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Forage harvesters —

Part 3:
Test methods

Récolteuses-hacheuses-chargeuses de fourrage —

Partie 3:
Méthodes d'essai

Reference number
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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 8909-3 was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 7, *Equipment for harvesting and conservation.*

ISO 8909 consists of the following parts, under the general title *Forage harvesters*:

— *Part 1: Vocabulary*

— *Part 2: Specification of characteristics and performance*

— *Part 3: Test methods*

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Forage harvesters —

Part 3:
Test methods

1 Scope

This part of ISO 8909 specifies test methods for evaluations of forage harvester function and performance, covering forage harvesters which cut the crop directly at full width or from spaced-apart plant rows, or which pick up precut crop.

It applies to forage harvesters with driven knives for chopping and which deliver the chopped crop into a container or a separate vehicle or trailer. The harvesters may be tractor-mounted, trailed or self-propelled.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 8909. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 8909 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 500:1991, *Agricultural tractors — Rear-mounted power take-off — Types 1, 2 and 3.*

ISO 730-1:1990, *Agricultural wheeled tractors — Rear-mounted three-point linkage — Part 1: Categories 1, 2 and 3.*

ISO 730-2:1979, *Agricultural wheeled tractors — Three-point linkage — Part 2: Category 1 N (Narrow hitch).*

ISO 730-3:1982, *Agricultural wheeled tractors — Three-point linkage — Part 3: Category 4.*

ISO 789-3:1993, *Agricultural tractors — Test procedures — Part 3: Turning and clearance diameters.*

ISO 3600:1981, *Tractors and machinery for agriculture and forestry — Operator manuals and technical publications — Presentation.*

ISO 3767-1:1991, *Tractors, machinery for agriculture and forestry, powered lawn and garden equipment — Symbols for operator controls and other displays — Part 1: Common symbols.*

ISO 3767-2:1991, *Tractors, machinery for agriculture and forestry, powered lawn and garden equipment — Symbols for operator controls and other displays — Part 2: Symbols for agricultural tractors and machinery.*

ISO 3965:1990, *Agricultural wheeled tractors — Maximum speeds — Method of determination.*

ISO 4254-1:1989, *Tractors and machinery for agriculture and forestry — Technical means for ensuring safety — Part 1: General.*

ISO 5007:1990, *Agricultural wheeled tractors — Operator's seat — Laboratory measurement of transmitted vibration.*

ISO 5008:1979, *Agricultural wheeled tractors and field machinery — Measurement of whole-body vibration of the operator.*

ISO 5131:1982, *Acoustics — Tractors and machinery for agriculture and forestry — Measurement of noise at the operator's position — Survey method.*

ISO 5675:1992, *Agricultural tractors and machinery — General purpose quick-action hydraulic couplers.*

ISO 5697:1982, *Agricultural and forestry vehicles — Determination of braking performance.*

ISO 5715:1983, *Equipment for harvesting — Dimensional compatibility of forage harvesting machinery.*

ISO 5718-1:1989, *Harvesting equipment — Flat blades for rotary mowers — Specifications — Part 1: Type A flat blades.*

ISO 5718-2:1991, *Harvesting equipment — Flat blades for rotary mowers — Part 2: Specifications for type B flat blades.*

ISO 6097:1989, *Tractors and self-propelled machines for agriculture — Performance of heating and ventilation systems in closed cabs — Test method.*

ISO 6489-1:1991, *Agricultural vehicles — Mechanical connections on towing vehicles — Part 1: Hook type.*

ISO 6489-2:1980, *Agricultural vehicles — Mechanical connections on towing vehicles — Part 2: Clevis type — Dimensions.*

ISO 8909-1:1994, *Forage harvesters — Part 1: Vocabulary.*

ISO 8909-2:1994, *Forage harvesters — Part 2: Specification of characteristics and performance.*

3 Definitions

For the purposes of this part of ISO 8909, the definitions given in ISO 8909-1 and the following definitions apply.

3.1 test machine: Machine whose performance is being assessed.

3.2 reference machine: Machine of known performance required to be used alongside the test machine.

3.3 test series: All the events and data comprising several test runs in one crop and set of conditions.

3.4 catch: Mass of the material collected from the harvester during a test run, in kilograms.

3.5 capacity: Continuous output (mass) on a wet and dry basis of chopped crop from the harvester per unit of time. The capacity is expressed in tonnes per hour.

3.6 power requirement: Time-averaged total power, in kilowatts, required to operate the harvester during a test run at rated operating speed, excluding the power for propulsion.

3.7 no-load power requirement: Time-averaged total power, in kilowatts, required to operate the harvester at the rated speed when stationary and with the attachments to be tested engaged.

3.8 specific energy requirement: Total harvester energy required per unit of crop mass on a wet and dry basis. It is expressed in kilowatt hours per tonne.

3.9 theoretical length of cut: Length of cut, in millimetres, calculated from the number of knives and the speeds and effective dimensions of all relevant components.

3.10 length of cut analyser: Apparatus for dividing a typical sample of the chopped forage harvested by the machine into particle length groups, to enable the percentage of cumulative undersize by mass to be determined from each group.

3.11 length of cut distribution graph: Logarithmic normal probability graph of percent cumulative undersize mass versus mean particle length data from the length of cut analysis for each sample. (See annex B.)

3.12 geometric mean length of cut: Particle length, in millimetres, calculated from the analysis data or taken from the length of cut distribution graph at the 50 % level of cumulative undersized mass. It denotes the fineness of chopped crop and is the most appropriate dimension for comparison with the theoretical length of cut.

3.13 geometric standard deviation of length of cut: Particle length taken from the length of cut distribution graph at the 84 % level of cumulative undersized mass divided by the mean length at the 50 % level of cumulative undersized mass; alternatively, it may be calculated mathematically from the analysis data. The geometric length of cut standard deviation is an index of the uniformity of cut.

3.14 whole-grain fraction: Percentage, to the nearest 0,5, of all undamaged grains or maize (corn) kernels present in samples of chopped forage, relative to the whole catch mass (or optionally to the calculated field grain population). Dye penetrants may be used to determine invisible grain surface damage.

4 General requirements

4.1 The test report (see clause 7) shall state how the forage harvester was selected or obtained for testing and the extent of any use prior to the test.

4.2 The forage harvester shall be operated in accordance with the manufacturer's instructions. The test report shall record, and give reasons for, any significant departures from them.

4.3 Commercially available accessories, as necessary or desirable for the various crops in which the forage harvester is to be used, shall be provided.

4.4 Setting and adjustments of the machine shall be in accordance with the manufacturer's instruction manual. Any necessary significant departures shall be reported.

4.5 A manufacturer's representative shall be invited to observe testing of the forage harvester.

5 Machine requirements for test

5.1 All significant details of the harvester shall be established and verified, using applicable terminology and measuring methods as indicated.

5.2 For self-propelled machines, measure the speed of any component at "no-load", with the engine governor control lever set to give rated engine speed. For PTO (power take-off)-driven machines, measure these speeds at the standard PTO speed (540 min^{-1} or 1 000 min^{-1}). Measure forward speeds of self-propelled forage harvesters on a hard horizontal surface, with the governor control lever set to give rated engine speed and the harvester mechanism engaged; report the size of tyres fitted; the inflation pressure shall be as recommended by the manufacturer.

For machines with stepless speed change mechanisms, determine the maximum and minimum speeds in each speed range. Otherwise, measure speeds obtained for all combinations of gears in accordance with ISO 3965.

5.3 Assess the suitability of construction and the geometry of the forage harvester in accordance with ISO 730-1, ISO 730-2, ISO 730-3, ISO 5675, ISO 5715, ISO 5718-1, ISO 5718-2, ISO 6489-1 and/or ISO 6489-2.

5.4 Assess the comprehensiveness and clarity of instructions in the operator's manual in accordance with ISO 3600.

5.5 Where applicable, check and report on compliance with safety and ergonomic requirements with particular reference to ISO 500, ISO 3767-1, ISO 3767-2, ISO 4254-1, ISO 5007, ISO 5008, ISO 5131, ISO 5697 and ISO 6097.

5.6 With self-propelled forage harvesters, measure the left-hand and right-hand turning diameters without the turning brakes engaged in accordance with ISO 789-3 and ISO 8909-1.

6 Specific performance tests

These shall be carried out in crops and conditions specifically selected to determine and define by physical measurement the principal performance aspects of the harvester. On each occasion a reference machine of already defined performance characteristics shall be tested alongside the test machine(s) in like manner to provide a reference for each type of performance measurement, especially with regard to machine setting, crop condition and characteristics, and seasonal differences.

6.1 Selection of crops

Only crops of uniform appearance, reasonably free from disease and weeds, and of at least average yield, shall be selected. The ground surface shall be as level and even as practicable, unless special tests are being conducted. The crops shall in general be standing well and shall be free of surface moisture. Any deviations from the prescribed conditions shall be recorded and stated in the test report.

Crops for performance tests should cover the range of greatest interest, nationally or regionally. With multi-purpose machines, at least two types of crop of the following should be harvested:

— grass: single species or mixtures, fresh and wilted, first growth;

— legumes: single species, fresh and wilted, first or second growth;

— row crops, e.g. maize (corn), sorghum or kale: single species, direct cut;

— forage cereals: single species or mixtures, fresh or wilted.

With machines specifically designed for row crops, at least two test series shall be carried out, if possible in dissimilar crops. The row spacing shall coincide with the recommended working widths of the gathering units. The average dry matter content of each crop as harvested shall be determined.

6.2 Reference machine

The reference machine shall be functionally sound, and fully identified by make, model, type, year of manufacture and other pertinent information: it shall be of similar design and capacity to the test machine and be operated at comparable settings.

6.3 Operator competence

The operators shall be adequately experienced with the type of test machine and with the reference machine.

6.4 Preparations for performance tests

At the time of the test, both the test and reference machines shall be in good order, the working components and crop-engaging surfaces shall be adequately run-in, and the knives shall have been newly sharpened. If a recutter screen or other chopping aid is fitted, this shall be stated in the test report.

Immediately prior to their testing, both machines shall be adjusted in accordance with the manufacturer's recommendations to give required performance under the prevailing conditions in the same area of crop to be used for the test. A theoretical length of cut shall be used which is most appropriate for the test crop and typical in the geographic region. After the commencement of the tests, no further adjustment of settings shall be permitted in any single test series. Important settings, like those governing the length of cut, shall be recorded in the test report.

6.5 Instrumentation and test apparatus

The following items of instrumentation and equipment shall be available in addition to normal test aids and measuring apparatus:

a) **equipment for accurately determining the mass of the catch,** such as a trailer and weighbridge or wheel weighing units, or self-emptying trailer fitted with load cells between the trailer body and running gear;

b) **length of cut analyser** for classifying samples of chopped forage;

c) **device for taking representative crop samples** safely from the delivery spout of the harvester.

For tractor-operated harvesters, PTO torque and rotational speed measuring instrumentation shall be provided.

For self-propelled machines, the total power to drive the forage harvester components shall be determined, using torque and rotational speed sensors.

6.6 Test procedure

6.6.1 Output and specific energy requirement tests

6.6.1.1 All tractors designated to operate a test and reference machine shall provide ample power at all times. With the tractor-operated test or reference machine attached and driven at recommended PTO speed, but with the outfit stationary, note the no-load power requirement. Then, with a container or trailer equipped for collecting the catch attached to the harvester, or pulled alongside by a separate tractor, drive the outfit into the crop at constant forward speed.

With self-propelled harvesters, the no-load power requirement shall be measured at rated engine speed with the outfit stationary and all other drives engaged. Then with a container or trailer attached to the harvester, or pulled alongside by a tractor, drive the outfit into the crop at constant forward speed.

With direct-cutting harvesters, use the full working width.

6.6.1.2 During the run-in, i.e. at least the first 5 s of harvester operation, allow the crop flow through the machine to stabilize, without the crop stream from the delivery spout being directed into the collecting device. Thereafter, start the test run during continuing work by directing the crop from the spout of the harvester into the catch-collecting trailer or container and simultaneously commence timing of the catch period. During the test run, take records of harvester power, or torque and rotational speed. Take at least one sample for length of cut analysis from the crop stream emanating from the delivery spout of the machine.

6.6.1.3 The catch period shall extend for at least 60 s or until a minimum of 1 t of material has been collected. On completion of the test run, measure the test length, weigh the catch, take two samples from the catch for dry matter content analysis by recognized methods, and determine the effective working width. Periodic checks of soil contamination may be applying a recognized laboratory procedure to the ashing of two further harvested samples, alongside a sample taken from the unharvested crop, for the comparison of silica content. From the data collected during each test run calculate the following:

a) forward speed, in kilometres per hour;

b) yield of crop harvested, wet and dry basis, in tonnes per hectare;

c) capacity on a wet and dry basis, in tonnes per hour;

d) no-load power requirement, in kilowatts;

e) power requirement, in kilowatts;

f) specific energy requirement, wet and dry basis, in kilowatt hours per tonne.

6.6.1.4 Test runs shall be repeated at least once at each of several different forward speeds so that reliable performance relationships are established for the range of speeds which is practicable in the prevailing conditions. At the highest acceptable forward speed, note the factors of circumstances preventing a further increase in speed and record them in the test report.

Carry out successive runs in adjacent strips of crop to minimize the effects of yield gradients in the field. Run the reference machine simultaneously in the same test area as the test machine. Unsuccessful test runs may be discarded only for valid reasons which shall be reported.

6.6.1.5 The data from a series of test runs may be used to plot the following graphs, using linear scales, with the independent and dependent variables as the x and y axes respectively:

— average total power requirement (y) versus output, wet basis and dry basis (x);

— specific energy requirement, wet basis and dry basis (y) versus output, wet basis and dry basis (x).

6.6.1.6 In at least one crop, make series of replicated test runs at the constant rate of approximately 80 % of maximum throughput and at progressively increasing dry matter contents of precut crop, and also at similar dry matter contents but at a different theoretical length of cut. From the data collected, draw additional graphs of specific energy requirement (y) versus crop dry matter content, wet and dry basis, and theoretical length of cut (x).

6.6.2 Front end losses

When direct-cutting row crop heads are used, the precut and front end losses may be determined optionally in the test run areas. Lost cobs or other unharvested plant materials, where these are important, shall be collected and their mass related to the respective area. After deduction of precut losses from front end losses, the results shall be expressed, in kilograms per hectare, of dry matter, or in terms of percentage dry matter yield.

6.6.3 Length of cut analysis

Analyse the samples taken from the harvester spout during the test runs by hand-sorting or by mechanical, pneumatic or other classification means. Permissible types of classification apparatus include stacks of actuated sieves and cascade separators. For any such device, a procedure giving good accuracy and repeatability needs to have been developed specifically.[1)] Minimum sample size is 1 l; the actual sample size shall satisfy the requirements of the length of cut analysis. For reducing the size of any sample taken, a recognized method of randomly dividing it shall be used.

Samples may be processed at harvest moisture content, or they may be dried prior to classification. The proven procedures for specific apparatus shall be adhered to, and the results obtained shall be checked periodically by hand-sorting or by mechanically classifying a sample of known length distribution.

Pertinent screening dimensions should be in geometric progression, with the smallest selected to be appropriate to the particle size spectrum of the sample. To provide a particle length for the 100 % undersize level, the mean length of the three largest pieces in each sample shall be determined.

1) Among other documents, see ISO/TR 10391:1992, *Forage harvesters — Method of determining by screening and expressing particle size of chopped forage material.*

From the results of each length of cut classification, determine the geometric mean length of cut and the geometric length of cut standard deviation by plotting a length of cut distribution graph, or by calculation (an example for crop divided into 10 length intervals is given in annex B). In grain-bearing crops, particularly maize (corn), it is preferred that the whole-grain fraction, as defined in 3.14, is measured additionally.

7 Test report

The test report shall contain the following information:

a) brief description, identification and photograph of the test machine, and statement on method of selection for test;

b) list of verified principal dimensions and specification;

c) lists of locations of test sites, crops and field and climatic conditions and machine settings and adjustments at each site;

d) brief descriptions of, or references to, test methods and procedures, including length of cut analysis;

e) the main data recorded during the test;

f) results, including any statistical analyses, of the test machine requirements and of the performance tests, in accordance with clauses 5 and 6;

g) results of any optional measurements and observations made in accordance with annex A, including a list of breakdowns with causes of all enforced stops due to mechanical faults, including wear, and with optional recommendations for functional and mechanical improvements;

h) brief summary of the comparative results of the tests conducted with the reference machine.

Annex A
(normative)

Optional measurements and observations

A.1 General

Subjective assessments may be carried out over an appropriate period extending up to a full harvest season and shall cover as wide a range as practicable of crop species, varieties of crop and ground conditions, as agreed with the manufacturer or his representative. Subjective findings shall be duly defined as such, and should be substantiated wherever possible.

A.2 Basic records

For each part of a field in which harvesting is carried out, basic records shall be kept of:

a) weather and atmospheric conditions;

b) crop species, variety, stage of maturity, dry matter content, average length, condition and average yield;

c) slope and state of ground;

d) size and shape of field and area harvested;

e) hours of operation: total and productive;

f) make and model of tractor for PTO-driven harvesters;

g) type and size of trailers used and whether pulled behind or alongside;

h) number of trailer loads and trailer contents by mass;

i) fuel used (self-propelled and engine-driven harvesters).

A.3 Assessment procedure

Throughout the test period, the general behaviour and functioning of the harvester may be assessed and be reported on subsequently, as indicated in A.3.1 and A.3.2.

A.3.1 All forage harvesters

A.3.1.1 Suitability for different crops and conditions, particularly:

a) efficiency and height of cutting and/or picking up crops in favourable and adverse conditions, including the accuracy of following and/or crossing crop rows;

b) adequacy of crop delivery into trailers of different size and construction during side and rear loading;

c) occurrence of blockages: frequency and type;

d) performance on slopes and rough ground, relative to level, smooth surfaces;

e) soil contamination of harvested material under typical and adverse conditions;

f) adequacy of adjustment provisions and remote controls;

g) suitability and effectiveness of special equipment;

h) effectiveness of protective devices in the drive line and for the prevention of damage by foreign objects;

i) factors and circumstances limiting performance.

A.3.1.2 Ease of adjustment, operation, servicing and maintenance:

a) attaching and detaching trailed and mounted machines to and from the tractor: note whether equal-angle hitching is required;

b) adjustment of cutting knife to shear bar clearance, feed speed, cutting rotor speed, belt and chain tensions, and direction of crop delivery;

c) knife setting, replacement and sharpening;

d) fitting and removal of accessories and special equipment;

e) short and full maintenance and lubrication routines;

f) changing from the working to the transport position, and vice versa;

g) changing head;

h) visibility of the crop intake region and of crop delivery to the trailers.

A.3.2 Self-propelled forage harvesters

Observations and comments on:

a) the ease of access to the driving position;

b) identification and ease of operation of the controls;

c) identification and visibility of instruments;

d) adequacy and ease of control of cab air-conditioning and heating systems, if fitted;

e) adequacy of any lighting equipment for work after dark;

f) convenience and safety of handling the machine on and off the road.

A.4 Durability and reliability

Component failures, signs of excessive wear and repairs which become necessary shall be reported relative to accumulated working time, in hours, and amount of work done, in tonnes or hectares.

A.5 Effectiveness of safety provisions

In conformity with national requirements, the effectiveness of safety guards and shields and of any special provisions for protecting the operator and bystanders shall be assessed by qualified personnel.

Annex B
(normative)

Determination of geometric mean length of cut and geometric standard deviation from results of length of cut analysis

B.1 Rationale

Research has provided strong evidence that the length distribution of chopped material on a mass basis follows a log-normal form. The calculations of the basic parameters of distributions assumes such a form.

B.2 Calculation of cut parameters

B.2.1 Geometric mean length, $\bar{x}$

The geometric mean length, $\bar{x}$, is calculated from the following formula which applies to n length classification intervals of the material:

$$\ln \bar{x} = \frac{\sum_{i=1}^{i=n} m_i \ln \bar{x}_i}{\sum_{i=1}^{i=n} m_i}$$

where

$\bar{x}_i$ is the mean length of material for the ith length classification interval;

m_i is the mass of material for the ith length classification interval.

In practice, m_i can be the actual mass of material or can be expressed as a percentage of the total sample mass, in which case

$$\sum_{i=1}^{i=n} m_i = 100$$

B.2.2 Geometric standard deviation, σ

The geometric standard deviation, σ, is calculated from the following formula:

$$(\ln \sigma)^2 = \frac{\sum_{i=1}^{i=n} m_i (\ln \bar{x}_i - \ln \bar{x})^2}{\sum_{i=1}^{i=n} m_i}$$

B.2.3 Calculation procedure

In the formulae in B.2.1 and B.2.2, use is made of the natural logarithm, ln, but the logarithm to base 10 (lg) could be used. The simplest procedure is to use the percentage mass in each length classification in relation to the total sample mass.

The mean length of material within a particular material length classification may be taken as either the arithmetic mean of the length at the upper limit of the interval $(x_u)_i$, and the length at the lower limit $(x_l)_i$, or as the geometric mean. In general, the difference between the means is small, but for a classification of material for which the length is much greater than the lateral dimensions, the arithmetic mean is more appropriate.

B.3 Length of cut parameters — Graphical determination

If the data are plotted on logarithmic normal probability graph paper, the points will lie on a straight line if the length of the material follows a log-normal distribution. The percentage mass of material for the upper limit of length for each class interval, $(x_u)_i$, is plotted on a cumulative basis, as shown in figure B.1.

B.3.1 Geometric mean length, $\bar{x}$

This may be determined from the graph by finding the length corresponding to 50 % on the probability scale. For a log-normal distribution, the geometric mean is equal to the median value. Therefore, 50 % by mass of the material is shorter than the median and 50 % by mass is longer.

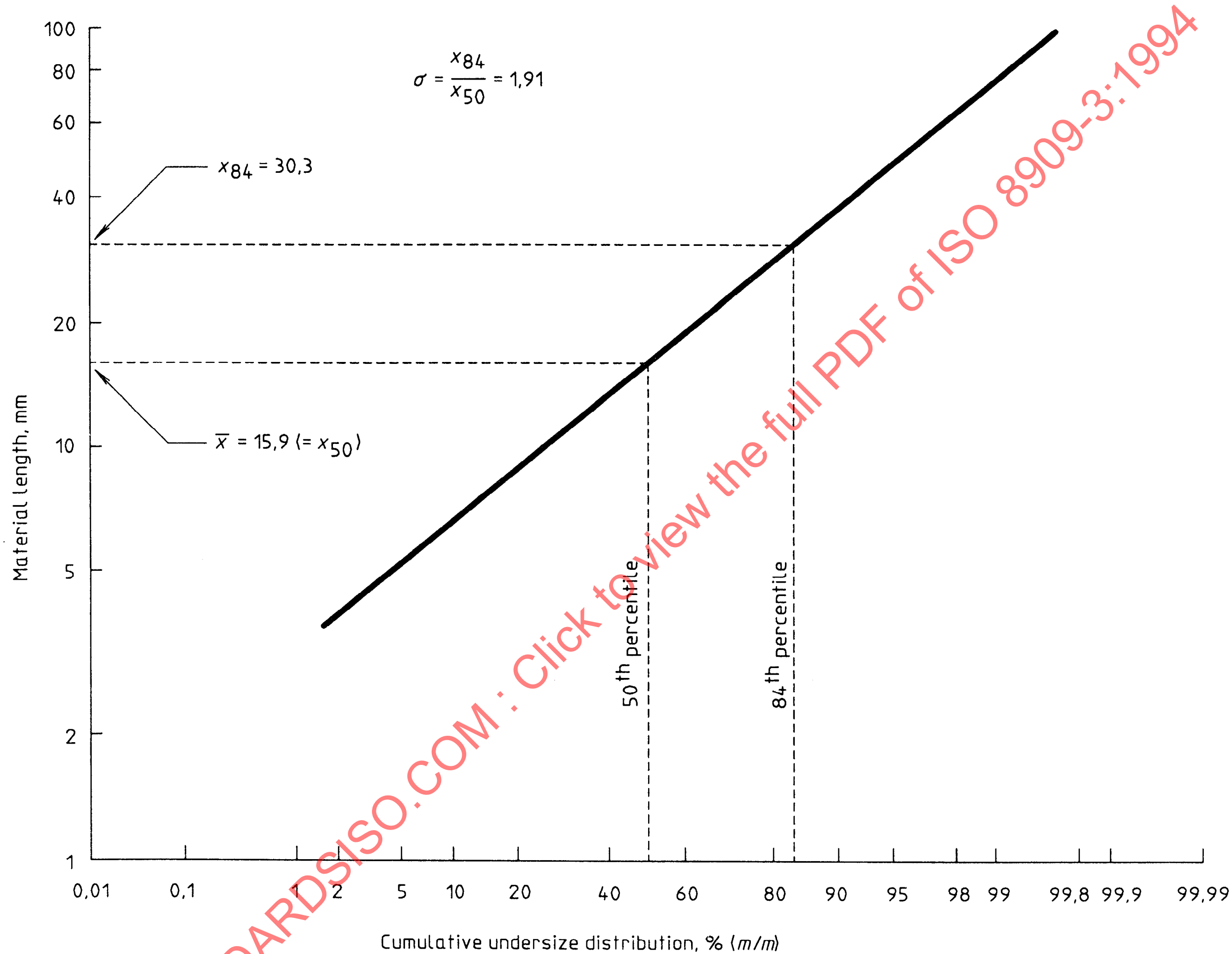

Figure B.1 — Example of distribution of material versus cumulative undersize by mass