



E03 • Rate calculations

E03.1 • Frictions/Acceleration

When dealing with a density channel coming from a differential pressure tool (or with a pseudo-density channel), it is necessary that the simulation reproduces the different terms involved in the measurement. The pressure gradient can be decomposed in three terms: hydrostatic head, friction gradient, and acceleration gradient:

$$\frac{dP}{dZ} = \left[\frac{dP}{dZ} \right]_{hydrostatic} + \left[\frac{dP}{dZ} \right]_{friction} + \left[\frac{dP}{dZ} \right]_{acceleration}$$

Hydrostatic head

The hydrostatic head component is calculated from the mixture density ρ_m , which is based on the PVT as well as the calculated phase holdups:

$$\left[\frac{dP}{dZ} \right]_{hydrostatic} = \rho_m g \cos(\theta)$$

Acceleration

The acceleration component is neglected except in the case of single phase gas or mist flow of a liquid-gas mixture. In those cases, the gradient is calculated as a correction of the total gradient, involving the mach numbers of the phases, as described by Duns and Ross.

Frictions

Friction calculations include the determination of the friction gradients along the pipe as well as along the tool (the latter term is ignored when a pressure derived density is used). All friction terms are estimated using a Moody type friction factor and are of the general form:

$$\left[\frac{dP}{dZ} \right]_{friction} = \frac{f \rho V^2}{2D}$$

When it must be calculated, friction along the tool requires the knowledge of the tool velocity as the considered velocity V , above, is the relative velocity between the tool and the fluid. This cable velocity is normally copied inside the interpretation when the density channel is defined. In the case where the reference density is defined as an average, the corresponding average cable speed is used. This is not



rigorous as the frictions are obviously not a linear function of the tool velocity, but it is assumed that there is a local linearity. Note that if you manually drop a gradio channel inside an interpretation, no cable speed is automatically copied and in that case the tool velocity is taken as 0.

E03.1.1 • Detailed friction equations

The general expression of the friction gradient is :

$$\frac{dP}{dZ} = \frac{f_p V^2}{8} \times \frac{S}{A}$$

where:

f is the Moody friction factor, function of the appropriate Reynolds number and roughness

S is the surface in contact with the fluid, A is the area opened to flow

r is the density

V is the speed of the fluid relative to the considered surface.

The density appearing in the above equations depends on the flow regime. For instance in annular flow, a liquid film is in contact with the pipe and only the liquid density is considered.

Friction along the pipe

The velocity to be considered is:

$$V_p = \frac{Vf \cdot D^2}{D^2 - d^2}$$

Vf is the fluid velocity

D is the pipe I.D.

d is the tool O.D.

The equivalent diameter as well as the Reynolds are:

$$D_e = (D - d) ; Re = \frac{\rho \cdot V_p^2 \cdot D_e}{\mu}$$

The friction factor in this case is noted f_p , and is a function of the relative roughness rt : $f_p = f_p(Re, rt)$

The ratio S/A is defined as : $\frac{S}{A} = \frac{\pi D}{\pi \left(\frac{D^2 - d^2}{4}\right)} = \frac{4 \cdot D}{D^2 - d^2}$

Finally, the pipe friction component is written:

$$\boxed{\frac{dP}{dZ_{pipe}} = \frac{f_p \rho V_p^2}{2} \times \frac{D}{(D^2 - d^2)}}$$



Tool friction component

The velocity to be considered is:

$$V_t = \frac{V_f \cdot D^2}{D^2 - d^2} - V_{cable}$$

V_f is the fluid velocity

D is the pipe I.D.

d is the tool O.D.

V_{cable} is the tool velocity. Note that this assumes a consistent sign convention between the fluid velocity and the cable speed.

The equivalent diameter for the Reynolds number is the same as before: $D_e = (D - d)$

and Re is given by
$$Re = \frac{\rho \cdot V_t^2 \cdot D_e}{\mu}$$

The friction factor in this case is noted f_p and no roughness is considered. $f_t = f_t(Re, 0)$.

The ratio S/A is defined as :
$$\frac{S}{A} = \frac{\pi d}{\pi \left(\frac{D^2 - d^2}{4}\right)} = \frac{4 \cdot d}{D^2 - d^2}$$

Finally, the tool friction component is written:

$$\frac{dP}{dZ_{tool}} = \frac{f_t \rho V_t^2}{2} \times \frac{d}{(D^2 - d^2)}$$

Total friction term and Emeraude results

The total friction gradient is the sum of the two terms derived above :

$$\frac{dP}{dZ_{friction}} = \frac{dP}{dZ_{pipe}} + \frac{dP}{dZ_{tool}} = \frac{f_p \rho V_p^2}{2} \times \frac{D}{(D^2 - d^2)} + \frac{f_t \rho V_t^2}{2} \times \frac{d}{(D^2 - d^2)}$$

In the Zone Rate Gradio page, Emeraude gives values referring to «Pipe friction » and « Tool friction ».

Their sum is the same as the sum of the two gradients above but their definition is different :

Pipe friction, as reported by Emeraude : the friction gradient if the tool was not present. This is calculated with D as the hydraulic diameter, the velocity being the actual fluid velocity V_f .

Tool friction, as reported by Emeraude : the additional gradient to the above term, due to the tool presence.

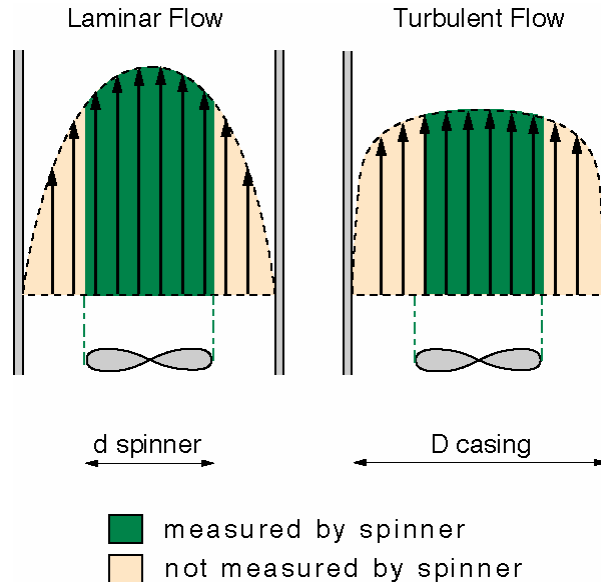
This is calculated as:

$$\frac{dP}{dZ}_{friction} - \frac{dP}{dZ}_{friction\ without\ tool}$$



E03.2 • Vapp / Vm relation

The velocity of the fluid inside a pipe cross section is not uniform but follows a defined profile as shown on the figure below. The spinner calibration gives an apparent velocity Vapp, which, if the spinner is well centralized, is a measure of the maximum velocity. What is needed for rate calculation is the average velocity Vm.



Vpcf: Velocity Profile Correction Factor

The relation between Vapp and Vm is influenced by the type of flow. It can be expressed by introducing a correction factor noted Vpcf (Velocity Profile Correction Factor) such that:

$$V_m = V_{pcf} \times V_{app}$$

Assuming a centralised spinner and a symmetrical flow profile around the pipe central axis, Vpcf can be correlated with the Reynolds number and the ratio between the spinner blade, and pipe diameter.

$$V_m = V_{pcf}(\rho, V_m, \dots) \times V_{app}$$

A value of 0.83 is assumed by default but a better estimate can be obtained by solving the above equation. The solution can only be obtained iteratively as Vm is an argument of Vpcf. When a gradiometer is used the density ρ is also dependent on Vm (through frictions). Emeraude solves this equation by using a non-linear regression scheme in order to minimize the function:

$$E(V_m) = [V_m / V_{pcf}(\rho, V_m, \mu, \dots) - V_{app}]^2$$

A value of 0.83 is assumed by default but a better estimate can be obtained by solving the above equation. In the conventional approach, the solution is obtained iteratively as Vm is an argument of Vpcf. In Emeraude, since we rely on the non-linear regression for inversion we need to simulate Vapp from assumed rate values:



$$V_{app} = \frac{V_m}{V_{pcf}}$$

In a single phase case this is done directly. In multiphase, the determination of the Reynolds number requires the prior determination of the mixture density and viscosity, based on holdup calculation. To the apparent velocity corresponds the following residual term in the non-linear regression:

$$E = \left[\frac{V_m}{V_{pcf}} - V_{app}^* \right]^2$$

Where V_{app}^* is the measured apparent velocity.

In single phase, this residual alone constitutes the complete function to be minimized. In multiphase, it is one residual among for others for the additional tools.

Vpcf multiplier

The correlation for V_{pcf} is based on assumptions that may not be valid in practice. An error in the correction factor leads to an error in the mixture velocity, and hence total downhole rates. An additional parameter is introduced that represents the potential error and allows for an adjustment of the model. This factor noted “ V_{pcf_Mult} ” below modifies the relation above to:

$$V_m = V_{pcf_mult} \times V_{pcf}(\rho, V_m, \dots) \times V_{app}$$

By default the value of the multiplier is 1. A different value can be determined when surface rates are available. The same value is then applied at all depths.

E03.3 • Single-phase interpretation

In single-phase interpretation the sole unknown is V_m the mixture velocity. One input needs to be a velocity or the temperature. The velocity input may be a spinner V_{app} , a direct mixture velocity.

r^*

If a density channel is available in the interpretation, the density used in the calculation of V_{pcf} is read from this channel (and necessary corrections are applied). Otherwise, if temperature and pressure channels are present, the density is calculated from the PVT model.

m

When T and P channels are available, the default viscosity is computed from the PVT model. Otherwise it must be supplied by the user.

When all inputs are defined V_m is obtained using non-linear regression to minimize the function:



$$E = \left[\frac{V_m}{V_{pcf}} - V_{app}^* \right]^2$$

At each iteration, the density ρ is estimated from the input value ρ^* correcting for frictions and deviation if necessary.

E03.4 • Matching surface conditions – Single-phase case

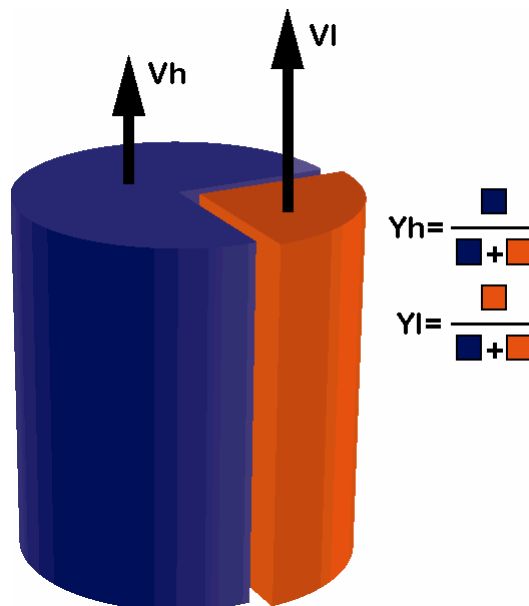
Matching surface rates involves the determination of the V_{pcf} multiplier coefficient, thereby changing the model predicting the V_{app} / V_m relation. This is made for the top calculation zone (i.e. above the top producing interval) and must be followed by a re-calculation of any prior rate result:

- Zonal calculation: V_m must be recalculated for all zones. Done automatically when selecting the “Match S.C.” option.
- Logs: All existing rates must be recalculated and the change in V_{pcf} affects the calculation at any depth.
On the top calculation zone, the estimate of the V_{pcf} multiplier is done as follows:
 - Set “ V_{pcf_Mult} ” = 1, and seek the best estimate of V_m from supplied input.
 - Compute V_{mSC} , expected downhole mixture velocity. In single phase $V_{mSC} = QSC \times B$ where B is the formation volume factor estimated for the T and P values of the zone.
 - $V_{pcf_Mult} = V_{mSC} / V_m$

E03.5 • Multiphase Interpretation – Theory

We consider first a situation with 2 phases, a light phase represented by the “l” subscript, and a heavy phase represented by “h”. The results are extended to 3 phases at the end of the section.

The figure below gives a hypothetical view of a pipe cross-section where the phases would be perfectly separated.





Holdups, Y_h and Y_l

Holdups are defined as the volume fraction that a phase occupies in the pipe section. They satisfy the relation:

$$Y_h + Y_l = 1$$

Average velocities, V_h and V_l

The actual velocity of a given phase:

$$V_h = \frac{Q_h}{A \times Y_h} ; \quad V_l = \frac{Q_l}{A \times Y_l}$$

where A is the pipe cross sectional area.

E03.5.1 • Case of Equal average velocities

The assumption is made to introduce some graphical representations and notations, and is by no means a required assumption in Emeraude. This assumption leads to:

$$\frac{Q_h}{Q_l} = \frac{Y_h}{Y_l}$$

From the spinner measurement, we can estimate the total mixture rate at any depth q_m and impose the condition:

$$Q_h + Q_l = Q_m$$

In this case solving for the individual rates is straightforward if we can measure one of the phase holdups. The holdup may be measured directly or assumed from a mixture density measurement if we know the individual phase density:

$$Y_h = \frac{\rho - \rho_l}{\rho_h - \rho_l}$$

Superficial velocities

The superficial velocities are introduced in order to simplify the subsequent discussion; they are defined as the rate of a given phase divided by the pipe cross section:

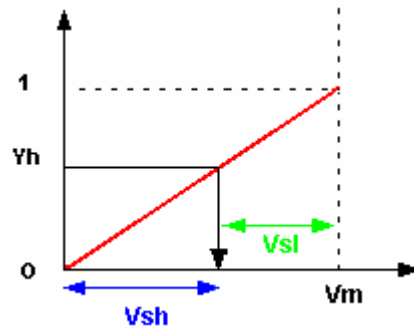
$$V_{sh} = \frac{Q_h}{A} ; \quad V_{sl} = \frac{Q_l}{A}$$

They satisfy the relation: $V_{sh} + V_{sl} = V_m$, where V_m is the average mixture velocity

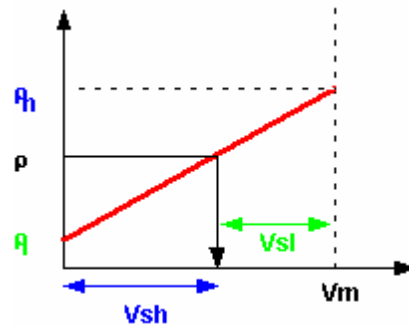
The average velocities can be expressed in terms of the superficial velocities:

$$V_h = \frac{V_{sh}}{Y_h} ; \quad V_l = \frac{V_{sl}}{Y_l}$$

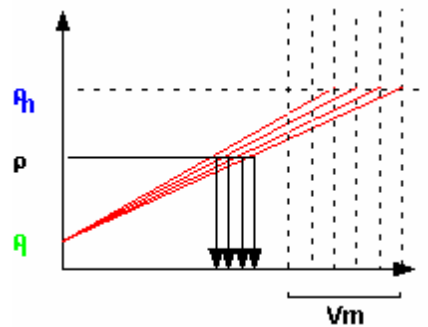
The problem described by the above equations is represented graphically when a solution is sought from a holdup value Y_h:



The X-axis gives the heavy phase superficial velocity, ranging from 0 to V_m . The complement between V_{sh} and V_m is by definition V_{sl} , superficial velocity of the light phase. The proportionality relation between holdups and rates is a straight line, plotted in red. From the measured holdup, the solution V_{sh} and V_{sl} are found by intercepting the red line. The same plot can be made when applied to a density measurement:



The plot is drawn assuming that the mixture velocity is known, and fixed. The actual calculation scheme used by Emeraude does not required V_m to be fixed but integrates its determination in a non-linear regression loop. For illustration purposes only, the plot below shows how the plot, and hence the relation changes with V_m .





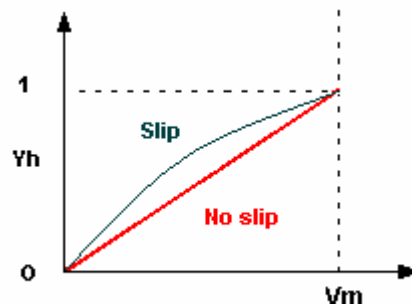
E03.5.2 • Unequal average velocities

Slippage velocity, V_s

The slippage velocity is defined as the difference between the average velocities:

$$V_s = V_l - V_h$$

A non zero slippage means that the light phase is travelling faster than the heavy phase. For a given rate ratio, the volume ratio of the light phase will be less than in the no slip situation. Conversely, the heavy phase holdup will be bigger. The relation between superficial velocities and heavy phase holdup (or mixture density) becomes non linear:



A similar change would apply to the density plot. As before, we can find a solution to the problem provided that we have a way of calculating V_m , and Y_h . The determination of Y_h is made using two-phase flow correlation's which either correlate directly Y_h or alternatively V_s . When V_s is predicted, Y_h can be estimated from the equation:

$$Y_h^2 \times V_s + Y_h \times (V_m - V_s) - V_{sh} = 0$$

This equation admits one, and only one root in $[0,1]$ for any value of V_s .

Note: Certain flow correlation's predict V_s as a function of Y_h . This renders the solution to the above equation iterative.

E03.5.3 • 3-phase flow

Use of the 2-phase flow models is extended to this situation by considering that one of the phases contains in fact 2 components. Within this mixed phase, the simplest assumption is to consider that there is no slippage between the two components. This assumption is made by some models in Emeraude but not all of them (see C3.6 below). The "3-Phase L-G" model applies the above equation twice: once in the liquid phase, between oil and water, and once between the liquid phase and the gas. An additional parameter is introduced in order to represent the split of the mixed phase rate into the two components:

- Mixed phase is oil+water:

Introduce **fo**, fraction of the oil rate to the liquid phase rate. If the model assumes no slippage between the oil and water (Liquid-Gas) then fo is also a volumetric ratio.

- Mixed phase is oil+gas:

Introduce **fg**, fraction of the gas rate to the hydrocarbon phase rate. The only situation where this is used is the Water-Hydrocarbon model which assumes no slippage within the hydrocarbon phase. Therefore fg is also the volumetric ratio in this case.



Slippage modifications

The 2-phase flow correlation's can be reduced to one equation predicting V_s as a function of the superficial velocities (and other known properties):

$$V_s = V_s(V_{sh}, V_{sl}, \rho_h, \rho_l, \mu_h, \mu_l)$$

For the flow correlation's concerned with Liquid-Gas flows, different flow regimes are distinguished leading to a set of such equations. In Emeraude, this relation is modified by the introduction of two additional parameters:

$$V_s = \max[V_m \times C_2, C_1 \times V_s(V_{sh}, V_{sl}, \rho_h, \rho_l, \mu_h, \mu_l)]$$

C_1 is a multiplier applied to the original slip correlation. It is originally equal to 1 but can be modified to match the surface conditions (see Surface Conditions). There is one slip multiplier for each correlation.

C_2 defines the maximum limit for the ratio V_s/V_m . By default this limit is undefined.

E03.6 • Two-phase flow models

There are 4 flow models in Emeraude (in addition to the single-phase model):

Liquid-Gas

The liquid phase can comprise oil, water, or a mixture of both. There is no slippage between oil and water. In 3-phase, the fraction of oil in the Liquid phase, **fo** is introduced. The initial **fo** value is based on the entered surface WOR. If the necessary measurements are available **fo** is determined by the non-linear regression. In this case a green light will appear in front of the **fo** button in the Zone Rate dialog.

Water-Hydrocarbons (G)

Liquid-Gas situation where the heavy phase is water and the light phase is mainly gas possibly with some oil (or condensate). There is no slippage between the oil and gas phases. If this model is used in 3-phase, the ratio of gas in the hydrocarbon phase, **fg**, is introduced. This value is fixed from the PVT CGR ratio.

Water-Hydrocarbons (L)

Liquid-Liquid situation where the heavy phase is water and the light phase is oil possibly with evolved gas. There is no slippage between the oil and gas phases. If this model is used in 3-phase, the ratio of gas in the hydrocarbon phase, **fg**, is introduced. This value is fixed from the PVT Rs ratio.



3-Phase L-G

This is the combination of a Liquid-Gas and Water-Oil models. There is slippage between the oil and water phases within the Liquid phase. There is also slippage between the gas and the mixed liquid. The oil fraction **fo** represents the ratio of the oil rate to the liquid rate. This model is only offered when there are enough measurements for fo to be a variable.

The following correlation's are available in Emeraude:

Liquid-Gas	Liquid-Liquid
Duns and Ross	Nicolas
Aziz and Govier	Choquette*
Beggs and Brill	ABB-Deviated
Artep	Nicolas*
Duckler*	Constant slippage
Hagedorn-Brown	
Petalas & Aziz	
Constant slippage	

One can use the Interpretation option of the Settings panel to disable some correlation or re-define the default correlation for each model. The deviation correction on the slippage predicted by the models with a “*” can be selected in the same dialog.

E03.7 • Multiphase interpretation – Calculation scheme

This section describes the steps involved in the simulation of all potential measurements, assuming a value for the rates. This calculation is done at every iteration of the non-linear regression that solves for the rates.

“Water-Hydrocarbons (G)” and “ Water-Hydrocarbons (L)”

Parameters: Vsh, Vsl, and fg

Variables:

- Vsh and Vsl

fg is not a variable but is fixed from PVT. Since no slippage is assumed between the oil and gas phases in this case, fg gives the rate fraction as well as volume fraction here.

Calculation steps:

1. Mixture velocity:

$$V_m = V_{sh} + V_{sl}$$

2. Get flow regime (not for the Liquid-Liquid case where bubble flow is assumed).



3. Calculate the overall PVT properties of the light phase:

$$\rho_l = [f_g \times \rho_g + (1 - f_g) \times \rho_o]$$

$$\mu_l = [f_g \times \mu_g + (1 - f_g) \times \mu_o]$$

4. Calculate the heavy phase holdup and the slippage velocity from the selected correlation:

$$Y_h = Y_h(V_{sh}, V_{sl}, \rho_h, \rho_l, \mu_h, \mu_l \dots) \quad ; \quad V_s = V_s(V_{sh}, V_{sl}, \rho_h, \rho_l, \mu_h, \mu_l \dots)$$

5. Get all holdups:

$$Y_w = Y_h \quad ; \quad Y_o = (1 - f_g) \times (1 - Y_w) \quad ; \quad Y_g = f_g \times (1 - Y_w)$$

6. Get all average velocities:

$$V_w = \frac{V_{sh}}{Y_w} \quad ; \quad V_o = \frac{V_{sl} \times (1 - f_g)}{Y_o} \quad ; \quad V_g = \frac{V_{sl} \times f_g}{Y_g}$$

If a spinner is used, steps to get Vapp

1. Mixture density:

$$\rho_m = \rho_w \times Y_w + \rho_o \times Y_o + \rho_g \times Y_g$$

2. Mixture viscosity:

$$\mu_m = \mu_w \times Y_w + \mu_o \times Y_o + \mu_g \times Y_g$$

3. Velocity profile correction factor:

$$V_{pcf} = V_{pcf}(V_m, \rho_m, \mu_m)$$

4. Apparent velocity:

$$V_{app} = \frac{V_m}{V_{pcf}}$$

If a gradiometer or a pressure derived density is used

If a density measurement is available, simulate that measurement by accounting for frictions as required. Also reproduce how the deviation is handled by the tool output (corrected, not corrected).

“Liquid-Gas” and “3-Phase L-G” models

Parameters: Vsh, Vsl, and fo

Variables:

- Vsh and Vsl
- fo, variable only in a 3-phase situation with enough measurements.

Calculation steps:

1. Mixture velocity:

$$V_m = V_{sh} + V_{sl}$$

2. Determine the volumetric fraction of oil in the liquid phase noted **fy_o**:

No slippage between oil and water (Liquid-Gas model): $f_{y_o} = f_o$

If the model assumes slippage between oil and water, the steps 1-4 of the procedure **A** above are executed with the input (superscript A designates parameters of procedure A):

$$V_{sh}^A = V_{sh} \times (1 - f_o) \quad ; \quad V_{sl}^A = V_{sh} \times f_o \quad ; \quad f_g^A = 0$$



Then f_{yO} can be obtained as: $f_{yO} = Y_o^A$

3. Get overall liquid phase properties required for further calculations

$$\rho_h = [f_{yO} \times \rho_o + (1 - f_{yO}) \times \rho_w]$$

$$\mu_h = [f_{yO} \times \mu_o + (1 - f_{yO}) \times \mu_w]$$

4. The heavy phase holdup and the slippage velocity (between gas and liquid) are calculated:

$$Y_h = Y_h(V_{sh}, V_{sl}, \rho_h, \rho_l, \mu_h, \mu_l \dots) \quad ; \quad V_s = V_s(V_{sh}, V_{sl}, \rho_h, \rho_l, \mu_h, \mu_l \dots)$$

5. Get all holdups:

$$Y_w = Y_h \times (1 - f_{yO}) \quad ; \quad Y_o = Y_h \times f_{yO} \quad ; \quad Y_g = Y_l$$

6. Get all average velocities:

$$V_w = \frac{V_{sh} \times (1 - f_o)}{Y_w} \quad ; \quad V_o = \frac{V_{sh} \times f_o}{Y_o} \quad ; \quad V_g = \frac{V_{sl}}{Y_g}$$

If a spinner is used, steps to get V_{app}

1. Mixture density:

$$\rho_m = \rho_w \times Y_w + \rho_o \times Y_o + \rho_g \times Y_g$$

2. Mixture viscosity:

$$\mu_m = \mu_w \times Y_w + \mu_o \times Y_o + \mu_g \times Y_g$$

3. Velocity profile correction factor:

$$V_{pcf} = V_{pcf}(V_m, \rho_m, \mu_m)$$

4. Predicted apparent velocity

$$V_{app} = \frac{V_m}{V_{pcf}}$$

If a gradiometer or a pressure derived density is used

If a density measurement is available, simulate that measurement by accounting for frictions as required. Also reproduce how the deviation is handled by the tool output (corrected, not corrected).

E03.8 • Surface Conditions

Matching the surface rates involves the determination of two multipliers (or three with the 3Phase L-G model), one for the model predicting V_{pcf} , one for the slip model(s). As the model is modified the change is global and any prior calculation is invalid:

- Zonal calculation: All zones must be re-calculated. Done automatically when selecting the “Match S.C.” option.
- Logs: All existing rates must be recalculated

A slip multiplier pertains to a particular correlation, and in practice is calculated for the correlation used on the top calculation zone. The calculation proceeds as follows:

- Top zone: Set $V_{pcf_Mult} = 1$, and $V_{slip_Mult} = 1$; Seek the best estimate of V_{sh} , V_{sl} (possibly f_o) from supplied input.
- Compute V_{mSC} , and V_{shSC} mixture and heavy phase superficial mixture velocities expected from the surface rates.
- $V_{pcf_Mult} = V_{mSC}/V_m$



- Vslip_Mult obtained by non-linear regression so that Vsh = VshSC

E03.9 • Apparent DownFlow

“Apparent Downflow” can occur in deviated wells with a high heavy phase holdup. For instance in a deviated well with a high water holdup, the water may be dragged upwards by the oil flowing up - on the high side of the pipe - , and fall back -on the low side of the pipe- if there is not enough energy to lift it. This circulation of water may be “seen” by the spinner as only downward flow when it is in fact due to an upward oil flow. Deciding that the flow is up when the spinners says it is down, can be done if additional information is available (zone pressure, temperature, etc).

When this “Apparent DownFlow” situation has been recognized, a specific option in the Zone Rate dialog can be used for quantitative interpretation. The option is available in both Liquid-Liquid and Liquid-Gas cases.

In this option, the superficial velocity of the light phase Vsl is assumed to be a function of the slip velocity, Vs and the Holdup:

$$V_{sl} = C \times V_s \times (1 - Y_h) \quad \text{where } C \text{ is a constant}$$

The spinner measurement is disregarded and the superficial velocity of the heavy phase is set to 0.

Correlation

When the “Apparent Downflow” option is selected, the slip correlation for the zone is automatically set to:

- Liquid-Gas: the bubble flow correlation of the Duckler model
- Liquid-Liquid: the “Deviated” correlation

Calculation Scheme

The scheme is again a non-linear regression with a unique variable, Vsl and a unique match point ρ the measured tool density (or Yw a measured water holdup)

Each iteration step assumes a value of Vsl. With the relation above and the equation relating Vs and Yh introduced in Multiphase Interpretation - Theory, it is possible to solve for Yh and Vs. Once we have Yh we can predict the density tool response, or water holdup.

The Apparent Downflow option is not offered with the “3-Phase L-G” model.

E03.10 • Multiphase interpretation - Problems and solution

The potential measurements are divided into 3 categories:

1. Velocity: Vapp, Vw, Vo, Vg, Qw, Qo, Qg
2. Holdup: Yw, Yo, Yg, ρ
3. Temperature

Required measurements in the array below must be relevant for the defined PVT.



PVT	Flow model	Variable	Required Measurements
Single phase	Single phase	Vm	1 velocity (or temperature)
Oil-Gas	Single phase	Vm	1 velocity (or temperature)
	Liquid-Gas	Vsh, Vsl	2 including 1 velocity (or temperature)
Water-Gas	Liquid-Gas	Vsh, Vsl	2 including 1 velocity (or temperature)
Gas – Condensate	Single phase	Vm	1 velocity (or temperature)
	Liquid-Gas	Vsh, Vsl	2 including 1 velocity (or temperature)
Water-Oil-Gas	Liquid-Gas	Vsh, Vsl (fo fixed)	2 including 1 velocity (or temperature)
		Vsh, Vsl, fo	3 including 1 velocity (or temperature)
	Water-Hydrocarbons (L)	Vsh, Vsl	2 including 1 velocity (or temperature)
Water-Gas-Condensate	Water-Hydrocarbons (G)	3-Phase L-G	3 including 1 velocity (or temperature)
		Vsh, Vsl	2 including 1 velocity (or temperature)

When a constant slippage model is used, and if enough measurements are available, the slippage velocity is taken as a variable.

The constant slippage model normally uses a slippage value entered by the user. In a situation where enough measurements are available, Emeraude will include the slippage value among the non-linear regression variables.

For instance, in a 2 phase Water-Oil situation, with measurements of V_{app} , V_w , ρ , there are enough data to calculate the slippage. In such a situation, if the constant slippage model is selected and Improve is executed, the slippage is updated and a green light will appear next to it, to indicate that it became a variable of the regression:

