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EPRI correlation for void fraction in vertical flow

and flow conditions. The number in parenthesis is the value of the minor edit/plot variable IREGJ, the vertical bubbly/slug flow junction flow regime number. The name in parenthesis is the subroutine used to calculate the correlation. It should be noted that the EPRI correlation implemention has some differences between bundles and pipes; this is discussed in Volume IV.

The correlation labeled EPRI is by Chexal and Lellouche.[3.3-30] The correlation has been recently modified[3.3-31,3.3-32] and many of the changes have been incorporated into RELAP5-3D© . The distribution coefficient C_0 is calculated from

$$C_0 = \frac{L(\alpha_g, P)}{K_0 + (1 - K_0)\alpha_g^{\,r}} \tag{3.3-76}$$

where

$$L(\alpha_g, P) = \frac{1 - \exp(-C_1\alpha_g)}{1 - \exp(-C_1)} \tag{3.3-77}$$

$$C_1 = \left|\frac{4P_{crit}^2}{P(P_{crit} - P)}\right| \tag{3.3-78}$$

P_{crit} = critical pressure

$$K_0 = B_1 + (1 - B_1)\left(\frac{\rho_g}{\rho_f}\right)^{1/4} \tag{3.3-79}$$

$$B_1 = \min(0.8, A_1) \tag{3.3-80}$$

$$A_1 = \frac{1}{1 + \exp\left[-\left(\frac{Re}{60{,}000}\right)\right]} \tag{3.3-81}$$

$$Re = Re_g \quad \text{if } Re_g > Re_f \text{ or } Re_g < 0 \tag{3.3-82}$$

$$= Re_f \quad \text{otherwise} \tag{3.3-83}$$

Re_f = local liquid superficial Reynolds number

$$= \frac{\rho_f j_f D_h}{\mu_f} \tag{3.3-84}$$

Re_g = local vapor/gas superficial Reynolds number

$$= \frac{\rho_g j_g D_h}{\mu_g} \qquad (3.3\text{-}85)$$

$$r = \frac{1 + 1.57\left(\frac{\rho_g}{\rho_f}\right)}{1 - B_1} . \qquad (3.3\text{-}86)$$

The sign of j_k is positive if phase k flows upwards and negative if it flows downwards. This convention determines the sign of Re_g, Re_f, and Re.

The vapor/gas drift velocity, v_{gj}, for the Chexal-Lellouche correlation is calculated from

$$v_{gj} = 1.41\left[\frac{(\rho_f - \rho_g)\sigma g}{\rho_f^2}\right]^{1/4} C_9 C_2 C_3 C_4 \qquad (3.3\text{-}87)$$

where

$$C_9 = (1 - \alpha_g)^{B_1} \quad \text{if } Re_g \geq 0 \qquad (3.3\text{-}88)$$

$$= (1 - \alpha_g)^{0.5} \quad \text{if } Re_g < 0. \qquad (3.3\text{-}89)$$

$$C_2 = 1 \quad \text{if } \frac{\rho_f}{\rho_g} \geq 18 \text{ and } C_5 \geq 1 \qquad (3.3\text{-}90)$$

$$= 1 \quad \text{if } \frac{\rho_f}{\rho_g} \geq 18 \text{ and } C_5 < 1 \text{ and } C_6 \geq 85 \qquad (3.3\text{-}91)$$

$$= \frac{1}{1 - \exp(-C_6)} \quad \text{if } \frac{\rho_f}{\rho_g} \geq 18 \text{ and } C_5 < 1 \text{ and } C_6 < 85 \qquad (3.3\text{-}92)$$

$$= 0.4757\left[\ln\left(\frac{\rho_f}{\rho_g}\right)\right]^{0.7} \quad \text{if } \frac{\rho_f}{\rho_g} < 18 \qquad (3.3\text{-}93)$$

$$C_5 = \left[150\left(\frac{\rho_g}{\rho_f}\right)\right]^{1/2} \qquad (3.3\text{-}94)$$

$$C_6 = \frac{C_5}{1 - C_5} \qquad (3.3\text{-}95)$$

$$C_4 = 1 \quad \text{if } C_7 \geq 1 \qquad (3.3\text{-}96)$$

$$= \frac{1}{1 - \exp(-C_8)} \qquad \text{if } C_7 < 1 \tag{3.3-97}$$

$$C_7 = \left(\frac{D_2}{D}\right)^{0.6} \tag{3.3-98}$$

$D_2 = 0.09144$ m (normalizing diameter)

$$C_8 = \frac{C_7}{1 - C_7} \tag{3.3-99}$$

The parameter C_3 depends on the directions of the vapor/gas and liquid flows:

Upflow (both j_g and j_f are positive)

$$C_3 = \max\left[0.50,\ 2\exp\left(-\frac{|Re_f|}{300{,}000}\right)\right] . \tag{3.3-100}$$

Downflow (both j_g and j_f are negative)

$$C_3 = \left(\frac{C_{10}}{2}\right)^{B_2} \tag{3.3-101}$$

$$B_2 = \frac{1}{1 + 0.05\left|\dfrac{Re_f}{350{,}000}\right|^{0.4}} \tag{3.3-102}$$

$$C_{10} = 2\exp\left[\left(\frac{|Re_f|}{350{,}000}\right)^{0.4}\right] - 1.7|Re_f|^{0.035}\exp\left[\frac{-|Re_f|}{60{,}000}\left(\frac{D_1}{D}\right)^2\right] + \left(\frac{D_1}{D}\right)^{0.1}|Re_f|^{0.001} \tag{3.3-103}$$

$D_1 = 0.0381$ m (normalizing diameter). (3.3-104)

Countercurrent Flow (j_g is positive, j_f is negative)

$$C_3 = \left(\frac{C_{10}}{2}\right)^{B_2} \tag{3.3-105}$$

$$B_2 = \frac{1}{1 + 0.05\left|\frac{Re_f}{350,000}\right|^{0.4}} \tag{3.3-106}$$

$$C_{10} = 2\exp\left[\left(\frac{|Re_f|}{350,000}\right)^{0.4}\right] - 1.7|Re_f|^{0.035}\exp\left[\frac{-|Re_f|}{60,000}\left(\frac{D_1}{D}\right)^2\right] + \left(\frac{D_1}{D}\right)^{0.1}|Re_f|^{0.001} \tag{3.3-107}$$

$$D_1 = 0.0381 \text{ (normalizing diameter).} \tag{3.3-108}$$

The parameters C_1, C_2, C_3, C_4, ..., C_{10} are from the Chexal-Lellouche correlation.[3.3-30, 3.3-31,3.3-32]

The correlation labeled Zuber-Findlay Slug Flow is by Zuber and Findlay.[3.3-33,3.3-34] The distribution parameter is given by

$$C_0 = 1.2 \tag{3.3-109}$$

and the drift velocity is given by

$$v_{gj} = 0.35\left[\frac{(\rho_f - \rho_g)gD}{\rho_f}\right]^{1/2} . \tag{3.3-110}$$

The correlation labeled Kataoka-Ishii is by Kataoka and Ishii.[3.3-35] The distribution parameter is given by the modified Rouhani correlation[3.3-36] used in TRAC-BF1,[3.3-37]

$$C_0 = C_\infty - (C_\infty - 1)\left(\frac{\rho_g}{\rho_f}\right)^{1/2} \tag{3.3-111}$$

$$C_\infty = 1 + 0.2\left[\frac{\rho_f(gD)^{1/2}}{|G| + 0.001}\right]^{1/2} \tag{3.3-112}$$

and the drift velocity is given by

$$v_{gj} = 0.0019(D^*)^{0.809}\left(\frac{\rho_g}{\rho_f}\right)^{-0.157} N_{\mu f}^{-0.562}\left[\frac{\sigma g(\rho_f - \rho_g)}{\rho_f^2}\right]^{1/4} \quad \text{for } D^* \leq 30 \tag{3.3-113}$$

$$v_{gj} = 0.030\left(\frac{\rho_g}{\rho_f}\right)^{-0.157} N_{\mu f}^{-0.562}\left[\frac{\sigma g(\rho_f - \rho_g)}{\rho_f^2}\right]^{1/4} \quad \text{for } D^* > 30 \tag{3.3-114}$$