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■論 文■

Influence of Calm Conditions on the Atmospheric Dispersion of Radioactive Effluents at KAERI Site

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한국원자력연구소 부지에서 방사성물질의 대기확산에 대한 정온상태의 영향

황원태 · 서경석 · 김은한 · 최영길 · 한문희 · 조규성*
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Abstract - The influence of calm conditions on the atmospheric dispersion analyses at KAERI site, which is located at a complex inland basin, was investigated. The U. S. NRC's computer programs XOQDOQ and PAVAN were used to estimate dispersion factors for routine and postulated accidental releases from nuclear facilities, respectively. The joint frequency distribution was obtained from the annual meteorological data measured in 1997 and used as input data of the computer programs. When the definition of calm is changed from 0.5 m sec^{-1} to 0.21 m sec^{-1}, the maximum sector dispersion factor becomes 1.62 and 2.16 times higher for routine and postulated accidental releases, respectively.
Key Words : calm, atmospheric dispersion analyses, wind speed, dispersion factor

요약 - 복잡한 내륙분지에 위치한 한국원자력연구소 부지에서 대기확산해석에 있어서 정온상태에 따른 영향을 고찰하였다. 미국 원자력규제위원회 전산프로그램 XOQDOQ와 PAVAN을 사용하여 원자력시설의 정상운영시와 가상사고시 대기확산인자를 평가하였다. 1997년에 측정된 연간 기상자료로부터 대기안정도에 따른 풍향, 풍속의 발생빈도분포를 작성하여 프로그램의 입력자료로 사용하였다. 정온에 대한 정의를 0.5 m sec^{-1}에서 0.21 m sec^{-1}로 변화시켰을 때 최대치를 나타내는 풍하방향에서의 확산인자는 정상운영시와 가상사고시에 대해 각각 1.62배, 2.16배 높았다.
중심어 : 정온, 대기확산해석, 풍속, 확산인자

INTRODUCTION

Radioactive effluents released into the environment from nuclear facilities may contribute to radiation exposure through several exposure pathways :

- External exposure from radioactive plume or from radionuclides deposited on the ground, and
- Internal exposure due to inhalation and ingestion of radioactive material.

The magnitude of exposure is dependent on atmospheric dispersion and deposition processes. The exposure doses under low wind speeds are higher; the dilution magnitude of effluents is inversely proportional to wind speed. Therefore, the accurate measurement of low wind speeds is important for realistic and accurate estimation of atmospheric dispersion.

Calm is defined as the absence of air motion or wind with a speed of less than 1 knot (≈ 0.45 m sec^{-1}) in the WMO (World Meteorological Organization) [1]. The U. S. NRC (Nuclear Regulatory Commission) and the JAESC (Japan

Atomic Energy Safety Commission) recommend that the anemometer should have a starting threshold of less than 0.45 m sec^{-1} and 0.5 m sec^{-1}, respectively, in determining the acceptability of a site and in evaluating the potential annual radiation doses to the public resulting from effluent releases [2,3]. As the improvement in accuracy of anemometer, the starting threshold of wind speed is becoming low gradually. Moreover, sonic anemometer can give very accurate wind speeds to as low as 0.01 m sec^{-1}.

There are several nuclear facilities such as HANARO research reactor and nuclear fuel fabrication plants at KAERI (Korea Atomic Energy Research Institute) site. The site is located at a complex inland basin which high occurrence probability of calm is represented.

In this study, the influence for calm conditions in the atmospheric dispersion analyses at KAERI site has been investigated for routine and postulated accidental releases using the annual meteorological data measured in 1997.

MATERIALS AND METHODS

Statistical Analysis of Meteorological Data

Meteorological data are being measured in accordance with the requirements of meteorological measurement programs at a tower of 75 m height at KAERI site. The measuring levels are 10 m, 27 m and 67 m. The anemometer of propeller type (WEATHERtronic Model 2031, U. S. A.) is used to measure wind speed. Starting threshold of the anemometer is 0.22 m sec^{-1}. In this study, the annual meteorological data measured at a level of 10 m in 1997 were statistically analyzed. Fig. 1 shows the wind rose which gives the distribution of wind directions and velocities over a year. The prevailing wind directions are SSW (7.45%) and SW (7.39%), and the average wind speed is 0.98m sec^{-1}. Table 1 shows the occurrence probability of each atmospheric stability class.

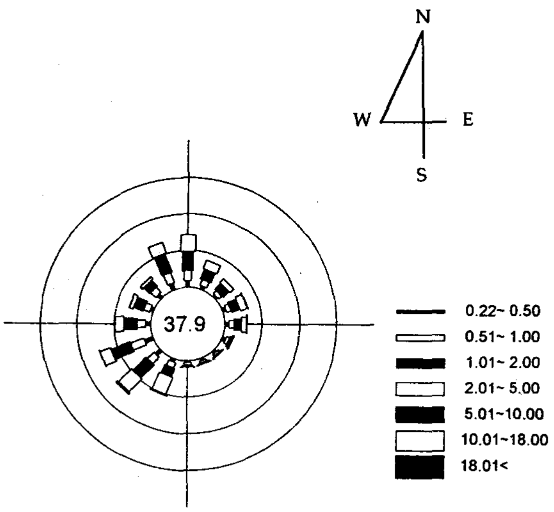

Fig. 1. Wind rose obtained at a level of 10 m at KAERI site in 1997.

Atmospheric Dispersion Analyses

The straight-line Gaussian plume model, which is based on the theory that material released to the atmosphere will be normally distributed about the plume centerline, is commonly used for assessing the consequences by the releases of the radioactive effluents from nuclear facilities. Prior to the estimates, the statistical meteorological data in the form of a joint frequency distribution (f_{ijk}), which represents the probability that wind blows from the direction of k with wind speed class i , and the atmospheric stability class j , should be prepared. Clearly,

$$\sum_i\sum_j\sum_k f_{ijk} = 1. \qquad (1)$$

Table 1. Occurrence probabilities of atmospheric stability classes.

Stability classification	Pasquill categories	Occurrence probabilities (%)
Extremely unstable	A	6.16
Moderately unstable	B	2.37
Slightly unstable	C	2.73
Neutral	D	24.63
Slightly stable	E	47.83
Moderately stable	F	14.68
Extremely stable	G	1.61

In routine releases, the U. S. NRC's computer program XOQDOQ [4], which implements Regulatory Guide 1.111, is used to estimate long-term (or annual) average dispersion factors ($(\chi/Q)_{long}$, sec m^{-3}). The dependance of $(\chi/Q)_{long}$ values for parameters f_{ijk} and $\overline{U_i}$ (mid-point value of i-th a wind speed class, m sec^{-1}) is as follows :

$$\left(\frac{\chi}{Q}\right)_{long} \propto \frac{f_{ijk}}{\overline{U_i}} \qquad (2)$$

In postulated accidental releases, the U. S. NRC's computer program PAVAN [5], which implements Regulatory Guide 1.145, is used to estimate short-term dispersion factors ($(\chi/Q)_{short}$, sec m^{-3}). The calculation procedures of $(\chi/Q)_{short}$ values are different from those of $(\chi/Q)_{long}$ values. For each sector, the χ/Q values are calculated for each combination of wind speed and atmospheric stability at particular distances. The χ/Q values calculated for each sector are then ordered from the greatest to the smallest and an associated cumulative distribution is derived based on the frequency distribution of wind speeds and stability classes. The smallest χ/Q value in the distribution has a corresponding cumulative frequency equal to the wind direction frequency for that sector. It then determines for each sector an upper envelope curve based on these data. From this upper envelope, the $(\chi/Q)_{short}$ value for 0-2 hour time period, which is equalled or exceeded 0.5%, is obtained.

In both computer programs, the occurrence probability of calm for each stability class is assigned proportionally to the directional frequency distribution of non-calm first wind speed class. By the classification of wind speed classes recommended in U. S. NRC's Regulatory Guide 1.23 [2], when the definition of calm is less than 0.21 m sec^{-1} and 0.5 m sec^{-1}, the non-calm first wind speed class is 0.22 m sec^{-1} $\leq U \leq$ 0.5 m sec^{-1} and 0.51 m sec^{-1} $\leq U \leq$ 0.75 m sec^{-1}, respectively. Table 2 shows the occurrence probability for both definitions of calm (*i.e.*, U_c=0.5 m sec^{-1} and U_c=0.21 m sec^{-1}) as a function of stability class, where U_c is the assumed upper wind speed of calm.

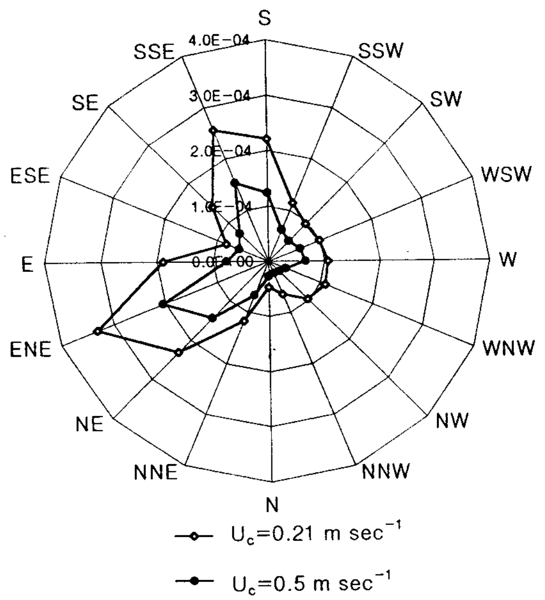

Fig. 2. Long-term dispersion factors ($(\chi/Q)_{long}$, sec m^{-3}) for 16 sectors at a distance of 800m in different calm conditions.

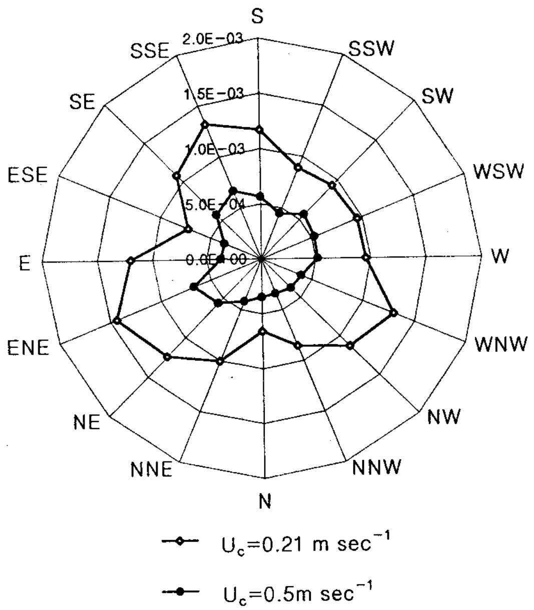

Fig. 3. Short-term dispersion factors ($(\chi/Q)_{short}$, sec m^{-3}) for 16 sectors at a distance of 800m in different calm conditions.

Table 2. Occurrence probability of calm as a function of atmospheric stability category(%).

Calm definition \ Stability	A	B	C	D	E	F	G	Total
U_c=0.21 m sec^{-1}	0.94	0.38	0.59	5.70	20.18	8.75	1.33	37.87
U_c=0.5 m sec^{-1}	1.59	0.68	0.90	7.91	24.61	10.36	1.43	47.48
Difference	0.65	0.30	0.31	2.21	4.43	1.61	0.10	9.61

RESULTS AND DISCUSSION

The χ/Q values were calculated for both definitions of calm (*i.e.*, U_c=0.5 m sec^{-1} and U_c=0.21 m sec^{-1}). The U. S. NRC's computer programs XOQDOQ and PAVAN were used to estimate χ/Q values for routine and potential accidental releases, respectively. The χ/Q values were estimated for 16 sectors at a distance of 800 m (emergency planning zone) from HANARO research reactor at KAERI site. The annual meteorological data measured at a level of 10 m at KAERI site in 1997 were used as input data of both computer programs. In this study, ground-level release was assumed.

Fig. 2 shows the $(\chi/Q)_{long}$ values for 16 sectors obtained for both definitions of calm. The maximum value was observed in ENE sector for both cases. The $(\chi/Q)_{long}$ value for U_c=0.21 m sec^{-1} was 1.62 times higher than that for U_c=0.5 m sec^{-1} in ENE sector. The maximum ratio of $(\chi/Q)_{long}$ between both cases was a factor of 3.69 in NW sector and the minimum ratio was a factor of 1.45 in ESE sector. The directional difference of the ratios between both cases is dependent on the frequency distributions in non-calm first wind speed class.

Fig. 3 shows the $(\chi/Q)_{short}$ values for 16 sectors obtained for both definitions of calm. The maximum value was observed in ENE sector for both cases. The directional difference of $(\chi/Q)_{short}$ values was small as compared with that of $(\chi/Q)_{long}$ values because of the method of choosing the 0.5% value for each sector. The $(\chi/Q)_{short}$ value for U_c=0.21 m sec^{-1} was 2.16 times higher than that for U_c =0.5 m sec^{-1} in ENE sector. The maximum ratio of $(\chi/Q)_{short}$ between both cases was a factor of 3.29 in WNW sector and the minimum ratio was a factor of 1.66 in SW sector.

The difference of results for both cases was distinctly observed because the occurrence probability of 0.22 m sec^{-1} $\leq U \leq$ 0.5 m sec^{-1} is by far lower than that of less than 0.21 m sec^{-1}. As shown in Table 1, the occurrence probability of wind speeds less than 0.21 m sec^{-1} is 37.87% and that of 0.22 m sec^{-1} $\leq U \leq$ 0.5 m sec^{-1} is 9.61%. If the occurrence probability of 0.22 m sec^{-1} $\leq U \leq$ 0.5 m sec^{-1} is relatively high, the χ/Q values for U_c=0.5 m sec^{-1} may be higher than those for U_c=0.21 m sec^{-1} because a mid-point value for each wind class is used in calculation.

CONCLUSIONS

The influence of calm conditions on the atmospheric dispersion at KAERI site was investigated using the annual meteorological data measured in 1997. The occurrence probability of calm at KAERI site (a complex basin) was high with 37.9% at the measuring level of 10 m. When the definition of calm is changed from 0.5 m sec^{-1} to 0.21 m sec^{-1}, the maximum dispersion factor becomes 1.61 and 2.16 times higher for routine and postulated accidental releases, respectively. Therefore, the calm condition should be carefully defined in case of the site where the occurrence probability of low wind speeds is high.

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