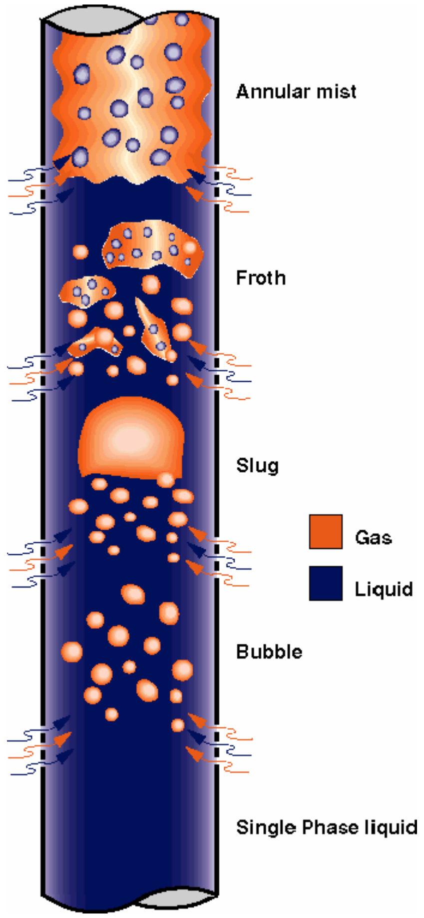
E04 • Flow models

E04.1 • Flow regimes

Most Liquid-Gas models consider the flow regimes described by the figure opposite. In horizontal or near horizontal flow, stratified flow regimes may also be considered (e.g. Beggs & Brill, Petalas & Aziz).

Liquid-Gas models provide a mean of calculating a flow, and for each flow regime, a slip or holdup correlation. In mist flow, the slippage is 0 in all cases.

In Liquid-Liquid situations, only bubble flow is considered.



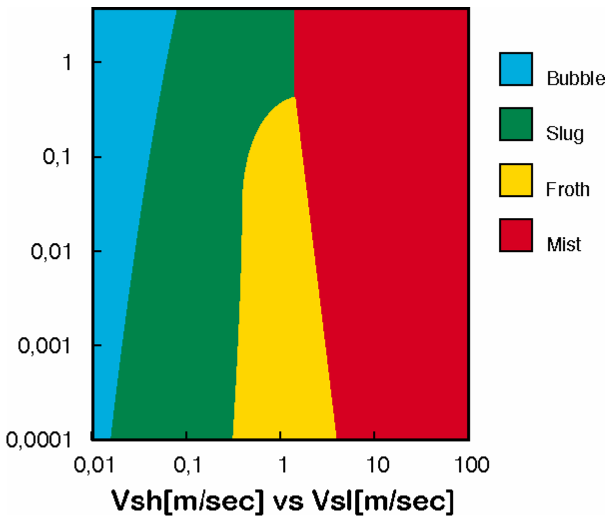
E04.2 • Aziz and Govier

Reference: Aziz K., Govier G., and Fogarasi, M., J., “Pressure Drop in Wells Producing Oil and Gas”, Can. Pet. Tech. (July-Sept 1972), 38-48.

Mechanistic model for Liquid-gas flows.

Only vertical flow is considered by the model.

Determination of the flow regimes is made using a single flow map plotted in terms of modified superficial velocities Y.Vsh vs X.Vsl, where X and Y are functions of the densities and interfacial tensions. An equivalent in terms of superficial velocities (for a particular value of the other parameters) is given below:

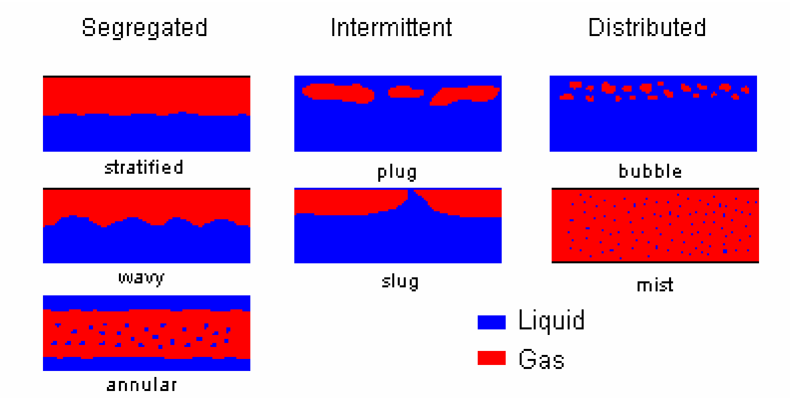


When calculations are made using a differential pressure density tool, the pipe friction is estimated using the method described in the above reference, except in mist flow, where the calculation is done according to Duns and Ross.

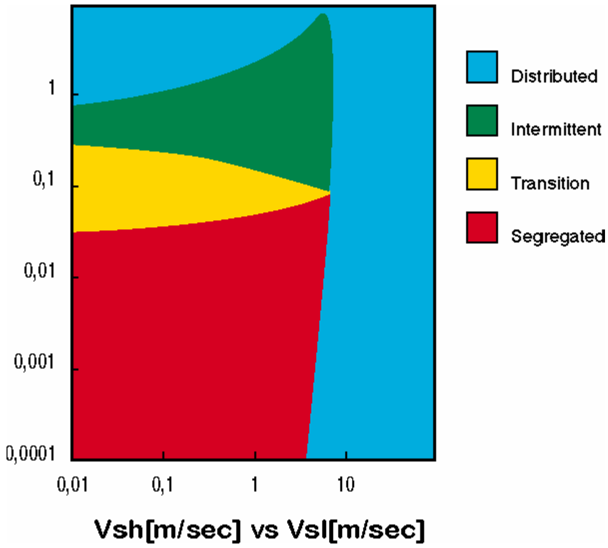
E04.3 • Beggs and Brill

Reference: Beggs H., Bill J., "A Study of Two-Phase Flow in Inclined Pipes", JPT (May 1973), 607-617.

Model based on experiments with air-water flow for various pipe inclinations. The model distinguishes the flow regimes below:



Beggs and brill present a unique flow map in terms of Froude number vs. Input liquid content. An equivalent in terms of Vsh vs. Vsl for a particular condition is shown below.



When calculations are made using a differential pressure density tool, the pipe friction is estimated using the method described in the above reference.

E04.4 • Artep

<u>Reference</u>: Ferschneider G., Ozon P.M., Duchet-Suchaux P.: "Models for Multiphase Flow in Oil Wells", Offshore Multiphase Production Conference, London, 14-15 Sept 1988.

Model for Liquid-Gas flow coupling a mechanistic derivation with a physical basis provided by experiments. The experiments were conducted in a flow loop at deviation between 0 and 90 degrees.

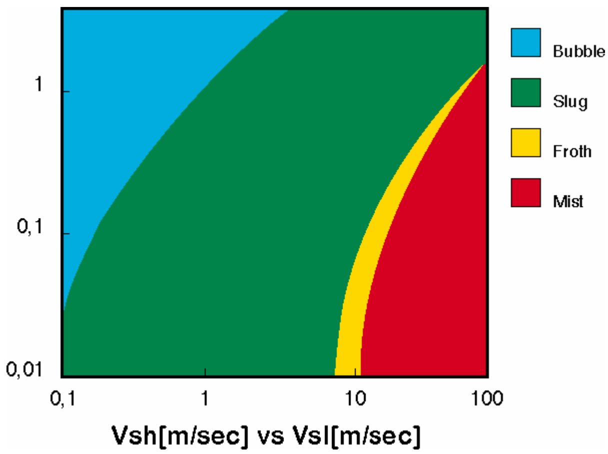
The correlation does not handle a deviation of 90°.

E04.5 • Duns and Ross

<u>Reference</u>: Duns H., and Ross N., "Vertical Flow of Gas and Liquid Mixtures in Wells", Proceedings of the Sixth World Petroleum Congress, Frankfurt (1963), Vol. 10, p 694.

<u>Only vertical upward flow is considered by the model.</u>

Experimental model derived from laboratory data for vertical Liquid-Gas flow and based on a unique flow map plotted as Liquid velocity number vs Gas velocity numbers. These numbers are functions of superficial velocities, liquid density and interfacial tension. An equivalent in terms of Vsh, and Vsl for particular value of the other parameters is shown on the following page:



When calculations are made using a differential pressure density tool, the pipe friction is estimated using the method described in the above reference.

E04.6 • Hagedorn and Brown

Reference: Hagedorn, A.R., & Brown, K.E., 'Experimental Study of Pressure Gradients Occurring During Continuous Two-Phase Flow in Small Diameter Vertical Conduits", JPT (April 1965), Vol. 17, p. 475.

Experimental model for Liquid-Gas flow. Experiment realised in a 1,500 ft vertical well. Tubing I.D: 1 in, 1 ¼ in, 1 ½ in.

Only vertical upward flow is considered by the model.

No flowmap. Single Holdup correlation provided for all conditions.

When calculations are made using a differential pressure density tool, the pipe friction is estimated using the method described in the above reference.

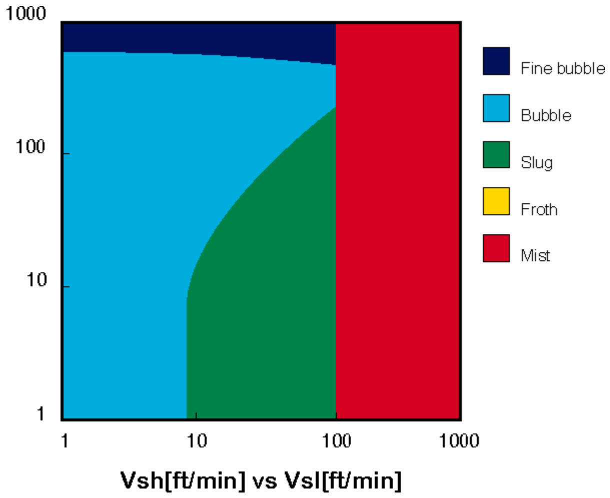
E04.7 • Dukler

Reference: Taitel, Y., Dukler, A.E., and Barnea, D., "Modelling Flow Pattern Transitions for Steady Upward Gas-Liquid Flow in Vertical Tubes", AIChe J. (1980) 26, 345-354.

Mechanistic approach for the flow map determination.

Only vertical flow is considered by the flowmap. Slip deviation correction is however applied in bubble flow (see below).

Unlike other models where a unique flowmap can be presented by using some parameter groups, this model always requires calculation of a specific flowmap in each situation. An example is shown below.



Slug flow: The slippage correlation is given in the above reference.

Bubble flow: Slippage is based on (in ft/min)

Vs = 60 x SqRoot(0.95 - (1 - Yh)*(1 - Yh)) + 1.50

Pipe deviation: Taken into account by correcting the slippage velocity with a factor defined in the Interpretation Settings dialog as either linear for all angles:

Vs = Vs x (1 + 0.04 x dev) where dev is the deviation in degrees

Or identical to the above until 45° and decreasing above this value (Ding et al.)

The default setting is the linear correction.

Note that changing the correction mode in the Interpretation Settings will potentially affect all existing interpretations using the Dukler correlation. It is left to the user to update calculations for zones/logs that are affected by the change.

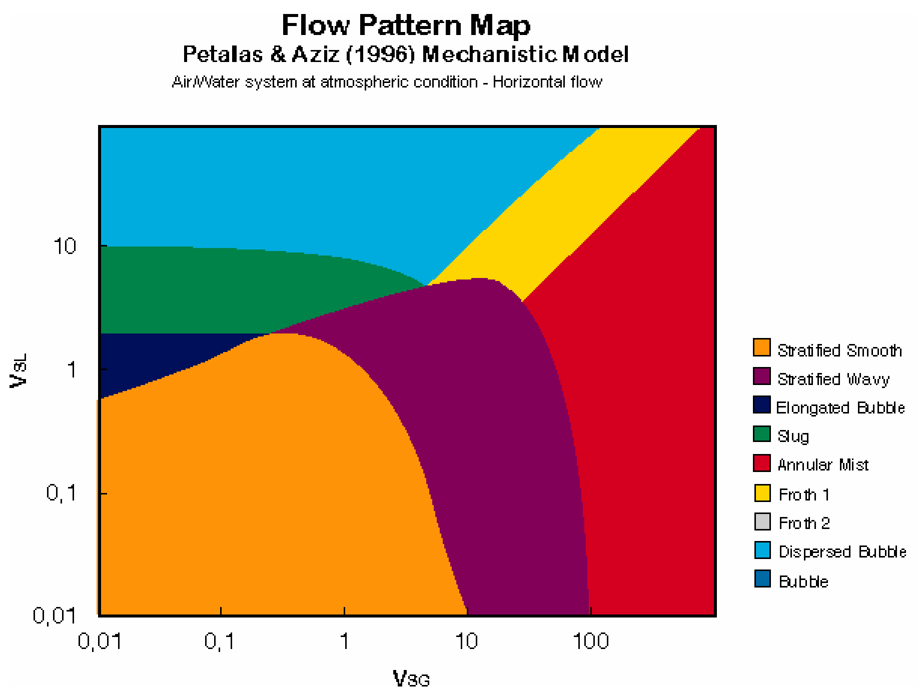
When calculations are made using a differential pressure density tool, the pipe friction is estimated using the same method as for Aziz & Govier in slug and bubble flows, and that of Duns and Ross in mist flow.

E04.8 • Petalas & Aziz

Acknowledgements: Integration of this model in Emeraude was made possible through the support of the Reservoir Simulation Industrial Affiliates Program at Stanford University (SUPRI-B and SUPRI-HW).

Reference: Petalas N., and Aziz, K., "Development and Testing of a New Mechanistic Model for Multiphase Flow in Pipes ", ASME Fluids Engineering Division Second International Symposium on Numerical Methods for Multiphase Flows, San Diego, Cal., July 7-11, 1996.

Mechanistic model for all pipe inclinations, geometries, and fluid properties. Empirical correlations involved in the model were developed based on the Multiphase Flow Database of Stanford University gathering 20,000 laboratory measurements and 1800 measurements from actual wells.



The model distinguishes the following regimes:

• Elongated bubbles
• Bubble
• Stratified smooth
• Stratified wavy
• Slug
• Annular-Mist
• Dispersed bubble
• Froth (transition between dispersed bubble and annular-mist).
• Froth II (transition between slug flow and annular-mist).

Stratified flow regimes are restricted to horizontal flow.

When displaying the flowmap, each point involves the actual calculation of all the gradient terms. This renders the flowmap display a lot slower than for other models, hence the default number of points equal to 10. When more resolution is required, It is advised not to increase the “Number of points” but instead to zoom-in on the region of interest.

E04.9 • Nicolas, Choquette, ABB-Deviated, Constant slippage

Nicolas, Choquette, and “ABB-deviated” are experimental correlations for Liquid-Liquid bubble flow. They all related the slippage velocity to the bubble rise velocity in a static column.

Nicolas

Reference: Nicolas, Y., and Witterholt E.J.: “Measurements of Multiphase Fluid Flow”, paper SPE 4023, 47th Annual SPE Fall Meeting, San Antonio, Texas, October 1972.

Slip deviation correction in Emeraude:

Pipe deviation is taken into account by correcting the slippage velocity with a factor defined in the Interpretation Settings dialog as either linear for all angles:

Vs = Vs x (1 + 0.04 x dev) where dev is the deviation in degrees

Or identical to the above until 45° and decreasing above this value (Ding et al.)

Note that changing the correction mode in the Interpretation Settings will potentially affect all existing interpretations using the Nicolas correlation. It is left to the user to update calculations for zones/logs that are affected by the change.

Choquette

Reference: Choquette, Stanford University M.S. Thesis.

This is a conventional slip velocity model in Water-Oil flow, represented as a chart giving the slippage versus the density difference for several values of water holdup .

Slip deviation correction in Emeraude:

Pipe deviation is taken into account by correcting the slippage velocity with a factor defined in the Interpretation Settings dialog as either linear for all angles:

Vs = Vs x (1 + 0.04 x dev) where dev is the deviation in degrees

Or identical to the above until 45° and decreasing above this value (Ding et al.)

Note that changing the correction mode in the Interpretation Settings will potentially affect all existing interpretations using the Choquette correlation. It is left to the user to update calculations for zones/logs that are affected by the change.

ABB – Deviated

Variation of the Choquette correlation specifically derived from deviated wells data. Recommended for Liquid-Liquid calculations in deviated wells.

Constant slippage

The slippage value is entered manually on each zone.

When calculations are made using a differential pressure density tool, the pipe friction for all the above models is estimated using a Moody friction factor based for an Reynolds number representative of the mixture.