NOMENCLATURE

(In order to use a common nomenclature some definitions and equations have been reformulated from their original versions. Care has been taken to ensure that equations remain correct)

A	Parameter modifiying homogeneous void fraction (-)
A_1	Constant in Friedel correlation (-)
A_2	Constant in Friedel correlation (-)
a	Constant in friction factor equation (-)
a	Distance from dividing streamline to side arm (m)
B	Constant in Chisholm equation (-)
B	Dimensionless displacement thickness (-)
b	Power in friction factor equation (-)
C	Diameter correction factor (-)
C	Constant in Chisholm equation (-)
C_c	Contraction coefficient (-)
C_G	Constant in friction factor expression for gas (-)
C_L	Constant in friction factor expression for liquid (-)
C_o	Constant in drift flux model (-)
C_1	Constant in Equation (4.8) (-)
C_1	Constant in Equation (4.30) (-)
C_2	Constant in Equation (4.8) (-)
C_2	Constant in Equation (4.30) (-)
C_3	Constant in Equation (4.33 (-)
C_4	Constant in Equation (4.33) (-)
C_5	Constant in equation for C_4 (-)
C_6	Constant in equation for C_4 (-)
c	Drop concentration (kg/m^3)
c_D	Drag coefficient (-)
c_d	Concentration in drops (kg/m^3)
c_F	Concentration in film (kg/m^3)
D	Dissipation (N/m^2)

D_{32}	Sauter mean diameter (m)
D_b	Bubble diameter (m)
D_d	Drop diameter (m)
D_g	Hydraulic diameter for gas part of the flow in stratified flow (m)
D_i	Inner diameter of annulus (m)
D_l	Hydraulic diameter for liquid part of the flow in stratified flow (m)
D_o	Outer diameter of annulus (m)
D_t	Pipe diameter (m)
E	Energy dissipation per unit mass (m^2/s^3)
E_1	Constant in Premoli et al. correlation, defined by Equation (2.45) (-)
E_2	Constant in Premoli et al. correlation, defined by Equation (2.46) (-)
E_f	Entrained fraction (-)
E_b	Rate of entrainment into boundary layer (
E_o	Initial fraction of liquid entrained (-)
E_{vD}	Rate of evaporation from the drops (kg/m^2s)
E_{vF}	Rate of evaporation from the film (kg/m^2s)
e	Wall roughness (m)
e	Eccentricity of annular geometry (-)
e	Parameter used by Pols et al.
F	Force (N)
F	Function in Equation (5.6) defined by one from Equations (5.7) to (5.11)
F_D	Drag force on drops
F_d	Fraction depositing by diffusion (-)
f	Frequency (1/s)
f	Friction factor (-)
f	Parameter used by Pols et al.
f_c	Nett centripetal force (m/s^2)
f_{con}	Friction factor for contraction specified by Equation (9.46)
f_{enl}	Friction factor for enlargement specified by Equation (9.46)
f_s	Friction factor for smooth wall (-)
f_s	Slug frequency (1/s)
G'	Fraction of gas taken off (-)
g	Gravitational acceleration (m/s^2)
j	Constant in Premoli *et al.* correlation, defined by Equation (2.44) (-)
K	Empirical correction factor for effect of diameter ratio in T-junctions (-)
K	Constant (-)
K	Discharge coefficient (-)
K_{12}	Momentum correction factor for run of T-junction (-)
k	Number of velocity heads lost (-)
k	Mass transfer coefficient for deposition (m/s)
k	Damping coefficient in theory of Shoham *et al.* (1/s)
k_{12}	Loss coefficient for flow along main pipe (-)
k_{13}	Loss coefficient for flow into side arm (-)
L	Pipe length (m)
L	Length of slug unit (m)
L_1	Parameter defined by Equation (2.58)
L_2	Parameter defined by Equation (2.58)
L_B	Length of Taylor bubble (m)
L_s	Length of liquid slug (m)
L'	Fraction of liquid taken off (-)
M	Mass (kg)

$\dot{M}$	Mass flow rate (kg/s)
$\dot{m}$	Mass flux (kg/m^{2}s)
N	Parameter in Rosin Rammler equation, Equation (6.63)
N	Power law exponent (-)
P	Periphery (m)
p	Pressure (N/m^2)
Q_{ge}	Volumetric rate of gas entrainment
$\dot{q}$	Heat flux (W/m^2)
R	Pipe or local radius in Venturi (m)
R_A	Rate of entrainment (kg/m^{2}s)
R_D	Rate of deposition (kg/m^{2}s)
R_c	Radius of curvature of a bend (m)
r	Radial coordinate (m)
r_o	Radius of arc as used by Shoham *et al.* (m)
S	Cross sectional area (m^2)
S_R	Area ratio (-)
s	Sheltering coefficient (-)
T	Dimensionless group (-)
t	Time (s)
U_R	Slip ratio (-)
u	Velocity (m/s)
u_{Di}	Velocity of drops from ith group (m/s)
u_{gs}	Gas superficial velocity or volume flux (m/s)
u_{ls}	Liquid superficial velocity or volume flux (m/s)
u_m	Mixture velocity (m/s)
u_l^*	Dimensionless velocity defined by equation (4.29) (-)
u_g^*	Dimensionless velocity defined by equation (4.29) (-)
u_τ	Shear velocity (m/s)
u_β	Wake velocity (m/s)
u'	Axial turbulence intensity (m/s)
V	Velocity (m/s)
V	Volume (m^3)
V_T	Dimensionless shear velocity (-)
$\dot{V}_i$	Volumetric flow rate of ith phase
v_{gd}	Drift velocity (m/s)
v'	Radial turbulence intensity (m/s)
W	Parameter in Equation (3.1) (-)
w'	Circumferential turbulence intensity (m/s)
$\overline{X}$	Parameter in Rosin Rammler equation, Equation (6.63)
X^2	Lockhart-Martinelli parameter (-)
x_g	Quality (-)
y	Distance from the wall (m)
y	Parameter defined after Equation (2.58)
y	Group defined after Equation (6.67)
z	Vertical or axial distance (m)
z_m	Mixing length (m)
Bo	Bond Number $(D_t^2 g(\rho_l - \rho_g)/\sigma)$ (-)
Bo_s	Bond number for aeration of slug $(D_t^2 g \rho_l^2/(\rho_l - \rho_g)\sigma)$ (-)
Fr	Froude number for bends defined by Equation (9.6)
Fr	Froude number for bends defined by Equation (9.14)

Fr_F	Froude number used by Friedel and defined in Equation (2.78) (-)
Fr_g	Gas Froude number used by Zapke and Kruger and defined as $u_g{*}^2$ (-)
Fr_l	Liquid Froude number used by Zapke and Kruger and defined as $u_l{*}^2$ (-)
Fr	Froude Number used in the Taitel/Dukler flow pattern transition model and defined in Equation (3.2, 7.17) (-)
Fr_{gGF}	Froude Number used by Grolman and Fortuiun ($u_{gs}^2/(1-\varepsilon_l)^2 gD_t$) (-)
Fr_θ	Froude number for flow around a bend defined by Gardner and Neller ($u_m^2/gR_b sin\theta$) (-)
Fr_{l13}	Froude number for phase split at a junction from Hart *et al.* and defined in Equation (10.29) (-)
Ku_g	Kutatdeladze number for gas ($u_{gs}\sqrt{\rho_g}/(\rho_l g\sigma)^{0.25}$
Ku_l	Kutatdeladze number for liquid ($u_{ls}\sqrt{\rho_l}/(\rho_l g\sigma)^{0.25}$
N_v	Dimensionless viscosity defined by Equation (6.46) (-)
Oh	Ohnesorge number ($\eta_l/\sqrt{[\rho_l \sigma D_t]}$) (-)
Re_D	Reynolds number for drop drag ($\rho_g\|u_{gs}-u_D\|D_t/\eta_g$) (-)
Re_e	Reynolds number based on roughness height (-)
Re_g	Reynolds number for gas ($\rho_g u_{gs} D_t/\eta_g$) (-)
Re_l	Reynolds number for liquid ($\rho_l u_{ls} D_t/\eta_l$) (-)
Re_{lF}	Reynolds number for liquid film in annular flow $\left(\dot{m}_{lF} D_t/\eta_l\right)$ (-)
$Re_{\Delta lF}$	Reynolds number for excess liquid film in annular flow $\left(\left[\dot{m}_{lF}-\dot{m}_{lFC}\right] D_t/\eta_l\right)$ (-)
Re_m	Mixture Reynolds number used by Beattie and Suguwara ($\rho_g u_{gs}+\rho_l u_{ls})D_t/3\eta_l$ (-)
Re_P	Reynolds number used by Primoli et al. $\left(\dot{m}D_t/\eta_l\right)$ (-)
Re_s	Reynolds number for slug in horizontal flow ($\rho_l u_m D_t/\eta_l$) (-)
Re_{TPH}	Reynolds number used in the homogeneous model $\left(\dot{m}D_t/\eta_{TPH}\right)$ (-)
Re_w	Reynolds number for wavy analysis used by Pols et al. ($\rho_g U\delta_b/\eta_l$) (-)
Re*	Reynolds number based on displacement thickness (-)
St	Strouhal number (fD_t/u_{ls}) (-)
St_g	Strouhal number for horizontal slug flow ($f_s D_t/u_{gs}$) (-)
We	Weber Number ($\rho_g u_{gs}^2 D_t/\sigma$) (-)
We_{crit}	Critical Weber Number (-)
We_F	Weber Number used by Friedel $\left(\dot{m}^2 D_t/\rho_{TPH}\sigma\right)$ (-)
We_{ls}	Weber Number ($\rho_l u_{ls}^2 D_t/\sigma$) (-)
We_m	Weber Number used by Tatterson *et al.* ($\rho_g u_g{*}^2\delta/\sigma$) (-)
$We_{\lambda T}$	Weber Number based on Taylor lengthscale ($\rho_g u_{gs}^2\lambda_T/\sigma$) (-)
$We_{\Delta lF}$	Weber number for excess liquid film in annular flow $\left(\left[\dot{m}_{lF}-\dot{m}_{lFC}\right]^2 D_t/\rho_l\sigma\right)$ (-)
dp/dz	Pressure gradient (N/m^3)

Symbols

δz	Length of element (m)
Δh_v	latent heat of evaporation (J/kg)
Δp	Pressure difference (Pa)
Δt	time interval (s)
$\Delta\rho$	difference in density (kg/m^3)
Γ	Pressure gradient ratio used by Muller-Steinhagen defined in equation (4.53) Parameter in equation for Taylor bubble velocity (-)

	Volumetric film flow rate per unit perimeter (m^2/s)
Γ^2	Ratio of pressure differences $\Delta p_{lo}/\Delta p_{go}$
α	Acceleration correction factor in vertical slug flow (-)
β	Bubble fraction in slug flow (-)
β	Inclination from horizontal (deg)
β_k	Velocity profile correction factors (-)
	Correlation coefficient (-)
δ	Film thickness (m)
δ	Thickness of boundary layer (m)
δ^*	Displacement thickness (m)
ε	Wall roughness (m)
ε_B	Void fraction on Taylor bubble part of vertical slug flow (-)
ε_g	Void fraction (-)
ε'_g	Void fraction used in accelerational part of pressure drop equation (-)
ε_l	Liquid holdup – (1 - Void fraction) (-)
Φ	Dimensionless heat flux (-)
ϕ^2	two-phase multiplier (-)
ϕ	Angular position (°)
Γ	Film flow rate per unit perimeter (kg/ms)
Γ_{con}	Dimensionless base pressure coefficient for contraction specified by Equation (9.45)
Γ_{enl}	Dimensionless base pressure coefficient for enlargement specified by Equation (9.36)
γ	Rate of momentum transport (kgm/s^2)
η	Dynamic viscosity (kg/ms)
η_d	Efficiency of drop deposition at a bend (-)
κ	von Karman constant (-)
κ_T	Ratio of kinetic energies (–)
Λ	Ratio of boundary layer to displacement thicknesses (-)
λ	Liquid volume fraction (-)
λ	Baker property correction factor $\left(\frac{\rho_g}{\rho_{air}}\frac{\rho_l}{\rho_{water}}\right)^{0.5}$
σ	Surface tension (kg/s^2 or N/m)
ρ	Density (kg/m^3)
ρ_{eff}	Effective density defined by Equation (9.33) (kg/m^3)
Θ	Fraction of wall wetted (-)
Θ_0	Fraction of wall wetted for idealised stratified flow with horizontal interface (-)
θ	Angle subtended by chord bounding segment at centre(-)
θ	Momentum thickness (m)
θ	Angle of convergence (°)
θ	Angle subtented at centre of pipe by liquid layer (°)
τ	Shear stress (N/m^2)
τ_c	Characteristic shear stress (N/m^2)
Λ	Baroczy parameter defined by equation (4.49) (-)
ψ	Baker property correction factor $\frac{\sigma_{water}}{\sigma}\left(\frac{\eta_l}{\eta_{water}}\left[\frac{\rho_{water}}{\rho_l}\right]^2\right)^{0.5}$

Subscripts

1	Upstream
1	Inlet pipe of dividing junction
2	Downstream
2	Run pipe of dividing junction
3	Side arm
B	Bubble
B	Taylor bubble
B	Bouyancy
c	Critical
c	cap
crit	Critical
DF	Difference drops/film
d	Drift
E	Energy
F	Film
FD	Difference film/drops
f	Frictional
g	Gas
go	All fluids flowing as gas
H,hom	Homogeneous
I	Irreversible
i	Interfacial
i	ith phase
l	Liquid
lE	Liquid entrained
lF	Liquid in film
lFC	Liquid in film at start of entrainment
lo	All fluids flowing as liquid
M	Momentum
MAX	Maximum
MP	Multiphase
m	Mean
o	Initial
p	Plug
R	Reversible
r	Relative
S	Slug
SP	Single phase
s	Superficial
s	Low void fraction zone
seg	Segment
T	Turbulence
TP	Two-phase
TB	Taylor bubble
t	Total
th	Throat of constriction
tt	Turbulent-turbulent
tv	Turbulent-laminar
VM	Volume median

v	Vapour
vt	Laminar-turbulent
vv	Laminar-laminar
w	Wall
w	Slug wake zone
z	Axial