# Fire Research Note

No. 772

## NOTES ON THE USE OF SMOKE EXTRACTORS FOR FIREFIGHTING

by

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March, 1969

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F.R. Note No. 772.

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SUMMARY

This note provides guidance on the ways smoke extractors may be used to assist firemen. Attention is given to the problem of establishing and maintaining a layer of fresh air below a layer of hot smoke and the controlled use of a current of air to dilute smoke and to direct its flow.

KEY WORDS: Extinguishing, smoke extractor.



MINISTRY OF TECHNOLOGY AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

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## 1. Introduction

This note follows a request by the Home Office Joint Committee of Design and Development for a brief review on ways smoke extractors may be used in operations against fire. Smoke extractors are primarily devices for moving air; they may push air into a fire, or they may suck air contaminated by smoke and combustion gases away from a fire. In the past, special fans have been used by the fire services for smoke extraction, but in recent years, fire brigades have begun to use high expansion foam apparatus which contain fans to produce a flow rate of air, and they may well be instances where these may be used as smoke extractors.

## 2. Physical aspects of the movement of smoke and air at fires

There are three physical aspects of the movement of smoke and air at fires which are relevant here. Firstly, as indicated above, smoke extractors in general can be used both to inject air or to remove smoke from a building. If the building were otherwise completely sealed, these appliances could produce this flow only for a very limited time until either a few inches head of pressure or suction respectively was produced in the building. Buildings in practice are not completely sealed and the injection of air into a building usually causes either air or smoke to be pushed out of the building at some other point. Likewise the suction of smoke out of the building causes air to be sucked in at other points. Secondly, the extent to which the atmosphere in the building is disturbed, is substantially greater when air is injected, than when smoke is extracted, since the flow of air at high speeds from a fan causes a great deal more turbulence in space near the injection point than would be the suction of the same amount of gas from the space, through the same size opening. Finally, the smoke produced by a fire is lighter than air and tends to rise. The smoke, therefore, tends to form a layer over any incoming air, particularly if the latter enters at a low level.

3. <u>Maintenance of separate smoke and air layer</u>

An important objective in the use of smoke extractors and indeed in all forms of fire ventilation is to keep the smoke and the air in separate layers. If extraction of smoke takes place near the top of the smoke layer, then this will not in itself cause much turbulence in the smoke so as to cause the smoke to be mixed up with the air layer underneath. If on the other hand, the air is injected at a high speed, then the resulting turbulence will tend to mix the whole atmosphere so that the whole space becomes smoky.

The undesirable feature of forceful mixing caused by injection of air may be mitigated if the air is injected below the smoke and if its velocity is reduced below a certain value, which depends on the temperature of the smoke, and the size of the opening through which it is being injected[1]. There will not then be enough turbulent energy in the injected air to overcome the natural tendency of the smoke to form a layer, and the injected air will tend to form a fairly clear layer under the smoke. Available information suggests that to achieve this effect the air velocity needs to be reduced to below 1.5 m/s (5 ft/s). The velocity of air from the delivery side of fans is usually greater than 15 m/s (50 ft/s); to reduce it to 1.5 m/s it is necessary to increase the area through which the air is delivered, for example, by using a large, porous bag.

Normally when air is being sucked into a building, either because of the natural air ventilation effect of the fire, or because of a suction effect of a smoke extractor, the available openings through which the air enters are sufficiently large to keep air speeds down to about 1.5 m/s. In this case, the entry of the air will not cause undue turbulence and the cold air will tend to form a layer under the hot smoke. However, if there is a serious limitation on the size of opening through which air is entering the premises, or if a high wind is blowing in the direction of the opening, then substantial turbulence will take place at the injection point, and again the whole space will tend to become smoke-logged.

4. <u>Direction of the smoke</u>

Under certain conditions it is possible to produce an air current along a channel or a passage which has sufficient force bodily to carry away the smoke down-stream of the air current, so that upstream of the point of injection of smoke there is clear air and downstream, there is mixed air and smoke. Thus, there may be quite a substantial fire in a corridor or in a room off a corridor with an open door that is producing a great deal of smoke. In the absence of a substantial air current, this corridor will tend to become smoke-logged in both directions.

If the airstream along the corridor is increased, the a layer of air would tend to form at ground level with the smoke backing against the current of air at ceiling level. At a sufficiently high speed, however, smoke will not back into the upstream air current at all. The air current necessary to overcome this backing tendency depends on the dimensions of the corridor and the size of the fire that is feeding smoke into it, but in general it is of the order of about 3 m/s (10 ft/s)[2]. Thus, a corridor of cross-sectional area of 5 $m^2$ (54 $ft^2$) would require a throughput of about 900 $m^3$/min (30,000 $ft^3$/min) to stop smoke backing upstream against advancing firemen. This figure applies to horizontal corridors. If the corridor is sloping slightly upwards away from the firemen, then a smaller flow rate of air would be required. However, if it is sloping towards the firemen, then a greater flow rate of air would be required. Again, in order to stop smoke coming out bodily through an open door from a substantial fire on the other side of the door, then an air velocity through the door of the order of 3 m/s would be required. Of course, a substantial area, at least equivalent to the size of the door, must be available on the other side of the fire in a compartment through which air is being directed, to allow the smoke of the fire to be pushed out on the other side. This leads to the principle of pressurization, since if the door is shut, then to prevent smoke coming out at all through the gaps round the door, it is necessary to establish enough pressure on the non-fire side of the door to cause a fairly high velocity of air through the gaps. The velocity is somewhat higher than 3 m/s in this instance, and is approximately 5 m/s (16 ft/s). However, the gaps round the door are so small (usually about 0.013 $m^2$ (20 $in^2$) ) that the flow rate round the edges of the door of about 4 $m^3$/min (140 $ft^3$/min) is sufficient to prevent smoke leaking back through the door. Here again, this can only work if there is at least a comparable area for smoke to leak out at the same rate.

## 5. Dilution of smoke

In circumstances where it is not possible to maintain layering of the smoke or to bring about direction of the smoke, then injection of air could still serve a useful purpose by bringing about a measure of dilution of the smoke; the more dilute the smoke the greater the visibility and the less is its toxicity. The extent to which this technique can be used depends on how much smoke is produced or is being fed into the compartment. From information on the relation between visibility of the smoke and its opacity[3], and on the opacity of different smokes produced by different materials[4], it is possible to estimate the flow rate of air needed to mix with the smoke from fires of a given size to produce a given visibility. Such estimates are given in Table 1 for fires with a surface area of 5 $m^2$ (54 $ft^2$) to produce a visibility of 5 m (16 ft).

Table 1

Flow rates of air required to dilute the smoke evolved from a fire in 5 $m^2$ (54 $ft^2$) of flaming surface to produce a visibility of 5 m (16 ft)

| Nature of burning material | Thickness mm | Air flow rate required for flaming fire | |
|---|---|---|---|
| | | $m^3$/min | $ft^3$/mim |
| Wood fibre insulating board | 12.7 | 28 | 1,000 |
| Polyurethane foam sandwich | 13.0 | 140 | 5,000 |
| Hardboard | 3.7 | 170 | 6,000 |
| Rigid P.V.C. | 1.6 | 280 | 10,000 |
| Chipboard | 12.7 | 310 | 11,000 |
| Flame retardant glass fibre reinforced polyester | 3.3 | 430 | 15,000 |

It is assumed here that both the smoke and air are being injected into a volume of comparatively small space, for example, a corridor or a hall and staircase and that the mixed input of smoke and air can be ejected from the building some distance from the point of injection of the air. It will be seen that very high flow rates of air are needed for many materials. If a large space is already smoke-logged it must be remembered that substantially more air may be required to clear the smoke that already exists. Thus, to improve the visibility in smoke from 0.5 m (1.6 ft) to 5 m would require an amount of air equal to about 2.5 times the volume of the smoke. In practice it is not often possible to specify certain limited areas of combustible in a fire, particularly when air is being fed into the fire, as this generally increases the combustion rate and increases the area of involvement of the fire. A more general situation is that there is fire in one room which is being maintained by an independent source of ventilation, for example, a window in the room, but which is producing a leak of smoke, round the edges of a closed door. Conditions may not allow pressurisation but could allow the smoke to be flushed out by dilution. A flow rate of the order of 20 $m^3$/min (700 $ft^3$/min) would then be sufficient to give good visibility in the space and to reduce the concentration of the carbon monoxide to such an extent as to render it unlikely that the atmosphere would be fatal in times less than half-an-hour.

## 6. Application to practical fire situations

Perhaps the best way of using a smoke extractor is to supplement the natural driving forces for ventilation in a fire in a way that increases the layer of cool air below hot smoke for firemen to work in. If the size of an opening in the ceiling in a compartment through which smoke is being ventilated is limited, for example, to a fraction of a square meter or a few square feet, but the size of the opening or door through which firemen are entering the compartment is, for example, 3 $m^2$ (33 $ft^2$) upward, then producing a flow of smoke through the ventilating hole by using a smoke extractor as a suction device, will encourage fresh air to flow through the opening in which firemen are entering at a rate which is not too large to destroy the layering of the smoke. Thus, the suction of 150 $m^3$/min (5,000 $ft^3$/min) of smoke will produce an air current inwards through a door of 3 $m^2$ area of only about 0.8 m/s (2.5 ft/s). If the compartment is a basement it would help in this situation if the air from the door was led directly into the lower half of the basement, rather than having to traverse the upper smoky layer of the basement first, since this process itself tends to induce mixing of the smoke. Another approach is usually to use a collapsible duct to feed the air into the lowest part of the basement that is accessible. However, as explained above, if this technique is adopted the velocity of the injection of the air should be reduced to about 1.5 m/s to limit mixing turbulence, if the intention is to create a layer of cool air below the smoke.

Injection of air rather than extraction of smoke greatly reduces the possibility of smoke and heat damage to the fan and ducting. This is particularly important when high expansion foam equipment is used for the purpose. The nets, nozzles and interior surfaces of this equipment would need to be thoroughly cleaned and checked after it has been used to extract smoke.

For fires in dwellings perhaps the best use of smoke extractors would be as a portable pressurization system. In this situation a smoke extractor would not be able to cope with the smoke from a fire advancing through an open door into the rest of the premises. However, if that door can be closed or if in some other way most of the smoke could be discouraged from entering the premises through that opening, then an air movement of capacity of about 150 $m^3$/min (5,000 $ft^3$/min) would be quite sufficient to establish a pressurization within the rest of the premises to prevent further smoke entering it. An alternative is to dilute the smoke so that reasonable visibilities can be obtained. This method can be invoked if the general leaks in a building are too great to allow pressurization.

## 7. References


(1) RASBASH, D. J., STARK, G. W. V. and ELKINS, G. H. A model study of the filling of compartments with inert gas. V.F.D.B. Conference, Karlsruhe, 1964, o. 27.

(2) THOMAS, P. H. The movement of smoke in horizontal passage against an air flow. Joint Fire Research Organization Fire Research Note No. 723/1968.

(3) RASBASH, D. J. Smoke and toxic products produced by fires. Trans. J. Plast. Inst. January, 1967, p.55.

(4) BOWES, P. C. and FIELD, J. Assessment of production of smoke by building materials in fires. Joint Fire Research Organization Fire Research Note in preparation.