

Additions to ventilation chimneys in livestock housing

Evaluation of wide-angle nozzles, diffusers and heightening of chimneys

Evaluation of additions to livestock housing chimneys such as wide-angle nozzles and diffusers without a closer consideration of the ventilation-technological associations can lead to a false estimation of ratings according to the Guideline VDI 3471 "Livestock housing emission reductions – pigs" [1] which in some special cases can have a decisive effect on the planning permission for a new or extended livestock building.

As far as the planning authorities are concerned, wide-angle nozzles are sometimes still included in requirements, or else are offered as a solution from ventilation firms, with the aim of increasing exhaust air velocity and exit and, with that, achieving a higher rating under the criterion housing ventilation according to VDI Guideline 3471.

An example is taken to emphasise that the evaluation is not simple and that in the majority of cases lengthening the chimney by around 1 m gives a successful solution – especially under the aspect of sensible energy use.

Similar rules apply to the classification of diffusers for pollution control. Without more precise observation, a 30 to 50 m higher minimum distance from domestic housing could be supported.

The exhaust plume height was chosen in addition to point ratings as a criterium in the evaluation of the different exhaust system components.

Description of additional chimney fits

Wide-angle nozzles

Wide-angle nozzles are chimney fits for livestock housing ventilation systems which cause a cone-formed reduction of the cross sectional area of the housing air exit. They are fitted on the end of the exhaust chimney. Through narrowing the exhaust cross section an increase in the exhaust air velocity is achieved. At the same time, however, this is linked with an increase in pressure loss and heightened energy requirement by the exhaust fans.

Diffusers

Diffusers are exhaust components which, through a continuous increasing of cross section, achieve a reduction in exhaust air velocity. This reduction lessens pressure losses caused when exhaust air enters the free air flow outdoors. This enables the exhaust air fan to shift a larger volume of air or else re-

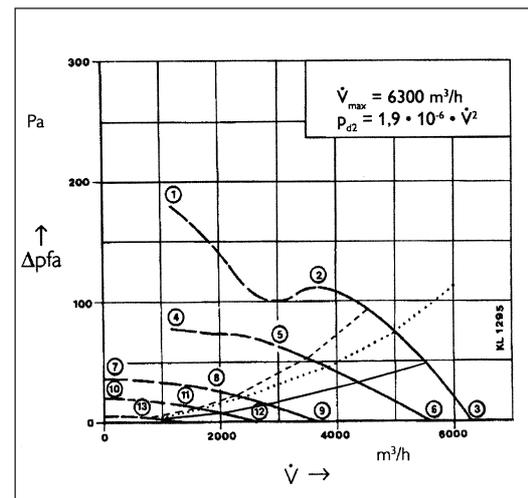


Fig. 1: Effects of a wide angle nozzle (line of dashes), a 1-m-chimney tube (dotted line) and of a diffuser (drawed line) on the housing facility characteristic curve (dotted line) and on various operating points (No. 1 to 13 present fan-specific operating points)

duces energy requirement when moving the same amount of air as before the fitting of a diffuser.

The effects of livestock housing chimney fits on the system characteristics and performance of exhaust fans

The ventilation system of a livestock house comprises different components for controlling intake and exit air (e.g. air intake flaps, pipelines or pipe bends). Each of these components is characterised through a certain pressure resistance and loss (friction, directional change, turbulence) which increase in line with the square of the velocity of the air flowing through the component.

The sum of the pressure losses of the individual components gives the total pressure loss of a housing ventilation system.

If one depicts with a total volume flow diagram the total pressure loss of a livestock house caused by differing volume flows moving through the housing ventilation system, one then finds the so-called house system pressure resistance characteristic line (in short: livestock housing characteristic line).

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Keywords

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Literature details are available from the publishers under LT 01126e or via Internet at <http://www.landwirtschaftsverlag.com/landtech/local/fliteratur.htm>

An example shown in *figure 1* indicates different characteristic lines for a particular fan presented in a pressure/volume flow diagram. Additionally the total pressure losses are taken into account in association with the volume flow of four identical housing systems with different exhaust air channelling.

In that the pressure loss of a 1 m chimney exhaust pipeline with maximum air flow is only around 4 Pascal [2], the system characteristic lines without the chimney fitments and those where the chimney has been lengthened by 1 m are almost identical.

The intersection point of the drawn line (system characteristic line with wide-angle nozzle) with the above fan characteristic line represents the working point for the summer air rate with wide-angle nozzle.

Effects of housing chimney fitments on exhaust air velocity, rating of housing ventilation according to Guideline 3471 and the exhaust air plume excess

Based upon

1. An exhaust air chimney with a height of 0.5 m over roof ridge and an exhaust air velocity of 8 m/s are given the following values (shown in table) for exhaust air velocity (with and without consideration of pressure loss from exhaust air components), the rating according to the above-mentioned VDI Guideline, and for the exhaust air plume excess with
2. the addition of a wide-angle nozzle,
3. the lengthening of the chimney with a 1 m extension,
4. and the fitting of a diffuser.

Through the calculations it could be assumed that the exhaust air fan need not be replaced by a more powerful one, as is often the case in many practical situations.

For the determination of exhaust air plume excess Δh , two formulae are available for the "cold sources" according to the relevant VDI Guidelines:

a) the equation given in the Guideline VDI 3471:

$$\Delta h = 1.5 \cdot \text{exhaust air volume flow} / (\text{chimney interior diameter} \cdot \text{wind velocity}).$$

This equation is from KTBL workpaper 126 "Application of the VDI Guideline 3471 Pigs and 3472 Poultry" [3] calculated empirically through smoke gas investigations on a free-standing house ventilation chimney.

b) the equation featured in the VDI Guideline 3782, Paper 3 [4] for "cold sources":

$$\Delta h = 3 \cdot \text{exhaust air velocity} \cdot \text{chimney interior diameter} / \text{wind velocity}$$

A standardisation, or at least a statement, on the differing formulae would be desirable whilst re-working the VDI Guidelines "Reducing Livestock Emissions" 3471 and 3472, in that the calculation of the exhaust

	1.) Standard practice	2.) Wide-angle nozzle	3.) 1m chimney extension	4.a) Diffuser	4.b)*
Livestock building height in m	8	8	8	8	8
Exhaust air exit height over roof ridge in m	0,5	1,01	1,5	1,12	2,12
Exhaust air exit height in m	8,5	9,01	9,5	9,12	10,12
Exhaust air exit velocity in m/s disregarding pressure losses	8	10	8	3.9	
Rating according to point B) table 4 of the VDI Guideline 3471 for aims 2 and 4	15	25	25	5	15
Exhaust air exit velocity in m/s with pressure losses taken into account	8	9,1	8	3,9 - 4.3 ⁺	
Rating according to point B) table 4 of the VDI Guideline 3471 for aims 2 and 6	15	15	25	5	15
Chimney diameter in m	0,47	0,47	0,47	0,47	0,47
Exhaust air exit diameter in m	0,47	0,42	0,47	0,675	0,675
Exhaust air exit opening in m ²	0,173	0,138	0,173	0,358	0,358
Exhaust air volume flow in m ³ /h	5000	4552	4950	5000 - 5550 ⁺	5000 - 5550 ⁺
Exhaust plume excess in m where u=1,5 m/s according to VDI Guideline 3471	2,96	2,99	2,92	2,06-2,28 ⁺	3,06-3,28 ⁺
Exhaust plume excess over groundlevel in m	11,46	12,00	12,42	11,18-11,40 ⁺	12,18-12,40 ⁺
Exhaust plume excess in m (u=1,5 m/s) according to VDI Guideline 3782 paper 3	7,52	7,64	7,52	5,27-5,80 ⁺	6,27-6,80 ⁺
Exhaust plume excess over groundlevel in m	16,02	16,65	17,02	14,39-14,92 ⁺	15,39-15,92 ⁺

* With regard to the results of the investigations at DLG Testing Station, Frankfurt (see [2]). According to these, the velocity profile of a diffuser when measured 1 m above the exhaust exit represents that of an exhaust chimney without diffuser at 2.5 m above the exhaust exit. Should the different lengths of the diffusers between 0.65 and 0.96 be included in the calculations, it may be assumed that velocity profiles of the same height are present where a 1 m piece of exhaust pipe is fitted between the exhaust chimney and diffuser.

+ Related to the housing ventilation system setting after fitting a diffuser.

air plume excess increase according to VDI 3782 Paper 3 gives a higher value to the factor of around 2.5 compared with that of the exhaust air plume excess calculated through Guideline VDI 3471.

Both formulae can only be applied, however, when it can be assumed that the flow of exhaust air plume out of the chimney into the free air is not disturbed by the livestock building (no housing influences). Ideally, this is the case where the chimney height is around 2.5 times the height of the livestock building.

In that it can be assumed, however, with the examples of the chosen exhaust air and wind velocities that there is no immediate downwash of the exhaust air plume on the leeward side of the building taking place, the qualitative differences in the calculated exhaust air plume heights can certainly be taken into account as starting points for an evaluation.

Conclusion

From these reflections it can be seen that an increase in chimney height from 0.5 to 1.5 m over roof ridge is to be preferred to the addition of a wide-angle nozzle, also from the pollution control aspect.

Also to be taken account of is the fact that the electricity consumption rises to a not in-

significant extent following the fitting of a wide-angle nozzle when compared with extending the chimney height (the energy requirement rises to the power of three with regard to induced volume flow).

Further, from the table it can be seen that the maximum volume flow after the fitment of a wide-angle nozzle was reduced by around 10%, a reaction certainly leading to a worsening of the interior climate.

Where diffusers are fitted, the results of the DLG test station in Groß Umstadt should be taken account of. This applies especially where a diffuser is retrofitted in an existing chimney.

In the case of crowded village structures, and with existing livestock housing with insufficient spacing according to VDI Guideline 3471, the fitting of a 1 m piece of exhaust air pipe between the existing exhaust air chimney and diffuser is certainly to be encouraged in order to avoid a possible increase of pollution in the neighbourhood.

If one views the difference in the exhaust air plume height according to VDI Guideline 3782, Paper 3 between example 1 and examples 4a or 4b, the calculated results compare well on a qualitative basis with the practical measurements of the DLG testing station (see *).