Smoke Extraction in Shopping Mall

Smoke is more dangerous to everyone in fires than heat, flames or structural collapse. In order to increasing know that occupant safety in a fire, which can provide an efficient smoke extraction system. Such systems can reduce property damage, both directly by reducing the spread of smoke, and indirectly by providing better view and easier method to the seat of the fire for fire fighters.

This document contains information on the smoke control system proposed a shopping mall (including retail shops, atrium and arcade).

1. General

The Smoke Extraction described in this document are arranged in the order presented in the Code of Practice for Minimum Fire Service Installations and Equipment (COP-FSI) and the Code of Practice for Inspection and Testing of Installations and Equipment – (COP-I&T), published by Hong Kong Fire Services Department (HKFSD).

2. Purposes and Objectives

The purpose of this document is to provide information to accomplish one or more of the following:

- Provide a protective environment for life safety in the means of escape from large-volume building spaces;
- Help smoke control in post fire;
- Reduce property loss by removing smoke and heat out of the shopping mall. Building materials and contents can be kept lower than their flammability temperature so as to reduce the risk of structural collapse;
- Control smoke more from fire area to adjacent zones;
- Provide conditions both within and outside the fire zone to help firemen in conducting rescue and extinguish operation;
3. Smoke Production and Movement

Smoke is a hot gases, it obeys the fundamental laws of fluid mechanics. Numbers of basic principles are defined by WFRC no. C49378 should be realized by all designers of smoke extract systems.

a) A smoke extract system does not affect the smoke from protected area. Instead, it only exhausts smoke which has migrated to the area of the extract opening under the influence;
b) A non-turbulent smoke layer, may be formed lower a horizontal ceiling, it does not entrain quantities of air unless excessive horizontal travel occurs;
c) As smoke production is largely related to fire size, which is not related to compartment volume. Simple approaches relating extract requirements to a percentage of air change per hour cannot be justified;
d) To maintain smoke layer at a given height, the mass flow rate of smoke being extracted must equal to the mass flow rate of smoke entering it;
e) Smoke removed by a smoke extraction system must be replaced by an equivalent volume of make-up air. If it enters in high speed, turbulence and mix air into an stable smoke layer and generate downward mixing;
f) Large areas may require to be divided into separate zones, since there is a limit to the size of a reservoir from which smoke can be extracted as smoke in an overlarge reservoir may lose and cool.

4. Smoke control and extraction system

The basic requirements of smoke control systems included three principles: Containment, Removal, Dilution.

In a building, air/smoke pressures are generated by:

1. Wind pressure – measurement by wind tunnel modelling. (Now also CFD )
3. Fire pressure – Max. = 15 Pa – 20 Pa
4. Stack effect : Tall building
5. Local Stack effect: across the door separating a fire room

Smoke extraction is a tool which the fire safety engineer may use to ensure suitable fire safety within a building. It is not in isolation, but is an integral part of the total package of fire safety measures designed for the shopping mall. Hence, smoke extraction in any building must be decided in context with the means of escape (MOE) and active suppression systems in the particular circumstances of that kind of building.

- Static smoke extraction system is proposed for the arcade and atrium;
- Dynamic smoke extraction system is proposed for the retail shop (except for kitchen and toilets).

COP-FSI defines “Static smoke extraction system” as “A smoke extraction system utilizing smoke reservoirs; localised ducting; and permanent openings and / or automatic opening of windows, panels or external louvers actuated by smoke detectors; to remove, on the principles of natural ventilation, smoke and products of combustion from a designated fire compartment.”
The COP-FSI defines “Dynamic smoke extraction system” as “A mechanical ventilating system capable of removing smoke and products of combustion from a designated fire compartment, and also supplying fresh air in such a manner as to maintain a specified smoke free zone below the smoke layer.”

In either systems case, smoke extraction systems should better be considered and may be found particularly useful in following conditions:

- Life safety purposes is benefit in building where MOE to the open air cannot be done within a certain period of time, since MOE could be affected with smoke and impassable.
- Reducing Fire-fighter access difficulties, fire spread and anything damage since rapid attack fire.
- Improvement of smoke clearance by natural or mechanical smoke purging system.

5. Determination and Identification of Design

There are many considerations and calculation are important in a design. Determination of fire size, smoke layer depth, smoke reservoirs, vent or fan sizes and so on. With these considerations a system can be designed for life safety, but also provide a secondary benefit in terms of fire-fighting and property protection functions.

5.1 Determine design fire size

It is difficult to design a smoke extract system to cope with any size of fire. In order to determine a fire size for design purposes, a chain careful consideration is necessary. All fire start small and grow larger. Large extent on the size of the fire produced large amount of smoke. Smoke extraction systems cannot generally be designed to cope with post-flashover and fully-developed fire.

It is unrealistic to choose a fixed design fire size, if there are no sprinklers and no obvious fire centres. We can expect the fire will continue to grow until flashover occurs since barring fire brigade intervention. However, a smoke extract system cannot generally be expected to cope with post-flashover conditions. A more realistic and theoretically sound approach is to assume a
growing fire. Either picking a fire size expected after a set time interval or choosing the fire before flashover, which can simplify the consideration. After simplifying a fire size, life safety and fire fighting system can also be designed.

Another satisfactory way of arriving at this size is by direct consideration of the building contents. The largest possible fire source in a fire compartment is an oil bath which is from other combustibles. If the building or compartment is a car park, tests have shown that fire is confined to a single car.

5.2 Determine acceptable smoke layer depth

Determining a acceptable smoke layer depth is necessary for having decided upon a design fire. Amount of smoke produced not only depends on the fire but also on the height of rise of the smoke plume. This is the height to the smoke layer base.

The higher the smoke layer base, the larger the quantity of smoke and the larger the plume rise which needs to be extracted. However the smoke layer base should be above the heads of people trying to escape beneath it. The suggested minimum heights defined by WFRC No. C49378 are Single-storey compartments - 2.5m; Upper storey of two-storey compartments - 3.0m

The base of the smoke layer less well-defined and the smoke tends to be cool, the larger smoke layer height is required on the upper of two storeys.

If the smoke control system is designed for fire fighter access only, a lower smoke base may be acceptable. Recommended smoke layer levels for this purpose are 2 - 2.5m (lower or single-storey), 2.5 - 3m (upper storey).

If designs which are related to property protection. It is establishing the smoke layer depth at a level that prevents smoke flowing into an adjoining area of the building.

5.3 Determined smoke reservoirs

It will be going to cool losing its buoyancy if smoke is held in too large an area. Smoke layer may being mixed into the clean air below. Maximum suggested reservoir sizes are: Natural extraction - 2,000m²; Power extraction - 2,600m².
For the purpose to limit the horizontal spread of smoke can either be permanent features of a building or dropping into position on operation of the alarm system. Smoke curtains are generally be used. In either case they must extend below the base of the smoke layer. Often the maximum practical depth of such screens determines smoke layer depth rather than vice versa.

5.4 Determined vent or fan sizes

During determining vent or fan sizes in power extraction, we need to design fan sizes for removing the volume of smoke. Fans should operate at a certain temperature. However, they will cool the smoke if sprinklers are installed it can be assumed. In such cases if we generally assume a maximum smoke temperature about 300 degree defined by WFRC No. C49378.

The fans should be rated to take account of frictional pressure losses in the ductwork, if the fans are connected to the extract points by ductwork

6. Smoke Control in Retail Shops

I suppose all retail shops in shopping mall in my research are designed in open-view and will be provided with dynamic smoke extraction system.

The COP-FSI specification of the system is summarized as follows:-

Basic Consideration
- system be simple and reliable
- control smoke away from egress / escape route
- extract air point at high level; at least one extract point to be within each 500 sq.m; and coverage distance < 30m
- make-up air rate be 80% of extract rate by mass
- make-up point at low level
- free grille area be based on air velocity:-
  < 6 m/s for mechanically propelled
  < 3 m/s for not mechanically propelled
- fire separation in compartment be maintained
- smoke discharge 5m away from any building openings
above 3m for horizontal discharge
above 6 m for downward discharge

Smoke Extraction Ductwork
- within same fire compartment: as DW142 standard;
- passing other compartments: to be of maximum Fire Resistance (B.S. 476: pt 24) of the passing compartments; and pass impact test of BS 5669 under dropping height of 1m
- pass pressure test of DW 143
- smoke extraction shaft contain no other services

Temperature Rating for Equipment
- temperature rating be 250 deg. C for 1 hour
- essential electrical supply and high temperature cabling
- switch, control device or houses in 2-hour F.R.P. enclosure
- smoke extract fans and other equipment exposed to hot smoke temperature to withstand: 250°C for 1 hour

Control and Actuation
- ‘fail-safe’ design
- zone actuation as by “Fire” signal in AFA systems, or from the independent smoke detectors for S.E.
- no interruption from other services
- multiplex control unit be approved type
- at F.S. panel, to provide with:- manual on / off control switch, and indication light on fan status
- fan status sensor be centrifugal switch or pressure switch

Standby or Duplicate Equipment
- apply for sleeping risk premises, or S.E. system used > 12 hr. per day
- duplicate on fan, motor, drive, starters, etc.
- automatic changeover on duty equipment in failure

Basement
- separate system for each compartment
- at least 2 independent plants and ductwork for each system
- E.A. be 8 air changes per hour of compartment volume
- emergency power for 2 adjacent compartments with highest electrical load
The smoke extraction system maintains the smoke layer at about 2.5m above the floor level. Smoke bulkhead is installed at the edge between each retail shop and arcade. In order to extract smoke out from the shop and control the smoke layer at 2.5m above the finished floor level, the smoke extraction system will be activated when activation of the cross-zone smoke detectors in the retail shop.

The smoke can enter to the smoke reservoir above the false ceiling and the smoke is contained within a shop and stop to move towards outside. The perforated ceiling with a minimum of 20% openings is installed inside the shops.

The large size of the shopping mall is good for providing enough make-up air so called natural air in take from the adjacent areas.

The dynamic smoke extraction system will be activated upon actuation of cross-zone smoke detectors in the retail shop, except for food court.

A second exit is provided at the back of retail shops. Such exit for the retail to satisfy the requirements of MOE.

7. Smoke Control in Atrium and Arcade

I supposed the roof of atrium and arcade is designed to be different level. Installation of air duct for dynamic smoke extraction system is not a good choice. Therefore, static smoke extraction system is proposed for the atrium.

The COP-FSI specification for the system is summarised below:-

Smoke Reservoir
- 500 sq.m
- perimeter to discharge < 30 m

Smoke Barrier
-non-combustible, 1 hr. F.R.
depth below lowest beam:-
800mm for “below ground” floor
500 mm for “above ground” floor
Smoke Extraction in Shopping Mall

- above finished floor >= 2 m
- “fail safe” design for movable barrier
- openings for other services < 100 mm x 100 mm
to prevent smoke from moving along the horizontal surface. To ensure there are an
enough deep layer to allow efficient venting.

Smoke Discharge
- free area > 2% of the serving floor area
- ½ of discharge be permanently open, or automatically actuated on smoke signal
- actuation be “fail-safe”, and back-up by essential supply
- smoke detector in each 250 sq.m
- manual quick release be provided at height < 1.8 m
- sign to remind not obstructing the vent

Such atrium and arcade design with larger smoke reservoir is same with a large smoke
containment for smoke filling which will longer MOE.

The shopping mall is divided into two or three large compartments. The
compartments are divided into five or six smoke zones. Natural make-up air intake
of area not less than the smoke vent will be provided at low level at the locations.

For the purpose that fresh air can be drawn in from compartments and fire shutters at
remote locations of a fire zone will not be descended at the same time, since each
compartment is subdivided with smoke barriers. Fire shutters are closed only when
the detectors installed at either side of the shutter is activated. Make-up fresh air can
still enter the fire zone if the shutter is closed in the event fire.

All natural make-up air intake will be opened to allow make-up fresh air to release the
hot smoke when actuation of smoke detectors in any smoke zone.

To maintain the air-conditioned environment at a designed temperature and humidity
during the normal condition. The smoke ventilators and outdoor air inlet openings
will be closed since the static smoke extraction system comprises smoke ventilators
for exhaust and fresh air make-up inlet openings.

If there are activation of smoke detectors, the smoke ventilators and outdoor air inlet
openings will be opened. All of them is arranged to open in the event of failure of
fire signal or electrical supply to the smoke ventilators. Fire service control center
provide manual override control too.

8. Conclusion

It should be noted that as buildings can be widely different, it is difficult to cover all eventualities. The design of any smoke extraction system involves experienced engineering design and judgement to specific design objectives.
**Reference**


5. Codes of Practice for Minimum Fire Service Installations and Equipment and Inspection and Testing of Installations and Equipment. Fire Services Department. Hong Kong.