

Users Manual

SPLITTER and MASHER

Spreadsheet Applications

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1 Overview

The Smart Well Pressure Transient Analysis system comprises two modules, Splitter and Masher. Splitter reads one or more ASCII data files containing raw EFM data, and writes a separate binary file for each well with the EFM data formatted for Masher. Masher reads the EFM data from the binary files, processes the data to identify periods of data that can be analyzed as buildup or falloff tests, and builds a workbook for each well.

2 Splitter

Splitter (workbook Splitter.xls) is used to reformat ASCII data into a consistent binary file format for Masher to read. Splitter can handle both delimited and fixed width data file formats.

2.1 FileFormat sheet

To use Splitter, first fill in the required and optional data fields in the FileFormat worksheet. Required data are highlighted in yellow; optional data are highlighted in green.

2.1.1 General section

Injection algebraic sign. Enter 1 if injection rates in the ASCII file are positive, -1 if injection rates in the ASCII file are negative.

Header rows. Enter the number of header rows in each ASCII data file. Splitter will skip these lines when reading the data files.

Format. Enter the type of formatting for the ASCII data files, 1 for delimited data and 2 for data in fixed width columns.

2.1.2 Delimit Characters

This section is used only for delimited data. For the Tab and Space fields, enter 1 if tabs and spaces, respectively, are used to delimit the data, otherwise enter 0. For the Other delimiters field, enter a list of the other delimiters as a text string. The most common delimiter is the comma, but other delimiters may be used as well.

2.1.3 Preview text

Enter a line of data from the ASCII file to be processed. The two lines above this field are guides to help you identify the beginning and ending positions for each column of data in a fixed-width file.

2.1.4 Field Setup

Enter information to tell splitter how to find the desired data fields in the ASCII text file. Date, Rate, and Pressure are always required. Time may be included as part of the Date field. If no Well ID is provided, all data are assumed to belong to the same well.

For delimited data, enter the Column number for each data field as it appears in the ASCII file. Enter 0 if the data field does not appear in the file.

For fixed-width data, enter the Start character position and Length for each field. Enter 0 for Start and Length if the data field is not present.

The Preview column to the right of the Field setup section shows how the Preview text will be parsed. The Preview values column shows the corresponding numeric values that would be written to the binary file.

2.2 Splitter sheet

The Splitter sheet is used to specify the location of the input and output files, the names of the wells to process, and the names of the individual data files to process.

2.2.1 Source directory

Enter the full pathname of the subdirectory where the input ASCII data files are located.

2.2.2 Destination directory

Enter the full pathname of the subdirectory where the output binary files are to be placed.

2.2.3 Wells

Enter the Well IDs for the wells to be processed, one well per row.

2.2.4 Files

Enter the names of the ASCII files to be processed. These files must be in ascending chronological order. Splitter may be run multiple times to append new data to the binary output files. To append data, enter only the files containing the new data.

2.2.5 Split button

Once the FileFormat and Splitter worksheets have been filled out, click the Split button to process the data. The status bar at the bottom of the Excel window will show the well and file currently being processed. The Status bar will display “Done.” to indicate that Splitter is finished. Caution—Note that the processing may take a long time. One benchmark run indicated that processing 2 years of 15-second data for 20 wells would take approximately 4 hours.

3 Masher

Masher (workbook Masher.xls) processes high frequency EFM data in binary files to identify potential buildup and falloff data. Masher also averages the high frequency EFM data over user-selected time intervals.

3.1 Field Data sheet

The Field Data sheet has places to enter data that apply for the entire field.

3.1.1 General Information section

Operator. Optional. Enter the name of the operator.

Field. Optional. Enter the name of the gas storage field.

Number of Wells. Required. Enter the number of wells in the field.

3.1.2 Engineering Data section

Initial pressure. Required. Enter the initial pressure of the storage reservoir in psia. This value is used as a reference pressure for fluid property correlations.

Gas specific gravity. Required. Enter the specific gravity of the storage gas, air=1.0. This value is used in calculating gas PVT properties.

H₂S content. Optional. Enter the H₂S content of the gas in mole percent. This value is used in calculating gas PVT properties.

CO₂ content. Optional. Enter the CO₂ content of the gas in mole percent. This value is used in calculating gas PVT properties.

N₂ content. Optional. Enter the N₂ content of the gas in mole percent. This value is used in calculating gas PVT properties.

Water compressibility. Required. Enter the compressibility of the reservoir brine at reservoir temperature and pressure. The default value of $2.5 \times 10^{-6} \text{ psi}^{-1}$ is probably good enough for most gas storage applications.

Wellhead temperature. Required. Enter the average flowing wellhead temperature for the field. This value is used in calculating bottomhole pressures from surface pressures.

3.1.3 Control Data section

Minimum flow time. Required. Enter the minimum duration of continuous flow (injection or withdrawal) prior to a candidate test period for the test to be considered valid.

Minimum shutin time. Required. Enter the minimum duration of shutin required for a candidate test period to be considered valid.

Minimum number data points. Required. Enter the minimum number of data points required for a candidate test period to be considered valid.

Points per cycle. Required. Enter the desired number of data points per log cycle after averaging the test data. Making this number smaller will make the derivative curve smoother; making it larger will give more data points. The default value of 25 seems to be a reasonable place to start.

Time window for averaging. Required. Enter the desired time window for averaging high frequency EFM data for the well history. This value must be large enough that the total number of averaged data points will be less than 32,000. To estimate the number of averaged data points, divide the duration of the period for which EFM data are being processed by the time window.

3.2 Well Data sheet

The Well Data sheet has a table of wells to be processed. The table also includes well-specific information.

Rec. No. Index number.

Active. Required. Enter 1 if the well is to be processed, 0 if the well is to be skipped.

Well ID. Required. Enter the Well ID.

Well Name. Optional. Enter the Well Name.

Well Type. Required. Enter “vertical”, “v”, or “vw” for a vertical well; enter “horizontal”, “h”, or “hw” for a horizontal well. The text may be in either upper or lower case.

Clip_Q500. Required. Enter a cutoff rate below which the flow rate (injection or withdrawal) will be considered 0, at a wellhead pressure of 500 psia. This rate is adjusted up or down for pressures higher or lower than 500 psia. The specific value required here is dependent on the metering configuration for the well.

t_{BMTR} . Required. Enter the time for the beginning of the middle time region for a vertical well, or the early linear flow period for a horizontal well.

t_{EMTR} . Required. Enter the time for the end of the middle time region for a vertical well, or the early linear flow period for a horizontal well.

MD, Top Perf. Optional. Enter the measured depth to the topmost perforation.

MD, Btm Perf. Optional. Enter the measured depth to the lowest perforation.

r_w . Required. Enter the wellbore radius in feet. Recommended value is one-half the bit diameter of the bit used to drill through the storage reservoir section.

A. Optional. Enter the estimated drainage area of the well.

T_f . Required. Enter the bottomhole or formation temperature for the well.

Net Pay. Required. Enter the thickness of reservoir quality rock in the storage interval.

Porosity. Required. Enter the porosity of the reservoir rock.

Water Sat. Required. Enter the connate water saturation of the reservoir.

Perm. Optional. Enter an estimate of the reservoir permeability.

3.2.1 Horizontal Well Data section

The data in this section are used only for horizontal wells.

Length. Required. Enter the length of the wellbore open to flow in the storage zone.

Z_{wD} . Required. Enter a number between 0.001 and 0.5 to specify the vertical position of the wellbore within the storage interval. This value is obtained by dividing the distance from the axis of the wellbore to the nearer of the upper and lower reservoir boundaries by the net pay. A value of 0.5 indicates that the well is centered vertically in the interval.

k_v/k_h . Required. Enter the ratio of permeability in the vertical direction to the geometric mean permeability in the horizontal plane.

k_x/k_y . Required. Enter the ratio of the permeability in the x -direction (in the horizontal plane, perpendicular to the axis of the wellbore) to that in the y -direction (parallel to the axis of the wellbore).

3.2.2 Tubing Segment 1..5 section

Enter data for at least 1, and up to 5, flow string segments. This data is used to convert wellhead pressure to bottomhole pressure.

Tbg Len. Required. Enter the length of the tubing (or casing) segment.

Tbg ID. Required. Enter the internal diameter of the segment.

Angle. Required. Enter the angle the segment makes with the vertical.

Roughness. Required. Enter the absolute roughness of the segment. Clean new tubing will typically have an absolute roughness of 0.00060 to 0.00065 inches.

After you have entered all the data, press the “Mash All” button to process the individual well data.

4 Individual Well workbooks

These workbooks (wellid_PBU.xls) are generated by Masher, one workbook for each well processed. The format for each workbook is slightly different depending on whether the well is vertical or horizontal. The discussion below will apply to both types of wells except as noted.

Two workbooks, PBUTemplate.xls and HWTemplate.xls, are used as templates for the individual well workbooks. Do not modify either of these!

Do not rename any of the sheets or charts in the individual well workbooks!

4.1 Input Data sheet

The Input Data sheet is filled out by Masher, and contains all of the well-specific data necessary to analyze the tests for the well.

4.2 Work sheet

The Work sheet is used as a workspace for the analysis. Do not modify this sheet!

4.3 Work-PQ chart

The Work-PQ chart shows a graph of rate and wellhead pressure vs. date for the test currently being analyzed. This chart is primarily used for quality control to determine whether or not a test is valid.

A good test will have a relatively stable flow rate prior to the test and a distinct transition from flowing to shutin on both rate and pressure curves. The large diamonds “Rate @ SI” and “WHP @ SI” indicate the reference rate and last flowing wellhead pressure prior to shutin used for the analysis. These points should fall on the rate and pressure curves, respectively, at the end of the flow period.

Three controls in the upper left corner of the chart are used to navigate through the list of wells and accept or reject each test.

Spinner button. Click the “up” arrow button to switch to the next test; click the “down” arrow to switch to the previous test.

Accept Analysis checkbox. Click this checkbox to accept this as a valid test; click again to ignore this test in calculating the average permeability. These changes become effective when you switch to another test.

Test ID droplist. Click the “down” arrow on the right side of this box to see a list of tests. Click on a test to switch directly to that test.

4.4 Work-SL chart

The Work-SL chart shows a straight line graph for the selected test. The graph is either a semilog graph, for a vertical well, or a square root of time graph, for a horizontal well. The time plotting function is the multirate equivalent adjusted time. For vertical wells, the radial equivalent time is used, while the linear flow equivalent time is used for horizontal wells. The pressure plotting function is the rate-normalized adjusted pressure change.

In addition to the three controls in common with the Work-PQ chart, the Work-SL chart has two slider bars on the bottom of the chart to adjust the beginning and end of the range of data to be analyzed. For a vertical well, data in the the middle time region (MTR) are used for the analysis. For a horizontal well, data in the early linear flow regime (ELF) are used for the analysis.

As you move, then release, the slider on one of the slider bars, the corresponding flow regime marker will move and the analysis will be updated to reflect the new position. The time corresponding to the position of each slider bar is shown in the text boxes on the flow regime limit lines.

Two straight lines will be drawn through the data within the selected region. The red line (“Best Fit” series) shows a line fit through the data for this test. The green line (“Composite” series) shows a line with a slope corresponding to the average permeability for all the valid tests, forced through the data for this test.

Once all the tests have been reviewed, the bad ones eliminated, and the appropriate flow regime identified for each test, the Composite line should lie virtually on top of the Best Fit line, indicating that all the tests are giving essentially the same permeability. To hide or show the Composite line, toggle the Hide/Show Composite button in the upper right corner of the chart.

4.5 Work-LL chart

The Work-LL chart is a log-log graph of the selected test, showing the rate normalized adjusted pressure change and the logarithmic derivative of the pressure change vs. the multirate equivalent adjusted time.

The MTR for a vertical well will have a horizontal pressure derivative, while the ELF for a horizontal well will have a derivative with a slope of $\frac{1}{2}$. For this chart, there are two straight lines fit through the pressure data and two through the derivative data. The red line (“Best Fit”) and the blue line (“Best Fit Deriv”) show the straight line fit through the selected pressure and pressure derivative data, respectively, for this test. The two green lines (“Composite” and “Composite Deriv”) show the position and slope corresponding to the average permeability from all the valid tests.

The two derivative lines provide a sensitive indicator of the deviation of the permeability for this test from the average. For example, if the test gives a permeability that is 10% higher than the average permeability, the blue derivative line will lie a vertical distance above the green

composite derivative line by the distance between 9 and 10 (or 90 and 100, etc) on the pressure axis.

4.6 PBU Summary sheet

The PBU Summary sheet is both a summary table of all the tests for this well and a work area sheet. Do not edit any cells in this sheet, except for the entries under the “Accept” column heading! To directly accept or reject a specific test, you may put a 1 or 0, respectively, in the Accept column for the test.

4.7 PBU Database sheet

The PBU Database sheet is a work area sheet. Do not edit any cells in this sheet!

4.8 S' vs q chart

The S' vs q chart shows a graph of the total skin factor $s' = s + D|q|$ vs. the flow rate q for all the tests for this well. Buildup tests are shown as red diamonds, and falloff tests as green squares. A solid symbol indicates a valid test data point, while an open symbol indicates a data point corresponding to a bad test.

The blue lines show the best fit through a graph of s' vs. $|q|$. The intercept gives the Darcy component of the skin factor, while the slope gives the non-Darcy component. These two components are shown in the text box on the lower left corner of the graph.

4.9 S' vs abs(q)

The S' vs abs(q) chart shows the same data as the S' vs q chart, plotted against the absolute value of the rate.

4.10 S' vs Date

The S' vs Date chart shows a graph of total skin vs. date. The blue diamonds show the estimated Darcy skin component.

4.11 k vs Date

The k vs Date chart shows a graph of permeability vs date. Data points for all correctly analyzed, valid, tests should lie along a single horizontal line. A trend in this graph suggests that the reservoir permeability is changing with time.

4.12 Well History

The Well History chart shows the averaged rate and pressure data for the well. The dates at which the tests occurred are marked with black diamonds; solid diamonds for valid tests, open diamonds for invalid ones.

4.13 EFM Data

The EFM Data sheet is a table of the averaged rate and pressure data for the well, along with some summary statistics. Do not edit the data in this table!