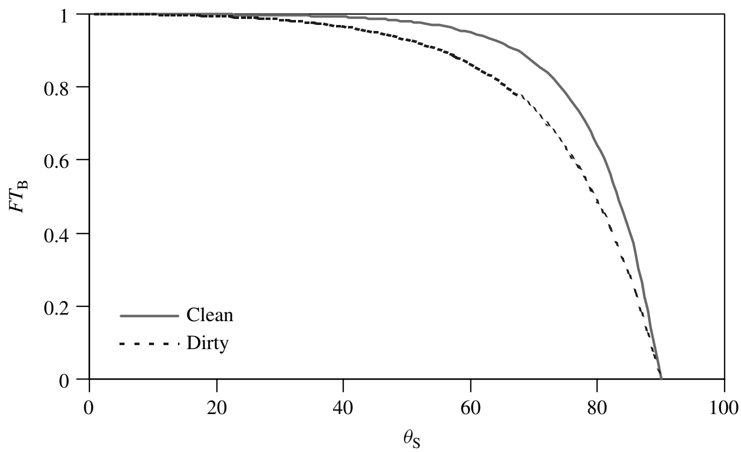

Figure 20.17 The relative transmittance FT_B is plotted against the angle of incidence θ_S, for a clean surface and also for a dust-covered surface

a pronounced knee close to 60°. In practical terms, that means the effects of the angle of incidence are negligible for all the θ_S values well below this figure. For example, $FT_B(40^\circ) = 0.98$.

The ASHRAE model is simple to use but has noticeable disadvantages. It cannot be used for $\theta_S > 80^\circ$, and, still worse, it cannot take into consideration the effects of dust. Dust is always present in real situations, and not only reduces the transmittance at normal incidence but also influences the shape of $FT_B(\theta_S)$. Figure 20.17 shows that the relative transmittance decreases because of dust at angles from about 40 to 80°. Real $FT_B(\theta_S)$ are best described [33] by

$$FT_B(\theta_S) = 1 - \frac{\exp\left(-\dfrac{\cos\theta_S}{a_r}\right) - \exp\left(-\dfrac{1}{a_r}\right)}{1 - \exp\left(-\dfrac{1}{a_r}\right)} \tag{20.46}$$

where a_r is an adjust parameter mainly associated with the degree of dirtiness, as shown in Table 20.4. Note that the degree of dirtiness is characterised by the corresponding relative normal transmittance, $T_{dirt}(0)/T_{clean}(0)$. Equation (20.46) applies for direct and circumsolar radiation components. The angular losses for isotropic diffuse and albedo radiation components are, respectively, approximated by [33]

$$FT_D(\beta) = 1 - \exp\left[-\frac{1}{a_r}\left[c_1\left(\sin\beta + \frac{\pi - \beta \cdot \dfrac{\pi}{180} - \sin\beta}{1+\cos\beta}\right)\right.\right.$$

$$\left.\left. + \; c_2\left(\sin\beta + \frac{\pi - \beta\dfrac{\pi}{180} - \sin\beta}{1+\cos\beta}\right)^2\right]\right] \tag{20.47}$$