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YVL 7.15, 18 May 1976
YVL 7.16, 27 June 1977

In the event of any differences in interpretation of this guide, the Finnish version shall take precedence over this translation.

EVALUATING THE DISPERSION OF RADIOACTIVE RELEASES FROM NUCLEAR POWER PLANTS UNDER OPERATING AND ACCIDENT CONDITIONS

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1. GENERAL

The dispersion of radioactive substances from nuclear power plants to the environment shall be evaluated by means of dispersion models. During normal operation, the evaluation of dispersion forms a part of the dose calculations based on measurements of releases. In case of accidents, there shall be preparedness for quick evaluation of the dispersion of gaseous effluents to form a basis for the protection of the population. In the licensing phase, the evaluation of dispersion shall be made in connection with the analysing of accidents that are used as a design basis.

2. SCOPE

This guide provides general guidelines for evaluating the dispersion of radioactive gaseous and liquid effluents to the environment under the operating conditions of nuclear power plants. In addition, this guide presents the assumptions that are made of the dispersion of radioactive gaseous effluents for the analysis of the accident conditions of the nuclear power plant, and general guidelines applied in dispersion graphs prepared for the accident conditions of the nuclear power plant.

3. EVALUATION OF ATMOSPHERIC DISPERSION OF GASEOUS EFFLUENTS RELEASED FROM NUCLEAR POWER PLANTS UNDER OPERATING CONDITIONS

Knowledge of the release data and meteorological dispersion conditions is necessary for evaluating the atmospheric dispersion of gaseous effluents.

The release data include the amounts, characteristics and effective release heights of airborne radioactive effluents. Downwash and plume rise are taken into account when determining the effective release height. The effect of the vertical exit velocity and temperature of the plume can be considered when the plume rise is calculated.

The necessary meteorological dispersion data comprise wind speed and direction and atmospheric stability class which are given by meteorological stations. Wind speed at levels where no measurements are conducted can be calculated. The atmospheric stability class is primarily determined by means of weather mast observations on the basis of vertical temperature difference and wind speed (Appendix 1) and secondarily only on the basis of vertical temperature difference (Appendix 2). The vertical temperature difference shall be measured at levels that are as representative as possible. If weather mast observations are temporarily missing, wind speed and direction and the stability class can be determined by means of ground-level observations at nearby meteorological stations. The stability class should be determined using the Pasquill-classification. The values of dispersion parameters (σ_y, σ_z) corresponding with the various stability classes, shall be corrected in respect of surface roughness. In addition, the presence of potential inversion layers shall be considered when determining values for vertical plume spread parameters.

The concentrations of radioactive substances and further, the radiation doses caused by them at the distance under investigation can be calculated on the basis of the release and dispersion data, using mathematical models as an aid. In general, the depletion of concentrations of radioactive substances in the air due to rainfall or deposition to the ground is not considered at short distances. Farther away, their effecct may be taken into account.

During the construction permit review, the long-term observations of nearby meteorological stations can serve as meteorological data in the description of atmospheric dispersion of gaseous effluents.

During operating license review and operation, the results obtained through the onsite meteorological programme are used as meteorological conditions in depicting the atmospheric dispersion of gaseous effluents when calculating radiation doses to the critical group. In calculating collective doses, it is recommended that observations of more distant meteorological stations be used as well, because changes in meteorological parameters may be significant especially on the coast, in the transition area between a water body and mainland. Meteorological observations are collected in periods of a month, three months, a grazing season and a calendar year (cf. Guide YVL 7.5). Only the data used for calculating radiation doses are reported. In addition, abnormal releases including prevailing dispersion conditions and induced radiation doses are reported separately (cf. Guide YVL 7.8).

4. EVALUATION OF AQUATIC DISPERSION OF LIQUID EFFLUENTS RELEASED FROM NUCLEAR POWER PLANTS UNDER OPERATING CONDITIONS

The release data include amounts and characteristics of radioactive effluents in liquid form, flow rates and temperatures of cooling water, and structures in the release point.

The dispersion of radioactive substances in the discharge water body is affected by streams that are either natural or induced by the operation of the plant, turbulent mixing of water, location of the discharge point, size and geometry of the discharge water body, forms of the bottom, recirculation of cooling water, sedimentation, and resuspension. Also radioactive decay can be taken into account.

The concentrations of radioactive substances and further, the radiation doses caused by them at the distance under investigation can be evaluated on the basis of the release and dispersion data.

During the construction permit review, a conservative dispersion model applicable to the discharge water body can be used in depicting the dispersion of radioactive liquid effluents.

A conservative dispersion model applicable to the discharge water body can also be used in depicting the dispersion of radioactive liquid effluents during operating license review and operation. As far as possible, this model should be compared with the results obtained from the hydrographic measurements of the discharge water body (flow measurements, variations in water level, recirculation etc.). The dispersion data used in calculating radiation doses shall also be reported. In addition, abnormal releases including prevailing dispersion conditions and induced radiation doses are reported separately (cf. Guide YVL 7.8).

5. EVALUATION OF ATMOSPHERIC DISPERSION OF GASEOUS EFFLUENTS RELEASED FROM NUCLEAR POWER PLANTS UNDER ACCIDENT CONDITIONS

5.1 Evaluation of dispersion in the assessment of a design-basis accident

The appendix of Guide YVL 7.1 presents the assumptions that are made for the release of radioactive gaseous effluents to the environment in a design-basis LOCA. As concerns other types of accident, assumptions for the dispersion can be made in the same way. The effective release height shall be determined separately for each power plant. Potential downwash shall be taken into account. The depletion of concentrations of radioactive substances in the air due to rainfall or deposition to the ground is not considered when calculating doses at the boundary of the plant site. When calculating collective doses, their effect may be taken into account.

In the analysis of a design-basis accident, the following assumptions shall be made concerning dispersion conditions: Diffusion factors are calculated as in Regulatory Guides 1.3 and 1.4. Weather classes are Pasquill classes.

Releases from the effective height of the stack

Time following accident	Dispersion conditions
0...8 h	The diffusion factors X/Q (s/m^3) are obtained from the curves of Figure 1a in Appendix 3 as functions of the distance x (m) from the release point at various effective release heights h (m). The wind speed u is 1 m/s and its direction is constant.
8...24 h	The diffusion factors are obtained from the curves of Figure 1b in Appendix 3 as functions of the distance at various release heights. The wind speed is 1m/s and its direction varies within a sector of 30°.

1...4 d The diffusion factors are obtained from the curves of Figure 1c in Appendix 3 as functions of the distance at various release heights. The following dispersion conditions are used to express maximum concentrations at different distances:

1 40% A and 60% C,
2 50% C and 50% D,
3 33.3% C, 33.3% D and 33.3% E,
4 33.3% D, 33.3% E and 33.3% F,
5 50% D and 50% F,
6 100% F.

The wind speed in classes A, B, E and F is 2 m/s and in classes C and D 3 m/s. The wind direction varies within a sector of 30^{o}.

4...30 d The dispersion factors are obtained from the curves of Figure 1d in Appendix 3 as functions of the distance at various release heights. The dispersion conditions are the same as above with the exception that the wind direction is within a sector of 30^{o} for 33.3% of the time.

Releases at ground level

Figure 2 in Appendix 3 shows the corrections to be made to the concentrations 0...8 h after the accident as functions of the distance at various cross-sectional areas A of the reactor building. The reason for this is the turbulence caused by the reactor building.

Time following accident	Dispersion conditions
0...8 h	Class F, wind speed 1 m/s and wind direction constant.
8...24 h	Class F, wind spped 1 m/s and wind direction varies within a sector of 30°.
1...4 d	Class F, wind speed 2 m/s and wind direction varies within a sector of 30°.
4...30 d	40% D and 60% F, wind speed in class D 3 m/s and in class F 2 m/s and wind direction within a sector of 30° for 33.3% of the time.

Figures 3a and 3b in Appendix 3 show the diffusion factors as functions of the distance.

5.2 Preparations to be made for evaluating dispersion in accident conditions

Dispersion graphs shall be prepared in case of accident conditions at nuclear power plants. The dispersion graphs shall extend up to a distance of about 50 km, but at the same time no great population centre shall be left in the vicinity of the area under survey. The dispersion graphs are prepared for 2...3 typical release heights, for four wind speed classes and at least for four stability levels, for instance for the following combinations of stability class: A...B, C...D, E...F...G, and C...D in the rain. Inaccuracies in the direction of the dispersion should also be taken into account.

In accident conditions, data obtained from the onsite meteorological programme are placed in the dispersion graphs. The effective release height is always assessed separately in each case. If there is no dispersion graph for a certain release height, an effort shall be made to evaluate the results on the basis of dispersion graphs prepared for adjacent release heights. Wind speed at heights where no measurements are conducted can be calculated. The stability class is primarily determined by means of vertical temperature difference and wind speed (cf. Appendix 1). The depletion of concentrations of radioactive substances due to deposition to the ground is not considered at short distances. The effect of rainfall can be taken into account also at short distances.

Besides dispersion graphs, also an evaluation method based on automatic data processing can be used.

6. RECOMMENDATIONS, REFERENCES

Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Release from Light-Water-Cooled Reactors, Regulatory Guide 1.111, U.S. Nuclear Regulatory Commission, Revision 1, July 1977.

Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Impelementing Appendix I, Regulatory Guide 1.113, U.S. Nuclear Regulatory Commission, Revision 1, April 1977.

G. Nordlund, A-L. Riekkinen and B. Tammelin, Pasquill-tyyppinen ilman epäpuhtauksien leviämismalli (Pasquill-Type Dispersion Model for Atmospheric Impurities), Bulletin No. 31, Institute of Meteorology, 1976.

Atmospheric Dispersion in Nuclear Power Plant Siting, Safety Series No. 50-SG-S3, International Atomic Energy Agency, 1980.

Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss-of-Coolant Accident for Boiling Water Reactors, Regulatory Guide 1.3, U.S. Atomic Energy Commission, Revision 2, June 1974.

Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss-of-Coolant Accident for Pressurized Water Reactors, Regulatory Guide 1.4, U.S. Atomic Energy Commission, Revision 2, June 1974.

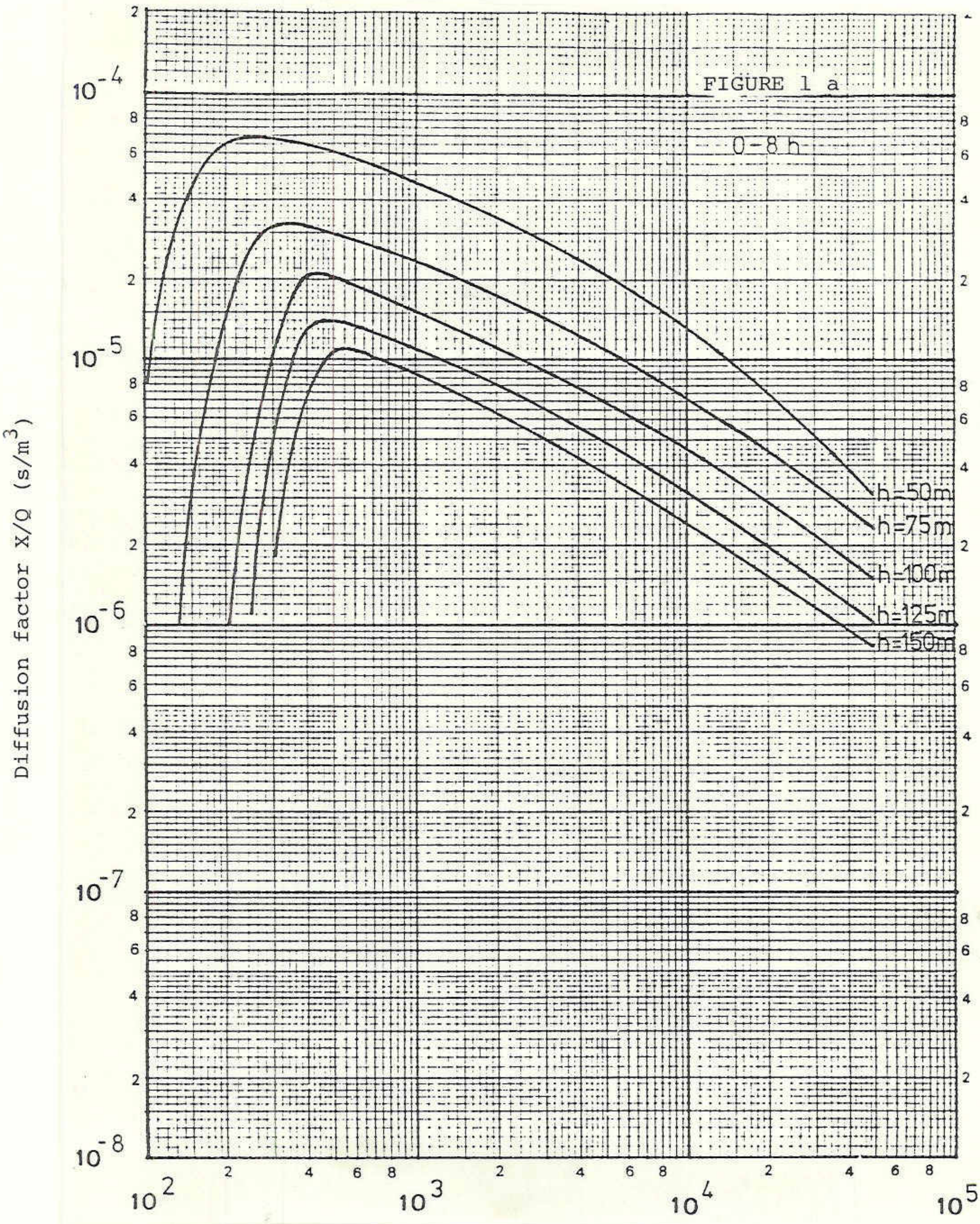
Stability classification based on vertical temperature change and wind speed

Wind speed u (m/s)	Stability class at various values of vertical temperature change for 100 metres (^{o}C)						
	≤-1.5	-1.4...-1.2	-1.1...-0.9	-0.8...-0.7	-0.6...0.0	0.1...2.0	>2.0
< 1	A	A	B	C	D	F	F
$1 \leq u < 2$	A	B	B	C	D	F	F
$2 \leq u < 3$	A	B	C	D	D	E	F
$3 \leq u < 5$	B	B	C	D	D	D	E
$5 \leq u < 7$	C	C	D	D	D	D	E
$7 \leq u$	D	D	D	D	D	D	D

A = very labile, B = moderately labile, C = slightly labile, D = neutral,
E = slightly stable, F = moderately stable.

Stability classification based on vertical temperature change

Stability class	Stability level	Vertical temperature change of air for 100 metres °C
A	very labile	< -1.9
B	moderately labile	-1.9...-1.7
C	slightly labile	-1.7...-1.5
D	neutral	-1.5...-0.5
E	slightly stable	-0.5... 1.5
F	moderately stable	1.5... 4.0
G	very stable	> 4.0



Distance from the release point (m)

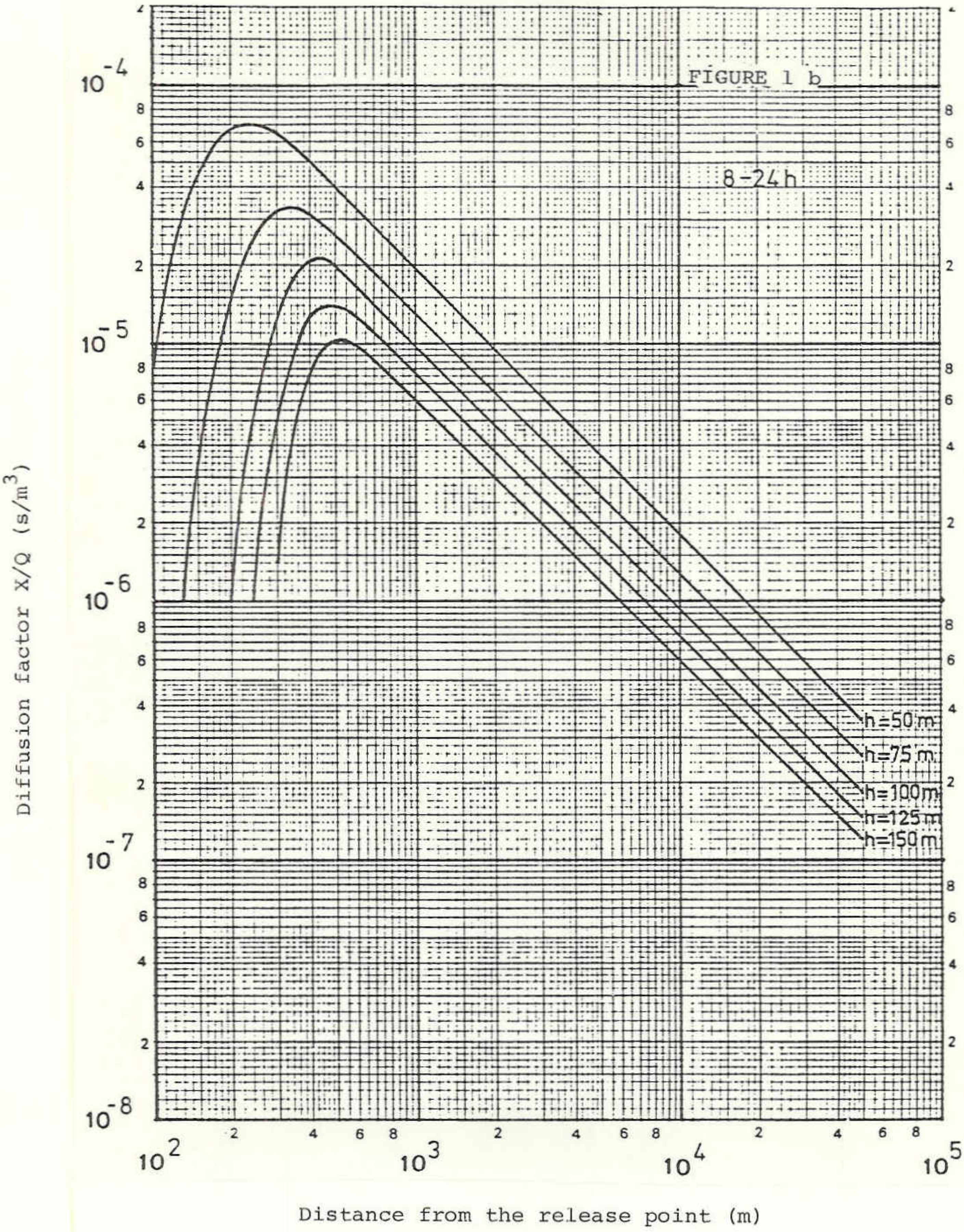


FIGURE 1 b
8-24h
h=50 m
h=75 m
h=100 m
h=125 m
h=150 m
Diffusion factor X/Q (s/m^3)
Distance from the release point (m)
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^2
10^3
10^4
10^5

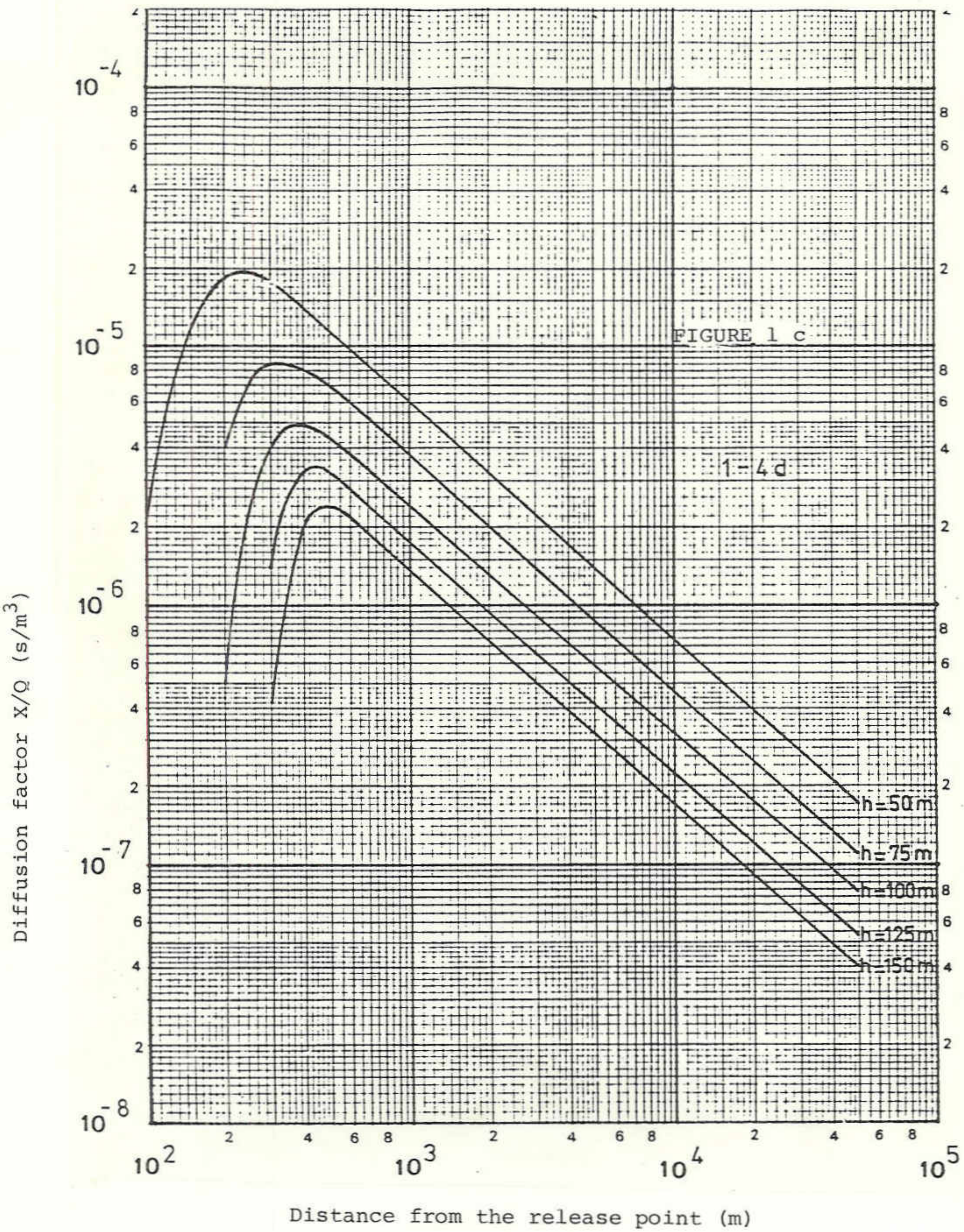


FIGURE 1 c
1-4 d
h=50 m
h=75 m
h=100 m
h=125 m
h=150 m
Diffusion factor X/Q (s/m³)
Distance from the release point (m)
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10²
10³
10⁴
10⁵

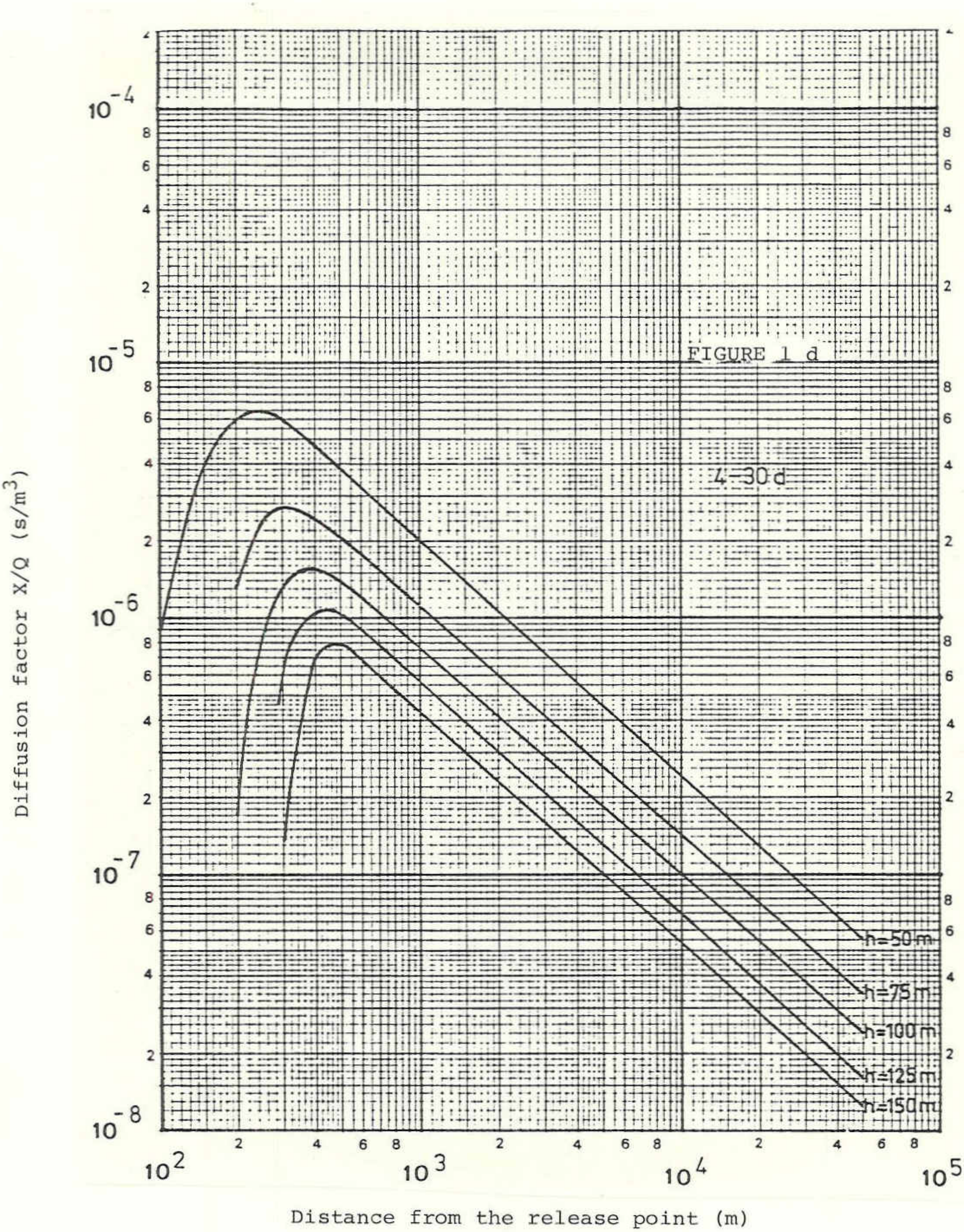


FIGURE 1 d
4-30 d
h=50 m
h=75 m
h=100 m
h=125 m
h=150 m
Diffusion factor X/Q (s/m³)
Distance from the release point (m)
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{2}
10^{3}
10^{4}
10^{5}

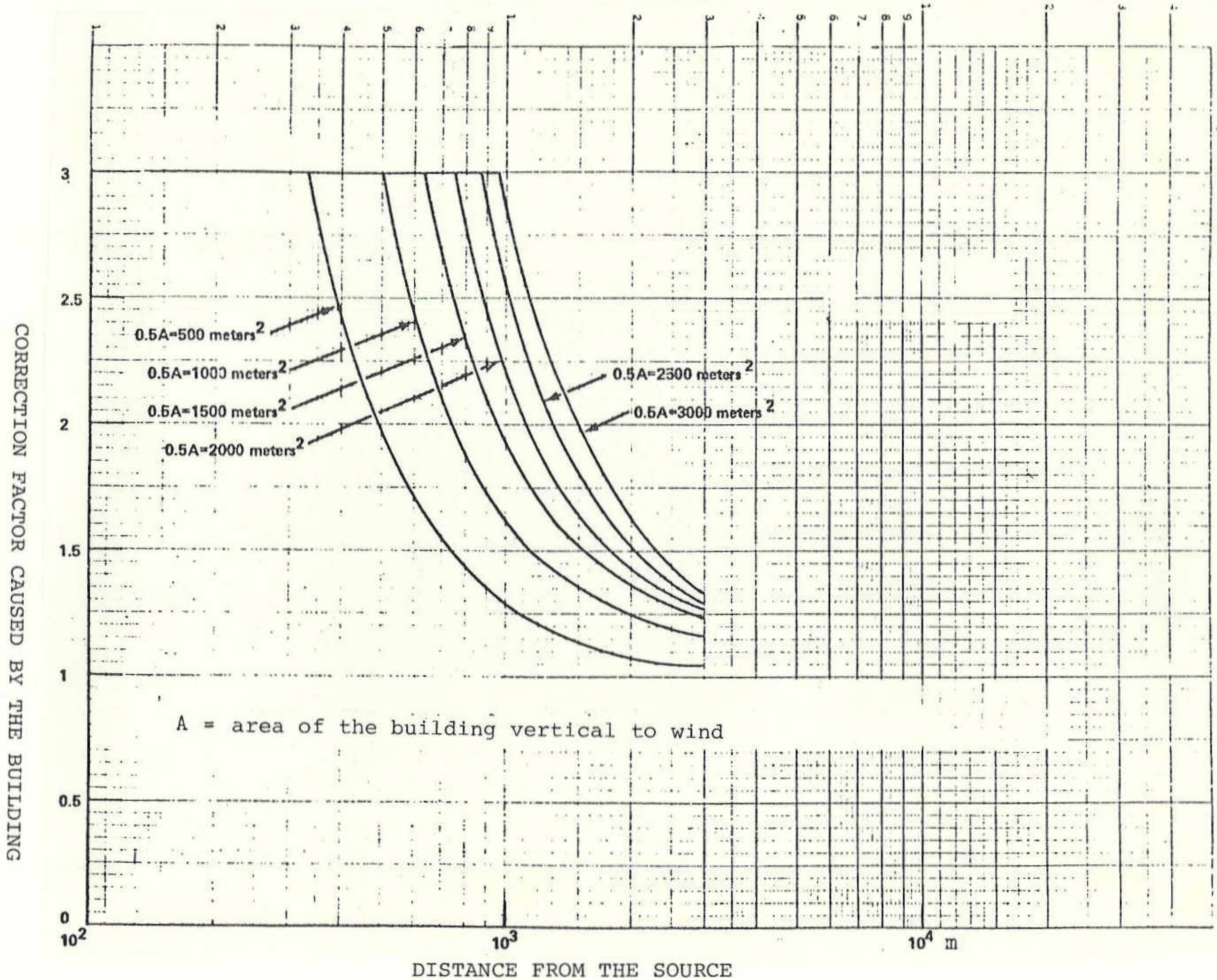


FIGURE 2. CORRECTION FACTOR THAT DEPENDS ON THE TURBULENCE CAUSED BY THE BUILDING

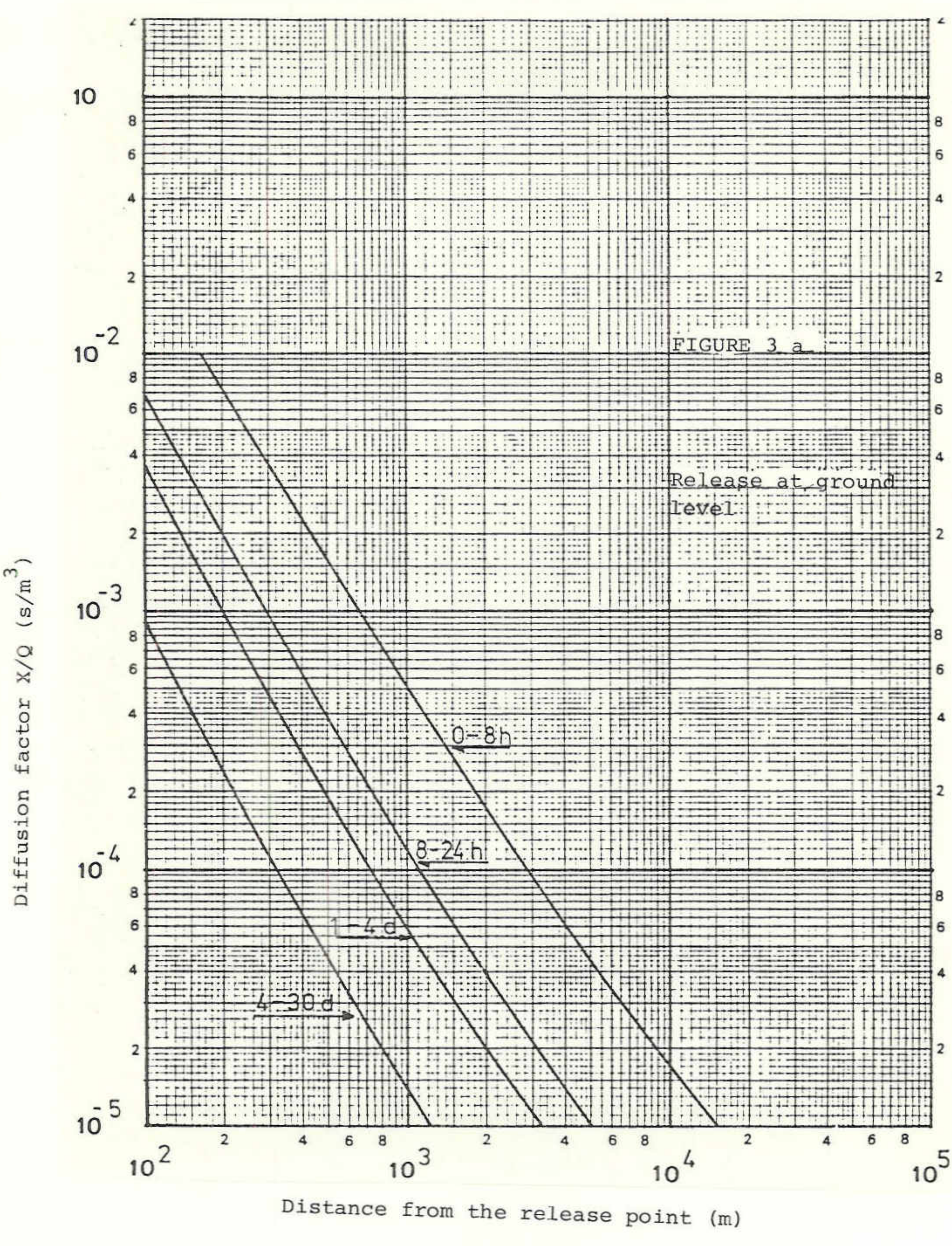
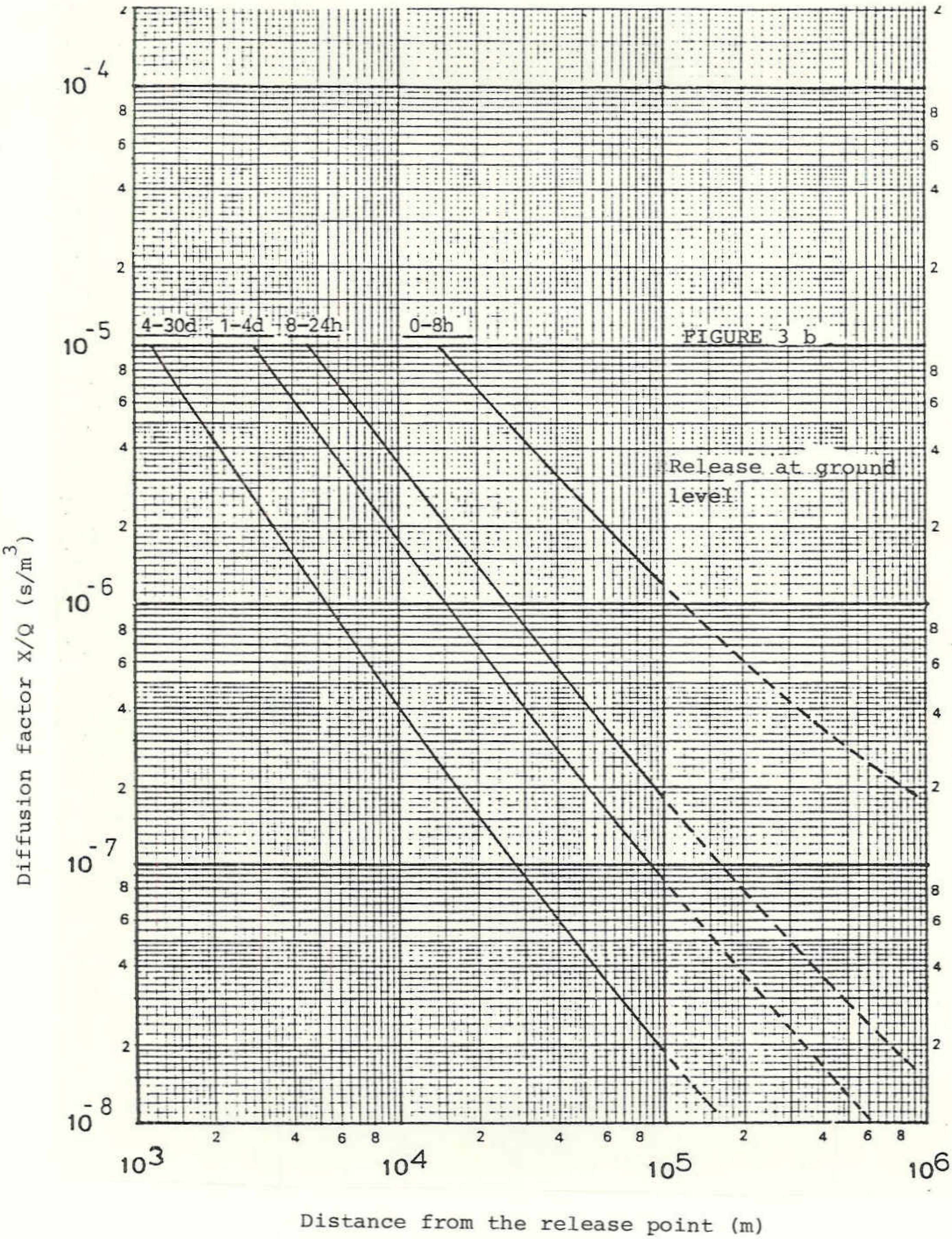


FIGURE 3 a
Release at ground level
0-8h
8-24h
1-4d
4-30d
Diffusion factor X/Q (s/m³)
Distance from the release point (m)
10
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10²
10³
10⁴
10⁵


4-30d
1-4d
8-24h
0-8h
FIGURE 3 b
Release at ground level
Diffusion factor X/Q (s/m3)
Distance from the release point (m)
10-4
10-5
10-6
10-7
10-8
10^3
10^4
10^5
10^6