Smoke Control and Mechanical Air Handling

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Summary

It is well known that smoke and toxic gases are the major killers associated with all fires. Modern day air conditioning systems, whilst providing a comfortable atmosphere for occupants of a building, have also provided the means by which smoke and toxic gases can move throughout a building, endangering the occupants safety. Current trends in air handling system design are to halt this migration of smoke, assist in providing safe escape routes, and aiding in quick extinguishment.

A number of methods referred to in our report attempt to accomplish these requirements, but it must be realised that these are not the only ways in which effective smoke handling can be achieved. New methods are still being tried and the scope for innovative engineering in mechanical air handling is enormous.

Introduction

It has long been recognised that smoke poses the major threat to human life. With the advent of modern air conditioning systems within buildings, this threat is no longer confined to the areas in which the smoke is generated. A prime example of this is the MGM Grand Hotel fire of 1980. Though confined to the first floor of the building, the fire resulted in 85 deaths, the majority of which occurred on floors far above the fire. These deaths were mainly due to the results of smoke inhalation. Other fires such as the Roosevelt Hotel fire (1963), and the Retirement Centre fire, Johnson City, Tennesee (1989), all highlight the need for smoke control in conjunction with air-conditioning systems.

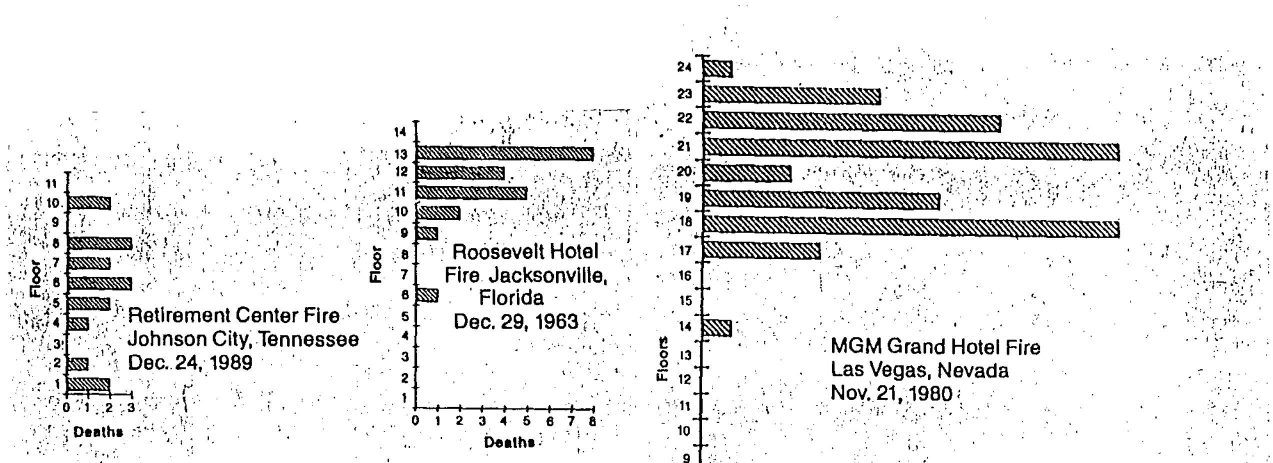

Figure 1. Deaths by floor for three fires where the fire was located on the first floor.

Figure 1.

This report deals with the role of mechanical air handling within a building and its effects on smoke control.

HVAC Systems

To understand how mechanical air handling can assist in smoke movement, you need some idea of how an air handling unit operates.

In buildings, the Heating, Ventilation, Air Conditioning (HVAC) systems operate to maintain a comfortable atmosphere within the building. HVAC systems have primarily provided cool conditions during Summer and warm conditions during Winter, but it has now been recognised that different areas within a building require different loadings.

During Winter some areas may require cooling due to the internal production of heat from equipment and lighting. It is the need for zoning that has caused the proliferation of different types of systems to be used (1).

Although no building's system will be identical, the fundamental components are basic to all HVAC systems, small or large.

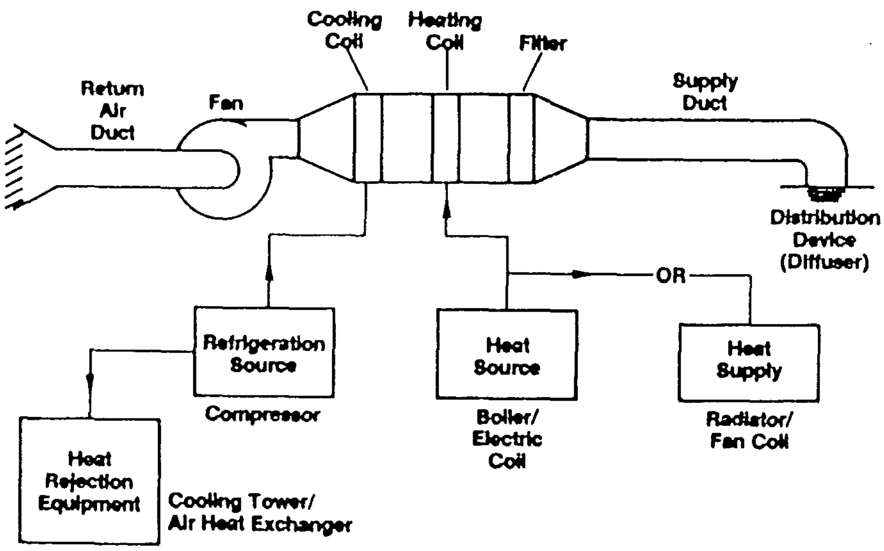

Figure 2.

Air, fresh and/or recirculated, enters the unit and passes through a fan, cooling and heating coils, and a filter before being distributed throughout the system via ducts. Air is then extracted from the building via another network and either re-enters the unit at the beginning or is vented outside. Throughout the network of ducts are fans and dampers that aid the distribution of air. Humidifiers and other apparatus are simply additions top the basic system.

The next step then is to integrate fire protection with the HVAC system.

Fire Alarm - HVAC System Integration

The first step to integration of fire protection with a HVAC system, is the use of fire dampers. These are located throughout the system, especially where ducts pass through fire walls, and close on activation to prevent smoke movement along ducts. Most are activated via a fusible link, but this can pose a problem in that large volumes of smoke may pass before temperatures are elevated sufficiently to melt the link. The solution then, is to connect these dampers to the overall smoke and fire detection system of the building.

To do this the HVAC system and the fire alarm system must work together. On the activation of smoke detectors, fire alarms, or sprinkler systems, pre-planned sequences involving the HVAC system (discussed later) need to be bought into play. Whether these are implemented manually or automatically, will depend on the system itself.

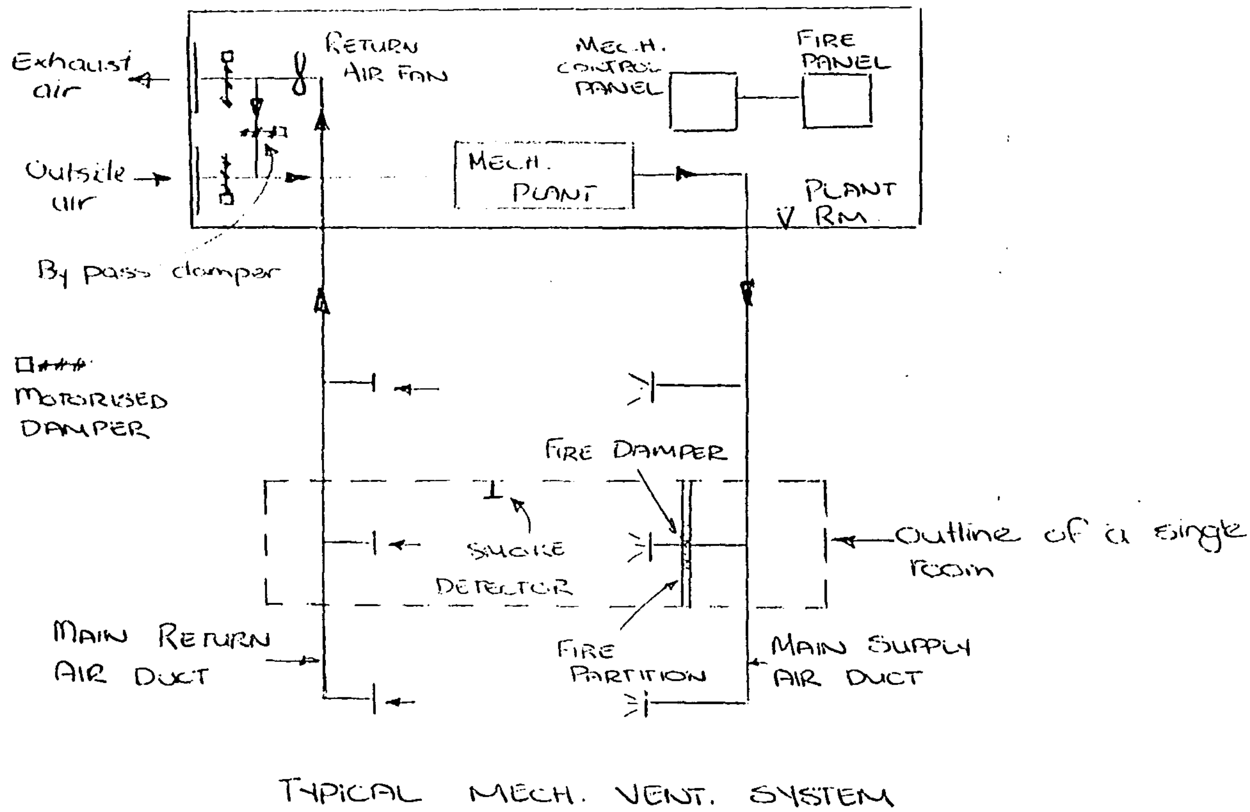

Figure 3.

If operated automatically, it is advisable that manual controls are also available, in case of malfunction and to allow fire services control over air movement during a fire.

Other means of initiating HVAC smoke control sequences can be to place smoke detectors in the ducts themselves. These however may not be reliable as early warning devices due to the dilution of air from the various sources.

The most reliable scheme then, is to integrate the fire alarm and HVAC systems to utilise the developments in passive and active smoke control.

Two Roles in Smoke Control

Then concept of using the HVAC system as a smoke control aid has developed considerably over the past 20 years. The principles of smoke control are now well established and it is recognised that two basic approaches exist; passive control and active control.

Passive Control

The foremost aim of an Engineer designing an HVAC system should be the prevention of smoke movement throughout the system. The achievement of this aim is gained by employment of passive procedures. The concept is to close the system down, and by using smoke dampers throughout, we inhibit forced movement of smoke in the system. We are incorporating the idea of compartmentation whereby the smoke and its source are confined to the fire zone only.

Active Control

It is now widely acknowledged that HVAC systems can play an active role in limiting smoke migration within buildings. Active smoke control is aimed at preventing smoke from overcoming people before they have escaped the building, by maintaining clean air escape routes. The main process by which this is achieved, is by **pressurisation.**

To attain pressurisation, clean air is injected, via the HVAC, to those zones not containing fire and smoke so as to set up positive pressure areas. This then inhibits the smoke due to its inability to flow from a low pressure zone (i.e. location of fire) to a high pressure zone.

The concept of pressurisation has previously been used in stairwells, lobbies, and other escape routes, but is only now being recognised as a viable option for use throughout the entire building.

There are three modes in which a pressurised system can operate:

(1) Plant off except in an emergency (single stage operation):

The problem with this approach is that there could be a delay between the discovery of a fire and the subsequent starting of the plant. Thus during the early stages of the fire large quantities of smoke could pass into the escape route before pressurisation commenced.

(2) Plant running continuously:

This option guarantees pressurisation during the early stages of fire but involves high running costs.

(3) Plant running continuously at reduced capacity except in emergency (two stage operation):

This is a compromise between the previous two options and is the preferred method. Sufficient air is available to prevent excessive smoke infiltration in the early stages of the fire, yet at the same time reduced capacity means that running costs are not excessive. Also fresh air ventilation is provided during normal operation of the building.

The other aspect of smoke control is fire **venting**. This process serves two purposes; one being the lowering of pressure in the fire zone thus aiding zonal pressure differences, and secondly to remove smoke and toxic fumes to assist in fire-fighting. This is achieved by allowing extraction to take place from the fire zone only.

Mechanical smoke handling is the combination of both these processes. This combination initially provides a safe means of escape after which the focus is to aid fire confinement whilst providing improved fire-fighting accessibility.

Basic System Schemes and Configurations

The **basic function** of these smoke handling systems are:

(1) The fire zone detector establishes nonfire zone pressure (some also decrease fire zone pressure by exhausting the fire zone)

(2) After the evacuation period (estimated at half an hour) pressurisation begins to give way to containment for the remainder of the buildings fire resistance ratings.

(3) After fire-fighting control is established, selected zones may be purged of smoke.

Some examples of **different configurations** are (2):

(1) *Nonfire Zone Pressurisation:*

Smoke detector in fire zone
(a) closes fire zone supply dampers
(b) closes fire zone return dampers
(c) closes return dampers in nonfire zones
(d) opens supply dampers in nonfire zones
(e) signals fans on maximum
(f) performs other detector functions.

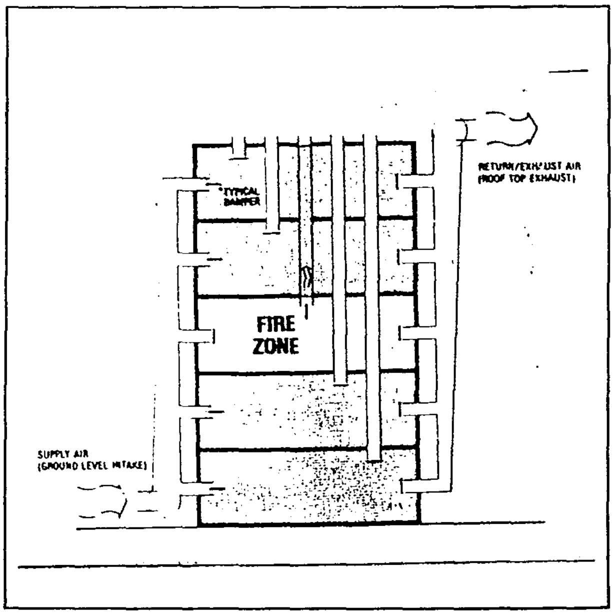

figure 3. system one

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(1) *Nonfire Zone Pressurisation With Fire Venting:*

Smoke detector in fire zone

(a) closes fire zone supply dampers
(b) closes return air cut-off dampers
(c) closes return dampers in nonfire zones
(d) opens supply dampers in nonfire zones
(e) opens the fire zone return dampers
(f) signals fans-on maximum
(g) performs other detector functions

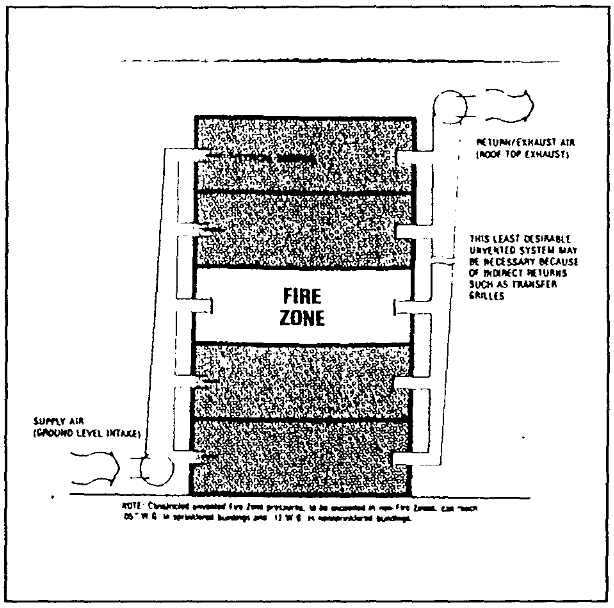

Figure 4. System Two

(3) *System Three:*

As for System Two, except separate dedicated vents are used, and those normally closed are opened while the return air dampers in the fire zone are closed.

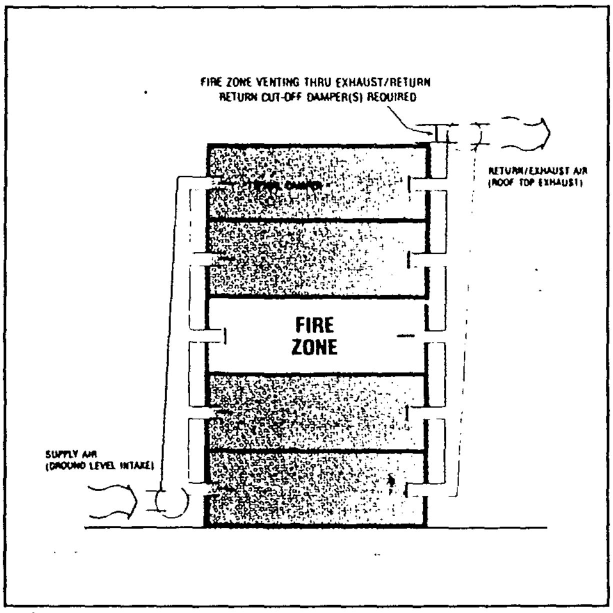

Figure 5. System Three

Conclusion

For many years HVAC systems had the reputation of aiding the spread of smoke, but new developments show that HVAC systems have a vital role to play in increasing fire safety within buildings.

To enable Engineers to design a HVAC system capable of effective smoke control, they must be aware of all the facets of passive and active control, and how the combination of the two will lead to more efficient smoke handling. They must recognise the advantages of the use of pressurisation and venting, and how these can be implemented to assist in fire escape and fire-fighting. They must also realise that the idea of smoke handling and control via the HVAC system is still in its fledging years, and that innovative ideas with continued research will inevitably lead to more reliable and efficient systems, benefitting Engineers and the public alike.

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