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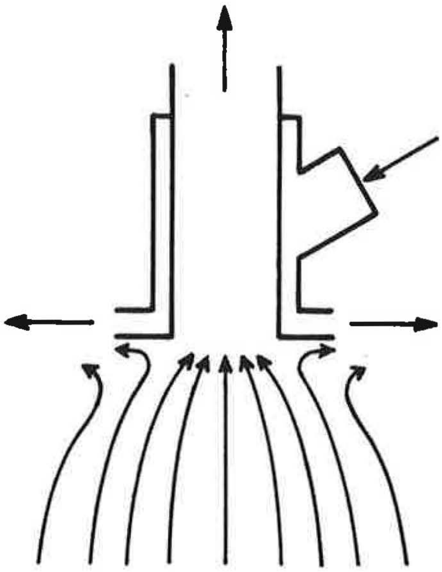

INDOOR ENVIRONMENTAL TECHNOLOGY
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C. E. HYLDGÅRD
AERODYNAMIC CONTROL OF EXHAUST
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AERODYNAMIC CONTROL OF EXHAUST

C. E. Hyldgård, University of Aalborg, Denmark

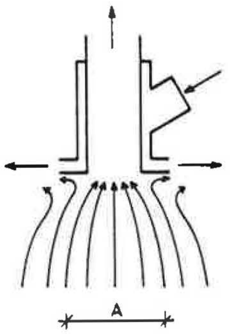
1. INTRODUCTION

It is well known that a normal exhaust opening will have an afflux of air equal from all directions. Therefore, the air velocity decreases with increasing distance from the exhaust opening. For the majority of exhaust openings the velocity will at a distance of only 0.5 m be so low that there is no draught problems. This circumstance facilitates the placement of exhaust openings in an ordinary ventilated room. On the other hand, the same circumstance makes it extremely difficult to use local exhaust, as the exhaust, if it is to be efficient, must be placed very close to the source of pollution.

The University of Aalborg, among others, has previously made experiments with combined injection and exhaust to obtain an improvement of the effect of the exhaust, but so far without success.

In the autumn of 1985 the University of Aalborg was approached by the manufacturer C. P. Aaberg, who had obtained aerodynamic control of the exhaust by means of injection. The remaining investigations comprising optimizations of the system with regard to effect, consumption, requirements for comfort, noise conditions etc. were performed at the University of Aalborg in 1985 and 1986.

2. THE AABERG PRINCIPLE



Figur 1. Outline. A = effective suction area.

The overall principle is that a radial jet around the suction opening entrains air from the environments, and this entrained air reduces the suction area to comprise the area A shown in figure 1. Thus, this system is more efficient at longer distances than conventionel systems. However, there should be proper balance between suction and injection. If the injection is too weak the radial jet will be bent and drawn into the suction. If the injection is too strong the velocity everywhere in front of the nozzle is increased, but the effective suction area A decreases. A closer investigation of the correspondence between the design of nozzle, the velocities and degree of efficiency has proved to be necessary.

3. CRITICAL INJECTION VELOCITY

For a given nozzle design, a given quantity of exhaust air and a given height of supply opening a critical injection velocity must be exceeded to obtain the air flow distribution shown in figure 1. Below the critical velocity the radial jet is bent and sucked out which only results in a lower effect than of a conventional suction. At the critical velocity the effect is quite contrary the desired effect, since the pollution is blown away from the nozzle instead of being affluxed towards the nozzle. The air flow distribution above the critical velocity will be as shown in figure 1. There is a certain hysteresic effect in the air flow distribution: If the injection velocity is to be reduced to ν_1 to change the air flow distribution, the injection velocity is to be increased to a value of $\nu_2 > \nu_1$ to regain the air flow distribution shown in figure 1. Due to the fact that disturbances from the environment, e.g. from persons passing, may give rise to changes in the air flow distribution the critical velocity will in this case be defined as the velocity, ν_2, which in a few seconds can establish the air flow distribution in figure 1. If the injection velocity is further increased the overall velocity in area A is also increased, but a larger quantity is entrained in the injection air so that the effective suction area A is a bit reduced. However, even very high injection velocities will in principle result in the air flow distribution in figure 1, and the higher the injection velocity is the less the air flow distribution will be affected by disturbances from the environments.

Previously, very small heights of supply openings have been used, e.g. $s = 0.15$ mm, and very high injection velocities, e.g. $v = 30$-50 m/s. Thus, much noise is created and a very high supply pressure is required for the injection. At the University of Aalborg the injection velocity has been reduced to a minimum without destroying the desired effect.

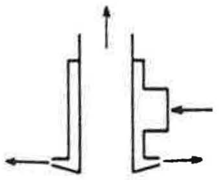


Figure 2. Outline of the nozzle used at the University of Aalborg. The sloping front flange gives a lower critical velocity and much less loss of pressure.

Figure 2 shows an outline of the nozzle developed at the University of Aalborg. It has been tested in different structures, but the one shown in figure 2 showed the best function when alle parameters were taken into consideration. For this structure the critical injection velocities shown in figure 3 are found as functions of the height of the supply openings and the quantity of exhaust air V_0.

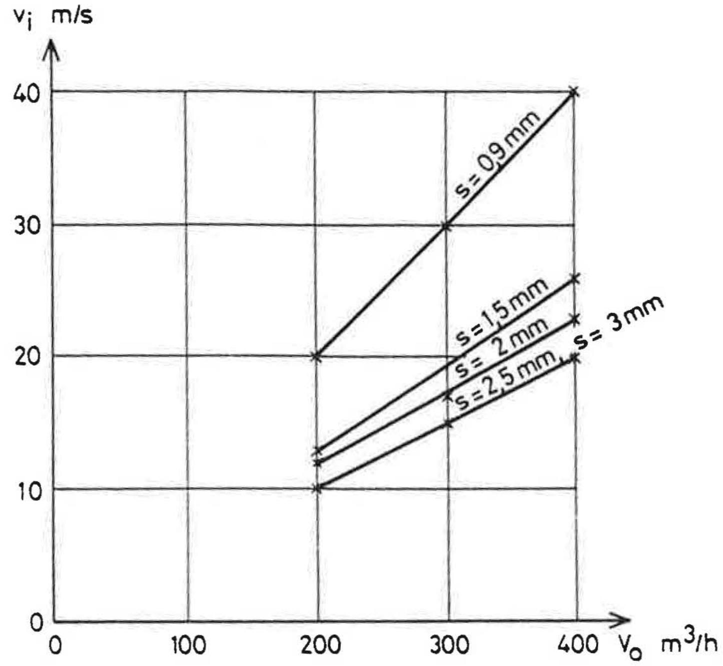


Figure 3. Critical injection air velocity v_i as a function of the quantity of exhaust air V_0. The height of the supply opening s is the parameter.

If the momentum flow in the injection at critical velocities $m_i \cdot v_i$ is related to the momentum flow in the exhaust $m_0 \cdot v_0$ the remarkable result shown in figure 4 is obtained.

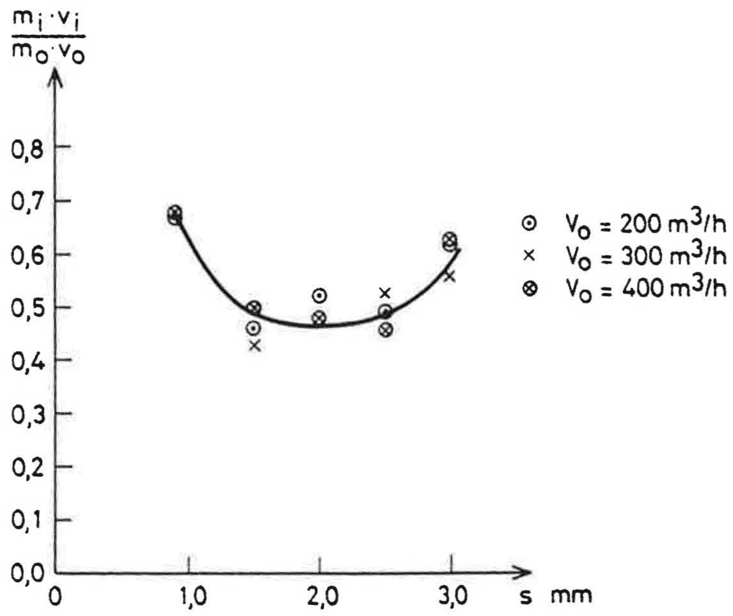


Figure 4. The ratio between the momentum flows in injection and exhaust as a function of the height of the supply opening s at the critical injection velocity. The quantity of exhaust air V_0 is the parameter.

Figures 3 and 4 indicate that the optimal height of supply opening is between 2 and 2.5 mm. Taking account of the consumption of the injection ventilator and to the generation of noise in the injection the height of 2.5 mm is preferable, and therefore this height has been chosen for the following investigations.

4. CLUTCH VELOCITIES

The clutch velocity in a place in front of the nozzle shall by this be defined as the velocity of the air in this place caused by the nozzle. The ratio between the own velocity of the pollution and the clutch velocity is decisive for whether or not local exhaust will catch local pollution. So the clutch velocity is significant.

If the nozzle is placed at the end of a table as shown in figure 5 the clutch velocities can be measured in the centre line partly for suction only, partly for suction with injection. Figure 5 shows the measured clutch velocities at a suction of 400 m^3/h in two situations: without injection and with an injection velocity of 25 m/s. Due to disturbances from the environments measuring of clutch velocities below approximately 0,15 m/s will be unreliable.

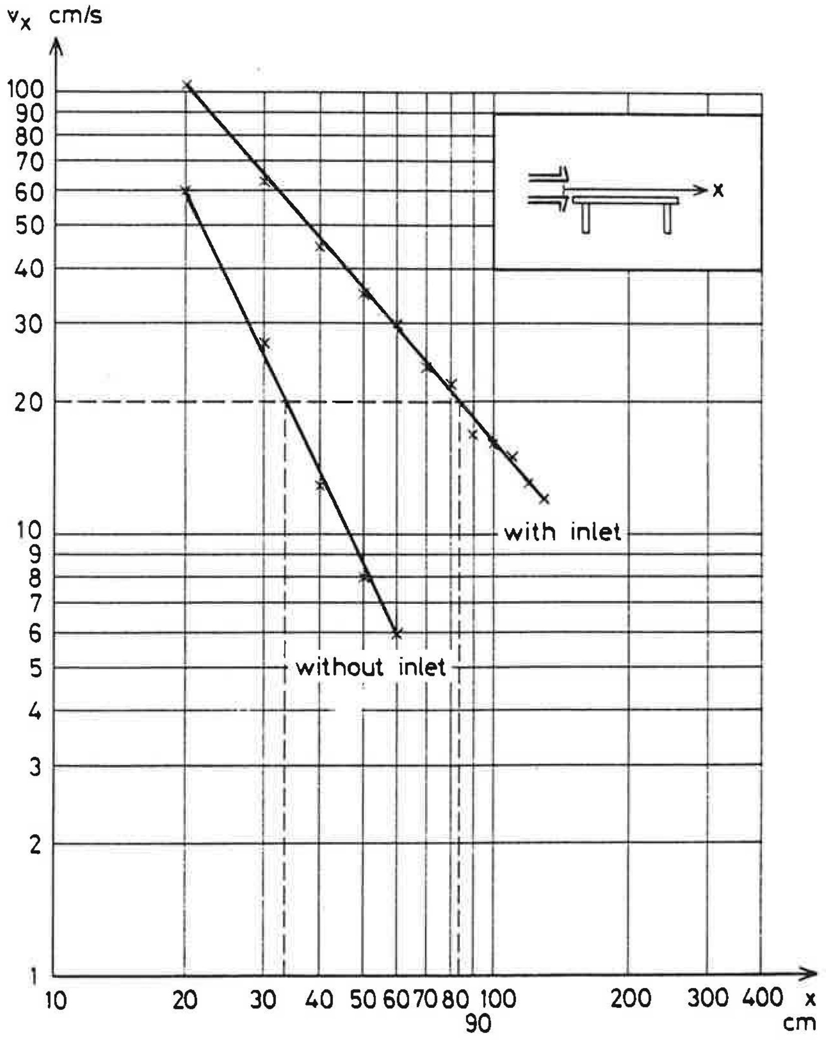


Figure 5. Clutch velocities v_x in the centre line in front of the nozzle at a suction of 400 m^3/h from the rear edge of a table in two situations: suction alone, and at the injection velocity 25 m/s.

It is seen from figure 5 that to obtain a clutch velocity of 20 cm/s conventional suction has a range of 34 cm while the same suction with addition of injection gives an effective range of 84 cm.

If the table shown in figure 5 is given a back wall where the nozzle is placed the clutch velocity at suction alone is increased. Thus the difference between the effective ranges in situations with and without injections is reduced. However, there is still a significant advantage when the injection is performed as shown in figure 6. It is an advantage when using a back wall that the Coanda effect results in the fact that the critical injection velocities are reduced significantly. Thus, at a suction of 400 m^3/h the critical injection velocity has been reduced to 6.5 m/s. When using a back wall the choice with regard to injection velocity in consideration of the desired clutch velocity and the allowable level of noise is more free.

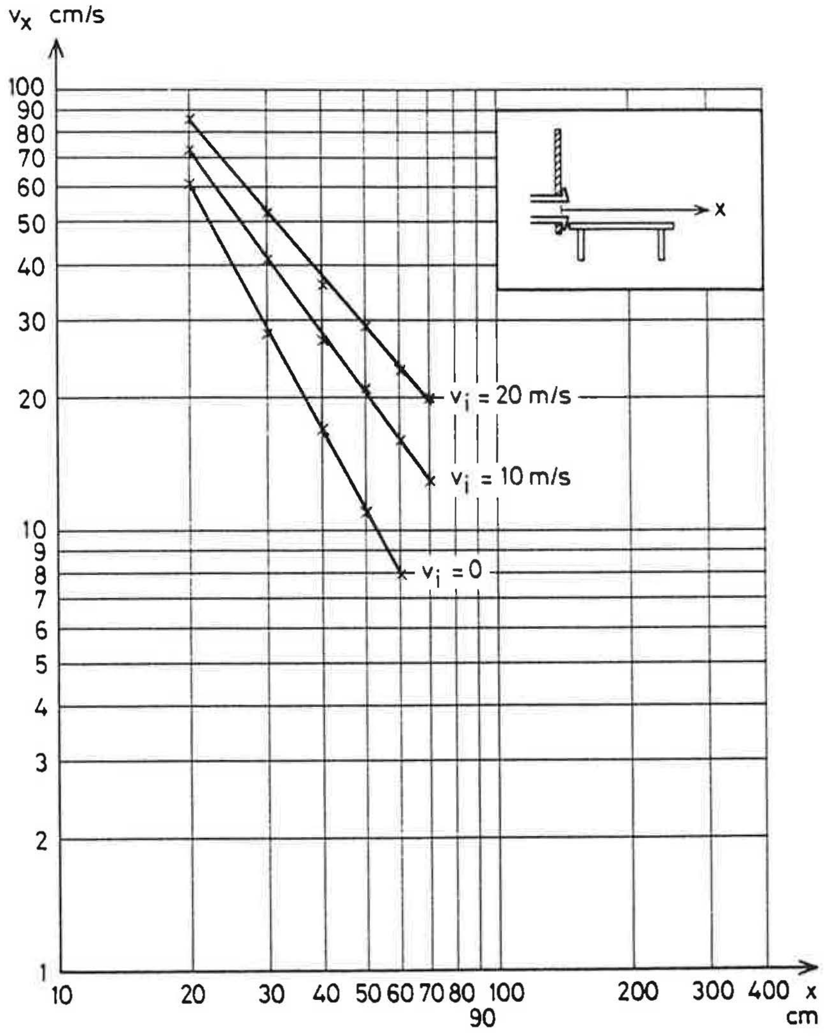


Figure 6. Clutch velocities v_x in the centre line at suction of 300 m^3/h from the back flange of a table measured in two situations: suction alone, and at the injection velocities v_i = 10 m/s and v_i = 20 m/s. The lowermost third of the supply inlet has been covered.

From figure 6 it is seen that the clutch velocity in the centre line can be increased simply by increasing the injection velocity. In return the suction area, i.e. the area denoted A in figure 1, is reduced. By increasing the injection velocity it is thus possible to create a more concentrated exhaust over longer distances.

5. SUCTION EFFICIENCY

It is important to investigate how large a quantity of local pollution can be removed directly using the method described, i.e. without being diffused into the air in the room. This is the only way of knowing whether or not the pollution is entrained in the injected air and thus distributed in the room.

At the University of Aalborg CO_2 has been used as tracer gas to determine the suction efficiency. A gas analyser was used to measure the CO_2 concentration in the suction after passing the exhaust ventilator. A constant quantity of CO_2 was first affluxed directly to the exhaust opening to determine the concentration which corresponded to 100% efficiency. Then the same quantity of CO_2 was affluxed through a pipe, 35 cm long and with 19 small holes, which was placed 10 cm from the front edge of the table. This position of working place was assumed to be the most exposed when pollution is developed. We define the efficiency of the suction at the given pollution as the CO_2 concentration in the suction in relation to the CO_2 concentration measured in the case where CO_2 was affluxed directly to the exhaust opening.

It is difficult to summarize the result of these efficiency measurements due to the large number of parameters, such as position of pollution, direction of supply and velocity, disturbances from the environments, the clutch velocities chosen, etc. However, the most significant result is that when all these parameters are in order the suction efficiency will typically be 95-100%. At the right ratios between injection and exhaust quantities and velocities an aerodynamically effective area leading directly to the exhaust opening can thus be created.

6. FIELDS OF APPLICATION

The described system is not suitable for exhaust of large areas such as a basin with acid or similar. For such purposes the effective suction area is too narrow.

On the other hand the system is superior to conventional systems when a pollution is punctiform and when manoeuvring space around the pollution is required, which makes it difficult to place an ordinary suction opening close enough to the source of pollution. In cases where pollution is to be removed from the breathing zone of an operator the system can be the only efficient means and it is far superior to conventional suction.

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**INSTITUTE OF BUILDING TECHNOLOGY AND STRUCTURAL ENGINEERING
THE UNIVERSITY OF ALLBORG
SOHNGAARDSHOLMSVEJ 57, DK-9000 AALBORG
TELEPHONE: Int. + 45 - 8 - 14 23 33**