

# **TIGHT-GAS PRODUCTION ANALYSIS:**

## **User Guide for a Type-Curve Matching Spreadsheet Program (TIGPA 2000.1)**

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# 1. What This Program Can Do for You?

The software, **TIGPA 2000.1** (Tight-Gas Production Analysis), is a MICROSOFT EXCEL™ spreadsheet program for production data analysis based on type-curve matching principles. **TIGPA 2000.1** is applicable for any type of well/reservoir/fluid system, but is particularly suitable for tight-gas wells. Tight-gas wells are expected to have the following two unique flow characteristics:

- long transient flow in the time scale due to the “tight” permeability, and
- near-linear “flow geometry” due to the combined effects of “tight” permeability and the practical necessity of hydraulic fracturing.

The above two flow characteristics turn out to be advantageous to the analysis of production data using type-curve methods.

**TIGPA 2000.1** can contribute to a well-reservoir study in the following five major technical aspects:

- Diagnosis of *stimulation effectiveness* (in terms of near-wellbore skin).
- Assessment of *recovery efficiency* (in terms of time-dependent recovery factor with respect to initial fluid-in-place and well spacing).
- Estimation of reservoir *flow properties* (in terms of permeability, flow capacity, and productivity factor).
- Estimation of reservoir *storage properties* (in terms of drainage pore volume/area and fluid-in-place).
- Projection of *future rate-time schedule* and *EUR* (Estimated Ultimate Recovery).

Additionally, the computerized type-curve matching and analysis reduce the turn-around time especially when large number of wells are involved.

We are continuously improving the spreadsheet program. Within the scope of the five major technical aspects mentioned above, current version puts more emphasis on the first four technical aspects (diagnosis and estimation) than the last aspect (future projection).



## 2. How to Open the Program?

### PROCEDURES:

- Double click the program TIGPA 2000.1.
- Click the ***Enable Macros*** button.
- Now you are in the **MAIN PROGRAM Window**.

### REMARKS:

- MICROSOFT EXCEL™ is required.
- There are two major parts in the **MAIN PROGRAM Window**: (1) input (two major files), and (2) execution functions (six major buttons and three minor buttons). All these will be described in Sections 3 and 4.





### **3. How to Execute the Program?**

There are five major steps to execute the program. These are:

- Input well-reservoir and fluid PVT information
- Input production data
- Perform type-curve matching
- Estimate well-reservoir properties
- Forecast future performance

They will be explained sequentially in the following sections (Sections 3.1 through 3.5).

### 3.1 Input Well-Reservoir and Fluid PVT Information

**WINDOW:** MAIN PROGRAM Window (see Fig. 3.1).

**MAIN PROGRAM**

Well ID: WELL A  
Field: DAKOTA  
Location: New Mexico  
Company: NMT

User PVT: [Dropdown Menu]

**RESERVOIR & PVT DATA**

**Required:**

Initial Reservoir Pressure, $p_i$	1625 psi
Flowing BHP, $p_{wf}$	550 psi
Producing Thickness, $h$	60 ft
Porosity, $\phi$	8.5 %
Initial Water Saturation, $S_{wi}$	40 %
Wellbore Radius, $r_w$	0.33 ft
Frac. of 360° Open to Flow, $\alpha$	0.159
Reservoir Temperature, $T$	107 °F
Specific Gravity, $\gamma$	0.6
Water Compressibility, $c_w$	0.000006 1/psi
Rock Compressibility, $c_r$	0.000003 1/psi
Mole Fraction of $N_2$	0 Frac.
Mole Fraction of $CO_2$	0 Frac.
Mole Fraction of $H_2S$	0 Frac.
Abandonment Rate, $q_{abd}$	5 Mscf/d
Current Cumulative Prod., $Q$	550464 Mscf

**Calculated:**

Initial z-Factor, $z_i$	0.8000
Initial FVF, $B_i$	1.4440 rb/Mscf
Initial Viscosity, $\mu_i$	0.0162 cp
Initial Total Compressibility, $c_{ti}$	3.70E-04 1/psi

**Optional:**

Date of First Prod., M/D/Y	5/1/71
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Buttons: Production Data, Matching, Rate vs. Time, Rate vs. Cum, Cum vs. Time, Estimation, Forecast, Save as, Save & Close

**Fig. 3.1 – The MAIN PROGRAM Window.**

#### PROCEDURES:

- Fill in well-field information including Well ID, Field name, Location, and Company name. They are for your record only, and have no influence on the production data analysis to be performed.
- Input reservoir and fluid-PVT data under section of **Reservoir & PVT Data**. Data is classified into three categories:
  - **Required** section: User must provide these data except the current cumulative production, which will be filled in automatically after the completion of production data input (see Section 3.2).
  - **Calculated** section:
    - Choose and click either **Program PVT** or **User PVT** option.
      - **Program PVT:** The program computes PVT properties (z-factor, FVF, viscosity, and total compressibility) for you based on published correlations and the information provided in the **Required** section. If you choose this option, all the listed information will be filled in automatically.

- **User PVT:** Input your own PVT properties. If you choose this option, just fill in values as normal way.
- **Optional** section: For your record only.

The above PVT options change the nature of the “required” information. **Table 3.1** summarizes what are really required based on the above two PVT options. As shown, the input format in the **MAIN PROGRAM Window** is based on the option of **Program PVT**. Some of the “required” inputs become unnecessary if you choose to input your own PVT data (i.e., **User PVT** option). Again, the current cumulative production, although marked as “required” in Table 3.1, is retrieved automatically from the production file by the program.

**Table 3.1 – Data requirements for two PVT options.**

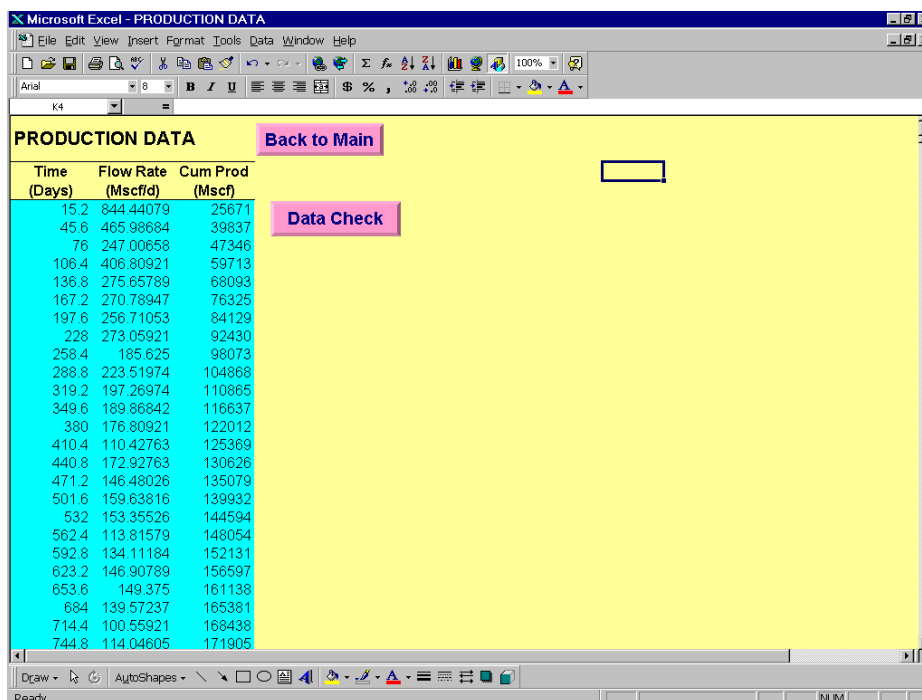
RESERVOIR & PVT DATA		PVT Options	
		Program PVT	User PVT
<b>Required:</b>			
Initial Reservoir Pressure, $p_i$	psi	●	●
Flowing BHP, $p_{wf}$	psi	●	●
Producing Thickness, $h$	ft	●	●
Porosity, $\phi$	%	●	●
Initial Water Saturation, $S_{wi}$	%	●	●
Wellbore Radius, $r_w$	ft	●	●
Frac. of 360° Open to Flow, $\sigma$	fraction	●	●
Reservoir Temperature, $T$	°F	●	–
Specific Gravity, $\gamma$	–	●	–
Water Compressibility, $c_w$	psi <sup>-1</sup>	●	●
Rock Compressibility, $c_f$	psi <sup>-1</sup>	●	●
Mole Fraction of N <sub>2</sub>	fraction	●	–
Mole Fraction of CO <sub>2</sub>	fraction	●	–
Mole Fraction of H <sub>2</sub> S	fraction	●	–
Abandonment Rate, $q_{abd}$	Mscf/d	●	●
Current Cumulative Prod., $Q$	Mscf	●	●
<b>Calculated:</b>			
Initial z-Factor, $z_i$	–	–	●
Initial FVF, $B_i$	rb/Mscf	–	●
Initial Viscosity, $\mu_i$	cp	–	●
Initial Total Compressibility, $c_{ti}$	psi <sup>-1</sup>	–	●
<b>Optional:</b>			
Date of First Prod.	M/D/Y	○	○
Date of Last Prod.	M/D/Y	○	○

● Required    – Not required    ○ Optional

**NOTE:** (1) Only US field units as specified in the **MAIN PROGRAM Window** are allowed. (2) PVT options are not available for liquid cases at current version.

## 3.2 Input Production Data

**WINDOW:** PRODUCTION DATA Window (see Fig. 3.2).



Time (Days)	Flow Rate (Mscf/d)	Cum Prod (Mscf)
15.2	844.44079	25671
45.6	465.98684	39837
76	247.00658	47346
106.4	406.80921	59713
136.8	275.65789	68093
167.2	270.78947	76325
197.6	256.71053	84129
228	273.05921	92430
258.4	185.625	98073
288.8	223.51974	104868
319.2	197.26974	110865
349.6	189.86842	116637
380	176.80921	122012
410.4	110.42763	125369
440.8	172.92763	130626
471.2	146.48026	135079
501.6	159.63816	139932
532	153.35526	144594
562.4	113.81579	148054
592.8	134.11184	152131
623.2	146.90789	156597
653.6	149.375	161138
684	139.57237	165381
714.4	100.55921	168438
744.8	114.04605	171905

**Fig. 3.2 – The PRODUCTION DATA Window.**

### PROCEDURES:

- Click the **Production Data** button (in the **MAIN PROGRAM Window**) will lead you to the **PRODUCTION DATA Window**.
- Open the EXCEL™ file where you have the production data. (EXCEL™ Open command). Your file should contain production information in terms of time (days), flow rate (or rate, Mscf/d), and cumulative production (or cum, Mscf).
- Select and copy the time, rate, and cum data. (EXCEL™ Copy command).
- Go back to **PRODUCTION DATA Window**.
- Go to Cell “A6” (the first data cell under the **Time** column).
- Paste into the program (as values). (EXCEL™ Paste Special command).
- Delete unwanted information, if necessary.
- As an option, you may need to correct down times.
 

The **Data Check** button provides an option to correct down times (shut-in times). The “corrected time” is the effective flowing-time. This procedure is recommended if your data has long shut-in time period(s). Continuous production is assumed in the type-curves. Therefore, excessive long shut-in period(s) can result in erroneous analysis.
- Click **Back to Main** button to go back to the **MAIN PROGRAM Window**.

### 3.3 Perform Type-Curve Matching

**WINDOW:** **MATCHING PROCESS Window** together with three sets of production type-curves (see Fig. 3.3):

- **RATE vs TIME** type-curves ( $q_{dD}$  vs.  $t_{dD}$ ; top-left),
- **CUM vs TIME** type-curves ( $Q_{dD}$  vs.  $t_{dD}$ ; bottom-left), and
- **RATE vs CUM** type-curves ( $q_{dD}$  vs.  $Q_{dD}$ ; top-right).

The purpose here is to perform matching between your production data and the designed type curves. Type curves (dimensionless) are generated by mathematical models with prescribed assumptions. The process to be performed here is essentially a “history matching” process.

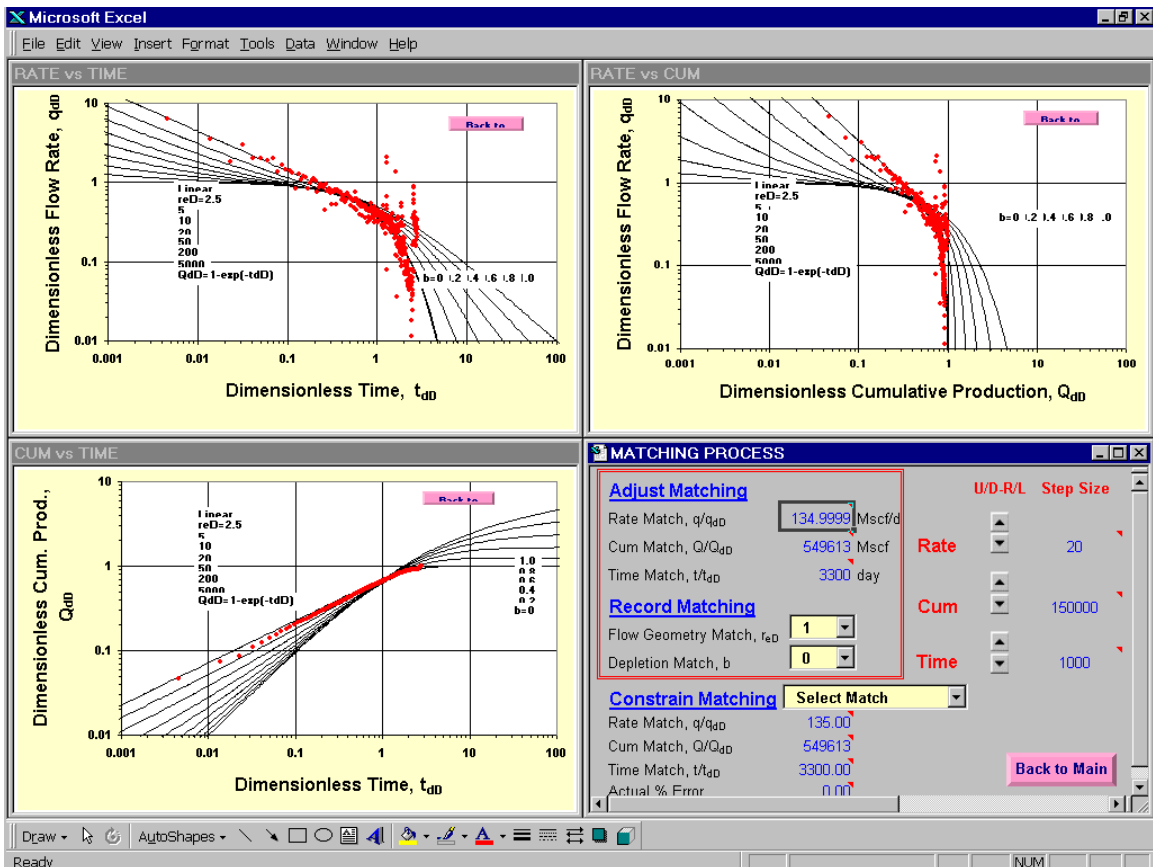


Fig. 3.3 – The MATCHING PROCESS Window.

## PROCEDURES:

- Click the **Matching** button (in the **MAIN PROGRAM Window**) to go to the **MATCHING PROCESS Window**. Also shown are the three sets of type-curves and your production data.
- From now on the procedures are divided into three major steps: (1) adjust matching, (2) record matching, and (3) constrain matching. The first two steps are required while the third step is recommended.

### Adjust Matching (Required)

This is the type-curve matching process. The purpose is to find a type curve that “best” matches your production data. The process involves adjusting the values of three matching parameters: **Rate Match** ( $q/q_{dD}$ ), **Cum Match** ( $Q/Q_{dD}$ ), and **Time Match** ( $t/t_{dD}$ ). Adjusting these values can be done by two alternative ways:

- manually change the values directly, or
- using the “arrow buttons” and **Step Size** controls.

The second method is easier to operate and is described below.

- Choose either **Rate Match**, **Cum Match**, or **Time Match** to start with.
- Input an appropriate **Step Size** corresponding to the selected match to control the “speed” of curve movements.
- Click the corresponding arrow-button to move *your* production curve (*not* the type-curves) up/down or right-left and try to obtain a match to one of the type curves. There are three sets of type curves you can match: (i) rate-time (top-left), (ii) cum-time (bottom-left), and (iii) rate-cum (top-right); see Fig. 3.3.
  - When adjusting the **Rate Match**, you should be able to see the up/down movements of your production curve in *both* rate-time (top-left) and rate-cum (top-right) windows. You also can see the simultaneous change in the **Rate Match** value.
  - When adjusting the **Cum Match**, you should be able to see the up/down movements of your production curve in cum-time (bottom-left) window and the right/left movements in the rate-cum (top-right) window. You also can see the simultaneous change in the **Cum Match** value.
  - When adjusting the **Time Match**, you should be able to see the right/left movements of your production curve in *both* rate-time (top-left) and cum-time (bottom-left) windows. You also can see the simultaneous change in the **Time Match** value.
- As an option, you can examine matches at a larger scale. Go back to the **MAIN PROGRAM Window**. There are three buttons under the **Matching** button: **Rate vs. Time**, **Rate vs. Cum**, and **Cum vs. Time**. Each one allows you to see the quality of the matching at a larger scale.

- Perform the second match, and then the third match. The process is iterative in the sense that the “best” match has to satisfy all three, rate, cum, and time, matches.

### Record Matching (Required)

Five matching parameters can be obtained from a type-curve matching process: (1) rate match,  $q/q_{dD}$ , (2) time match,  $t/t_{dD}$ , (3) cum match,  $Q/Q_{dD}$ , (4) flow geometry match,  $r_{eD}$ , and (5) depletion match (or Arps’ decline exponent),  $b$ . The program simultaneously updates and records the first three matching parameters during a matching process.

*You are required* to record the **Flow Geometry Match**  $r_{eD}$  and **Depletion Match**  $b$ , based on your final match and the allowable values provided. These two matching parameters may not be easy to read from the window. The same type-curves are presented in **Appendix A** to assist the correct readings. Also, if your data does not exhibit clear boundary effects to identify definite  $b$  value, choose  $b = 0$  (for a conservative future).

Click **Back to Main** button to go back to the **MAIN PROGRAM Window** if you are not interested in the **Constrain Matching**.

### Constrain Matching (Recommended)

In principle, only one unique set of reservoir properties is associated with a given set of production data. Specifically, the results obtained by different sets of type-curves (rate-time, cum-time, and rate-cum) should be the same. In practice, this may not be true because of, e.g., data quality. You may need to “force” the three type-curve matches (rate-time, cum-time, and rate-cum) into a set of consistent answers. **Constrain Matching** is designed to accomplish this task. The criterion of the constrain is related to four matching parameters: rate, cum, time, and flow-geometry matches. The criterion is nothing to do with the depletion match.

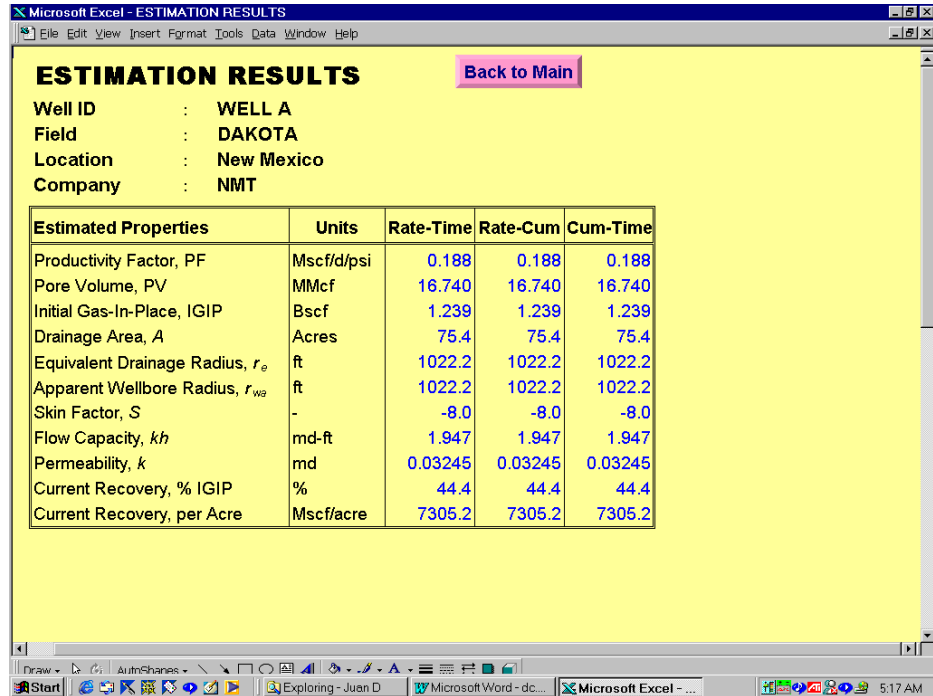
The matching parameter you want to constrain is selected in the **Select Match**. There, you may choose **Constrain Rate-Match**, **Constrain Cum-Match**, or **Constrain Time-Match**. In all cases, the program considers the flow-geometry match selected in the earlier step is a fixed value. The % error shown should be zero if you exercise this **Constrain Matching** option.

You should expect to see identical results (Section 3.4) in all three types of matches.

Click **Back to Main** button to go back to the **MAIN PROGRAM Window**.

### 3.4 Estimate Well-Reservoir Properties

**WINDOW:** ESTIMATION RESULTS Window (see Fig. 3.4).



**ESTIMATION RESULTS** [Back to Main](#)

Well ID : WELL A  
 Field : DAKOTA  
 Location : New Mexico  
 Company : NMT

Estimated Properties	Units	Rate-Time	Rate-Cum	Cum-Time
Productivity Factor, PF	Mscf/d/psi	0.188	0.188	0.188
Pore Volume, PV	MMcf	16.740	16.740	16.740
Initial Gas-In-Place, IGIP	Bscf	1.239	1.239	1.239
Drainage Area, A	Acres	75.4	75.4	75.4
Equivalent Drainage Radius, $r_e$	ft	1022.2	1022.2	1022.2
Apparent Wellbore Radius, $r_{wa}$	ft	1022.2	1022.2	1022.2
Skin Factor, S	-	-8.0	-8.0	-8.0
Flow Capacity, $kh$	md-ft	1.947	1.947	1.947
Permeability, $k$	md	0.03245	0.03245	0.03245
Current Recovery, % IGIP	%	44.4	44.4	44.4
Current Recovery, per Acre	Mscf/acre	7305.2	7305.2	7305.2

**Fig. 3.4 – The ESTIMATION RESULTS Window.**

#### PROCEDURES:

- Click *Estimation* button (in the **MAIN PROGRAM Window**) to go to the **ESTIMATION RESULTS Window**.
- Calculated reservoir properties are listed for each set of type-curve matching. As pointed out in the previous section, they should be identical if you constrained the type-curve matches. They should agree with each other within a reasonable range even without constraining. If this is not true, you need to identify what are the causes and, perhaps, rematch the data.
- Click *Back to Main* button to go back to the **MAIN PROGRAM Window**.



### 3.5 Forecast Future Performance

**WINDOW:** FORECAST Window together with three final real-time matches (see Fig. 3.5):

- *REAL RATE vs CUM* match,
- *REAL CUM vs TIME* match, and
- *REAL RATE vs TIME* match.

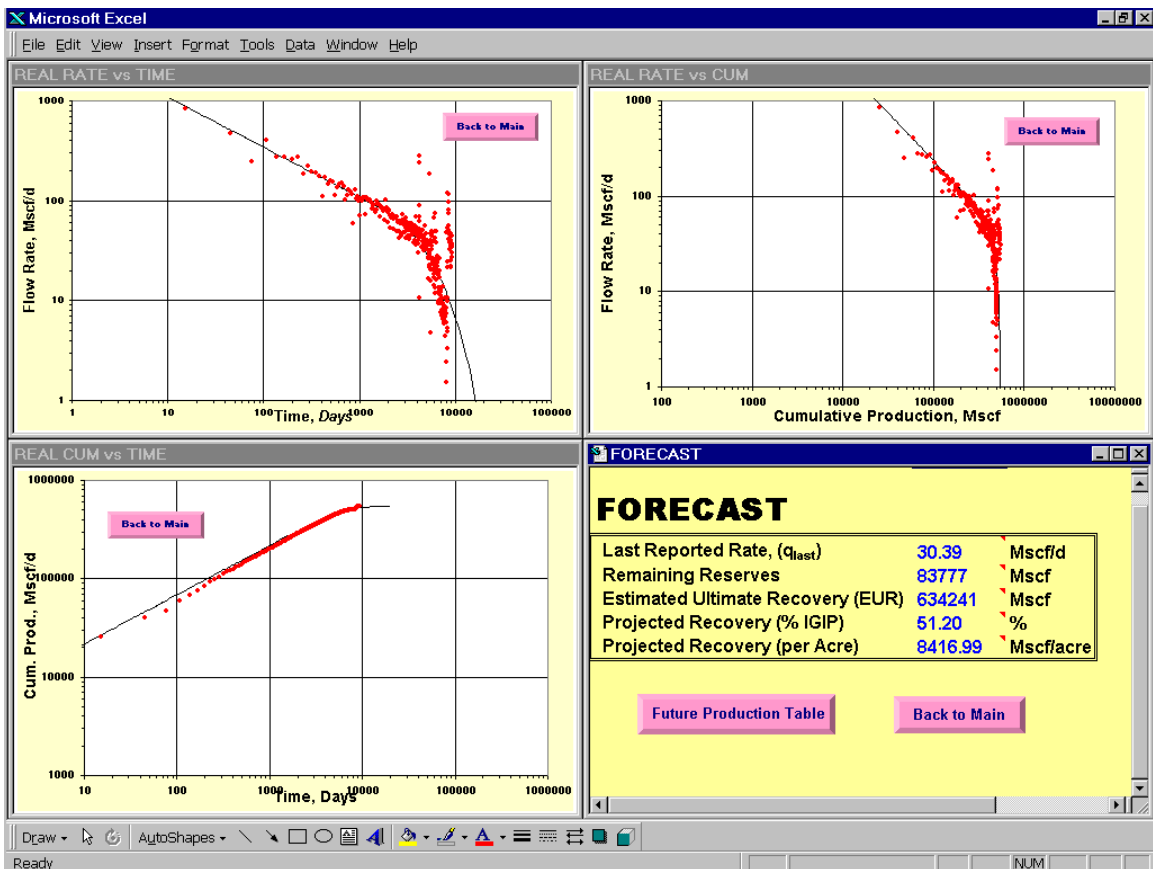
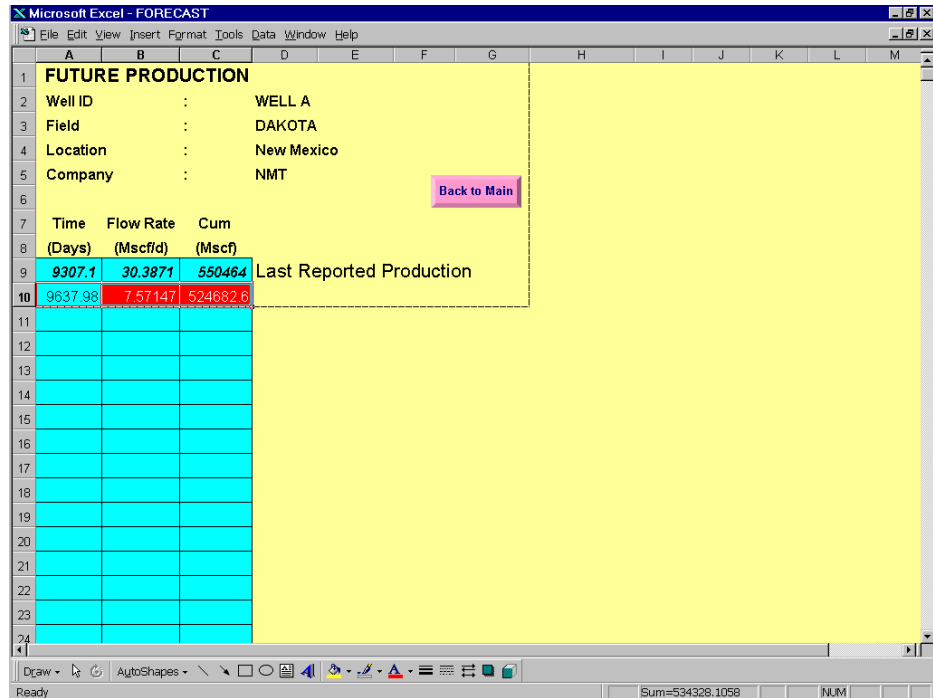


Fig. 3.5 – The FORECAST Window.

#### PROCEDURES:

- Click **Forecast** button (in the **MAIN PROGRAM Window**) to go to the **FORECAST Window**.
- Here, you can examine your matches (rate-time, cum-time, and rate-cum) at the *real-time* scales. The continuous solid-line is the “best” match of the type-curve model. The portion beyond your last production data is the future projection. Also shown are the estimated remaining reserves, EUR (Estimated Ultimate Recovery), and projected recovery (% IGIP and per acre).

- Click the ***Future Production Table*** button to see or export (e.g., for economic analysis) the tabulated rate and cum forecasts; see **Fig. 3.6**.
- Click ***Back to Main*** button to go back to the **MAIN PROGRAM Window**.



**Fig. 3.6 – The FUTURE PRODUCTION Window.**

## 4. How to Close the Program?

### PROCEDURES:

Either one of the followings:

- Save As: Click ***Save As*** button (in the **MAIN PROGRAM Window**) to save the file under different name.
- Save and Close: Click ***Save & Close*** button (in the **MAIN PROGRAM Window**) to close the program. Current data, plots, and results will override the previous data, plots, and results.



## Appendix A: Type Curves

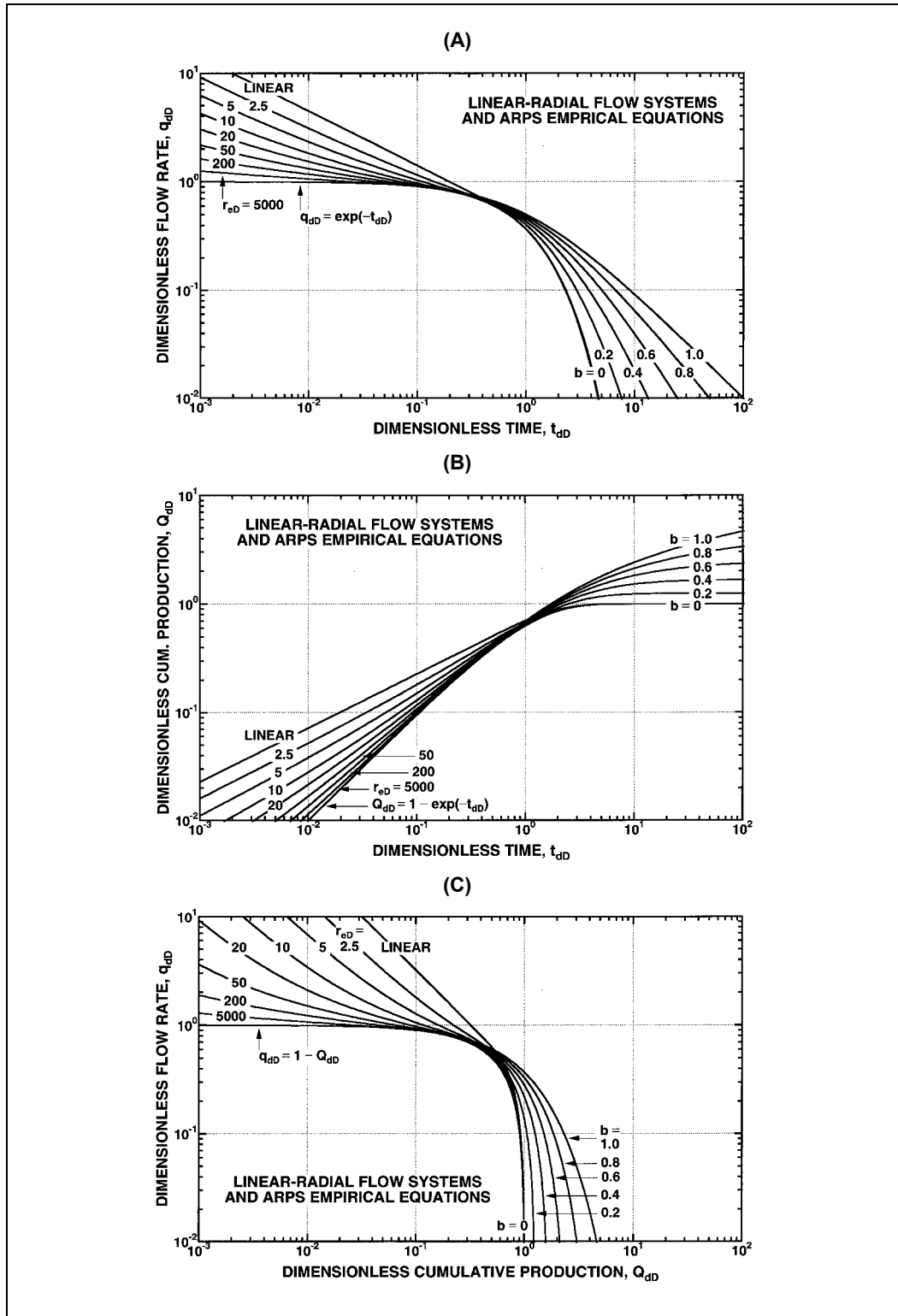


Fig. A.1 – Type curves of (A) flow rate vs. time; (B) cumulative production vs. time; (C) flow rate vs. cumulative production.



## **Appendix B: Technical Description**

All the theory and equations behind this type-curve spreadsheet program are based on the following paper:

Chen, H.Y. and Teufel, L.W.: "A New Rate-Time Type Curve for Analysis of Tight-Gas Linear and Radial Flows," paper SPE 63094 presented at the SPE Annual Technical Conference and Exhibition, Dallas, Texas, 1–4 Oct. 2000.

The paper is attached next.





## Program and Data Files

- Simulated Example:
  - EXAMPLE
  - EXAMPLE DATA
  - TIGPA2000
- Field Examples:
  - WELLA\_TCM
  - WELLB\_TCM

## Exercise

Perform the following steps:

1. Open the program “EXAMPLE.”
2. Change  $p_i$  from 2,000 psi to 3,000 psi and  $S_{wi}$  from 20% to 30%.
3. Import the production data in the “EXAMPLE DATA” into the “EXAMPLE.”
4. Perform matching.
5. Close the program “EXAMPLE.”
6. Compare your results with that shown in “TIGPA2000.”