Bailey® infi 90®

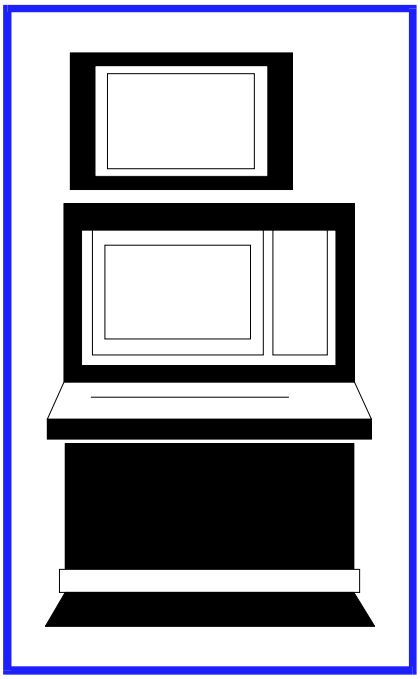
E97-811-4

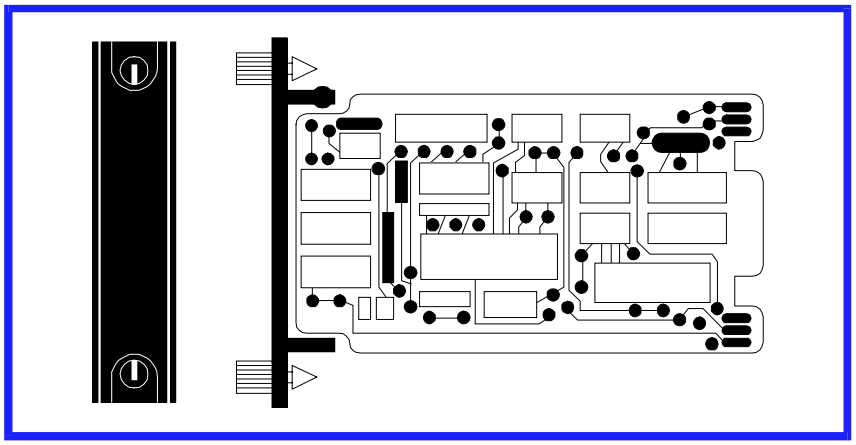
Instruction

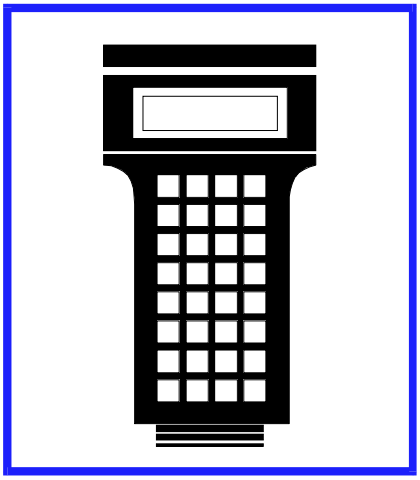
LAN-90® Process Control View (PCV®)

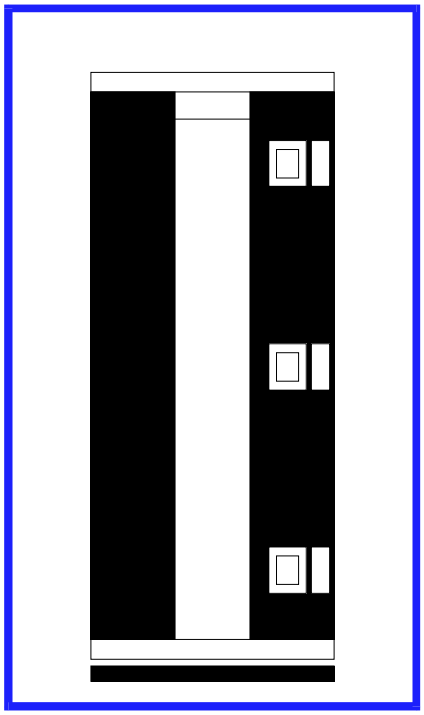
Quality Analysis and Control (QAC)

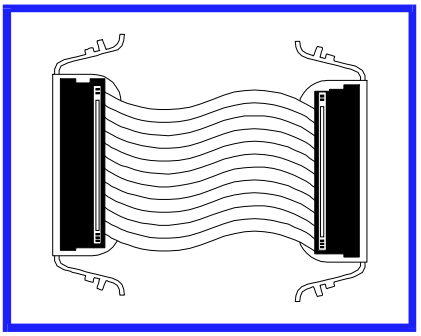
(Software Release 5.2)

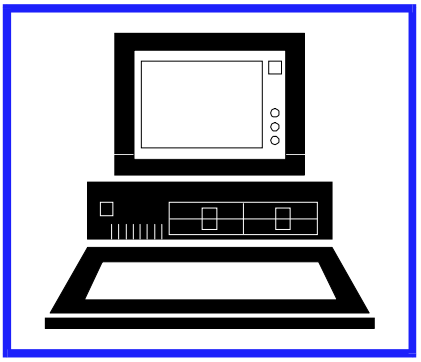












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WARNING notices as used in this instruction apply to hazards or unsafe practices that could result in personal injury or death.

CAUTION notices apply to hazards or unsafe practices that could result in property damage.

NOTES highlight procedures and contain information that assists the operator in understanding the information contained in this instruction.

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Preface

This manual applies to Software Release 5.2. Quality Analysis and Control package. It provides general information and specific instructions on installing and configuring the QAC package.

This manual, together with the Installation Manual, Operation Manual and Configuration Manual, provides a complete description of the LAN-90 Process Control View (PCV) QAC package.

This manual can be used as:

- A reference guide for system engineers and technicians responsible for configuring the QAC package for its intended application and as an operation guide for those who want to use the generated reports.

- An operation guide for process control operators using the LAN-90 PCV console.

This manual assumes the reader has a general knowledge of CRT-based process control systems.

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List of Effective Pages

Total number of pages in this instruction is 51, consisting of the following:

Page No.	Change Date
Preface	Original
List of Effective Pages	Original
iii through vi	Original
1-1 through 1-2	Original
2-1 through 2-3	Original
3-1 through 3-3	Original
4-1 through 4-14	Original
5-1 through 5-3	Original
6-1 through 6-3	Original
7-1 through 7-5	Original
8-1 through 8-1	Original
A-1 through A-9	Original
Index-1 through Index-2	Original

When an update is received, insert the latest changed pages and dispose of the superseded pages.

NOTE: On an update page, the changed text or table is indicated by a vertical bar in the outer margin of the page adjacent to the changed area. A changed figure is indicated by a vertical bar in the outer margin next to the figure caption. The date the update was prepared will appear beside the page number.

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SECTION 1 - INTRODUCTION

QUALITY ANALYSIS AND CONTROL (QAC)

The QAC package uses trend data for real-time and historical SPC and TSA analysis. Trend data is collected by sampling process variables on a regular basis and storing the collected values on the computer's hard disk.

If you have the optional Lab Data Entry package, process variables that are sampled manually can also be trended and analyzed.

SPC has five different Shewhart charts, one-sided Cumulative Sum (CUSUM) charts, and Exponentially Weighted Moving Average (EWMA) charts. Process standards can be set or limits can be calculated from the data. Key SPC variables are calculated and displayed automatically. Out-of-specification situations are highlighted and generate alarms. The rules used to determine an out-of-spec situation can be modified for Shewhart charts.

TSA has raw data plots, histograms, auto correlation and power spectrum plots, cross correlation plots, and coherence and coherent power/power spectrum plots.

CONVENTIONS USED IN THIS MANUAL

You will find the following conventions used throughout this manual:

NOTE: Used to highlight important or additional information.

CAUTION	Used to highlight information that, if ignored, could result in property or information damage.

WARNING	Used to highlight information that, if ignored, could result in personal injury.

bold Used for anything you must type exactly as shown. For example, you could be told to press **y** or type **ls /dev/hd0t77** (QNX4 example).

italic Used for information you must provide. For example, if you are told to enter a *filename*, you type the actual name of the file instead of the italicized word. Also used to show information displayed by the computer.

Initial Capitals	Used for menu and screen titles.
`small text`	Used to show the contents of text files.
<Key>	Used for the names of special keys (non-alphabetic, non-numeric, non-punctuational) that can be found on the regular QWERTY keyboard or can be found on both the Elsag Bailey operator and regular keyboards. Some of the key names used are:

<Enter>	the enter key
<Num+>	the plus key on the numeric keypad
<Space>	the space bar
<PgUp>	the page up key
<Left>	the left cursor key

{Key}	Used for the names of keys found only on the Elsag Bailey operator keyboards. Some of the Elsag Bailey operator keyboard key names are {Silence} and {DoubleUp}.
<Key Key>	When two or more keys are to be pressed together, the key names appear together within the brackets or braces. For example, to reboot the computer, you can press <Ctrl Alt Shift Del>; that is, press the Ctrl, Shift, Alt, and Del keys in that order without releasing any one until you have pressed them all.
"name"	Used for filenames, directory names, and device names.

SECTION 2 - INSTALLATION

OVERVIEW

Usually Quality Analysis & Control is installed with the base system and no special installation instructions are required. Refer to the ***LAN-90 PCV Installation Manual (I-E97-811-1***) for information on installing base system software.

This section is intended for users who purchase the QAC option as a separate package and install it after the base system has been installed.

INSTALLING QAC ON AN EXISTING SYSTEM

The QAC disks must be loaded onto all of the computers on the network.

> **NOTE:** Do NOT load the software on diskless computers. Diskless computers use the programs found on the boot node and are automatically ***loaded*** with the primary/redundant nodes.

To install the QAC package, follow the path depicted in Figure 2-1:

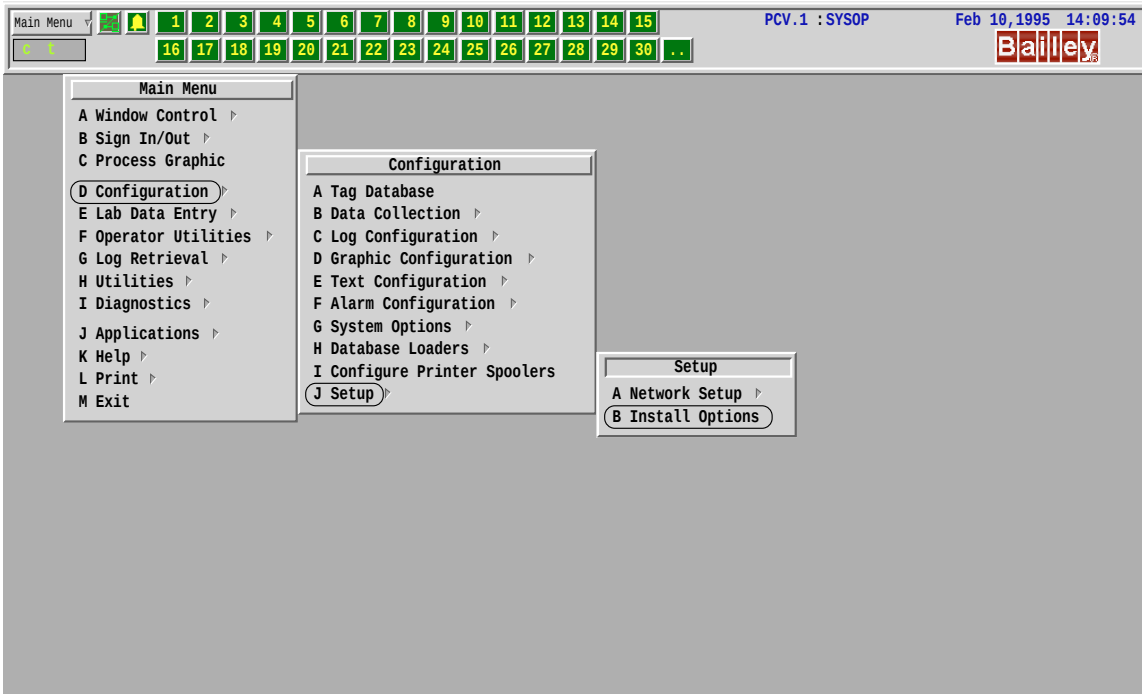

Figure 2-1. Accessing the PCV Setup Utility

Loading QAC

QAC is shipped as an archived volume.

When the installation program asks you to place the first disk in the floppy drive, insert the QAC disk and press <Enter>.

When the program asks if you have other disks to install, press <F10> to continue to the next step.

> **NOTE:** If you are loading a computer that acts as the boot node for diskless nodes, load all optional disks required by the diskless nodes on the computer as well as its own. On a non-redundant network, load all diskless node options on the primary node; on a redundant network, load all diskless node options on both the primary and redundant nodes.

Set the Start-up Options

To access the System Options Utility, follow the menu path depicted in Figure 2-2*:*

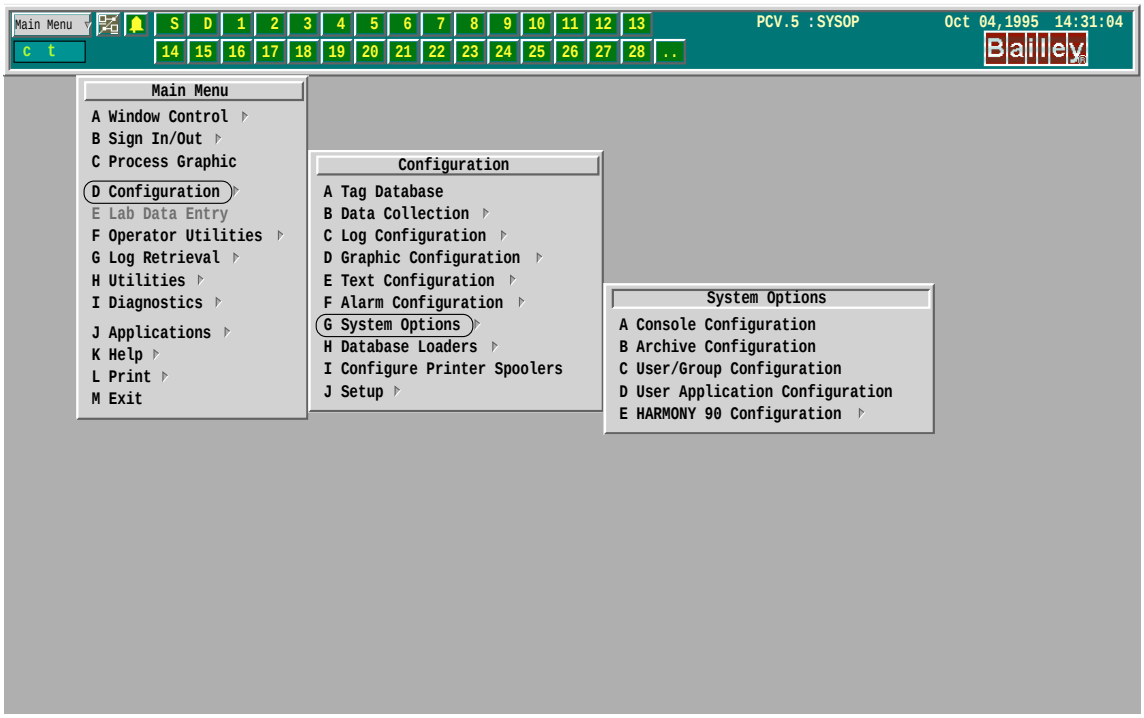

Figure 2-2. Accessing the PCV System Options Utility

This yields the Console List display. At the Console List display, select <F2> to edit the console options. The first page contains a field which enables or disables the SPC Manager.

Enable SPC Manager by moving the cursor to the Enable field. You may also enable SPC Alarming.

To save the changes you have made, select menu option <F1>. The program asks if you want to *Save Changes? (Y/N)*. To save your changes, press **Y**; to abandon any changes, press **N**. In either case, you will be returned to the System Options screen.

When you have finished setting and saving your system options, press <F10> to exit.

Modifying LAN-90 QAC Programs

The level of sigma control can be modified by changing a system start-up option. The system uses 3 sigma limits by default. To use 2 sigma limits, perform the following steps:

Access the QNX prompt and type:

cd /bci/pcv/etc/win/pcvExec
vedit startup.cf

Locate and modify the start-up parameters of the SPC display task as follows:

pcvSpc.update -S, SPC, U

Save the modified file and shut down the system. Restart for the changes to take effect.

Shut Down and Restart the Computer

Once you have finished the installation procedure, select **Exit** from the Main menu, then choose **Exit and Shutdown**. When the shutdown complete dialog box is presented, reboot by pressing <Ctrl-Alt-Shift-Del>. The server will then restart with the QAC option enabled.

SECTION 3 - USING TREND CHARTS

USING A TREND DISPLAY

A trend chart plots a tag's collected values on a grid. Time is shown along the horizontal axis (oldest to newest reading left to right), and the value is shown along the vertical axis. A vertical cursor bar is displayed in the plot area.

To the right of the plot, boxes display information about each tag plotted on the chart (Figure 3-1). There can be up to 5 tags per chart.

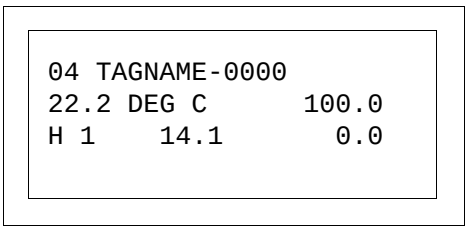

Figure 3-1. Trend Box

At the top center of each box is the tag name. Below the tag name is the live value of the tag and its engineering units. An alarm indicator is displayed in the lower left corner if the tag is in alarm.

The value of the plotted sample at the cursor bar position is displayed at the bottom center. The upper and lower display limits of the chart for the tag are displayed on the right.

The letters or numbers at the upper left corner of the trend box are the trend select keys. To be able to scroll through historical data, you must first select the trend by typing these keys. If the selection indicator is only a single digit or letter, you must press that key and <Enter> to select the trend. The color of the trend select number indicates the color of the tag's plot.

Once you have selected a trend chart, you can scroll through the historical data. Table 3-1 describes how you can view the trend data.

Table 3-1. Using a Trend Display

To:	Press:
Select a trend chart,	The trend select keys of any trend on the chart.
Move the cursor within the displayed time span,	<Left> and <Right> to move one sample at a time, <Alt Left> and <Alt Right> to move ten samples at a time, <Home> to move to the rightmost sample, <End> to move to the leftmost sample.
Move to an older time span than is displayed (pan backward),	{DoubleLeft} or <Ctrl Left>
Move to a newer time span than is displayed (pan forward),	{DoubleRight} or <Ctrl Right>
Move directly to a specified time span,	{Pan} or <Num-> then, at the prompt, enter the date and time you would like to move to. The format of the entry is: dd-mon-yyyy hh:mm:ss
Double the length of the time span displayed (zoom out),	{DoubleUp} or <Ctrl Up>
Halve the length of the time span displayed (zoom in),	{DoubleDown} or <Ctrl Down>
Double or halve the length of the time span more than once at a time,	{Zoom} or <Num*> then, at the prompt, enter the number of times you would like to zoom in or out. Enter a positive number to zoom out; enter a negative number to zoom in.
Change the range of values displayed for a tag,	The trend select keys for the tag. The cursor will be displayed in the upper chart limit field, and you can enter a new value. Move to the lower chart limit field by pressing <Down>, then enter a new value for the lower limit. When you are finished, press <Esc>.
Toggle the display of the background grid off and on,	<Ctrl G>
Unselect a trend chart,	<Esc>

SPC charts provide all the capabilities of regular trend charts, and you can mark a set of data to use for SPC calculations.

TSA can be performed on any regular trend charts, and you can mark a set of data to use for time series analysis.

SPC charts look very much like regular trend charts except that calculations and parameters are shown in the place of the bottom four trend control boxes, and, in addition to the trend trace, the grid area also displays traces for the SPC control limits.

The ***Operation manual*** (I-E97-811-2.2) and ***Configuration manual*** (I-E97-811-2.1) describe how to use a trend chart.

The trend control box is the same as that of a regular trend display. The only thing to be aware of is that the live value displayed on the middle line of the trend control box is the live, raw value of the trend, not the most recently calculated value. The value of the trace (the calculated value) at the time cursor is displayed in the middle of the bottom of the trend control box.

SPC control limits are always displayed as cyan (light blue) dashed lines on the chart. The trend trace is displayed in the color indicated by the trend select keys in the trend control box, except when the chart is in alarm. When a chart is in alarm, the trend trace is drawn in a contrasting color (either red or yellow).

When you move the time cursor to a region of the trend trace that is in alarm, the SPC alarm description is displayed below the lower-left corner of the chart.

You can add comments to SPC charts. Comments appear as small exclamation marks ("!") along the bottom edge of the grid area, and the text of the comment appears below the center of the chart when the time cursor is positioned on the exclamation mark ("!").

All the functions for moving around a regular trend chart are available in SPC charts. SPC charts also provide addition functions for recalculating limits.

To recalculate limits on a chart you mark a range of data to use in the limit calculations, then recalculate limits based on this selected range of data.

SECTION 4 - USING SPC CHARTS

COMMON SPC CHART FUNCTIONS

There are things that are common to all SPC charts:

- Selecting a range of data to use in calculations.
- Editing the samples included in the selected range.
- Clearing a range selection.
- Recalculating limits.
- Setting old limits for the current time.
- Changing the display resolution.
- Changing the sample rate.
- Adding comments to a chart.

Selecting a Range of Data to Use in Calculations

To mark the first edge of the range to analyze, position the time cursor at one end of the range, then press <Tab>. This marks that end with a vertical bar. To indicate the other end of the range, simply move the time cursor to the position of the other end. You do not set a second mark for the other end of the range; it is marked by the position of the time cursor.

Both ends do not have to be displayed in the currently displayed time span; you can mark one end, pan to the other end, and then perform the limit calculations.

Any selected data set is not cleared when the calculations are accepted or rejected. Use <Shift Tab> to clear the selection.

To perform calculations, SPC charts require a minimum number of samples. The number of samples required depends on the type of chart. Table 4-1 lists the minimum number of samples that are required in the data range for each type of SPC chart:

Table 4-1. Minimum Number of Samples Required for SPC Calculations

Type SPC Chart	Minimum Number Samples
Shewhart Charts	20
CUSUM Charts	20
EWMA Charts	50

To select a data range, you need to have Configuration level access or greater.

Editing the Samples Included in the Selected Data Range

The editing function is common to all SPC chart types. With this function you can:

- Change the starting date/time of the selected data range.
- Change the ending date/time of the selected data range.
- Mark points to be ignored in the calculations.

Editing can be performed after the recalculation dialog is called up for any chart. To display the recalculation dialog press **R.**

While in the data editing mode, you can use all the cursor movement, panning, and zooming keys described for the regular trend displays.

You also have three special editing functions available:

Start Date If you want to change the start date/time of the selected range, position the time cursor at the new start position, then press <Tab>. This moves the start of the selected range to the time cursor position.

End Date If you want to change the end date/time of the selected range, position the time cursor at the new end position, then press <Tab>. This moves the end of the selected range to the time cursor position.

Delete You can mark individual points to be ignored in the calculation by positioning the time cursor over top of the samples to be ignored, then pressing **D**. Samples to be ignored are circled.

Clearing the Range Selection

To clear a selected range, press <Shift Tab>. The mark does not have to be in the currently displayed time span in order to clear it.

Recalculating Limits

Once a range has been marked, limits can be recalculated by pressing **R**. This calls up a recalculation dialog which provides various recalculation functions; the functions available depend on the type of SPC chart being used.

The following functions are common to all SPC recalculation menus:

Cancel If you decide that you do not want to use the new limits you have calculated, you can click on the **Cancel** button to abandon any changes you have made and return to the trend display with the tagged range still set.

Accept When you have finished calculating a new set of limits for the current range, you set the new limits by clicking on the **Accept** button to accept them. This accepts the limits for the selected data range only.

Reset If you decide that you do not want to use the new limits you have calculated, you can reset the original limits (the limits active at the time you started to recalculate) without leaving the recalculation menu by clicking on the **Reset** button.

Changing the Display Resolution

When an SPC trend is selected for control, you can change the display resolution by a method other than zooming.

The display resolution for the SPC chart is shown on the second last line of the calculation and parameters box (Figure 4-1). You can change the display resolution via the Properties dialog, press **P** for the chart.

Display resolution determines the amount of time between two displayed points on the trend chart. The greater the display resolution the closer together are the displayed points, and the greater the displayed time span.

The display resolution has no effect on SPC calculations.

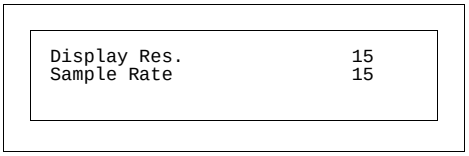

Figure 4-1. Display Resolution and Sample Rate

Changing the Sample Rate

Sample rate determines the fraction of collected samples that will be used in the SPC calculations.

The sample rate used for calculation is shown on the last line of the SPC calculation and parameters box (Figure 4-1). You can change the sample rate via the Properties dialog (Press **P**) for the chart.

By default, the sample rate used in calculations is the same as the sample rate used to collect data. This means every sample collected is used in the SPC calculations.

You cannot set a calculation sample rate that is faster than the actual collection sample rate.

You can set a sample rate that is slower than the collection sample rate, and only a fraction of the actual samples will be used in the calculations.

You cannot set a sample rate for discrete trends (Sample Rate is shown as *DISCRETE*).

Adding Comments to an SPC Chart

Descriptive comments can be added to SPC charts by using the Comment function.

Select the trend, then position the time cursor at the time you want to add a comment, then click the right mouse button on the comment selection. A prompt dialog will appear in which to enter the comment.

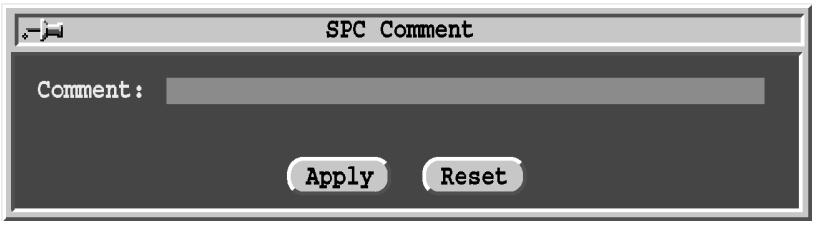

Figure 4-2. SPC Comment Menu

An exclamation mark (!) appears at the bottom of the grid area at the point where the comment was added. The descriptive text appears just below the chart as long as the time cursor is to the right (forward in time) of the comment and to the left (backward in time) of any other comment. Figure 4-3 illustrates how a comment is displayed.

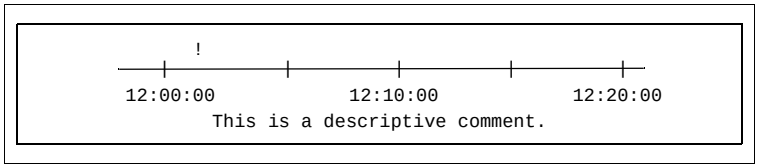

Figure 4-3. Comment Display on an SPC Chart

To enter comments, you must have Control level access or greater.

Making Control Limits Current

Any control limits shown on the SPC chart can be selected as the current limits.

Select the trend, then position the cursor on the appropriate time, then press **C**. A prompt dialog will appear. Select **Yes** to make these control limits current.

SHEWHART CHARTS

Shewhart displays are two-chart displays; the upper chart shows a plot of the averages of the variable, and the lower chart shows a plot of the variability of the variable.

There are five different SPC chart combinations available:

- X-Bar R, Mean and Range charts,
- X-Bar S, Mean and Standard Deviation charts,
- X moving R, Individual and Moving Range charts,
- Me Midr, Median and Mid-Range for Median charts,
- Me-R, Median and Range for Median charts.

All the charts operate the same way.

Each SPC display only shows one combination; both the upper and lower charts trend the same trend variable.

The grid area displays the trend trace, center line, upper control limit, and lower control limit. The points plotted for the trend trace are calculated from a sub-grouping of raw points, depending on the type of Shewhart chart. The center line, upper control limit, and lower control limit are calculated from a selected range of data or set according to predefined standards.

Each chart has one trend control box for the trend, and below it appear the SPC calculations. An example of a Shewhart trend control box, and calculation and parameter box is shown in Figure 4-3. The calculation fields are described in Table 4-2.

NOTE: Making changes to X-Bar R charts will usually also affect X-Bar S charts and vice-versa. Also changes to MeMr charts will affect MeR charts and vice-versa.

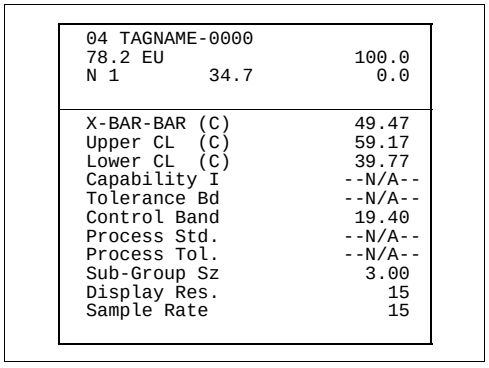

Figure 4-4. Shewhart Trend Control Box and Calculation (for XBar chart)

Table 4-2. Shewhart Calculation Fields

Field	Description
Center Line (X)	Shows the value of the center line at the time cursor position. The description for the center line depends on the type of Shewhart chart: X-BAR-BAR, R-BAR, S-BAR, X-BAR, mR-BAR, M-Median, MR-Median, R-Median If limits are calculated from data, (C) is displayed. If limits are based on standards entered, (S) is displayed.
Upper CL (X)	Shows the value of the upper control limit at the time cursor position. If limits are calculated from data, (C) is displayed. If limits are based on standards entered, (S) is displayed.
Lower CL (X)	Shows the value of the lower control limit at the time cursor position. If limits are calculated from data, (C) is displayed. If limits are based on standards entered, (S) is displayed.
Capability I	If standards have been entered, the capability index is displayed here, otherwise this field shows --N/A--.
Tolerance Bd	If standards have been entered, the tolerance band is displayed here, otherwise this field shows --N/A--. The tolerance band is double the process tolerance.
Control Band	The control band shows the difference between the upper control limit and lower control limit.
Process Std.	If a process standard has been entered, it is shown here, otherwise this field shows --N/A--. The process standard is the **target** center line for the chart. A process standard (and the process tolerance) can be entered using the recalculation menu.
Process Tol.	If a process tolerance has been entered, it is shown here, otherwise this field shows --N/A--. The process tolerance specifies the acceptable variation from the process standard. A process tolerance (and the process standard) can be entered by using the recalculation menu.
Sub-Group Sz.	Specifies the size of the subgroup used in calculations. This value can be altered directly from the Properties Dialog (press **P**). Changing the subgroup size affects all Shewhart charts that use the same trend tag: - XBar, R(x), S changing one changes the others - X, movingR cannot be changed (fixed at 1) - Me, Mr, R(m) changing one changes the others. Changing subgroup size also affects historical data.
Display Res.	Display resolution can be set directly from the Properties Dialog press **P** or indirectly by using the "zoom" keys. The display resolution has no influence on the SPC calculations. See ***Changing the Display Resolution*** for details.
Sample Rate	The sample rate used for calculations; can be set by pressing **S**. See ***Changing the Sample Rate*** for details.

Toggling the Display of Sigma Lines

After a trend has been selected, the sigma lines between the center line and the control limits can be enabled via the Properties dialog for the chart (press **P**).

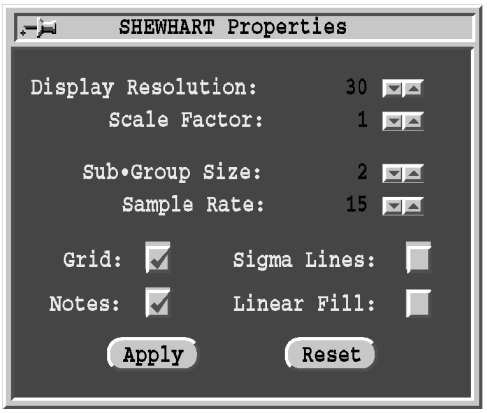

Figure 4-5. Properties Dialog for Shewhart Charts

The state of the display of sigma lines is remembered when you exit the display. If you had the display of sigma lines turned on when you left a Shewhart display, then they will be displayed the next time you call up a Shewhart display.

Recalculating Limits Based on Data

To recalculate control limits based on the data, select a range of data, then press **R**.

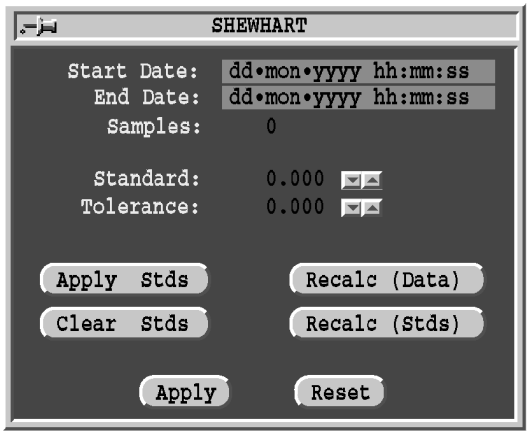

Figure 4-6. Recalculation Dialog for Shewhart Charts

To test your data range, click on the **Recalc** (Data) button to calculate new limits based on the data. To accept these limits click on the **Accept** button.

Calculating a Capability Index

You can calculate a capability index when using control limits based on the data and by setting standards using the recalculation menu.

Before recalculating limits based on data, enter the process standard and process tolerance on the recalculation dialog. Then click on the **Apply Stds** and **Recalc** (Data) buttons to calculate the capability index. Click on the **Accept** button to accept these calculations. You can clear any process standards set by clicking on the **Clear Stds** button.

Recalculating Limits Based on Standards

Using the recalculation dialog, you can calculate control limits based on standards. Enter the process standard and tolerance then click on the **Apply Stds** button to apply them. Then click on the **Recalc (Stds)** button to recalculate the limits based on the standards. Click on the **Accept** button to accept these calculations.

CUSUM CHARTS

CUSUM charts are single charts that show the cumulative sum of a variable's deviation from target.

CUSUM charts are one-sided. They either show the sum of positive deviations (upper CUSUM charts) or the sum of negative deviations (lower CUSUM charts). To see both sums on a single display, both types of CUSUM charts can be set up on the same display.

Each CUSUM chart only shows one trend.

The grid area displays the trend trace, and critical boundary. The points plotted for the trend trace are the cumulative sum of the sample values for the trend less the target value. A single control limit, the critical boundary, is plotted.

Each chart has one trend control box for the trend, and below it appear the SPC calculations. An example of a CUSUM trend control box and calculation and parameter box is shown in Figure 4-7. Table 4-3 describes the calculation fields.

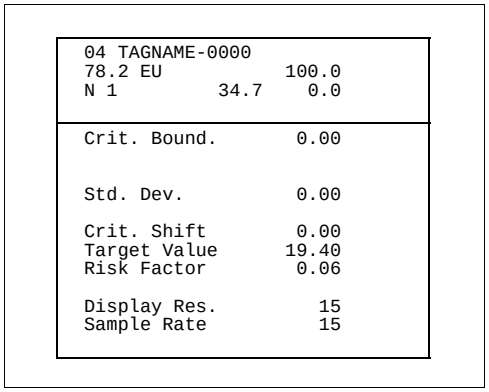

Figure 4-7. The CUSUM Trend Control Box and Calculations

Table 4-3. CUSUM Calculation Fields

Field	Description
Crit. Bound.	Displays the value of the critical boundary at the time cursor position
Std. Dev.	The standard deviation calculated from the data set range.
Crit. Shift.	The critical shift; the shift in the mean that is to be detected. This can be manually set via the Properties dialog for the chart (press **P** to display the Properties dialog). To calculate the critical shift use the Recalculation dialog (press **R** to display the Recalculation dialog). If a data range has been selected, this setting is used only for the selected range.
Target Value	The target value for the trended variable. This can either be set or calculated from a data range. To set the target value, use the Properties dialog. To calculate a target use the Recalculation dialog. If a data range has been selected, this setting is used only for the selected data range.
Risk Factor	The risk factor. The default value is 0.06 (type I error risk factor). This can be entered via the Properties dialog. If a data range has been selected, this setting is used only for the selected data range.
Display Res.	Display resolution can be set directly via the Properties dialog or indirectly by using the ***zoom*** keys. The display resolution has no influence on the SPC calculations. See ***Changing the Display Resolution*** for details.
Sample Rate	The sample rate used for calculations can be set via the Properties dialog. See ***Changing the Sample Rate*** for details.

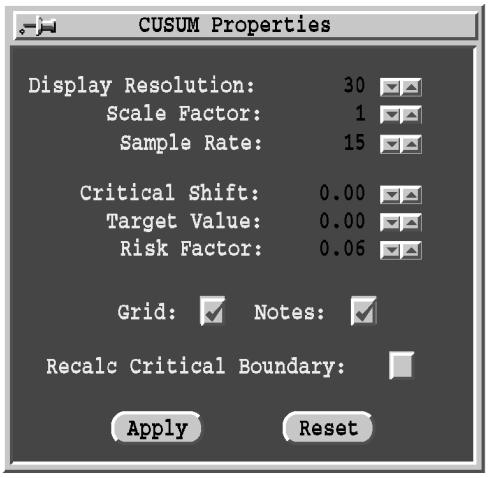

Figure 4-8. Properties Menu for CUSUM Charts

Recalculating the Critical Boundary

To calculate the limits for a range of data:

1. Select a range of data to use.
2. Press **R** to display the Recalculation dialog.
3. Click on the **Calc Limits** button.
4. Click on the **Accept** button to accept the calculations.

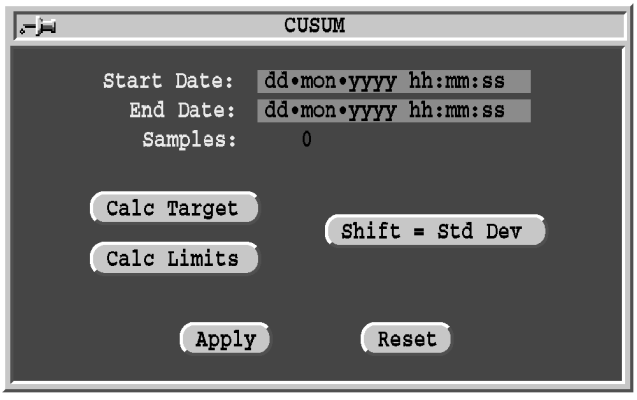

Figure 4-9. CUSUM Recalculation Menu

This calculates both the standard deviation for the range and the critical boundary (using the critical shift already set).

If you want to use a critical shift equal to the standard deviation, click on the **Shift = Std Dev** button, then click on the **Calc Limits** button to calculate the critical boundary again.

To accept the critical boundary calculated, click on the **Accept** button. To cancel the newly calculated critical boundary value, click on the **Cancel** button.

Calculating a Target Value

To calculate the mean for a range of data:

1. Select a range of data to use.
2. Press **R** (to display the Recalculation dialog).
3. Click on the **Calc Target** button.

This sets the target value equal to the mean for the range of data.

To accept the target value calculated, click on the **Accept** button. To cancel the newly calculated target value, click on the **Cancel** button.

EWMA CHARTS

EWMA charts are single charts that show the exponentially weighted moving average of the trend.

Each EWMA chart only shows one trend.

The grid area displays the trend trace, center line, upper control limit, and lower control limit. The points plotted for the trend trace are the predicted values for the samples. The predictions are based on the previous point plus a weighted factor based on previous values; the influence of older values decreases exponentially. The center line, upper control limit, and lower control limit are calculated from a selected range of data, or set according to predefined standards.

Each chart has one trend control box for the trend, and below it appear the SPC calculations. An example of an EWMA trend box is shown in Figure 4-10. Table 4-4 describes the calculation fields.

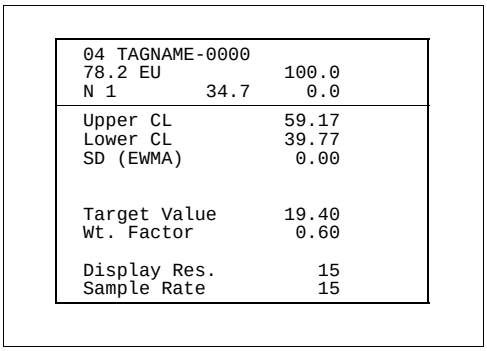

Figure 4-10. EWMA Control Box and Calculations

Table 4-4. EWMA Calculation Fields

Field	Description
Upper CL	The value of the upper control limit at the time cursor position.
Lower CL	The value of the lower control limit at the time cursor position.
SD (EWMA)	The standard deviation calculated for the selected data range.
Target Value	The target value for the trended variable. This can either be set or calculated from a data range. To set the target value, use the Properties dialog (press **P**); to calculate a target value, use the Recalculation dialog (press **R**). If a range has been selected, this setting is only used for the selected range.
Wt. Factor	The weighting factor determines the degree of influence past values will have in the calculations. This can be entered via the Properties dialog. If a range has been selected, this setting is only used for the selected range.
Display Res.	Display resolution can be set directly via the properties dialog indirectly by using the ***zoom*** keys. The display resolution has no influence on the SPC calculations. See ***Changing the Display Resolution*** for details.
Sample Res.	The sample rate used for calculations; can be set via the properties dialog. See ***Changing the Sample Rate*** for details.

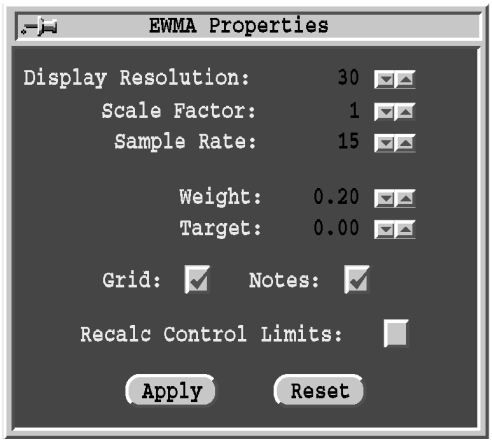

Figure 4-11. EWMA Properties Menu

Recalculating Limits

To recalculate the limits for an EWMA chart, select a range of data, then press **R** to display the Recalculation dialog.

A weighting factor can be entered directly.

When you have selected a weighting factor for the calculations, recalculate the limits by clicking on the **Recalc Limits** button.

If you want to use the limits you have calculated, click on the **Accept** button to accept the new limits. If you want to abandon any calculations you have performed, click on the **Cancel** button.

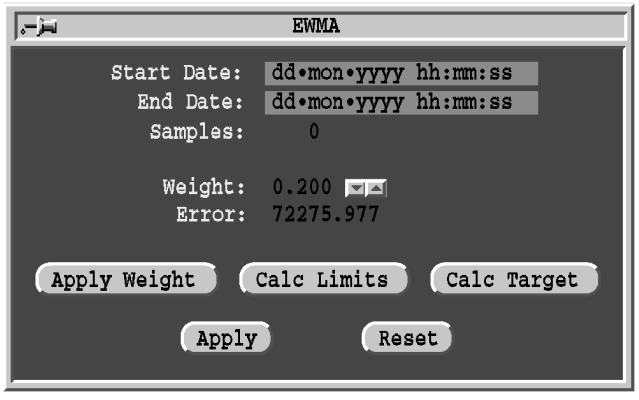

Figure 4-12. EWMA Recalculation Dialog

Calculating a Target Value

To calculate the mean for a range of data:

- Make sure the trend is selected.
- Select a range of data to use.
- Press **R** to display the Recalculation dialog.
- Click on the **Recalc Target** button.

This sets the target value equal to the mean of the range of data.

To accept the target value calculated, click on the **Accept** button. To cancel the newly calculated target value, click on the **Cancel** button.

SECTION 5 - USING TSA CHARTS

OVERVIEW

TSA can be performed on any regular trend chart.

TSA allows you to select ranges of data for one or more trends to analyze for variability in both the time and frequency domains.

Selecting Data for Analysis

To select data ranges, you can:

- Use all the data shown in the displayed time span, or
- Select a range of data for each trend.

If you are able to display the time span you want to use by using the ***zoom*** and ***pan*** keys, and you want to use the same range for all trends on the chart, you can simply Menu click (the right mouse button) on the Main Trend Box area to display the Trend Menu. From this menu choose the TSA option. This will display the TSA windows for the data set shown in the trend display.

If you want a range of data that is different than the displayed time span or if you want to use different ranges for the different trends on the chart, you will have to select a range for each trend. To select a range for each trend:

- Select a trend to be analyzed.
- Move the cursor to one end of the range to be analyzed.
- Press <Tab> to mark that end (a bar, the same color as the trace, will indicate the mark).
- Move to the time cursor to the other end of the range.
- Press <Tab> to mark the other end of the range.
- Press <Esc> to unselect the trend.

Repeat the above steps for each trend to be included in the analysis, but do not unselect the last trend you mark a range for. Instead, Menu click on the main trend box area and choose the TSA option from the menu.

The order in which you select the different ranges is not significant.

If you want to remove a selected range for a trend:

- Make sure the trend is selected,
- Press <Shift Tab> to clear all marks set for the current trend.

After selecting ranges of data to analyze, Menu click on the main trend box area to display the Trend Menu. From this menu choose the TSA option. This will display the TSA windows for the data ranges you have selected.

Using the TSA Displays

There are two TSA windows. The top is a summary window indicating what trend data has been selected. The bottom window displays the actual TSA graphs. If you have selected only one trend to analyze only univariate analysis is performed. Otherwise, both univariate and bivariate analysis is performed.

For univariate TSA, the following graphs can be displayed:

- Frequency Distribution histograms,
- Auto-Correlation charts and Power Spectrum charts,
- Cumulative Power Spectrum charts.

For bivariate TSA, the following graphs can be displayed:

- Frequency Distribution histograms,
- Cross-Correlation charts,
- Power Spectrum vs. Coherent Power and Cumulative Power Spectrum charts.

The raw data and ***de-trended*** data can also be displayed.

Moving Between TSA Displays

To move between the pages of TSA displays, press <PgUp> and <PgDn>.

Moving Around a TSA Chart

Once a TSA chart has been selected, you can move the sample cursor by pressing <Left>, <Right>, <Alt Left>, and <Alt Right>. The value of the trace at the data sample cursor position is shown in the trend control box at the right edge of the chart.

Turning TSA Trend Traces On and Off

To turn the display of a trace on the currently selected chart on or off, click on the trend tag name for that trace to toggle the display of the trace on or off.

Turning off certain traces can be useful when printing the TSA display on a black and white printer.

SECTION 6 - CONFIGURING SPC CHART ALARMS

CONFIGURING SPC ALARMS

To configure SPC alarming for a trend, call up a graphic of the SPC chart. Right click on the main trace area of the chart and select **Alarm Properties** from the popup menu. This will display the SPC Alarm Properties dialog (Figure 6-1).

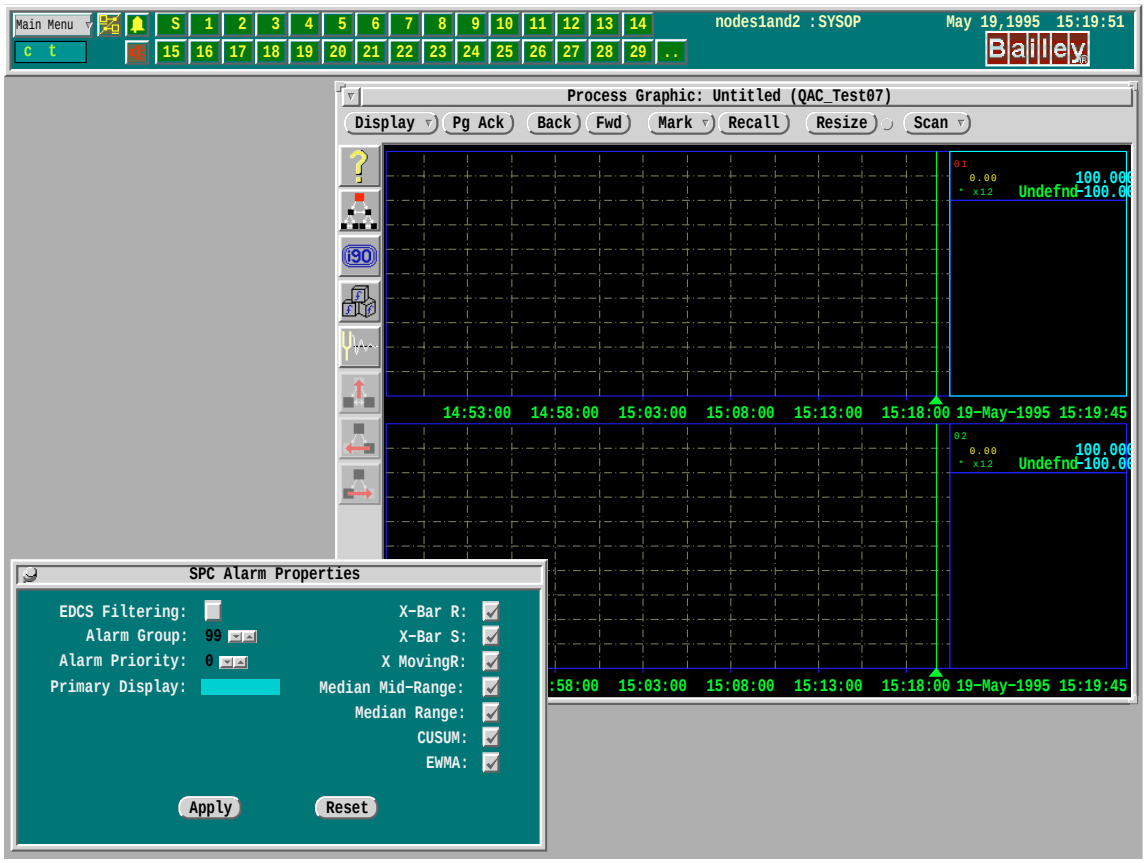

Figure 6-1. SPC Alarm Properties

The fields of this dialog are described in Table 6-1.

Table 6-1. SPC Alarm Properties Dialog Fields

Field	Description
EDCS Filtering	This field is used to determine whether the EDCS (Enhanced Data Collection System) delivers filtered or non-filtered events to the SPC Alarm Manager. If non-filtered events are delivered then the SPC Alarm Manager may report SPC alarms that do not show up on any chart. This is due to the fact that data retrieved from the EDCS is always filtered and may have lost the conditions that caused the SPC alarm to occur. If this becomes an issue, it is recommended that you disable the EDCS filter for the tag being charted.
Alarm Group	Enter an alarm group number for the SPC out-of-spec alarms generated by this tag (0 - 99, S, D.) If you set a non-zero alarm group, the SPC alarms are displayed the same way as process tag alarms: the alarm indicator in the upper left corner of the screen displays the alarm group number and the alarm summary display lists the tag information and type of alarm. If you set an alarm group of 0 (zero), no SPC alarms will ever be displayed for this tag. The Charts to Alarm check box must be checked for any chart to alarm, even if the Alarm Group is non-zero.
Alarm Priority	Enter a value to specify the priority of the SPC Alarm. Higher priority alarms always appear first on the alarm summary display. The valid range is (0-3) where: 0 = no priority 1 = highest priority 3 = lowest priority.
Primary Display	Enter the name of the display that can be called up directly from the alarm summary display. If an SPC trend is set to display an alarm and an out-of-spec situation occurs, you can look at it on the alarm summary display. The alarm summary always displays a letter beside each tag listed. Pressing that key takes you to the primary display. If you are using the SPC alarming, you will probably assign the name of the display showing the SPC chart for the trend as the primary display name. If you are building your SPC charts on-line, then the name of the primary display will have the format **f#x**, where # is the function key number the group summary display is assigned to (1 - 30), and x is the alphabetic key the SPC trend display is assigned to on the group summary display (a - t).
Charts to Alarm	Because a single trend can be plotted on more than one type of SPC chart at the same time, you can specify which particular chart or charts you want to have SPC alarms displayed for. For each of the six types of SPC charts, select whether or not you want alarming by checking or unchecking the check box. The six types of SPC charts are: X-Bar R Mean - Range X-Bar S Mean - Std Deviation X movingR Individual - Moving Range Me-Midr Median - Midrange Me-R Median - Range CUSUM Cumulative Sum EWMA Exponentially Weighted Moving Average No alarm will ever be displayed if the Alarm Group field has been set to 0 (zero), even if one or more of the chart type check boxes have been checked.

NOTE: To conform to the ordering of the dialog, order the table entries according to the numbers.

When entry is complete, select the **Apply** button to accept the changes. The **Reset** button may also be used to clear the changes that have been made.

NOTE: Only SPC charts of live process data can display alarms. SPC charts using manually entered lab data cannot display alarms (but alarm situations will be marked on the *SPC* chart*).*

SECTION 7 - EDITING THE SPC ALARM RULES

EDITING THE SPC ALARM RULES

SPC uses a set of rules referred to as the Western Electric Rules to determine when a Shewhart SPC chart is in alarm. These rules are:

- A single point beyond the 3 sigma limit
- 2 out of 3 consecutive points beyond the 2 sigma limit
- 4 out of 5 consecutive points beyond the 1 sigma limit
- 8 consecutive points on one side of the median

If any of these conditions are met, the Shewhart chart is considered to be in alarm and the points causing the alarm are highlighted and the alarm rule is displayed on the SPC display.

To edit the SPC alarm rules, you must have configuration or unrestricted level access. If you have control or view only level access, you will only be able to view the rules.

There are three ways you can modify the SPC alarming rules:

- Add new rules.
- Edit the parameters of existing rules.
- Delete rules.

To edit the SPC Alarm Rule List, select the edit SPC rules selection from the trend configuration section of the main menu system (Figure 7-1).

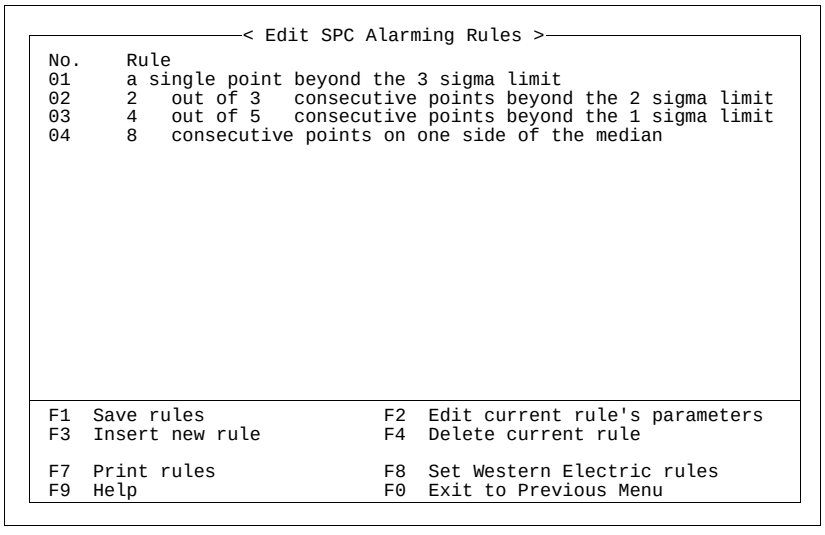

Figure 7-1. Edit SPC Alarming Rules Screen

ADDING NEW RULES

You can add rules anywhere in the rule list. The order of the rules only determines the order in which the SPC program tests each new point to see if any of the alarm conditions are met. If a new point meets two or more of the alarm conditions at the same time, the SPC program will only report the first rule on the SPC display. For this reason, you should put the most serious alarm conditions towards the top of the list. Up to 15 separate rules can be configured

To insert a new rule:

1. Select a general rule format.

2. Specify the parameters of the rule.

Move the cursor to the position you want to add the new rule by pressing <Up>,<Down>, <PgUp>{PrevPage}, <PgDn>{NextPage}, <Home>, and <End>. The new rule will be inserted at the cursor position and the currently highlighted rule and all others below it will move down by one line. To add a rule to the end of the list, move the cursor to the blank position just past the last rule on the list.

Press <F3>. This calls up a pop-up window listing five general rule formats (Figure 7-2). The general rule formats available are described in Table 7-1. You can return to the rule list without inserting a new rule by pressing <F10> at the pop-up windows.

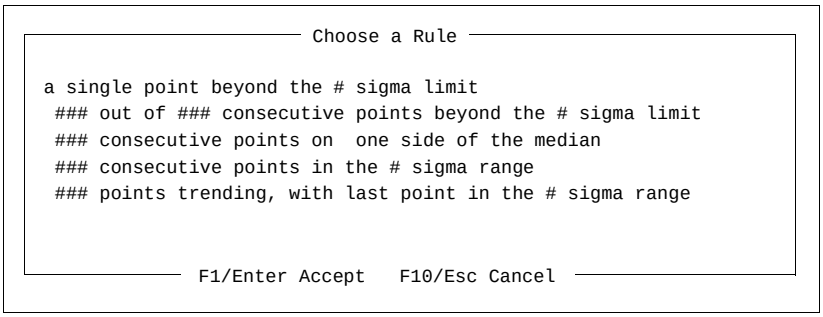

Figure 7-2. Insert Rule Pop-Up Window

Table 7-1. SPC Rule Formats

Rule	Description
a single point beyond the # sigma limit	This rule lets you specify the sigma limit beyond which any point is considered in alarm. Both the positive and negative sigma limits are included in this rule. Example: "a single point beyond the 3 sigma limit." If a point fell above the positive 3 sigma limit or below the negative 3 sigma limit, that point would be in alarm.
### out of ### consecutive points beyond the # sigma limit	This rule checks for a fraction of consecutive points falling beyond a given sigma limit. Example: "2 out of 3 consecutive points beyond the 2 sigma limit." If a first point fell outside the 2 sigma limit, then a second fell within it, then the third point fell outside the 2 sigma limit, the third point would be considered in alarm.
### consecutive points on one side of the median	This rule checks for a run of points all on the same side of the center line. Example: "8 consecutive points on one side of the median." If there were eight points below the center line, the eighth point would be in alarm.
### consecutive points in the # sigma range	This rule checks for a run of points all in the same sigma range. The n th sigma range falls between sigma limit n and sigma limit n-1. Example: "3 consecutive points in the 3 sigma range." If there were three points in a row between the 2 sigma and 3 sigma limit, the third point would be in alarm.
### points trending, with last point in the # sigma range	This rule checks for a steady rise or fall of consecutive points with the last point falling in the n th sigma range (the n th sigma range falls between sigma limit n and sigma limit n-1). If you wanted to catch any steadily increasing or decreasing set of points (no matter which region the last point fell in), you would set up three rules, one for each of the three sigma regions. Example: "7 points trending, with the last point in the 2 sigma range." If there were 7 points in a row, each greater in value than the point before, and the 7th point fell between the positive 2 and 3 sigma limits, then the 7th point would be in alarm.

Select a rule format by pressing <Up> and <Down> to highlight the rule you want, then press <F1>. This displays another pop-up window for editing the parameters of the rule (Figure 7-3).

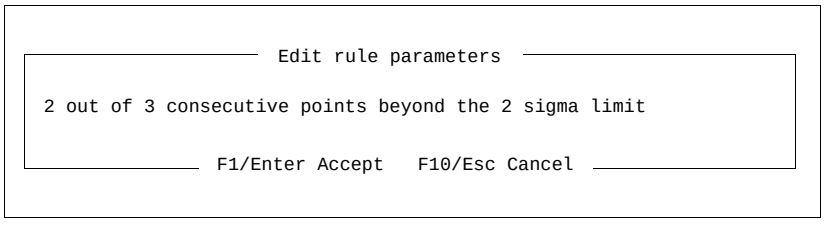

Figure 7-3. Edit Rule Parameters Pop-up Window

Enter the values you want for the configurable rule parameters. The configurable parameters are underlined. To move between parameters, press <Right> and <Left>.

When you have finished entering the parameters, insert the new rule in the list by pressing <F1>.

EDITING AN EXISTING RULE

If an existing rule meets the general format you want to use, but you want to use different parameters, you can simply edit the parameters.

Move the cursor to the rule you want to edit by pressing <Up>, <Down>,<PgUp>, <PgDn>, <Home>, and <End>, then press <F2> to display a pop-up window displaying the rule selected.

> **NOTE:** If you try to edit the parameters of the blank rule at the bottom of the list, you are actually inserting a new rule, and you get the Choose a Rule pop-up window described under ***ADDING NEW RULES***

The configurable parameters are underlined. To move between parameters, press <Right> and <Left>.

When you have finished entering the new parameters, set the new parameters by press <F1>. If you don't want to change the existing rule, press <F10> to return to the rule editing menu.

Deleting a Rule

To delete a rule, move the cursor to the rule you want to delete by pressing <Up>, <Down>, <PgUp>, <PgDn>, <Home>, and <End>, then press <F4>. You will be asked if you want to delete the selected rule. Press **Y** (for Yes) to delete the rule, or press **N** (for No) to keep the rule.

> **NOTE:** It is not possible to have a blank list of SPC alarm rules. There always has to be at least one rule. If you delete all the rules and save the blank rule list, the default Western Electric rules will be set. You will see the Western Electric rules listed the next time you call up the Edit SPC Alarming Rules screen.

SAVING THE RULES

When you have finished editing the rules, save your changes by pressing <F1>.

To exit from the SPC rule list, press <F10>.

PRINTING THE RULES

You can print out the list of rules by pressing <F7>. The listing is sent to the $spool printer.

> **NOTE:** Do not attempt to print the list of rules unless a printer is attached to your system.

SETTING WESTERN ELECTRIC RULES

If you want to restore the default Western Electric rules, press <F8>. You will be asked if you want to change the existing rules. Press **Y** (for Yes) to change the rule list to the Western Electric rules, or press **N** (for No) to keep the existing rule list.

SECTION 8 - CONFIGURING SPC AND TSA DISPLAYS

CONFIGURING GRAPHIC DISPLAYS ON-LINE

For instructions on configuring QAC displays please see the ***LAN-90 Process Control View Configuration manual.***

APPENDIX A - FORMULAS FOR SPC CALCULATIONS

INTRODUCTION

This appendix outlines the formulas used by SPC calculations.

The Sections in the Appendix describe:

- ***SHEWHART CALCULATIONS***
- ***CUSUM CALCULATIONS***
- ***EWMA CALCULATIONS***

SHEWHART CALCULATIONS

This Section describes the calculations used for:

- ***Mean (XBar) Charts***
- ***Individual Sample (X) Chart***
- ***Median (Me) Chart***
- ***Range (R) Chart***
- ***Standard Deviation (S) Chart***
- ***Moving Range (mR) Chart***
- ***Mid-Range for Median (Mr) Chart***
- ***Range For Median (R) Chart***
- ***Capability Calculations***

Variables Used

The following variables are used in the calculations:

N	Number of Samples
n	Subgroup Size
k	Number of Subgroups in the Sample Set
CL	Center Line
LCL	Lower Control Limit
UCL	Upper Control Limit
$\overline{X_0}$ or $\overline{Me_0}$ or $\overline{Mr_0}$	Process Standard
σ_0	Process Tolerance

NOTE: Subgroups are independent, not overlapping (i.e., $N = nk$).

Mean (XBar) Charts

Trace

The values plotted are the mean of each subgroup:

$$\bar{X} = \sum_{i=1}^{n} \frac{X_i}{n}$$

Limits (Based on Data)

The center line is the mean of all subgroup means, and the control limits are based on the mean of all subgroup ranges:

$$CL = \bar{\bar{X}} = \sum_{i=1}^{k} \frac{\bar{X}_i}{k}$$

$$UCL = \bar{\bar{X}} + A_2\bar{R}$$

$$LCL = \bar{\bar{X}} - A_2\bar{R}$$

(See ***Range (R) Chart*** for $\bar{R}$ and Table A-1 for A_2.)

Limits (Based on Standards)

The center line is the process standard entered, and the control limits are based on the process tolerance entered:

$$CL = \overline{X_0}$$

$$UCL = \overline{X_0} + A\sigma_0$$

$$LCL = \overline{X_0} - A\sigma_0$$

(See Table A-1 for *A.)*

Individual Sample (X) Chart

Trace

The values plotted are the individual sample points:

$$X$$

Limits (Based on Data)

The center line is the mean of all samples, and the control limits are based on the moving range:

$$CL = \bar{X} = \sum_{i=1}^{N} \frac{X_i}{N}$$

$$UCL = \bar{X} + E_2\overline{mR}$$

$$LCL = \bar{X} - E_2\overline{mR}$$

where: $E_2 = 2.66 = \frac{3}{d_2}$, $d_2 = 1.128$

(See Table A-1 for d_2.)

(See ***Moving Range (mR) Chart*** for $\overline{mR}$.)

Limits (Based on Standards)

The center line is the process standard entered, and the control limits are based on the process tolerance entered:

$$CL = \bar{X}_0$$

$$UCL = \bar{X}_0 + 3\sigma_0$$

$$LCL = \bar{X}_0 - 3\sigma_0$$

Median (Me) Chart

Trace

The values plotted are the median of each subgroup:

$$Me = median(X_1 \ldots X_n)$$

Limits (Based on Data)

The center line is the median value of all subgroup medians, and the control limits are based on the median of all subgroup ranges:

$$CL = \overline{Me} = median(Me_1 \ldots Me_k)$$

$$UCL = \overline{Me} + A_4\tilde{R}$$

$$LCL = \overline{Me} - A_4\tilde{R}$$

(See ***Range For Median (R) Chart*** for $\tilde{R}$ and Table A-2 for A_4.)

Limits (Based on Standarts)

The center line $\overline{Me}_0$ is the process standard entered, and the control limits are based on the process tolerance σ_0 entered:

$$CL = \overline{Me}_0$$

$$UCL = \overline{Me_0} + \tilde{A}\sigma_0$$

$$LCL = Me_0 - \tilde{A}\sigma_0$$

(See Table A-2 for $\tilde{A}$.)

Range (R) Chart

Trace

The values plotted are the range of each subgroup:

$$R = max(X_1 \ldots X_n) - min(X_1 \ldots X_n)$$

Limits (Based on Data)

The center line is the mean of all subgroup ranges, and control limits are based on this mean:

$$CL = \bar{R} = \sum_{i=1}^{k} \frac{R_i}{k}$$

$$UCL = D_4\bar{R}$$

$$LCL = D_3\bar{R}$$

(See Table A-1 for D_3 and D_4.)

Limits (Based on Standards)

The center line and control limits are based on the process tolerance σ_0 entered:

$$CL = d_2\sigma_0$$

$$UCL = D_2\sigma_0$$

$$LCL = D_1\sigma_0$$

(See Table A-1 for d_2, D_1, and D_2.)

Standard Deviation (S) Chart

Trace

The values plotted are the standard deviation of each subgroup:

$$S = \sum_{i=1}^{n} \frac{(X_i - \bar{X})^2}{n-1}$$

Limits (Based on Data)

The center line is the mean of all subgroup standard Si deviations, and the control limits are based on this mean:

$$CL = \bar{S} = \sum_{i=1}^{k} \frac{S_i}{k}$$

$$UCL = B_4\bar{S}$$

$$LCL = B_3\bar{S}$$

(See Table A-1 for B_3 and B_4.)

Limits (Based on Standards)

The center line and control limits are based on the process tolerance σ_0 entered:

$$CL = c_4\sigma_0$$

$$UCL = B_6\sigma_0$$

$$LCL = B_5\sigma_0$$

(See Table A-1 for c_4, B_5 and B_6.)

Moving Range (mR) Chart

Trace

The values plotted are the absolute difference between the current sample and the previous sample

$$mR = |X_i - X_{i-1}|$$

Limits (Based on Data)

The center line the mean of the moving ranges between all subgroups, and the control limits are based on this mean:

$$CL = \overline{mR} = \sum_{i=1}^{N-1} \frac{mR_i}{\overline{N-1}}$$

$$UCL = D_4\overline{mR}$$

$$LCL = D_3\overline{mR}$$

Where: $D_4 = 3.267$, $D_3 = 0$

(See Table A-1 for D_4 and D_3.)

Limits (Based on Standards)

The center line and control limits are based on the process tolerance σ_0 entered:

$$CL = d_2\sigma_0$$

$$UCL = D_2\sigma_0$$

$$LCL = D_1\sigma_0$$

Where: $d_2 = 1.128$, $D_1 = 0$, $D_2 = 3.686$

(See Table A-1 for d_2, D_2, and D_1.)

Mid-Range for Median (Mr) Chart

Trace

The values plotted are the mid-ranges of each subgroup:

$$Mr = \frac{R}{2} = \frac{max(X_1 \ldots X_n) - min(X_1 \ldots X_n)}{2}$$

Limits (Based on Data)

The center line is the median of all subgroup mid-ranges, and the control limits are based on the median of all subgroup ranges:

$$CL = \overline{Mr} = median(Mr_1 \ldots Mr_k)$$

$$UCL = \overline{Mr} + A_5\tilde{R}$$

$$LCL = \overline{Mr} - A_5\tilde{R}$$

(See ***Range For Median (R) Chart*** for $\tilde{R}$ and Table A-2 for A_5.)

Limits (Based on Standards)

The center line is the process standard entered, $\overline{Mr_0}$, and the control limits are based on the process tolerance σ_0 entered:

$$CL = \overline{Mr_0}$$

$$UCL = \overline{Mr_0} + \tilde{A}'\sigma_0$$

$$LCL = \overline{Mr_0} - \tilde{A}'\sigma_0$$

(See Table A-2 for $\tilde{A}'$.)

Range For Median (R) Chart

Trace

The values plotted are the ranges of each subgroup:

$$R = max(X_1 \ldots X_n) - min(X_1 \ldots X_n)$$

Limits (Based on Data)

The center line is the median of all subgroup ranges, and the control limits are based on this mean:

$$CL = \tilde{R} = median(R_1 \ldots R_k)$$

$$UCL = D_6\tilde{R}$$

$$LCL = D_5\tilde{R}$$

(See Table A-2 for D_5 and D_6.)

Limits (Based on Standards)

The center line and control limits are based on the process tolerance σ_0 entered:

$$CL = d_4\sigma_0$$

$$UCL = D_6 d_4\sigma_0$$

$$LCL = D_5 d_4\sigma_0$$

(See Table A-2 for D_5 and D_6).

Capability Calculations

Control Band (CB)

$CB = UCL - LCL$

Tolerance Band (TB)

$$TB = 2\sigma_0 = (\bar{X}_0 + \sigma_0) - (\bar{X}_0 - \sigma_0) = UpperSpec - LowerSpec$$

n = subgroup size

Process Capability Index (Cp or Cpk)

$$Cp = \frac{TB}{\sqrt{n}CB} = \frac{TB}{ProcessCapability}$$

$$Cpk = min\left(\frac{UpperSpec\bar{X}}{3S}, \frac{\bar{X} - LowerSpec}{3S}\right)$$

Table A-1. Factors for Computation of Shewhart Charts

n	d_2	d_3	A^1	A_2^2	D_1^3	D_2^4	D_3^5	D_4^6	c_4^7	B_3^8	B_4^9	B_5^{10}	B_6^{11}
2	1.128	0.853	2.121	1.880	0.000	3.686	0.000	3.267	0.7979	0.000	3.267	0.000	2.606
3	1.693	0.888	1.732	1.023	0.000	4.358	0.000	2.574	0.8862	0.000	2.568	0.000	2.276
4	2.509	0.880	1.500	0.729	0.000	4.698	0.000	2.282	0.9213	0.000	2.266	0.000	2.088
5	2.356	0.864	1.342	0.577	0.000	4.918	0.000	2.114	0.9400	0.000	2.089	0.000	1.964
6	2.534	0.848	1.225	0.483	0.000	5.078	0.000	2.004	0.9515	0.030	1.970	0.029	1.874
7	2.704	0.833	1.134	0.419	0.204	5.204	0.076	1.924	0.9594	0.118	1.882	0.113	1.806
8	2.847	0.820	1.061	0.373	0.388	5.306	0.136	1.864	0.9650	0.185	1.815	0.179	1.751
9	2.970	0.808	1.000	0.337	0.547	5.393	0.184	1.816	0.9693	0.239	1.761	0.232	1.707
10	3.078	0.797	0.949	0.308	0.687	5.469	0.223	1.777	0.9727	0.284	1.716	0.276	1.669
11	3.173	0.787	0.905	0.285	0.811	5.535	0.256	1.744	0.9754	0.321	1.679	0.313	1.637
12	3.258	0.778	0.866	0.266	0.922	5.594	0.283	1.717	0.9776	0.354	1.646	0.346	1.610
13	3.336	0.770	0.832	0.249	1.025	5.647	0.307	1.693	0.9794	0.382	1.618	0.374	1.585
14	3.407	0.763	0.802	0.235	1.118	5.696	0.328	1.672	0.9810	0.406	1.594	0.399	1.563
15	3.472	0.756	0.775	0.223	1.203	5.741	0.347	1.653	0.9823	0.428	1.572	0.421	1.544
16	3.532	0.750	0.705	0.212	1.282	5.782	0.363	1.637	0.9835	0.448	1.552	0.440	1.526
17	3.588	0.744	0.728	0.203	1.356	5.820	0.378	1.622	0.9845	0.466	1.534	0.458	1.511
18	3.640	0.739	0.707	0.194	1.424	5.856	0.391	1.608	0.9854	0.482	1.518	0.475	1.496
19	3.689	0.734	0.688	0.187	1.487	5.891	0.403	1.597	0.9862	0.497	1.503	0.490	1.483
20	3.735	0.729	0.671	0.180	1.549	5.921	0.415	1.585	0.9869	0.510	1.490	0.504	1.470
21	3.778	0.724	0.655	0.173	1.605	5.951	0.425	1.575	0.9876	0.523	1.477	0.516	1.459
22	3.819	0.720	0.640	0.167	1.659	5.979	0.434	1.566	0.9882	0.534	1.466	0.528	1.448
23	3.858	0.716	0.626	0.162	1.710	6.006	0.443	1.557	0.9887	0.545	1.455	0.539	1.439
24	3.895	0.712	0.612	0.157	1.759	6.031	0.451	1.548	0.9892	0.555	1.445	0.549	1.429
25	3.931	0.708	0.600	0.135	1.806	6.056	0.459	1.541	0.9896	0.565	1.435	0.559	1.420

NOTE: These formulas represent "3 sigma control". For "2 sigma control", replace "3" with "2".

1. $A = 3/\sqrt{n}$
2. $A_2 = 3/d_2\sqrt{n}$
3. $D_1 = d_2 - 3d_3$
4. $D_2 = d_2 + 3d_3$

5. $D_3 = 1 - 3d_3/d_2$

6. $D_4 = 1 + 3d_3/d_2$

7. $c_4 = 4(n-1)/(4n-3)$

8. $B_3 = 1 - 3/(c_4\sqrt{2(n-1)})$

9. $B_4 = 1 + 3/(c_4\sqrt{2(n-1)})$

10. $B_5 = c_4 - 3/(\sqrt{2(n-1)})$

11. $B_6 = c_4 + 3/(\sqrt{2(n-1)})$

Table A-2. Factors for Median Charts and Mid-Range Charts

n	$\bar{A}$	$\bar{A}'$	A_4	A_5	D_5	D_6	d_4
2	2.121	2.121	2.224	2.224	0.000	3.865	0.954
3	2.014	1.806	1.265	1.137	0.000	2.745	1.588
4	1.637	1.637	0.829	0.829	0.000	2.375	1.978
5	1.615	1.532	0.712	0.679	0.000	2.179	2.257
6	1.387	1.458	0.562	0.590	0.000	2.055	2.472
7	1.385	1.402	0.520	0.530	0.078	1.967	2.645
8	1.233	1.358	0.441	0.486	0.139	1.901	2.791
9	1.240	1.322	0.419	0.453	0.187	1.850	2.916
10	1.260	1.293	0.369	0.427	0.227	1.809	3.024

CUSUM CALCULATIONS

Variables Used

The following variables are used in the calculations:

N	number of observations
T	target value
D	critical shift
α	risk factor

CUSUM Chart

Trace

The cumulative sum of deviations from a target value is plotted:

$$s_t = \sum_{i=0}^{t} \left(X_t - \left(T \pm \frac{D}{2} \right) \right)$$

Limit (Critical Boundary)

The critical boundary is based on the standard deviation of the samples and the critical shift and risk factor entered:

$$h = \left(\frac{S^2}{\pm D}\right) ln\left(\frac{1}{\alpha}\right)$$

where $S = \sqrt{\sum_{i=1}^{N} \frac{(X_i - \bar{X})^2}{N-1}}$

If you set the critical shift equal to the standard deviation, the formula simplifies to:

$$h = \pm D ln\left(\frac{1}{\alpha}\right)$$

EWMA CALCULATIONS

Variables Used

The following variables are used in the calculations:

N	number of samples
T	target value
λ	weighting factor
S	standard deviation
CL	center line
UCL	upper control limit
LCL	lower control limit

EWMA Chart

Trace

The predicted next value is plotted:

$$\hat{X}_{t+1} = \hat{X}_t + \lambda\left(X_t - \hat{X}_t\right)$$

Limits

The center line is the target value and the control limits are based on the standard deviation and weight factor:

$$CL = T$$

$$UCL = T + 3S\sqrt{\frac{\lambda}{2-\lambda}}$$

$$LCL = T - 3S\sqrt{\frac{\lambda}{2-\lambda}}$$

where: $S = \sqrt{\sum_{t=1}^{N} \frac{(X_t - \bar{X})^2}{N-1}}$

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