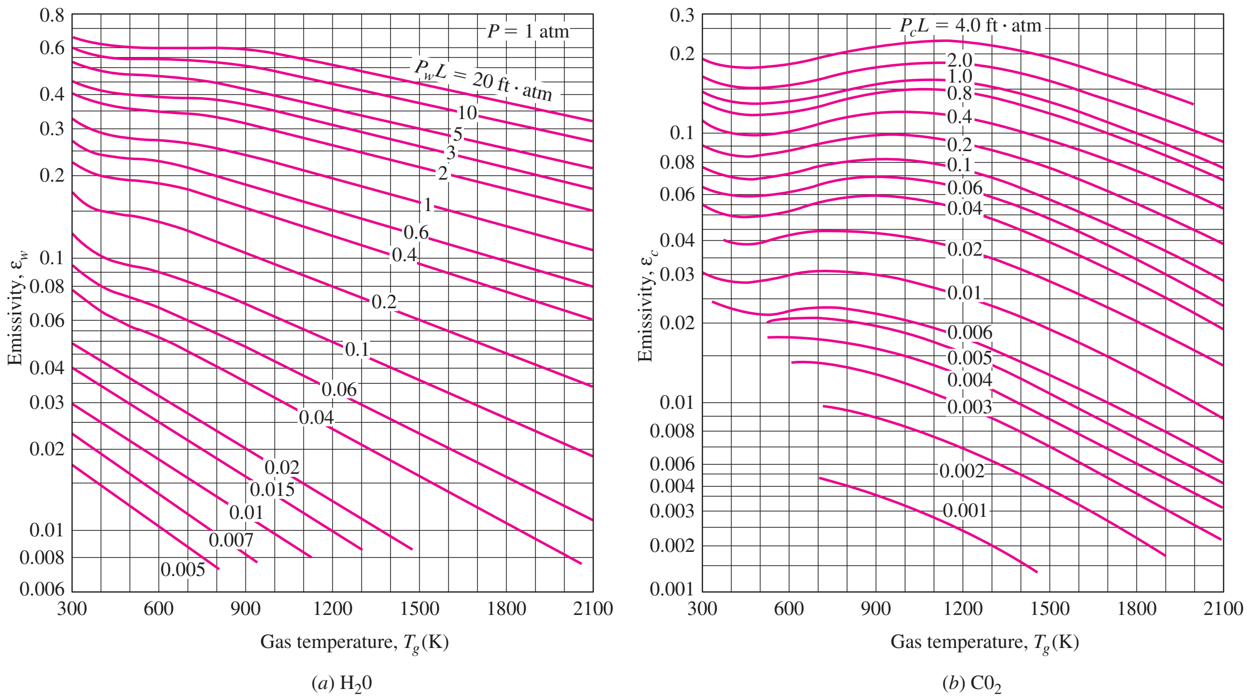

FIGURE 12–36

Emissivities of H_2O and CO_2 gases in a mixture of nonparticipating gases at a total pressure of 1 atm for a mean beam length of L (1 m · atm = 3.28 ft · atm) (from Hottel, 1954, Ref. 6).

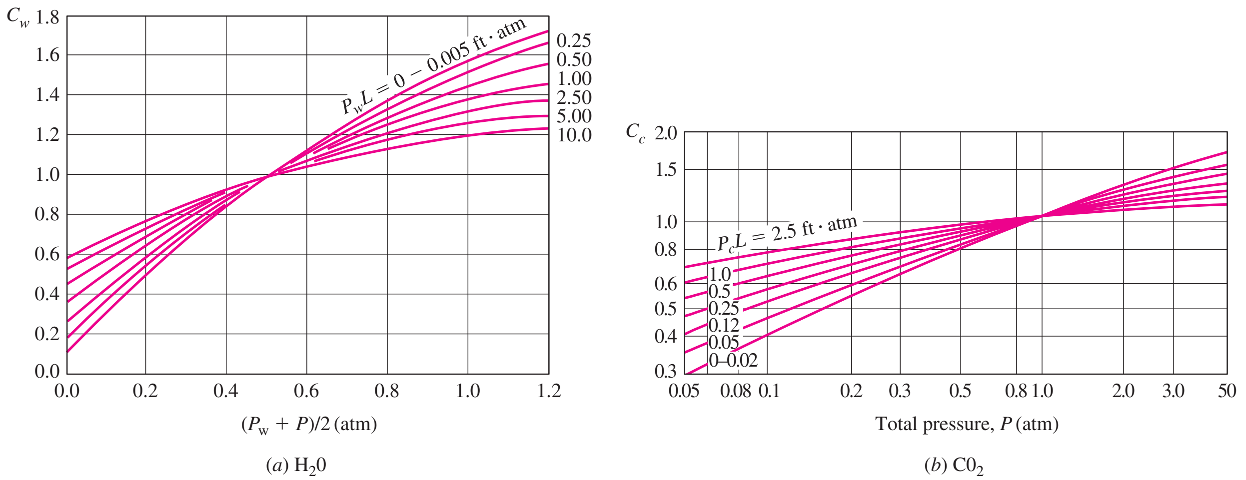

FIGURE 12–37

Correction factors for the emissivities of H_2O and CO_2 gases at pressures other than 1 atm for use in the relations $\varepsilon_w = C_w \varepsilon_{w,\,1\text{ atm}}$ and $\varepsilon_c = C_c \varepsilon_{c,\,1\text{ atm}}$ (1 m · atm = 3.28 ft · atm) (from Hottel, 1954, Ref. 6).

Emissivity at a total pressure P other than $P = 1$ atm is determined by multiplying the emissivity value at 1 atm by a **pressure correction factor** C_w obtained from Figure 12–37*a* for water vapor. That is,

$$\varepsilon_w = C_w \varepsilon_{w,\,1\,\text{atm}} \tag{12-52}$$

Note that $C_w = 1$ for $P = 1$ atm and thus $(P_w + P)/2 \cong 0.5$ (a very low concentration of water vapor is used in the preparation of the emissivity chart in Fig. 12–36*a* and thus P_w is very low). Emissivity values are presented in a similar manner for a mixture of CO_2 and nonparticipating gases in Fig. 12–36*b* and 12–37*b*.

Now the question that comes to mind is what will happen if the CO_2 and H_2O gases exist *together* in a mixture with nonparticipating gases. The emissivity of each participating gas can still be determined as explained above using its partial pressure, but the effective emissivity of the mixture cannot be determined by simply adding the emissivities of individual gases (although this would be the case if different gases emitted at different wavelengths). Instead, it should be determined from

$$\begin{aligned}\varepsilon_g &= \varepsilon_c + \varepsilon_w - \Delta\varepsilon \\ &= C_c \varepsilon_{c,\,1\,\text{atm}} + C_w \varepsilon_{w,\,1\,\text{atm}} - \Delta\varepsilon\end{aligned} \tag{12-53}$$

where $\Delta\varepsilon$ is the **emissivity correction factor,** which accounts for the overlap of emission bands. For a gas mixture that contains both CO_2 and H_2O gases, $\Delta\varepsilon$ is plotted in Figure 12–38.

The emissivity of a gas also depends on the *mean length* an emitted radiation beam travels in the gas before reaching a bounding surface, and thus the shape and the size of the gas body involved. During their experiments in the 1930s, Hottel and his coworkers considered the emission of radiation from a hemispherical gas body to a small surface element located at the center of the base of the hemisphere. Therefore, the given charts represent emissivity data for the emission of radiation from a hemispherical gas body of radius L toward the center of the base of the hemisphere. It is certainly desirable to extend the reported emissivity data to gas bodies of other geometries, and this

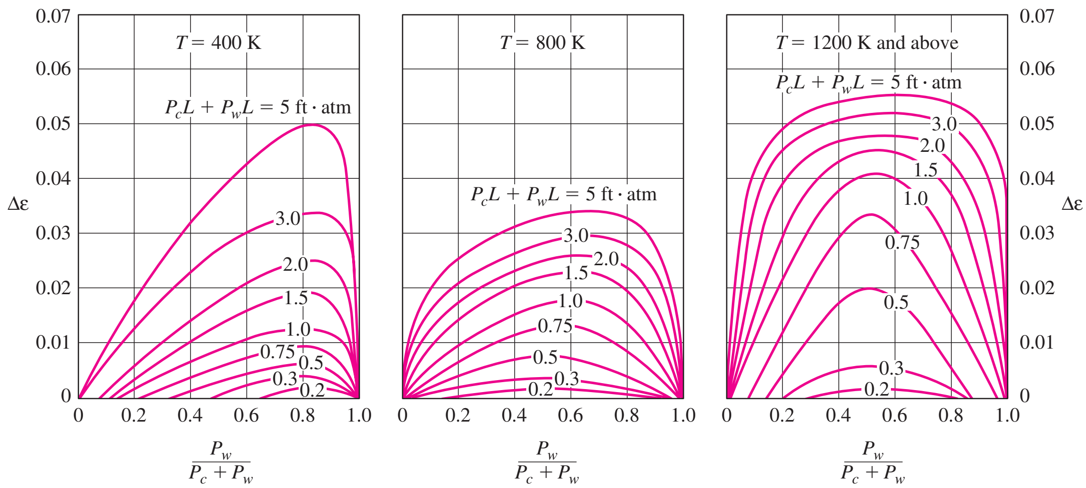

FIGURE 12–38

Emissivity correction $\Delta\varepsilon$ for use in $\varepsilon_g = \varepsilon_w + \varepsilon_c - \Delta\varepsilon$ when both CO_2 and H_2O vapor are present in a gas mixture ($1\text{ m} \cdot \text{atm} = 328\text{ ft} \cdot \text{atm}$) (from Hottel, 1954, Ref. 6).

is done by introducing the concept of **mean beam length** *L,* which represents the radius of an equivalent hemisphere. The mean beam lengths for various gas geometries are listed in Table 12–4. More extensive lists are available in the literature [such as Hottel (1954, Ref. 6), and Siegel and Howell, (1992, Ref. 14)]. The emissivities associated with these geometries can be determined from Figures 12–36 through 12–38 by using the appropriate mean beam length.

Following a procedure recommended by Hottel, the absorptivity of a gas that contains CO_2 and H_2O gases for radiation emitted by a source at temperature T_s can be determined similarly from

$$\alpha_g = \alpha_c + \alpha_w - \Delta\alpha \tag{12-54}$$

where $\Delta\alpha = \Delta\varepsilon$ and is determined from Figure 12–38 at the source temperature T_s. The absorptivities of CO_2 and H_2O can be determined from the emissivity charts (Figs. 12–36 and 12–37) as

CO_2:
$$\alpha_c = C_c \times (T_g/T_s)^{0.65} \times \varepsilon_c(T_s, P_cLT_s/T_g) \tag{12-55}$$

and

H_2O:
$$\alpha_w = C_w \times (T_g/T_s)^{0.45} \times \varepsilon_w(T_s, P_wLT_s/T_g) \tag{12-56}$$

The notation indicates that the emissivities should be evaluated using T_s instead of T_g (both in K or R), P_cLT_s/T_g instead of P_cL, and P_wLT_s/T_g instead of P_wL. Note that the absorptivity of the gas depends on the source temperature T_s as well as the gas temperature T_g. Also, $\alpha = \varepsilon$ when $T_s = T_g$, as expected. The pressure correction factors C_c and C_w are evaluated using P_cL and P_wL, as in emissivity calculations.

When the total emissivity of a gas ε_g at temperature T_g is known, the emissive power of the gas (radiation emitted by the gas per unit surface area) can

TABLE 12–4

Mean beam length L for various gas volume shapes

Gas Volume Geometry	L
Hemisphere of radius R radiating to the center of its base	R
Sphere of diameter D radiating to its surface	$0.65D$
Infinite circular cylinder of diameter D radiating to curved surface	$0.95D$
Semi-infinite circular cylinder of diameter D radiating to its base	$0.65D$
Semi-infinite circular cylinder of diameter D radiating to center of its base	$0.90D$
Infinite semicircular cylinder of radius R radiating to center of its base	$1.26R$
Circular cylinder of height equal to diameter D radiating to entire surface	$0.60D$
Circular cylinder of height equal to diameter D radiating to center of its base	$0.71D$
Infinite slab of thickness D radiating to either bounding plane	$1.80D$
Cube of side length L radiating to any face	$0.66L$
Arbitrary shape of volume V and surface area A_s radiating to surface	$3.6V/A_s$