2.01 CONSIDERATION OF WIND TUNNEL STUDIES IN DISPERSION CALCULATIONS WITH THE NEW MODEL AUSTAL2000 –CASE STUDY: DISCHARGE OF FLUE GAS VIA COOLING TOWERS

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INTRODUCTION

The *Technical Instructions on Air Quality Control* (German abbrev.: TA Luft) serves the protection of the public and the neighborhood against harmful environmental effects in general and particularly against harmful air pollution. This guideline has to be considered at installing and operating plants requiring a permission.

This regulatory guideline was adapted in 2002 to the progressed state-of-the-art and to the new legislation of the European Community. In this context the calculation method to derive the air pollution load caused by plants under the permission act was also updated.

Instead of a Gaussian model the more sophisticated particle model AUSTAL2000 *(Janicke, L., 2003)* of Langrangian type is used in the frame of permission procedures. It was developed on behalf of the German Federal Environmental Agency.

The dispersion model AUSTAL2000 comprises for cases with flue gas discharge via cooling tower the special water vapour plume rise approach of the VDI guideline 3784/2.
But there is no procedure defined to consider in those cases the effects of buildings on the dispersion characteristics.

A frequently used investigative method to gain information on how buildings influence the dispersion regime in the surroundings of a plant is the execution of experiments in a boundary layer wind tunnel.

PROPERTIES OF COOLING TOWER PLUMES

Comparing stack plumes with cooling tower plumes the latter possess considerable larger thermal capacities. This fact results for conditions up to average wind velocities in an essentially greater effective source height (cooling tower height plus plume rise) und as consequence in lower ground level pollutant concentrations. During strong wind conditions the effective source heights for cooling towers are commonly smaller than for stack plumes.

Referred to the cooling tower exit level height the wind velocity exceeds the vertical velocity of the vapour plume jet. Caused by the concrete shell induced vortices this results in a partial down-wash effect of the plume. Such effects of vortex separation and cavitation zones can be caused at unfavourable wind directions also by other buildings (e.g. boiler houses).

METHODS

Wind tunnel experiments

During dispersion experiments in a wind tunnel (atmospheric boundary layer flow tunnel) so-called amplification factors are derived to be applied to dispersion calculations as a corrective approach. Those factors are created as ratio of the ground-level concentration values with and without buildings.

The factors are determined in terms of the wind velocity and the source distance for direction ranges of similar effects. These ranges are fixed during a set of initial experiments prior to the main operational experiments. Because of the fact that the building effects are mainly occurring under strong winds and resulting well-mixed, neutral (thermal stratification) condition no differentiation in terms of turbulence class is normally accounted for.

Figure 1 shows a sample of such a set of amplification factors for one wind velocity class.

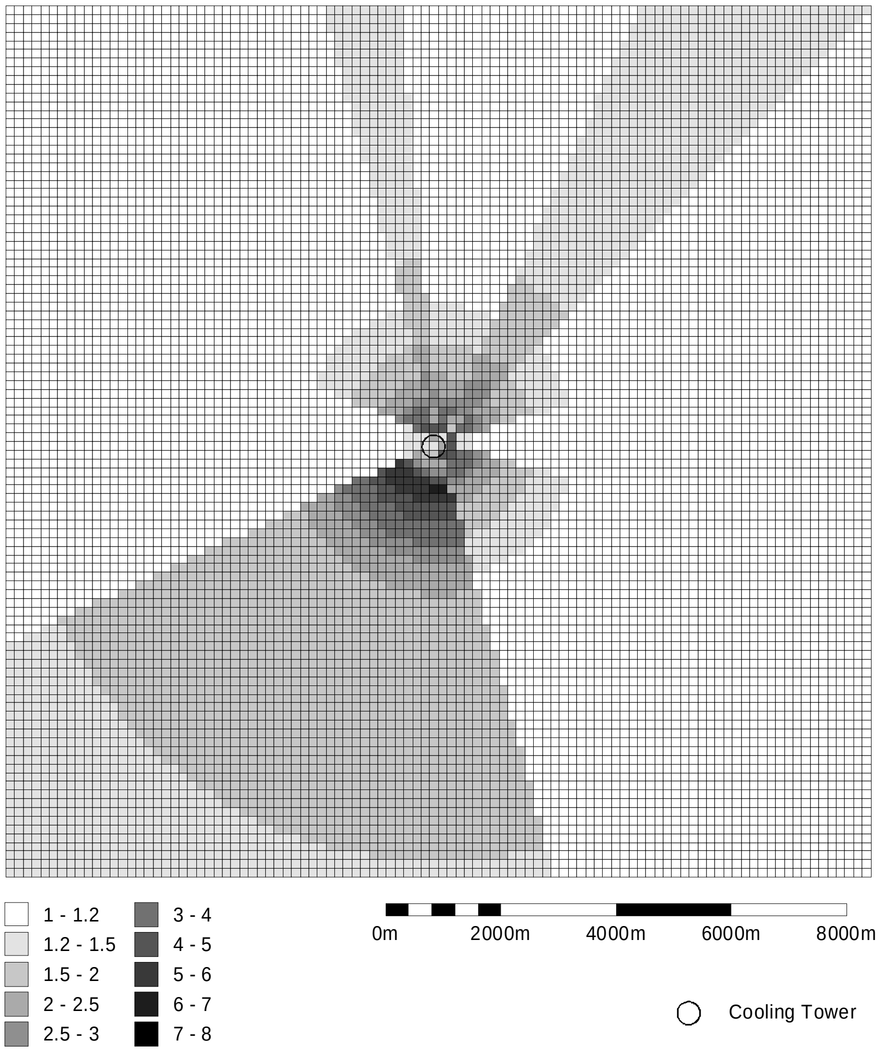

Figure 1. Amplification factors for the wind velocities between 5,5 and 6,9 m/s derived for a cooling tower of 175 m height

Concept of combining wind tunnel experiments and dispersion model

For each meteorological situation, characterized by wind direction sector, wind velocity class and turbulence class at first the corresponding concentration field is calculated. In order to achieve this data matrix for all single meteorological situations time series with constant conditions respectively lasting 24 hours are created.

The 36 wind direction sectors, 9 wind velocity classes and 6 turbulence classes describe in total 1944 possible meteorological situations, of which indeed 396 do not exist because of definition causes (e.g. not existing stable thermal layering during strong wind condition).

For each of those meteorological situations the concentration field is calculated by AUSTAL2000 considering the cooling tower plume rise. The result in each grid cell of all

concentration fields is then multiplied by the amplification factor corresponding to the actual situation.
Subsequently the 1548 modified concentration fields are being weighted according to a meteorological statistics which is representative in time for the specific site. In this step for each pollutant under consideration the frequency of occurrence of the meteorological condition is folded into the data as a probability factor and the its air quality index is statistically evaluated.
The annual average $\bar{c}(x,y)$ for a receptor point with the coordinates (x,y) is calculated according to the following equation:

$$\bar{c}(x,y) = \sum_{TC=1}^{6} \sum_{WV=1}^{9} \sum_{WD=1}^{36} c(TC,WV,WD,x,y) * AF(WV,x,y) * F(TC,WV,WD)$$

$TC = turbulence\ class$

$WV = wind\ velocity\ class$

$WD = wind\ direction\ sector$

$AF = amplification\ factor$

$F = frequency\ of\ meteorological\ condition$

RESULTS
From dispersion calculations with and without amplification factors (from the wind tunnel experiments) the influence of these factors on the annual average concentrations considering representative meteorological data for the site can be deduced.

Figure 2 shows the relative increase of the annual concentration values around a cooling tower with the amplification factors (see Fig. 1) from the described method applied.
Related to the maximum of the pollutant load at ground level which is located because of the wind direction distribution north-east of the source the increase is with 5% only minor in relevance for this example. During single strong wind conditions this difference can be as high as 300% but the frequency of occurrence reduce this effect.

The relative increase of the annual average is however strongly depending on the individual geometry of the buildings at the special site. Particularly in those cases when cooling towers do not or do only marginally overtop the surrounding buildings, large amplification factors can occur. In consequence the concentration maximum related to the annual average can be much higher reaching 200% and more.

CONCLUSION
The described method can be regarded as a reasonable extension of the existing dispersion model approach for stacks as sources. It was already applied to several permitting procedures for large coal and lignite power plants using this concept of discharging the scrubbed flue gas via the cooling towers.
There are attempts in the energy producer alliance ongoing reflecting the standardisation of this approach. At present applying this method is suggested and discussed between the consultant who performs the impact statement and the responsible local authority.

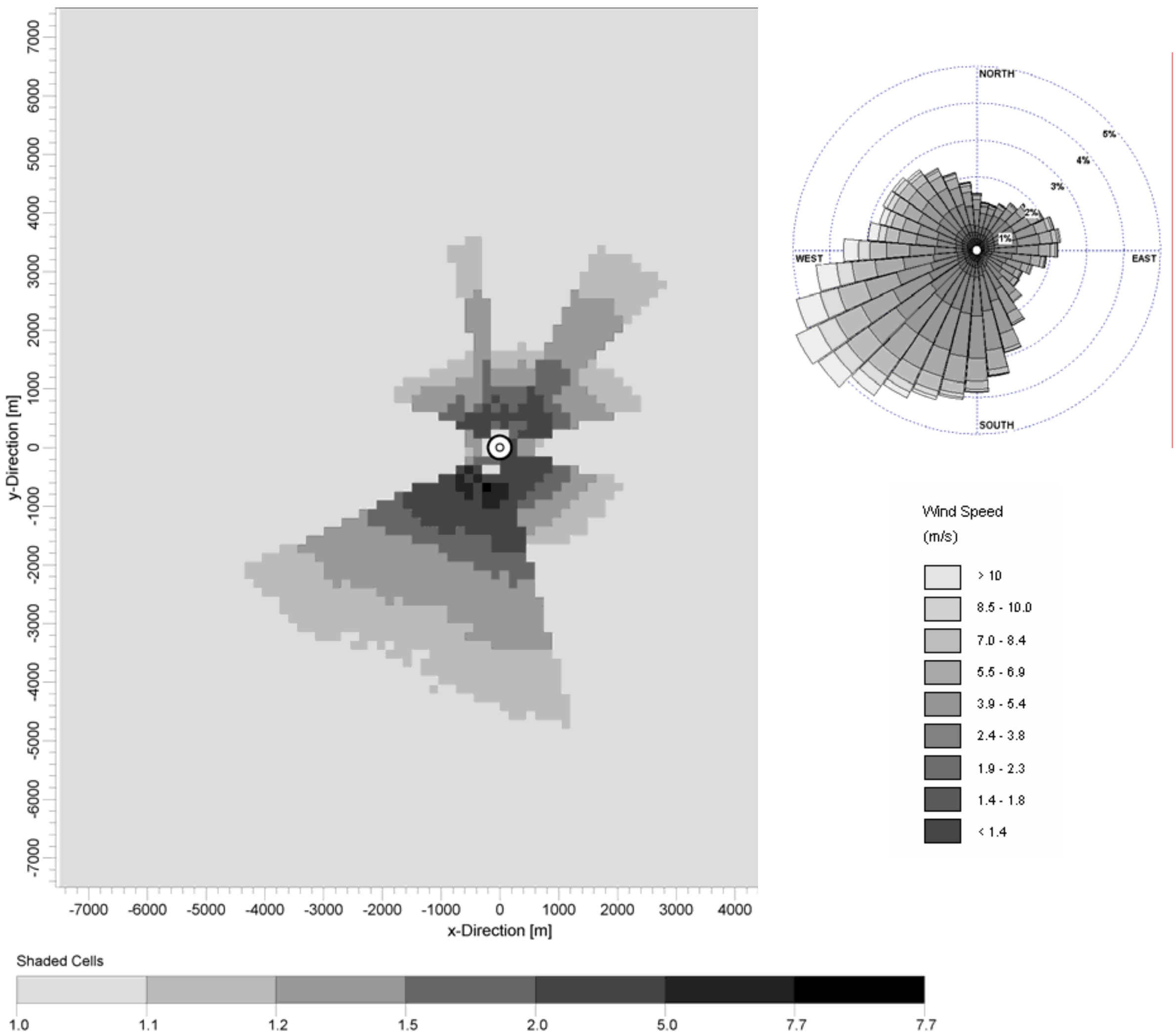

Figure 2. Relative increase of the annual concentration considering the amplification factors

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