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Determination of Industrial Stack Heights

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Determination of industrial stack heights

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One field of application of micrometeorological methods and results is that of air pollution meteorology. The number of problems where these method have been employed successfully increased considerably during the last few years. In this connexion I would like to discuss the outlines of a method of supplying meteorological information to air pollution authorities which enables them to decide on minimum heights of industrial stacks. This method has recently been proposed by a working group of meteorologists to the 'V.D.I.-Kommission Reinhaltung der Luft'. It should be added here, that this kind of information must not necessarily be the only type of information on which the authorities can base their decision but can be supplemented by other information.

One of the most frequent questions the meteorologist is being asked in connexion with air pollution problems is the following: given an industrial source, which is emitting noxious gases under known technical conditions—such as efflux velocity, efflux temperature, total flue gas volume, source strength of the gas considered—how high must the source be, so that a certain surface concentration of this material is exceeded only in a limited number of cases? This question seems to be simple and straightforward, but the meteorological problems involved are not easily solved. Besides, the economical consequences of the given answer are not negligible.

The time averaged concentration field at the surface $z = 0$ in lee of an isolated, elevated and continuous point source in case of reflexion of the gas at the surface is given by

$$\bar{s}(x, y, 0) = \frac{Q}{\pi \bar{u} \sigma_y(x)\, \sigma_z(x)} \exp\left\{-\frac{y^2}{2\sigma_y^2(x)}\right\} \exp\left\{-\frac{h^2}{2\sigma_z^2(x)}\right\},$$

where $\bar{s}$ is the time averaged concentration, Q the intensity of the source, $\bar{u}$ the mean wind velocity, which is assumed to be constant throughout the layer in which the diffusion takes place (here $\bar{u}$ is taken as a vertical mean of the time averaged wind velocity weighted with the vertical concentration distribution), σ_y, σ_z the standard deviations of the horizontal and vertical Gaussian concentration distribution, respectively, and h the effective source height above ground.

Besides the problem of determining the effective source height, which has been discussed in the paper by Briggs, the other main problem connected with the use of the above formula is to state σ_y and σ_z as functions of source distance and in relation to the actual weather situation. Hay & Pasquill (1959) have proposed a semi-empirical method to determine σ_y and σ_z in case turbulence measurements at the source are available. However, in nearly all cases turbulence measurements over a long range of time and under all weather situations are not available at the place where the source will be or is located.

A scheme was therefore proposed (Klug 1969) which relates time of day and year, surface wind velocity, cloudiness, type of clouds and source height to values of σ_y and σ_z in six diffusion categories. The values of σ_y and σ_z are those as obtained by diffusion experiments in the atmosphere. The scheme is objective and can therefore be programmed for a computer. With this scheme it is possible to compute from a synoptic observation together with the technical source data and an assumed chimney building height the maximum concentration at the surface and its distance from the source according to the schematic diagram in figure 1.

To come back to our question mentioned in the beginning, one can think now of the following procedure. Assuming one has hourly synoptic observations over some years from a weather

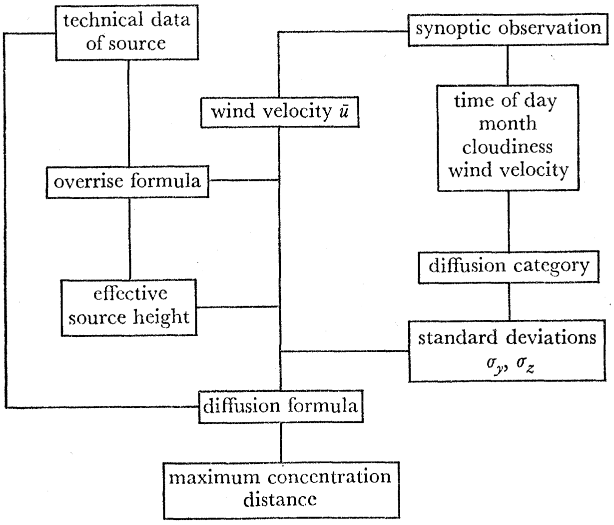

FIGURE 1. Schematic diagram for computing maximum concentration at the surface and its source distance from synoptic observations and technical data of the source.

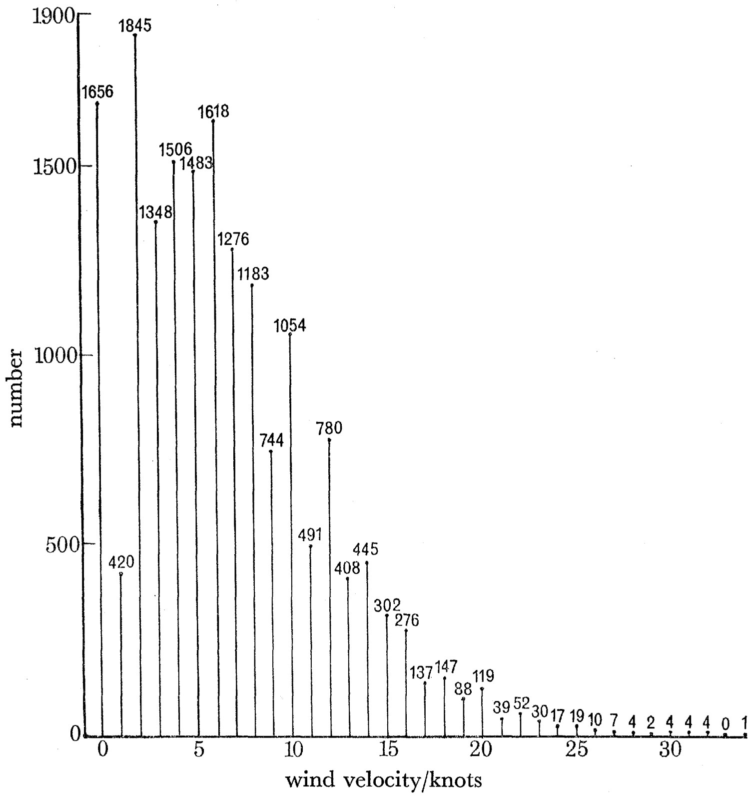

FIGURE 2. Frequency of observed wind velocities for 2 years of hourly observations at Rhein–Main airport. 1 knot = 0.514 m s^{-1}.

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station in the area or characteristic for the area where the source is located. These synoptic observations contain all the necessary information to use the diffusion category scheme mentioned above. One is therefore in the position to compute frequency statistics of wind velocities on one hand and of diffusion categories on the other. With the frequency statistics of diffusion categories

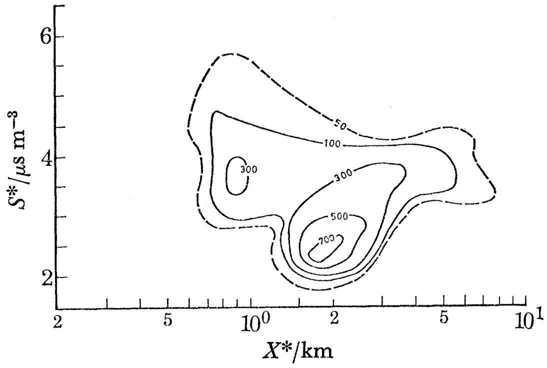

FIGURE 3. Frequency density diagram of normalized maximum concentration $\bar{s}/Q$ and its distance X^* from the source after 2 years of hourly observations at Rhein–Main airport. Isolines give number of cases per reference solenoid of μs m^{-3} × 0.2 km. Chimney height 60 m and average technical conditions.

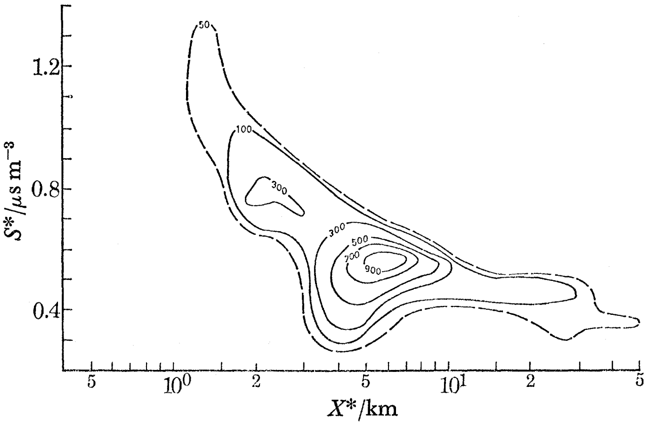

FIGURE 4. Same as figure 3, but chimney height 100 m and reference solenoid 0.1 μs m^{-3} × 1.0 km.

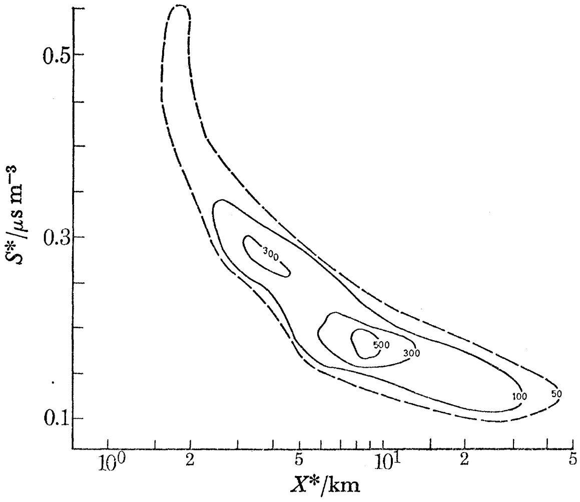

FIGURE 5. Same as figure 3, but chimney height 140 m and reference solenoid 0.05 μs m^{-3} × 1.0 km.

and wind velocities it is possible to compute frequency density diagrams in a coordinate system of normalized (by source intensity) maximum concentrations and their distances from the assumed source.

To illustrate the results by such a method the frequency statistic of wind velocities and the frequency density diagram mentioned are given as obtained by Nester (1966) from the hourly synoptic observations of Rhein–Main airport for two years (figures 2 to 5). This has been done for three different chimney building heights (60, 100 and 140 m) and average technical conditions of the source. It is interesting—but not surprising—to note, that high concentration values are connected with small distances from the source. These cases are unstable weather situations, where strong vertical mixing of the lower atmosphere occurs.

From these diagrams the percentage of maximum concentrations above a given threshold concentration and assumed chimney height can be read off and if an allowable percentage above this threshold concentration can be given, the chimney building height can be adjusted accordingly. This method allows also some refinement, for example, the statistics can be split up for different wind directions, if needed.

Although the maximum concentration can be wrong in certain situations by a factor of 2 when we use the abovementioned formula and the diffusion category scheme, it is felt, that such errors cancel out in the statistics. In summing up, we believe that by this method objective information can be supplied by the meteorologist to air pollution authorities, on which these can base their decisions on concrete air pollution measures.

REFERENCES (Klug)

Hay, J. S. & Pasquill, F. 1959 Diffusion from a continuous source in relation to the spectrum and scale of turbulence. *Adv. Geophys.* **6**, 345.

Klug, W. 1969 Ein Verfahren zur Bestimmung der Ausbreitungsbedingungen aus synoptischen Beobachtungen. *Staub* (in the Press).

Nester, K. 1966 Häufigkeitsstatistische Aussagen über Maximalkonzentrationen von Schornsteinabgasen auf Grund synoptischer Wetterbeobachtungen. Thesis, Met. Inst. T. H. Darmstadt.