

# Package ‘EngrExpt’

January 20, 2025

**Version** 0.1-8

**Date** 2009-08-21

**Title** Data sets from ``Introductory Statistics for Engineering Experimentation''

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**Description** Datasets from Nelson, Coffin and Copeland ``Introductory Statistics for Engineering Experimentation'' (Elsevier, 2003) with sample code.

**Depends** R (>= 2.9.0), lattice

**LazyLoad** yes

**LazyData** yes

**License** GPL (>= 2)

**Repository** CRAN

**Date/Publication** 2012-10-29 08:57:01

**NeedsCompilation** no

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absorb	<i>Oil absorption of silica</i>
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### Description

Time ordered measurements of oil absorption from silica samples produced during one manufacturing shift.

### Format

A data frame with 102 observations on the following variable.

absorb a numeric vector

### Details

As stated in Nelson, Coffin and Copeland (2003, p. 424), "One key quality parameter in the making of silica is the amount of oil that it can absorb since silica is often mixed with rubber and oil in various applications (battery separators, tires, shoe soles, etc.)"

### References

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

## Examples

```
str(absorb)
summary(absorb$absorb)
densityplot(~ absorb, absorb,
            xlab = "Average oil absorption of silica samples")
qqmath(~ absorb, absorb,
       ylab = "Average oil absorption of silica samples",
       xlab = "Standard normal quantiles", aspect = 1)
```

---

adhesion

*Adhesive qualities of a lens coating*

---

## Description

These data are from two experiments to examine the effect of formulation changes on the adhesive properties of a eye glass lens coating. If the coating would not adhere to the lens surface then the formulation would not be marketable. The first experiment (adhesion) considered only pH (i.e., one factor). In this experiemnt three formulations were made (one at each of three pH levles) and ten samples from each formulation were tested. The test procedure for measuring adhesion is known to contain a large amount of test error. In the second experiment ( adhesion2 the effect of pH (3 levels) and a catalyst (2 levels) were tested. The data consists of five samples were taken from and tested from each of the six formulations.

## Format

adhesion is a data frame with 30 observations on the following 2 variables.

adhesion a numeric vector

pH a numeric vector at three distinct levels

adhesion2 is a data frame with 30 observations on the following 3 variables.

cat a factor with levels A and B

pH a numeric vector

adhesion a numeric vector

## References

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```

str(adhesion)
xtabs(~ pH, adhesion)
xyplot(adhesion ~ pH, adhesion,
       ylab = "Adhesion of a lens coating", xlab = "pH",
       type = c("g", "p", "a"))
dotplot(as.factor(pH) ~ adhesion, adhesion, ylab = "pH",
       type = c("p", "a"), xlab = "Adhesion of a lens coating")
str(adhesion2)
xtabs(~ cat + pH, adhesion2)
dotplot(as.factor(pH) ~ adhesion, adhesion2, groups = cat,
       type = c("p", "a"), ylab = "pH",
       auto.key = list(space = "right", lines = TRUE,
                       title = "Catalyst"))

```

---

alum

*Aluminum impurity amounts*


---

**Description**

As described in Nelson, Coffin and Copeland (2003), “ Over a 2-hour period, twenty-five 200 gm samples were drawn at random from a process that recycles plastic, and the amount of aluminum impurities in the sample in ppm was determined for each sample. ”

**Format**

A data frame with 25 observations on the following variable.

ppm amount of aluminum impurities (ppm)

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```

str(alum)
qqmath(~ ppm, alum, xlab = "Standard normal quantiles",
      aspect = 1, ylab = "Amount of aluminum impurities (ppm)",
      type = c("g", "p"))
qqmath(~ log(ppm), alum, xlab = "Standard normal quantiles",
      aspect = 1, type = c("g", "p"),
      ylab = "Natural log of amount of aluminum impurities (log(ppm))")

```

---

 applicat

*Application of powder coating*


---

### Description

As described in Nelson, Coffin and Copeland (2003), “The application of powder coating (a type of paint used on appliances and, in limited settings, cars) is done by spraying the material through a ‘gun’ that has an electrical charge on it. There are three factors to consider in setting up the application booth: the gun distance from the target item, the charge and the pressure (flow rate) of the material through the gun. This data set contains data from 18 runs.” Note that there is no data for the high flow rate, high charges, and low distance as these combinations were infeasible from an operations standpoint (they were such that too much paint would be applied to the target).

### Format

A data frame with 18 observations on the following 4 variables.

distance distance of the gun from the target (inches) - an ordered factor with levels 11 < 13 < 15

charge charge used (kvolts) - an ordered factor with levels 35 < 45 < 55

flowrate flow rate in gm/min. - an ordered factor with levels 94 < 124

gloss a measure of the resulting gloss

### References

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

### Examples

```
str(applicat)
dotplot(distance ~ gloss|flowrate, applicat, groups = charge,
         type = c("p", "a"), layout = c(1,2),
         ylab = "Gun distance from target (in.)",
         strip = FALSE, strip.left = TRUE,
         auto.key = list(columns = 3, lines = TRUE), xlab =
"Gloss for two flow rates (gm/min) and three charges (kvolts)")
dotplot(charge ~ gloss|flowrate, applicat, groups = distance,
         type = c("p", "a"), layout = c(1,2),
         ylab = "Charge (kvolts)",
         strip = FALSE, strip.left = TRUE,
         auto.key = list(columns = 3, lines = TRUE), xlab =
"Gloss for two flow rates (gm/min) and three distances from target (in)")
```

---

assay	<i>Yield from two processes</i>
-------	---------------------------------

---

**Description**

A resin is one component in paint formulations. A chemist was working on a process for producing a resin needed in a paint formulation. Two competing processes were tested for the amount of resin they could produce.

**Format**

A data frame with 9 observations on the following 2 variables.

process a factor with levels A and B

yield a numeric vector

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(assay)
summary(assay)
dotplot(process ~ yield, assay)
```

---

bacteria	<i>Bacteria count in water samples</i>
----------	--

---

**Description**

As described in Nelson, Coffin and Copeland (2003), “Purified water is used in one step in the production of a medical device. The water is tested daily for bacteria. These data are the results from 50 days of testing. They are the counts of a particular strain of bacteria in a 100 ml. sample of water.”

**Format**

A data frame with 50 observations on the following variable.

level bacteria count

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(bacteria)
qqmath(~ level, bacteria, aspect = 1,
       xlab = "Standard normal quantiles",
       ylab = "Bacteria count")
```

---

bath

*Electrical resistance after water bath*


---

**Description**

In a production process a rubber material is extruded in a continuous ribbon (about 2 feet in width). In one step of the process the product passes through a water bath. In this experiment the time spent in the bath and the temperature of the bath were varied to determine their effect on the electrical resistance of the final product.

**Format**

A data frame with 4 observations on the following 3 variables.

time time in the bath (coded as levels -1 and 1)  
temp temperature in the bath (coded as levels -1 and 1)  
er electrical resistance of the final produce (ohm/m<sup>2</sup>)

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(bath)
dotplot(ordered(time) ~ er, bath, groups = temp, type = c("p", "a"),
       xlab = expression("Electrical resistance (ohm/" * m^2 * ")"),
       ylab = "Time in bath (coded)",
       auto.key = list(columns = 2, lines = TRUE))
summary(fm1 <- lm(er ~ time * temp, bath))
summary(fm2 <- lm(er ~ time + temp, bath))
summary(fm3 <- lm(er ~ temp, bath))
```



---

 battery

*Battery lifetime in laptop computers*


---

**Description**

Data from a study on the effect of different processors on the battery lifetime in laptop computers.

**Format**

A data frame with 30 observations on the following 2 variables.

type processor type - a factor with levels A, B and C

lifetime a numeric vector

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(battery)
densityplot(~ lifetime, battery, groups = type,
            xlab = "Battery lifetime (hours)",
            auto.key = list(columns = 3, lines = TRUE))
densityplot(~ lifetime, battery, groups = type,
            scales = list(x = list(log = 2)),
            xlab = "Battery lifetime (hours) - logarithmic scale",
            auto.key = list(columns = 3, lines = TRUE))
dotplot(reorder(as.factor(type), lifetime) ~ lifetime, battery,
        jitter.y = TRUE,
        xlab = "Battery lifetime (hours)",
        ylab = "Type", type = c("p", "a"))
dotplot(reorder(as.factor(type), lifetime) ~ lifetime, battery,
        jitter.y = TRUE, scales = list(x = list(log = 2)),
        xlab = "Battery lifetime (hours) - logarithmic scale",
        ylab = "Type", type = c("p", "a"))
```

---

 bright

*Brightness of de-inked newspaper*


---

**Description**

One step of recycling newsprint is to "de-ink" the newsprint, that is to remove the ink. The brightness of the paper pulp after a de-inking process is a measure of how well the process to remove the ink worked. A half-fraction of a  $2^5$  factorial experiment was run to test various factors on the ability to de-ink newsprint.

**Usage**

```
data(bright)
```

**Format**

A data frame with 16 observations on the following 6 variables.

type type of alkali - an ordered factor with levels A < B

percent percentage of alkali (25% or 75%)

time time pulp is soaked (30 or 40 minutes)

hardness water hardness (150 or 250)

speed agitation rate - an ordered factor with levels S < F

bright Brightness of pulp

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(bright)
options(contrasts = c("contr.treatment", "contr.helmert"))
summary(fm1 <- lm(bright ~ (type + percent + time + hardness + speed)^2,
                 bright))
qqmath(coef(fm1)[-1], aspect = 1,
       panel = function(...)
       {
         panel.grid(h = -1, v = -1)
         panel.qqmath(...)
         panel.qqmathline(..., alpha = 0.5, lty = 2)
       },
       xlab = "Standard normal quantiles",
       ylab = "First- and second-order effects")
summary(fm2 <- lm(bright ~ (type + hardness)^2, bright))
dotplot(type ~ bright, bright, groups = hardness,
        type = c("p", "a"), jitter.y = TRUE,
        xlab = "Brightness of pulp (lines and point styles are levels of water hardness)",
        ylab = "Alkali type", aspect = 0.4,
        auto.key = list(lines = TRUE, columns = 2))
```

---

calcium

*Calcium levels before and after taking vitamin*

---

### Description

The serum calcium levels in 11 test subjects before taking a multi-vitamin containing calcium and three hours after taking the vitamin.

### Format

A data frame with 11 observations on the following 2 variables.

hrs0 serum calcium level (mg/dl) at time zero

hrs3 serum calcium level (mg/dl) three hours after taking the multi-vitamin containing calcium

### Details

This was a small pilot study to test the effectiveness of the multi-vitamin with respect to calcium absorption.

### References

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

### Examples

```
str(calcium)
show(p11 <-
  xyplot(hrs3 ~ hrs0, calcium, type = c("g","p"), aspect = "iso",
    xlab = "Calcium level (mg/dl) before taking multi-vitamin",
    ylab =
      "Calcium level (mg/dl) 3 hours after taking multi-vitamin"))
tmd(p11)
```

---

caliper

*Diameters of rods measured by two calipers*

---

### Description

Diameters of 14 metal rods measured once each with each of two calipers.

**Format**

A data frame with 14 observations on the following 3 variables.

part indicator of which part is measured - a factor

calipera measurement with caliper type A

caliperb measurement with caliper type B

**Details**

This is an experiment to study the relationship between the measurements taken by the two calipers on various parts. The diameter of each part is not of interest.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(caliper)
show(p11 <-
  xyplot(caliperb ~ calipera, caliper,
         type = c("g", "p"), aspect = "iso",
         xlab = "Measurement with caliper A",
         ylab = "Measurement with caliper B"))
tmd(p11)
```

---

ccthickn

*Clear coat thickness*

---

**Description**

Measurements of film build from 40 test panels sprayed in a pilot plant spray booth to study paint equipment set-up. Target film build was 65 microns.

**Format**

A data frame with 40 observations on the following variable.

thickness clear coat thickness (microns)

**Details**

Cars are coated (i.e., painted) in layers. The “film build” (i.e. thickness) of each layer of the coating has an effect on the properties of the paint (performance and appearance) so it is important to maintain the correct film builds. The final layer of paint on a car is called the clear coat; the film build of this layer was to be 65 microns.

## References

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

## Examples

```
str(ccthickn)
densityplot(~ thickness, ccthickn, xlab = "Clear coat thickness (microns)")
qqmath(~ thickness, ccthickn, aspect = 1,
       ylab = "Clear coat thickness (microns)",
       xlab = "Standard normal quantiles",
       type = c("g", "p"),
       panel=function(...)
       {
         panel.qqmathline(..., alpha = 0.5, lty = 2)
         panel.qqmath(...)
       })
```

---

cement

*Drying times of concrete*

---

## Description

Drying times of different concrete mixes used in a sidewalk. Mix 'A' is the conventional mix. Mixes 'B' and 'C' are experimental, and more expensive, mixes.

## Format

A data frame with 19 observations on the following 2 variables.

type concrete mix - a factor with levels A, B and C

time time (hr) until concrete is dry enough to walk on

## References

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

## Examples

```
str(cement)
dotplot(reorder(type, time) ~ time, cement, type = c("p", "a"),
       jitter.y = TRUE, ylab = "Mix type",
       xlab = "Time until concrete is dry enough to walk on (hours)")
qqmath(~ time, cement, groups = type, aspect = 'xy',
       xlab = "Standard normal quantiles",
       type = c("g", "p"),
       panel=function(...)
       {
```

```

    panel.qqmathline(..., alpha = 0.5, lty = 2)
    panel.qqmath(...)
  },
  ylab = "Time until concrete is dry enough to walk on (hours)",
  auto.key = list(space = "right", title = "Type", lines = TRUE))
summary(fm1 <- aov(time ~ type, cement))
TukeyHSD(fm1)

```

---

 cheese

*Percentage fat in cheese*


---

### Description

A manufacturer of cheese supplies a major pizza chain from three different manufacturing locations. Samples from 6 different batches at each of three different plants were assayed for the percentage fat content.

### Format

A data frame with 90 observations on the following 3 variables.

plant the plant where the cheese was manufactured - a factor with levels A, B and C

batch the batch of cheese - a factor with levels a to f. Note that batch a from plant A is not related to batch a from plants B or C

fat fat content of the cheese (%)

### References

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

### Examples

```

str(cheese)
bwplot(batch ~ fat|plant, cheese, layout = c(1,3), strip = FALSE,
        strip.left = TRUE,
        xlab = "Percentage fat content of batches from three plants")
dotplot(reorder(reorder(plant:batch, fat), as.numeric(plant)) ~ fat |
        reorder(plant, fat), cheese, strip = FALSE, strip.left = TRUE,
        layout = c(1, 3), scales = list(y = list(relation = "free")),
        aspect = 0.2, type = c("p", "a"), xlab =
        "Percentage fat content - lines join mean fat content per batch",
        ylab = "Batch within plant", jitter.y = TRUE)

```

chemreac

*Yield of a chemical reaction***Description**

The yield of a chemical reaction was determined in a replicated  $2^3$  factorial design.

**Format**

A data frame with 16 observations on the following 4 variables.

temp temperature in degrees C - an ordered factor with levels 120 < 140

cat catalyst - a factor with levels A and B

time time reaction was run, in minutes - an ordered factor with levels 10 < 30

yield yield of the reaction

**Examples**

```
str(chemreac)
dotplot(temp ~ yield | time, chemreac, groups = cat,
         strip = FALSE, strip.left = TRUE, type = c("p", "a"), layout = c(1,2),
         auto.key = list(space = "right", title = "Catalyst", lines = TRUE))
summary(fm1 <- lm(yield ~ (time + temp + cat)^3, chemreac))
summary(fm2 <- lm(yield ~ time * temp + cat, chemreac))
```

computer

*Repair time of computers***Description**

Data from a study of the repair time for different brands of computers in different configurations.

**Format**

A data frame with 36 observations on the following 3 variables.

brand a factor with levels A B C

type an ordered factor with levels Inexpensive home < Expensive home < Business

time time to repair computer (minutes)

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(computer)
dotplot(type ~ time, computer, groups = brand,
        auto.key = list(columns = 3, lines = TRUE),
        type = c("p", "a"), jitter.y = TRUE,
        xlab = "Time to repair computer (minutes)")
summary(fm1 <- lm(time ~ brand * type, computer))
summary(fm2 <- lm(time ~ brand + type, computer))
summary(fm3 <- lm(time ~ type, computer))
```

---

cure

*Yield from a chemical curing process*


---

**Description**

Process engineers wish to determine a “bake window”, the combination of time and temperature in a curing process, that will maximize the yield of the product.

**Format**

A data frame with 18 observations on the following 3 variables.

time time - an ordered factor with levels 20 < 40

temp temperature - an ordered factor with levels Low < Med < High

yield yield of parts

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(cure)
dotplot(temp ~ yield, cure, groups = time, type = c("p", "a"),
        jitter.y = TRUE, xlab = "Yield of parts")
summary(fm1 <- lm(yield ~ time * temp, cure))
```



---

curl	<i>Curl of transparencies</i>
------	-------------------------------

---

## Description

The current formulation of a coating on transparencies used in ink-jet printers causes them to curl. These data are from experiments conducted on a new formulation of the coating to reduce the amount of curl.

## Format

A data frame with 12 observations on the following 3 variables.

catalyst amount of catalyst

compa amount of component a (the second component)

curl a measure of the curl

## Details

These data were collected when transparencies were still widely used for presentations. With the proliferation of projectors, transparencies are being used less and less. However, coatings on paper will continue to be an area of research as coatings have to interact with a variety of printers and inks in order to be useful.

## References

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

## Examples

```
str(curl)
xtabs(~ catalyst + compa, curl)  ## display the experimental design
xyplot(curl ~ compa | ordered(catalyst), curl,
        type = c("g", "p", "r"), layout = c(3,1),
        xlab = "Amount of component `a` - panels are amount of catalyst",
        ylab = "Amount of curl")
```

---

 defoam

*Height of solution with defoamer*


---

### Description

The height of a solution containing a “defoamer” in a 50-ml graduated cylinder after being heated to a particular temperature.

### Format

A data frame with 27 observations on the following 4 variables.

conc concentration of defoamer - a factor with levels L < M < H

pH pH of defoamer - a factor with levels L < M < H

temp temperature of defoamer - a factor with levels L < M < H

height height of solution in the graduated cylinder

### Details

A defoamer is a product that controls the formation of foam in industrial processes such as one might find in the food industry.

### References

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

### Examples

```
str(defoam)
dotplot(pH ~ height|conc, defoam, groups = temp, aspect = 0.3,
        xlab = "Height of solution", type = c("p","a"),
        auto.key = list(space = "right", lines = TRUE,
                       title = "Temperature"),
        strip = FALSE, strip.left = TRUE,
        ylab = "pH within concentration")
summary(fm1 <- lm(height ~ (conc + pH + temp)^2, defoam))
summary(fm2 <- lm(height ~ (pH + temp)^3, defoam))
```

---

deink

*De-inking of newsprint*

---

### Description

De-inking of newsprint

### Format

A data frame with 27 observations on the following 3 variables.

alkali amount of alkali in the solution

hardness hardness of the water - an ordered factor with levels 50 < 150 < 250

bright a measure of brightness

### Details

One step of recycling newsprint is to "de-ink" the newsprint, that is to remove the ink. The brightness of the paper pulp after a de-inking process is a measure of how well the process to remove the ink worked.

### References

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

### Examples

```
str(deink)
xtabs(~ alkali + hardness, deink)
dotplot(hardness ~ bright, deink, groups = alkali,
        auto.key = list(columns = 3, lines = TRUE),
        type = c("p", "a"), aspect = 'xy',
        xlab = "Brightness by amount of alkali",
        ylab = "Hardness of the water")
```

---

deink2

*De-inking of newsprint*

---

### Description

De-inking of newsprint

**Format**

A data frame with 15 observations on the following 3 variables.

formula a factor with levels A, B and C

newspaper a factor with levels A, B, C, D and E

bright a numeric vector

**Details**

One step of recycling newsprint is to "de-ink" the newsprint, that is to remove the ink. The brightness of the paper pulp after a de-inking process is a measure of how well the process to remove the ink worked. In this experiment three formulations were tested on three newspapers (not all newsprint and ink are identical).

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(deink2)
```

---

dhaze

*Haze of lenses after abrasion*

---

**Description**

Haze of lenses after 150 test cycles of abrasion

**Usage**

```
data(dhaze)
```

**Format**

A data frame with 28 observations on the following 2 variables.

treatment a factor with levels A, B, C and D

dhaze a numeric vector

**Details**

A maker of coatings for eye glass lenses tested three treatments (or coating formulations) for the ability to withstand wear (simulated with an abrasion test) as measured by haze. Low haze is desirable.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(dhaze)
```

---

diagnostic	<i>Consistency of diagnostic kits</i>
------------	---------------------------------------

---

**Description**

Consistency of diagnostic kits

**Format**

A data frame with 16 observations on the following 2 variables.

kit1 measurement using kit 1

kit2 measurement using kit 2

**Details**

Diagnostic kits are used in clinics or laboratories to test samples (e.g., blood) for some condition (i.e., illness). One kit can often test many samples. In this case one kit can test at least 16 samples. This study was to look the consistency between kits used to test the same set of samples. The samples would have been divided such that both kits could be used to test the sample and then the results compared.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(diagnostic)
show(plt1 <-
  xyplot(kit2 ~ kit1, diagnostic,
         aspect = "iso", type = c("g", "p"),
         xlab = "Measurement using kit 1",
         ylab = "Measurement using kit 2"))
tmd(plt1)
show(plt2 <-
  xyplot(kit2 ~ kit1, diagnostic, aspect = "iso",
         xlab = "Measurement using kit 1 - logarithmic axis",
         ylab = "Measurement using kit 2 - logarithmic axis",
         scales = list(log = 2)))
tmd(plt2)
```

---

diameter	<i>Diameter of product</i>
----------	----------------------------

---

### Description

The diameter of tracking balls for computer mice from two different production lines. The nominal diameter of the ball is 2 cm.

### Format

A data frame with 20 observations on the following 2 variables.

line a factor with levels A B

diameter diameter of the tracking ball (cm.)

### References

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

### Examples

```
str(diameter)
dotplot(line ~ diameter, diameter, type = c("p", "a"),
        jitter.y = TRUE, aspect = 0.2, ylab = "Line",
        xlab = "Diameter of tracking ball (cm.)")
bwplot(line ~ diameter, diameter, type = c("p", "a"),
        jitter.y = TRUE, aspect = 0.2, ylab = "Line",
        xlab = "Diameter of tracking ball (cm.)")
```

---

drought	<i>Water usage in 2001 and 2002</i>
---------	-------------------------------------

---

### Description

In 2002, Colorado experienced a drought and many towns on the front range (a geographical district close to the Rocky mountains) issued mandatory or voluntary water restrictions on outdoor watering. These data are comparative water usage between 2001 and 2002 for five such towns.

### Format

A data frame with 5 observations on the following 3 variables.

town a factor with levels A, B, C, D and E

j2001 water usage (millions of gallons) in 2001

j2002 water usage (millions of gallons) in 2001

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(drought)
```

---

drums	<i>Weights of drums before and after filling</i>
-------	--

---

**Description**

Weights of drums before and after being filled with a chemical product.

**Format**

A data frame with 30 observations on the following 3 variables.

number a numeric vector

empty a numeric vector

full a numeric vector

**Details**

These data were collected to study a filling process that filled drums of material based on an assumed weight of the empty drum.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(drums)
```

---

dry	<i>Moisture content after drying</i>
-----	--------------------------------------

---

**Description**

Moisture content after drying

**Format**

A data frame with 16 observations on the following 3 variables.

rate a factor with levels SLOW and FAST

type type of dryer - a factor with levels BATCH and TUNNEL

response Moisture content of final product (%)

**Details**

A production process used two types of dryers. The product could pass through the tunnel dryer as a web of material or the product could be coiled on larger rollers and then placed into a dryer. The question was how to best set each dryer to obtain a moisture content of 63(%).

**Examples**

```
str(dry)
```

---

epoxy	<i>Effect of epoxy level on appearance</i>
-------	--

---

**Description**

Effect of epoxy level on appearance

**Format**

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

epoxy level of epoxy in formulation

lw longwave measure of appearance

**Details**

Long wave is a measurement used to characterize a surface, such as the paint on an auto. In this instance higher LW was desired and the amount epoxy was one component of the paint that was known to impact the LW properties of the final product.



**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(epoxy)
```

---

exposure

*Appearance of panels after exposure to weather*

---

**Description**

Appearance of panels after exposure to weather

**Format**

A data frame with 36 observations on the following 2 variables.

form formulation of paint - a factor with levels A, B and C

rating appearance rating

**Details**

One way to test the durability of a new auto paint formulation is to hang coated test panels outside and expose them to the elements. After some time has passed the appearance of the panels are rated. If their appearance is poor then that formulation is not desirable.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(exposure)
```

---

fbuild	<i>Appearance for film builds</i>
--------	-----------------------------------

---

**Description**

Appearance for film builds

**Format**

A data frame with 9 observations on the following 2 variables.

build a numeric vector

gloss a numeric vector

**Details**

Film build is the thickness of a coating, such as an automotive paint. Gloss is an appearance measure with higher gloss generally being preferred.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(fbuild)
```

---

fill	<i>Fill amount in tamped cylinders</i>
------	--

---

**Description**

Fill amount in tamped cylinders

**Format**

A data frame with 18 observations on the following 3 variables.

distance a numeric vector

tamps a numeric vector

fill a numeric vector

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(fill)
```

---

fillweight

*Fill weight by batch*

---

**Description**

Fill weight by batch

**Format**

A data frame with 20 observations on the following 3 variables.

run a factor with levels A, B, C and D

tube a factor with levels A, B, C, D and E

weight a numeric vector

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(fillweight)
```

---

fish

*Toxin concentrations in fish by site*

---

**Description**

Toxin concentrations in fish by site

**Format**

fish is a data frame with 16 observations on the following 2 variables.

site a factor with levels A, B, C and D

toxin a numeric vector

fish2 is a data frame with 16 observations on the following 2 variables.

site a factor with levels E, F, G and H

toxin a numeric vector

**Details**

Prior to beginning mining operations a new precious metals mine had to run an extensive environmental study of the surrounding area, particularly down stream from their construction site. Thus, a baseline of data was collected over many years so that any environmental impact of the facility could be quantified. One step in the study was to collect fish along a stream and measure the amount of various toxins found in the fish.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(fish)
dotplot(reorder(site, toxin) ~ toxin, fish, jitter.y = TRUE,
        aspect = 0.3, xlab = "Amount of toxin (mg/kg wet weight)")
str(fish2)
dotplot(reorder(site, toxin) ~ toxin, fish2, jitter.y = TRUE,
        aspect = 0.3, xlab = "Amount of toxin (mg/kg wet weight)")
```

---

 fluoride

*Fluoride levels from water sources*


---

**Description**

Fluoride levels from water sources

**Format**

A data frame with 58 observations on the following 2 variables.

source a factor with levels A B C

fluoride a numeric vector

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(fluoride)
```

---

gloss	<i>Gloss of paint on cars</i>
-------	-------------------------------

---

**Description**

Gloss of paint on cars

**Format**

A data frame with 40 observations on the following 2 variables.

color a factor with levels Black, Green, Silver and White

gloss a numeric vector

**Details**

The final coat of paint on a car is typically a clear coat. This layer is applied on top of the layer with the color and formulations must be compatible with many base colors. This data was used to investigate the performance of a formulation on the appearance of the coating when used with various base colors.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(gloss)
```

---

labcomp	<i>Inter-lab study</i>
---------	------------------------

---

**Description**

Inter-lab study

**Format**

A data frame with 28 observations on the following 3 variables.

lab a factor with levels A, B, C and D

pt1 a numeric vector

pt5 a numeric vector

**Details**

This study was an "inter-lab" study to investigate measurements taken on a product at various facilities. In particular, this company has a research lab, a pilot line lab, and multiple labs at plants. When characterizing products and especially in trouble shooting performance issues samples may be tested at multiple facilities and it is important to know if there is an impact of location on the resulting measurements. For this study material was sent to each lab and tested 7 times by two testing methods, a 1-point method at all labs and a 5-point method at two of the labs.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(labcomp)
```

---

lw	<i>Automotive paint formulation</i>
----	-------------------------------------

---

**Description**

Automotive paint formulation

**Format**

A data frame with 24 observations on the following 3 variables.

lw a numeric vector

comp1 a factor with levels A, B, C and D

comp2 a factor with levels A, B and C

**Details**

LW (longwave) is a surface appearance measure. This data was from an experiment to choose the best combination of two components in an automotive paint formulation. The goal is to maximize the LW measure.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(lw)
```

---

lsw	<i>Appearance measures of automotive paints</i>
-----	---

---

**Description**

Appearance measures of automotive paints

**Format**

A data frame with 13 observations on the following 2 variables.

lw a numeric vector

sw a numeric vector

**Details**

Longwave (LW) and shortwave (SW) are two surface quality measurements. Both are important in the development of coating formulations. This data was gathered to examine the relationship between the two measures.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(lsw)
```

---

moisture	<i>Moisture content of a silica product</i>
----------	---

---

**Description**

Moisture content of a silica product

**Format**

A data frame with 8 observations on the following 5 variables.

temp temperature in degrees Fahrenheit - an ordered factor with levels 200 < 300

speed process speed - an ordered factor with levels A and B

solids percent solids - an ordered factor with levels 10 < 15

pH pH of the process - an ordered factor with levels 6.5 < 7

moisture moisture content of the product

**Details**

These data were collected from an experiment run in a pilot plant to try to increase the moisture content of a product through production changes.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(moisture)
```

---

mw

*Appearance measure of paint*

---

**Description**

Appearance measure of paint

**Format**

A data frame with 32 observations on the following 6 variables.

a a factor with levels H L

b a factor with levels H L

c a factor with levels H L

d a factor with levels H L

e a factor with levels H L

mw a numeric vector

**Details**

These data are from a designed experiment to study the impact of 5 process factors on the molecular weight of a paint. The Mw is the response of interest as it in turn impacts quality characteristics of the paint. This study was run to better understand the influence of processing variables on the resulting Mw of the formulations.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(mw)
```



---

odor	<i>Odor, yellowing and hardness of optical coating</i>
------	--

---

**Description**

Odor, yellowing and hardness of optical coating

**Format**

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

odor a numeric vector

yellowing a numeric vector

hardness a numeric vector

**Details**

These data are quality data gathered from 35 random samples of a raw material used in a lens coating. It is beneficial to understand the relationships between desired quality characteristics of a product as one must often compromise one characteristic for another.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(odor)
```

---

oven	<i>Drying of silica</i>
------	-------------------------

---

**Description**

Drying of silica

**Format**

A data frame with 30 observations on the following 3 variables.

brand a factor with levels A B C

type a factor with levels A B

moisture a numeric vector

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(oven)
```

---

ph	<i>pH measurements in a chemical process</i>
----	--

---

**Description**

pH measurements in a chemical process

**Format**

A data frame with 35 observations on the following 2 variables.

batch a factor with levels A, B and C

ph a numeric vector

**Details**

For each of three batches of material numerous pH readings were taken over the course of the production process. For this material the pH should be consistent throughout production.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(ph)
summary(ph)
dotplot(batch ~ ph, ph, pch = 21, jitter.y = TRUE)
ph$obs <- as.integer(gl(12, 1, len = 35))
xyplot(ph ~ obs|batch, ph, type = c("g","b"), layout = c(1,3),
       strip = FALSE, strip.left = TRUE, xlab = NULL)
```

---

phmeas

*Comparison of instruments to measure pH*

---

**Description**

Comparison of instruments to measure pH

**Format**

A data frame with 11 observations on the following 2 variables.

phold a numeric vector

phnew a numeric vector

**Details**

These data were collected to compare an old instrument to a new instrument. Eleven samples were tested with both instruments.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(phmeas)
```

---

pigment

*Yellowing of paint for different pigments*

---

**Description**

Yellowing of paint for different pigments

**Format**

A data frame with 9 observations on the following 3 variables.

batch a factor with levels A, B and C

pigment a factor with levels A, B and C

deltab a numeric vector

**Details**

This experiment was to study the impact of pigments on the quality of a white paint. The measure of interest was delta b (smaller is better). Three batches of paint were used to test each of the three pigments (so there were three measurements for each pigment, one from each batch).

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(pigment)
```

---

protein	<i>Assay of protein in blood</i>
---------	----------------------------------

---

**Description**

Assay of protein in blood

**Format**

A data frame with 54 observations on the following 5 variables.

gender a factor with levels F and M

age a numeric vector

duration a numeric vector

levela a numeric vector

protein a numeric vector

**Details**

The response of interest in this data set is the protein level from a new diagnostic test.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(protein)
```

---

purity	<i>Purity of product from a filtration process</i>
--------	--

---

**Description**

Purity of product from a filtration process

**Format**

A data frame with 12 observations on the following 4 variables.

tech indicator factor for technician

fac1 a factor with 3 levels

fac2 a factor with 2 levels

purity a response factor

**Details**

This experiment was run by two technicians to study the impact of two process factors on the purity of the product after filtration.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(purity)
```

---

railcar	<i>Rail car hold times</i>
---------	----------------------------

---

**Description**

Rail car hold times

**Format**

A data frame with 53 observations on the following variable.

days a numeric vector

**Details**

A company ships product to customers in rail cars. The rail cars are delivered by the railroad to a rail siding at the customer's facility. This data records the time that a railcar is held at a customer facility.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(railcar)
str(railcar2)
```

---

 railcar3

---

*Moisture level versus type of rail car*


---

**Description**

Moisture level versus type of rail car

**Format**

A data frame with 17 observations on the following 2 variables.

type a factor with levels A B

moisture a numeric vector

**Details**

Rail cars are used to ship bulk product to customers. A company has two primary styles of cars that it uses for a product that has specific moisture specifications. A customer was seeing variability in the moisture levels of the product when it reached their site.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(railcar3)
```

---

ratings	<i>Ratings of raw materials</i>
---------	---------------------------------

---

**Description**

Ratings of raw materials

**Format**

A data frame with 26 observations on the following variable.

rating a numeric vector

**Details**

A company has a new raw material that they wish to quickly evaluate. To do so they rate how well their process is running at key steps when using the new material. The rating is done on a scale of 1 - 10 at each key step and then averaged.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(ratings)
```

---

ratings2	<i>Product ratings and moisture content</i>
----------	---

---

**Description**

Product ratings and moisture content

**Format**

A data frame with 26 observations on the following 2 variables.

rating a numeric vector

moisture a numeric vector

**Details**

A company has a new raw material that they wish to quickly evaluate. To do so they rate how well their process is running at key steps when using the new material. The rating is done on a scale of 1 - 10 at each key step and then averaged. In addition the moisture level of the raw material was recorded for each batch.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(ratings2)
```

---

reflect

*Anti-reflective coating measurements*

---

**Description**

Anti-reflective coating measurements

**Format**

A data frame with 8 observations on the following 5 variables.

binder a factor with levels A and B

base a factor with levels A and B

time a factor with levels H and L

ratio a factor with levels A and B

reflect a numeric vector

**Details**

This experiment was to test components in an anti-reflective coating. The goal was to minimize the reflectance (reflect).

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(reflect)
```



---

safety	<i>Safety violations over time</i>
--------	------------------------------------

---

**Description**

Safety violations over time

**Format**

A data frame with 30 observations on the following 4 variables.

year a numeric vector

place a factor with levels CA, KY, MI, NY, TN and TX

employees a numeric vector

cases a numeric vector

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(safety)
```

---

sales	<i>Sales versus capital expenditure</i>
-------	---

---

**Description**

Sales versus capital expenditure over 48 months

**Format**

A data frame with 48 observations (ordered by month) on the following 3 variables.

capital a numeric vector

pindex a numeric vector

sales a numeric vector

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(sales)
```

---

sarea                      *Surface area of silica*

---

### Description

Measurements of the surface area ( $m^2/g$ ) of three batches of silica as performed by four different lab technicians.

### Format

A data frame with 12 observations on the following 3 variables.

batch a factor with levels a, b and c

tech a factor with levels A, B, C and D

sarea the surface area in  $m^2/g$  as measured by the lab technician on a sample from the batch

### References

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

### Examples

```
str(sarea)
xtabs(sarea ~ batch + tech, sarea)
dotplot(reorder(tech, sarea) ~ sarea, sarea,
        groups = batch, type = c("p", "a"), aspect = "xy",
        ylab = "Technician",
        xlab = expression("Measured surface area " * (m^2/g) *
                          " of silica batches"),
        auto.key = list(columns = 3, lines = TRUE)
)
```

---

separate                      *Electrical resistance of battery separators*

---

### Description

Electrical resistance of battery separators

### Format

A data frame with 24 observations on the following 4 variables.

silica a factor with levels High Low

time a factor with levels High Low

temp a factor with levels High Low

y a numeric vector

**Details**

This experiment was run to study the effect of three process factors on the electrical resistance of a battery separator (extruded from a rubber, oil, and silica mix). Each of the three factors, occur at two levels, designated "High" and "Low".

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(separate)
```

---

soap	<i>Soap sales by packaging type</i>
------	-------------------------------------

---

**Description**

Soap sales by packaging type over a 5 week study

**Format**

A data frame with 5 observations on the following 3 variables.

box number of box packages sold

foil number of foil packages sold

shrink number of shrink wrapped packages sold

**Details**

An in-store study was run to test consumer preference of packaging for a soap. The study was run for 5 weeks with the number of packages sold each week recorded. Note, after the third week there was a supply disruption so there were no boxed soaps available for sale.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(soap)
```

---

stab	<i>Stability of a chemical product</i>
------	--

---

**Description**

Stability of a chemical product

**Format**

A data frame with 12 observations on the following 4 variables.

temp a numeric factor at two levels

humidity a numeric factor at two levels

time a numeric factor at three levels

y a numeric vector

**Details**

The stability of the active ingredient is critical. This study looks at the impact of temperature and humidity on the stability of the active ingredient over time.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(stab)
```

---

stretch	<i>Stretch of hot pizza cheese</i>
---------	------------------------------------

---

**Description**

Stretch of hot pizza cheese

**Format**

A data frame with 30 observations on the following 3 variables.

temp a numeric vector

cheese a numeric vector

stretch a numeric vector

**Details**

A critical quality measure of pizza cheese is how well it stretches when it is hot. This study was to evaluate the amount of cheese and the temperature at which the pizza was cooked on the stretch of the hot cheese. Measuring the stretch of pizza cheese is not a precise science, thus, five measurements were taken on each pizza. One pizza was used for each temperature/cheese combination.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(stretch)
```

---

surfarea	<i>Surface area of silica</i>
----------	-------------------------------

---

**Description**

Measurements of the surface area, in  $m^2/g$ , of samples of silica, a chemical product with many applications, such as a filler in rubber products. The surface area is a key property of the product.

**Format**

A data frame with 32 observations on the following variable.

area a numeric vector

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(surfarea)
with(surfarea, summary(area))
qqmath(~ area, surfarea, aspect = 1, type = c("g", "p"),
       xlab = "Standard normal quantiles",
       ylab = expression("Surface area " * (m^2/g) *
                          " of batches of silica"))
print(qqmath(~ area, surfarea, aspect = 1, type = c("g", "p"),
            xlab = "Standard normal quantiles",
            ylab = expression("Surface area " * (m^2/g))),
      pos = c(0,0,0.33,1), more = TRUE)
print(densityplot(~ area, surfarea,
                  xlab = expression("Surface area "*(m^2/g)*
                                    " of batches of silica"),
                  pos = c(0.3,0,1,1))
```

---



*Lifetime of chlorine tablets*


---

**Description**

Lifetime of chlorine tablets

**Format**

A data frame with 30 observations on the following 2 variables.

batch a factor with levels A B C

time a numeric vector

**Details**

One batch of chlorine tablets (for use in home swimming pools) was suspected of having a problem. To test the batch ten tablets from that batch as well as ten tablets from each of two other batches were tested and compared.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(tablets)
```

---

temprate

*Effect of water bath on moisture content*


---

**Description**

Effect of water bath on moisture content

**Format**

A data frame with 12 observations on the following 3 variables.

temp a numeric vector

rate a factor with levels FAST MED SLOW

response a numeric vector

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(temprate)
```

---

tennis	<i>Durability of tennis ball covers</i>
--------	---

---

**Description**

Durability of tennis ball covers

**Format**

A data frame with 20 observations on the following 2 variables.

type a factor with levels A, B, C and D

wear a numeric vector

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(tennis)
```

---

tensile	<i>Tensile breaking strength of steel samples</i>
---------	---

---

**Description**

The breaking strength of samples of steel that were stress tested. This data set is called break in Nelson, Coffin and Copeland (2003). We changed the name because break is a reserved word in R.

**Format**

A data frame with 18 observations on the following variable.

bstrength breaking strength (unknown units)

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(tensile)
qqmath(~ bstrength, tensile, aspect = 1,
       xlab = "Standard normal quantiles",
       ylab = "Breaking strength of steel samples (unknown units)")
```

---

 thinfilm

*Strength of thin film coatings*


---

**Description**

Strength of thin film coatings

**Format**

A data frame with 30 observations on the following 3 variables.

material a factor with levels foil glass

comp a numeric vector

maxload a numeric vector

**Details**

“Thin films”, a coating cured on some substrate other than the actual product, are used by researchers in development. Glass and foil are two substrates that are often used. This study was used to study the impact of a component of the coating on the strength of the coating. The researcher also wanted to know if the substrate used to cure the thin film had an impact on the results.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(thinfilm)
```



---

timetemp	<i>Time to nominal temperature</i>
----------	------------------------------------

---

### Description

The time for a painted panel to reach a nominal temperature of -10 C versus the temperature in a freezer to prepare the panel. Two types of panels were used, original equipment manufacturer (OEM) panels and repair panels. The repair panels have an extra coat of paint.

### Format

A data frame with 24 observations on the following 3 variables.

time time, in minutes, for the panel to reach the nominal temperature of -10 C

temp temperature in the freezer from which the panel is extracted

type a factor with levels Repair OEM

### Details

A freezer is used to simulate exposure to cold on automotive paint test panels. A durability test is to be conducted at -10 C. The test is conducted on two types of panels (one type has an additional coat of paint) and there is some time needed to retrieve the panel from the freezer and to place it in the test equipment. This study was run to determine the optimal freezer setting for running the durability test.

### References

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

### Examples

```
str(timetemp)
xyplot(time ~ temp, timetemp, groups = type,
       type = c("g", "p", "r"), aspect = 'xy',
       ylab = "Time to reach -10C (min.)",
       xlab = "Temperature in freezer (degrees C)",
       auto.key = list(columns = 2, lines = TRUE))
```

---

 tpaste

*Turbidity of a toothpaste formulation*


---

### Description

Results from an experiment to assess the turbidity of a toothpaste formulation. The three factors that are varied at the NaCl level, the reaction temperature and the addition rate of a particular component.

### Format

A data frame with 8 observations on the following 4 variables.

NaCl NaCl level (2 or 20 ml.)

temp Reaction temperature (50 or 80 degrees C)

rate Addition rate (30 or 60 seconds)

turbidity a numeric vector

### References

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

### Examples

```
str(tpaste)
opt <- options(contrasts = c("contr.treatment", "contr.helmert"))
summary(fm6 <- lm(turbidity ~ (NaCl + temp + rate)^3, tpaste))$coefficients
qqmath(coef(fm6)[-1], xlab = "Standard normal quantiles",
        ylab = "Estimated coefficients", aspect = 1, type = c("g", "p"),
        panel = function(...){panel.qqmath(...); panel.qqmathline(...,lty=2,alpha=0.5)})
xyplot(sort(abs(coef(fm6)[-1])) ~ sqrt(qchisq(ppoints(7), df = 1)),
        xlab = "Quantiles of absolute value of the standard normal",
        ylab = "Absolute value of estimated coefficients", type = c("g", "p"))
summary(fm7 <- lm(turbidity ~ NaCl * rate, tpaste))
options(opt)
```

---

 urine

*Mercury level in employee urine samples*


---

### Description

Mercury level in employee urine samples

**Format**

A data frame with 12 observations on the following 5 variables.

month an ordered factor with levels from January to December

person1 mercury concentration in person 1's urine

person2 mercury concentration in person 2's urine

person3 mercury concentration in person 3's urine

person4 mercury concentration in person 4's urine

**Details**

Employees who work in a high risk area of a chemical plant are monitored monthly for mercury exposure.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(urine)
dotplot(month ~ person1 + person2 + person3 + person4, urine,
        outer = FALSE, type = c("p", "l"),
        auto.key = list(columns = 2, lines = TRUE, points = FALSE),
        xlab = "Mercury level in urine")
```

---

uvcoatin

---

*Comparison of eyeglass ultra-violet coatings*


---

**Description**

Comparison of eyeglass ultra-violet coatings

**Format**

A data frame with 10 observations on the following 3 variables.

a a numeric vector of differences in haze values for the commercial coating

b a numeric vector of differences in haze values for the commercial coating

diff a numeric vector of the differences in the two above vectors

**Details**

A field test of a new coating was conducted with 10 volunteers who wore glasses on a regular basis. Each subject had one lens coated with a commercial product and one lens coated with a test product. The coatings were applied to the lens in a random fashion such that some subjects had the commercial coating on their right lens and some on their left lens. The haze of each lens was measured at the beginning and the end of the study with the difference in haze being the measure of interest.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(uvcoatin)
```

---

uvoven	<i>UV absorbance for lens cured in different ovens</i>
--------	--

---

**Description**

UV absorbance for lens cured in different ovens

**Format**

A data frame with 60 observations on the following 2 variables.

oven oven - a factor with levels A B

uv UV absorbance

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(uvoven)
summary(uvoven)
densityplot(~ uv, uvoven, groups = oven, auto.key = list(columns = 2),
            xlab = "UV absorbance")
qqmath(~ uv, uvoven, groups = oven,
        auto.key = list(space = "right", title = "Oven"),
        xlab = "Standard normal quantiles", type = c("p", "g"),
        ylab = "UV absorbance",
        panel = function(...)
        {
```

```

panel.qqmath(...)
panel.qqmathline(..., alpha = 0.5)
})

```

---

viscosity                      *Time to gelling of paint samples*

---

### Description

Time to gelling of paint samples

### Format

A data frame with 17 observations on the following variable.

time a numeric vector

### References

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

### Examples

```

str(viscosity)
with(viscosity, summary(time))
qqmath(~ time, viscosity, aspect = 1,
       xlab = "Standard normal quantiles",
       ylab = "Time until paint sample gelled")
qqmath(~ sqrt(time), viscosity, aspect = 1,
       xlab = "Standard normal quantiles",
       ylab = "Square root of time until paint sample gelled")

```

---

vitamin                              *Calcium levels before and after vitamin supplement*

---

### Description

Calcium levels before and after vitamin supplement

### Format

A data frame with 49 observations on the following 3 variables.

treatment formulation - a factor with levels A, B and C

before Calcium level before the vitamin

after Calcium level after the vitamin

## References

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

## Examples

```
str(vitamin)
summary(vitamin)
show(plt1 <- xyplot(after ~ before, vitamin, groups = treatment,
  auto.key = list(space = "right", title = "Formulation", lines = TRUE),
  aspect = "iso",
  type = c("g", "p", "smooth"),
  xlab = "Calcium level before the vitamin",
  ylab = "Calcium level after the vitamin"))
tmd(plt1, aspect = 1)
densityplot(~ I(after - before), vitamin, groups = treatment,
  auto.key = list(columns = 3, lines = TRUE),
  xlab = "Change in calcium level after taking vitamin")
```

---

wash

*Appearance of washed and unwashed panels*

---

## Description

Appearance ratings of washed and unwashed panels

## Format

A data frame with 36 observations on the following 3 variables.

type type of treatment - a factor with levels NW (not washed) and W (washed)

time1 initial rating

time2 rating after 2 weeks

## Details

A particular durability test of paint involves applying drops of acid on the panel. After a particular time point the panel is rated for its ability to withstand the acid. This study involved washing (or not washing) panels and then storing them for two weeks to see if there was a residual effect of the acid on the panel. This was important as panels are often stored and used in presentations so the researchers needed to know if they should wash the panels before storing them.

## References

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```

str(wash)
summary(wash)
show(plt1 <- xyplot(time2 ~ time1, wash, groups = type,
  auto.key = list(columns = 2, lines = TRUE),
  aspect = "iso",
  type = c("g", "p", "smooth"),
  xlab = "Initial rating",
  ylab = "Rating after 2 weeks",
  jitter.x = TRUE, jitter.y = TRUE))
tmd(plt1)
densityplot(~ I(time2 - time1), wash, groups = type,
  auto.key = list(columns = 2, lines = TRUE),
  xlab = "Change in rating after two weeks")

```

---

water

*Bacteria concentrations in water samples*


---

**Description**

Bacteria concentrations in water samples

**Format**

A data frame with 50 observations on the following variable.

bacteria bacteria concentration (ppm)

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```

str(water)
qqmath(~ bacteria, water, aspect = 1,
  xlab = "Standard normal quantiles",
  ylab = "Bacteria concentration (ppm)")
histogram(~ bacteria, water, breaks = 0:14 - 0.5,
  xlab = "Bacteria concentration (ppm)")
xtabs(~ bacteria, water)

```

---

webtraff	<i>Web site traffic during a marketing campaign</i>
----------	---

---

**Description**

Web site traffic during a marketing campaign

**Format**

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

weeks weeks into the marketing campaign - an ordered factor with levels 1 to 5

traffic web site traffic (1000's of hits per day)

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(webtraff)
dotplot(weeks ~ traffic, webtraff, type = c("p","a"),
        xlab = "Web traffic (1000's of hits per day)",
        ylab = "Weeks into the marketing campaign")
```

---

webvisit	<i>Web site visits over a 3-week period</i>
----------	---

---

**Description**

Web site visits over a 3-week period

**Format**

A data frame with 21 observations on the following variable.

visits a numeric vector

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)



**Examples**

```
str(webvisit)
densityplot(~ visits, webvisit,
            xlab = "Web site visits in a 3-week period")
qqmath(~ visits, webvisit, aspect = 1, type = c("g", "p"),
       ylab = "Web site visits in a 3-week period",
       xlab = "Standard normal quantiles")
with(webvisit, summary(visits))
```

---

weight

*Weight plastic bags held before breaking*


---

**Description**

Weight plastic bags held before breaking

**Format**

A data frame with 43 observations on the following variable.

weight a numeric vector

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(weight)
densityplot(~ weight, weight, xlab = "Weight bag held before breaking")
qqmath(~ weight, weight, ylab = "Weight bag held before breaking",
       aspect = 1, type = c("g", "p"), xlab = "Standard normal quantiles")
```

---

whitearea

*Comparison of mixing processes*


---

**Description**

The percentage of “white area” in a sample of a dark product is used to evaluate how well a white raw material has been mixed into the product. Data are obtained from two processes.

**Format**

A data frame with 48 observations on the following 2 variables.

process a factor with levels A B

whitearea a numeric vector

**Examples**

```
str(whitearea)
qqmath(~ whitearea, whitearea, groups = process, aspect = 1,
       auto.key = list(space = "right", title = "Process"),
       xlab = "Standard normal quantiles",
       ylab = "White area")
t.test(whitearea ~ process, whitearea)
```

---

yellow

*Initial and 1 month color measure of coated lens*

---

**Description**

Initial and 1 month color measure of coated lens

**Format**

A data frame with 23 observations on the following 2 variables.

b1 a numeric vector of initial color measurements

b2 a numeric vector of color measurements after one month

**Details**

It is undesirable to see color changes in a lens over time.

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(yellow)
show(plt1 <- xyplot(b2 ~ b1, yellow, aspect = 'iso', type = c("g", "p"),
                  xlab = "Initial color measure of lens",
                  ylab = "Color measure after 1 month"))
show(tmd(plt1))
```

---

yield	<i>Yield of a chemical process</i>
-------	------------------------------------

---

**Description**

Yield of a chemical process

**Format**

A data frame with 20 observations on the following 3 variables.

temp temperature of the slurry(degrees C)

pH pH of the slurry

yield yield of the process (tons)

**References**

Peter R. Nelson, Marie Coffin and Karen A. F. Copeland (2003), *Introductory Statistics for Engineering Experimentation*, Elsevier. (Appendix A)

**Examples**

```
str(yield)
xyplot(yield ~ temp|cut(pH, seq(6.25,6.85,len = 4), ordered = TRUE),
       yield, type = c("g","p","r"),
       xlab = "Temperature of the slurry (degrees C)",
       ylab = "Yield (tons)")
```

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