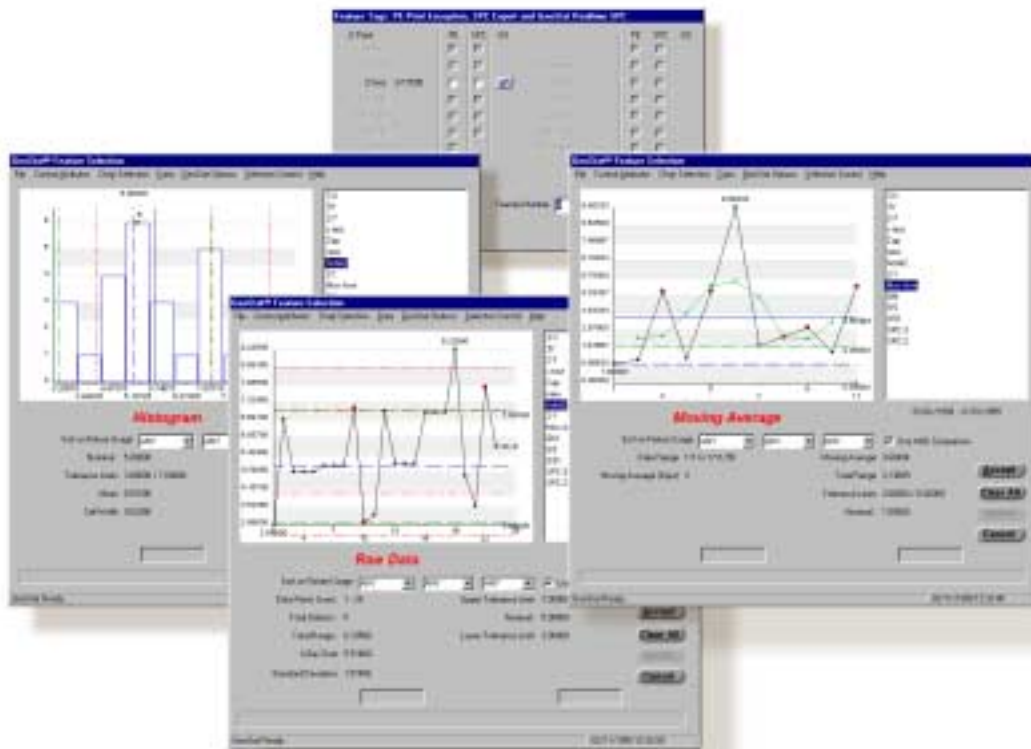


GeoStat



**Integrated SPC for Geomet
Universal CMM Software**

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GeoStat

Interactive SPC Software

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Before You Begin

When you bought this software, we believe you made a good decision. Why? Because you now have unleashed the power of integrated Geomet Universal CMM Software to perform the drudgery of data accumulation and performing calculations. More importantly, it means that you are now involved in Statistical Process Control (SPC).

Statistical Process Control (SPC) has become very important in and necessary in industry today as it can enable manufacturers to tune their processes and improve their quality adding a competitive edge over those without SPC.

The first goal of SPC is to determine the nominal, controlled behavior of a manufacturing process as only then can you possibly know when it changes and is “out-of-control”. Once you find a point where the behavior does change, you can look to designate or assign cause of that change. Removing the cause should put the process back in control. Remember that the key to improving quality is to control the process that makes the product.

You should have a sound understanding in SPC before you start using this software. The manual, by its very nature, can only be a reference for usage of the software. It cannot be an acceptable replacement for an instructional course on the theory and application of SPC. One book on the subject that we recommend is AT&T's Statistical Quality Control Handbook, available through the American Society of Quality Control. Another example is Basic Business Statistics – Concepts and Application, 7th Edition available through bookstores at most colleges and universities.

How to Use This Manual

Please refer the chapter in this manual that contains the information you require.

Chapter 1, “Introducing GeoStat”

Reviews the basic concepts of GeoStat. The standard user interface is described taking you through the menu hierarchy and icons. How to select features names or individual data points for processing. Applying filters through the use of fixtures and dates.

Chapter 2, “Working with GeoStat”

Describes how to work with GeoStat Header Records and GeoStat Data Records. Use Limits Tests to provide first warnings when out-of-control conditions exist. Apply Chart Controls for Standard Deviation Control Levels, Histogram Cell Groups and Moving Averages.

Chapter 3, “Interaction with Geomet”

Describes how GeoStat processes data directly from Geomet part inspections. The use of Feature Tagging is demonstrated allowing you to gather only the data required for study.

Chapter 4, “Charting Capabilities”

Lists the charts available in GeoStat, techniques used to enhance and filter the data for more precise control and the use of Fixtures, date filtering and sorting.

Chapter 5, “Data – Import/Export”

Describes how you can import data from other applications such as Excel or text documents. Exporting data in ASCII format can be done from a single record or the entire GeoStat database. Applying export filters to configure the data to be read by most other applications.

Appendix A, “Tables”

Provides the common tables used in GeoStat and SPC in general.

Appendix B, “Glossary of Symbols”

This appendix provides descriptions for the most commonly used symbols used in this Users Guide and SPC in general.

Appendix C, “Glossary of Terms”

This appendix provides descriptions for the most commonly used terms used in this Users Guide.

Conventions used in this manual

The following conventional terms, text formatting, and symbols are used throughout this GeoStat Users Guide.

Convention	Meaning
<i>[File->Print]</i>	From the File drop-down menu, the Print command is selected.
<F12>	The symbols < > represent a selected keystroke from the keyboard or a left-click button within GeoStat. Example: <F12> indicates that you should press the F12 (function key). <Accept> indicates you should left-click on the Accept button on the dialog shown.

1

Introducing GeoStat

- ✓ ***Taking a Tour of GeoStat***
 - Activating GeoStat
 - Accessing GeoStat from within Geomet
- ✓ ***The GeoStat Menu Structure***
 - Drop-Down Menus
 - File Drop-Down Commands
 - Control Attributes Drop-Down Commands
 - Chart Selection Drop-Down Commands
 - Data Drop-Down Commands
 - GeoStat Options Drop-Down Commands
 - Selection Control Drop-Down Commands
- ✓ ***Selecting GeoStat Data***
- ✓ ***Applying Filters***
 - Filtering through Date Ranges
 - Filtering with Fixtures
- ✓ ***GeoStat Options***
 - Activate Fixture Filters
 - Activate the Status Bar
 - Setting Report Precision
 - Setting 6 Sigma σ

Taking a Tour of GeoStat

GeoStat is an interactive member of the Geomet Universal CMM Software family. The term *interactive* implies that GeoStat performs SPC data processing and reporting as Geomet performs a part inspection. This allows monitoring of the control process within Geomet immediately after the completion of a part inspection.

This chapter will describe the structure and commands available within GeoStat.

Activating GeoStat

All Geomet System versions 1.05 or greater offer GeoStat as a released option. If you have not acquired an Access Code to activate GeoStat, please contact Helmel Engineering to purchase one.

To enter your access code you should be in Geomet and not running a program. Simultaneously depress the <Ctrl> + <Alt> + <u> keys. An Access Code dialog will be displayed waiting for your entry.



In the Access Code Dialog example shown here you will see that GeoStat is “grayed-out” indicating that GeoStat is not active. Enter your Authorized Access Code and left-click on <Accept> or press the <Enter> key on your keyboard and GeoStat will become enabled.

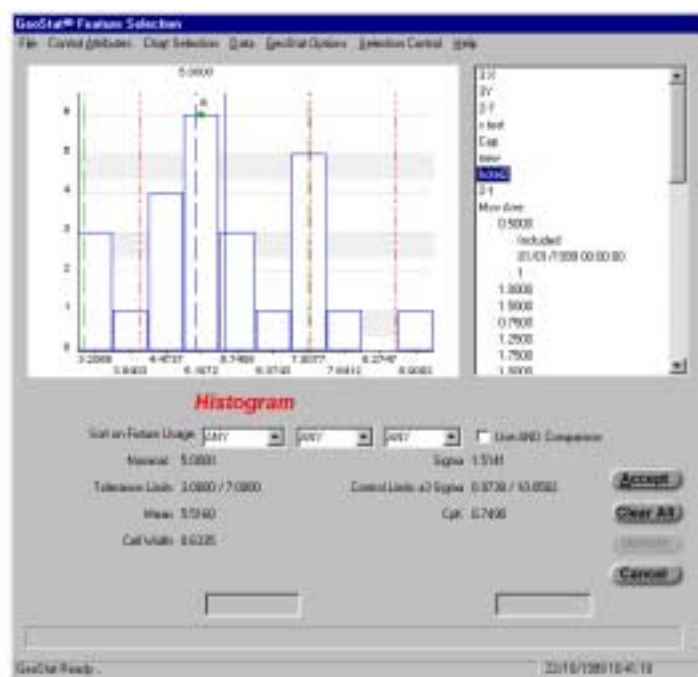
If you want to remove GeoStat from your system, re-enter the Access Code and a <Remove> button will appear. Left-click on the <Remove> button and GeoStat will be disabled.

Accessing GeoStat from within Geomet

Accessing GeoStat requires that you save your current inspection. If this has been done, press the <F12> function key or from the drop-down menu [Analysis->GeoStat].

GeoStat uses the current part inspection file name as the basis for creating the matching GeoStat file. For example: if your part inspection is called "Widget.GMT" your GeoStat file will be called "Widget.GST" and is stored in a separate folder *see appendix 1 for default locations*.

*It should be noted that Geomet and GeoStat **will not** verify that the file name has been recycled or renamed and that the GeoStat results no longer correlate with a new part inspection. For example if you run a part program called "Widget.GMT" collecting feature attributes in "Widget.GST" you can not rename the main file to "Widget2.GMT". By doing so you will not collect any further data for GeoStat on subsequent inspection runs. GeoStat maintains all feature pointers inside the original GeoStat "Widget.GST" file.*



The GeoStat Display

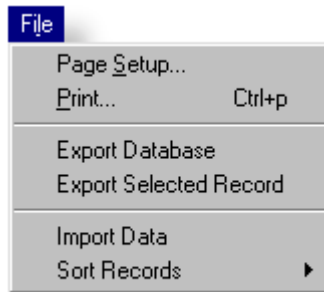
GeoStat provides access to all features and commands directly from the main GeoStat display. Selecting a feature to view requires that you left-click on the feature name. In the example above *hotel2* is selected.

The GeoStat Menu Structure

Drop Down Menus



File Pull-Down Commands



Page Setup: Accesses the underlying printer controls such as orientation, size, margins, or printer specific capabilities.

Print: Prints the current Chart.

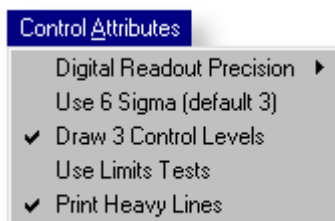
Export Database: Creates or appends an ASCII data file with the entire contents of the filtered data for all features. The ASCII format is configurable under *[GeoStat Options]*.

Export Selected Record: Creates or appends an ASCII data file with all filtered data of the currently selected feature. The ASCII format is configurable under *[GeoStat Options]*.

Import Data: Allows the importing of ASCII data into the currently selected feature.

Sort Records: Performs one of two sort techniques of all data matching the filter criteria. You can sort on Operator or Date.

Control Attributes Pull-Down Commands



Digital Readout Precision: allows you to choose 2-5 decimal precision on all values.

Use 6 Sigma: You can choose to apply 3 or 6 sigma.

Draw 3 Control Levels: Draws additional Control levels at $\pm 1-2-3$ or $\pm 2-4-6 \sigma$ levels.

Use Limits Tests: When activated, provides auto-prompts when reviewing charts when control limits have been exceeded.

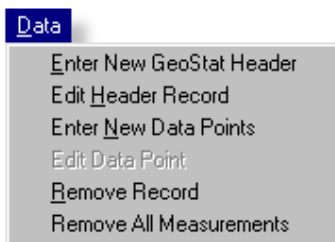
Print Heavy Lines: Used when printing to high-resolution printers to enhance visibility of lines being drawn.

Chart Selection Pull-Down Commands



Provides drop-down menu chart selection for the currently selected feature. The availability of these selections will be validated against such criteria as number of subgroups, date ranges, etc.

Data Pull-Down Commands



Enter New GeoStat Header: Manually enters a new feature header against which data will be imported.

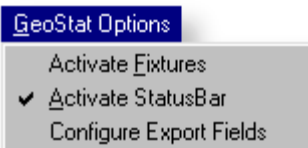
Edit Header: Edit all fields in an existing feature header.

Enter New Data Points: Manually enter feature data points into the currently selected feature.

Edit Data Point: Not available at this time.

Remove Record: Removes the currently selected feature header and all associated data points.

GeoStat Options Pull-Down Commands

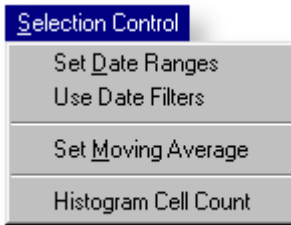


Activate Fixture: Allows fixture filtering to be set for all data being evaluated.

Activate Status Bar: Activates the status bar located on the bottom of GeoStat providing the fly-by help notes and active clock.

Configure Export Fields: Allows the selection of data used in the exporting of ASCII data files.

Selection Control Pull-Down Commands



Set Date Ranges: Use this command to establish a range of dates for processing the data.

Use Date Filters: Activates or deactivates the usage of date ranges.

Set Moving Average: Sets the number of days that GeoStat will use in the calculation of Moving Averages and Moving Ranges.

Histogram Cell Count: Sets the cell count Histograms will use when processing the frequency and grouping GeoStat data.

Selecting GeoStat Data

The GeoStat display provides you direct access to all data by selecting, or highlighting the feature. To highlight a feature, left-click with your mouse on the name located in the data display located right of the chart. In the example shown here, the feature named “hotel2” is highlighted and the corresponding Histogram Chart is displayed.

By double clicking on a feature name you can expand it to show the actual data that is available. In the example, feature ID “Mov Ave” is shown in its expanded form. To obtain additional information any data point can be expanded to show the attributes.

These include a data/time stamp, operator, and fixtures in use. Whether it is include or removed from the final calculation and an attached note. When a data field has no data, then the expanded information will exclude it.



Applying Filters

GeoStat data can be filtered using two different methods. One method is the use of dates the second method is through the use of fixtures. These methods can work together for greater control.

Filtering through Date Ranges

Once you have a feature name selected you can apply a date range filter. This can be activated through the Drop-Down menu [*Selection Control* -> *Set Date Ranges*].

variation: 2.696

Date : 01/01/1999 Enter Ending Date : 25/10/1999

Cancel Finish

Enter a date using the following format mm / dd / yyyy or mm / dd / yy.

25/10/1999 09:37:23

When you activate this command, GeoStat will scan the selected record and obtain the current date range. Enter into the data fields the start and stop dates of the new range and press the <Enter> key.

GeoStat will then recalculate the entire database and filter only those data points that fall within the date range. Note that the date range includes the start and stop dates.

Filtering with Fixtures

The use of fixtures allows you to group together production that has been manufactured from the same fixture. We use fixtures as a category that covers such criteria as machining center ID's, individual fixtures, shift identifiers or any other usage that may work with your manufacturing environment. The fixture data is alphanumeric and is case sensitive.

Sort on Fixture Usage ANY ANY ANY ☐ Use AND Comparison

Data Points Used: 1 - 25 Upper Tolerance Limit: 7 000

Fixture Selection Boxes

As shown above, up to three fixtures can be used with GeoStat. These fixtures correspond to what was placed in the header of the Geomet part inspection. You can not add or change the fixtures directly inside GeoStat.

When you select a feature name, the fixtures used are extracted and placed into the corresponding fixture fields. These are drop-

Raw Data

Fixture Usage ANY ANY

ANY
f1
f1-1
NONE

down selection boxes that you access by left clicking on the down arrow next to the fixture field as shown in the example. This listing shown in the drop-down will represent all unique fixture names used in the feature along with “ANY” and “NONE”. To select one of the entries, highlight the choice and left-click.

You can set the comparison between the three fixtures with the use of the “Use AND Comparison” check box. This will apply the following rules when filtering:

When using AND (☒ Use AND Comparison) then the condition must match so that Fixture1 AND Fixture2 AND Fixture3 must all match before it is added to the process.

When using OR (☐ Use AND Comparison) the following test is applied where if Fixture1 OR fixture2 OR fixture3 is true then the record is added to the process.

After you have selected the fixtures and the search comparison, the <Update> button becomes available. Press the <Update> button and the displayed data will update to reflect the new filters.

GeoStat Options

Activate the Status Bar

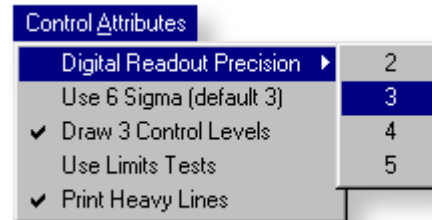
GeoStat offers a status bar that is used to provide fly-by help and to

display the current time and date. To activate the status bar, select *[GeoStat Options->Activate GeoStat StatusBar]*.



Setting Report Precision

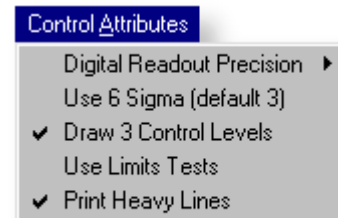
GeoStat maintains its own precision level for the reporting of values. This setting is applied to both the printed values and displayed values in the charts. This setting is a global setting for all reports and charts.



To set the precision levels choose from the drop-down menu; *[Control Attributes->Digital Readout Precision]*. Then from the pop-out menu, select the desired precision level.

Setting 6 Sigma σ

GeoStat can calculate either three or six standard deviations. This setting is a global setting that effects all charts. Once set, the drop-down menu will show a check next to *[Control Attributes->Use 6 Sigma (default 3)]*. Please note that this setting affects all GeoStat data files and is not configurable independently.



2 Working with GeoStat

✓ ***The GeoStat Database***

- General Description
- GeoStat Header Records
- Editing GeoStat Header Records
- Control Limit Override
- Removing Header Records
- GeoStat Data Records
- Manually Entering Data Records
- Deleting and Editing Data Records
- Sorting by Operator
- Sorting by Date

Working with GeoStat

The GeoStat Database

General Description

GeoStat maintains one database for each part program. These databases are identified by the part program name followed by the extension “GST”. For example, if your part program is called “Widget.GMT” your GeoStat database will be called “Widget.GST”.

The default location for these databases can be found at:

C:\My Documents\Geomet 101\GeoStat Data\

You can change the default location from the System Options inside Geomet, refer to help located inside Geomet.

The GeoStat Database consists of two record types, the Header and Actual Data. The Header maintains the feature identification and what attribute is being recorded. The Actual Data is attached to the Header and is a complete gathering of all data captured against the Header.

GeoStat Header Records

The GeoStat Header is automatically created when you tag a feature’s attribute inside Geomet or manually when selecting from the GeoStat menu [Data->Enter New GeoStat Header].



The Header maintains the following data:

Characteristic Name: A Unique name to identify the attribute. For example a feature such as an XY ID Circle with a number of 4 might have a name “4 X” indicating the X component of feature number 4.

Nominal Value: This is a basic value for the data to apply upper and lower tolerance against. The nominal should be the same value as reported in the inspection process.

(+) Plus: This is the Upper Specification Limit (USL).

(-) Minus: This is the Lower Specification Limit (LSL).

Subgroup Size: This value represents the number of measurements of a given group used in all SPC calculations. In GeoStat the minimum subgroup is 2.

Subgroup Lookback: This is a moving subgroup value that will “lookback” x number of subgroups when updating charts. For example if the lookback was set at 10, then GeoStat will only read in from the database 10 subgroups for displaying, reporting and charting.

Upper Tolerance Limit: This value defaults to the USL.

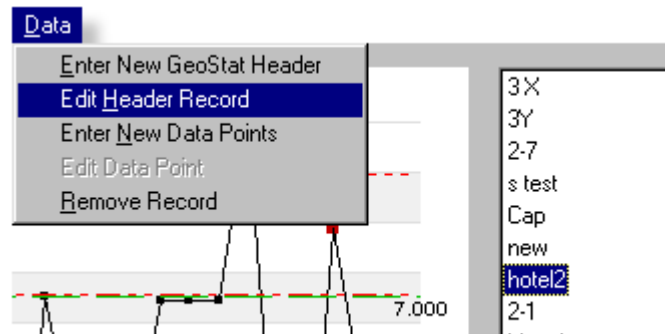
Lower Tolerance Limit: This value defaults to the LSL.

Note: You can override the Upper and Lower Tolerance Limits if you want to control a tighter process.

When a Header has been accepted by pressing the <OK> button or the <Enter> key, GeoStat will add it to the database and initialize the attached Actual Data list.

Editing GeoStat Header Records

You can edit an existing GeoStat Header Record at any time. To edit, select the Feature ID in the list on the right side of GeoStat and from the drop-down menus select *[Data->Edit Header Record]*.

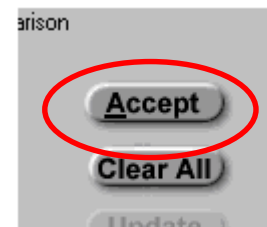


This example shows the current data associated with “hotel2” and will be displayed allowing you access to edit any field. After accepting your changes, GeoStat will recalculate all displayed data, reported values and selected charts.

Editing allows you the ability to perform “what-if” calculations such

as increasing the subgroup size or the look back value on subgroups and instantly see the change to the reported values.

Note: While you are in GeoStat, any changes you make by editing the Header Records will not become permanent until you press the <Accept> button. If you elect not to make a permanent change to the database, press <Cancel>.

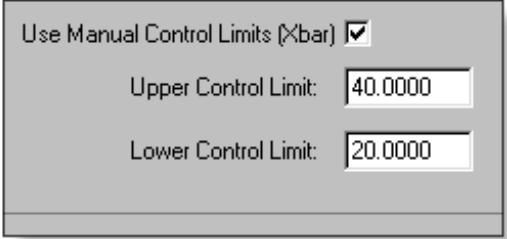


Control Limit Override

GeoStat allows you to elect an override when recalculating the standard deviation, USL and LSL for the Xbar chart only.

On the GeoStat Header dialog, you can elect this option by placing a check next to the label; “Use Manual Control Limits (Xbar)”. When selecting this feature the two entry controls for USL and LSL become active.

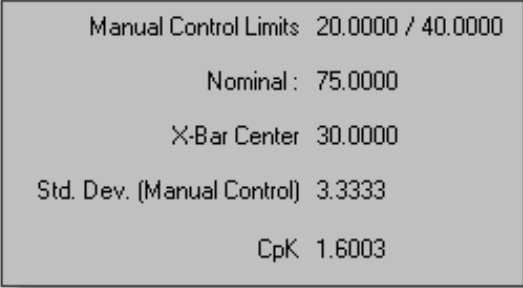
You can now enter a fixed value for use on the Xbar chart. One condition that this may be desirable is when you want to monitor your production against a set of values derived from a pilot (or test) run. On the report and chart, the control limits and standard deviation is marked with “Manual” indicating the calculations were compared against a entered value.



Use Manual Control Limits (Xbar) ☒

Upper Control Limit: 40.0000

Lower Control Limit: 20.0000



Manual Control Limits 20.0000 / 40.0000

Nominal: 75.0000

X-Bar Center 30.0000

Std. Dev. (Manual Control) 3.3333

CpK 1.6003

The screenshot shows the GeoStat software interface. A menu is open with the following options: "Enter New GeoStat Header", "Edit Header Record", "Enter New Data Points", "Edit Data Point", and "Remove Record". The "Remove Record" option is highlighted in blue. In the background, a graph is visible with a horizontal axis labeled "7.000" and a vertical axis. A red dot is visible on the graph, and a line connects it to the "Remove Record" option in the menu. To the right of the graph, there is a list of data points: "3X", "3Y", "2-7", "s test", "Cap", "new", "hotel2", "2-1", and "Mov Ave". The "hotel2" entry is highlighted in blue.

GeoStat Data Records

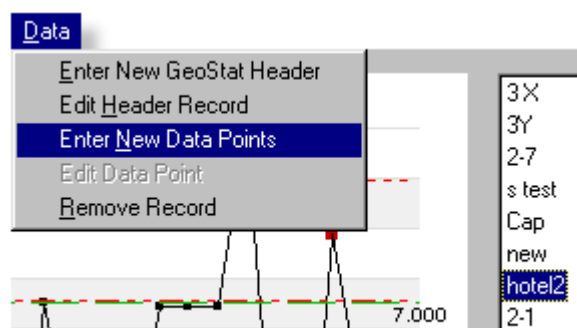
[illegible]

Measurements can also have an operator, serial number and general text attached to it. GeoStat only displays fields that have data.

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Geomet Version 5.00

Manually Entering Data Records

You can enter GeoStat Data Records against an existing Header. To enter, select the Feature ID in the list on the right side of GeoStat then from the drop-down menus select *[Data->Enter New Data Points]*. If the command in the menu is grayed-out, you have not selected a Feature ID from



the existing list.

The manual entry box allows you to enter data against the selected feature ID.

The Date field will default to the current date upon opening. The serial number field increments by one with every press of the <OK> button or <Enter> key.

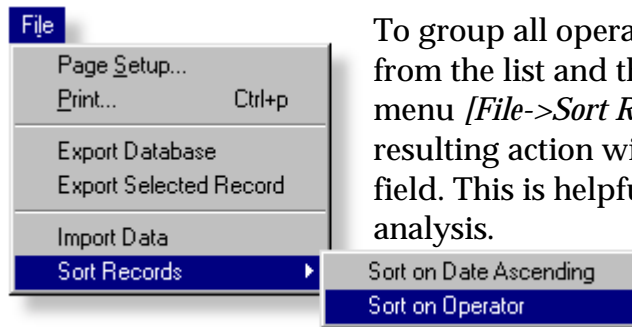
The operator, notes and fixture fields are optional.

A screenshot of the 'GeoStat - Data Entry' dialog box. It contains several input fields: 'Feature ID' (with 'hotel2' selected), 'Enter measured data:' (with '1' entered), 'Date / Time Stamp' (with '25/10/1999'), 'Serial Number' (with '1'), 'Enter text to place on report here' (empty), 'Operator' (empty), and 'Fixture Usage' (three empty checkboxes). At the bottom right are 'OK' and 'Cancel' buttons.

Deleting and Editing Data Records

For data integrity, GeoStat does not allow access to editing or deleting individual data records.

Sorting by Operator



To group all operators together, select the Feature ID from the list and then choose from the drop-down menu [*File->Sort Records->Sort on Operator*]. The resulting action will sort that record by the operator field. This is helpful when exporting data for further analysis.

Sorting by Date

Sorting by the date is similar to sorting by the operator as described above. Normally data that has been captured directly from Geomet is automatically entered using the time and date stamp in ascending order. However, data that is manually entered or imported does not use the date as the deciding factor. Apply the sort by date to correct the sequence of entry for the database.

3 Interaction with Geomet

- ✓ ***Geomet and GeoStat***
 - Creating a New GeoStat Database
 - Activating Feature Tagging
 - Selecting Single Attributes

Interaction with Geomet

Geomet and GeoStat

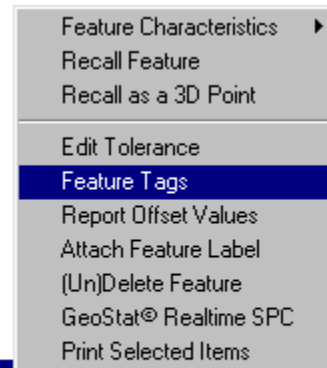
Creating a New GeoStat Database

As described earlier, GeoStat uses the name of the part program as the base name for the database. Before you start assigning tags to features to be used in GeoStat you must save your part program.

Once this has been accomplished, activating Feature Tags inside Geomet will automatically create the GeoStat database.

Activating Feature Tagging

From your Geomet Part Program you can activate the feature tagging by selecting the feature to work with and right-click to bring up the feature menu *see example*. Select the menu command *[Feature Tags]*, which will pass the features values from which you can then select the GeoStat button to create a record.



4 -Z Point
Z= -0.1750"

Selecting Single Attributes

The Feature Tagging dialog configures itself for the current feature. The example here we have a -X Point with a actual value of -0.0195. We circled the GS column showing the GeoStat button, which has a ✓ placed in the button. This check indicates that GeoStat already has an assigned record for this feature.



When you left-click on the button either the create a new GeoStat Header or edit an existing GeoStat Header dialog will appear, *please review GeoStat Header Records in chapter 2 for further explanation*.

For complete help on other tagging features inside Geomet, please refer to the on-line help located inside Geomet.

4

Charting Capabilities

- ✓ **Selecting a Chart for Viewing**
 - Using 3 or 6 Sigma σ
 - Draw Standard Deviation Levels
 - Using Limit Tests
- ✓ **Histogram**
 - Definition
 - Setting Cell Count
- ✓ **Moving Average**
 - Definition
 - Setting Moving Period
- ✓ **Moving Range**
- ✓ **Range**
 - Definition
- ✓ **Raw Data**
 - Definition
- ✓ **Xbar**
- ✓ **Xbar Control**
- ✓ **Printing Charts**
 - Printing Single Charts
 - Printing Batch Charts

Charting Capabilities

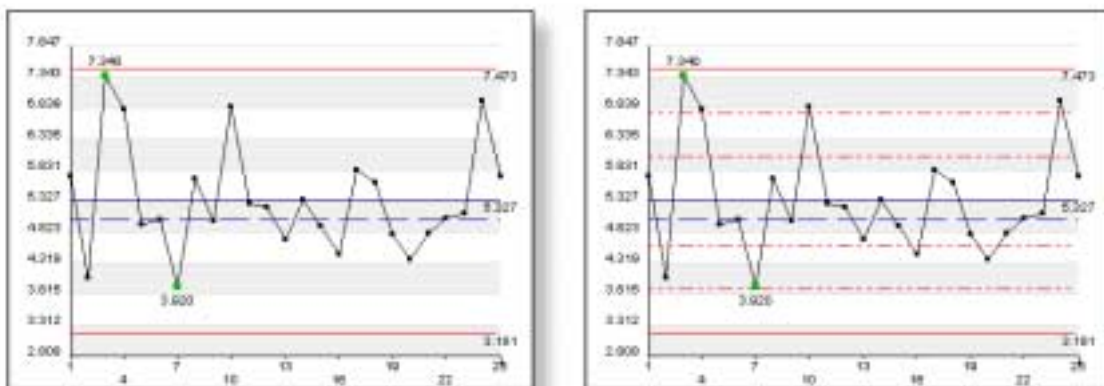
Configuring the Charts

Using 3 or 6 Sigma σ

GeoStat offers you the choice of working with Standard Deviation of 3 or 6 for all reporting and charting. The setting of this value is located using the menu [*Control Attributes->Use 6 Sigma (default 3)*]. This setting is global to GeoStat in that it affects all data files.

Draw Standard Deviation Levels

GeoStat provides you with the option to show each Standard Deviation Level directly on the charts.



In the examples above, the chart on the right shows the three standard deviation levels. The setting is global to GeoStat and all available charts and can be found in the menus under [*Control Attributes->Draw 3 Control Levels*].

Using Limit Tests

The use of Limit Tests provides a warning when you first view a chart that has an out-of-control value in it. When GeoStat updates the viewing of a chart it monitors all calculated data and compares it against the 3 or standard deviation limit for all charts except Raw Data. The Raw Data chart compares the measurements against USL and LSL.



Limit tests are helpful as an early warning indicator in production environments where several operators may be asked to review and print charts. To activate this option choose from the menu [*Control Attributes->Use Limit Tests*].

Histogram

Definition

The Histogram capability offered by GeoStat is best described as *frequency histogram*. The graph borders extend to include all measurement data points and are proportional to the frequencies within the cells. Each bar is centered on the midpoints of the cells with a height proportional to the frequencies in their respective cells.

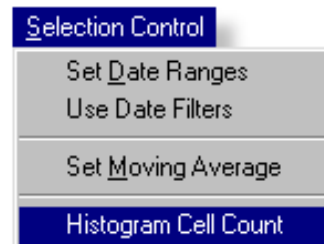
The chart also draws lines representing the Nominal, Upper/Lower Specification Limits, Xbar and Control Limits.



Setting Cell Count

Changing the Histogram Cell Count can be accomplished by selecting from the menus [*Selection Control*->*Histogram Cell Count*]. A dialog will appear that defaults to the current setting. The valid ranges for Histograms are a minimum of 4 and a maximum of 200.

The cell count is a global setting that effects all Histograms being displayed and is not configurable between different Geomet Part Programs.



Moving Average

Definition

A Moving Average Chart is designed for smoothing a time series and is highly subjective and dependent of the length of the period used in constructing the averages.

Understanding the process of moving average will help you in deciding how to set the period value, which in Geomet is always considered days.

To eliminate cyclical fluctuations, the period should be a value that corresponds to the estimated length of a cycle. This period can also be set as a multiple, example; if the cyclical period is 3 days, an acceptable setting for the period is 3, 6, 9, etc.



Date	Total (millions)	Moving Total $MT_{(x)}$	Moving Ave $MA_{(x)}$
1/1/99	6.6		
1/2/99	7.2	21.90	7.30
1/3/99	8.1	23.00	7.67
1/4/99	7.7	22.30	7.43
1/5/99	6.5	19.40	6.47
1/6/99	5.2	18.80	6.27
1/7/99	7.1	19.80	6.60
1/8/99	7.5	22.30	7.43
1/9/99	7.7	21.70	7.23
1/10/99	6.5	21.00	7.00
1/11/99	6.8	21.40	7.13
1/12/99	8.1	23.10	7.70
1/13/99	8.2	24.20	8.07
1/14/99	7.9	22.00	7.33
1/15/99	5.9	20.00	6.67
1/16/99	6.2	18.60	6.20
1/17/99	6.5	20.00	6.67
1/18/99	7.3	21.20	7.07
1/19/99	7.4	21.50	7.17
1/20/99	6.8	21.20	7.07
1/21/99	7.0	19.80	6.60
1/22/99	6.0	18.90	6.30
1/23/99	5.9	19.40	6.47
1/24/99	7.5	21.00	7.00
1/25/99	7.6	22.20	7.40
1/26/99	7.1		

Moving Average : Table 4-1

To understand how Moving Average is calculated, refer to table 4-1.

We have recorded the average production value of Widgets for consecutive days starting 1/1/99. The first step is to apply the following formula to obtain the moving total over the period of 3 days.

$$\begin{aligned}
 X_1 + X_2 + X_3 &= MT_{(2)} = 6.6 + 7.2 + 8.1 = 21.9 \\
 X_2 + X_3 + X_4 &= MT_{(3)} = 7.2 + 8.1 + 7.7 = 23.0 \\
 X_3 + X_4 + X_5 &= MT_{(4)} = 8.1 + 7.7 + 6.5 = 22.30
 \end{aligned}$$

Then we compute $MA_{(x)}$ by dividing $MT_{(x)}$ by the period length L.

$$\begin{aligned}
 21.9 / 3 &= 7.30 = MA_{(2)} \\
 23.0 / 3 &= 7.67 = MA_{(3)} \\
 22.30 / 3 &= 7.43 = MA_{(4)}
 \end{aligned}$$

The resulting moving average is plotted centered on the middle value of the period. For example the moving average for 1/1/99 to 1/3/99 is 7.30 and is plotted against 1/2/99.

Therefore we can not obtain moving averages for the first and last day of our date range for a 3-day period (L). The number of days that we do not plot moving averages for are the first $(L-1)/2$ and the last $(L-1)/2$ days.

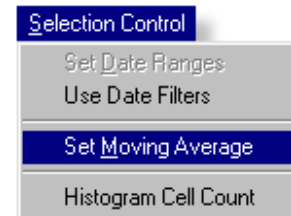


When displaying the Moving Average Chart, there are two X-Y lines being drawn. The black line represents the daily average and the moving average is represented in green.

This chart does not employ exponential smoothing commonly referred as *exponential weighted* moving average.

Setting Moving Period

Changing the Moving Average Period can be accomplished by selecting from the menus [*Selection Control*->*Set Moving Average*]. A dialog will appear that defaults to the current setting. The valid ranges for Histograms are a minimum of 3 and a maximum of 1056 or 3 years.



Besides the minimum and maximum range, GeoStat also validates that the entered period length is an odd number.

The period length is a global setting that effects all Moving Average Charts being displayed and is not configurable between different Geomet Part Programs.



Moving Range

Definition

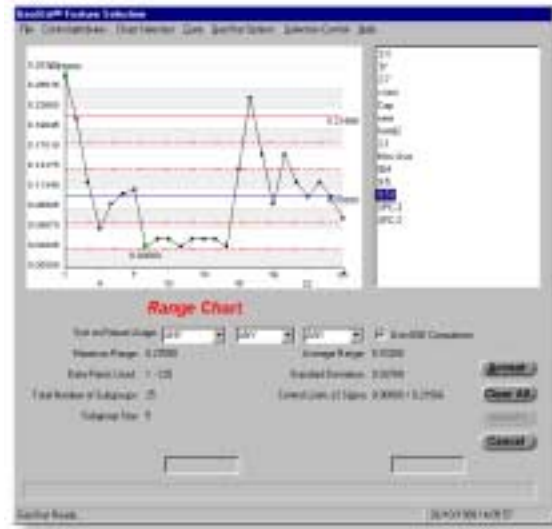
Setting Moving Period

See Setting Moving Period in the previous section.

Range

Definition

The Range Chart (**R**) monitors variability of the process by charting the difference of the largest and smallest within a subgroup of measurements. The range charts work together with the Xbar Chart and should be reviewed prior to developing the Xbar chart. A typical **R** chart should be set with a subgroup of 2 or more but should not be greater than 10. The sampling size or subgroup look back should be 20 or more, if possible, but not less than 10. **R** charts will enable you to determine whether the variability of a process is in control or whether shifts are occurring over time. If the process range is in control, then it can be used to develop control limits for the average.



Control limit ranges for R charts are calculated using the following equation:

$$UCL = Rbar + SL * Rbar * (d_3 / d_2)$$

$$LCL = Rbar - SL * Rbar * (d_3 / d_2)$$

where:

Rbar = average of all the observed ranges.

SL = GeoStat Control Limit Setting 3 or 6.

d₃ = Table of factors, refer to appendix C.

d₂ = Table of factors, refer to appendix C.

Raw Data Chart

Definition

The Raw Data Chart charts all measurement observations exclusive of their subgroups, but limited to the subgroup look back value. For example if the subgroup size is 5 and the look back is 10 there will be 50 plotted measurements.

From these measurements GeoStat will compute the Standard Deviation, Xbar and total range. The chart will reflect these values and be scaled between the LSL and USL or, if required the largest extent of measurements.

This chart is useful as an aid in observing the overall pattern of your manufacturing process. Additionally it provides a visual reference when conditions such as out-of-control or out-of-specification exist.



XBar

Definition

The Xbar chart monitors variability of the process by charting the average of the measurements within a subgroup. This chart is used after the **R** chart in the control process.

The combination of the **R** and Xbar charts offer the most sensitive control in identifying and tracing causes to your process. The data plotted for each subgroup is derived from the following equation:

$$\bar{X} = (X_1 + X_2 + X_3 + \dots + X_n) / n$$

where:

n = subgroup size

$X_1..X_n$ = measurements within each subgroup

The Estimate of averages of the subgroup averages and Control limit ranges for Xbar charts are calculated using the following equation:

$$\bar{\bar{X}} = (\bar{X}_1 + \bar{X}_2 + \bar{X}_3 + \dots + \bar{X}_k) / k$$

$$UCL = \bar{\bar{X}} + SL * (Rbar / (d_2\sqrt{n}))$$

$$LCL = \bar{\bar{X}} - SL * (Rbar / (d_2\sqrt{n}))$$

where:

$\bar{\bar{X}}$ = average of all subgroup averages.

$\bar{X}_{(n)}$ = sample mean for subgroup n .

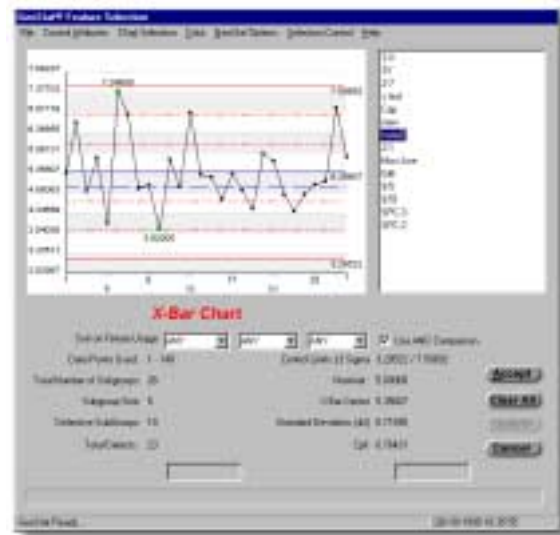
$Rbar$ = average of all the observed ranges.

k = number of subgroups.

SL = GeoStat Control Limit Setting 3 or 6.

d_2 = Table of factors, refer to appendix C.

In addition, the process capability index or CpK is reported here, see *Glossary of Terms for definition*.



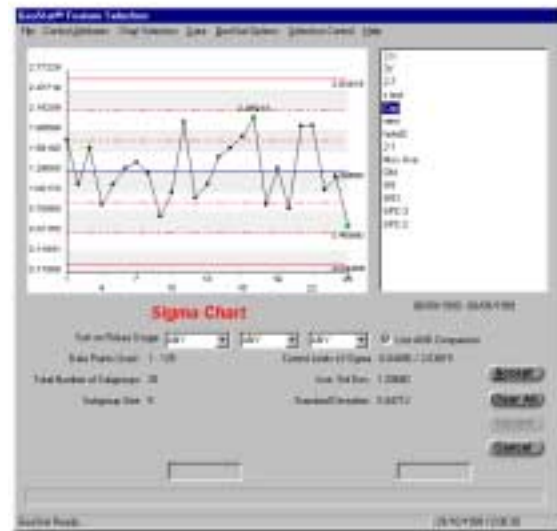
Sigma

Definition

The Sigma Chart when used with the \bar{R} chart provides monitoring of the variation of a process over time. Unlike the Xbar chart which works with the estimated mean of subgroup, the Sigma chart monitors the variation within the subgroup. The plotted observations are the Standard Deviation σ for each subgroup.

The average sigma is derived from the estimated mean of all calculated subgroup σ values.

The standard deviation for all subgroups are then calculated from the subgroup σ values and the control limits, 3 or 6, is then reported to complete the chart.



Tests for Instability

Definition

GeoStat provide 4 standard tests when viewing the control charts Xbar and Sigma. These tests are performed to provide the operator an early warning that an “unnatural” pattern is forming.

The 4 tests that are performed include:

Test 1: Any point outside of the control limits.

Test 2: Two out of three successive points fall in Zone C or beyond.

Test 3: Four out of five successive points fall in Zone B or beyond.

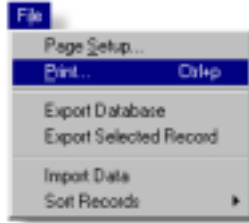
Test 4: any 8 consecutive data points on one side of the centerline.

GeoStat will display warning statements in the lower message area of the display. If more than one test fails, the message will indicate all, as shown in the example above.



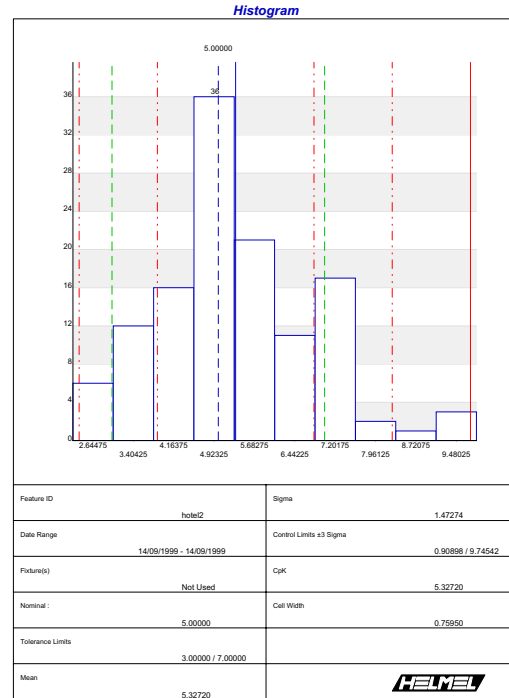
Printing Charts

Printing Single Charts



Printing on demand is accomplished through the pull-down menu command *[File-*

>Print]. GeoStat does not support printing directly from a Geomet part program.



Printing Batch Charts

Printing several charts at one time will be released in GeoStat release 2 due in the first quarter 2000.



Data - Import/Export

✓ ***Importing Data***

- Definition
- Data File Structure
- Importing a Data File
- Example from Excel
- Example from Word

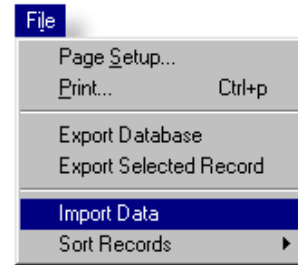
✓ ***Exporting Data***

- Definition
- Configuring Export Fields
- Exporting the Entire Database
- Exporting One Feature

Importing Data

Definition

In GeoStat you can attach measurements against an established GeoStat Header through the use of the Import command [*File->Import Data*]. This command opens an ASCII data file that has columns of data that use comma or spaces to specify data. Most applications from spreadsheets, word processors and other measurement devices can write ASCII data files.



Data File Structure

GeoStat works with several data structure formats allowing flexibility as to the data fields that are required. The structures of the data fields are:

Actual, Date, Time, Serial Number, Operator, Fixture1, Fixture2, Fixture3

where:

- **Actual Data:** is any valid number.
- **Date:** can be any of the following examples:

1/25/1999	01/25/1999
January 25 1999	Jan 25 1999
25 January 1999	25 Jan 1999

It should be noted that we require full year, 1999 not 99.

- **Time:** can be any of the following examples:

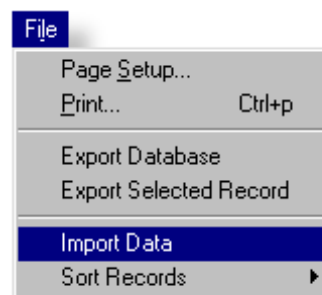
09:30:00	(hours:minutes:seconds)
09:30	(hours:minutes)
21:30:00	

The time format should conform to the 24-hour format where 21:00 is equal to 9:00 p.m.

- **Serial Number:** is any alphanumeric string.
- **Operator:** is any alphanumeric string.
- **Fixtures:** are any alphanumeric strings.

Importing a Data File

Before you begin the import process, you should select which Feature ID, or GeoStat Header Record to attach the incoming data to. After you have your feature chosen select the data file from the Open File Dialog located at *[File->Import Data]*. Find your ASCII text file and press <Open>. GeoStat will extract the measurements from the data structure as described above.



GeoStat extracts the data starting with the measurement value in the left column. It is not required to have data in all fields, as the examples below will illustrate.

GeoStat evaluates the first data line to determine if it contains column labels. If it determines that the first letter is not a number, then it will skip that line and proceed with the next. This should be noted when creating labels for columns. A label “Circle 2” will be evaluated as a label where “2 Circle” will extract the “2” as a measurement value.



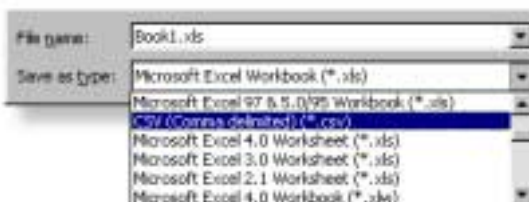
Example from Excel

One way data can be created is through the use of the Microsoft Excel spreadsheet. In the example below we created a file which we will then enter the measurement data.

Meas. Value	Date	Time	Serial Number	Operator	Fixture 1	Fixture 2	Fixture 3
10.251	10/19/99			John			
10.2605	10/19/99	08:00		John			H1A
10.2598	10/19/99				H2B		
10.2594	10/19/99	8:05:00	00102	John			

In the example above we have data in different fields allowing us the ability to skip data when it is not required. *Note: on the enclosed CD you will find this example file titled “datatables.xls”.*

When you have entered all your data proceed to save your work. Choose from the menu command *[File->Save As]* a save dialog will appear. Set the format in the



drop-down “Save as type:” “CSV (Comma delimited)(*.csv)”. Provide a file name and the location to store the data.

Exporting Data

Definition

GeoStat provides an export capability to save your measurement data in the ASCII text form for use with other applications. These text files are comma delimited and the format for the data is controlled by the command Configure Export Fields.

Configure Export Fields

To configure the ASCII export characteristics for all data being exported select from the menu; *[GeoStat Options->Configure Export Fields]*. You can define the following fields for the export format:



1. Feature ID
2. Date and Time
3. Operator
4. Serial Number
5. Fixtures
6. Export By Subgroups

By selecting fields 1,2,3,4 or 5 or any combination of, you are configuring the ASCII export to place in comma delimited format the respective data. The columns are constructed as follows:



Feature ID, Actual, Date/Time, Serial Number, Operator, Fixture1, Fixture2, Fixture3

An example of a record being exported with all field tags selected will look like:

3 X, 1.1230, 25/10/1999 00:00:00, 1, John, f1, f2, f3

An example that has only Feature ID selected would look like:

3 X, 1.1230

When you select “Export By Subgroups” all other options will become grayed-out and unavailable. This method is used to allow grouping of data for use in applications such as Excel spreadsheets. When you select this option, your output will look like:

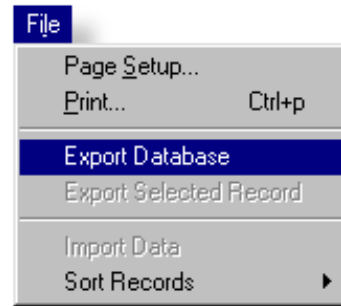
9.9805, 49.9805, -10.0195, -0.0195, 9.9805,
25.5000, 25.0000, 25.0000, 24.5000, 24.5000,

Each line across will contain one full subgroup as defined in the Feature Header. This will allow for better assignment of calculations where each row is a subgroup.

Exporting the Entire Database

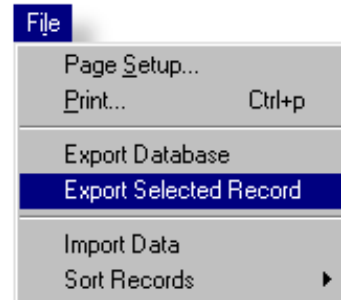
To Export all measurement data select from the menu *[File->Export Database]*. This command will export all data within the database in an ASCII text field using the format as specified in Configure Export Fields.

If you specify an existing file, GeoStat will prompt you whether to over-write or replace the file.



Exporting One Feature

To Export only the measurement data from on feature, select the Feature ID and then choose from the menu *[File->Export Selected Record]*.



A Tables

✓ *Control Chart Factors*

Observations in Sample	d_2	d_3
2	1.128	0.853
3	1.693	0.888
4	2.059	0.880
5	2.326	0.864
6	2.534	0.848
7	2.704	0.833
8	2.847	0.820
9	2.970	0.808
10	3.078	0.797
11	3.173	0.787
12	3.258	0.778
13	3.336	0.770
14	3.407	0.763
15	3.472	0.756
16	3.532	0.750
17	3.588	0.744
18	3.640	0.739
19	3.689	0.733
20	3.735	0.729
21	3.778	0.724
22	3.819	0.720
23	3.858	0.716
24	3.895	0.712
25	3.931	0.708

B Glossary of Symbols

✓ *Statistic Symbols used in GeoStat*

Symbol	Description	Note
σ	Sigma	Standard Deviation
LCL	Lower Control Limit	Lowest Control Point for acceptable values
LSL	Lower Specification Limit	Nominal – Lower Tolerance
R	Range	Total Range example: Range Chart
Rbar	R-Bar	Average of all observed values
SL	Sigma Limit	Specifies 3 or 6 Sigma Level
UCL	Upper Control Limit	Highest Control Point for acceptable values
USL	Upper Specification Limit	Nominal + Upper Tolerance
Xbar	X-Bar	Average of each observed subgroups
Xbarbar	X-Bar Bar	Average of all Xbar values



Glossary of Terms

*.csv:	a comma delimited file format used in Microsoft Excel to save data into a ASCII formatted file.
*.GST:	the extension used for native file formats within GeoStat.
*.GMT:	the extension used for native file formats within Geomet.
ASCII:	American Standard Code for Information Interchange. The file format used by GeoStat for import and export of measurement results for use by other applications.
Attributes:	a single characteristic of a measured feature. Example: the X location of a XY Circle.
Cell Count:	the number of cells, or bars, GeoStat will use in the creation of a Histogram.
Centerline:	either the Xbar of control and range charts or the nominal or raw data charts.
Control Levels:	when activated, GeoStat draw control levels at 1-2 standard deviation on a 3 sigma control or 2-4 standard deviation levels when configured for 6 sigma. These lines represent Zones A, B and C.
CpK:	Process capability index. The reported value is the lesser of $(USL - \text{Mean}) / (SL * \sigma)$ and $(\text{Mean} - LSL) / (SL * \sigma)$.
Date Range:	a user defined range of dates that GeoStat will use when building the measurement files to be used in SPC.
Double clicking:	the process of applying two fast-button presses from the mouse using the left button. Used in selection and expanding processes.
Feature ID:	the visible name of a feature shown the data display of the GeoStat window.

Feature Tagging:	the process of assigning a feature within Geomet to be exported to GeoStat.
Fixtures:	user defined fields in Geomet and GeoStat that allow segregating of measurement results to reflect location of manufacture, fixtures assigned too, etc.
Header:	the record identifier for a single attribute that GeoStat will capture all common measurements against. The Header maintains the tolerance values, subgroup sizes, and subgroup lookback and is shown in GeoStat as the Feature ID.
Histogram:	shown as a bar graph whose heights of the bars represent the frequency of distribution of all measurements. The bars, or cell widths, are inclusive of the measurement range.
LCL:	Lower Control Limit. The calculated limits of control based on - 3 or - 6 standard deviation.
Limit Test:	provides a popup warning box when viewing a control charts that has point(s) outside the control limits or when exceeding the specification limits on a Raw Data chart.
LSL:	Lower Specification Limit (Nominal – Lower Tolerance).
Moving Average:	smoothing calculation of a set of observations over a time period.
Moving Period:	the number of days used as the smoothing factor for Moving Average and Moving Range charts.
Nominal:	the basic value from the print for the measured feature.
Print Heavy Lines:	doubles the weight of printed lines when using high-resolution printers.
R (Range):	the difference of the largest and smallest within a subgroup of measurements.
Raw Data:	provides a chart that represents all measurement values with regard to the LSL – Nominal – USL levels.
Report Precision:	the number of places to the right of the decimal place for all charts and calculated results.
Subgroup Lookback:	a user defined value that will represent how many subgroups GeoStat will use in calculating values for all charts.
Test 1:	a test to review the current chart for any data points that exceed the control limits. Test 1 applies to the Xbar and Sigma charts only.

Test 2:	a test to review the current chart for any 2 data points from 3 consecutive data points that are in Zone C or beyond. Test 2 applies to the Xbar and Sigma charts only.
Test 3:	a test to review the current chart for any 4 data points from 5 consecutive data points that are in Zone B or beyond. Test 3 applies to the Xbar and Sigma charts only.
Test 4:	a test to review the current chart for any 8 consecutive data points on the same side of the Xbar line. Test 4 applies to the Xbar and Sigma charts only.
UCL:	Upper Control Limit. The calculated limits of control based on + 3 or + 6 standard deviation.
Unnatural:	a pattern of data points that fail to balance themselves around the centerline of the control chart. GeoStat uses Test1, 2, 3 and 4 for identify these.
USL:	Upper Specification Limit (Nominal + Upper Tolerance).
Zone A,B,C:	these zones represent three equally spaced levels between the centerline to either ± 3 or 6 standard deviations. They are also referred as “one sigma zone” or “two sigma zone”, etc. Zone A is equal to $\bar{X} \pm 1$ standard deviation when configured for 3 sigma.

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