
**Cigarettes — Generation and collection
of total particulate matter using a
routine analytical smoking machine
with an intense smoking regime**

*Cigarettes — Génération et collecte de la matière particulaire totale
au moyen d'une machine à fumer analytique de routine avec un
régime de fumage intense*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 126, *Tobacco and tobacco products*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Historically, a set of ISO standards have been developed to specify the requirements of analytical cigarette smoking machines and their use for the quantitative determination of a number of cigarette smoke constituents [such as total particulate matter (TPM), nicotine-free dry particulate matter, water, nicotine or benzo[a]pyrene] with a unique standard smoking regime. The description of this smoking regime is provided in ISO 3308.

Later, requirements to provide smoke constituents data with an intense smoking regime, different from the ISO 3308 smoking regime, originated from different countries and the Conferences of the Parties to the Framework Convention on Tobacco Control, resulting in a need to specify the conditions for the use of the intense smoking regime on analytical cigarette-smoking machines. The specifications for the use of the intense smoking regime on analytical cigarette-smoking machines are provided in ISO 20778.

This document is the result of the work performed by ISO/TC 126, comprising experts from members and liaison organizations, including WHO. Elaboration of this document took into account practical work conducted in the framework of a collaborative study involving 35 laboratories (published as Technical Report ISO/TR 19478-1 and ISO/TR 19478-2). It provides specifications for the generation and collection of TPM using analytical cigarette smoking machines with an intense smoking regime.

No machine smoking regime can represent all human smoking behaviour:

- it is recommended that cigarettes also be tested under conditions of a different intensity of machine smoking than those specified in this document;
- machine smoking testing is useful to characterize cigarette emissions for design and regulatory purposes, but communication of machine measurements to smokers can result in misunderstandings about exposure and risk across brands;
- smoke emission data from machine measurements may be used as inputs for product hazard assessment, but they are not intended to be nor are they valid as measures of human exposure or risks. Communicating differences between products in machine measurements as differences in exposure or risk is a misuse of testing using ISO standards.

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Cigarettes — Generation and collection of total particulate matter using a routine analytical smoking machine with an intense smoking regime

1 Scope

This document specifies a method for the generation and collection of total particulate matter (TPM) present in the smoke from cigarettes using a routine analytical smoking machine with an intense smoking regime. It is not applicable to the determination of water or nicotine-free dry particulate matter when using the extraction procedure specified in ISO 4387:2000, 7.9.1 or the subsequent measurement of water specified in ISO 10362-1 or ISO 10362-2.

NOTE The type of analytical smoking machine used could impact the mass of TPM collected on the smoke trap. This might be due to either incomplete collection or evaporation of water and other volatile compounds from the smoke trap.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2971, *Cigarettes and filter rods — Determination of nominal diameter — Method using a non-contact optical measuring apparatus*

ISO 3402, *Tobacco and tobacco products — Atmosphere for conditioning and testing*

ISO 4387, *Cigarettes — Determination of total and nicotine-free dry particulate matter using a routine analytical smoking machine*

ISO 8243, *Cigarettes — Sampling*

ISO 20778, *Cigarettes — Routine analytical cigarette-smoking machine — Definitions and standard conditions with an intense smoking regime*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4387 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at <https://www.iso.org/obp>

— IEC Electropedia: available at <http://www.electropedia.org/>

3.1

smoking run

specific smoking process to produce such smoke from a sample of cigarettes as is necessary for the generation and collection of the smoke components

[SOURCE: ISO 4387:2000, 3.5, modified]

3.2 monitor test piece

sample produced for a specific test purpose, validated to fulfil requirements within specified tolerances and intended to be used for laboratory purposes only and labelled to clearly indicate that it is not for human use

Note 1 to entry: A monitor test piece is a sample taken from a batch of cigarettes that show the greatest homogeneity with regard to their physical, chemical and smoke yield characteristics.

[SOURCE: ISO 16055:2012, 3.1]

4 Principle

The test cigarettes are sampled then conditioned. The test cigarettes are smoked on an analytical smoking machine with simultaneous collection of TPM in a glass fibre filter trap. If used, the consistency of the laboratory smoking process and subsequent analytical procedures are controlled by using monitor test pieces specified in ISO 16055. The mass of the TPM (expressed as milligrams per cigarette) so collected is determined gravimetrically if needed. The TPM is extracted from the trap and might be used for the subsequent determination of smoke constituents.

5 Apparatus

Normal laboratory apparatus and, in particular, the following items:

- 5.1 **Routine analytical cigarette-smoking machine**, conforming to the requirements of ISO 20778.
 - 5.2 **Soap bubble flow meter**, graduated at 55 ml to an accuracy of $\pm 0,6$ ml and with a resolution of 0,2 ml.
 - 5.3 **Apparatus for the determination of puff duration and frequency**.
 - 5.4 **Analytical balance**, suitable for measuring to the nearest 0,1 mg.
- NOTE The weighing of filter pad holders can be affected by static electricity, necessitating the use of an antistatic device.
- 5.5 **Conditioning enclosure**, maintained under the conditions specified in ISO 3402.
 - 5.6 **Length-measuring device**, suitable for measuring to the nearest 0,5 mm.
 - 5.7 **Device for the determination of diameter**, in accordance with ISO 2971.
 - 5.8 **Smoke trap sealing device**, end caps made from a non-hygroscopic and chemically inert material.
 - 5.9 **Gloves**, made of cotton, or the non-talc surgical type.
 - 5.10 **Tape**, 10 mm to 20 mm-wide cellophane tape or equivalent material.
- NOTE The tape is not needed if cigarette holders with an integrated ventilation blocking function are used.
- 5.11 **Modified cigarette holder**, specially designed for intense smoking on an analytical cigarette-smoking machine, as specified in ISO 20778.

6 Sampling

A laboratory sample shall be taken by a sampling scheme such as one of those given in ISO 8243.

This sample will normally contain cigarettes taken from different parts of the population. Make up the test sample required for the test by randomly selecting cigarettes from the different parts of the population represented in the laboratory sample.

7 Generation and collection of total particulate matter

7.1 Preparation of the cigarettes for smoking

7.1.1 General

If N cigarettes of a given type are to be smoked, $C \times N$ cigarettes shall be prepared from Q cigarettes for conditioning and butt marking.

The symbols used in [Clause 7](#) are as follows:

- N is the number of cigarettes of a given type to be smoked, resulting from sampling at one point in time or from a sub-period sample;
- C is a multiplying factor, of value greater than 1, to allow for loss due to damage or selection procedures between initial sampling and smoking;
- Q is the total number of cigarettes available (laboratory sample);
- n is the number of replicate determinations of TPM;
- q is the number of cigarettes smoked into the same trap;
- P is the total number of packets of cigarettes available.

The multiplier C is usually at least 1,2 to provide extra cigarettes in case some are damaged and for optional tests (see [7.6](#)). If selection by mass or draw resistance (or any other parameter) is necessary, C will have to be much larger (experience suggests 2 to 4) depending on the selection process.

The precision normally required generally demands that $80 \leq N \leq 100$. This number may be considerably augmented if the variability of the sample is high; on the contrary, in certain comparisons made of homogeneous samples, this number may be reduced. It may also be reduced when N represents a sub-period sample. N shall never be less than 20 when 10 cigarettes are smoked per trap, or less than 21 when three cigarettes are smoked per trap.

It is necessary for 20 cigarettes to be smoked when 10 cigarettes are smoked per trap, thus providing a replicate analysis and data replication.

The N cigarettes to be smoked will be tested in $n = N/q$ collections if q cigarettes are smoked into one trap. As far as possible these n collections should correspond to different test portions of the test sample. Selection of each test portion will depend upon the form of the test sample.

If the number of cigarettes to be smoked is specified in a determination method, it should be referred to.

7.1.2 Selection of test portions from a bulk of Q cigarettes

If the test sample is in the form of a single bulk, consisting of Q cigarettes, $C \times N$ cigarettes shall be selected at random so that every cigarette has an equal probability of being selected.

7.1.3 Selection of test portions from P packets

If the test sample consists of P packets, the selection procedure depends upon the number of cigarettes in each packet (Q/P) compared with q .

If $Q/P \geq C \times q$, select a test portion by choosing a single packet at random, then randomly select $C \times q$ cigarettes from that packet.

If $Q/P < C \times q$, select the smallest number of packets (k) such that

$$\frac{Q \times k}{P} \geq C \times q$$

and randomly choose an equal (or as near equal as possible) number of cigarettes from each packet to form the test portion of $C \times q$ cigarettes.

7.1.4 Duplicate test portions

Provided that the test sample is sufficiently large ($\geq 2C \times N$), a duplicate set of n test portions should be reserved. In this event the parallel selection of a test portion and its duplicate would seem sensible. In this case the two selection conditions of 7.1.3 would need to be changed to $Q/P \geq 2C \times q$ and $Q/P < 2C \times q$.

7.2 Marking the butt length

7.2.1 Standard butt length

The standard butt length to which cigarettes shall be marked shall be the greatest of the following three lengths:

- 23 mm,
- length of filter +8 mm, or
- length of overwrap +3 mm,

where the overwrap is defined as any wrapper applied to the mouth end of the cigarette, and the length of the filter is defined as the total length of the cigarette minus the length of the tobacco portion.

NOTE Butt length is defined in ISO 20778 as the length of unburnt cigarette remaining at the moment when smoking is stopped.

7.2.2 Measurement of length of filter

The length of filter as defined in 7.2.1 shall be the mean value of 10 filter plugs taken from the laboratory sample, measured to an accuracy of 0,5 mm. Express the mean to the nearest 0,5 mm.

NOTE In some instances it can be necessary to measure more than 10 cigarettes. When the variation in filter length can be demonstrated to be well controlled, a smaller number of measurements might be sufficient.

7.2.3 Measurement of length of overwrap

The length of overwrap as defined in 7.2.1 shall be the mean value of 10 overwraps taken from the laboratory sample, measured to an accuracy of 0,5 mm. Express the mean to the nearest 0,5 mm.

NOTE In some instances it can be necessary to measure more than 10 cigarettes. When the variation in overwrap length can be demonstrated to be well controlled, a smaller number of measurements might be sufficient.

7.2.4 Butt length to be marked on the cigarettes before conditioning

Draw a line, using a fine soft-tipped marker, at the standard butt length, to an accuracy of 0,5 mm, from the mouth end for the particular cigarette type.

Care should be taken to avoid damaging the cigarettes during butt marking. Any cigarettes accidentally torn or punctured during marking, or any found during marking to be defective, shall be discarded and replaced with spare cigarettes from the test portion.

If cigarettes are to be smoked on a smoking machine on which the butt length in accordance to 7.2.1 can be pre-set, it is not necessary to mark the butt lengths on the cigarettes themselves.

7.3 Sealing the filter ventilation holes

The filter ventilation holes of the cigarettes shall be sealed. There are two methods for this:

- 1) A modified cigarette holder is used on the analytical cigarette-smoking machine, according to ISO 20778.
- 2) The ventilation holes are sealed with a tape, according to the following process: a 10 mm to 20 mm wide cellophane tape shall be applied (manually or with an over-tipping machine) around the entire circumference of the cigarette, with the end of the tape not extending beyond the mouth end of the cigarette. If the position of the ventilation holes is not known, it shall be verified that the tape or the modified cigarette holder covers them. No wrinkles or air holes shall appear. The tape shall circle the cigarette once with a small overlap.

NOTE Cigarettes with no filter ventilation holes do not need to be sealed.

7.4 Selection of cigarettes

If a selection by mass or draw resistance (or any other parameter) is necessary because of the nature of the problem being studied, the selection shall not be considered as a method of reducing the number of cigarettes to be smoked.

7.5 Conditioning

Condition all the test portions in the conditioning atmosphere specified in ISO 3402 for a minimum of 48 h and a maximum of 10 days.

If for any reason test samples are to be kept for longer than 10 days before conditioning, store them in original packaging or in airtight containers just large enough to contain the sample.

The testing atmosphere in the laboratory where the smoking is to be carried out shall be in accordance with ISO 3402.

Transfer the test portions to the smoking location in airtight containers (just large enough to contain the portions) unless the smoking location and the conditioning location are adjoining and have identical atmospheres.

7.6 Preliminary tests before smoking

The following data may be required in the test report:

- a) total length of the cigarette;
- b) nominal diameter, determined in accordance with ISO 2971;
- c) average mass of the conditioned cigarettes selected for the smoking operation (in milligrams per cigarette).

7.7 Smoking and collection of particulate matter

7.7.1 Smoking plan

Choose a smoking plan; examples of plans are given in [Annex A](#).

The plan shall show the number of cigarettes to be smoked into each trap (q) and the number in the conditioning sample ($C \times N$).

The plan should include the use of a test portion of monitor test pieces. The test pieces are included in the plan as if they were a type of cigarette and prepared and smoked as in [7.7](#), [7.8](#) and [7.9](#).

7.7.2 Preparation of smoke traps and cigarette holders

For all operations, the operator shall prevent contamination from the fingers by wearing gloves of a suitable material ([5.9](#)).

Insert filter discs which have been conditioned in the test atmosphere for at least 12 h into their holders, and assemble, placing the rough side of the filter disc so that it will face the oncoming smoke. After assembly, examine the filter holders to ensure that the discs have been properly fitted. Weigh the assembled smoke traps to the nearest 0,1 mg.

If the smoke trap is designed to contain the perforated disc (washer), insert it and fit the sealing devices (end caps). If the cigarette holder is designed to contain a perforated disc, insert it into the cigarette holder before attaching the labyrinth seals (see ISO 20778).

7.7.3 Setting up the smoking machine

7.7.3.1 General

If necessary, replace any protective filters on the machine. Switch on the machine and allow it to warm up on automatic cycling for at least 20 min.

With the machine warmed up, check that the puff duration and puff frequency on each channel are in accordance with the standard conditions.

The puff volume should be checked if it is suspected that the smoking machine is subject to a large change in temperature during use.

7.7.3.2 Measurement of puff duration

A timer shall be used to measure the period of time which elapses between the triggering operations which begin and end a puffing action of the smoking machine. The accuracy of the timing device shall be such as to ensure that a 1 % error in the puff duration can be detected. The timer should be coupled directly to the triggering circuits.

7.7.3.3 Checking of puff frequency

Measure the period of time which elapses between the triggering operations which begin successive puffing actions of the smoking machine, thus determining the puff frequency. The timer used shall be suitable for measuring to the nearest 0,1 s and should, preferably, be coupled directly to the triggering circuits.

7.7.3.4 Measurement of puff volume

The displacement of the bubble in a soap bubble flow meter ([5.2](#)) gives a direct measurement of puff volume and also provides a check for leaks in the system. A suitable indicator graduated at 55 ml shall have a resolution of at least 0,2 ml. It shall be connected through a standard pressure drop device of $1 \times (1 \pm 5 \%)$ kPa to the cigarette holder of the smoking machine channel under test. Before use for a

series of measurements, wet the instrument twice with detergent solution and then allow it to drain for a period of between 30 s and 45 s.

Fit the prepared smoking trap or traps and cigarette holders onto the machine. Attach a plastic insert of an appropriate size for the labyrinth seals in the cigarette holder to the resistance in the tube from the soap bubble flow meter indicator. Prepare the soap bubble flow meter by wetting the inside of the tube with the detergent solution to above the top graduation mark. Connect the indicator to the cigarette holder in port 1 and determine the puff volume; adjust if necessary to $(55,0 \pm 0,6)$ ml. Repeat for all remaining ports in turn.

Repeat the determinations until the necessary precision of measurement is obtained. If the number of replicates exceeds three, continue until the correct precision is obtained but replace the pad before smoking, reweigh the smoke trap and recheck the puff volume with the new pad in place. Measure the temperature and relative humidity of the air surrounding the smoking machine and note the atmospheric pressure.

7.7.4 Procedure for smoking run

Insert the conditioned cigarettes from the test portion into the cigarette holders. Avoid any leaks or deformations. Any cigarettes found to have obvious defects, or which have been damaged during insertion, shall be discarded and replaced with spare, conditioned cigarettes.

Ensure that the cigarettes are positioned correctly so that the axes of the cigarettes coincide with the axes of the ports. If necessary adjust the position of each cigarette so that when the burning coal reaches the butt mark, the puff termination device is activated.

If the burning through of cotton thread is used to terminate smoking at the butt mark, the cotton shall just touch the cigarette at the butt mark, without modifying the cigarette positioning.

Ensure the puff counters are set to zero and light each cigarette at the beginning of its first puff. Should it be necessary to relight a cigarette, an electrical lighter may be used. The electrical lighter shall not touch the cigarette during the lighting or relighting process. When each butt mark has been reached, remove the burning coal from the cigarette and note the final reading of the puff counters if necessary. After the smoking process is complete, it could be necessary to leave the cigarette butt in place for at least 30 s to enable deposition of any residual smoke in the trap.

Avoid disturbance of the smoking by artificial removal of ash. Allow the ash to fall naturally into the ashtray.

If required, new cigarettes shall be inserted immediately and the smoking process repeated until the predetermined number of cigarettes, in accordance with the smoking plan, has been smoked into the smoke trap. Immediately begin the collection of TPM as described in [7.8](#).

7.8 Collection of total particulate matter

Remove the smoke traps from the smoking machine (gloves shall be worn). If attached, remove the complete cigarette holder or the labyrinth seals, washer and caps from the smoke trap.

Cover the front and back apertures of the trap with the sealing devices ([5.8](#)).

It is recommended, particularly when plain cigarettes have been smoked, that the removal of the holder be conducted with the smoke trap held with its cigarette-facing side downwards to avoid any possible contaminants from the cigarette holder reaching the filter disc.

If needed, immediately after smoking weigh the smoke traps to the nearest 0,1 mg.

Check the back of each filter disc to ensure that there are no brown stains indicating overloading or pad damage. Discard any disc showing such stains or damage.

Glass fibre filter pads of 44 mm diameter are capable of retaining up to 150 mg of TPM and pads of 92 mm diameter are capable of retaining 600 mg of TPM. If, during smoking, this mass is exceeded,

the number of cigarettes shall be reduced and a calculation made to allow for the reduced number of cigarettes smoked.

The collected TPM can be used for further analysis of smoke constituents present in the particulate phase (such as nicotine).

7.9 Calculation of total particulate matter

The TPM content, m_{TPM} , for each channel, expressed in milligrams per cigarette, is given by the formula:

$$m_{\text{TPM}} = \frac{m_1 - m_0}{q}$$

where

- m_0 is the mass of the smoke trap before smoking, in milligrams;
- m_1 is the mass of the smoke trap after smoking, in milligrams;
- q is the number of cigarettes smoked into the trap.

8 Test report

The test report shall show the method used and the results obtained. It shall also mention any operating conditions not specified in this document, or regarded as optional, as well as any circumstances that may have influenced the results. The test report shall include all details required for complete identification of the sample. If appropriate, the information given below in a) to d) shall be recorded.

a) Characteristic data about the cigarette

All details necessary for the identification of the cigarettes smoked shall be given. In the case of commercial cigarettes this should include:

- name of manufacturer and country of manufacture;
- product name;
- packet number (of the product sampled that day);
- marks on any tax stamp;
- printed smoke yields (if any);
- length of cigarette;
- length of filter;
- length of overwrap.

b) Data about sampling

- type of sampling procedure;
- date of sampling;
- place of purchase or sampling;
- kind of sampling point;
- sampling point (e.g. address of retail outlet or machine number);
- number of cigarettes in laboratory sample.

c) Description of test

- reference to this document;
- date of test;
- type of smoking machine used;
- type of smoke trap used;
- total number of cigarettes smoked;
- number of cigarettes smoked into each smoke trap;
- conditioned cigarette weight;
- butt length;
- room temperature (in degrees Celsius) during smoking operation;
- relative humidity (in percent) during smoking operation;
- atmospheric pressure (in kilopascals) during smoking operation.

d) Test results

The expression of the laboratory data depends on the purpose for which the data are required, and the level of laboratory precision. Details should include the following:

- average length of the cigarettes to the nearest 0,1 mm;
- average length of the filter to the nearest 0,5 mm;
- average length of the overwrap to the nearest 0,5 mm;
- butt length to which cigarettes were smoked;
- average diameter of the cigarettes to the nearest 0,01 mm;
- average number of puffs per cigarette for each channel to the nearest 0,1 puff.

NOTE If the length of the cigarettes is measured with the length-measuring device described in [5.6](#), the average length of the cigarettes can only be obtained to the nearest 0,5 mm.

Annex A (informative)

Smoking plans

A.1 General

In the majority of cases, the results of mechanical smoking permit a comparison of types of cigarettes (treatments). This comparison should be made according to a smoking plan established in advance; the smoking plan should take account of the following:

- a) the capacity and the variability of the smoking machine: number of channels;
- b) the capacity of the smoke traps: this determines the number of cigarettes to be smoked in each channel;
- c) the nature of the cigarettes: for those of high condensate yield it is prudent to reduce the number to be smoked in each channel;
- d) required precision: the results of smoking always give a certain variability; the distribution of the treatments in each smoking run and of the smoking runs in time should reduce the effects of uncontrolled or badly controlled factors (mechanical or personal); in general, the larger the test portion, the greater the precision.

The order of magnitude of the number N of cigarettes in a test portion is fixed for each type as a function of various factors, in particular:

- the precision sought;
- the time necessary for the smoking processes, which is itself related to the capacity of the machine.

The exact value to be selected for N , chosen in the ranges given in 7.1, taking into account the preceding factors, is determined by calculation for each experiment taking into account the parameters which characterize it.

The different parameters are related by the formula:

$$t \times N = s \times c \times q$$

where

- t is the number of types to be compared (treatments);
- s is the number of smoking runs to be carried out;
- c is the number of channels on the machine;
- q is the number of cigarettes smoked into the same trap.

The examples of smoking plans proposed below illustrate the preceding remarks. They could correspond to the following objectives:

EXAMPLE 1 Comparison of two types of cigarettes on one single-channel smoking machine. The smoke trap can collect the condensate of three cigarettes.

EXAMPLE 2 Comparison of three types of cigarettes on one single-channel smoking machine. The smoke trap can collect the condensate of 10 cigarettes.

EXAMPLE 3 Comparison of two types of cigarettes on one four-channel smoking machine. The smoke trap can collect the condensate of three normal cigarettes.

EXAMPLE 4 Comparison of 20 types of cigarettes on one 20-channel smoking machine. The smoke trap can collect the condensate of three normal cigarettes. Higher precision required.

EXAMPLE 5 Comparison of five types of cigarettes on one 20-channel smoking machine. The smoke trap can collect the condensate of three normal cigarettes. Higher precision required.

A.2 EXAMPLE 1: Comparison of two types of cigarettes on one single-channel smoking machine

| | |
|---|--------------------------------------|
| Number of treatments | $t = 2$ (A, B) |
| Number of cigarettes in the test sample | $N = 24$ |
| Number of cigarettes per channel | $q = 3$ |
| Number of channels | $c = 1$ |
| Number of smoking runs | $s = 16$ (1, 2, ... 16) |
| Thus testing 48 cigarettes | $2 \times 24 = 16 \times 1 \times 3$ |

The number N of cigarettes to be smoked is limited to 24 of each type, so that the duration of the smoking process is not too long. Each smoking run carries only one treatment. Distribute the runs in time while repeating the sequence shown in [Table A.1](#) four times (k represents successive values 0, 4, 8 and 12):

Table A.1

| Run | Treatment |
|---------|-----------|
| $1 + k$ | A |
| $2 + k$ | B |
| $3 + k$ | B |
| $4 + k$ | A |

A.3 EXAMPLE 2: Comparison of three types of cigarettes on one single-channel smoking machine

| | |
|---|--------------------------------------|
| Number of treatments | $t = 3$ (A, B, C) |
| Number of cigarettes in the test sample | $N = 30$ |
| Number of cigarettes per channel | $q = 10$ |
| Number of channels | $c = 1$ |
| Number of smoking runs | $s = 9$ (1, 2, ... 9) |
| Thus testing 90 cigarettes | $3 \times 30 = 9 \times 1 \times 10$ |

Each smoking run carries only one treatment. The runs are distributed in time in an ordered fashion, for example by means of the matrix in [Table A.2](#).

| | | |
|---|---|---|
| B | A | C |
| C | B | A |
| A | C | B |

Table A.2

| Run | Treatment |
|-----|-----------|
| 1 | B |
| 2 | A |
| 3 | C |
| 4 | C |
| 5 | B |
| 6 | A |
| 7 | A |
| 8 | C |
| 9 | B |

A.4 EXAMPLE 3: Comparison of two types of cigarettes on one four-channel smoking machine

| | |
|---|-------------------------------------|
| Number of treatments | $t = 2$ (A, B) |
| Number of cigarettes in the test sample | $N = 48$ |
| Number of cigarettes per channel | $q = 3$ |
| Number of channels | $c = 4$ (a, b, c, d) |
| Number of smoking runs | $s = 8$ (1, 2, ... 8) |
| Thus testing 96 cigarettes | $2 \times 48 = 8 \times 4 \times 3$ |

Allocate the smoking channels to the two treatments utilizing the matrix in [Table A.3](#), which is constructed for four treatments but which is easily adapted to the case of two treatments by identifying A with C on the one hand and B with D on the other. (In general, all matrices of dimensions g can be utilized for a number of treatments which are sub-multiples of g .)

| | | | |
|---|---|---|---|
| A | B | C | D |
| D | C | A | B |
| B | A | D | C |
| C | D | B | A |

Table A.3

| Run | Channel | | | |
|-----|---------|---|---|---|
| | a | b | c | d |
| 1 | A | B | A | B |
| 2 | B | A | A | B |
| 3 | B | A | B | A |
| 4 | A | B | B | A |
| 5 | A | B | A | B |
| 6 | B | A | A | B |
| 7 | B | A | B | A |
| 8 | A | B | B | A |

In each smoking run, two channels are allocated to each treatment. For example, in run 6:

- cigarette A is smoked in channels b and c;
- cigarette B is smoked in channels a and d.

Each type is smoked four times in each of the four channels.

A.5 EXAMPLE 4: Comparison of 20 types of cigarettes on one 20-channel smoking machine

| | |
|---|--|
| Number of treatments | $t = 20$ (A, B, ... T) |
| Number of cigarettes in the test sample | $N = 60$ |
| Number of cigarettes per channel | $q = 3$ |
| Number of channels | $c = 20$ (a, b, ... t) |
| Number of smoking runs | $s = 20$ (1, 2, ... 20) |
| Thus testing 1 200 cigarettes | $20 \times 60 = 20 \times 20 \times 3$ |