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# USERS GUIDE FOR THE GAUSSIAN TYPE DISPERSION MODELS CONCX AND CONDEP

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## SUMMARY

This report presents the basis for the use of the Gaussian type dispersion models CONCX and CONDEP operative at the Norwegian Institute for Air Research (NILU). It also contains a description of how to run the programs.

Program CONCX calculates short term downwind concentrations at ground level or in specified receptor points for various distances for selected meteorological conditions. Input to the program consists of information of the source and the meteorological conditions to be considered. Primary output from the program consists of a table with final plume height and concentrations given for each downwind distance and meteorological condition.

Program CONDEP calculates long term sector averaged concentrations for twelve $30^0$-sectors in specified receptor points or in a given grid. The input consists of source data for up to 50 point sources and a meteorological joint frequency matrix of four wind speed classes, four stability classes and twelve wind sectors. The output from the program consists of a table with effective plume height for each source and meteorological condition considered. Another table presents sector average concentration and deposition in specified receptor points or in a specified grid.

Both programs take into account the effects of stack downwash, buildings, wind profiles, deposition, topography and penetration through an elevated stable layer.

# CONTENTS

Page

SUMMARY .......... 1

1 INTRODUCTION .......... 3

2 THE GAUSSIAN PLUME EQUATION .......... 3

2.1 Short-term Gaussian equation .......... 3
2.2 Long-term Gaussian equation .......... 5

3 ELEMENTS OF THE GAUSSIAN PLUME EQUATION .......... 6

3.1 Wind speed .......... 6
3.2 Atmospheric stability .......... 7
3.3 Diffusion parameters .......... 8
3.4 Stack downwash .......... 9
3.5 Plume rise equations .......... 10
3.5.1 Neutral-Unstable Momentum Rise .......... 10
3.5.2 Neutral-Unstable Buoyancy Rise .......... 10
3.5.3 Stability Parameter .......... 11
3.5.4 Stable Momentum Rise .......... 11
3.5.5 Stable Buoyancy Rise .......... 12
3.6 Building effects .......... 12
3.7 Plume penetration .......... 14
3.8 Topography .......... 15
3.9 Dry deposition .......... 16
3.10 Wet deposition .......... 16

4 EXECUTION OF THE MODELS-TEST EXAMPLES .......... 18

4.1 Program CONCX-test example .......... 18
4.1.1 Program dialogue .......... 18
4.1.2 Program output .......... 20
4.2 Program CONDEP-test example .......... 22
4.2.1 Program dialogue .......... 22
4.2.2 Program output .......... 25

5 REFERENCES .......... 29

# USER'S GUIDE FOR THE GAUSSIAN TYPE DISPERSION MODELS CONCX AND CONDEP

## 1 INTRODUCTION

This report presents the basics of the Gaussian type dispersion models in operation at the Norwegian Institute for Air Research (NILU) including a description of the programs CONCX and CONDEP.

## 2 THE GAUSSIAN PLUME EQUATION

The Gaussian plume equation calculates the downwind concentration of gas being continuously emitted from a single source.

### 2.1 SHORT-TERM GAUSSIAN EQUATION

Program CONCX calculates the short-term impact defined as follows:

$$
\begin{aligned}
C(x, y, z) = {} & \frac{Qe^{-\lambda t}}{2\pi u \sigma_y \sigma_z} \exp \left[- \frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \\
& \cdot \left\{ \exp \left[- \frac{1}{2} \left(\frac{z-H}{\sigma_z}\right)^2\right] + \exp \left[- \frac{1}{2} \left(\frac{z+H}{\sigma_z}\right)^2\right] \right. \\
& + \sum_{n=1}^{3} \left\{\exp \left[- \frac{1}{2} \left(\frac{z-H-2nL}{\sigma_z}\right)^2\right] + \exp \left[- \frac{1}{2} \left(\frac{z+H-2nL}{\sigma_z}\right)^2\right] \right. \\
& \left. \left. + \exp \left[- \frac{1}{2} \left(\frac{z-H+2nL}{\sigma_z}\right)^2\right] + \exp \left[- \frac{1}{2} \left(\frac{z+H+2nL}{\sigma_z}\right)^2\right]\right\}\right\}
\end{aligned}
\tag{1}
$$

Where:

$(x, y, z)$ = location of the receptor point given in rectangular co-ordinates with the origin at ground level at the source location and x-axis parallel to wind direction
$Q$ = continuous source emission rate of the air pollutant
$H$ = effective plume height
$\lambda$ = scavenging coefficient due to wet deposition
$t$ = transport time
$\bar{u}$ = mean transport wind speed
$\sigma_y, \sigma_z$ = standard deviation of the concentration in the horizontal and vertical directions respectively.
$L$ = mixing height
$n$ = number of reflections $(N=3)$.

It is assumed that:

- the pollutant transfer by advection in the transport direction is greater than by turbulent diffusion;

- steady state conditions are prevailing, which implies that all variables and parameters are constant in time;

The assumption which neglects the turbulent diffusion in the transport direction relative to advection implies that the Gaussian plume equation should usually be applied for average transport speeds of more than 1 m/s.

The use of a constant average transport speed and a fixed wind direction during the basic time period reflects the assumption of a stationary and homogeneous horizontal wind field. Directional wind shear in the boundary layer is not considered.

## 2.2 LONG TERM GAUSSIAN EQUATION

Program CONDEP calculates long term average concentrations including the effects of dry deposition and plume tilting. In this case the sector model can be used, where it is assumed that there is no horizontal crosswind variation in concentration within an angular sector equal to the resolution of the wind-direction data. The formula for ground level concentration from a number p of continuous point sources within a number r sectors of arbitrary angular width $2\pi/r$ (in radians) is as follows:

$$C(x,y,0) = (r/2\pi) \sum_{i=1}^{p} \sum_{l=1}^{4} \sum_{m=1}^{4} f(k_i,l,m)\, Q_i D(x_i,u,l)/x_i \qquad (2)$$

where the dispersion function $D(x_i,u,l)$ is defined as:

$$D(x_i,u,l) = \sqrt{\frac{2}{\pi}}\, \Big[ \Big(\frac{1+\alpha}{2}\Big) \exp\Big(-\frac{1}{2}\Big(\frac{H'}{\sigma_z}\Big)^2\Big) + \sum_{n=1}^{3} \exp\Big(-\frac{1}{2}\Big(\frac{H'+2nL}{\sigma_z}\Big)^2\Big)$$

$$+ \exp\Big(-\frac{1}{2}\Big(\frac{H'-2nL}{\sigma_z}\Big)^2\Big)\Big]/(u\sigma_z) \qquad (3)$$

where

$f(k,l,m)$ = joint frequency function

$k_i$ = index identifying the wind sector appropriate for the ith point source

$l$ = index identifying the wind speed class

$m$ = index identifying the stability class

$\alpha$ = reflection coefficient due to deposition,

$H' = H - \frac{V_t x}{u}$ = effective height including tilting of the plume

$V_t$ = gravitational settling speed of coarse particles

$L$ = the mixing height

the other parameters are described in equation (1) above.

# 3 ELEMENTS OF THE GAUSSIAN PLUME EQUATION

## 3.1 WIND SPEED

The mean transport wind speed should be representative of the conditions throughout the vertical height interval in which the plume is dispersing. The wind speed in the lower atmosphere varies with height above ground. Since wind measurements are generally performed near ground level (10 m above ground), an adjustment for the expected height range of dispersion has to be made. The variation of wind speed with height depends also upon the atmospheric stability.

The height dependency of the wind speed is described by a power law:

$$\bar{u}\,(z) = \bar{u}\,(z_o)\,\left(\frac{z}{z_o}\right)^m \tag{4}$$

with

$z$ = height above ground,
$z_o$ = reference height above ground,
$\bar{u}$ = time average wind speed,
$m$ = wind profile exponent;

The mean transport speed representative of an appropriate height range, e.g. from the effective source height (H) to ground level (for dispersion calculations), may then be calculated by integration:

$$\bar{u} = \frac{1}{\Delta z} \int \bar{u}\,(z)\,dz = \frac{1}{(z_2 - z_1)} \int_{z_1}^{z_2} \bar{u}\,(z_o) \cdot \left(\frac{z}{z_o}\right)^m dz, \tag{5}$$

Several empirical values of wind profile exponents (m) for different turbulence conditions have been published. The wind profile exponents are user input parameters, and in the NILU models the following values have been applied as standard values:

| Stability class | m |
|---|---|
| Unstable | 0.20 |
| Neutral | 0.28 |
| Slightly stable | 0.36 |
| Stable | 0.42 |

## 3.2 ATMOSPHERIC STABILITY

The diffusion of air pollutants in the lower atmosphere is strongly influenced by the local atmospheric stability. The diffusion of effluents is more rapid in the unstable than in the stable atmosphere.

The stability of the atmosphere can be derived from vertical and horizontal turbulence measurements, or from measurements of the vertical temperature profile and wind speed. Estimates of the net radiation or cloud cover, ceiling height, and solar elevation have also been used. For practical reasons the turbulence situations of the atmosphere are usually described by a discrete set of stability classes.

Different turbulent classification schemes have been developed and used. Pasquill defined 6 turbulence classes:

A = extremely unstable
B = moderately unstable
C = slightly unstable
D = neutral
E = slightly stable
F = moderately stable

The meteorological data used to dermined the turbulence type are usually the surface wind speed, daytime insolation, and nighttime cloudiness.

In the NILU data input for dispersion models, the 3 unstable classes have been combined into one. The stability classes are usually defined by vertical temperature gradients and by direct measurements of the standard deviation of the horizontal wind direction fluctuations, where such data are available. The stability classes are defined as follows:

| Stability class | Temperature gradient dT (deg/100 m) | Corresponds to: | |
|---|---|---|---|
| | | Pasquill | Brookhaven |
| Unstable | dT <-1 | A + B + C | $B_1 + B_2$ |
| Neutral | $-1 \leq$ dT < 0 | D | C |
| Slightly stable | $0 \leq$ dT < 1 | E | - |
| Stable | dT $\leq$ 1 | F | D |

## 3.3 DIFFUSION PARAMETERS

A main assumption for solving the diffusion equation is the existence of a Gaussian normal distribution of the plume concentrations perpendicular to the transport direction. The diffusion parameters $\sigma_y$ and $\sigma_z$ are defined as the standard deviations of the concentration distributions in the lateral and vertical, respectively. They are functions of the downwind distance from the emission source and of the stability of the atmosphere. The standard deviations have been determined from tracer experiments carried out during different wind and turbulence conditions.

The most appropriate set of diffusion parameters should be selected for each particular application. The choice will be dependent upon source height, surface roughness and, in some cases, averaging time or transport distance. A set of different parameters has been evaluated at NILU and represents the basis for our selection of stability classes.

When direct turbulence measurements are not available, the following form of diffusion parameters is used:

$$\sigma_y(x) = ax^p, \qquad \sigma_z(x) = bx^q. \qquad (6)$$

The most commonly used coefficients are listed in the Table 1 below, and apply to averaging times of up to one hour.

Table 1: Commonly used dispersion coefficients applicable for different source types and surface roughness.

| Source and surface specifications | Coefficients | Unst. | Neutr. | Sl.stable | Stable |
|---|---|---|---|---|---|
| Surface and low sources, Rough surface, urban area Ref.: Mc Elroy, J.L. Pooler, F, 1968 | a | 1.7 | 0.91 | 1.02 | - |
| | p | 0.72 | 0.73 | 0.65 | - |
| | b | 0.08 | 0.91 | 1.93 | - |
| | q | 1.2 | 0.70 | 0.47 | - |
| High stacks, Smooth to medium rough surface Ref.: Smith, M. 1968 | a | 0.36 | 0.32 | 0.31 | 0.31 |
| | p | 0.86 | 0.78 | 0.74 | 0.71 |
| | b | 0.33 | 0.22 | 0.16 | 0.06 |
| | q | 0.86 | 0.78 | 0.74 | 0.71 |
| Sea surface Ref.: Raynor et al. 1977 | a | 0.012 | 0.058 | 0.127 | - |
| | p | 1.19 | 0.877 | 0.783 | - |
| | b | 0.253 | 0.531 | 0.167 | - |
| | q | 0.637 | 0.418 | 0.578 | - |

## 3.4 STACK DOWNWASH

An effluent emitted vertically from a stack can rise due to its momentum or can be brought downward by the low pressure in the wake of the stack, which occurs depends on the ratio of the exit gas velocity, $W_s$, to the crosswind velocity, U.

The physical stack height is modified according to Briggs (1974):

$$h'_s = \begin{cases} h_s + 2\,(W_s/U - 1.5)D_s & \text{for } W_s < 1.5\ U \\ h_s & \text{for } W_s \geq 1.5\ U \end{cases} \tag{7}$$

where $h_s$ is the physical stack height, $W_s$ is the exit gas velocity and $D_s$ is the inside stack-top diameter. The modified stack height $h'_s$ is further used to calculate the effective plume height.

## 3.5 PLUME RISE EQUATIONS

The plume rise due to momentum or buoyancy is estimated using Briggs algorithm (Briggs 1969, 1971 and 1975). The calculated values of $\Delta H_m$ and $\Delta H_b$ in this chapter, and $h_s'$ in chapter 3.4 are further used to evaluated the effects of buildings, penetration and topography in the following chapters to end up with the final plume height, H.

### 3.5.1 Neutral-Unstable Momentum Rise

Regardless of the atmospheric stability, neutral-unstable momentum rise is calculated. The plume rise is calculated as follows:

$$\Delta H_m = 3D_sW_s/U. \tag{8}$$

This equation is most applicable when $W_s/U$ is greater than 4. Since momentum rise occurs quite close to the point of release, the distance to final rise is set equal to zero.

### 3.5.2 Neutral-Unstable Buoyancy Rise

The value of the buoyancy flux parameter, F ($m^4/s^3$), is needed for computing the distance to final rise and the plume rise.

$$F = (gW_sD_s^2\Delta T)/(4T_s), \tag{9}$$

where $\Delta T = T_s - T_a$, $T_s$ is the stack gas temperature (K), and $T_a$ is the ambient air temperature (K).

The distance to final rise $x_f$ (in kilometers) is the distance at which atmospheric turbulence begins to dominate entrainment.

For F less than 55,

$$x_f = 0.049F^{5/8}. \tag{10}$$

For F equal to or greater than 55,

$$x_f = 0.119F^{2/5}. \tag{11}$$

The plume rise, $\Delta H$ (in meters), is determined from the equations:

For F less than 55,

$$\Delta H_b = 21.425F^{3/4}/U. \tag{12}$$

For F equal to or greater than 55,

$$\Delta H_b = 38.71F^{3/5}/U. \tag{13}$$

If the neutral-unstable momentum rise (previously calculated from Eq. 8) is higher than the neutral-unstable buoyancy rise calculated here, momentum rise applies and the distance to final rise is set equal to zero.

### 3.5.3 Stability Parameter

For stable situations, the stability parameter s is calculated from the equation:

$$s = g(\delta\Theta/\delta z)/T_a. \tag{14}$$

As an approximation, $\delta\Theta/\delta z$ is taken as 0.02 K/m for the light stable class, and 0.035 K/m for the stable class.

### 3.5.4 Stable Momentum Rise

When the stack gas temperature is less than the ambient air temperature, it is assumed that the plume rise is dominated by momentum. The plume rise is then calculated by using the equation:

$$\Delta H_m = 1.5[(W_s^2 D_s^2 T_a)/(4T_s U)]^{1/3} s^{-1/6}. \tag{15}$$

This value of $\Delta H_m$ is compared with the value for neutral-unstable momentum rise (Eq. 8) and the lower of the two values is used as the resulting plume height.

### 3.5.5 Stable Buoyancy Rise

For situations where $T_s \geq T_a$, buoyancy is assumed to dominate. The distance to final rise (in kilometers) is determined by the equation:

$$x_f = 0.0020715Us^{-1/2} . \tag{16}$$

The plume rise is determined by:

$$\Delta H_b = 2.6[F/(U \cdot s)]^{1/3} . \tag{17}$$

The stable buoyancy rise for calm conditions is also evaluated:

$$\Delta H_b = 4F^{1/4}s^{-3/8} . \tag{18}$$

The lower of the two values obtained from Eqs. 17 and 18 is taken as the plume rise.

If the stable momentum rise is higher than the stable buoyancy rise calculated here, momentum rise applies and the distance to final rise is set equal to zero.

## 3.6 BUILDING EFFECTS

Briggs (1974) has outlined a useful procedure for estimating the effective height of emission incorporated building-induced disturbances to the flow. The procedure is as follows:

1) Calculate the following height h´:

   $$h' = h_s + \Delta H_m \tag{19}$$

   where $\Delta H_m$ is the momentum plume rise, eqs. (8) or (15).

   If stack downwash occurs, $h' = h_s'$ from Chapter 3.4.

Let $L_B$ be the smaller of the frontal building dimensions $H_B$ or $W_B$.

a) If $h'$ is greater than $H_B + 1.5\ L_B$, the plume is above the region of building influence. Continue to the next chapter to check for penetration by using $h_e = h' + \Delta H$ as the effective plume height. $\Delta H$ is the plume rise from chapter 3.5.

b) If $h'$ is less than $H_B$, set

$$h'' = h' - 1.5\ L_B \tag{20}$$

c) If $h'$ is between $H_B$ and $H_B + 1.5\ L_B$, set

$$h'' = 2h' - (H + 1.5\ L_B) \tag{21}$$

For the cases b) and c) the plume may remain aloft or may be entrained into the wake cavity and became essentially a ground level source.

If $h''$ is greater than $0.5\ L_B$, the plume remains elevated and concentrations can be calculated by using standard formulaes with modified stack height equal $h''$, and effective plume height $h_e = h'' + \Delta H$. Continue to the next chapter to check for penetration by using $h_e$ as the effektive plume height.

If $h''$ is less than $0.5\ L_B$, the plume is trapped in the cavity zone and should be treated as a ground source with initial dimensions equal the projected frontal area of the building, A.

For the cases b) and c), where the plume is influenced by the buildings, an additional dispersion factor is combined with the standard dilution factor as follows (Briggs, 1970).

$$\sigma_y = (\sigma_y^2 + cA/\pi)^{1/2} \tag{22}$$

$$\sigma_z = (\sigma_z^2 + cA/\pi)^{1/2} \tag{23}$$

where $c = 1.0$ and $A = H_B W_B$

## 3.7 PLUME PENETRATION

A buoyant plume rising into a well-mixed layer capped by stable air may partially or completely penetrate the elevated stable layer. To compute ground level concentrations for this situation, the fraction of the plume that penetrates the stable layer is first estimated and then the emission rate, $Q_s$, and effective plume height, $h_e$, for the material remaining within the mixed layer are modified.

The fraction P of the plume that penetrates the elevated stable layer is estimated as follows (Weil and Brower, 1984):

1) no penetration:

$$P = 0 \quad \text{if} \quad \frac{Z_i'}{\Delta H} \geq 1.5 \tag{24}$$

2) total penetration:

$$P = 1 \quad \text{if} \quad \frac{Z_i'}{\Delta H} \leq 0.5 \tag{25}$$

3) partial penetration:

$$P = 1.5 - \frac{Z_i'}{\Delta h} \quad \text{if} \quad 0.5 < \frac{Z_i'}{\Delta h} < 1.5 \tag{26}$$

where $\Delta h$ is the predicted plume rise and $Z_i' = Z_i - h_s$, where $Z_i$ is the height of the stable layer aloft, and $h_s$ is the stack height.

The plume material remaining within the mixed layer is assumed to contribute to ground level concentrations. The modified source strenght, Q is then:

$$Q = Q_s\ (1-P) \tag{27}$$

where $Q_s$ is the emission rate on top of the stack.

To modify the effective plume height for plumes trapped within the mixed layer, it is assumed that the plume rize due to penetration, $\Delta H_p$, is linearly varying between $0.62\ Z_i'$ for no penetration and $Z_i'$ for total penetration.

Thus for partial penetration ($0<P<1$):

$$\Delta H_p = (0.62 + 0.38P)Z_i' \qquad (28)$$

The modified plume height to be used further, $h_m$, is the lowest value of the hight in the unlimited atmosphere, $h_e$, from chapter 3.6, and the height due to penetration, such as:

$$h_m = \min (h_e, h_p), \quad h_p = h_s' + \Delta H_p \qquad (29)$$

Continue to the next chapter to check for terrain effects by using $h_m$ for the effective plume height.

## 3.8 TOPOGRAPHY

The effect of elevated terrain on the ground level concentrations is included by reducing the effective plume height, $h_m$, assuming:

$$H = h_m - \Delta H_t, \qquad \Delta H_t = k \cdot h_t \qquad (30)$$

where $h_t$ is the height of terrain above stack base level and k is a terrain factor ($0 < k < 1$) dependent upon steepness, distance from source, stability etc.

In the models CONCX and CONDEP the effective topography, $\Delta H_t$, is a direct input from the user. A method to evaluate the effect of a hill on a source as a function of distance from the source is given in Table 2 below.

Table 2: Terrain factor ,k, to evaluate the effect of a hill on a source with stack height $h_s$.

| Distance (x) | k |
|---|---|
| $0 < x \le 5\ h_s$ | 0.7 |
| $5\ h_s < x \le 10\ h_s$ | 0.5 |
| $10\ h_s < x \le 20\ h_s$ | 0.3 |
| $20\ h_s < x \le 30\ h_s$ | 0.1 |
| $30\ h_s < x$ | 0.0 |

## 3.9 DRY DEPOSITION

Dry deposition of an effluent emitted from a source is calculated for long term average concentration only (CONDEP). Adverse effects of deposition are mainly caused by long term values of dry deposition.

The deposition method used in the model CONDEP is the "partial reflection" model summarized by Overcamp (1976). This theory includes a reflection coefficient, $\alpha$, on the image source term in the Gaussian dispersion formula, which is thus a fraction of the strenght of the real source. This coefficient is determined by setting the deposition flux equal to the difference in fluxes from the real and the image terms. The plume is also allowed to "tilt" to incorporate gravitational settling of large particles, as described in the sector average Gaussian formula (2).

The reflection coefficient, $\alpha$ ($X_G$), are computed by solving an implicit relation for $X_G$, the distance to where the plume reach the ground:

$$\left[H - \frac{v_t \cdot X_G}{u}\right] \frac{\sigma_z(x)}{\sigma_z(X_G)} = z + H - \frac{v_t x}{u} \qquad (31)$$

and the following equation for $\alpha(x)$:

$$\alpha(x) = 1 - 2v_d/(v_t+v_d+(uH-v_t x)\ \sigma_z^{-1}\ (d\sigma_z/dx)) \qquad (32)$$

where

$v_d$ = deposition velocity for the effluent
$v_t$ = gravitational settling speed for coarse particles

the other parameters are as described earlier.

## 3.10 WET DEPOSITION

The wet deposition method is included in the short term model CONCX only, due to the fact that the half-life for wet removal processes is ranging from about two hours to one day.

The teoretical treatment of wet deposition is often divided into rainout (within cloud scavenging) and washout (below cloud scavenging). In practical applications the two processes are generally lumped together since they can be modeled similarly.

The concentration, C, is assumed to decrease exponentially with time:

$$C(t) = C_o(t)e^{-\lambda t} \qquad (33)$$

where $\lambda$ is the scavenging coefficient ($\text{time}^{-1}$) and t is the time since the precipitation startet. The flux of effluent to the ground due to precipitation is given by:

$$F_{wet} = \int_o^{Z_w} \lambda C \, dz \qquad (34)$$

where $Z_w$ is the height of the wetted plume layer. For rain falling completely through a Gaussian plume:

$$F_{wet} = \frac{\lambda Q e^{-\lambda t}}{(2\pi)^{1/2} \sigma_y \cdot u} \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \qquad (35)$$

The method is, strictly speaking, applicable only to particles of a single size and to highly reactive gases, which are irreversibly captured by the precipitation. For practical applications, lumped coefficients take into account particle size distributions and partly reactive gases.

The scavenging coefficient, $\lambda$, is theoretically a function of droplet size spectrum, physical and chemical characteristics of the particle or gas, and precipitation rate. Field experiments (McMahon and Denison, 1979) in which $\lambda$ was measured for particles, gave a median value for $\lambda$ of $1.5\text{X}10^{-4}$ $s^{-1}$ and a range from $0.4\text{x}10^{-5}$ $s^{-1}$ to $3\text{x}10^{-3}$ $s^{-1}$. The median value of $\lambda$ for $SO_2$ is about $2\text{x}10^{-5}$ $s^{-1}$, and one laboratory experiment showed that

$$\lambda = 17\text{x}10^{-5} \cdot J^{0.6}, \qquad (36)$$

where J is rainfall in millimeters per hour.

# 4 EXECUTION OF THE MODELS - TEST EXAMPLES

Both CONCX and CONDEP are interactive programs with input sequence dialogue on the screen. All the input records are read in free format, and the input sequence is dependent of the options used. However, a typical run-example of the two programs including the dialogue to the screen, are presented below. The answers from the user are underlined.

## 4.1 PROGRAM CONCX - TEST EXAMPLE

### 4.1.1 Program dialogue

```
                    PROGRAM CONCX
TYPE              : MAIN PROGRAM
DATE              : 1985-01-22
EDITOR            : T. BØHLER
SUPPORT           : T. BØHLER
LAST VERSION      : 3,1987-10-01
REFERENCE         : NILU TR 8/87
DESCRIPTION       :

Calculates downwind concentrations and wet removal fluxes for speci-
fied distances downwind from the source, either ground level center-
plume concentrations or in specified points of the plume. Only an
individual source can be considered.

Plume-rise : Briggs plume rize formulaes (1969, 1971, 1976).

Name of the file where the results are to be stored : CONCX-RES
```

NV = Number of wind classes
ZO = Height for wind observations (m)
INT = Sector average concentrations
1: Yes
0: No
WET = Wet removal coefficient (pr.sec)
HMIX = Mixing height
RN = Wind profile exponent
CZ,PZ = Diffusion coefficients (vertical)
CY,PY = Diffusion coefficients (horisontal)
VM = Average wind speed (m/s)
X = Downwind distances (m)

```
Enter NV,ZO,INT,WET,HMIX: 4,10.0,0,0.0,150.

Alternative diffusion coefficients:

1: Brookhaven (open,flat terrain)
2: McElroy-Pooler (urban area)
3: Own values

Enter 1,2 or 3  : 1,

Brookhavens diffusion coefficients:

CY =    .36   .32   .31   .31
PY =    .86   .78   .74   .71
CZ =    .33   .22   .16   .06
PZ =    .86   .78   .74   .71

OK?(Yes:1,No:0): 1,

Wind profile exponent,RN :    .20   .28   .36   .42

OK?(Yes:1,No:0): 1,

Enter VM(IM),IM=1, 4 : 3.,5.,8.,12.

Standard downwind distances(m):

 100.0    300.0    500.0    800.0  1000.0   2000.0   3000.0   5000.0   8000.0 10000.0

OK?(Yes:1,No:0): 1,
```

```
Number of sources: 1,

IH     = Plume rise option
         0: Fixed plume rise equal HS
         1: plume rise calculations
Q      = Source strength
         (g/sec) gives conc. in (microgr/m3)
HS     = Stack height (m)
TG     = Stack gas temperature (deg K)
TA     = Ambient air temperature (deg K)
W      = Stack gas velocity (m/s)
D      = Stack diameter (m)
HT     = Elevated surface (m)
BH     = Building height (m)
BB     = Building widht (m)
NAME   = Source-identification

Enter IH,Q,HS,TG,TA,W,D,HT,BH,BB,NAME

:1,10.0,50.0,473.0,273.0,15.0,2.50, 0.0, 0.0, 0.0,TEST1

Results in specified points?(Yes:1,No:0) : 0,

The results are stored on file named : CONCX-RES

STOP PROGRAM CONCX
```

### 4.1.2 Program output

```
SOURCE             : TEST1
STACK HEIGHT       : 50.0 METERS
SOURCE STRENGTH    : 10.0 G/SEC
STACK DIMENSIONS   : D = 2.5 M, W = 15.0 M/S, TG= 473.0 K, TA= 273.0 K
ELEVATED SURFACE   : HT= .0 M
MIXING HEIGHT      : HMIX = 150.0 M
BUILDING DIMENSIONS: HB = .0 M, BB = .0 M
```

```
RN =     .20     .28     .36     .42
CY =     .36     .32     .31     .31
PY =     .86     .78     .74     .71
CZ =     .33     .22     .16     .06
PZ =     .86     .78     .74     .71
```

```
***************************************************
* HEFF : EFFECTIVE PLUME HEIGHT DUE TO PLUME RISE *
* HNEW : MODIFIED PLUME HEIGHT DUE TO PENETRATION *
* XDIST: DISTANCE TO FINAL PLUME RISE             *
* PS   : PENETRATION COEFFICIENT                  *
* IDH  : PLUME RISE REGION:                       *
*        1 :NO BUILDING EFFECTS                   *
*        2 :REDUCED STACK HEIGHT DUE TO BUILDINGS *
*        3 :TRAPPED IN THE CAVITY SONE            *
***************************************************
```

| STABILITY CLASS | U10 | HEFF | HNEW | XDIST | PS | IDH |
|---|---|---|---|---|---|---|
| UNSTABLE | 3.0 | 195.7 | 142.9 | 742.4 | .81 | 1 |
| | 5.0 | 137.4 | 125.5 | 742.4 | .36 | 1 |
| | 8.0 | 103.9 | 103.9 | 742.4 | .00 | 1 |
| | 12.0 | 83.5 | 83.5 | 742.4 | .00 | 1 |
| NEUTRAL | 3.0 | 178.1 | 139.3 | 742.4 | .72 | 1 |
| | 5.0 | 126.9 | 119.6 | 742.4 | .20 | 1 |
| | 8.0 | 96.5 | 96.5 | 742.4 | .00 | 1 |
| | 12.0 | 78.5 | 78.5 | 742.4 | .00 | 1 |
| LIGHT STABLE | 3.0 | 126.3 | 119.2 | 413.8 | .19 | 1 |
| | 5.0 | 114.3 | 114.3 | 689.6 | .00 | 1 |
| | 8.0 | 102.8 | 102.8 | 1103.4 | .00 | 1 |
| | 12.0 | 94.1 | 94.1 | 1655.1 | .00 | 1 |
| STABLE | 3.0 | 111.3 | 111.3 | 344.5 | .00 | 1 |
| | 5.0 | 101.7 | 101.7 | 574.2 | .00 | 1 |
| | 8.0 | 91.5 | 91.5 | 918.7 | .00 | 1 |
| | 12.0 | 84.3 | 84.3 | 1378.0 | .00 | 1 |

```
****************************************************
*  BRIGGS PLUME RISE FORMULAS (1969,1971,1976)     *
*  CENTER-PLUME GROUND LEVEL CONCENTRATIONS(UG/M3) *
****************************************************
```

| | | DOWNWIND DISTANCE(M) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| STABILITY | WIND (M/S) | 100.0 | 300.0 | 500.0 | 800.0 | 1000.0 | 2000.0 | 3000.0 | 5000.0 | 8000.0 | 10000.0 |
| UNSTABLE | 3.0 | .0 | .5 | 5.2 | 8.3 | 8.0 | 4.7 | 3.3 | 2.0 | 1.2 | 0.9 |
| | 5.0 | .0 | 2.6 | 13.2 | 18.3 | 17.1 | 10.0 | 7.0 | 4.4 | 2.5 | 1.9 |
| | 8.0 | .0 | 9.0 | 19.5 | 19.7 | 17.6 | 10.0 | 7.1 | 4.4 | 2.6 | 1.9 |
| | 12.0 | .0 | 16.5 | 19.5 | 14.9 | 12.6 | 7.0 | 4.9 | 3.1 | 1.8 | 1.3 |
| NEUTRAL | 3.0 | .0 | .0 | .0 | .2 | 1.0 | 7.2 | 8.2 | 6.2 | 4.3 | 3.6 |
| | 5.0 | .0 | .0 | .0 | 1.7 | 4.5 | 14.5 | 14.9 | 11.0 | 7.7 | 6.4 |
| | 8.0 | .0 | .0 | .6 | 6.6 | 10.7 | 15.0 | 13.0 | 9.2 | 6.4 | 5.3 |
| | 12.0 | .0 | .1 | 3.3 | 12.1 | 14.9 | 12.7 | 9.6 | 6.5 | 4.5 | 3.8 |
| LIGHT STABLE | 3.0 | .0 | .0 | .0 | .0 | .0 | 3.4 | 10.2 | 16.6 | 15.8 | 14.0 |
| | 5.0 | .0 | .0 | .0 | .0 | .0 | 3.9 | 9.4 | 13.1 | 11.9 | 10.5 |
| | 8.0 | .0 | .0 | .0 | .0 | .1 | 4.2 | 7.9 | 9.2 | 7.8 | 6.8 |
| | 12.0 | .0 | .0 | .0 | .0 | .2 | 4.5 | 6.8 | 6.8 | 5.5 | 4.7 |
| STABLE | 3.0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .6 | 1.7 |
| | 5.0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .9 | 1.9 |
| | 8.0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .1 | 1.2 | 2.2 |
| | 12.0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .2 | 1.4 | 2.2 |

```
END OF PROGRAM CONCX
```

## 4.2 PROGRAM CONDEP - TEST EXAMPLE

### 4.1.2 Program dialogue

```
                    PROGRAM CONDEP
TYPE              : MAIN PROGRAM
DATO              : 1985-01-22
EDITOR            : T. BØHLER
SUPPORT           : T. BØHLER
LAST VERSION      : 3, 1987-10-01
REFERENCE         : NILU TR 8/87
DESCRIPTION       :

Calculates  seasonal  averaged  concentrations in an area for up to 50
sources and 1600 reseptorpoints. Plume rise formulas: Briggs formulaes
(1969, 1971, 1976).

NAME ON RESULTFILE: TEST-CONDEP

CHOICE OF DISPERSION PARAMETERS
1: BROOKHAVEN
2: MCELROY-POOLER
3: OWN VALUES
ENTER 1,2 OR 3 : 1,

BROOKHAVENS DISPERSION PARAMETERS :
CY=     .36    .32    .31    .31
PY=     .86    .78    .74    .71
CZ=     .33    .22    .16    .06
PZ=     .86    .78    .74    .71
OK?(YES:1,NO:0): 1,

WIND PROFILE EXPONENT,RN :    .20    .28    .36    .42
OK?(YES:1,NO:0): 1,

INPUT OF MIXING HEIGHT FOR EACH STABILITY CLASS
ENTER HMIX(I),I=1,4 : 800,800,200,200
```

```
ENTER VM(IM),IM=1,4: 1.5,3.0,5.0,8.0

VT = GRAVITATIONAL SPEED (M/S)
VD = DEPOSITION SPEED (M/S)
DT = DEPOSITION PERIOD (HOURS)
TA = AIR-TEMPERATURE (K)
ENTER VT,VD,DT,TA : 0.0,0.02,8760.0,280.0,

ENTER PLACE,PERIOD : MONGSTAD,WINTER

ENTER METFREC-MATRIX(4,4,12) :
   0.0,0.3,0.1,0.0,0.0,0.8,0.1,0.1,0.1,0.7,0.0,0.0,0.1,0.2,0.0,0.0
   0.0,0.2,0.1,0.0,0.1,0.6,0.3,0.0,0.0,0.5,0.1,0.0,0.0,0.0,0.0,0.0
   0.1,0.3,0.1,0.2,0.0,0.3,0.5,0.1,0.0,0.7,0.6,0.0,0.0,0.4,0.6,0.0
   0.2,0.2,0.2,0.4,0.3,2.1,2.8,2.0,0.1,2.4,3.2,1.0,0.0,0.8,1.1,0.3
   0.1,0.2,0.2,0.1,0.2,2.4,3.0,1.3,0.0,4.5,4.2,0.4,0.2,5.3,2.3,0.5
   0.0,0.0,0.1,0.0,0.1,1.1,0.9,0.0,0.0,3.1,3.0,0.5,0.1,8.3,2.5,0.3
   0.0,0.1,0.1,0.1,0.0,0.4,0.4,0.1,0.1,0.5,0.8,0.1,0.1,3.1,2.0,0.1
   0.0,0.0,0.2,0.1,0.0,0.1,0.3,0.0,0.0,0.4,0.7,0.0,0.0,3.1,1.5,0.1
   0.1,0.2,0.2,0.1,0.0,0.0,0.0,0.0,0.0,0.1,0.2,0.2,0.0,0.8,2.1,0.1
   0.0,0.0,0.3,0.0,0.0,0.0,0.1,0.0,0.0,0.1,0.1,0.0,0.0,0.5,0.5,0.0
   0.0,0.0,0.2,0.0,0.0,0.2,0.1,0.0,0.0,0.3,0.1,0.0,0.4,1.1,0.1,0.0
   0.1,0.2,0.1,0.0,0.1,0.6,0.1,0.0,0.1,0.8,0.1,0.0,2.2,1.8,0.1,0.2

SECTOR AVERAGED CONCENTRATION(YES:1,NO:0)? : 1,

GRID(0) OR RECEPTORPOINTS(1) ? : 0,

ENTER XMIN,YMIN,XMAX,YMAX,DGRID : -2000.,-2000.,9000.,11000.,1000.

TOPOGRAPHY(YES:1,NO:0) ? : 1,
```

```
ENTER TOPOGRAPHY-MATRIX (12,14):
   0.0,0.0,0.0,10.,20.,10.,0.0,5.0,10.,20.,10.,10.,
   0.0,0.0,0.0,10.,10.,10.,0.0,5.0,10.,15.,10.,10.,
   0.0,0.0,0.0,0.0,5.0,5.0,0.0,0.0,5.0,10.,10.,5.0
   0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,5.0,5.0,5.0,5.0,
   0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,5.0,5.0,
   0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,
   0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,
   0.0,0.0,5.0,10.,10.,5.0,0.0,0.0,0.0,0.0,0.0,0.0,
   0.0,0.0,0.0,5.0,10.,15.,10.,0.0,0.0,0.0,0.0,0.0,
   5.0,0.0,0.0,0.0,5.0,5.0,15.,10.,0.0,0.0,0.0,0.0,
   10.,0.0,0.0,0.0,0.0,0.0,10.,20.,5.0,0.0,0.0,0.0,
   10.,5.0,0.0,0.0,0.0,0.0,0.0,10.,5.0,0.0,0.0,0.0,
   10.,10.,5.0,0.0,0.0,0.0,0.0,10.,20.,5.0,10.,5.0,
   10.,5.0,5.0,0.0,0.0,0.0,0.0,5.0,10.,10.,5.0,5.0,

IPR    = PLUME RISE OPTION :
         0:FIXED PLUME RISE EQUAL HS
         1:PLUME RISE CALCULATIONS
X,Y    = SOURCE-COORDINATES (M)
Q      = EMISSION-RATE:
         (G/SEC) GIVES CONC IN (MICROG/M3)
HS     = STACK HEIGHT (M)
TG     = EXIT GAS TEMPERATURE (K)
W      = EXIT GAS VELOCITY (M/S)
D      = STACK DIAMETER (M)
BH     = BUILDING HEIGHT (M)
BB       BUILDING WIDTH (M)
NAME   = SOURCE-IDENTIFICATION

NUMBER OF SOURCES : 1,

ENTER IPR,X,Y,Q,HS,TG,W,D,BH,BB,NAME :
1,3210.,4650.,100.0,150,523.0,20.0,2.0, 0.0, 0.0,TEST1

ENTER PLOTTING OPTION (0:NO,1:YES) : 0,

THE RESULTS ARE STORED ON FILE : TEST-CONDEP

STOP PROGRAM CONDEP
```

### 4.2.2 Program output

```
PROGRAM CONDEP

JOINT FREQUENCY DISTRIBUTION OF STABILITY, WIND SPEED AND -DIRECTION

PLACE :MONGSTAD          PERIOD : WINTER

STABILITY CLASSES
1 : UNSTABLE
2 : NEUTRAL
3 : LIGHT STABLE
4 : STABLE

       FF         1.5 M/S             3.0 M/S             5.0 M/S             8.0 M/S
   DD    1    2    3    4    1    2    3    4    1    2    3    4    1    2    3    4
   30   .0   .3   .1   .0   .0   .8   .1   .1   .1   .7   .0   .0   .1   .2   .0   .0
   60   .0   .2   .1   .0   .1   .6   .3   .0   .0   .5   .1   .0   .0   .0   .0   .0
   90   .1   .3   .1   .2   .0   .3   .5   .1   .0   .7   .6   .0   .0   .4   .6   .0
  120   .2   .2   .2   .4   .3  2.1  2.8  2.0   .1  2.4  3.2  1.0   .0   .8  1.1   .3
  150   .1   .2   .2   .1   .2  2.4  3.0  1.3   .0  4.5  4.2   .4   .2  5.3  2.3   .5
  180   .0   .0   .1   .0   .1  1.1   .9   .0   .0  3.1  3.0   .5   .1  8.3  2.5   .3
  210   .0   .1   .1   .1   .0   .4   .4   .1   .1   .5   .8   .1   .1  3.1  2.0   .1
  240   .0   .0   .2   .1   .0   .1   .3   .0   .0   .4   .7   .0   .0  3.1  1.5   .1
  270   .1   .2   .2   .1   .0   .0   .0   .0   .0   .1   .2   .2   .0   .8  2.1   .1
  300   .0   .0   .3   .0   .0   .0   .1   .0   .0   .1   .1   .0   .0   .5   .5   .0
  330   .0   .0   .2   .0   .0   .2   .1   .0   .0   .3   .1   .0   .4  1.1   .1   .0
  360   .1   .2   .1   .0   .1   .6   .1   .0   .1   .8   .1   .0  2.2  1.8   .1   .2
```

```
***************************************************
*  BRIGGS PLUME RISE FORMULAS(1969,1971,1976)     *
*  HMIX :MIXING HEIGHT DUE TO STABILITY           *
*  HEFF :EFFECTIVE PLUME HEIGHT DUE TO PLUME RISE *
*  HNEW :MODIFIED PLUME HEIGHT DUE TO PENETRATION *
*  XDIST:DISTANCE TO FINAL PLUME RISE             *
*  PS   :PENETRATION COEFFICIENT                  *
*  IDH  :PLUME RISE REGION:                       *
*        1 :NO BUILDING EFFECTS                   *
*        2 :REDUCED STACK HEIGHT DUE TO BUILDINGS *
*        3 :TRAPPED IN THE CAVITY SONE            *
***************************************************
```

```
SOURCE NO : 1

NAME        X        Y       Q       HS       D      W       TG       BH      BB
TEST1    3210.0   4650.0   100.0   150.0     2.0    20.0    523.0     .0      .0
```

| STABILITY CLASS | HMIX | U10 | HEFF | HNEW | XDIST | PS | IDH |
|---|---|---|---|---|---|---|---|
| UNSTABLE | 800.0 | 1.5 | 375.1 | 375.1 | 723.5 | .00 | 1 |
| | | 3.0 | 262.6 | 262.6 | 723.5 | .00 | 1 |
| | | 5.0 | 217.5 | 217.5 | 723.5 | .00 | 1 |
| | | 8.0 | 192.2 | 192.2 | 723.5 | .00 | 1 |
| NEUTRAL | 800.0 | 1.5 | 331.3 | 331.3 | 723.5 | .00 | 1 |
| | | 3.0 | 240.6 | 240.6 | 723.5 | .00 | 1 |
| | | 5.0 | 204.4 | 204.4 | 723.5 | .00 | 1 |
| | | 8.0 | 184.0 | 184.0 | 723.5 | .00 | 1 |
| LIGHT STABLE | 200.0 | 1.5 | 233.2 | 198.1 | 311.2 | .90 | 1 |
| | | 3.0 | 216.0 | 195.1 | 622.3 | .74 | 1 |
| | | 5.0 | 205.7 | 192.4 | 1037.2 | .60 | 1 |
| | | 8.0 | 197.6 | 189.5 | 1659.6 | .45 | 1 |
| STABLE | 200.0 | 1.5 | 215.4 | 195.0 | 276.7 | .74 | 1 |
| | | 3.0 | 201.9 | 191.2 | 553.4 | .54 | 1 |
| | | 5.0 | 193.8 | 187.8 | 922.4 | .36 | 1 |
| | | 8.0 | 187.4 | 184.1 | 1475.9 | .16 | 1 |

```
GRAVITATIONAL SPEED   :    .00 M/S
DEPOSITION SPEED      :    .02 M/S
DEPOSITION PERIOD     : 2160.0 HOURS
AIR-TEMPERATURE       :  280.0 K
```

| XREC | YREC | HTOP | CONC(UG/M3) | DEP(G/M2) |
|---|---|---|---|---|
| -2000. | -2000. | 10. | 1.36E-01 | 2.11E-02 |
| -1000. | -2000. | 5. | 1.45E-01 | 2.25E-02 |
| 0. | -2000. | 5. | 1.55E-01 | 2.41E-02 |
| 1000. | -2000. | 0. | 1.60E-01 | 2.48E-02 |
| 2000. | -2000. | 0. | 3.07E-01 | 4.78E-02 |
| 3000. | -2000. | 0. | 3.13E-01 | 4.86E-02 |
| 4000. | -2000. | 0. | 3.10E-01 | 4.83E-02 |
| 5000. | -2000. | 5. | 1.14E-01 | 1.77E-02 |
| 6000. | -2000. | 10. | 1.10E-01 | 1.71E-02 |
| 7000. | -2000. | 10. | 1.02E-01 | 1.59E-02 |
| 8000. | -2000. | 5. | 9.35E-02 | 1.45E-02 |
| 9000. | -2000. | 5. | 8.56E-02 | 1.33E-02 |
|  |  |  | ⋮ | ⋮ |
| -2000. | 8000. | 0. | 6.70E-01 | 1.04E-01 |
| -1000. | 8000. | 0. | 7.01E-01 | 1.09E-01 |
| 0. | 8000. | 0. | 1.27E+00 | 1.08E-01 |
| 1000. | 8000. | 0. | 1.29E+00 | 2.00E-01 |
| 2000. | 8000. | 0. | 1.26E+00 | 1.97E-01 |
| 3000. | 8000. | 0. | 1.15E+00 | 1.80E-01 |
| 4000. | 8000. | 0. | 1.16E+00 | 1.80E-01 |
| 5000. | 8000. | 0. | 3.89E-01 | 6.04E-02 |
| 6000. | 8000. | 5. | 3.97E-01 | 6.18E-02 |
| 7000. | 8000. | 5. | 3.07E-01 | 4.77E-02 |
| 8000. | 8000. | 5. | 2.83E-01 | 4.40E-02 |
| 9000. | 8000. | 5. | 2.58E-01 | 4.01E-02 |
|  |  |  | ⋮ | ⋮ |
| -2000. | 11000. | 0. | 9.15E-01 | 1.42E-01 |
| -1000. | 11000. | 0. | 9.77E-01 | 1.52E-01 |
| 0. | 11000. | 0. | 1.03E+00 | 1.60E-01 |
| 1000. | 11000. | 10. | 1.11E+00 | 1.72E-01 |
| 2000. | 11000. | 20. | 9.79E-01 | 1.52E-01 |
| 3000. | 11000. | 10. | 9.59E-01 | 1.49E-01 |
| 4000. | 11000. | 0. | 9.22E-01 | 1.43E-01 |
| 5000. | 11000. | 5. | 3.26E-01 | 5.08E-02 |
| 6000. | 11000. | 10. | 3.19E-01 | 4.96E-02 |
| 7000. | 11000. | 20. | 3.11E-01 | 4.83E-02 |
| 8000. | 11000. | 10. | 2.84E-01 | 4.42E-02 |
| 9000. | 11000. | 10. | 2.64E-01 | 4.11E-02 |

END OF PROGRAM CONDEP

# 5 REFERENCES

Briggs, G.A. (1969) Plume Rise. Springfield, U.S. Atomic Energy Commission.

Briggs, G.A. (1971) Some Recent Analyses of Plume Rise Observation. In: Proceedings of the Second International Clean Air Congress. Ed. by H.M. Englund and W.T. Berry. New York Academic Press. pp. 1029-1032.

Briggs, G.A. (1974) Diffusion Estimation for Small Emissions. In: Atmospheric Turbulence and Diffusion Laboratory 1973 Annual Report 1973. Oak Ridge, Atmos. Turbulence and Diffusion Lab.

Briggs, G.A. (1975) Plume rise predictions. In: Lectures on Air Pollution and Environmental Impact Analysis. Ed. by D.A. Haugen. Boston, MA., Amer.Meteor.Soc. pp. 59-111.

Gifford, F.A. (1968) An Outline of Theories of Diffusion in the Lower Layers of the Atmosphere. In: Meteorology and Atomic Energy - 1968. Ed by D.H. Slade. Springfield, Va., U.S. Atomic Energy Commission. pp 65-116.

McElroy, J.L. and Pooler, F. (1968) St. Louis Dispersion Study. Vol II: Analysis. Arlington, Virg., National Air Pollution Control Administration.

McMahon, T.A. and Denison, P.J. (1979) Empirical Atmospheric Deposition Parameters - A Survey. Atmos. Environ., 13, 571-585.

Overcamp, T.J. (1976) A general Gaussian Diffusion - Deposition Model for Elevated Point Sources. J. Appl. Meteorol., 15, 1167-1171.

Raynor, G.S., Brown, R.M. and Sethu Raman, S. (1978) A comparison of diffusion from a small island and an undisturbed ocean site. J. Appl. Meteorol., 17, 129-139.

Smith, M. (1968) Recommended guide for the prediction of the dispersion of the airborne effluents. New York, The American Society of Mechanical Engineers.

Weil, J.C. and Brower, R.P. (1984) An updated Gaussian Plume Model for Tall Stacks. J. of Air Poll. Contr. Ass., 34, 818-827.

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POSTBOKS 64, N-2001 LILLESTRØM

| | | | |
|---|---|---|---|
| RAPPORTTYPE<br>TEKNISK RAPPORT | RAPPORTNR. TR 8/87 | ISBN-82-7247-861-7 | |
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| TITTEL<br>User´s Guide for the Gaussian type dispersion models CONCX and CONDEP. | | PROSJEKTLEDER<br>Trond Bøhler | |
| | | NILU PROSJEKT NR.<br>E-8547 | |
| FORFATTER(E)<br>Trond Bøhler | | TILGJENGELIGHET<br>A | |
| | | OPPDRAGSGIVERS REF. | |

OPPDRAGSGIVER (NAVN OG ADRESSE)
Norsk institutt for luftforskning (NILU)
Postboks 64
2001 Lillestrøm

3 STIKKORD (à maks. 20 anslag)

| Programbeskrivelse | Spredningsmodell | Gaussisk |
|---|---|---|

REFERAT (maks. 300 anslag, 7 linjer)

Rapporten inneholder en brukerbeskrivelse av de Gaussiske programmene CONCX og CONDEP, som beregner henholdsvis korttids- og langtidsverdier av konsentrasjoner for utslipp fra en eller flere skorsteiner. Rapporten inneholder en teoretisk del med bakgrunn for beregningene i tillegg til beregningseksempler.

TITLE
User´s Guide for the Gaussian type dispersion models CONCX and CONDEP

ABSTRACT (max. 300 characters, 7 lines)

This report consists of a user´s guide for the gaussian programs CONCX and CONDEP, which calculates short term and long term ground level concentrations, respectively, due to emission from one or more sources. The report contains a theoretical description of the theory included in the models, in addition to description of how to run the models.

| | | |
|---|---|---|
| * Kategorier: | Åpen - kan bestilles fra NILU | A |
| | Må bestilles gjennom oppdragsgiver | B |
| | Kan ikke utleveres | C |