

Improve Air Quality and Energy Efficiency by Optimizing Capture Efficiency with Nederman Articulated Extraction Arms (AEA)

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1. Introduction to Capturing



Image 1.1

Different types of capture devices.

Many types of work processes generate fumes, dust or vapors. The pollutants affect the quality of the breathing air as well as the environment, premises and goods.

To improve work environment, increase production efficiency and minimize emissions, Nederman has developed and produced local exhaust ventilation (LEV) equipment for capturing and filtering fumes, dust and vapors for decades. Image 1.1 shows some examples.

1.1 Capturing Strategy

Capturing is one of Nederman's key technologies and the strategy is to capture the pollutants as close to the source as possible. In that way, a high capture rate is achieved with minimum energy use.

Nederman capture products are used to:

- Capture hazardous airborne substances before they reach the breathing zone.
- Capture contaminating particles before they pollute environment, premises and goods.
- Capture and extract materials and liquids from an undesired location.

1.2 Capturing Study

The contents of this whitepaper is based on:

- MSc thesis made by Attila Deak at International Centre for Indoor Environment and Energy at Danish Technical University in Copenhagen [1]. The work was presented in January 2016 and contained both new knowledge as well as findings that strengthens existing knowledge.
- Nederman lab tests of capture products.
- Health and Safety Executive guidelines [2].

The investigations and tests in the study are based on the capture situation in a laboratory with a Nederman FX75 extraction arm (see image 1.2), but most of the result can be generalized and applied to other airborne pollutants and capture equipment.



Image 1.2

Nederman FX75 arm with mini hood.

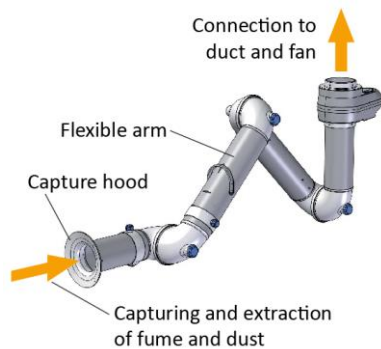


Figure 2.1
Articulated extraction arm (AEA).

2. Capture Efficiency in General

An established solution for capturing pollutants as close to the source as possible, is to use an articulated extraction arm (AEA), as shown in figure 2.1. The AEA is connected to a vacuum source to create air movements that capture and extract the pollutants. The user positions the flexible AEA as close to the source as possible.

2.1 Capture Situation

To dimension and use an extraction system as effective as possible, it is important to understand the parameters that affects the AEA's capture efficiency.

2.1.1 Context

- Background ventilation in room creates cross-draught.
- Placement of other equipment in the room.
- Persons working in the room, stationary or moving.

2.1.2 User situation

- Characteristic of pollutant; particle size, velocity, density, temperature, etc.
- Size of working area.
- Working setup; size and position of working equipment.

2.1.3 AEA characteristic

- Performance of AEA; airflow rate, air velocity, flexibility and maneuverability.
- Position of AEA in relation to pollution source.
- Type of capture hood on AEA.

2.2 Dimensioning and Optimization

It is not always possible to control the parameters that are affecting the capture efficiency. To secure high capture efficiency and be independent of all variables, the recommended AEA airflows is set high.

By integrating the recommendations from this whitepaper in the layout and dimensioning of an extraction system, as well as in user instructions, it is possible to optimize the system for high capture efficiency and low energy use. With correct positioning of hood, the airflow rate can be

reduced. A spin-off effect is reduced noise levels that contributes to a healthier and quieter workplace.

2.3 Capture Velocity

The minimum hood induced air velocity necessary to capture and convey the contaminant into the hood is referred to as capture velocity. This velocity will be a result of the hood airflow rate and hood configuration [3].

2.3.1 Required capture velocities

An important parameter to define the needed capture velocity is the process type. The required capture velocity according to the contaminant cloud release is presented in table 2.2 [2].

Table 2.2
Required capture velocities [2].

| Contaminant cloud release | Example of process | Capture velocity (m/s) |
|---|------------------------|------------------------|
| Into still air with little or no energy | Evaporation from tanks | 0.25 to 0.5 |
| Into fairly still air with low energy | Welding Soldering | 0.5 to 1.0** |
| Into moving air with moderate energy | Crushing Spraying | 1.0 to 2.5 |
| Into turbulent air with high energy* | Cutting Grinding | 2.5 to >10 |

*These types of clouds are difficult to control using capture hoods.

** Nederman experience is that processes generating radiation, s.a welding, require capture velocity in the high end of this range, whereas soldering is in the low end.

The tests in the study are based on the first level, evaporation from tanks, but the result can also be applied to the second level, soldering and welding.

2.4 Capture Hoods

By mounting a larger capture hood on the AEA, the capture zone can be enlarged and disturbing airflows can be screened off. This improves the capture efficiency of the AEA.

Capture hoods are available in different sizes, shapes and materials to allow the AEA to be adapted to the actual user situation. Some examples are shown in image 2.3.



Image 2.3

Example of capture hoods mounted on AEA.

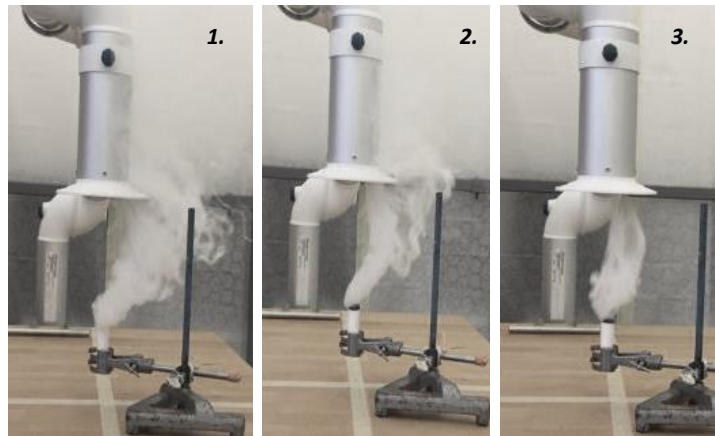
3. Influence of Cross-draught and Hood Position

Capture efficiency is strongly influenced by cross-draught and positioning of capture hood [1].

Image 3.1 shows an example of the effects of horizontal cross-draught of 0.25 m/s from left and AEA positioned above. The smoke is captured with a FX75 arm with mini hood. The capture rates for the different airflows are:

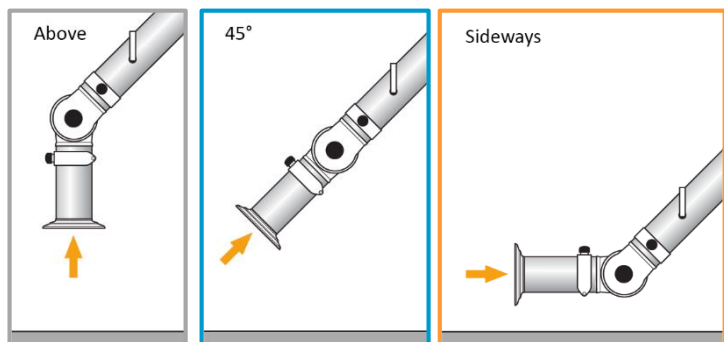
- Image 1: Airflow: 60 m³/h, capturing rate 0%
- Image 2: Airflow: 105 m³/h, capturing rate 78%
- Image 3: Airflow: 151 m³/h, capturing rate 100%

Image 3.1
Smoke visualization with horizontal cross-draught of 0.25 m/s from left.



The tests are made for three different capture hood positions to investigate how this affects the capture rate. The hood positions are shown in figure 3.2 and called *above*, *45°* and *sideways*. In the following diagrams their test values will be shown with the color of each frame below.

Figure 3.2
Tested capture hood positions.



All tests in this chapter are made with Nederman FX75 with mini hood (see image 1.2).

3.1 Test with no Cross-draught

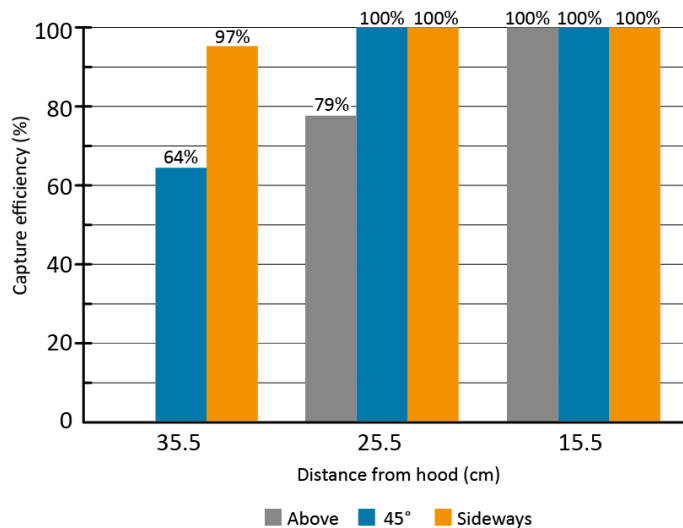
Even though a scenario with no cross-draught is hardly possible, it is interesting to have as a reference. The capture efficiency was measured for different hood positions and with different distances to the pollution source.

The result from capture test without cross-draught is shown in figure 3.3 and there are some interesting findings:

- Hood position *sideways* has considerably higher capture efficiency than the other positions.
- Hood in 45° position is second best.
- Hood placed *above* is worst and requires higher airflow.

Despite low airflow of $60 \text{ m}^3/\text{h}$ and long capture distance of 35.5 cm, the AEA placed *sideways* achieves a capture rate of 97%, which is remarkable.

Figure 3.3
Capture efficiency as a function of hood position and distance to source.
Airflow: $60 \text{ m}^3/\text{h}$. No cross-draught.



3.2 Test with Horizontal Cross-draught

To investigate the capture efficiency in a more realistic context, horizontal cross-draught from the side was added. The capture efficiency was measured with three different cross-draught velocities, different hood positions and different airflows. The distance between pollution source and hood was 15.5 cm, but shorter for the higher cross-draught velocities to reach 100% capturing.

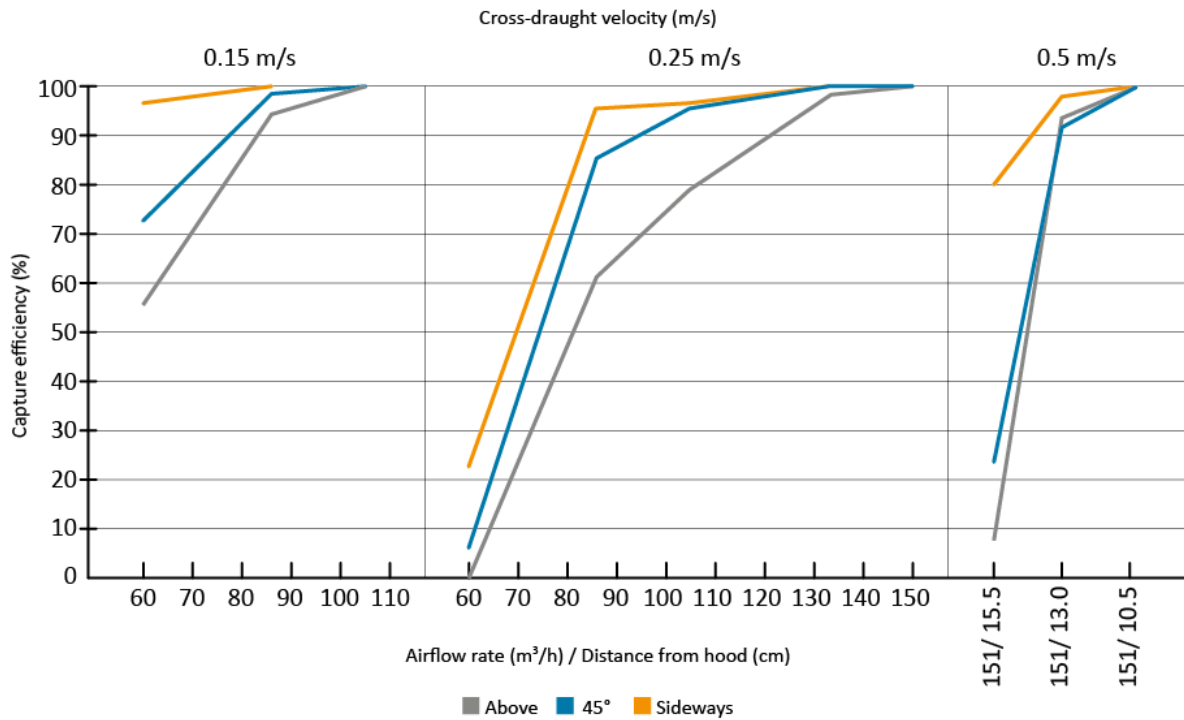


Figure 3.4

Capture efficiency as a function of cross-draught velocity, airflow rate and hood position. Horizontal cross-draught from the side. Distance between pollution source and hood is 15.5 cm unless otherwise stated.

The result from capture test with horizontal cross-draught from the side is shown in figure 3.4 and there are some interesting findings:

- Hood position *sideways* is the most efficient. Even when the cross-draught is 0.5 m/s, this position have 97% capture efficiency with a slightly shorter distance (13 cm) from source.
- Hood in 45° position is second best.
- Hood placed *above* is worst and requires higher airflow.

The test shows how important the position of the hood is. The hood positioned *above* the source have shown the lowest capture rate and the one positioned *sideways* the highest one.

The effect of the hood position was more noticeable for lower airflow rates and low cross-draught velocities. For example, for 60 m³/h flow rate with 0.15 m/s cross draught, an improvement of 41% in capture efficiency was achieved by moving the hood from *above* to *sideways*.

Thereby, it can be concluded that it is advantageous to position the hood *sideways*, when the contaminant cloud has low upward velocity and the work process allows this hood position, to reach higher capture efficiency.

3.3 Test with Vertical Cross-draught

A scenario with vertical cross-draught from above have another impact on capture efficiency. This was measured with three different cross-draught velocities, different hood positions and different airflows. The distance from source was 15.5 cm, where distance is not mentioned below.

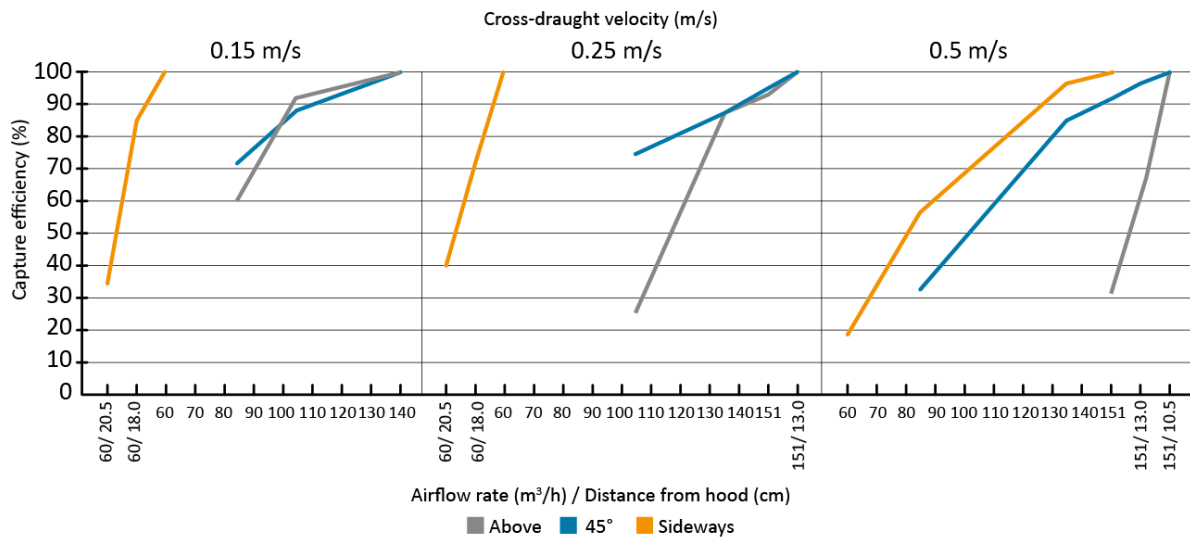


Figure 3.5

Capture efficiency as a function of cross-draught velocity, airflow rate and hood position. Vertical cross-draught from above. Distance between pollution source and hood is 15.5 cm unless otherwise stated.

For vertical cross-draught, the hood position relative to the source, had very high impact on the capture efficiency. See figure 3.5.

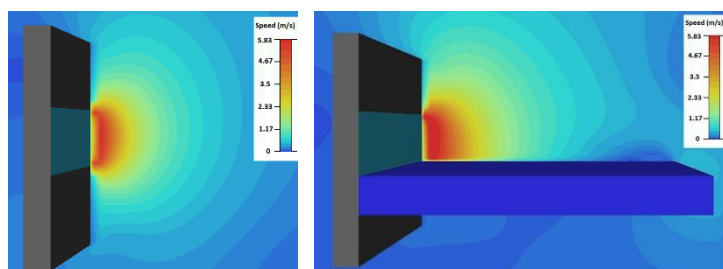
The reason for this is that the cross-draught direction and the AEA airflow direction counteract each other when AEA is positioned *above* and *45°*. For *sideways* the cross-draught is beneficial by pushing the contaminant down towards the table and closer to the hood.

- *Sideways* is best.
- *45°* position has reduced efficiency.
- *Above* shows poor performance, unless airflow is very high.

The reason for the high capture rate of the *sideways* positioned hood, both at horizontal and vertical cross-draught, is the guiding and blocking effect of the table. See figure 3.6.

Figure 3.6

Air velocity simulation showing guiding and blocking effect of table. The vertical wall to the left in the images represents the AEA capture area.



4. Operator Influence on Capture Efficiency

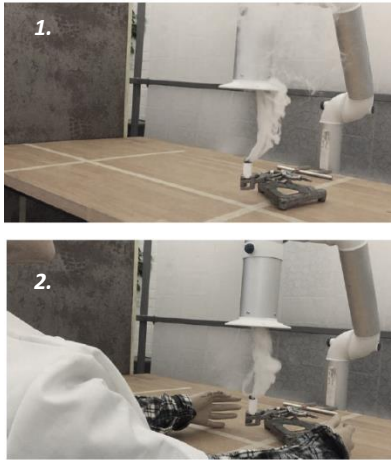


Image 4.1

Capture efficiency without (1) and with (2) thermal manikin.

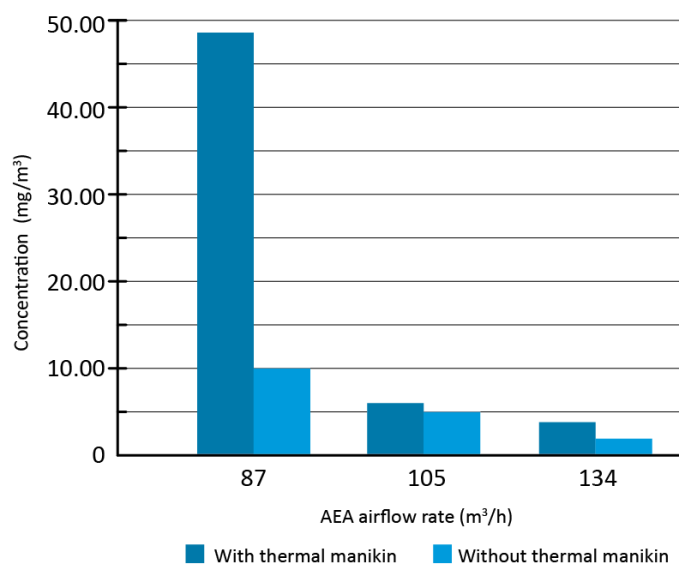
In a work situation, the operator is affecting the entire capture situation [1]. In the tests, a static, thermal manikin was used to simulate a real operator. See figure 4.1. The test showed that:

- The capture rate at 70 m³/h were 56% without thermal manikin and 97% with thermal manikin.
- At horizontal cross-draught from the side, an operator sitting with the arms on the table, increases the capture efficiency by 13%.
- At vertical cross-draught from above, an operator sitting with the arms on the table, decreases the capture efficiency by 14%, because the table and body creates turbulence.

4.1 Contaminant exposure

At vertical cross-draught from above, the operator's body significantly influence the contaminant exposure. The reason for this is that the contaminants spread over the table were taken by the convective flow around the body and thus reach the breathing zone in higher concentrations. See figure 4.2.

Figure 4.2
Exposure measured with and without thermal manikin, as a function of AEA airflow rate at a vertical cross-draught from above of 0.15 m/s.



5. Impact of Extended Capture Hood

By mounting a larger hood to the AEA, in this case the combi hood, the capture efficiency increases dramatically [1].

Using a larger hood has the following benefits:

- Allows longer distance from hood to pollution source.
- Allows lower airflow, which means energy savings.
- Gives higher capture rate at heavy cross-draught flows and velocities.

At horizontal cross-draught from the side, the design of the large hood creates increased capture rate, and it also partly protects the pollution source from the disturbing cross-draught airflows.

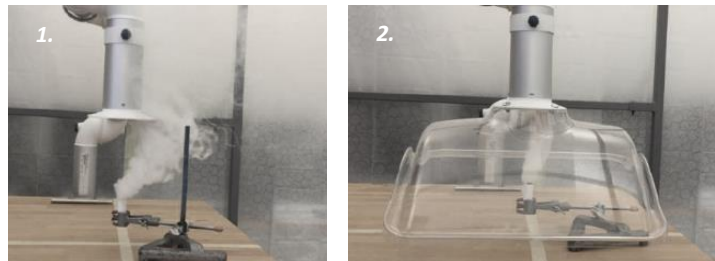
Image 5.1 shows the difference in capture efficiency at low airflow, $60 \text{ m}^3/\text{h}$, with 0.25 m/s cross-draught from left:

Image 1: Mini hood, capture rate 0%

Image 2: Combi hood, capture rate 100%

Image 5.1

Capture efficiency with mini hood (1) and combi hood (2).



At vertical cross-draught from above, the effects of the large hood were even higher, because the whole area of pollution source was protected from cross-draught by the hood.

6. Capture Zone

The airflow from the AEA creates a capture zone where the air velocity is higher close to the hood inlet and decrease rapidly with the distance from the hood opening [1].

Figure 6.1 shows the capture velocity contours for FX75 with mini hood. The test are made without cross-draught and with no table.

Figure 6.1
Velocity contours for FX75 with mini hood, showing % of air velocity in AEA tube at different distances from opening.

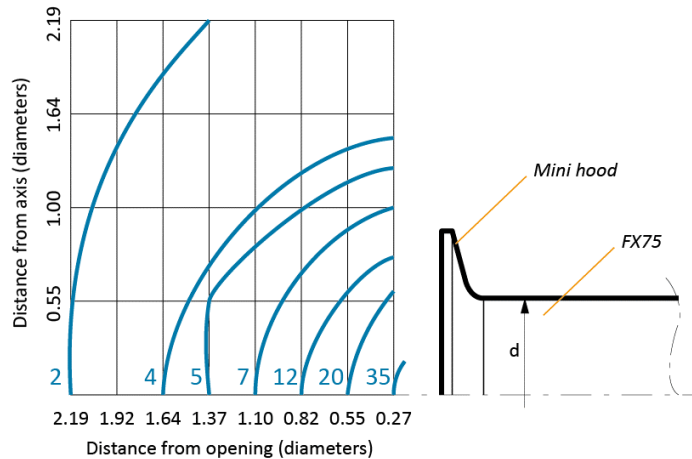
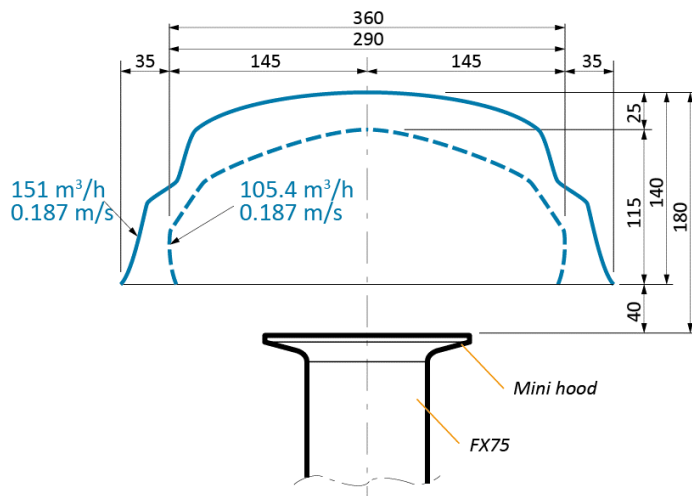


Figure 6.2 shows the capture zones at two different airflows. The capture zone is defined for the conditions; extract 97% of the contaminant with 0.25 m/s horizontal cross-draught. The test is made with FX75 with mini hood positioned sideways over a table.

The result of the test shows that if the airflow is increased by 43%, the capture zone increases by 50%. However, it is more efficient to adjust the hood position than increasing the airflow.

Figure 6.2
Capture zone (work zone) in front of AEA hood positioned horizontally above table. Distances in mm.



7. Hood Distance to Source

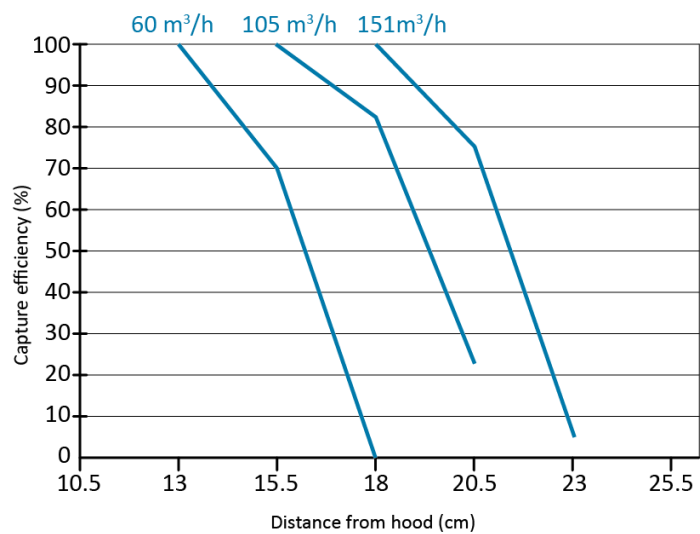
The distance between the capture hood and the pollution source is crucial for the capture efficiency [1].

The tests shown in figure 7.1 were made with a FX75 with mini hood positioned sideways and a horizontal cross-draught from the side with air velocity of 0.15 m/s.

The test result shows that if the hood moves as little as 5 cm away from source (from 13 cm to 18 cm) the capture efficiency goes from 100% to 0% at low airflow (60 m³/h).

Figure 7.1

Capture efficiency as function of distance between the hood and the pollution source.



8. Influence of Vertical Partition



Image 8.1

Example of vertical partition.

It is relatively common with vertical partitions around the working area in an attempt to improve the capture efficiency [1]. See image 8.1.

Earlier, it was shown how the guiding and blocking effect of the table had a positive impact on the capture efficiency. However, the test with vertical partition at vertical cross-draught showed no corresponding positive effect.

Tests with AEA airflow of $134 \text{ m}^3/\text{h}$, mini hood positioned above, vertical partitions and with a vertical cross-draught from above of 0.25 m/s , showed that the walls reduces or have no influence on the capture efficiency. The partitions were placed on both sides of the hood at 26 cm and 20 cm from the centerline axis. The measuring result is shown in figure 8.2.

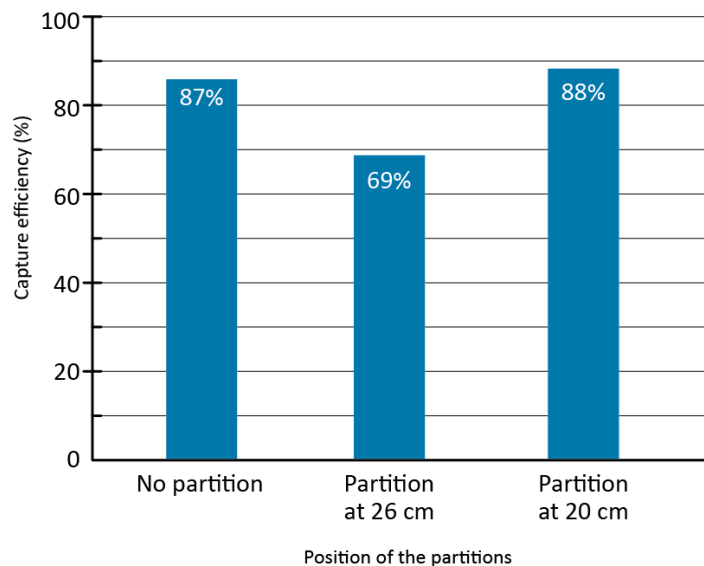


Figure 8.2

Comparison between no partition and with vertical partitions at different distance from AEA. Vertical cross-draught from above.

Vertical cross-draught is a worst case scenario. Most likely, the result would be different for horizontal cross-draught from the side. In that case the only benefit from vertical partition can be to reduce cross-draught created by people or equipment passing by the working area of AEAs.

It is also important to be aware that different types of partitions close to the working zone will limit the flexibility and maneuverability of the AEA.

9. Recommendations

The test results described in this whitepaper, gives us new knowledge and strengthens existing knowledge. Therefore we can give the following recommendations:

9.1 Workplace Layout

When designing the entire workplace/room, consider the following recommendations:

- Always avoid high background air velocities, especially vertical cross-draught from above.
- A work table has a guiding and blocking effect that improves the capture efficiency.
- Vertical partitions, at vertical cross-draught, decreases or has no effect on the capture efficiency.

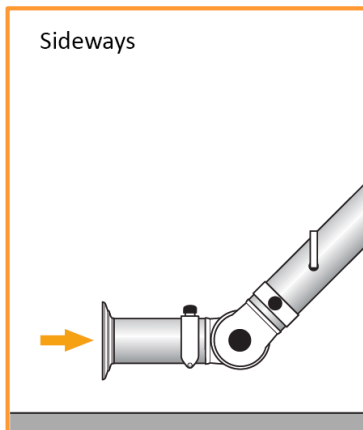


Figure 9.1

Hood sideways positioned, close to the table, for most efficient capturing.



Image 9.2

Example of larger capture hoods.

9.2 Hood Position

- Always try to use the AEA in *sideways* position, close to the table, when the contaminant cloud has low upward velocity. This gives higher capture efficiency at lower airflows even if the cross-draught is high. This means a more energy efficient LEV system. See figure 9.1.
- *Sideways* positioned hood is more likely not to interfere with the work process and makes it easier to place the hood closer to the pollution source.
- Always try to position the hood as close to the pollution source as possible. In cases where the distance needs to be longer, add a larger hood to increase the capture zone or, if this is not possible, increase the airflow.

9.3 Hood Type and Size

Always try to use larger capture hoods, which covers the process, when there is enough space around the pollution source. See examples in image 9.2.

9.4 Capture Area

It is important that the capture zone overlaps the work zone. If it is not, the best solution is to add a larger hood to increase the capture zone. If this is not possible, the airflow has to be increased.

10. References

- [1] Attila Deak; *Exhaust efficiency and exposure with local exhaust ventilation (LEV) in laboratories* (MSc Thesis at International Centre for Indoor Environment and Energy at Danish Technical University in Copenhagen, 2016).
- [2] Health and Safety Executive; *HSG258 Controlling airborne contaminants at work: A guide to local exhaust ventilation (LEV)*.
- [3] A. C. of G. I. Hygienists, ACGIH: *Industrial Ventilation Manual*, vol. 552, 1998.