ENVIRONMENTAL SCIENCE AND ENGINEERING

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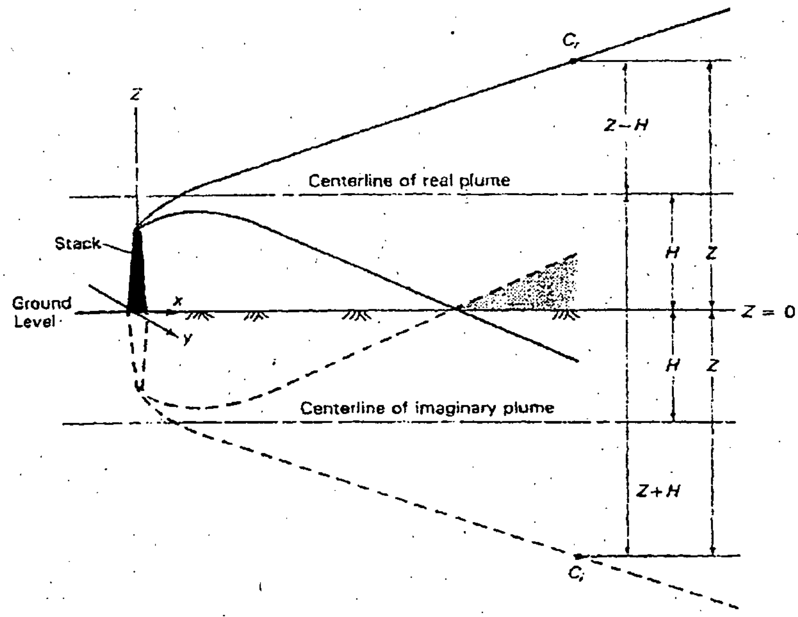

Figure 13–20 Definition sketch showing plume dispersion in the vertical direction and the reflection of pollutants at ground level

C_r and C_i = concentration due to real and imaginary sources, respectively.

point (at a location $Z + H$) is added to the concentration in the real plume. The plume diffusion equation, in its most common form, then becomes

$$C = \frac{Q}{2\pi\sigma_y\sigma_z\bar{u}} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\left\{\exp\left[-\frac{1}{2}\left(\frac{Z-H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{Z+H}{\sigma_z}\right)^2\right]\right\} \tag{13.28}$$

where,

- C is the pollutant concentration (kg/m³) at a receptor located at (x, y, z)
- σ_y and σ_z are diffusion coefficients in the y and z directions, respectively (m), and are functions of the downwind distance x from the source;
- $\bar{u}$ is the mean wind speed through the layer in which diffusion takes place (m/s);

- x, y, and z are spatial coordinates of the receptor (m) relative to the source (the x-axis is oriented in the direction of the mean wind, y is at right angles to x in the horizontal plane, z is in the vertical plane, and Z is the vertical coordinate relative to ground level);
- H is the effective height of the pollutant release (m); and
- Q is the source emission rate (kg/s)

Some of the assumptions made to develop this equation are as follows:

1. All of the pollutants are emitted from a point source of infinite strength.
2. The wind is uniform through the layer in which dispersion occurs, and an average or mean wind can be used in the equation. In practice, the wind used in the equation is taken to be the wind at the top of a stack for an elevated source, estimated using Equation 13.25.
3. The concentration distribution across the width and depth of the plume is Gaussian.
4. The edges of the plume are where the concentration of pollutant has decreased to one-tenth of the plume centerline value.
5. The pollutant under consideration is not lost by decay, chemical reaction, or deposition; i.e., it is conservative. The method of images is used to assure that pollutants are not lost to the ground. (It is supposed that all of the pollutant which impinges at the earth's surface is fully "reflected.")
6. The equation is to be used over relatively flat, homogeneous terrain. It should not be used routinely in coastal or mountainous areas, in any area where building profiles are highly irregular, or where the plume travels over warm bare soil and then over colder snow or ice-covered surfaces.
7. The equation represents a steady state solution ($\delta Q/\delta t = 0$) over the averaging period.
8. The pollutants have the same density as the air surrounding them. This assumption is remarkably close for the case of stack gases from fossil-fuel-fired combustion processes. It is satisfactory for small particles, but not for particles which have a finite and significant fall velocity.

Note how the equation reduces to a simpler form for concentrations at specific ground-level locations, such as at a distance y from the centerline ($Z = 0$) or on the centerline of the plume ($y = 0$, $Z = 0$).

The values of σ_y and σ_z have been determined empirically and are conveniently graphed as functions of x and atmospheric turbulence or stability categories in Figure 13–21. Table 13–17 describes the method for determining the stability categories based on wind speed, time of day (radiation), and cloud cover. Category A corresponds to an extremely unstable atmosphere, F to a very stable atmosphere, and D to a near-neutral atmosphere. The curves in Figure 13–21 are for continuous point-source plumes over averaging periods of 10 minutes or so. They should not be used to describe the diffusion of a puff in three dimensions. Using data from Figure 13–21, Equation 13.28 gives the 10-minute average