TEA Systems Standard Data, Storage and Formats

Data Fundamentals

Data Flow

Raw metrology data, direct from the tool, must be imported and converted into the Weir PW data format. The conversion is automatic and only requires the user to select the data file and the data source.

The conversion sequence will re-format the data into the Weir PW Standard format, specified later in this manual, and save it into a Microsoft Excel® workbook of the same name as the data set.

After the initial import, the raw data file can be ignored or discarded. All further Weir PW analyses use the workbook. Workbooks of course can be re-opened directly into Weir PW and handled like any other Excel workbook.

Raw data can only be imported using the Weir PW main screen.

Weir PW workbooks can be opened from the Weir PW main or the analysis screens.

Additional data sets are frequently generated by modeling. These may include focus uniformity, optimum feature uniformity, or combined analysis sets. These data sets can also be loaded into the Weir interface for modeling.

Data Culling Methods

Weir PW employs multiple devices for removing poor or unwanted data. Separate techniques allow the selection of sub-sets of data based on exposure condition, during model regression and by direct selection of site and point-level data using the interactive mouse. These methods can be employed by the user singularly or in multiples.

Wafer Selection

Graphic check boxes are provided in the data selection screen to allow subset selection of data based on the wafer ID or number. Single or any combination of multiple wafers can be selected.

Exposure Condition

After data is first imported into the Weir PW standard format, the user can view and modify the basic exposure criteria specified for the dataset. Exposure criteria are specified on a field-by-field basis using the graphic layout interface of the main screen. There are six criteria available for customization, they are:

1. Focus
2. Exposure Dose
3. Numeric Aperture (NA)
4. Partial Coherence – Inner Ring (PCi)
5. Partial Coherence – Outer Ring (PCo)
6. Stage and Scan Direction

The Stage or Scan Direction criterion allows four settings, "Up", "Down", "Left" or "Right".

Graphic check boxes are provided in the data selection screen to allow subset selection of data based on the value ranges of any of these six criteria. Because the criteria are specific field based, the entire field is removed from the analysis.

Culling Data by Field Site Location

The data selection interfaces allow individual field sites to be selected for inclusion or removal from the analysis. This is usually accomplished using the mouse or by check-boxes for selection.

Data for a single or selected data sites can also be easily removed from an analysis. Using the following method, data can be easily restored at a later date if desired.

The "Sites" spreadsheet contains one row for each site location with site #1 beginning on row #2 of the spreadsheet because of the Header row. If a row is empty – without data or X and Y location entries – then the Weir assumes the data is not present or wanted. Any data entries whose Test number corresponds to the empty row will not be loaded for an analysis even if they are present on the data sheet. Note however, that Test number (data sheet) = Test number (Sites sheet) = (Row number –1) of the Sites sheet so that test #10 information must always be on row 11 of the sites sheet.

To remove selected data sites from the data:

?? Right click on the "Sites" tab of the workbook and select the "Move or Copy" pop-up menu item.

?? Check the "Create a copy" box on the "Move or Copy" window and optionally highlight the "Sites" entry in the "Before Sheet" window to place the copy in after the current worksheet. A new worksheet called "Sites (2)" will be created and can be used as a backup.

?? Return to the "Sites" worksheet.

?? Select the Test number to be removed by highlighting all entries in the row.

?? Press the "Delete" key.

- o This will erase and leave a blank row of data.
- o DO NOT use the "Edit/Delete" menu selection from the top of the row. This selection may delete the entire row, moving all subsequent rows up and out of their proper location.

?? Sites can later be re-installed into the data by either copying data from the "Sites (2)" spreadsheet or by deleting the current sheet and renaming the copy to "Sites".

Range and Sigma Culling

Culling examines the data and organizes it around a logical population center. Depending upon the current type of data and analysis screen, the population grouping changes as needed. For example:

?? Feature data populations can organize around the data associated with a specific site on the field.

?? Data culling during a model operation will examine the residuals remaining after a coefficient fit and remove outlier points that exceed the specified allowable range or sigma variation.

There are two variables for culling data, Range and Sigma.

Range culling will examine each population and remove data based upon a user specified range from the mean of the population.

Sigma culling allows the user to input a standard deviation value, such as "1.25 sigma". The culling software then removes all data members whose variation from the population mean

exceeds the limit, in the case 1.25 times a standard deviation; assuming a Normal, Binomial population distribution.

Model-Culled Data

Weir PW's models employ singular value decomposition (SVD) methods of regression as opposed to the commonly used "least-squares" regression. This approach allow two methods of data removal to be employed, user-specified Range and Sigma culling and a new adaptive-element technique.

"Range and Sigma" culling functions similar to the methods previously described however the population now consists of the points measured value as compared to it's model-fitted value, in other words, the residuals.

All interfaces, including the Process Window analysis, include fields for user-entry of Range and Sigma.

Adaptive Element modeling occurs automatically during the model sequence. The independent variables matrix is de-convolved into three separate matrices characterizing, among other factors, the layout covariance and singular points. Singular points are un-representative of the true distribution of the data and are automatically removed or lessened in their weighting on the regression.

A final control over the functionality of the calculated model coefficients is given to the engineer in the form of validity testing. Selection of a simple check-box entry provides automated coefficient validity checking. If validity checking is selected, coefficients judged invalid by their estimation uncertainty are replaced with zero values, and the model is re-calculated to provide the most accurate control surface correction for the process or equipment. Employment of validity checking in during process or tool setup results in greater accuracy of equipment tuning and minimizes the "ringing" that so often results from repeated over- and under-correction in automated process control sequences.

Mouse-selected culling

Many of the interfaces allow you to box in a selection of the data and then display, plot or cull it from the analysis. Data culled in this manner can also be re-inserted using the same method, see section "**Error! Reference source not found.**" on page **Error! Bookmark not defined.**.

Culling by selected variable range

The data selection and process window interfaces in Weir PW provide culling by range for any variable. Each selection has a command button, a variable selection combo field and High/Low range limits fields.

Pressing the range command button with plot a histogram of the variable selected in the combo box. Use the quartile designators for Q0 and Q4 to specify the low and high range values. Data points will then be removed when the data selection command button is selected. The number of points culled will appear in the status panel and on the range command button.

Weir PSFM provides data culling in the analysis screen by comparing the X and Y focus values. Large differences in X and Y metrology values are assumed to be metrology failures. The "Cull Analysis" command button will display a graphic and the number of points removed with the current selection.

Culling by Wafer Radius

The Raw Data metrology, Spatial Analysis and Focus Analysis interfaces provide a "Cull Radius" command button and radius field. Metrology sites located outside of the radius value specified in the radius field are excluded from the analysis.

The "Cull Radius" button, when pressed, will display an plot of the variable value verses it's distance from the wafer center. A 3rd order polynomial is fit to the data and displayed as a message on the graph.

Graphic assistance

Histograms are the best tools for observing population spreads. Selecting a histogram or the data culling button provides the user with the ability to visualize the population shape prior to entering the data.

Use either the histogram graphic selection or box–in a portion of the data on a vector or contour plot to plot the histogram.

A BoxPlot appears over the histogram to show the systematic range of data distribution. The quartile values for the box plot are summarized below the right hand section of the graph's abscissa.

Viewing Data

There are three basic methods of viewing or accessing the current data set.

1. Raw, modeled and residual data are always available through their storage in the worksheets of the data workbook.
2. Any graph or table's data can be viewed, and separately saved, in a separate worksheet generated by selecting the "Data/View Data" menu item of the interface.
3. Any subset of data in a vector or contour plot can be viewed, or plotted or saved, in a separate worksheet generated by boxing in the area of the graph while depressing the left mouse-button.

Storage of data

Weir PW requires the prior installation of Microsoft Excel®.

Raw metrology data is converted into the Weir Standard Format and stored an Excel Workbook of the same name as the raw data file. Workbooks contain a minimum of three spreadsheets; a measurement data sheet of the same name as the file, a "Sites" sheet containing the location and format of each unique data site and an "Information" data sheet with header information on the die size, offsets, metrology tool name, etc.

See the section "Weir Standard Format" for detailed descriptions of the Weir Standard format.

Weir Spreadsheet Data Formats

Data is typically imported from a metrology tool's binary or ASCII format data file. The data formats are then converted into the Weir Standard Format and stored into Spreadsheets. After a data set has been imported into a spreadsheet, the spreadsheet should then be opened and re-used for future work since there is no need to re-import the raw data.

Minimum Workbook Format

There's a minimum of three worksheets stored in each workbook:

✍✍DataSheet

1. The primary, imported data as measured. The sheet-name is the same as the data set name.

✍✍"Sites"

2. A sheet of field locations and feature family information.

✍✍"Information"

3. Header information containing die-size, flat location etc.

Formats and conventions for these are discussed below.

Weir Standard Format

The as-measured metrology is stored in this sheet shown in Figure 1. The name of the sheet should default to the name of the raw data file.

Rules for construction:

✍✍The name of the sheet should default to the name of the raw data file. That is, a raw data file named "SlitData5_1_NA45PC35.tlg" should store data in a sheet named: "SlitData5_1_NA45PC35". The workbook will also, by default, be the same name as the raw data file.

✍✍Sheet names are limited to a maximum of 31 characters.

✍✍Naming restrictions follow standard Microsoft Excel™.

✍✍Cell "A1" must contain a comment note with the text "DATASHEET"

NOTES:

✍✍Any number of datasheets can be stored in a workbook.

✍✍Each datasheet is designated with a spreadsheet comment "DATASHEET" stored in cell "A1", being the same name as the workbook system file designates the primary data.

✍✍Position information – columns "B" through "E" -- must be filled in for each row of measured data.

✍✍For data that is not overlay or registration, columns can be left blank – that is, without any data – and individual row entries may be left blank.

Additional data can be used to store information such as measured reticle information and data derived by Weir during an analysis.

Figure 1: Data spreadsheet for the Weir Standard Format.

Data Storage Convention

Metrology data is stored in columns. Data starts in column 2, the "B" column. Headers should be located in row 1. The first four columns are standard to any data set. They define the location of the measurement.

Header	Cell Location	Function
"Wafer"	B1	Designator for each substrate. May be any alphanumeric
"Test"	C1	Key for each unique site location on the field providing a pointer to the row location in the "Sites" spreadsheet. Defines a unique field position and feature type. Stored as an integer number, designating the row number of the detailed information stored on the "Sites" spreadsheet.
"Diex"	D1	An integer designating the column location of the die on the wafer. Diex location zero (0) is located at the center of the wafer.
"Diey"	E1	An integer designating the row location of the die on the wafer. Diex location zero (0) is located at the center of the wafer.

Measured Data Storage

A maximum of eight (8) measurement categories can be stored in each datasheet beginning in column "F". The name of each measurement should be stored in row #1 of the column. Weir PW Reports and lot-object storage of the data will then use this name.

The following detail the metrology variables stored and their associated column headers

Overlay, Focus and Registration Metrology

Data is stored as microns of measurement.

Column "F":   X-axis measured data.

Column "G":   Y-Axis measured data.

Column "H":   (Optional), (X+Y)/2 average measurement.

Critical Dimension and other metrology

Column "F":   First Feature defined by the user or by the import program

Column "G"   2nd feature entered

Any number of variables, up to the number of columns limited by Excel, can be stored in the spreadsheet.

The first variable must be located in column "F".

Only the first nine (9) columns "F" to "N" are loaded into the active Weir program. You can cut/paste columns of data into these first 9 columns to change their order of appearance or to select different combinations for analysis.

The units of measure for each column are stored in the "Sites" worksheet. They can be interactively changed from the Weir program by accessing the "Data/Units Setup" menu.
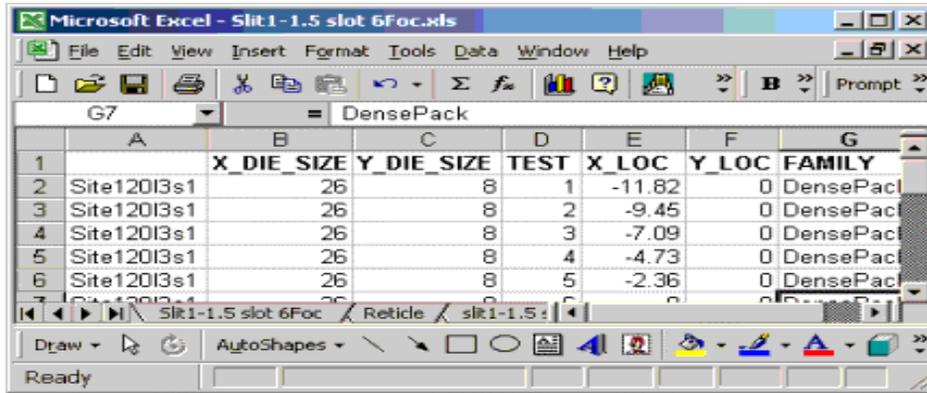
Sites Format

Figure 2: "Sites" worksheet with feature locations on field.

Stores information on the X and Y Field location of individual test sites. Also stores die size information but this is not currently used. For diesize information , please see the Information datasheet.

NOTES:

&&*Heading values are in row 1, starting in column "B".*

&&*Any data may be placed in column "A".*

&&*Overlay and Registration data formats require only columns "B" through "F"*

&&*Column "G", the "FAMILY", is used for linewidth and other metrology to describe the feature type as "DensePacked" or "Isolated"*

Sites Data Storage Convention

Metrology data is stored in columns. Data starts in column 2, the "B" column. Headers should be located in row 1.

Header	Cell Location	Function
"X_DIE_SIZE"	B1	Not currently used but data must be present in the data.
"Y_DIE_SIZE"	C1	Not currently used but data must be present in the data.

Header	Cell Location	Function
"TEST"	D1	Correlates with the "TEST" column of the data sheet previously discussed. Data Begins on row 2 with a value of "1". Subsequent rows must include a value of "row-1" for each test number. *NOTE*: Rows may be left blank – without data -- but keep the rule **test number= row number –1** Any data row that does not have a corresponding site row on the "Sites" spreadsheet, and location information, will be excluded from the loaded lot object.
"X_LOC"	E1	X-Location of the measured site on the exposure field. Values stored in millimeters. *Note*: (X,Y) = (0,0) is located at the field center.
"Y_LOC"	F1	Y-Location of the measured site on the exposure field. Values stored in millimeters. *Note*: (X,Y) = (0,0) is located at the field center.
"FAMILY"	G1	Used only for non-overlay (non-registration) data. May contain the values of: ?? IsoLine ?? DensePack ?? Via

Information Sheet Format

Stores header information for the data sheet including:

- ?? the orientation of the wafer (wafer flat),
- ?? the die size,
- ?? description of the features measured including;
- ?? and more.

NOTES:

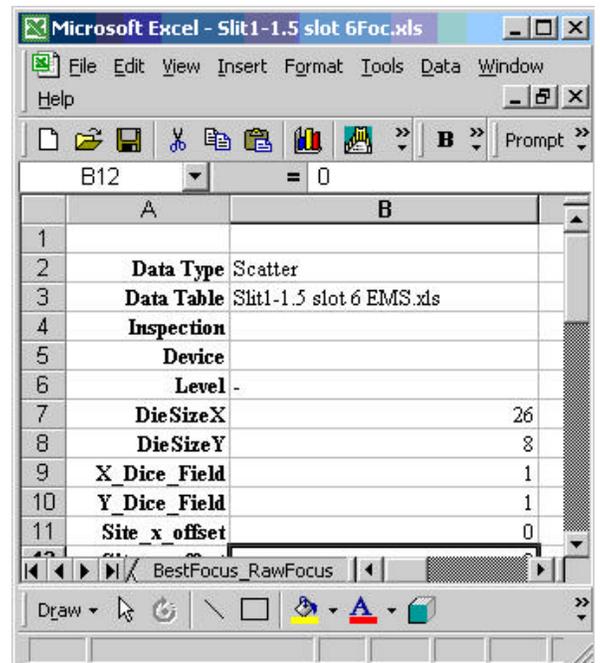- *?? Heading values are in column "A" and start in row #2*

Figure 3: Information Spreadsheet format

✍✍ALL dimensional values are stored in units of millimeters.

✍✍Row Heading names are critical, their sort order is not.

Row Heading	Stored Value
Data Type	Overlay, Registration, CD-SEM, Scatter or Focus
Data Table	File name, example: "Slit1-1.5 slot 6 EMS.xls"
Inspection	Not used
Device	Device or product name.
Level	Layer or level name
DieSizeX	X die size in millimeters
DieSizeY	Y die size in millimeters
X_Dice_Field	Number of die located in the exposure field. Typically = 1
Y_Dice_Field	1
Site_x_offset	Offset of the field site array in millimeters from field center.
Site_y_offset	
Die_x_offset	Offset of the wafer array in millimeters from wafer center
Die_y_offset	
Die_x_array	Offset of the wafer array in fractional whole-die values. May be whole or fractional.
Die_y_array	-0.5
Flat Location	Flat or Notch location: UP, DOWN, LEFT or RIGHT
Metrologynom	Metrology tool Name; sn199201
Lot	Lot Name
Job	Metrology tool Recipe Name
Date	4-Oct-99
Title	ASML Slit Profile size 1: 1.5 wafer 200
Comments	Any number of lines of text. Contents will vary depending upon the data source. Typically used to contain notes inserted by the user.
Exposure Tool	Exposure Tool, Stepper or Scanner name
MeasureTime	Time of day the data was measured: 17:34:00
Process Step	A process step number for the layer.
Technology	The technology used in the device.
Stepper Job	The stepper or scanner recipe name
Rework	Integer number beginning at 0. Rework cycle of current data set.
User_name	User or operator name from the metrology tool.
Stepper_ID	Exposure tool designator, may be exposure tool name.
Reticle	Reticle designator or name.
FilePath	Original Data file full pathname, not critical

Row Heading	Stored Value
WorkBookPath	Original Stored full pathname of the workbook, not critical
DataFolder	Original Data folder name, not critical

Manual Manipulation of Data Sets

Why manually manipulate data? There are many reasons for doing so beyond the normal data handling scope of the Weir analysis. You may wish to subtract reticle data from metrology measurements, subtract the performance results of wafers loaded into two cassettes or compare UltraFlat to Standard flatness substrates by subtracting the metrology from each and looking only at the difference metrology.

You can manually manipulate or combine data sets after a data file has been imported into a Weir Spreadsheet. The primary data file is always the first spreadsheet of the workbook; the spreadsheet will be the same name as the file itself. Weir uses the first five (5) columns of the spreadsheet for positional information; that is columns "A" through "E".

Two or, if present, three data columns are imported for each row; F:"X_reg" , G:"Y_reg" and H:"Zmean". The titles of these columns are located in row 1 of the spreadsheet. Their text labels are not important and can be any valid column-name. Weir will follow the given data label in reports.

NOTE:

✍✍*You can add additional columns of data to the worksheet without effect on the Weir PSFM analysis. These columns are loaded as data but are not used in the Weir PSFM portion of the analysis.*

✍✍*Saving the original 3 columns of data into locations above column "H" is a good method for retaining your original dataset.*

You can delete or add data rows at any time. When you delete a row you can either remove the contents of the cells or remove the entire row. Remember that position on the field is keyed by the "Test" number in column "C". Test numbers in the data do not have to be sequential but they must have a corresponding entry on the "Sites" worksheet or data will not be loaded.

Data values can be easily manipulated if you are familiar with the basic Microsoft Excel® commands. There are three key items to watch for to insure a valid comparison:

✍✍Make sure that your field locations and test numbers are the same on both data set.

✍✍You may not want to subtract the metrology of a field in the wafer center from one on the wafer's edge. Site values are also critical because they define where the metrology is located on the wafers edge.

✍✍Insure that each data set has the same number of rows. Remove, if necessary, rows that do not match.

✍✍If you use Excel functions to calculate a data value remember that Excel saves the function into the cell even though the data value is displayed. If you then copy the cell value to a new location, Excel will copy the formula not the value.

?? An example of an Excel functin: "J232 = (F232+G232)/2"

?? You copy cell values, rather than formula, by using the menu command "Edit/Paste Special" and then selecting the "Values" radio button.

Example: Subtracting two data sets

- ✍✍ Load both workbooks into Excel.

  - ?? It's a good idea to save the workbooks to new names.

- ✍✍ Examine the Summary Data section of the "Information" spreadsheet to determine the total number of data points.

  - ?? If they are equal you can probably simply paste from one workbook to the other.

  - ?? If they are not equal, use the "Window/Arrange" menu command to display and compare the rows that differ. Delete any rows prior to copy.

- ✍✍ Highlight the data columns you wish to copy.

- ✍✍ Paste the highlighted columns into columns "I" through "K" of the target data worksheet.

- ✍✍ In cell "L2" insert the formula "=(E2-I2)"

- ✍✍ Copy the contents of cell L2 into columns "L,M and N" and into all rows that contain data.

- ✍✍ You now have the original data (columns F-H), the second data set (columns I-K) and a difference data set (columns L-N)

  - ?? If loaded now, Weir PSFM will work only with columns F-H

- ✍✍ Highlight all rows in columns F-H

- ✍✍ Select the "Insert/Columns" menu item

  - ?? Three "new" and blank data columns will be inserted F,G and H

- ✍✍ Highlight columns L,M and N (rows 1 to "N") then "N" is the total number of rows.

- ✍✍ Select the "Copy" menu or copy button to copy the contents into memory

- ✍✍ Click on cell F1

- ✍✍ Select "Edit/Paste Special" from the menu, select the "Values" radio button and press "OK". The new data values will be copied.

- ✍✍ Optionally delete the columns beyond column H.

- ✍✍ Load the workbook into Weir and analyze

Note: If you renamed the workbook to a new file name, then the first time you load data into Weir it will ask you if you wish to use the data spreadsheet containing the old name. Simply answer "Yes" and proceed.

Units of measurement specification

Units of measurement, by default, are assumed to be microns.

Units can be changed by either the raw data import program or by manually editing them using the Weir main menu path "Data/Units Setup".

Available units for variables

Weir software accepts the following units of measurement:
- ✍✍ Microns
- ✍✍ Angstroms

✍✍Nanometers
✍✍Millimeters
✍✍Centimeters
✍✍Meters
✍✍Degrees
✍✍Radians
✍✍Seconds
✍✍Hours
✍✍Minutes
✍✍MilliSeconds
✍✍Centigrade
✍✍Farenheit
✍✍DegPerSecond   (Thermal Flow)
✍✍KdegMinutes   (Energy Flow)

Storage and Designation

Metrology units can be specified uniquely for each individual variable imported. They are stored on the "Sites" worksheet, starting in column "H". The software stores one variables designation in each column, the unit value being located in row two of the column.

G	H	I	J
Family	TOP_UNITS	BOTTOM_UNITS	SLOPE_UNITS
Edges_1_2	µm	µm	Radians