effective mid-range of the jet fan profile and

(ii) In-duct smoke detector is located at the start point of the exhaust duct.

(iii) Jet fans system is only operated upon activation of 2 smoke detectors. This is to minimize any false alarm.

3.3.2 The jet fans system shall be provided with a secondary source of power supply through automatic operation of an emergency generator in case of failure of the primary power supply source.

3.3.3 The jet fans shall be distributed at a spacing of 2/3 of the tested effective range of the particular jet fan. The tested effective range of the jet fan shall be taken as the distance up to the point at 0.2m/s of the air-velocity distribution profile.

3.3.4 The minimum headroom for the installation of the jet fans system is 3m.

3.3.5 The interaction of the various components of the jet fans system shall be in the following manner:

a) Each group of exhaust fans for each smoke control zone shall be interlocked with its corresponding groups of jet fans for that zone.

b) If the group of exhaust fans stops/fails in any smoke control zone, its corresponding groups of jet fans in that zone shall stop. But if any of the exhaust fan is still in operation in a particular smoke control zone, all the jet fans shall continue to operate in that zone.

c) The exhaust fan shall continue to run even if any corresponding group of jet fans fails.

d) The other groups of jet fans shall continue to run even if any one group of jet fans fails.

e) If the fire alarm signal is isolated, the exhaust fans and jet fans shall continue to run at high speed. If the fireman stops the fans and restart them, both the exhaust fans and jet fans shall continue to run at high speed. This continues to be so until the fans are reset to low speed at the field control panel.

3.3.6 The jet fans system shall be independent of any systems serving other parts of the building.

3.3.7 The jet fans system design shall be such that the bulk air velocity induced by the jet fans is sufficient to stop the advance of the ceiling jet within 5m from the fire location in the direction opposite to the induced bulk air flow.

3.3.8 There shall be at least one viable approach route (i.e. where acceptance criteria for fire fighters are met – please see section 4.2 and **Annex B** for illustration) for the fire-fighters to any possible fire location up to a distance of 5m from that fire. As such, information as to the viable approach route should be displayed at the main fire alarm panel. This can be achieved by arranging the sprinkler control zone to correspond with that of the smoke control zone. Upon detection of the fire within a particular smoke control zone/sprinkler zone, reference can be made to the display showing the viable approach route for that particular smoke control zone.

3.3.9 The MV sub-panel in each smoke control zone is to be connected to the main MV panel, such that any isolation of jet fans system at a particular zone is automatically displayed at the main MV panel.

3.3.10 The car park main MV panel at FCC/Guard House and remote local panel are required to show the status lights of the fan speeds (i.e. low and high speeds) for the supply and exhaust fans. The panels are also required to have the individual group of jet fans indication lights interlocked with the main exhaust fans in the respective smoke control zones.

3.3.11 In the event of failure of the primary source of power supply and subsequent operation of the secondary power supply, the mode of operation of the jet fans system during the fire mode shall follow that prior to the failure of the primary power supply. For example, if the operation of jet fans system in a particular smoke control zone is switched off by the fireman during fire mode condition and the primary source of power fails, the subsequent operation of the secondary power supply will be such that the jet fans system remains in the previous fire mode condition i.e. non-operational mode for that smoke control zone while the other smoke control zones resume operation.

3.3.12 The jet fans system design shall take into consideration the presence of any down-stand beams and other obstruction that are of depths of more than 1/10 of the car park floor to ceiling height so as to account for any resistance to airflow and turbulence.

3.3.13 On activation of the jet fans system, the movement of smoke towards the extract point(s) should not adversely affect the means of escape and cause smoke to be blown into the lobby area or exit staircases.

3.3.14 The operation of the jet fans system should be such that there are no stagnant areas where smoke can accumulate in the event of fire.

3.3.15 The operation of the jet fans system should not cause the volume of air movement to be greater than that volume extracted by the main exhaust fans.

3.4 Wiring arrangement of jet fans

3.4.1 All jet fans shall be connected to the local jet fan control panel in groups of not more than 3 jet fans.

3.4.2 Each group will be connected by fire rated cabling.

3.4.3 Each group of jet fans will be protected by a MCB (main circuit breaker).

3.4.4 The incoming power supply for the jet fan panel shall comply with CP5. Should there be a fault with 1 jet fan, it will trip the MCB of the group only; it will not trip the main RCB protecting the other groups. As each group of 3 jet fans is protected by a MCB, this MCB will trip before affecting the main MCB at the incoming power supply in the event of an overload.

3.4.5 The jet fans shall also be wired in a zigzag configuration and no two consecutive jet fans in a straight line is to be wired as the same group. In the event of failure of 1 group of jet fans, the next corresponding group will be able to drive the smoke towards the exhaust location to be extracted (please see **Annex A**). Should 1 group of jet fans, all other groups shall still continue to run.

3.4.6 The location of the local control panel for the operation of the jet fans within each zone shall be in a relatively safe area within the zone and be spaced as least 5m apart from the local control panels of adjacent zones. This is to minimize the risk of a fire affecting all the control panels if they be spaced closely together, and thus rendering the ineffectiveness of the jet fans system.

3.5 Provision of supply air

3.5.1 Supply air to the car park can be provided via mechanized supply air fans or by permanent openings of at least 2.5% of the floor area. Whether supply air is provided via permanent openings or by mechanized supply fans, the maximum inlet air speed should be 2m/s to prevent recirculation of smoke. Supply air can be provided by natural and mechanical means provided the acceptance criteria as stipulated in section 4.2 can be achieved though fire modelling.

3.5.2 The air velocity within escape routes and ramps shall not exceed 5m/s to prevent escapees from being hindered by the air flow.

3.5.3 The replacement air intakes shall face away from any smoke exhaust points and sited at least 5m apart so as to prevent recirculation of smoke. If the supply and exhaust louvers are located on the same building façade, they shall also be separated at least 5m apart.

3.5.4 The replacement air intake should also be located on the opposing end of the smoke exhaust points so that there is no opposing flow between the supply air and the smoke that is drawn towards the exhaust fan.

3.6 Exhaust fan design

3.6.1 The car park shall be provided with at least 12 air-change per hour during fire condition. A lower air-change may be permitted provided the acceptance criteria as stipulated in section 4.2 can be achieved though fire modelling.

3.6.2 The capacity of the exhaust fan and any associated ducting should be calculated on the basis that the pressure in the car park close to the extract points is equal to the external atmospheric pressure.

3.6.3 Each smoke control zone of the car park shall have its own exhaust fan system. The exhaust fan system in each zone should be designed to run in at least two parts, such that the total exhaust capacity does not fall below 50% of the required rate of extract in the event of failure of any one part and that a fault or failure of the exhaust fan system in one zone will not affect the operation of the exhaust fan system in the other zones. The above requirement is also applicable for mechanized supply fan system, if it is used. (**Note**: If there is sharing of the exhaust air fans, see clause 3.2.2.)

3.6.4 The smoke discharge points should be located such that the smoke extracted from the smoke exhaust fans does not affect any occupied area or means of escape at the level where smoke is discharged.

3.7 Fire resistance of jet fans system

3.7.1 The jet fans system such as the mechanized air supply fans, smoke exhaust fans, jet fans, duct works and wiring shall be capable of operating effectively at 250^0C for 2 hours. The fans, ducts and wiring shall be tested in accordance with BS7346:Part 2, BS476:Part 24 and SS CP 299 respectively.

4. VERIFICATION OF JET FANS SYSTEM DESIGN

4.1 Hot smoke test / CFD fire modelling

4.1.1 The effectiveness of the jet fans system design shall be demonstrated using hot smoke test (see section 6.1). The heat release rate of the fuel load for the hot smoke test must be at least 1MW. The relevant PE or Fire Safety Engineer should decide on the fire location(s) that is(are) deemed most onerous with justification.

In addition to the hot smoke test, CFD fire modelling will also be required in the following instances:

a) If air-change per hour is smaller than 12.
b) If there are general goods vehicle or coaches where design fire size exceeds 4 MW (i.e. car fire).
c) If replacement air is a combination of natural and mechanical means.
d) If spacing of jet fans is more than 2/3 of the tested effective range.

The CFD study is to be endorsed by a FSE to verify the conformance of the jet fans system with the acceptance criteria as stipulated in section 4.2. The FSE is also required to put up a fire engineering report. Some of the accepted fire modelling software includes FDS, Swift-AVL, Fluent and Pheonics.

4.2 Acceptance criteria

4.2.1 Not more than 1000m^2 of the car park space can be smoke-logged for at least 20 mins, regardless of whether the fire is located within the smoke control zone or across the zone boundaries (Note: After the 20mins duration, smoke is expected to remain confined within the 1000m^2 area). Within this smoke-logged area, there shall be at least 1 viable route for the fire-fighters where the following conditions are satisfied:

a) Smoke temperature shall not exceed 250^{0}C at a height of 1.7m from floor level.

b) Visibility shall not be less than 5m at a height of 1.7m from floor level.

These conditions shall commence at a distance of 5m from the fire location in the direction opposite to the induced bulk air flow induced by the jet fans. All other areas outside the smoke-logged area shall be kept substantially free from smoke i.e. smoke temperature not more than 60^{0}C and visibility of at least 25m (please see **Annex A**).

(**Note** : If hot smoke test is performed, assessment is to be made on the operation of the jet fans system, movement of smoke towards the extraction points and smoke spread. The latter 2 aspects can be generally verified using the above visibility criterion. The temperature criterion need not be verified in view of the nature of the hot smoke test.)

4.3 CFD fire modelling input parameters

4.3.1 Fire Size

4.3.1.1 The design fire size shall be based on at least 4MW steady-state fire (i.e. car fire). For general goods vehicle, the design fire size shall be based on at least 10MW steady state fire (FSE is expected to provide justification for the bigger fire size other than the car fire).

4.3.2 Type of fire

4.3.2.1 The type of fire shall be flaming polyurethane.

4.3.3 Location of fire

4.3.3.1 Generally, the fire should be located furthest away from the exhaust points and in between zones. The relevant PE or Fire Safety Engineer should decide on the fire location(s) that is(are) deemed most onerous with justification.

4.3.4 Down-stand beams and other obstruction

4.3.4.1 The CFD model shall take into consideration the presence of any down-stand beams and other obstruction that are of depths of more than 1/10 of the car park floor to ceiling height so as to account for any resistance to airflow and turbulence.

4.3.5 Jet fan velocity profile

4.3.5.1 Validation model of the velocity profile is to be carried out for a single jet fan. The data from the model shall be compared against physical test data. As such, the jet fan shall be tested for velocity profile by an accredited testing laboratory for comparison with the simulated velocity profile. The test report is to be attached to the Fire Engineering Report.

The equation to be used for the deviation between the CFD profile and actual test profile is as follows:

Equation : Deviation = [(A-B) / B] X 100%

Where : A = distance/width/height from CFD profile
B = distance/width/height from actual test profile

The deviation of the distance, width and height of the actual profile from the simulated profile at the various air velocities should be within 10%.

4.3.6 Duration of fire simulation

4.3.6.1 The duration of the fire simulation shall be at least 20mins.

4.3.7 Sprinkler activation

4.3.7.1 The model shall assume there is no sprinkler activation for the design fire size specified in section 4.3.1.

4.3.8 Grid resolution

4.3.8.1 The grid size to be used in the fire model shall not be larger than 0.2m X 0.2m X 0.2m in the smoke control zone where fire is located and its adjacent zones. Other than these zones, the grid size shall not be larger than 0.4m X 0.4m X 0.4m. Alternatively, the relevant PE or FSE undertakes a grid resolution study to ascertain the appropriate grid size needed for the fire size and smoke flows modeled (e.g. outcome of study showing that additional resolution does not make much of a difference to the results).

4.4 Sensitivity study

4.4.1 A sensitivity study is to be carried out to show the impact of 1 group of jet fan failure nearest the fire on the overall effectiveness of the jet fans system. This study is applicable to both fire modelling and hot smoke test. Notwithstanding the failure of 1 group of jet fans, the acceptance criteria must still be maintained.

5. OPERATIONS AND MAINTENANCE MANUAL

5.1 An operations and maintenance manual shall be attached. The manual shall contain the roles and responsibilities of the building owner/operator, the restrictions placed on the building, identification of the sub-systems, servicing and maintenance plan, fault identification, etc. The manual can also be used as a guide for future renovations and changes to the building.

6. COMMISSIONING TEST

6.1 The Registered Inspector who carries out commissioning test of the jet fans system may make reference to Table 2 of BS 7346 - Part 7 as a guide. When hot smoke test is performed, the PE/FSE shall use a test fire size of 1MW. Reference may be made to AS 4391 on hot smoke test.

(**Note** : This standard is more relevant for an engineered smoke control system rather than jet fans system. Nevertheless, there are some aspects in this standard where the PE may find useful, such as how the test can be prepared and carried out in a proper manner.)