CEA CONF--11611
FR9303881

HARMONIZATION OF FRENCH AND GERMAN CALCULATION PROCEDURES FOR ATMOSPHERIC DISPERSION FOLLOWING ACCIDENTAL RELEASES FROM NUCLEAR POWER PLANTS

K. Maßmeyer, R. Martens
Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH, Schwertnergasse 1, D-5000 Köln 1

K. Nester
Kernforschungszentrum Karlsruhe, IMK, Postfach 3640, D-7500 Karlsruhe

H. Schnadt
TÜV Rheinland, Postfach 10 17 50, D-5000 Köln 1

B. Crabol, E. Romeo
CEA (IPSN) B.P. No. 6, F-92260 Fontenay-aux-Roses, Cedex

Ensuite tout de Protection et de Sûreté Nucléaire

Summary

In case of an accident in a nuclear power plant near the French-German border different schemes for dispersion calculations in both countries will currently be applied. An intercomparison of these schemes initiated from the German-French Commission for the safety of nuclear installations (DFK) revealed in some meteorological situations large differences in the resulting concentrations for radionuclides.

An ad hoc working group was installed by the DFK with the mandate to analyse the reasons for the different model results and also to consider new theoretical concepts. The working group has agreed to apply a Gaussian puff model for emergency response calculations. The results of the model - based on turbulence parameterization via similarity approach or spectral theory - have been compared with tracer experiments for different emission heights and atmospheric stability regimes. As a reference the old modelling approaches have been included in the study. The simulations with the similarity approach and the spectral theory show a slightly better agreement to the measured concentration data than the schemes used in the past. Instead of diffusion categories both new approaches allow a continuous characterization of the atmospheric dispersion conditions. Because the spectral approach incorporates the sampling time of the meteorological data as an adjustable parameter, thereby offering the possibility to adjust the dispersion model to different emission scenarios, this turbulence parameterization scheme will be foreseen as the basis for a joint French-German puff model.

1. Introduction

The assessment of radiological consequences resulting from accidental releases of a nuclear power plant is based on the calculation of atmospheric transport of radionuclides. An intercomparison of the calculation procedures applied in Germany and France shows differences characterized as follows:

- the relevant guideline in Germany [1] recommends application of the Gaussian plume model and dispersion parameters derived from the dispersion experiments carried out at the research centers of Jülich and Karlsruhe. These parameters are appropriate for release times of about 30 minutes.
- official guidelines to calculate the radiological consequences do not exist in France. At the Institute de Protection et de Sûreté Nucléaire (IPSN) radiological consequence assessment can be done by using three different procedures which are based on Gaussian models (nomograms, plume or puff model) applying the dispersion parameters after Doury [2].

Under the mandate of the German-French Commission for the safety of nuclear installations, an intercomparison of these two methods had been carried out in 1987. Source distances up to 20 km and a release for 30 minutes at a constant rate had been considered. The results revealed differences in the magnitude of the maximum surface concentrations as well as in the location of the maximum surface concentrations. Those differences could be attributed to the different formulations of the dispersion parameters. In case of an accident at a nuclear power plant located near the French-German border, the application of both methods could result in different emergency actions in both countries. Therefore the advisory board of the DFK gave another mandate to review and update the procedures for calculation of atmospheric transport of radionuclides to come up with a calculation scheme for emergency actions which should be used in both countries.

2. Update of the modeling concepts

In october 1987 a workshop of the DFK (1988) dealt with a discussion of appropriate methods for calculating atmospheric dispersion for emergency actions focussing on source distances up to 20 km. The French and German participants agreed that a Gaussian puff model should be used to calculate the atmospheric dispersion following a nuclear accident. Different ways to determine the diffusion parameters have been discussed. A spectral approach has been favoured by the French side, while a combined similarity and convective scaling approach has been given preference by the German participants.

In contrast to the parameterization schemes used up to now the new approaches are based on boundary layer parameters like friction velocity, convective scaling velocity, boundary layer height and roughness length. These parameters can be derived from site specific meteorological measurements like temperature gradient and wind speed. They enable a calculation of dispersion parameters independent of a turbulence classification scheme like the Pasquill-Gifford scheme. A detailed description of the theories has been given in [3]

3. Comparison of the parameterization schemes

3.1 Turbulence parameters

The methods of turbulence parameterization by similarity approach and by spectral theory have been compared for typical meteorological conditions in France and Germany, averaging times of the meteorological parameters of T = 0.5 h and travel times t up to some 1000 s. For source heights ranging from 10 m to 180 m above ground and for unstable and neutral atmospheric stability both methods show similar results. Typical deviations between the dispersion parameters are of the order of some 10 %. Under stable conditions, however, the horizontal dispersion parameters derived from the spectral approach are much larger than the dispersion parameters calculated by the similarity method. These differences can be attributed to the large scale part of the turbulence spectrum (e.g. meandering of the windfield) which is not included in the similarity approach. Excluding the large scale part from the turbulence spectrum the spectral theory yields dispersion parameters comparable to the similarity approach [3]

3.2 Time-integrated surface concentration

The decision whether the updated modelling techniques are superior to those used in the past could be supported by a comparison of measured and calculated tracer concentrations based on dispersion experiments, especially those which have been the basis of the old parameterization schemes. Therefore the dispersion experiments carried out at the Karlsruhe Nuclear Research Center (KfK) and additionally experiments under low wind speed conditions performed by the NOAA at Oak Ridge, Tennessee have been chosen for this purpose. For both experimental series the measured and calculated time-integrated surface concentrations have been compared using different performance

measures [3]. For short only the intercomparison of the models with the data of the KfK-experiments will be reported here. The results of the intercomparison of the spectral approach with NOAA-data have been published in a report by Romeo [4].

Thomas and Nester (1985) [5] have summarized the results of the tracer experiments at the Karlsruhe Nuclear Research Center. The test field consisted of open spaces and built-up as well as wooded areas. The dispersion experiments comprised source heights of 60, 100, 160, and 195 m. Besides the measured concentrations and the emission data comprehensive information about the meteorological conditions up to a height of 200 m had been available. During most of the experiments two tracers have been released from different heights in several time intervals. The sampling time has been 0.5 h. For 39 sampling periods the old and new modelling approaches have been compared with the measurements.

Generally the application of different performance measures result in a similar rating of the ability of a model to calculate tracer distributions specific for each dispersion experiment. Typical examples of the performance of the new parametrization techniques can be given by an intercomparison of measured and calculated time integrated tracer-concentrations for 60 m emission height. The dispersion experiments have been grouped in 3 different stability regimes (unstable - diffusion categories A and B, neutral - diffusion categories C and D, stable - diffusion categories E and F). Only those receptor points have been retained in the datasets where the measured tracer concentrations exceed 1 % of the maximum concentration detected during each experiment. The resulting datasets comprised 112 to 167 receptor points per stability regime. They have been evaluated using the bootstrap resampling method [6]. As performance measures the fractional bias (FB) and the normalized mean square error (NMSE) have been used, the first giving an estimate of the models ability to describe high concentration values, the latter one as a global indicator for the scatter between observations and predictions. Means and confidence intervals of the two performance measures have been calculated. The results are summarized in fig. 1 and 2. The evaluation of the experiments during stable stratification has been omitted due to large deviations between modelled and measured data.

$$FB = \frac{2\,(\overline{C_c} - \overline{C_p})}{(\overline{C_c} + \overline{C_p})}$$

C_c: observed concentration
C_p: calculated concentration

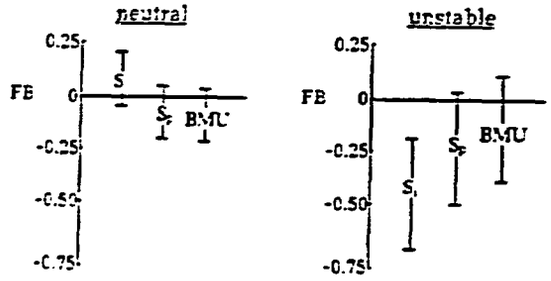

Fig 1: Fractional bias (FB) and confidence limits (95 %-percentile) between measured and calculated concentration data at Karlsruhe Nuclear Research Center for 60 m emission height (Si = similarity approach, Sp = spectral approach, BMU = German Guideline [1])

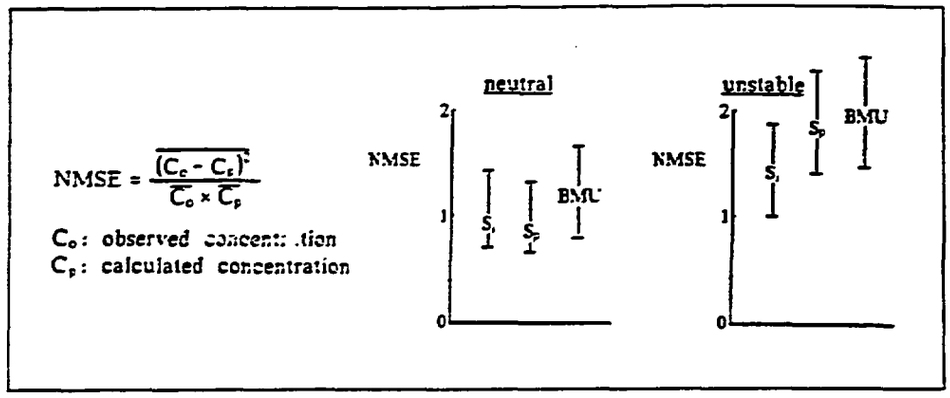

Fig. 2: Normalized mean square error (NMSE) and confidence limits (95 %-percentile) between measured and calculated concentration data at Karlsruhe Nuclear Research Center for 60 m emission height (Si = similarity approach Sp = spectral approach. BMU = German guideline [1])

The evaluation of the experiments under unstable and neutral conditions shows that both new approaches give better results than the model of Doury (not included in fig. 1 and 2). The similarity approach and the spectral approach implemented in a puff model give results of the same quality as the calculations with the Gaussian plume model [1]. In contrast to the plume model - using dispersion parameters which have partly been deduced from the KfK-experiments - the new approaches work on the basis of turbulence parameterizations which use only site specific topographical (roughness length) and meteorological information (e g temperature gradient, wind speed).

However for stable stratification both new techniques fail in the prediction of the concentrations. During most of the experiments under stable conditions broad distributions of tracer concentrations have been observed at ground level. This plume geometry could not be reproduced by similarity or spectral approach. Additional calculations with the puff model using actual turbulence information in emission height (horizontal and vertical wind direction fluctuations as detected by vector wind vanes) or wind shear information using a Lagrangean particle model did not give significantly better results. Mesoscale circulation systems like meanders - attributable to the large scale turbulence - have often been reported as a mechanism for broadening of tracer plumes. They can be excluded as a reason for the resulting concentration field because time dependent wind direction data have been used for the dispersion calculations. No large scale periodicity could be detected in the time series of the wind direction in 60 m height above the ground. We assume that under stable stratification local flows have developed near the ground (due to the inhomogeneity of the experimental area and the slightly uneven terrain) which are responsible for the detected broad concentration distributions.

4. Conclusions

It can be summarized that the dispersion calculations using the similarity approach and the spectral theory show a slightly better agreement to the measured concentration data than the schemes used in the past. Both approaches only use site specific meteorological data to calculate the necessary input parameters by conventional boundary layer theory. The main advantage as compared to the older parameterization schemes is the independance from the dispersion experiments analysed. The dispersion parameters can easily be determined from temperature gradient and wind speed measurements. They allow a continuous characterization of the atmospheric dispersion independent of diffusion categories.

The spectral approach incorporates the sampling time of the meteorological data as an adjustable parameter. This allows an adjustment of the dispersion model to different emission scenarios (short release, long term release). Therefore this turbulence parameterization scheme is proposed as the basis for a joint French-German puff model. However the ability of the spectral approach to handle short term releases adequately has additionally to be tested against field data. The future work will concentrate on the implementation of the model at a nuclear site, to run it with real time data and to analyse the results in order to show its operationality.

In the context of a workshop entitled "Objectives for next generation of practical short-range atmospheric dispersion models" Olesen has pointed out that considering the situation in Europe models have been developed in an unnecessarily disorganized manner. We are so far from having an optimum rate of technology transfer [7]. Our results which have been discussed during this workshop may also be seen as a contribution to an international harmonization of calculation procedures aiming at an easier use of each other's products and results.

References

[1] BMU - Bundesminister für Umwelt, Naturschutz und Reaktorsicherheit (ed.): "Leitfaden für den Fachberater Strahlenschutz der Katastrophenschutzleitung bei kerntechnischen Notfällen", Veröffentlichungen der Strahlenschutzkommission, Band 13, G. Fischer Verlag, Stuttgart (1989).

[2] Doury, A.: "Une methode de calcul pratique et generale pour la prevision numerique des pollutions vehiculees par l'atmosphere", Rapport CEA-R-4280 (rev 1) (1976).

[3] DFK - Deutsch-Franzosische Kommission fur Fragen der Sicherheit kerntechnischer Einrichtungen "Deutsch-Franzosisches Seminar über Gauß'sche Ausbreitungsmodelle" Tagungsbericht - DFK-Bericht 66 1 (D) (1988)

[4] Romeo, E., . "Contribution a l'etude de la diffusion turbulente d'un polluant dans l' atmosphere" These presentée à l'Université de Pierre et Marie Curie Paris IV pour obtenir le diplome de doctorat mechanique, Academie de Paris (1992).

[5] Thomas, P. and Nester, K.: "Experimental Determination of the Atmospheric Dispersion Parameters at the Karlsruhe Nuclear Research Center for Emission Heights of 60 m and 100 m", Nuclear Technology, 68, pp 293-310 (1985)

[6] Hanna, S.R. "Confidence Limits for Air Quality Model Evaluations as estimated by Bootstrap and Jackknife Resampling Methods", Atmospheric Environment, 23 (6), pp. 1385-1398 (1989).

[7] Olesen, H.R. "Background and objectives of the workshop", in "Objectives for next generation of practical short-range atmospheric dispersion models", Risoe National Laboratory (DCAR), Roskilde Denmark (1992).