

# Package: qcc (via r-universe)

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**Title** Quality Control Charts

**Description** Shewhart quality control charts for continuous, attribute and count data. Cusum and EWMA charts. Operating characteristic curves. Process capability analysis. Pareto chart and cause-and-effect chart. Multivariate control charts.

**Depends** R (>= 3.0), ggplot2 (>= 3.4)

**Imports** MASS, utils, graphics, grDevices, grid, gridExtra, scales, cli, crayon

**Suggests** knitr (>= 1.12), rmarkdown (>= 0.9)

**License** GPL (>= 2)

**VignetteBuilder** knitr

**URL** <https://luca-scr.github.io/qcc/>

**BugReports** <https://github.com/luca-scr/qcc/issues>

**ByteCompile** true

**LazyData** true

**Repository** <https://luca-scr.r-universe.dev>

**RemoteUrl** <https://github.com/luca-scr/qcc>

**RemoteRef** HEAD

**RemoteSha** 5b59e5cd41442cb8d8ce354408f8a4f189f38de0

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qcc-package

*Quality Control Charts*


---

## Description

Shewhart quality control charts for continuous, attribute and count data. Cusum and EWMA charts. Operating characteristic curves. Process capability analysis. Pareto chart and cause-and-effect chart. Multivariate control charts.

## Details

See [vignette and documentation](#) accompanying the package.

**Author(s)**

Luca Scrucca

**References**

Scrucca, L. (2004). qcc: an R package for quality control charting and statistical process control. *R News* 4/1, 11-17.

**See Also**

[qcc](#), [mqcc](#), [cusum](#), [ewma](#), [ocCurves](#), [processCapability](#), [paretoChart](#), [causeEffectDiagram](#).

---

antifreeze

*Water content of antifreeze data*

---

**Description**

Water content (in ppm) of batches of antifreeze.

**Usage**

```
data(antifreeze)
```

**Format**

A data frame with observations on 34 successive batches of antifreeze:

**water** water content (in ppm)

**References**

Wetherill, G.B. and Brown, D.W. (1991) *Statistical Process Control*. New York: Chapman & Hall, p. 120

**Examples**

```
data(antifreeze)
describe(antifreeze)
```

---

boiler	<i>Boiler temperature data</i>
--------	--------------------------------

---

**Description**

Temperature readings from the eight configured burners on a boiler.

**Usage**

```
data(boiler)
```

**Format**

A data frame with 25 observations on the following 8 variables:

- t1** temperature reading 1
- t2** temperature reading 2
- t3** temperature reading 3
- t4** temperature reading 4
- t5** temperature reading 5
- t6** temperature reading 6
- t7** temperature reading 7
- t8** temperature reading 8

**References**

Mason, R.L. and Young, J.C. (2002) *Multivariate Statistical Process Control with Industrial Applications*, SIAM, p. 86.

**Examples**

```
data(boiler)
describe(boiler)
boxplot(boiler)
```



```

                                "Moisture"),
Methods = c("Brake",
            "Engager",
            "Angle"),
Machines = c("Speed",
            "Lathes",
            "Bits",
            "Sockets")),
effect = "Surface Flaws")

```

---

circuit

*Circuit boards data*


---

### Description

Number of nonconformities observed in 26 successive samples of 100 printed circuit boards. Sample 6 and 20 are outside the control limits. Sample 6 was examined by a new inspector and he did not recognize several type of nonconformities that could have been present. Furthermore, the unusually large number of nonconformities in sample 20 resulted from a temperature control problem in the wave soldering machine, which was subsequently repaired. The last 20 samples are further samples collected on inspection units (each formed by 100 boards).

### Usage

```
data(circuit)
```

### Format

A data frame with 46 observations on the following 4 variables.

**sample** sample number

**x** number of defectives in 100 printed circuit boards (inspection unit)

**size** sample size

**trial** trial sample indicator (TRUE/FALSE)

### References

Montgomery, D.C. (1991) *Introduction to Statistical Quality Control*, 2nd ed, New York, John Wiley & Sons, pp. 173–175

### Examples

```

data(circuit)
describe(circuit, by = trial)
boxplot(x/size ~ trial, data = circuit)
plot(x/size ~ sample, data = circuit, type="b")

```

cusum

*Cusum chart***Description**

Create an object of class 'cusum.qcc' to compute a Cusum chart for statistical quality control.

**Usage**

```
cusum(data, sizes, center, std.dev,
      decision.interval = 5, se.shift = 1,
      head.start = 0,
      newdata, newsizes, ...)

## S3 method for class 'cusum.qcc'
print(x, digits = getOption("digits"), ...)

## S3 method for class 'cusum.qcc'
plot(x,
     xtime = NULL,
     add.stats = qcc.options("add.stats"),
     chart.all = qcc.options("chart.all"),
     fill = qcc.options("fill"),
     label.bounds = c("LDB", "UDB"),
     title, xlab, ylab, xlim, ylim,
     digits = getOption("digits"), ...)
```

**Arguments**

data	a data frame, a matrix or a vector containing observed data for the variable to chart. Each row of a data frame or a matrix, and each value of a vector, refers to a sample or "rationale group".
sizes	a value or a vector of values specifying the sample sizes associated with each group. If not provided the sample sizes are obtained counting the non-NA elements of each row of a data frame or a matrix; sample sizes are set all equal to one if data is a vector.
center	a value specifying the center of group statistics or the "target" value of the process.
std.dev	a value or an available method specifying the within-group standard deviation(s) of the process. Several methods are available for estimating the standard deviation. See <a href="#">sd.xbar</a> and <a href="#">sd.xbar.one</a> for, respectively, the grouped data case and the individual observations case.
decision.interval	A numeric value specifying the number of standard errors of the summary statistics at which the cumulative sum is out of control.

<code>se.shift</code>	The amount of shift to detect in the process, measured in standard errors of the summary statistics.
<code>head.start</code>	The initializing value for the above-target and below-target cumulative sums, measured in standard errors of the summary statistics. Use zero for the traditional Cusum chart, or a positive value less than the <code>decision.interval</code> for a Fast Initial Response.
<code>newdata</code>	a data frame, matrix or vector, as for the <code>data</code> argument, providing further data to plot but not included in the computations.
<code>newsizes</code>	a vector as for the <code>sizes</code> argument providing further data sizes to plot but not included in the computations.
<code>xtime</code>	a vector of date-time values as returned by <code>Sys.time</code> and <code>Sys.Date</code> . If provided it is used for x-axis so it must be of the same length as the statistic charted.
<code>add.stats</code>	a logical value indicating whether statistics and other information should be printed at the bottom of the chart.
<code>chart.all</code>	a logical value indicating whether both statistics for data and for <code>newdata</code> (if given) should be plotted.
<code>fill</code>	a logical value specifying if the in-control area should be filled with the color specified in <code>qcc.options("zones")\$fill</code> .
<code>label.bounds</code>	a character vector specifying the labels for the the decision interval boundaries.
<code>title</code>	a character string specifying the main title. Set <code>title = NULL</code> to remove the title.
<code>xlab, ylab</code>	a string giving the label for the x-axis and the y-axis.
<code>xlim, ylim</code>	a numeric vector specifying the limits for the x-axis and the y-axis.
<code>digits</code>	the number of significant digits to use.
<code>x</code>	an object of class <code>'cusum.qcc'</code> .
<code>...</code>	additional arguments to be passed to the generic function.

### Details

Cusum charts display how the group summary statistics deviate above or below the process center or target value, relative to the standard errors of the summary statistics. Useful to detect small and permanent variation on the mean of the process.

### Value

Returns an object of class `'cusum.qcc'`.

### Author(s)

Luca Scrucca



## References

- Mason, R.L. and Young, J.C. (2002) *Multivariate Statistical Process Control with Industrial Applications*, SIAM.
- Montgomery, D.C. (2013) *Introduction to Statistical Quality Control*, 7th ed. New York: John Wiley & Sons.
- Ryan, T. P. (2011), *Statistical Methods for Quality Improvement*, 3rd ed. New York: John Wiley & Sons, Inc.
- Scrucca, L. (2004). qcc: an R package for quality control charting and statistical process control. *R News* 4/1, 11-17.
- Wetherill, G.B. and Brown, D.W. (1991) *Statistical Process Control*. New York: Chapman & Hall.

## See Also

[qcc](#), [ewma](#)

## Examples

```
##
## Grouped-data
##
data(pistonrings)
diameter <- qccGroups(data = pistonrings, diameter, sample)

q <- cusum(diameter[1:25,], decision.interval = 4, se.shift = 1)
summary(q)
plot(q)

q <- cusum(diameter[1:25,], newdata=diameter[26:40,])
summary(q)
plot(q, chart.all=FALSE)

##
## Individual observations
##
data(viscosity)
q <- with(viscosity, cusum(viscosity[trial], newdata = viscosity[!trial]))
plot(q)
```

---

describe

*Descriptive statistics*

---

## Description

Compute and print descriptive statistics for a matrix or data frame, eventually conditioning on another variable.

**Usage**

```
describe(data, by, detailed = FALSE, ...)  
## S3 method for class 'describe'  
print(x, digits = getOption("digits") - 3, ...)
```

**Arguments**

<code>data</code>	a matrix or data frame.
<code>by</code>	a factor or character vector specifying the conditioning variable. This may be a variable included in <code>data</code> or an object defined in the current environment.
<code>detailed</code>	a logical specifying if detailed statistics should be provided.
<code>...</code>	additional arguments to be passed to the generic function.
<code>x</code>	an object of class 'describe'.
<code>digits</code>	the number of significant digits to use.

**Details**

This function provides simple descriptive statistics for different types of variables, such as numeric, factor, and logical, conditioning or not on another variable.

**Author(s)**

Luca Scrucca

**See Also**

[summary](#), [by](#)

**Examples**

```
data(warpbreaks)  
describe(warpbreaks)  
describe(warpbreaks, detail = TRUE)  
describe(warpbreaks, by = wool)
```

---

dyedcloth

*Dyed cloth data*

---

**Description**

In a textile finishing plant, dyed cloth is inspected for the occurrence of defects per 50 square meters. The data on ten rolls of cloth are presented.

**Usage**

```
data(dyedcloth)
```

**Format**

A data frame with 10 observations on the following 2 variables.

**x** number of nonconformities per 50 square meters (inspection units)

**size** number of inspection units in roll (variable sample size)

**References**

Montgomery, D.C. (1991) *Introduction to Statistical Quality Control*, 2nd ed, New York, John Wiley & Sons, pp. 183–184

**Examples**

```
data(dyedcloth)
describe(dyedcloth)
dyedcloth <- transform(dyedcloth, sample = seq(nrow(dyedcloth)))
plot(x/size ~ sample, data = dyedcloth, type="b")
```

---

 ellipseChart

*Multivariate Quality Control Charts*


---

**Description**

Plot an ellipse chart for a bivariate quality control data.

**Usage**

```
ellipseChart(object, chart.all = TRUE, show.id = FALSE, ngrid = 50,
             confidence.level, correct.multiple = TRUE,
             title, xlim, ylim, xlab, ylab,
             restore.par = TRUE, ...)
```

**Arguments**

object	an object of class 'mqcc'.
chart.all	a logical value indicating whether both statistics for data and for newdata (if given) should be plotted.
show.id	a logical value indicating whether to plot point labels (TRUE) or symbols (FALSE) for group means.
ngrid	a value for the size of the grid over which the ellipse is evaluated.
confidence.level	a numeric value between 0 and 1 specifying the confidence level of the computed probability limits.
correct.multiple	a logical value indicating whether to correct or not for multiple comparisons.

<code>title</code>	a character string specifying the main title. Set <code>title = FALSE</code> or <code>title = NA</code> to remove the title.
<code>xlim</code>	a numeric vector specifying the limits for the x-axis.
<code>ylim</code>	a numeric vector specifying the limits for the y-axis.
<code>xlab</code>	a string giving the label for the x-axis.
<code>ylab</code>	a string giving the label for the y-axis.
<code>restore.par</code>	a logical value indicating whether the previous <code>par</code> settings must be restored. If you need to add points, lines, etc. to a control chart set this to <code>FALSE</code> .
<code>...</code>	additional arguments to be passed to the generic <code>points</code> function.

### Author(s)

Luca Scrucca

### References

Mason, R.L. and Young, J.C. (2002) *Multivariate Statistical Process Control with Industrial Applications*, SIAM.

Montgomery, D.C. (2013) *Introduction to Statistical Quality Control*, 7th ed. New York: John Wiley & Sons.

Ryan, T. P. (2011), *Statistical Methods for Quality Improvement*, 3rd ed. New York: John Wiley & Sons, Inc.

### See Also

[mqcc](#), [stats.T2](#), [stats.T2.single](#)

### Examples

```
# See examples in help(mqcc)
```

---

ewma

*EWMA chart*

---

### Description

Create an object of class `'ewma.qcc'` to compute and draw an Exponential Weighted Moving Average (EWMA) chart for statistical quality control.

**Usage**

```
ewma(data, sizes, center, std.dev,
      lambda = 0.2, nsigmas = 3,
      newdata, newsizes, ...)

## S3 method for class 'ewma.qcc'
print(x, digits = getOption("digits"), ...)

## S3 method for class 'ewma.qcc'
plot(x,
      xtime,
      add.stats = qcc.options("add.stats"),
      chart.all = qcc.options("chart.all"),
      fill = qcc.options("fill"),
      label.center = "CL",
      label.limits = c("LCL", "UCL"),
      title, xlab, ylab, xlim, ylim,
      digits = getOption("digits"), ...)
```

**Arguments**

<code>data</code>	a data frame, a matrix or a vector containing observed data for the variable to chart. Each row of a data frame or a matrix, and each value of a vector, refers to a sample or "rationale group".
<code>sizes</code>	a value or a vector of values specifying the sample sizes associated with each group. If not provided the sample sizes are obtained counting the non-NA elements of each row of a data frame or a matrix; sample sizes are set all equal to one if data is a vector.
<code>center</code>	a value specifying the center of group statistics or target.
<code>std.dev</code>	a value or an available method specifying the within-group standard deviation(s) of the process. Several methods are available for estimating the standard deviation. See <a href="#">sd.xbar</a> and <a href="#">sd.xbar.one</a> for, respectively, the grouped data case and the individual observations case.
<code>lambda</code>	the smoothing parameter $0 \leq \lambda \leq 1$
<code>nsigmas</code>	a numeric value specifying the number of sigmas to use for computing control limits.
<code>newdata</code>	a data frame, matrix or vector, as for the data argument, providing further data to plot but not included in the computations.
<code>newsizes</code>	a vector as for the sizes argument providing further data sizes to plot but not included in the computations.
<code>xtime</code>	a vector of date-time values as returned by <a href="#">Sys.time</a> and <a href="#">Sys.Date</a> . If provided it is used for x-axis so it must be of the same length as the statistic charted.
<code>add.stats</code>	a logical value indicating whether statistics and other information should be printed at the bottom of the chart.

<code>chart.all</code>	a logical value indicating whether both statistics for data and for newdata (if given) should be plotted.
<code>fill</code>	a logical value specifying if the in-control area should be filled with the color specified in <code>qcc.options("zones")\$fill</code> .
<code>label.center</code>	a character specifying the label for center line.
<code>label.limits</code>	a character vector specifying the labels for control limits.
<code>title</code>	a character string specifying the main title. Set <code>title = NULL</code> to remove the title.
<code>xlab, ylab</code>	a string giving the label for the x-axis and the y-axis.
<code>xlim, ylim</code>	a numeric vector specifying the limits for the x-axis and the y-axis.
<code>digits</code>	the number of significant digits to use.
<code>x</code>	an object of class 'ewma.qcc'.
<code>...</code>	additional arguments to be passed to the generic function.

### Details

EWMA chart smooths a series of data based on a moving average with weights which decay exponentially. Useful to detect small and permanent variation on the mean of the process.

### Value

Returns an object of class 'ewma.qcc'.

### Author(s)

Luca Scrucca

### References

Mason, R.L. and Young, J.C. (2002) *Multivariate Statistical Process Control with Industrial Applications*, SIAM.

Montgomery, D.C. (2013) *Introduction to Statistical Quality Control*, 7th ed. New York: John Wiley & Sons.

Ryan, T. P. (2011), *Statistical Methods for Quality Improvement*, 3rd ed. New York: John Wiley & Sons, Inc.

Scrucca, L. (2004). qcc: an R package for quality control charting and statistical process control. *R News* 4/1, 11-17.

Wetherill, G.B. and Brown, D.W. (1991) *Statistical Process Control*. New York: Chapman & Hall.

### See Also

[qcc](#), [ewmaSmooth](#), [cusum](#)

**Examples**

```
##
## Grouped-data
##
data(pistonrings)
diameter <- qccGroups(data = pistonrings, diameter, sample)

q = ewma(diameter[1:25,], lambda=0.2, nsigmas=3)
summary(q)
plot(q)

ewma(diameter[1:25,], lambda=0.2, nsigmas=2.7, newdata=diameter[26:40,])

##
## Individual observations
##
data(viscosity)
with(viscosity,
      ewma(viscosity[trial], lambda = 0.2, nsigmas = 2.7,
            newdata = viscosity[!trial]))
```

ewmaSmooth

*EWMA smoothing function***Description**

Compute Exponential Weighted Moving Average.

**Usage**

```
ewmaSmooth(x, y, lambda = 0.2, start, ...)
```

**Arguments**

x	a vector of x-values.
y	a vector of y-values.
lambda	the smoothing parameter.
start	the starting value.
...	additional arguments (currently not used).

**Details**

EWMA function smooths a series of data based on a moving average with weights which decay exponentially.

For each  $y_t$  value the smoothed value is computed as

$$z_t = \lambda y_t + (1 - \lambda) z_{t-1}$$

where  $0 \leq \lambda \leq 1$  is the parameter which controls the weights applied.

**Value**

Returns a list with elements:

x	ordered x-values
y	smoothed y-values
lambda	the smoothing parameter
start	the starting value

**Author(s)**

Luca Scrucca

**References**

Montgomery, D.C. (2013) *Introduction to Statistical Quality Control*, 7th ed. New York: John Wiley & Sons.

Wetherill, G.B. and Brown, D.W. (1991) *Statistical Process Control*. New York: Chapman & Hall.

**See Also**

[qcc](#), [cusum](#)

**Examples**

```
x <- 1:50
y <- rnorm(50, sin(x/5), 0.5)
plot(x,y)
lines(ewmaSmooth(x,y,lambda=0.1), col="red")
```

---

mqcc

*Multivariate Quality Control Charts*

---

**Description**

Create an object of class 'mqcc' to perform multivariate statistical quality control.

**Usage**

```
mqcc(data, type = c("T2", "T2.single"), center, cov,
      limits = TRUE, pred.limits = FALSE,
      data.name, labels, newdata, newlabels,
      confidence.level = (1 - 0.0027)^p,
      plot = TRUE, ...)
```

```
## S3 method for class 'mqcc'
print(x, digits = getOption("digits"), ...)
```



```
## S3 method for class 'mqcc'
plot(x,
      add.stats = qcc.options("add.stats"),
      chart.all = qcc.options("chart.all"),
      fill = qcc.options("fill"),
      label.limits = c("LCL", "UCL"),
      label.pred.limits = c("LPL", "UPL"),
      title, xlab, ylab, ylim, axes.las = 0,
      digits = getOption("digits"),
      restore.par = TRUE, ...)
```

### Arguments

data	For subgrouped data, a list with a data frame or a matrix for each variable to monitor. Each row of the data frame or matrix refers to a sample or "rationale" group. For individual observations, where each sample has a single observation, users can provide a list with a data frame or a matrix having a single column, or a data frame or a matrix where each rows refer to samples and columns to variables. See examples.						
type	a character string specifying the type of chart: <table style="margin-left: 2em;"> <thead> <tr> <th></th> <th>Chart description</th> </tr> </thead> <tbody> <tr> <td>"T2"</td> <td>Hotelling <math>T^2</math> chart for subgrouped data</td> </tr> <tr> <td>"T2.single"</td> <td>Hotelling <math>T^2</math> chart for individual observations</td> </tr> </tbody> </table>		Chart description	"T2"	Hotelling $T^2$ chart for subgrouped data	"T2.single"	Hotelling $T^2$ chart for individual observations
	Chart description						
"T2"	Hotelling $T^2$ chart for subgrouped data						
"T2.single"	Hotelling $T^2$ chart for individual observations						
center	a vector of values to use for center of input variables.						
cov	a matrix of values to use for the covariance matrix of input variables.						
limits	a logical indicating if control limits (Phase I) must be computed (by default using <code>limits.T2</code> or <code>limits.T2.single</code> ) and plotted, or a two-values vector specifying control limits.						
pred.limits	a logical indicating if prediction limits (Phase II) must be computed (by default using <code>limits.T2</code> or <code>limits.T2.single</code> ) and plotted, or a two-values vector specifying prediction limits.						
data.name	a string specifying the name of the variable which appears on the plots. If not provided is taken from the object given as data.						
labels	a character vector of labels for each group.						
newdata	a data frame, matrix or vector, as for the data argument, providing further data to plot but not included in the computations.						
newlabels	a character vector of labels for each new group defined in the argument newdata.						
confidence.level	a numeric value between 0 and 1 specifying the confidence level of the computed probability limits. By default is set at $(1 - 0.0027)^p$ where $p$ is the number of variables, and 0.0027 is the probability of Type I error for a single Shewhart chart at the usual 3-sigma control level.						
plot	logical. If TRUE a quality chart is plotted.						

<code>add.stats</code>	a logical value indicating whether statistics and other information should be printed at the bottom of the chart.
<code>chart.all</code>	a logical value indicating whether both statistics for data and for newdata (if given) should be plotted.
<code>fill</code>	a logical value specifying if the in-control area should be filled with the color specified in <code>qcc.options("zones")\$fill</code> .
<code>label.limits</code>	a character vector specifying the labels for control limits (Phase I).
<code>label.pred.limits</code>	a character vector specifying the labels for prediction control limits (Phase II).
<code>title</code>	a character string specifying the main title. Set <code>title = FALSE</code> or <code>title = NA</code> to remove the title.
<code>xlab</code>	a string giving the label for the x-axis.
<code>ylab</code>	a string giving the label for the y-axis.
<code>ylim</code>	a numeric vector specifying the limits for the y-axis.
<code>axes.las</code>	numeric in <code>{0,1,2,3}</code> specifying the style of axis labels. See <code>help(par)</code> .
<code>digits</code>	the number of significant digits to use when <code>add.stats = TRUE</code> .
<code>restore.par</code>	a logical value indicating whether the previous <code>par</code> settings must be restored. If you need to add points, lines, etc. to a control chart set this to <code>FALSE</code> .
<code>x</code>	an object of class <code>'mqcc'</code> .
<code>...</code>	additional arguments to be passed to the generic function.

**Value**

Returns an object of class `'mqcc'`.

**Author(s)**

Luca Scrucca

**References**

- Mason, R.L. and Young, J.C. (2002) *Multivariate Statistical Process Control with Industrial Applications*, SIAM.
- Montgomery, D.C. (2013) *Introduction to Statistical Quality Control*, 7th ed. New York: John Wiley & Sons.
- Ryan, T. P. (2011), *Statistical Methods for Quality Improvement*, 3rd ed. New York: John Wiley & Sons, Inc.
- Scrucca, L. (2004). `qcc`: an R package for quality control charting and statistical process control. *R News* 4/1, 11-17.
- Wetherill, G.B. and Brown, D.W. (1991) *Statistical Process Control*. New York: Chapman & Hall.

**See Also**

[stats.T2](#), [stats.T2.single](#), [limits.T2](#), [limits.T2.single](#), [ellipseChart](#), [qcc](#)

**Examples**

```

##
## Subgrouped data
##

data(RyanMultivar)
str(RyanMultivar)

q <- mqcc(RyanMultivar, type = "T2")
summary(q)
ellipseChart(q)
ellipseChart(q, show.id = TRUE)
q <- mqcc(RyanMultivar, type = "T2", pred.limits = TRUE)

# Xbar-charts for single variables computed adjusting the
# confidence level of the T^2 chart:
q1 <- with(RyanMultivar,
           qcc(X1, type = "xbar", confidence.level = q$confidence.level^(1/2)))
summary(q1)
q2 <- with(RyanMultivar,
           qcc(X2, type = "xbar", confidence.level = q$confidence.level^(1/2)))
summary(q2)

require(MASS)
# generate new "in control" data
Xnew <- list(X1 = matrix(NA, 10, 4), X2 = matrix(NA, 10, 4))
for(i in 1:4)
  { x <- mvrnorm(10, mu = q$center, Sigma = q$cov)
    Xnew$X1[,i] <- x[,1]
    Xnew$X2[,i] <- x[,2]
  }
qq <- mqcc(RyanMultivar, type = "T2", newdata = Xnew, pred.limits = TRUE)
summary(qq)

# generate new "out of control" data
Xnew <- list(X1 = matrix(NA, 10, 4), X2 = matrix(NA, 10, 4))
for(i in 1:4)
  { x <- mvrnorm(10, mu = 1.2*q$center, Sigma = q$cov)
    Xnew$X1[,i] <- x[,1]
    Xnew$X2[,i] <- x[,2]
  }
qq <- mqcc(RyanMultivar, type = "T2", newdata = Xnew, pred.limits = TRUE)
summary(qq)

##
## Individual observations data
##

data(boiler)
str(boiler)

q <- mqcc(boiler, type = "T2.single", confidence.level = 0.999)

```

```

summary(q)

# generate new "in control" data
boilerNew <- mvrnorm(10, mu = q$center, Sigma = q$cov)
qq <- mqcc(boiler, type = "T2.single", confidence.level = 0.999,
           newdata = boilerNew, pred.limits = TRUE)
summary(qq)

# generate new "out of control" data
boilerNew <- mvrnorm(10, mu = 1.01*q$center, Sigma = q$cov)
qq <- mqcc(boiler, type = "T2.single", confidence.level = 0.999,
           newdata = boilerNew, pred.limits = TRUE)
summary(qq)

# provides "robust" estimates of means and covariance matrix
rob <- cov.rob(boiler)
qrob <- mqcc(boiler, type = "T2.single", center = rob$center, cov = rob$cov)
summary(qrob)

```

---

ocCurves

*Operating Characteristic Function*


---

## Description

Draws the operating characteristic curves for a 'qcc' object.

## Usage

```

ocCurves(object, ...)

ocCurves.xbar(object,
               size = c(1, 5, 10, 15, 20),
               shift = seq(0, 5, by = 0.1),
               nsigmas = object$nsigmas, ...)

ocCurves.R(object,
             size = c(2, 5, 10, 15, 20),
             multiplier = seq(1, 6, by = 0.1),
             nsigmas = object$nsigmas, ...)

ocCurves.S(object,
             size = c(2, 5, 10, 15, 20),
             multiplier = seq(1, 6, by = 0.1),
             nsigmas = object$nsigmas, ...)

ocCurves.p(object, ...)

ocCurves.c(object, ...)

```

```
## S3 method for class 'ocCurves'
print(x, digits = getOption("digits"), ...)

## S3 method for class 'ocCurves'
plot(x, what = c("beta", "ARL"),
      title, xlab, ylab, lty, lwd, col, ...)
```

### Arguments

<code>object</code>	an object of class 'qcc'.
<code>size</code>	a vector of values specifying the sample sizes for which to draw the OC curves.
<code>shift, multiplier</code>	a vector of values specifying the shift or multiplier values (in units of sigma).
<code>nsigmas</code>	a numeric value specifying the number of sigmas to use for computing control limits; if <code>nsigmas</code> is NULL, <code>object\$conf</code> is used to set up probability limits.
<code>x</code>	an object of class 'ocCurves'.
<code>digits</code>	the number of significant digits to use.
<code>what</code>	a string specifying the quantity to plot on the y-axis. Possible values are "beta" for the probability of not detecting a shift, and "ARL" for the average run length.
<code>title</code>	a character string specifying the main title. Set <code>title = NULL</code> to remove the title.
<code>xlab, ylab</code>	a string giving the label for the x-axis and the y-axis.
<code>lty, lwd, col</code>	values or vector of values controlling the line type, line width and colour of curves.
<code>...</code>	catches further ignored arguments.

### Details

An operating characteristic curve graphically provides information about the probability of not detecting a shift in the process. `ocCurves` is a generic function which calls the proper function depending on the type of 'qcc' object. Further arguments provided through `...` are passed to the specific function depending on the type of chart.

The probabilities are based on the conventional assumptions about process distributions: the normal distribution for " $\bar{x}$ ", "R", and "S", the binomial distribution for "p" and "np", and the Poisson distribution for "c" and "u". They are all sensitive to departures from those assumptions, but to varying degrees. The performance of the "S" chart, and especially the "R" chart, are likely to be seriously affected by longer tails.

### Value

The function returns an object of class 'ocCurves' which contains a matrix or a vector of beta values (the probability of type II error) and ARL (average run length).

### Author(s)

Luca Scrucca

## References

- Mason, R.L. and Young, J.C. (2002) *Multivariate Statistical Process Control with Industrial Applications*, SIAM.
- Montgomery, D.C. (2013) *Introduction to Statistical Quality Control*, 7th ed. New York: John Wiley & Sons.
- Ryan, T. P. (2011), *Statistical Methods for Quality Improvement*, 3rd ed. New York: John Wiley & Sons, Inc.
- Scrucca, L. (2004). qcc: an R package for quality control charting and statistical process control. *R News* 4/1, 11-17.
- Wetherill, G.B. and Brown, D.W. (1991) *Statistical Process Control*. New York: Chapman & Hall.

## See Also

[qcc](#)

## Examples

```
data(pistonrings)
diameter <- qccGroups(diameter, sample, data = pistonrings)
oc <- ocCurves.xbar(qcc(diameter, type="xbar", nsigmas=3))
oc
plot(oc)

data(orangejuice)
oc <- with(orangejuice,
           ocCurves(qcc(D[trial], sizes=size[trial], type="p")))
oc
plot(oc)

data(circuit)
oc <- with(circuit,
           ocCurves(qcc(x[trial], sizes=size[trial], type="c")))
oc
plot(oc)
```

---

orangejuice

*Orange juice data*

---

## Description

Frozen orange juice concentrate is packed in 6-oz cardboard cans. These cans are formed on a machine by spinning them from cardboard stock and attaching a metal bottom panel. A can is then inspected to determine whether, when filled, the liquid could possibly leak either on the side seam or around the bottom joint. If this occurs, a can is considered nonconforming. The data were collected as 30 samples of 50 cans each at half-hour intervals over a three-shift period in which the machine was in continuous operation. From sample 15 used a new batch of cardboard stock was put into production. Sample 23 was obtained when an inexperienced operator was temporarily assigned to

the machine. After the first 30 samples, a machine adjustment was made. Then further 24 samples were taken from the process.

### Usage

```
data(orangejuice)
```

### Format

A data frame with 54 observations on the following 4 variables:

**sample** sample id  
**D** number of defectives  
**size** sample sizes  
**trial** trial samples (TRUE/FALSE)

### References

Montgomery, D.C. (1991) *Introduction to Statistical Quality Control*, 2nd ed, New York, John Wiley & Sons, pp. 152–155.

### Examples

```
data(orangejuice)
orangejuice <- transform(orangejuice, d = D/size)
describe(orangejuice, by = trial)
boxplot(d ~ trial, data = orangejuice)
plot(d ~ sample, data = orangejuice, type = "b", pch = ifelse(trial, 1, 19))
```

---

orangejuice2

*Orange juice data – Part 2*

---

### Description

A full description of the problem is given in [orangejuice](#).

This dataset contains samples taken after the machine adjustment was made.

### Usage

```
data(orangejuice)
```

### Format

A data frame with 64 observations on the following 4 variables:

**sample** sample id  
**D** number of defectives  
**size** sample sizes  
**trial** trial samples (TRUE/FALSE)

## References

Montgomery, D.C. (1991) *Introduction to Statistical Quality Control*, 2nd ed, New York, John Wiley & Sons, pp. 155–159.

## Examples

```
data(orangejuice2)
orangejuice2 <- transform(orangejuice2, d = D/size)
describe(orangejuice2, by = trial)
boxplot(d ~ trial, data = orangejuice2)
plot(d ~ sample, data = orangejuice2, type = "b", pch = ifelse(trial, 1, 19))
```

---

paretoChart

*Pareto chart*

---

## Description

Computes a table of statistics and plot a Pareto chart.

## Usage

```
paretoChart(data, ...)

## S3 method for class 'paretoChart'
plot(x, title, xlab,
      ylab = "Frequency", ylab2 = "Cumulative percentage",
      ylim, col = blues.colors(nlevels), ...)
```

## Arguments

data	a vector of values. names(data) are used for labelling the bars.
plot	a logical specifying if the chart should be provided (TRUE, default).
x	an object of class 'paretoChart' returned by a call to paretoChart() function.
title	a character string specifying the main title. Set title = NULL to remove the title.
xlab	a string specifying the label for the x-axis.
ylab	a string specifying the label for the y-axis.
ylab2	a string specifying the label for the second y-axis on the right side.
ylim	a numeric vector specifying the limits for the y-axis.
col	a value for the color, a vector of colors, or a palette for the bars. See the help for <a href="#">colors</a> and <a href="#">palette</a> .
...	catch other optional arguments.



**Details**

A Pareto chart is a barplot where the categories are ordered in non increasing order, and a line is also added to show the cumulative sum.

**Value**

Returns an object of class 'paretoChart' containing the descriptive statistics used to draw the Pareto chart. This object has associated a print and plot method.

**Author(s)**

Luca Scrucca

**References**

Mason, R.L. and Young, J.C. (2002) *Multivariate Statistical Process Control with Industrial Applications*, SIAM.

Montgomery, D.C. (2013) *Introduction to Statistical Quality Control*, 7th ed. New York: John Wiley & Sons.

Ryan, T. P. (2011), *Statistical Methods for Quality Improvement*, 3rd ed. New York: John Wiley & Sons, Inc.

Scrucca, L. (2004). qcc: an R package for quality control charting and statistical process control. *R News* 4/1, 11-17.

Wetherill, G.B. and Brown, D.W. (1991) *Statistical Process Control*. New York: Chapman & Hall.

**See Also**

[barplot](#)

**Examples**

```
defect <- c(80, 27, 66, 94, 33)
names(defect) <- c("price code", "schedule date", "supplier code", "contact num.", "part num.")
pc = paretoChart(defect, ylab = "Error frequency")
pc
plot(pc)

plot(paretoChart(defect, ylab = "Error frequency"), col=rainbow(length(defect)))
```

---

pcmanufact

*Personal computer manufacturer data*

---

### Description

A personal computer manufacturer counts the number of nonconformities per unit on the final assembly line. He collects data on 20 samples of 5 computers each.

### Usage

```
data(pcmanufact)
```

### Format

A data frame with 10 observations on the following 2 variables.

**x** number of nonconformities (inspection units)

**size** number of computers inspected

### References

Montgomery, D.C. (1991) *Introduction to Statistical Quality Control*, 2nd ed, New York, John Wiley & Sons, pp. 181–182

### Examples

```
data(pcmanufact)
describe(pcmanufact)
pcmanufact <- transform(pcmanufact, sample = seq(nrow(pcmanufact)))
plot(x/size ~ sample, data = pcmanufact, type="b")
```

---

pistonrings

*Piston rings data*

---

### Description

Piston rings for an automotive engine are produced by a forging process. The inside diameter of the rings manufactured by the process is measured on 25 samples, each of size 5, for the control phase I, when preliminary samples from a process being considered 'in control' are used to construct control charts. Then, further 15 samples, again each of size 5, are obtained for phase II.

### Usage

```
data(pistonrings)
```

**Format**

A data frame with 200 observations on the following 3 variables.

**diameter** a numeric vector

**sample** sample ID

**trial** preliminary sample indicator (TRUE/FALSE)

**References**

Montgomery, D.C. (1991) *Introduction to Statistical Quality Control*, 2nd ed, New York, John Wiley & Sons, pp. 206–213

**Examples**

```
data(pistonrings)
describe(pistonrings, by = trial)
boxplot(diameter ~ trial, data = pistonrings)
plot(diameter ~ sample, data = pistonrings, cex=0.7)
with(pistonrings, lines(tapply(diameter, sample, mean)))
```

---

processCapability      *Process capability analysis*

---

**Description**

Computes process capability indices for a 'qcc' object of type "xbar" and plot the histogram.

**Usage**

```
processCapability(object, spec.limits, target,
                 std.dev, nsigmas,
                 confidence.level = 0.95, ...)

## S3 method for class 'processCapability'
print(x, digits = getOption("digits"), ...)

## S3 method for class 'processCapability'
plot(x,
     add.stats = qcc.options("add.stats"),
     breaks = nclass.scott,
     fill = adjustcolor(qcc.options("zones")$fill, alpha.f = 0.5),
     color = "white", title, xlab,
     digits = getOption("digits"), ...)
```

**Arguments**

object	a 'qcc' object of type "xbar"
spec.limits	a two-values vector specifying the lower and upper specification limits. For one-sided specification limits, the value of the missing limit must be set to NA.
target	a value specifying the target of the process. If missing the value from the 'qcc' object is used if not NULL, otherwise the target is set at the middle value between specification limits.
std.dev	a value specifying the within-group standard deviation. If not provided is taken from the 'qcc' object.
nsigmas	a numeric value specifying the number of sigmas to use. If not provided is taken from the 'qcc' object.
confidence.level	a numeric value between 0 and 1 specifying the level to use for computing confidence intervals.
x	an object of class 'processCapability'.
add.stats	a logical value indicating whether statistics and capability indices should be added at the bottom of the chart.
breaks	a value or a function used to select the number of bins in a histogram. See the help for <a href="#">nclass.scott</a> for more details.
fill, color	values specifying the colour of the filled area and the border used for drawing the histogram.
title	a character string specifying the plot title. Set title = NULL to remove the title.
xlab	a character string specifying the label for the x-axis.
digits	the number of significant digits to use.
...	catches further ignored arguments.

**Details**

This function calculates confidence limits for  $C_p$  using the method described by Chou et al. (1990). Approximate confidence limits for  $C_{pl}$ ,  $C_{pu}$  and  $C_{pk}$  are computed using the method in Bissell (1990). Confidence limits for  $C_{pm}$  are based on the method of Boyles (1991); this method is approximate and it assumes that the target is midway between the specification limits.

**Value**

Invisibly returns a list with components:

nobs	number of observations
center	center
std.dev	standard deviation
target	target
spec.limits	a vector of values giving the lower specification limit (LSL) and the upper specification limit (USL)

indices	a matrix of capability indices ( $C_p, C_{pl}, C_{pu}, C_{pk}, C_{pm}$ ) and the corresponding confidence limits.
exp	a vector of values giving the expected fraction, based on a normal approximation, of the observations less than LSL and greater than USL.
obs	a vector of values giving the fraction of observations less than LSL and greater than USL.

**Author(s)**

Luca Scrucca

**References**

- Bissell, A.F. (1990) *How reliable is your capability index?*, Applied Statistics, 39, 331-340.
- Boyles, R.A. (1991) *The Taguchi capability index*, Journal of Quality Technology, 23, 107-126.
- Chou, Y., Owen D.B. and Borrego S.A. (1990) *Lower Confidence Limits on Process Capability Indices*, Journal of Quality Technology, 22, 223-229.
- Montgomery, D.C. (2013) *Introduction to Statistical Quality Control*, 7th ed. New York: John Wiley & Sons.
- Wetherill, G.B. and Brown, D.W. (1991) *Statistical Process Control*. New York: Chapman & Hall.

**See Also**

[qcc](#)

**Examples**

```
data(pistonrings)
diameter <- qccGroups(data = pistonrings, diameter, sample)
q <- qcc(diameter[1:25,], type="xbar", nsigmas=3)
pc <- processCapability(q, spec.limits=c(73.95,74.05))
pc
plot(pc)
plot(processCapability(q, spec.limits=c(73.95,74.05), target=74.02))
plot(processCapability(q, spec.limits=c(73.99,74.01)))
plot(processCapability(q, spec.limits = c(73.99, 74.1)))
```

---

qcc

*Quality Control Charts*

---

**Description**

Create an object of class 'qcc' to perform statistical quality control. This object may then be used to plot Shewhart charts, drawing OC curves, computes capability indices, and more.

**Usage**

```

qcc(data,
     type = c("xbar", "R", "S", "xbar.one", "p", "np", "c", "u", "g"),
     sizes, center, std.dev, limits,
     newdata, newsizes,
     nsigmas = 3, confidence.level,
     rules = c(1,4), ...)

## S3 method for class 'qcc'
print(x, digits = getOption("digits"), ...)

## S3 method for class 'qcc'
plot(x,
     xtime = NULL,
     add.stats = qcc.options("add.stats"),
     chart.all = qcc.options("chart.all"),
     fill = qcc.options("fill"),
     label.center = "CL",
     label.limits = c("LCL ", "UCL"),
     title, xlab, ylab, xlim, ylim,
     digits = getOption("digits"), ...)

```

**Arguments**

**data** a data frame, a matrix or a vector containing observed data for the variable to chart. Each row of a data frame or a matrix, and each value of a vector, refers to a sample or "rationale group".

**type** a character string specifying the group statistics to compute. Available methods are:

	Statistic charted	Chart description
"xbar"	mean	means of a continuous process variable
"R"	range	ranges of a continuous process variable
"S"	standard deviation	standard deviations of a continuous variable
"xbar.one"	mean	one-at-time data of a continuous process variable
"p"	proportion	proportion of nonconforming units
"np"	count	number of nonconforming units
"c"	count	nonconformities per unit
"u"	count	average nonconformities per unit
"g"	count	number of non-events between events

Furthermore, a user specified type of chart, say "newchart", can be provided. This requires the definition of "stats.newchart", "sd.newchart", and "limits.newchart". As an example, see [stats.xbar](#).

**sizes** a value or a vector of values specifying the sample sizes associated with each group. For continuous data provided as data frame or matrix the sample sizes

are obtained counting the non-NA elements of each row. For "p", "np" and "u" charts the argument sizes is required.

center	a value specifying the center of group statistics or the "target" value of the process.
std.dev	a value or an available method specifying the within-group standard deviation(s) of the process. Several methods are available for estimating the standard deviation in case of a continuous process variable; see <a href="#">sd.xbar</a> , <a href="#">sd.xbar.one</a> , <a href="#">sd.R</a> , <a href="#">sd.S</a> .
limits	a two-values vector specifying control limits.
newdata	a data frame, matrix or vector, as for the data argument, providing further data to plot but not included in the computations.
newsizes	a vector as for the sizes argument providing further data sizes to plot but not included in the computations.
nsigmas	a numeric value specifying the number of sigmas to use for computing control limits. It is ignored when the <code>confidence.level</code> argument is provided.
confidence.level	a numeric value between 0 and 1 specifying the confidence level of the computed probability limits.
rules	a value or a vector of values specifying the rules to apply to the chart. See <a href="#">qccRules</a> for possible values and their meaning.
xtime	a vector of date-time values as returned by <a href="#">Sys.time</a> and <a href="#">Sys.Date</a> . If provided it is used for x-axis so it must be of the same length as the statistic charted.
add.stats	a logical value indicating whether statistics and other information should be printed at the bottom of the chart.
chart.all	a logical value indicating whether both statistics for data and for newdata (if given) should be plotted.
fill	a logical value specifying if the in-control area should be filled with the color specified in <code>qcc.options("zones")\$fill</code> .
label.center	a character specifying the label for center line.
label.limits	a character vector specifying the labels for control limits.
title	a character string specifying the main title. Set <code>title = NULL</code> to remove the title.
xlab, ylab	a string giving the label for the x-axis and the y-axis.
xlim, ylim	a numeric vector specifying the limits for the x-axis and the y-axis.
digits	the number of significant digits to use.
x	an object of class 'qcc'.
...	additional arguments to be passed to the generic function.

**Value**

Returns an object of class 'qcc'.

**Author(s)**

Luca Scrucca

## References

- Mason, R.L. and Young, J.C. (2002) *Multivariate Statistical Process Control with Industrial Applications*, SIAM.
- Montgomery, D.C. (2013) *Introduction to Statistical Quality Control*, 7th ed. New York: John Wiley & Sons.
- Ryan, T. P. (2011), *Statistical Methods for Quality Improvement*, 3rd ed. New York: John Wiley & Sons, Inc.
- Scrucca, L. (2004). qcc: an R package for quality control charting and statistical process control. *R News* 4/1, 11-17.
- Wetherill, G.B. and Brown, D.W. (1991) *Statistical Process Control*. New York: Chapman & Hall.

## See Also

[qccRules](#), [cusum](#), [ewma](#), [ocCurves](#), [processCapability](#), [qccGroups](#)

## Examples

```
##
## Continuous data
##
data(pistonrings)
diameter <- qccGroups(data = pistonrings, diameter, sample)

(q <- qcc(diameter[1:25,], type="xbar"))
plot(q)

(q <- qcc(diameter[1:25,], type="xbar", newdata=diameter[26:40,]))
plot(q)

q <- qcc(diameter[1:25,], type="xbar", newdata=diameter[26:40,])
plot(q, chart.all=FALSE)

plot(qcc(diameter[1:25,], type="xbar", newdata=diameter[26:40,], nsigmas=2))

plot(qcc(diameter[1:25,], type="xbar", newdata=diameter[26:40,], confidence.level=0.99))

q <- qcc(diameter[1:25,], type="R")
q
plot(q)

plot(qcc(diameter[1:25,], type="R", newdata=diameter[26:40,]))

plot(qcc(diameter[1:25,], type="S"))

plot(qcc(diameter[1:25,], type="S", newdata=diameter[26:40,]))

plot(qcc(diameter[1:25,], type="xbar", newdata=diameter[26:40,], rules = 1:4))

# variable control limits
out <- c(9, 10, 30, 35, 45, 64, 65, 74, 75, 85, 99, 100)
```



```

diameter <- qccGroups(data = pistonrings[-out,], diameter, sample)
plot(qcc(diameter[1:25,], type="xbar"))
plot(qcc(diameter[1:25,], type="R"))
plot(qcc(diameter[1:25,], type="S"))
plot(qcc(diameter[1:25,], type="xbar", newdata=diameter[26:40,]))
plot(qcc(diameter[1:25,], type="R", newdata=diameter[26:40,]))
plot(qcc(diameter[1:25,], type="S", newdata=diameter[26:40,]))

##
## Attribute data
##

data(orangejuice)

q <- with(orangejuice,
         qcc(D[trial], sizes=size[trial], type="p"))
q
plot(q)

# remove out-of-control points (see help(orangejuice) for the reasons)
outofctrl <- c(15,23)
q1 <- with(orangejuice[-outofctrl,],
         qcc(D[trial], sizes=size[trial], type="p"))
plot(q1)
q1 <- with(orangejuice[-outofctrl,],
         qcc(D[trial], sizes=size[trial], type="p",
             newdata=D[!trial], newsizes=size[!trial]))
plot(q1)

data(orangejuice2)
q2 <- with(orangejuice2,
         qcc(D[trial], sizes=size[trial], type="p"))
plot(q2)
q2 <- with(orangejuice2,
         qcc(D[trial], sizes=size[trial], type="p",
             newdata=D[!trial], newsizes=size[!trial]))
plot(q2)

data(circuit)
plot(with(circuit, qcc(x[trial], sizes=size[trial], type="c")))

# remove out-of-control points (see help(circuit) for the reasons)
outofctrl <- c(15,23)
q1 <- with(orangejuice[-outofctrl,],
         qcc(D[trial], sizes=size[trial], type="p"))
plot(q1)
q1 <- with(orangejuice[-outofctrl,],
         qcc(D[trial], sizes=size[trial], type="p",
             newdata=D[!trial], newsizes=size[!trial]))
plot(q1)

outofctrl <- c(6,20)
q1 <- with(circuit[-outofctrl,],

```

```

      qcc(x[trial], sizes=size[trial], type="c"))
plot(q1)
q1 <- with(circuit[-outofctrl,],
           qcc(x[trial], sizes=size[trial], type="c",
              newdata = x[!trial], newsizes = size[!trial]))
plot(q1)
q1 <- with(circuit[-outofctrl,],
           qcc(x[trial], sizes=size[trial], type="u",
              newdata = x[!trial], newsizes = size[!trial]))
plot(q1)

data(pcmanufact)
q1 <- with(pcmanufact, qcc(x, sizes=size, type="u"))
q1
plot(q1)

data(dyedcloth)
# variable control limits
plot(with(dyedcloth, qcc(x, sizes=size, type="u")))
# standardized control chart
q <- with(dyedcloth, qcc(x, sizes=size, type="u"))
z <- (q$statistics - q$center)/sqrt(q$center/q$size)
plot(qcc(z, sizes = 1, type = "u", center = 0, std.dev = 1, limits = c(-3,3)),
     title = "Standardized u chart")

##
## Continuous one-at-time data
##

data(viscosity)
q <- with(viscosity,
          qcc(viscosity[trial], type = "xbar.one"))
q
plot(q)
# batch 4 is out-of-control because of a process temperature controller
# failure; remove it and recompute
viscosity <- viscosity[-4,]
plot(with(viscosity,
          qcc(viscosity[trial], type = "xbar.one", newdata = viscosity[!trial])))

```

**Description**

These functions are provided for compatibility with older versions of the package **qcc**, and they will likely be removed in the future.

**Usage**

```

qcc.groups(...)
pareto.chart(...)
process.capability(...)
oc.curves(...)
cause.and.effect(...)
qcc.overdispersion.test(...)

```

**Arguments**

... all arguments are passed down.

**See Also**

[deprecated](#)

---

qcc.options	<i>Set or return options for the <b>qcc</b> package.</i>
-------------	--

---

**Description**

This function can be used to control the behavior of the 'qcc' library such as the background color, out-of-control points appearance, and many others.

**Usage**

```
qcc.options(...)
```

**Arguments**

... the option to be set or retrieved. See details.

**Details**

The available options are:

`exp.R.unscaled` a vector specifying, for each sample size, the expected value of the relative range (i.e.  $R/\sigma$ ) for a normal distribution. This appears as  $d_2$  on most tables containing factors for the construction of control charts.

`se.R.unscaled` a vector specifying, for each sample size, the standard error of the relative range (i.e.  $R/\sigma$ ) for a normal distribution. This appears as  $d_3$  on most tables containing factors for the construction of control charts.

`beyond.limits$pch` plotting character used to highlight points beyond control limits.

`beyond.limits$col` color used to highlight points beyond control limits.

`violating.runs$pch` plotting character used to highlight points violating runs.

`violating.runs$col` color used to highlight points violating runs.

run.length the maximum value of a run before to signal a point as out of control.  
 bg.margin background color used to draw the margin of the charts.  
 bg.figure background color used to draw the figure of the charts.  
 cex character expansion used to draw plot annotations (labels, title, tickmarks, etc.).  
 font.stats font used to draw text at the bottom of control charts.  
 cex.stats character expansion used to draw text at the bottom of control charts.

### Value

If the functions is called with no argument return a list of available options.

If an option argument is provided the corresponding value is returned.

If a value is associated with an option argument, such option is set and the list of updated option values is invisibly returned. In this case the list `.qcc.options` is modified and any modification will remain in effect for the rest of the session.

### Author(s)

Luca Scrucca

### See Also

[qcc](#)

### Examples

```
old <- qcc.options() # save defaults
qcc.options("cex.stats") # get a single parameter
qcc.options("cex.stats"=1.2) # change parameters
qcc.options(bg.margin="azure2")
qcc.options("violating.runs" = list(pch = 15, col = "purple"))
qcc.options("beyond.limits" = list(pch = 15, col = "orangered"))
qcc(rnorm(100), type = "xbar.one", std.dev = 0.7) # see the results
qcc.options(old) # restore old defaults
```

---

qccGroups

*Grouping data based on a sample indicator*

---

### Description

This function allows to easily group data to use as input to the `qcc()` function.

### Usage

```
qccGroups(data, x, sample)
```

**Arguments**

data	a data frame (or a similar structure which can be coerced to be a <code>data.frame</code> ) providing the observed data. If not provided, the input to the following arguments must be objects defined in the calling environment.
x	a name from data or a vector of observed data values.
sample	a name from data or a vector of sample indicators defining the rationale sub-groups of data values.

**Value**

The function returns a matrix of suitable dimensions. If one or more group have fewer observations than others, NA values are used to fill empty values.

**Author(s)**

Luca Scrucca

**See Also**

[qcc](#)

**Examples**

```
data(pistonrings)
# create a matrix of 40 samples made of 5 observations each
qccGroups(data = pistonrings, diameter, sample)
# remove some observations to get still a 40x5 matrix but filled with NAs
qccGroups(data = pistonrings[-c(1,2,50,52,199),], diameter, sample)
```

---

qccOverdispersionTest *Overdispersion test for binomial and poisson data*

---

**Description**

This function allows to test for overdispersed data in the binomial and poisson case.

**Usage**

```
qccOverdispersionTest(x, size,
  type = ifelse(missing(size), "poisson", "binomial"))
```

**Arguments**

x	a vector of observed data values
size	for binomial data, a vector of sample sizes
type	a character string specifying the distribution for testing, either "poisson" or "binomial". By default, if size is provided a binomial distribution is assumed, otherwise a poisson distribution.

**Details**

This very simple test amounts to compute the test statistic

$$D = s^2/\sigma^2 \times (n - 1)$$

where  $s^2$  is the observed variance,  $\sigma^2$  is the theoretical variance, and  $n$  is the number of observations. The test statistic is compared to the critical value of a Chi-square distribution with  $n - 1$  degrees of freedom.

**Value**

The function returns a matrix of results.

**Author(s)**

Luca Scrucca

**References**

Wetherill, G.B. and Brown, D.W. (1991) *Statistical Process Control*, New York, Chapman and Hall, pp. 216–218

**Examples**

```
# data from Wetherill and Brown (1991) pp. 212--213, 216--218:
x <- c(12,11,18,11,10,16,9,11,14,15,11,9,10,13,12,
      8,12,13,10,12,13,16,12,18,16,10,16,10,12,14)
size <- rep(50, length(x))
qccOverdispersionTest(x, size)

x <- c(11,8,13,11,13,17,25,23,11,16,9,15,10,16,12,
      8,9,15,4,12,12,12,15,17,14,17,12,12,7,16)
qccOverdispersionTest(x)
```

---

rules

*Rules for Shewhart charts*

---

**Description**

Function which implements rules to signal out of control points in Shewhart charts.

**Usage**

```
qccRules(object, rules = object$rules)
```

**Arguments**

- object            an object of class 'qcc'.
- rules            a vector of values specifying the rules used to declare a process out-of-control. Possible values are:
1. One point plots outside 3-sigma control limits.
  2. Two of three consecutive points plot beyond a 2-sigma limit.
  3. Four of five consecutive points plot beyond a 1-sigma limit.
  4. Eight consecutive points plot on one side of the center line.
- These are often known as *Western Electric rules*.

**Value**

The function returns a vector of the same length as the statistics charted with value NA if no rule is violated, and numerical values corresponding to the violated rule. If more than one rule is violated, the value returned corresponds to the most serious violation.

**Author(s)**

Luca Scrucca

---

RyanMultivar

*Ryan's (2011) multivariate data for quality control*

---

**Description**

Multivariate data from Ryan (2011, Table 9.2).

**Usage**

```
data(RyanMultivar)
```

**Format**

Multivariate data on 20 samples of size 4 for two variables.

**RyanMultivar** a list of two data frames, X1 and X2, one for each variable.

**References**

Ryan, T. P. (2011), *Statistical Methods for Quality Improvement*, 3rd ed. New York: John Wiley & Sons, Inc.

**Examples**

```
data(RyanMultivar)
str(RyanMultivar)
```

---

`stats.c`*Functions to plot Shewhart c chart*

---

**Description**

Statistics used in computing and drawing a Shewhart c chart.

**Usage**

```
stats.c(data, sizes)
sd.c(data, sizes, ...)
limits.c(center, std.dev, sizes, nsigmas = NULL, conf = NULL)
```

**Arguments**

<code>data</code>	the observed data values
<code>center</code>	sample/group center statistic.
<code>sizes</code>	samples sizes.
<code>std.dev</code>	within group standard deviation.
<code>nsigmas</code>	a numeric value specifying the number of sigmas to use for computing control limits. It is ignored when the <code>conf</code> argument is provided.
<code>conf</code>	a numeric value in $(0, 1)$ specifying the confidence level to use for computing control limits.
<code>...</code>	catches further ignored arguments.

**Value**

The function `stats.c` returns a list with components `statistics` and `center`.

The function `sd.c` returns `std.dev` the standard deviation of the statistic charted.

The function `limits.c` returns a matrix with lower and upper control limits.

**Author(s)**

Luca Scrucca

**References**

Montgomery, D.C. (2013) *Introduction to Statistical Quality Control*, 7th ed. New York: John Wiley & Sons.

Wetherill, G.B. and Brown, D.W. (1991) *Statistical Process Control*. New York: Chapman & Hall.

**See Also**

[qcc](#)



---

stats.g                      *Statistics used in computing and drawing a Shewhart g chart*

---

### Description

These functions are used to compute statistics required by the g chart (geometric distribution) for use with the **qcc** package.

### Usage

```
stats.g(data, sizes)
sd.g(data, sizes, ...)
limits.g(center, std.dev, sizes, nsigmas = NULL, conf = NULL)
```

### Arguments

data	the observed data values
center	sample center statistic
sizes	sample sizes (not used)
std.dev	standard deviation of geometric distribution
nsigmas	a numeric value specifying the number of sigmas to use for computing control limits. It is ignored when the conf argument is provided.
conf	a numeric value in (0, 1) specifying the confidence level to use for computing control limits.
...	catches further ignored arguments.

### Details

The g chart plots the number of non-events between events. np charts do not work well when the probability of an event is rare (see example below). Instead of plotting the number of events, the g chart plots the number of non-events between events.

### Value

The function `stats.g()` returns a list with components `statistics` and `center`.

The function `sd.g()` returns `std.dev` the standard deviation  $\sqrt{(1-p)/p}$ .

The function `limits.g()` returns a matrix with lower and upper control limits.

### Note

The geometric distribution is quite skewed so it is best to set `conf` at the required confidence interval ( $0 < \text{conf} < 1$ ) rather than as a multiplier of sigma.

### Author(s)

Greg Snow <greg.snow@ihc.com>

## References

Kaminsky, FC et. al. (1992) *Statistical Control Charts Based on a Geometric Distribution*, Journal of Quality Technology, 24, pp 63–69.

Yang, Z et. al. (2002) On the Performance of Geometric Charts with Estimated Control Limits, *Journal of Quality Technology*, 34, pp 448–458.

## See Also

qcc

## Examples

```
success <- rbinom(1000, 1, 0.01)
num.noevent <- diff(which(c(1,success)==1))-1
qcc(success, type = "np", sizes = 1)
qcc(num.noevent, type = "g")
```

---

stats.np

*Statistics used in computing and drawing a Shewhart np chart*

---

## Description

These functions are used to compute statistics required by the np chart.

## Usage

```
stats.np(data, sizes)
sd.np(data, sizes, ...)
limits.np(center, std.dev, sizes, nsigmas = NULL, conf = NULL)
```

## Arguments

data	the observed data values
center	sample/group center statistic.
sizes	samples sizes.
std.dev	within group standard deviation.
nsigmas	a numeric value specifying the number of sigmas to use for computing control limits. It is ignored when the conf argument is provided.
conf	a numeric value in (0, 1) specifying the confidence level to use for computing control limits.
...	catches further ignored arguments.

**Value**

The function `stats.np` returns a list with components `statistics` and `center`.

The function `sd.np` returns `std.dev` the standard deviation of the statistic charted.

The function `limits.np` returns a matrix with lower and upper control limits.

**Author(s)**

Luca Scrucca

**References**

Montgomery, D.C. (2013) *Introduction to Statistical Quality Control*, 7th ed. New York: John Wiley & Sons.

Wetherill, G.B. and Brown, D.W. (1991) *Statistical Process Control*. New York: Chapman & Hall.

**See Also**

[qcc](#)

---

stats.p

*Statistics used in computing and drawing a Shewhart p chart*

---

**Description**

These functions are used to compute statistics required by the p chart.

**Usage**

```
stats.p(data, sizes)
sd.p(data, sizes, ...)
limits.p(center, std.dev, sizes, nsigmas = NULL, conf = NULL)
```

**Arguments**

<code>data</code>	the observed data values
<code>center</code>	sample/group center statistic.
<code>sizes</code>	samples sizes.
<code>std.dev</code>	within group standard deviation.
<code>nsigmas</code>	a numeric value specifying the number of sigmas to use for computing control limits. It is ignored when the <code>conf</code> argument is provided.
<code>conf</code>	a numeric value in $(0, 1)$ specifying the confidence level to use for computing control limits.
<code>...</code>	catches further ignored arguments.

**Value**

The function `stats.p` returns a list with components `statistics` and `center`.

The function `sd.p` returns `std.dev` the standard deviation of the statistic charted.

The function `limits.p` returns a matrix with lower and upper control limits.

**Author(s)**

Luca Scrucca

**References**

Montgomery, D.C. (2013) *Introduction to Statistical Quality Control*, 7th ed. New York: John Wiley & Sons.

Wetherill, G.B. and Brown, D.W. (1991) *Statistical Process Control*. New York: Chapman & Hall.

**See Also**

[qcc](#)

---

stats.R

*Statistics used in computing and drawing a Shewhart R chart*

---

**Description**

These functions are used to compute statistics required by the R chart.

**Usage**

```
stats.R(data, sizes)
sd.R(data, sizes, std.dev = c("UWAVE-R", "MVLUE-R"), ...)
limits.R(center, std.dev, sizes, nsigmas = NULL, conf = NULL)
```

**Arguments**

<code>data</code>	the observed data values
<code>center</code>	sample/group center statistic.
<code>sizes</code>	samples sizes. Optional
<code>std.dev</code>	within group standard deviation. Optional for <code>sd.R</code> function, required for <code>limits.R</code> . See <a href="#">sd.xbar</a> .
<code>nsigmas</code>	a numeric value specifying the number of sigmas to use for computing control limits. It is ignored when the <code>conf</code> argument is provided.
<code>conf</code>	a numeric value in $(0, 1)$ specifying the confidence level to use for computing control limits.
<code>...</code>	catches further ignored arguments.

**Value**

The function `stats.R` returns a list with components `statistics` and `center`.

The function `sd.R` returns `std.dev` the standard deviation of the statistic charted.

The function `limits.R` returns a matrix with lower and upper control limits.

**Author(s)**

Luca Scrucca

**References**

Montgomery, D.C. (2013) *Introduction to Statistical Quality Control*, 7th ed. New York: John Wiley & Sons.

Wetherill, G.B. and Brown, D.W. (1991) *Statistical Process Control*. New York: Chapman & Hall.

**See Also**

[qcc](#)

---

stats.S

*Functions to plot Shewhart S chart*

---

**Description**

These functions are used to compute statistics required by the S chart.

**Usage**

```
stats.S(data, sizes)
sd.S(data, sizes, std.dev = c("UWAVE-SD", "MVLUE-SD", "RMSDF"), ...)
limits.S(center, std.dev, sizes, nsigmas = NULL, conf = NULL)
```

**Arguments**

<code>data</code>	the observed data values
<code>center</code>	sample/group center statistic.
<code>sizes</code>	samples sizes. Optional
<code>std.dev</code>	within group standard deviation. Optional for <code>sd.S</code> function, required for <code>limits.S</code> . See <a href="#">sd.xbar</a> .
<code>nsigmas</code>	a numeric value specifying the number of sigmas to use for computing control limits. It is ignored when the <code>conf</code> argument is provided.
<code>conf</code>	a numeric value in $(0, 1)$ specifying the confidence level to use for computing control limits.
<code>...</code>	catches further ignored arguments.

**Value**

The function `stats.S` returns a list with components `statistics` and `center`.

The function `sd.S` returns `std.dev` the standard deviation of the statistic charted.

The function `limits.S` returns a matrix with lower and upper control limits.

**Author(s)**

Luca Scrucca

**References**

Montgomery, D.C. (2013) *Introduction to Statistical Quality Control*, 7th ed. New York: John Wiley & Sons.

Wetherill, G.B. and Brown, D.W. (1991) *Statistical Process Control*. New York: Chapman & Hall.

**See Also**

[qcc](#)

---

stats.T2

*Statistics used in computing and drawing the Hotelling  $T^2$  chart for subgrouped data*

---

**Description**

These functions are used to compute statistics required by the  $T^2$  chart.

**Usage**

```
stats.T2(data, center = NULL, cov = NULL)
```

```
limits.T2(ngroups, size, nvars, conf)
```

**Arguments**

<code>data</code>	the observed data values
<code>center</code>	a vector of values to use for center of input variables.
<code>cov</code>	a matrix of values to use for the covariance matrix of input variables.
<code>ngroups</code>	number of groups
<code>size</code>	sample size
<code>nvars</code>	number of variables
<code>conf</code>	confidence level ( $0 < \text{conf} < 1$ )

**Value**

The function `stats.T2` returns a list with components:

<code>statistics</code>	a vector of values for the $T^2$ statistic
<code>means</code>	a matrix of within group means for each variable
<code>center</code>	sample/group center statistic
<code>S</code>	covariance matrix

The function `limits.T2` returns a list with components:

<code>control</code>	control limits
<code>prediction</code>	pred.limits

**Author(s)**

Luca Scrucca

**References**

- Mason, R.L. and Young, J.C. (2002) *Multivariate Statistical Process Control with Industrial Applications*, SIAM.
- Montgomery, D.C. (2013) *Introduction to Statistical Quality Control*, 7th ed. New York: John Wiley & Sons.
- Ryan, T. P. (2011), *Statistical Methods for Quality Improvement*, 3rd ed. New York: John Wiley & Sons, Inc.

**See Also**

[mqcc](#), [stats.T2.single](#)

---

<code>stats.T2.single</code>	<i>Statistics used in computing and drawing the Hotelling <math>T^2</math> chart for individual observations data</i>
------------------------------	---

---

**Description**

These functions are used to compute statistics required by the  $T^2$  chart for individual observations.

**Usage**

```
stats.T2.single(data, center = NULL, cov = NULL)
```

```
limits.T2.single(ngroups, size, nvars, conf)
```

**Arguments**

data	the observed data values
center	a vector of values to use for center of input variables.
cov	a matrix of values to use for the covariance matrix of input variables.
ngroups	number of groups
size	sample size
nvars	number of variables
conf	confidence level ( $0 < \text{conf} < 1$ )

**Value**

The function `stats.T2.single` returns a list with components:

statistics	a vector of values for the $T^2$ statistic
means	a matrix of within group means for each variable (which is equal to data since sample are of sizes one)
center	sample/group center statistic
S	covariance matrix

The function `limits.T2.single` returns a list with components:

control	control limits
prediction	pred.limits

**Author(s)**

Luca Scrucca

**References**

- Mason, R.L. and Young, J.C. (2002) *Multivariate Statistical Process Control with Industrial Applications*, SIAM.
- Montgomery, D.C. (2013) *Introduction to Statistical Quality Control*, 7th ed. New York: John Wiley & Sons.
- Ryan, T. P. (2011), *Statistical Methods for Quality Improvement*, 3rd ed. New York: John Wiley & Sons, Inc.

**See Also**

[mqcc](#), [stats.T2](#)



---

`stats.u`*Statistics used in computing and drawing a Shewhart u chart*

---

**Description**

These functions are used to compute statistics required by the u chart.

**Usage**

```
stats.u(data, sizes)
sd.u(data, sizes, ...)
limits.u(center, std.dev, sizes, nsigmas = NULL, conf = NULL)
```

**Arguments**

<code>data</code>	the observed data values
<code>center</code>	sample/group center statistic.
<code>sizes</code>	samples sizes.
<code>std.dev</code>	within group standard deviation.
<code>nsigmas</code>	a numeric value specifying the number of sigmas to use for computing control limits. It is ignored when the <code>conf</code> argument is provided.
<code>conf</code>	a numeric value in $(0, 1)$ specifying the confidence level to use for computing control limits.
<code>...</code>	catches further ignored arguments.

**Value**

The function `stats.u` returns a list with components `statistics` and `center`.

The function `sd.u` returns `std.dev` the standard deviation of the statistic charted.

The function `limits.u` returns a matrix with lower and upper control limits.

**Author(s)**

Luca Scrucca

**References**

Montgomery, D.C. (2013) *Introduction to Statistical Quality Control*, 7th ed. New York: John Wiley & Sons.

Wetherill, G.B. and Brown, D.W. (1991) *Statistical Process Control*. New York: Chapman & Hall.

**See Also**

[qcc](#)

---

 stats.xbar

*Statistics used in computing and drawing a Shewhart xbar chart*


---

### Description

These functions are used to compute statistics required by the xbar chart.

### Usage

```
stats.xbar(data, sizes)
sd.xbar(data, sizes,
        std.dev = c("UWAVE-R", "UWAVE-SD", "MVLUE-R", "MVLUE-SD", "RMSDF"),
        ...)
limits.xbar(center, std.dev, sizes, nsigmas = NULL, conf = NULL)
```

### Arguments

data	the observed data values
center	sample/group center statistic
sizes	samples sizes. Optional
std.dev	within group standard deviation. Optional for sd.xbar function, required for limits.xbar. See details.
nsigmas	a numeric value specifying the number of sigmas to use for computing control limits. It is ignored when the conf argument is provided.
conf	a numeric value in (0, 1) specifying the confidence level to use for computing control limits.
...	catches further ignored arguments.

### Details

The following methods are available for estimating the process standard deviation:

- "UWAVE-R" UnWeighted AVErage of within-group estimates based on within-group Ranges
- "UWAVE-SD" UnWeighted AVErage of within-group estimates based on within-group Standard Deviations
- "MVLUE-R" Minimum Variance Linear Unbiased Estimator computed as a weighted average of within-group estimates based on within-group Ranges
- "MVLUE-SD" Minimum Variance Linear Unbiased Estimator computed as a weighted average of within-group estimates based on within-group Standard Deviations
- "RMSDF" Root-Mean-Square estimator computed as a weighted average of within-group estimates based on within-group Standard Deviations

Depending on the chart, a method may be available or not, or set as the default according to the following table:

Detailed definitions of formulae implemented are available in the SAS/QC User's Guide.

**Value**

The function `stats.xbar` returns a list with components `statistics` and `center`.

The function `sd.xbar` returns `std.dev` the standard deviation of the statistic charted. This is based on results from Burr (1969).

The function `limits.xbar` returns a matrix with lower and upper control limits.

**Author(s)**

Luca Scrucca

**References**

Burr, I.W. (1969) Control charts for measurements with varying sample sizes. *Journal of Quality Technology*, 1(3), 163-167.

Montgomery, D.C. (2013) *Introduction to Statistical Quality Control*, 7th ed. New York: John Wiley & Sons.

Wetherill, G.B. and Brown, D.W. (1991) *Statistical Process Control*. New York: Chapman & Hall.

**See Also**

[qcc](#)

---

stats.xbar.one	<i>Statistics used in computing and drawing a Shewhart xbar chart for one-at-time data</i>
----------------	--

---

**Description**

These functions are used to compute statistics required by the xbar chart for one-at-time data.

**Usage**

```
stats.xbar.one(data, sizes)
sd.xbar.one(data, sizes, std.dev = c("MR", "SD"), r = 2, ...)
limits.xbar.one(center, std.dev, sizes, nsigmas = NULL, conf = NULL)
```

**Arguments**

data	the observed data values
center	sample/group center statistic.
sizes	samples sizes. Not needed, size = 1 is used.
r	number of successive pairs of observations for computing the standard deviation based on moving ranges of r points.
std.dev	within group standard deviation. Optional for <code>sd.xbar.one</code> function, required for <code>limits.xbar.one</code> . See details.

nsigmas	a numeric value specifying the number of sigmas to use for computing control limits. It is ignored when the conf argument is provided.
conf	a numeric value in (0, 1) specifying the confidence level to use for computing control limits.
...	catches further ignored arguments.

### Details

Methods available for estimating the process standard deviation:

- "MR" = moving range: this estimate is based on the scaled mean of moving ranges
- "SD" = sample standard deviation: this estimate is defined as  $sd(x)/cd(n)$ , where n is the number of individual measurements of x.

### Value

The function `stats.xbar.one` returns a list with components `statistics` and `center`.

The function `sd.xbar.one` returns `std.dev` the standard deviation of the statistic charted.

The function `limits.xbar.one` returns a matrix with lower and upper control limits.

### Author(s)

Luca Scrucca

### References

Montgomery, D.C. (2013) *Introduction to Statistical Quality Control*, 7th ed. New York: John Wiley & Sons.

Ryan, T. P. (2011), *Statistical Methods for Quality Improvement*, 3rd ed. New York: John Wiley & Sons, Inc.

Wetherill, G.B. and Brown, D.W. (1991) *Statistical Process Control*. New York: Chapman & Hall.

### See Also

[qcc](#)

### Examples

```
# Water content of antifreeze data (Wetherill and Brown, 1991, p. 120)
x <- c(2.23, 2.53, 2.62, 2.63, 2.58, 2.44, 2.49, 2.34, 2.95, 2.54, 2.60, 2.45,
      2.17, 2.58, 2.57, 2.44, 2.38, 2.23, 2.23, 2.54, 2.66, 2.84, 2.81, 2.39,
      2.56, 2.70, 3.00, 2.81, 2.77, 2.89, 2.54, 2.98, 2.35, 2.53)
# the Shewhart control chart for one-at-time data
# 1) using MR (default)
qcc(x, type="xbar.one", data.name="Water content (in ppm) of batches of antifreeze")
# 2) using SD
qcc(x, type="xbar.one", std.dev = "SD", data.name="Water content (in ppm) of batches of antifreeze")

# "as the size increases further, we would expect sigma-hat to settle down
```

```
# at a value close to the overall sigma-hat" (Wetherill and Brown, 1991,
# p. 121)
sigma <- NA
k <- 2:24
for (j in k)
  sigma[j] <- sd.xbar.one(x, k=j)
plot(k, sigma[k], type="b") # plot estimates of sigma for
abline(h=sd(x), col=2, lty=2) # different values of k
```

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viscosity

*Viscosity for aircraft primer paint data*

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## Description

"The viscosity of an aircraft primer paint is an important quality characteristic. The product is produced in batches, and because each batch takes several hours to produce, the production rate is too slow to allow for rational subgroups of size greater than one." (Montgomery, 2005, p. 232)

## Usage

```
data(viscosity)
```

## Format

A data frame with 35 observations on the following 3 variables.

**batch** batch number

**viscosity** viscosity measure

**trial** preliminary sample indicator (TRUE/FALSE)

## References

Montgomery, D.C. (2005) *Introduction to Statistical Quality Control*, 5th ed, New York, John Wiley & Sons, pp. 232-235

## Examples

```
data(viscosity)
describe(viscosity, by = trial)
plot(viscosity ~ batch, data = viscosity, type = "o",
      pch = ifelse(trial, 19, 1))
```

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