MatchingPro®

MatchingPro® is the latest innovative history matching (HM) technology from NITEC that is very easy to use, fully utilizes available computing resources, and provides fast, reliable HM solutions. ***MatchingPro*** only requires a reservoir simulation model combined with historical production, injection, and pressure data to accurately and efficiently determine the best HM solution based on the selected HM parameters. Unlike other HM tools, ***MatchingPro*** utilizes all historical production and pressure data points.

MatchingPro can function in auto or manual modes to achieve a high quality HM solution. In the ***MatchingPro*** auto mode, simulation cases are designed, run, and evaluated without user intervention. The number of simulation cases required is typically six to eight times the number of HM parameters. HM quality measurements are updated and displayed with each new simulation case that is run. The process is expedited by utilizing multiple computer CPUs, when available.

MatchingPro's cutting edge technology makes use of Artificial Neural Networks (ANN), Genetic Algorithms (GA), and statistical methods. These algorithms quickly reveal the complex relationships among the HM parameters and the simulation results (the mismatch in simulated versus historical volumes and pressures). ***MatchingPro*** quantifies the quality of each HM case and recommends the best combination of HM parameters to achieve the best HM solution. ***MatchingPro*** can also determine multiple HM solutions (model characterizations) and provide a quantification of their probabilities of occurrence.

Reservoir simulation is a key tool in the asset manager's quest to maximize recoveries and enhance reserves. History matching of reservoir simulation models is a critical step in the reservoir evaluation and field development process.

*Use **MatchingPro** to rapidly achieve better history match solutions!*

MatchingPro History Matching	Traditional History Matching
♦ Uses time and resources efficiently	♦ Consumes significant time and man-hours
♦ Calculates multiple HM solutions	♦ Calculates one HM solution
♦ Quantifies uncertainty	♦ Visualize results subjectively
♦ Searches for global minimum	♦ Finds one local minimum solution
♦ Performs multiple simultaneous calculations	♦ Performs single serial calculations
♦ Varies all HM parameters simultaneously	♦ Varies one HM parameter at a time
♦ Determines complex non-linear correlations	♦ Can mentally deduce one parameter sensitivity
♦ Utilizes genetic algorithms and artificial neural networks	♦ Assumes insensitivity to other HM parameters
♦ Utilizes statistical methods for minimization	♦ Uses human intuition-based interpretative approach
♦ Provides analysis, plotting, and display capabilities	♦ Provides standard line plots ("Normal Line plots")
♦ Utilizes all historical data	♦ Requires thinning of historical data

Benefits of MatchingPro

- Reduces Number of Simulation Runs
- Reduces HM Run Analysis Time
- Requires Limited User Intervention
- Quantifies HM Quality
- Creates Multiple, Acceptable HM Solutions
- Efficient Search for Global Minimum
- Interfaces with Many Simulators
- Utilizes all historical data points

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The *MatchingPro* Process

MatchingPro streamlines the history matching process. Once the historical data are loaded and the HM parameters and objective functions are defined, ***MatchingPro*** commences a pre-determined iterative process. Simulation cases are created, run, analyzed, and displayed as each case is completed until the entire routine is finished. Once all of the runs are executed, the final plot reveals the best HM solution.

Data Loading

The observed performance data sets are easily loaded into ***MatchingPro***. This includes: individual well monthly production or injection volumes; static reservoir pressures from build-up tests or shut in wells; and dynamic bottom-hole pressures from flowing wells. Thinning of the historical data is not required.

HM Parameters and Objective Function Definition

The HM parameters and their associated physical ranges are defined via an interactive window (Figure 1). The parameters can be continuous or discrete by defining them as real (linear or logarithmic), or as integer.

In order to search for the best solution (defined as a set of HM parameters) or multiple solutions, an objective function is defined (Figure 2). The objective function weighs each "mismatch variable" (oil, water, and gas production, injection, and pressure) for use in the minimization calculations. The mismatch can be minimized for selected wells, gathering centers, or the total field. ***MatchingPro*** includes a default objective function that is applicable to most situations. The objective function can be modified at any time during the history matching exercise (auto or manual mode) and does not require repeating of the simulation cases or regeneration of the correlation model.

MatchingPro Process Initiation

Once the objective function is defined, ***MatchingPro*** requires a few simple steps before the pre-determined iterative process can occur. The ***MatchingPro*** auto process setup defaults to a set of simulation runs and ANN and GA processes that are tailored to common reservoir problems. However, the defaults can be overridden by individually specifying the number of scoping, investigation, and minimization runs to be executed.

Result Viewing and Interpretation

While the ***MatchingPro*** auto process progresses, a chart of the objective function value (a measure of the total HM mismatch) for each case is displayed and updated. Status bars reveal the current progress by indicating the number of completed, active, and queued simulation runs. This process is based on the number of HM parameters, analysis of the results at various stages in the process, and experience with the process algorithms. The smallest objective function value (Figure 3) corresponds to the smallest mismatch based on the objective function definition. The best HM solutions will typically occur in the last few simulation runs.

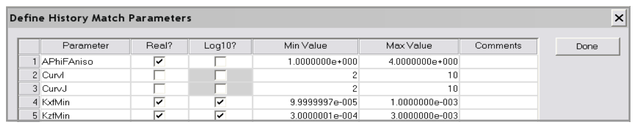


Figure 1—History Match Parameters Definition

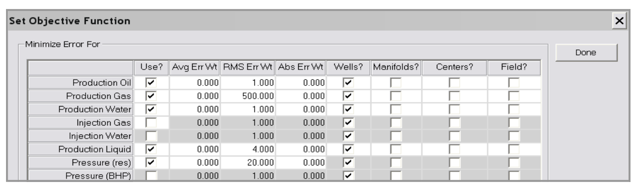


Figure 2—Objective Function Definition

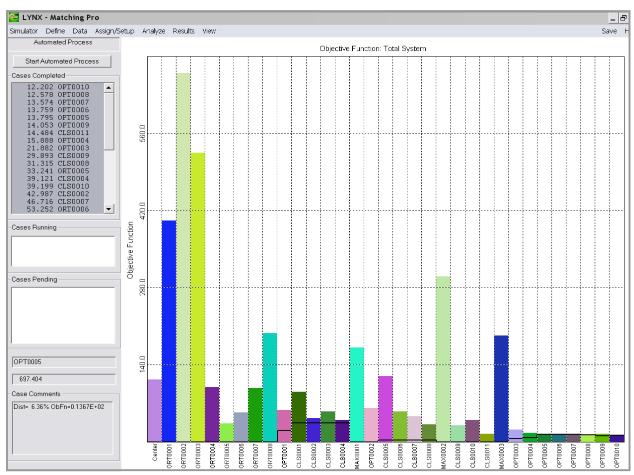


Figure 3—Completed History Match Cases

Multiple HM Solutions

One of the unique features of ***MatchingPro*** is the ability to generate multiple history match solutions for the same HM problem. ***MatchingPro*** also calculates the probability of occurrence of the set of HM parameters determined for each acceptable HM solution. The minimized objective function value is typically very similar for each solution. However, these different solutions may result in very different performances in the prediction cases. This highlights the well known non-uniqueness of HM solutions.

Once the ***MatchingPro*** process has completed and a satisfactory history match solution has been found as exhibited by the very low objective function value (Figure 3), the user can utilize ***MatchingPro's*** solution clustering algorithm to determine multiple HM solutions. These solutions may be equally acceptable from the perspective of the objective function (overall HM error), but will have different values for the individual HM parameters

The user can utilize ***MatchingPro's*** Monte Carlo technology to sample the correlation model, say one million times. From this sample, the user can request the number of multiple HM solutions desired. ***MatchingPro's*** clustering technology groups these solutions accordingly and calculates the probability of occurrence for each (Figure 4).

Each of these solutions has different HM parameter values, but the objective function value is very similar indicating an equally acceptable solution (Figure 5).

While the HM parameter values appear similar, experience indicates that very minor differences in the final HM parameters can result in significant variations in prediction results.

Figure 6 shows the predicted performance for a well in a large field where three HM solutions were generated. The predicted performance for the same operating scenario was quite different for the three cases.

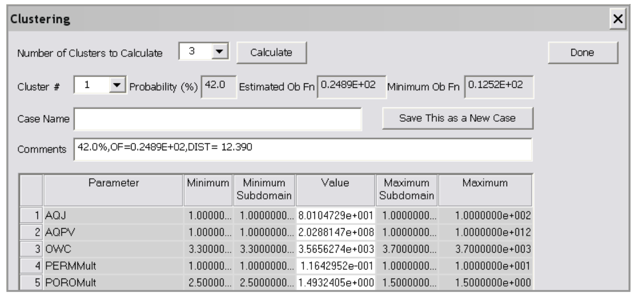


Figure 4—One of Multiple HM Solutions

	AQJ	AQPV	OWC	PERMMult	POROMult
A1	2.0124128e+000	2.5561206e+011	3.5433201e+003	2.4657424e-001	1.1964288e+000
A2	2.1816943e+000	2.5265550e+011	3.5481157e+003	2.6533189e-001	1.1909019e+000
A3	2.0676370e+000	2.9934466e+011	3.5487073e+003	2.5977680e-001	1.2017276e+000
CLS0001	2.0468192e+000	6.8822342e+011	3.6260952e+003	1.8617412e-001	1.4198650e+000
CLS0002	1.5394729e+000	6.2575161e+010	3.6891411e+003	1.0145210e-001	1.0364323e+000
CLS0003	1.1419632e+001	2.4752310e+011	3.6857454e+003	3.6460683e-001	1.1027839e+000
CLS0004	1.3847901e+000	5.8834280e+010	3.6053367e+003	3.1164932e-001	1.2759347e+000

Figure 5—HM Parameters for Multiple HM Solutions (A1, A2, A3)

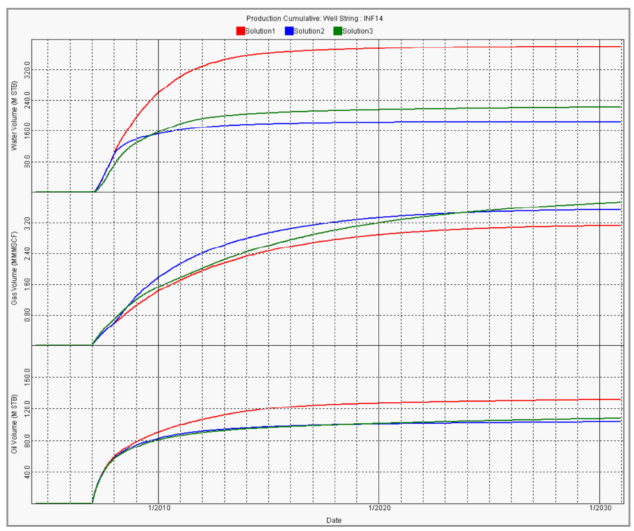


Figure 6—Common Prediction for Multiple HM Solutions

Case Study: Sample Reservoir

The sample reservoir is an actual reservoir located in the United States that has been modified to protect confidentiality. This reservoir has 15 years of history, 34 production wells, and 7 water injection wells. ***MatchingPro*** was used to achieve a satisfactory history match of the historical oil, water, and gas production and reservoir pressure.

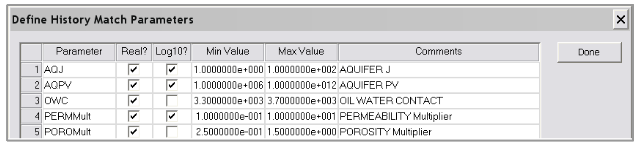
Five HM parameters (Figure 7) were identified and the minimum and maximum values for each were selected. AQJ and AQPV were parameters in the Fetkovich aquifer function. OWC was the original oil-water contact in the reservoir. PERMMult and PoroMult were global multipliers for the permeability and porosity distributions in all layers, respectively.

Default values were selected for the number of scoping, investigation, and minimization simulation cases to be processed. During the case creation, simulation run, and analysis process, the user is continuously updated on the status of the runs and the HM results.

MatchingPro's auto mode was used to create and process 42 simulation cases using the SENSOR® reservoir simulator developed and marketed by Coats Engineering. The HM parameters were varied for each of the cases. The HM objective function plot was generated by ***MatchingPro*** (Figure 8). In completing the runs for the 42 cases, the total processing time required to achieve the history match was approximately 15 times the processing time for a single, average simulation run. This is because most of the runs are independent of each other and they were executed simultaneously using multiple CPUs. There was no user intervention during the process.

Figure 9 shows the individual HM parameter values for various cases generated during the ***MatchingPro*** process.

The conventional total field production rate plot is displayed in Figure 10. The historical production and two simulation cases are shown—the Center (initial "mid-point") case and the best HM solution (OPT0012).



Define History Match Parameters

	Parameter	Real?	Log10?	Min Value	Max Value	Comments
1	AQJ	✓	✓	1.0000000e+000	1.0000000e+002	AQUIFER J
2	AQPV	✓	✓	1.0000000e+006	1.0000000e+012	AQUIFER PV
3	OWC	✓		3.3000000e+003	3.7000000e+003	OIL WATER CONTACT
4	PERMMult	✓	✓	1.0000000e-001	1.0000000e+001	PERMEABILITY Multiplier
5	POROMult	✓		2.5000000e-001	1.5000000e+000	POROSITY Multiplier

Figure 7—History Match Parameters Definition

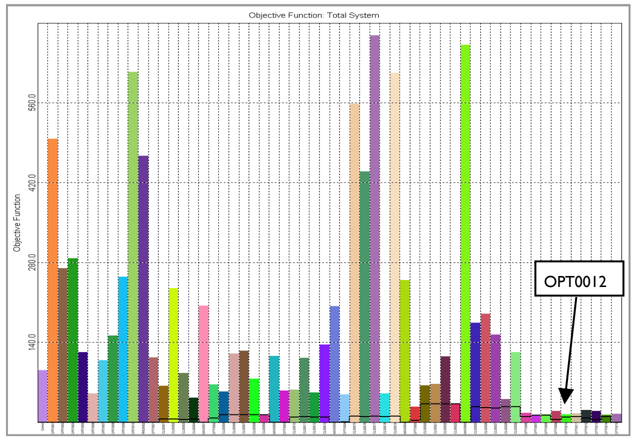


Figure 8—Objective Function by Simulation Case

	AQJ	AQPV	OWC	PERMMult	POROMult
OPT0007	2.0598567e+000	2.8621835e+011	3.5499006e+003	2.7141771e-001	1.2080915e+000
OPT0008	2.0498061e+000	2.8192670e+011	3.5502678e+003	2.7278143e-001	1.2087119e+000
OPT0009	2.2115536e+000	3.9392556e+011	3.5418499e+003	2.2251274e-001	1.2417490e+000
OPT0010	2.2106280e+000	2.4199119e+011	3.5450681e+003	2.5270379e-001	1.1828344e+000
OPT0011	1.9616556e+000	3.2533945e+011	3.5430525e+003	2.5899589e-001	1.2151169e+000
OPT0012	2.3362288e+000	3.4344426e+011	3.5587512e+003	2.6087725e-001	1.2116386e+000
OPT0013	2.0013552e+000	7.7006103e+010	3.5505671e+003	2.6036981e-001	1.3204433e+000
OPT0014	2.0679781e+000	2.8835630e+011	3.5488408e+003	2.6246098e-001	1.2053182e+000

Figure 9—HM Parameter Values

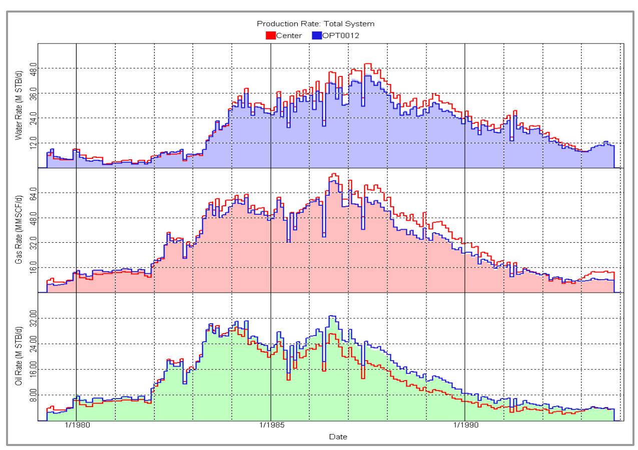


Figure 10—Field Production Rate vs. Time