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Push-Pull Ventilation in a painting shop for large steel constructions.

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Introduction

This paper describes the analysis of a push-pull ventilation system for a painting shop that is used for painting steel chimneys and windmill towers. The items to be painted are cylindrical with a diameter from 0.8 to 5 m and the length can be up to 50 m.

The painting shop is 16 m wide, 54 m long and the room height is 6.5 m.

Application of the paint mainly takes place with spray guns. A radiant heat system with panels under the ceiling heats the painting shop to 18 degrees Celsius in the wintertime.

The ventilation system must ensure that target levels and regulatory requirements to IAQ are fulfilled, i.e. the supply of fresh air and the removal of solvents released from the painting process. The necessary airflow rate for a paint shop of this type is normally in Denmark based on the following assumptions:

- downward airflow with a velocity of at least 0.2 m/s in the working area
- an air change of 60 times per hour in the working area
- special requirements for fresh air supply rates related to the type of paint and amount of paint in use

To fulfil the above requirements with a traditional ventilation system, the amount of fresh air supplied to the paint shop should be very large (360,000 m^3/h). This solution is very energy consuming due to the heating of the large airflow rate in the wintertime. It is not very efficient to ventilate the entire building in this way since a typical working situation will include only a few workers working in a minor part of the painting shop, while painted items are drying in the rest of the painting shop.

A push-pull ventilation system that can be activated individually in 12 working zones of the painting shop, has the potential to fulfil the regulatory requirements for the occupational indoor air quality with a significantly lower airflow rate and energy consumption. This solution is analysed in the following.

Description of the system

The push-pull system is based on an air supply slot near the ceiling and an exhaust slot in the floor under the item that is being painted. The supply slot directs a plane air jet towards the item causing the paint solvents to be captured and exhausted. The exhaust airflow rate must be higher than the airflow rate of the supply jet due to the entrainment of surrounding air. The amount of air for this entrainment should then be supplied at low momentum from an additional air supply. A number of CFD calculations have been performed to investigate the effect of:

- inlet velocity and width of the inlet slot
- size of the item that is being painted
- position of the inlet related to the item size
- sensibility to the position of the item that is being painted
- supply method and amount of additional air

Results

Figure 1 shows an investigation of the amount of additional air supply. If the additional air supply and thereby the exhaust airflow rate is too low the entrainment in the jet will draw air from the lower part of the room to the upper part and mixing will occur. This will result in lower capture efficiency. In the right-hand side of figure 1, the additional air supply is reduced by 50 %. The result can be seen in the near-floor region where the zone with flow towards the exhaust is reduced.

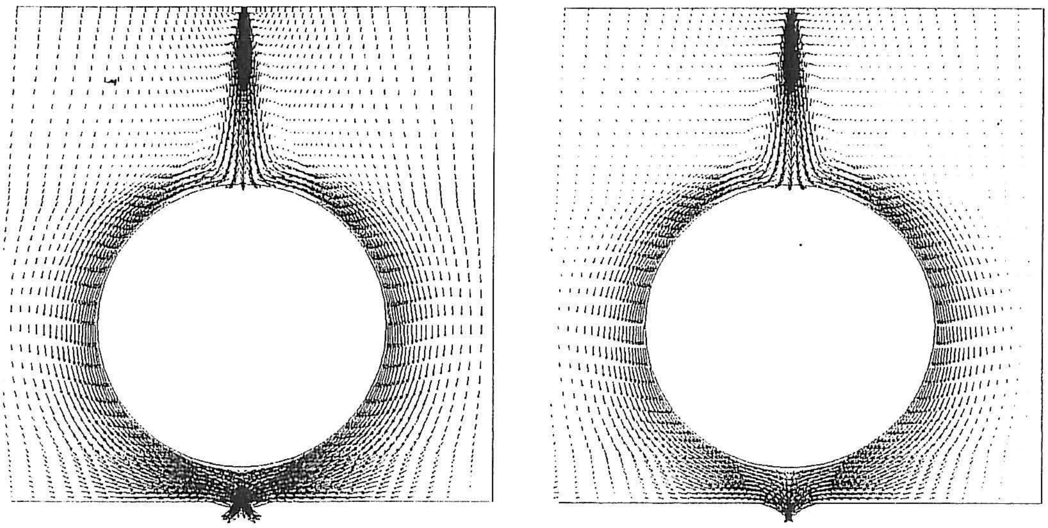

Figure 1. Jet velocity $u_0 = 1.0$ m/s, inlet slot width $h_0 = 0.1$ m, the additional air supply is 0.52 m^3/sm (left) and 0.26 m^3/sm (right).

Figure 2 shows a comparison of two different methods to supply the additional air. The picture to the left shows the airflow when the additional air for entrainment is supplied through the entire ceiling, and the picture to the right shows the situation when it is supplied through a smaller area around the main supply jet. The simulation shows that there is no significant effect on the airflow around the circular item.

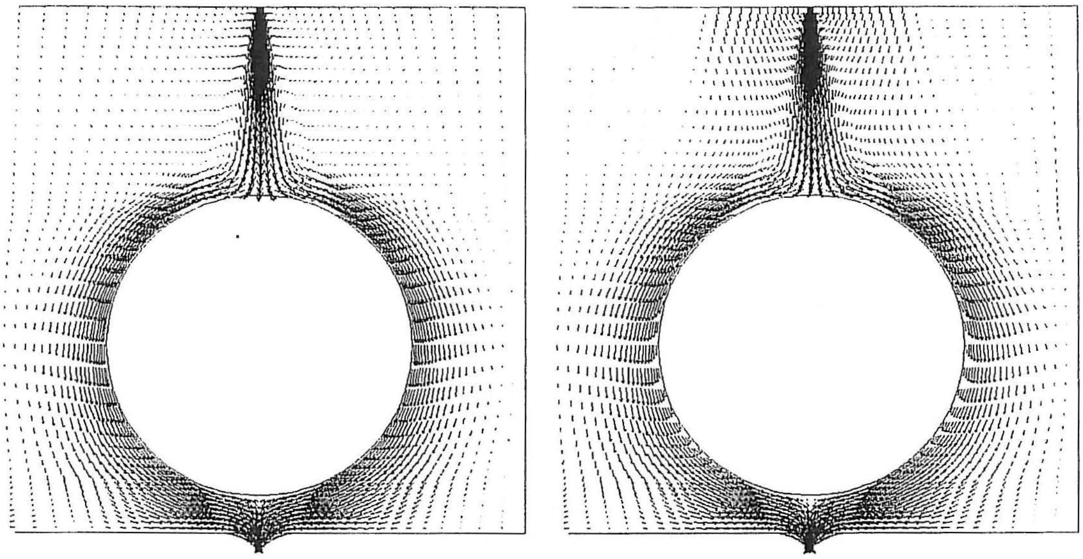

Figure 2. Additional air supply through the entire ceiling (left) and through a smaller area around the supply jet (right).

Figure 3 shows the sensibility to an inaccurate position of the item that is being painted. A small item has been placed in the centreline and displaced 10 and 20 cm respectively. The simulations indicate that such a displacement will not affect the airflow pattern considerably, which means that the solution is not sensitive to minor deviations from the optimal position of items.

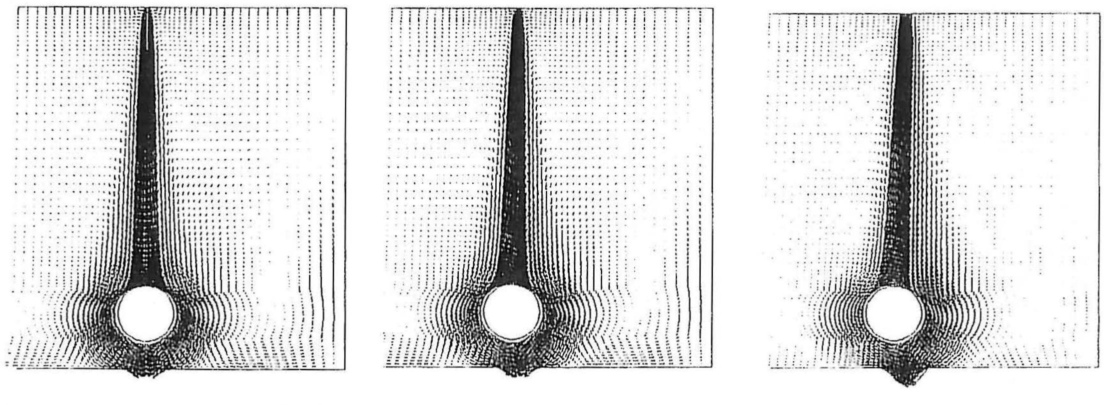

Figure 3. Item placed in the centreline (left), displaced 10 cm (middle) and 20 cm (right).

Conclusion

A system with a 20-cm slot inlet and additional air supplied with low momentum on both sides of the jet was chosen. To test if the system worked satisfactory a number of smoke tests were performed in the painting shop. The smoke tests showed that the system worked satisfactory with airflow patterns similar to the predictions (figure 4).

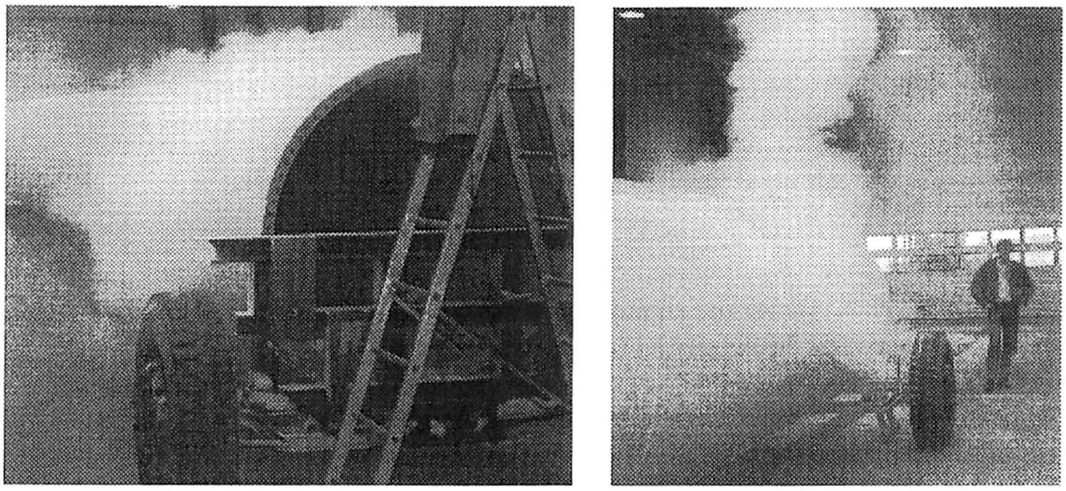

Figure 4. Smoke tests in the painting shop verify that the system works satisfactory.

The total airflow rate was 15000 m^3/h for each of 12 ventilation zones. Only six of the 12 ventilation zones can be operated simultaneously and thus the maximum airflow rate for the entire system is 90.000 m^3/h or 25 % of a traditional ventilation system. The table below shows the energy savings compared with a traditional ventilation system.

	Reference system MWh/year	Energy savings MWh/year	Energy savings %
Heating	1176	921	78
Electricity	237	153	65
Total	1413	1074	76

It is concluded that the investigations have resulted in a well working ventilation system with considerable energy savings compared with a traditional system.

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