



**KAPPA**

# B03 – Guided Interpretation #3



This session assumes that you have followed the first two guided sessions, or that you are familiar with Emerade. The purpose of this third example is to illustrate the use of the 'Global Regression' and the two different interpretation methods offered in the software: 'Zoned' and 'Continuous'.

The data for this example is from a deviated well with three phase flow. Three passes have been run and the toolstring was designed to measure, among others, the water and gas phase holdups.

### B03.1 • Opening B03

- Start Emerade and Open the file B03.ke2 located in the Emerade Examples directory.

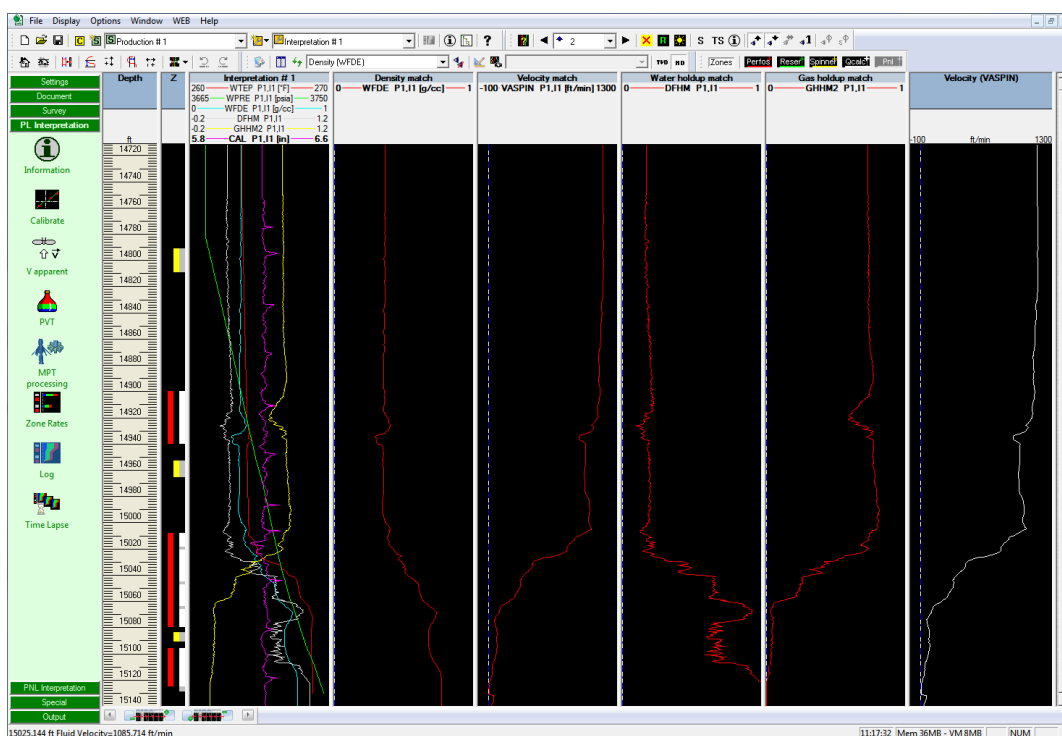


Fig. B03.1 • B03 file

In addition to the Z track, the screen shows the interpretation track with the reference channels (density, temperature, pressure and holdups), and the match tracks.

In the browser, the General Well Data is complete with all relevant information entered. The document has one survey called Production #1, and the surface rates are given.

An interpretation was initialized and carried out, up to the creation of rate calculation zones. The interpretation reference channels are defined for Temperature, Pressure, Water and Gas holdups. You can click on the 'PVT' option to check the selected PVT model. This model is 3-phase and has been matched on lab data.

### B03.2 • Interpretation with the 'Zoned' method

- In PL Interpretation tab, go to Information.
- Keep the defaults: 'Zoned' method and Init based on 'Zone local values'.
- Close the window with OK.
- Click on 'Zones rates'.

The 'Init' tab of the 'Zone Rates' dialog is displayed and shows the default selection made by the software. We saw that the PVT has the potential for 3 phases. Since there are enough measurements (density and water and gas holdups here) Emeraude suggests the '3-Phase L-G' model. This model combines a Liquid-Gas and Liquid-Liquid slippage correlations.

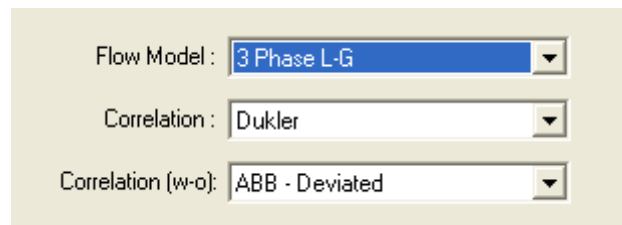


Fig. B03.2 • 'Zone Rates' Init

With the selection above, the Dukler correlation is used to calculate the slippage between the gas and mixed liquid phases. Within the liquid phase the ABB-Deviated correlation is used to compute the slippage velocity between the oil and the water phases.

- Accept the current selection. Go to the 'Rate Calculation' tab, Fig. B03.3.

All 3 rates have been calculated from the current input by running a regression on each calculation zone. Each regression is run independent of the others, to find the local value of  $Q_w, Q_o, Q_g$  by matching the measured and simulated values on the calculation zone.

In the 'Zoned' approach, Emeraude treats only the rates as variables, and the holdups are inferred from the selected slip model(s). In this case there are two slippage velocities. Note that the water-oil slippage is given relative to the liquid phase; hence the reported value is equal to:

$$\text{Slip } W - O = (V_w - V_o) \times (Y_o + Y_w)$$

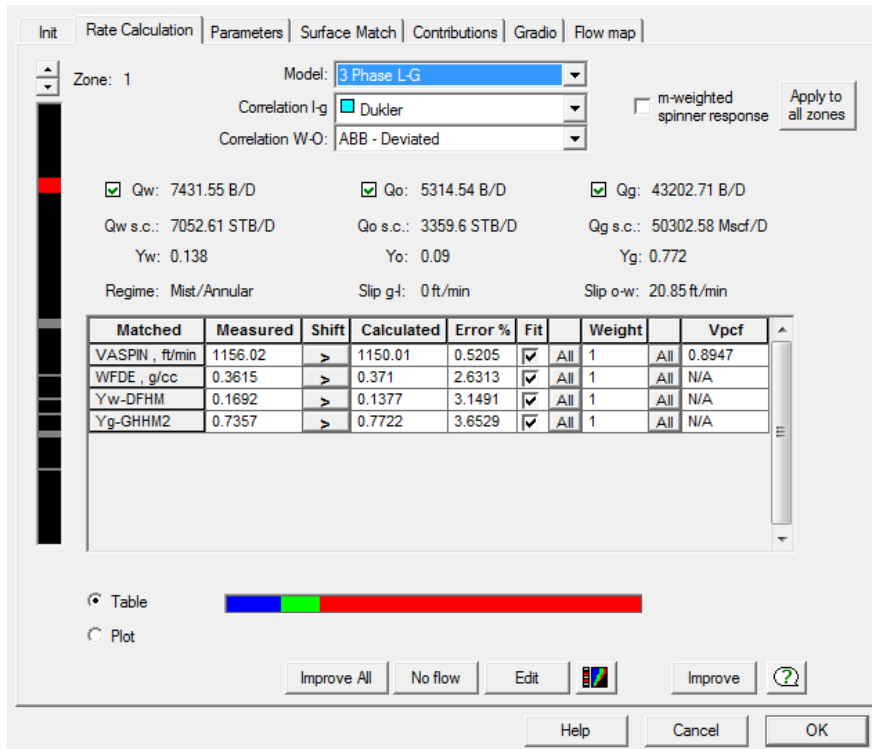



Fig. B03.3 • 'Zone Rates' Calculation; top zone

- Move to the bottom zone, set it to 'No Flow'.
- Validate the Zone Rates results with OK.
- Generate both schematic and complete logs, keeping the default depth increments for both the complete and the schematic logs (the default depth increment value for the schematic log is based on 50 points over the default log interval).
- Reset the horizontal scales with .

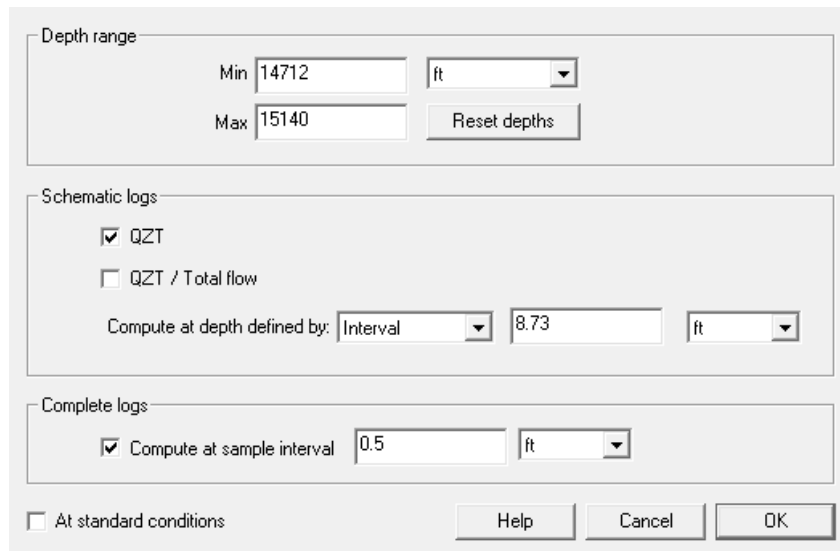


Fig. B03.4 • Rate log settings

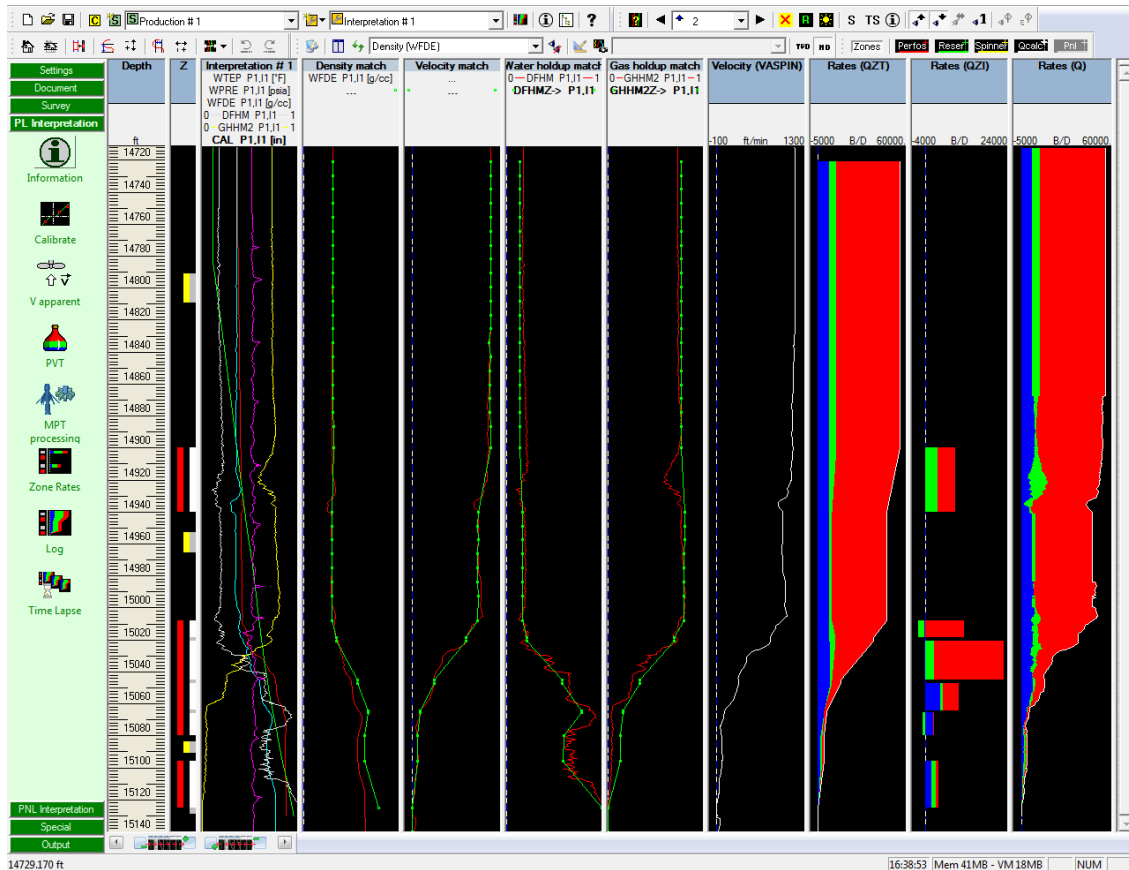


Fig. B03.5 • Rate logs generated

The QZI logs show that the second contributing interval is producing gas and taking water and oil at the same time. This is certainly not physical and other contributing zones show a similar behavior. The reason for this is that all zones have been solved independently and contributions obtained by successive differences after the fact. It should be clear that this procedure does not guarantee the identity of signs for the contributions of any zone.

The Global Regression can be used to resolve inconsistencies of this type when they arise, by imposing additional constraints to the solution. This is illustrated in the following section.

It should be pointed out that there is some redundancy in the input measurements and some inconsistency as well. This is revealed by the fact that the regression does not succeed to match at the same time, the holdups, and the density. The relative weights assigned in the regression on the measurements will of course drive the solution towards one side or the other.

- Hide the Q, the velocity (VASPIN) and the Reference channel tracks. Tile.

### B03.2.1 • Imposing all positive contributions

- Go to 'Zone Rates', and activate the 'Contributions' tab, Fig. B03.6.

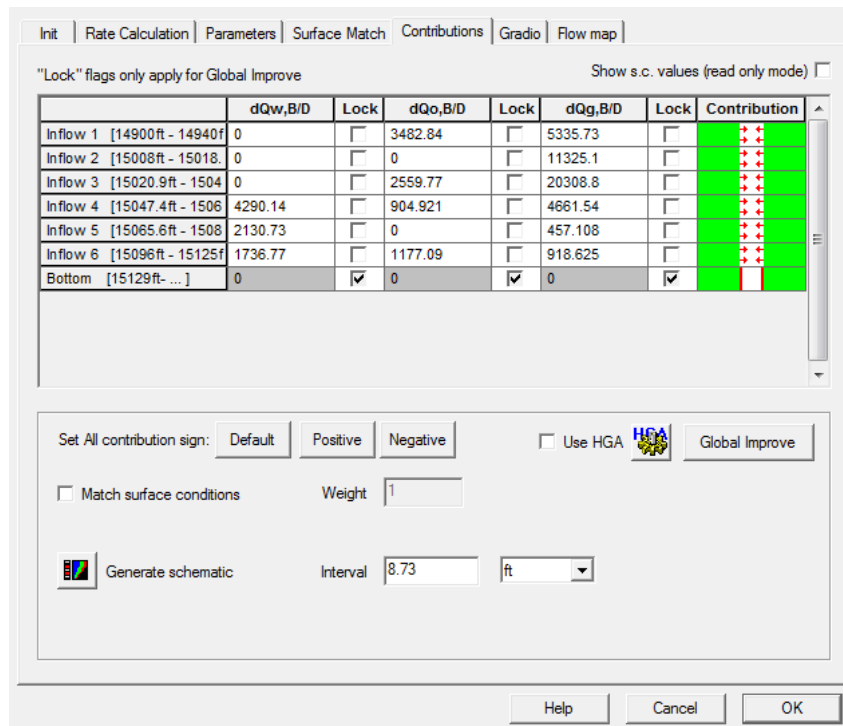


Fig. B03.6 • Contributions

The dialog displays the list of the inflow zones, and the contribution for each phase. All values in the dialog are editable; if a value is changed the cumulative rates are recalculated. If you change a value before running 'Global Improve', the value can be fixed by checking the lock checkbox. Contributions from the well bottom are zero and they do not need to be taken as variables.

They are already locked.

- Check the 'Match surface conditions' box.
- Click on the 'Positive' button, then on 'Global Improve'.

The Global Regression starts. Values inside the grid are updated after each iteration. This time, all zones are treated simultaneously and the unknowns are the contributions. The goal is not only to match the input measurements, but also to satisfy the defined constraints. When the regression is over, a text at the bottom of the dialog gives the value of the objective function, an indication of the match quality. It can be seen that the sign constraint has been honored and the Global regression ends up with the best possible match, given those constraints and the input measurements. As in the first step of the diagnosis, it is important to realize that the Global regression only worries about the error on the calculation zones. The match outside of those zones is simply not considered. Therefore, everything relies on the position of the calculation zones, and the stability of the data in those zones. This is an essential difference with the 'Continuous' method, described in section B03.3.

- Validate the results with 'OK'.

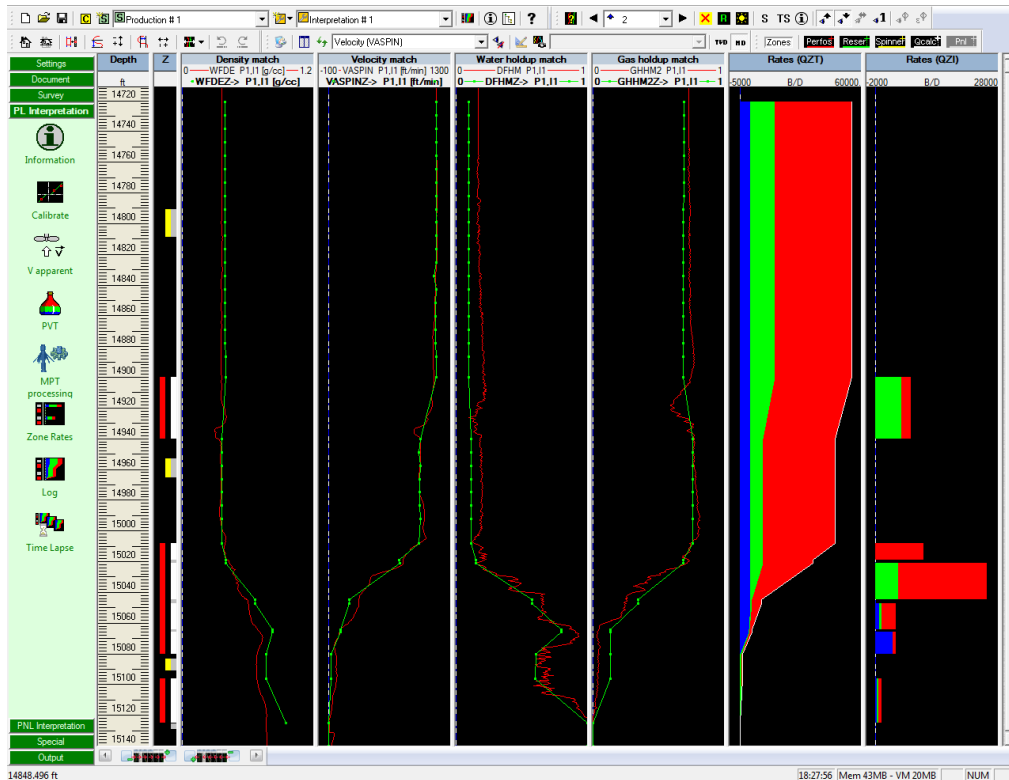


Fig. B03.7 • All phase contributions with the same sign on each interval

### B03.2.2 • Imposing other constraints

In the 'Contributions' tab you can type the inflow zones as 'Undefined', 'Closed', 'Producing', or 'Thieve'. The same can be done in the 'Zones' dialog called from the toolbars with Zones. Note that this dialog can also be accessed with a double click on the inflow zones in the log tracks.

This means that you can type the zones beforehand, i.e. before entering the 'Zone Rates' option. Beware that a 'Set/Reset' in the 'Init' tab resets all flags to Undefined.

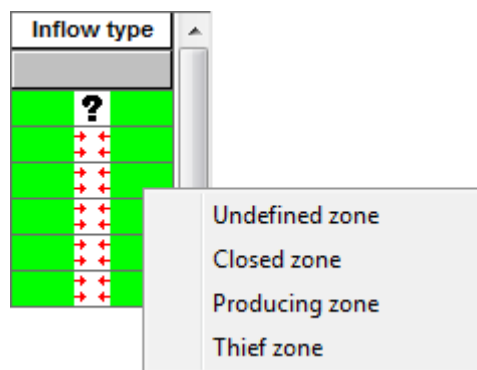




Fig. B03.8 • Inflow status in the 'Zones' dialog

In the Contribution tab you can also lock any value before running the Global Improve, as explained earlier.

### B03.3 • Interpretation with the 'Continuous' method

The 'Continuous' method differs from the 'Zoned' method in seeking in the Global Regression an agreement between the schematic logs and the data everywhere, and not just on the calculation zones. If we look at the previous Figure B03.7, we see that schematics are ... schematic, i.e. they do not show much variation outside inflow zones. This is linked to the fact that holdups are controlled by the slip model predictions. In order to give the schematics the ability to reproduce the local variations seen on the data, the 'Continuous' method treats the holdups as variables (in addition to the rates) but constrains them by the slip model holdup predictions. In other words, the holdups are freed but the process tries 'not to go too far' from the slip model prediction.

- Create a new interpretation from Interpretation #1 (default choices). Do not tick 'All elements' as we would retrieve the current solution as well, and here we want to restart from scratch, keeping the position of the calculation zones, but not the solution.
- Select the 'Continuous' method and keep an Init based on 'Zone local values'. *There are some settings associated with the Continuous method which you can check with . They represent additional constraint on the slippage velocities.*
- Click on  and uncheck 'constrain slippage sign'.
- Close the window with OK.

'Zone Rates' is renamed 'Inflow Rates' to emphasize that the 'Continuous' methods is really about solving at once for the inflows, rather than solving the zones individually.

- Click on 'Inflow Rates'.

A first solution has been obtained, based on a series of local regressions. The difference with the 'Zoned' approach so far is that holdups were treated as variables while the slip models were used as constraints. This first solution is in any case not the one we are after since the Continuous method really aims at running the Global Improve.

- Check the 'Match surface conditions' box.
- Set the 'Bottom' zone to 'Closed' by clicking in the 'Contribution' column.
- Move the window to see the changes in the schematics as the regression is going on.
- Click on 'Global Improve'. The schematics are updated after each iteration and the successive rates are seen on the QZT and QZI tracks.
- Validate the Inflow Rates results with OK.

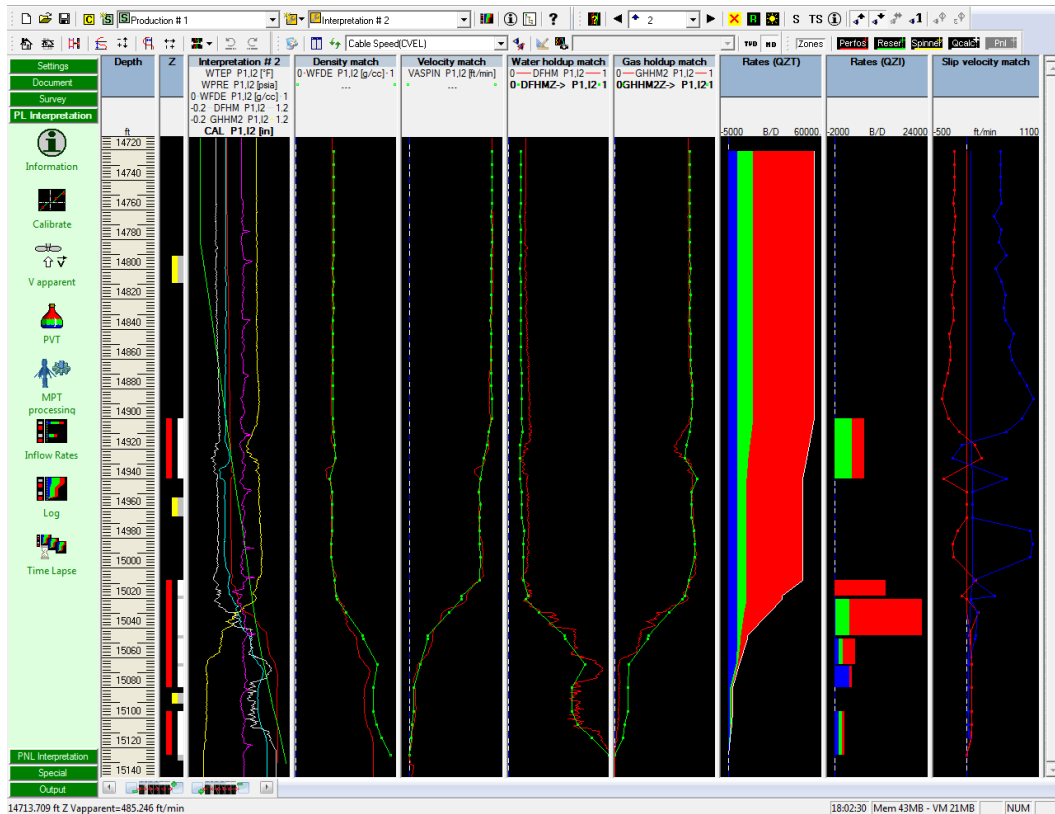


Fig. B03.9 • All phase contributions with the continuous method

It is now interesting to compare the results of both methods. The 'Continuous' method gives a better match for the density, the water holdup and the gas holdup. A new curve is displayed on the right side titled 'Slip velocity match'. As the 'Continuous' method allows the holdups to differ from the slip model holdup prediction, this track shows the difference between the slip model predictions (solid lines) and the slip velocities used by Emerade for liquid-gas (in red) and for oil-water (in blue). Only the deviation from the slip models allows matching closely the holdups and the density.

The weight of the slip model constraint can be modified in the 'Rate calculation' tab. The last 2 lines of the table represent the two additional residuals on Yw and Yg. One column represents the current solution (this is the 'Calculated') while the other represents the model prediction (in the 'Measured' column). In situations where there are enough inputs to determine everything from the data, the 'Fit' check boxes on those lines are unticked automatically – see Guided Sessions #8 and #9.

Yw	0.1089	>	0.1426	3.3629	<input checked="" type="checkbox"/>	All	1	All	N/A
Yg	0.7161	>	0.7705	5.4418	<input checked="" type="checkbox"/>	All	1	All	N/A

It is possible to switch between the 'Zoned' and 'Continuous' methods at any stage of the diagnosis.

### B03.4 • Quick Interpretation mode

Holding the shift key and pressing the 'Inflow Rates' button (the button appears with a small red thunder), allows running the Global Regression without launching the 'Inflow Rates' dialog assuming that the inflows, the PVT and the interpretation inputs are properly defined. It is a way of quickly obtaining a first interpretation with all default settings.

- Create a new interpretation from Interpretation #1 (make sure to copy from this one, with the defaults).
- Select 'Continuous' method (constrain slippage sign is on by default) and 'Zone local values'. Close the window with OK.
- Double-click on the inflow zones and in the subsequent 'Zones' dialog, change the type of the bottom zone to 'Closed'.
- Leave the 'Zones' dialog with 'OK'.
- Hold the shift key and press the 'Inflow Rates' button.

The regression starts automatically and the curves are updated as the regression is in progress.

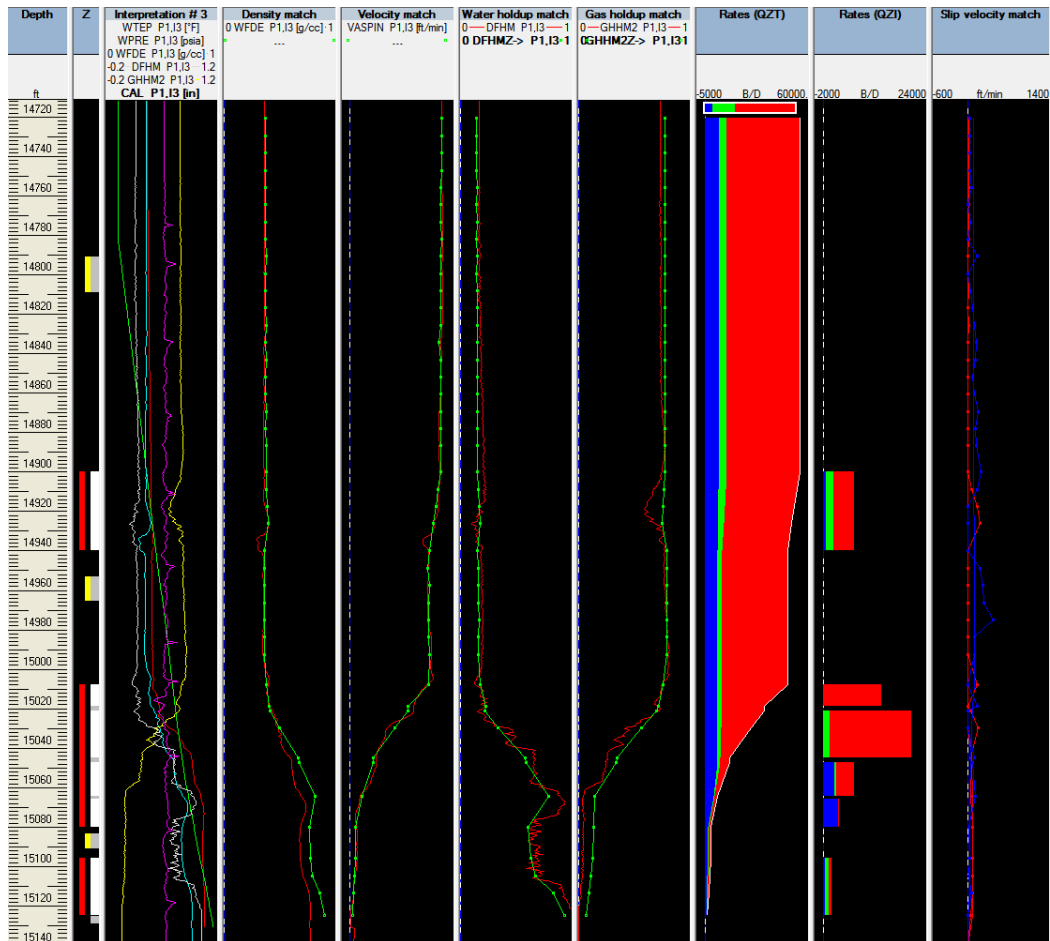


Fig. B03.10 • results with quick interpretation method

The results are different from those in Fig. B3.9 as in the automatic mode, the 'Match surface conditions' is not ticked (by default) and the 'constrain slippage sign' is ticked (by default).

In this interpretation, the slippage constraint forces the light phase to go faster than the heavy phase on upflow. One can see in the 'Slip velocity match' track, that the slippage velocity between liquid and gas (red dotted line) is positive. In the interpretation #2, with no constraint on the slippage velocity, the red dotted line is negative which would mean that the liquid goes faster than the gas.

### B03.5 • Hybrid Genetic Algorithm (HGA)

It is possible to couple the Global Regression with a pre-processing called HGA, for 'Hybrid Genetic Algorithm'. This pre-processing is particularly suited at avoiding local traps or finding a better starting point for the regression. Access to HGA is enabled in the 'Misc' tab of the 'Interpretation - Settings' panel.

When enabled, access the Global Regression through the 'Contributions' tab of the 'Zone Rates' dialog. This option shows two additional controls:

- A check box to use HGA in the next run
- A button to view/edit the HGA parameters. *This should normally not be changed.*

When running a Global Regression with the HGA option checked, a dialog appears to show the HGA progress, Fig. B03.11.

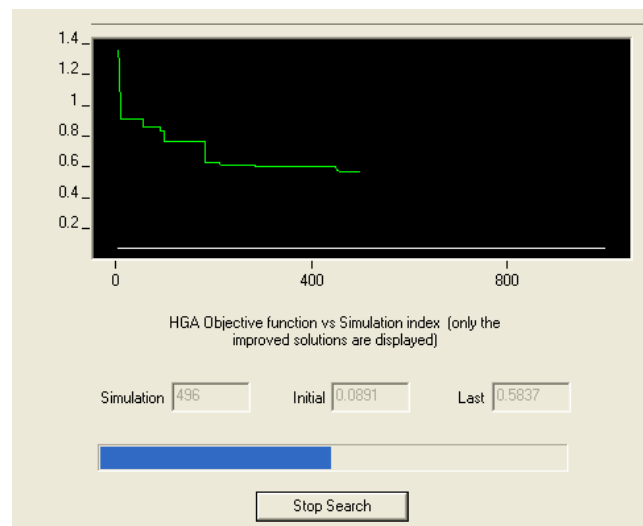


Fig. B03.11 • HGA progression dialog

In this dialog, the following information is plotted/displayed:

- In white, the value of the objective function corresponding to the solution before the call (base case).
- In green, the value of the objective function for the consecutive improvements in HGA.

#### Typical behavior

HGA is not 'biased' by the starting point and it will usually start with solutions having a much higher (worse) objective functions than the base case. Also, a Genetic Algorithm improves the solution iteratively, but unlike a classical optimization, it does not provide a systematic improvement at each iteration. This will be translated in the plot where new points are drawn only when there is an improvement. So the plot may seem to be halted for some time and then start again. An automatic scaling is executed every 5 new points.

If HGA finds a solution with an objective function smaller than the base case, then after completion or termination, this solution will be used as the new starting point of the Global Regression. If HGA stops without such a better solution, the Global Regression starts from the base case. *Note that you can stop HGA at any point, in particular if you see that it successfully reduced the objective function.*

You can experiment with HGA on the current example but it is better done in Interpretation#1, the one using the 'Zoned' approach. In the others, the CPU cost is much more significant and the process will be much slower.

*This concludes the third Guided Interpretation. Again, it must be stressed that the input data for this example is partly synthetic. The objective of the chapter was only to demonstrate software options that can be applied to resolve inconsistencies in rate profiles.*