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Agricultural grain driers — Determination of drying performance —

Part 1:
General

Séchoirs à grains agricoles — Détermination des performances de séchage —

Partie 1: Généralités

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 11520-1 was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 7, *Equipment for harvesting and conservation.*

ISO 11520 consists of the following parts, under the general title *Agricultural grain driers — Determination of drying performance*:

— *Part 1: General*

— *Part 2: Specification of crop quality, moisture content and performance correction method*

Annex A forms an integral part of this part of ISO 11520. Annexes B to E are for information only.

Introduction

It is envisaged that many grain drier tests will be carried out by independent bodies, either to help manufacturers in development work or for specification of performance to potential purchaser/owner or other interested body. While it is possible to conduct a test on the basis that only input and output parameters are recorded, the extra cost of making internal measurements is likely to be small relative to the benefit in a diagnostic sense of the additional data. For this reason the standard includes procedures to make such measurements.

Agricultural grain driers — Determination of drying performance —

Part 1:
General

1 Scope

This part of ISO 11520 describes methods for evaluating the drying performance of continuous flow and batch grain driers. The methods specified are for determining the evaporation rate which the machines concerned are able to achieve under the steady-state conditions prevailing during the tests. Methods for correcting observed performance to other input and standard ambient conditions are described.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 11520. 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 11520 are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 520:1977, *Cereals and pulses — Determination of the mass of 1 000 grains.*

ISO 712:1985, *Cereals and cereal products — Determination of moisture content (Routine reference method).*

ISO 3966:1977, *Measurement of fluid flow in closed conduits — Velocity area method using Pitot static tubes.*

ISO 7194:1983, *Measurement of fluid flow in closed conduits — Velocity-area methods of flow measurement in swirling or asymmetrical flow conditions in circular ducts by means of current-meters or Pitot static tubes.*

ISO 7971:1986, *Cereals — Determination of bulk density, called "mass per hectolitre" (Reference method).*

3 Definitions

For the purposes of this part of ISO 11520, the following definitions apply.

3.1 continuous-flow drier: Drier in which the material being dried moves through the machine in a substantially continuous stream and is discharged without being recirculated.

3.2 batch drier: Drier in which the drying chamber is completely emptied between the drying of separate batches of grain.

3.3 ambient air temperature and relative humidity: Mean dry bulb temperature and mean relative humidity of the atmosphere measured as close as possible to the main air intake(s) of the drier, but not affected by the drier;

the mean value of relative humidity over a period is that corresponding to the mean absolute humidity and mean dry bulb temperature of the air over that period.

3.4 standard ambient conditions: Ambient conditions of temperature, pressure and relative humidity to which the results of a drier test shall be corrected.

NOTE — See ISO 11520-2.

3.5 steady state: For a continuous-flow drier, a period during which both the moisture content of discharged grain and the temperature of the exhaust air are stable.

3.6 residence time: For a continuous-flow drier, the mean time taken for grain to travel from the input to the output.

3.7 stabilization period: Period during which a continuous-flow drier is operated so that it approaches steady state.

3.8 test period: Period during which a continuous-flow drier, operating at a single steady state for at least one residence time, or a batch drier, completing a single full cycle of drying and cooling, is monitored to enable its thermodynamic performance to be assessed.

3.9 input moisture content: Mean wet basis moisture content (m.c.w.b.) of the grain entering the drier during the period of time equal to a test period and beginning one residence time prior to the start of the test period.

3.10 output moisture content: Mean wet basis moisture content (m.c.w.b.) of the grain leaving the drier during a test period.

3.11 input: Mean mass flow rate of damp grain at the input moisture content into a continuous-flow drier during a test period.

3.12 output: ⟨continuous-flow drier⟩ Mean mass flow rate of dried grain which is output during a test period.

3.13 output: ⟨batch drier⟩ Mass of the dried batch divided by the sum of the test period and the filling and emptying period.

3.14 volumetric drier holding capacity: ⟨continuous-flow drier⟩ Volume of grain in the drier after a period of stable operation.

3.15 volumetric drier holding capacity: ⟨batch drier⟩ Volume of grain required to fill the drier at the input moisture content.

3.16 drying air temperature: Mean temperature of the air to be used for drying the grain, measured at a number of points as close as practicable to its entry to the grain bed.

3.17 cooling air temperature: Mean temperature of the air to be used for cooling the grain, measured at a number of points as close as practicable to its entry to the grain bed.

3.18 exhaust air temperature: Mean temperature of the air exhausting from the drier.

3.19 discharged grain temperature: Temperature of grain immediately after discharge from the drier.

3.20 evaporation: Total mass of water evaporated during a test period.

3.21 evaporation rate: Mean rate of evaporation measured over the test period for a continuous-flow drier or over the residence time for a batch drier.

3.22 specific total energy consumption: Total energy used per kilogram of water evaporated.

NOTE — Energy used by conveyors and elevators is not included unless they form an integral part of the drier.

3.23 specific thermal energy consumption: Thermal energy used per kilogram of water evaporated.

3.24 indirect heating: Form of heating in which a heat exchanger is used to heat the air for drying.

3.25 direct heating: Form of heating in which a drier uses fuel that is combusted in the air which is passed through the crop.

4 Symbols and abbreviations

Symbol	Quantity	Unit
A	total mass of grain required for test	kg
B	rated output	kg/s
E	evaporation mass	kg
F	fuel consumption	kg/s
G	holding capacity of drier	kg
H	net calorific value of fuel	J/kg
I	electrical current	A
J	specific fuel consumption	kg/kg
M	moisture content of grain, wet basis	%
N	anticipated number of test periods	1
P	power	W
Q	specific heat consumption	J/kg
S	specific energy consumption	J/kg
U	electrical tension	V
V	volumetric capacity of drier	m^3
W	energy consumption	J
X	flow rate of heating media in heat exchanger	kg/s
c	specific heat capacity	J/(kg·K)
d	depth of grain bed	m
f	face area at point of air entry to grain bed	m^2
g	correction factor for air density	1
h	specific enthalpy	J/kg
m	mass of grain	kg
m'	mass flow of grain	kg/s
p	pressure	Pa
q_V	air volume flow rate	m^3/s
q_m	air mass flow rate	kg/s
r	proportion of air recirculation	1
s	standard deviation	
t	duration of test period	s
v	air superficial velocity	m/s
w	mass of water	kg
x	absolute humidity of air	kg/kg

Symbol	Quantity	Unit
Θ	thermodynamic temperature of air	K
ε	relative error	1
θ	Celsius temperature of air	°C
ρ	density	kg/m^3
τ	residence time in drier	s
υ	specific volume of dry air	m^3/kg
ψ	relative humidity of air	1
$\cos\phi$	power-factor	1
η	thermal efficiency of heater	1

Subscripts

a	ambient, atmosphere
b	barometric
c	cooling
d	drying
e	electrical
f	final; at drier exit
g	grain
h	heating media in heat exchanger
i	initial, at drier inlet
n	total
o	observed value
s	corrected value at standard or specified conditions
t	thermal
v	vapour
w	wet bulb
x	exhaust

5 Principle

For continuous-flow drying the basis of the test is to monitor the drier during a relatively short period with steady-state conditions fully established, rather than over a long period with fluctuating conditions. For batch driers the basis is to monitor the drier during a full cycle of operation. This approach allows

— the drier to achieve maximum evaporation for the test conditions;

— the comparison of results between different driers;

— the results to be corrected to specified input and standard ambient conditions.

6 Instrumentation and specifications

6.1 Automatic recording

If an automatic recording system is used, it should be as immune as possible to electrical interference induced in the sensor cables by nearby electrical equipment. Sensor cables should be installed, as far as possible, away from cables carrying large currents.

6.2 Sensors for air properties

6.2.1 Air temperature

The temperature measuring system shall have a maximum error of 1 °C or 1,5 % of the measured value in degrees Celsius, whichever is greater. Radiation shielding shall be used where a sensor is in direct line of sight of surfaces which have temperatures greater than 500 °C.

Sensors shall be capable of maintaining the prescribed accuracy when operating in an airstream which may contain dust and fine particles.

6.2.2 Air humidity

Measuring systems for relative humidity (r.h.) shall have a maximum error of five percentage points of relative humidity. Other sensors shall be sufficiently accurate to enable r.h. to be calculated to within five percentage points.

6.2.3 Static pressure

Sensors shall be constructed in accordance with ISO 3966. A manometer of suitable range, and able to operate in different mode, is required. It shall have a maximum measurement error of 5 % of the measured value.

6.2.4 Barometric pressure

If an aneroid barometer is used, its calibration shall be checked.

6.3 Grain properties

6.3.1 Grain moisture content

The moisture content of samples of grain shall be determined in accordance with ISO 712.

NOTE — If moisture content is determined by the rapid method, although rapid moisture meters are not, in general, very accurate they are normally consistent between samples over short periods and so provide a very good indication of trends in the moisture content of grain being discharged from the drier.

6.3.2 Grain mass

The mass of grain discharged from the drier shall be measured on a device with a maximum error of 1 % of the measured grain mass.

NOTE — The mass of any tare, e.g. trailer, should be as small as feasible. If the mass of grain is determined by subtraction of two masses, this will increase the error in the measurement of grain mass.

6.4 Energy

Energy consumption shall be measured within ± 2 % of the measured value.

6.4.1 Electrical energy

Electricity consumption shall be measured by an integrating measuring instrument or by continuous measurement of voltage, current and power factor.

6.4.2 Fuels

If the fuels is combusted *in situ*, the net calorific value of the fuel shall be

— determined in accordance with an appropriate national standard;

— taken from an appropriate source, e.g. the standard specification of the fuel; or

— the value certified by the supplier.

The method of measurement of the mass of fuel depends on the energy source for the air heater, e.g. liquid petroleum fuel (diesel oil, liquified gas, etc.), gaseous fuel (natural gas, propane, etc.), solid fuel (coal, straw, etc.) or thermal fluid (hot water, steam, etc.). See annex C.

7 Preparation for test

7.1 Specification of the drier

A record shall be made of the drier specification. Annex E gives a checklist to be followed. As many of the points in the checklist as are applicable shall be recorded.

7.2 Preparation of grain

For a continuous-flow drier, the quantity of dry grain required for a test is given by

$$A = 1{,}1\ [G + N\ (1{,}5\ G + Bt)]$$

where G is taken to be the nominal drier holding capacity. This formula provides for 1,5 complete residence times to separate each test period and a safety margin of 10 %.

For a batch drier, the minimum quantity of dry grain required is

$$A = NG$$

If a safety factor is required, the quantity shall be increased to:

$$A = (N + 1)G$$

7.3 Installation of sensors

7.3.1 Sensors for air temperature

Sensors for temperature shall have a maximum error of 1 °C of 1,5 % of the measured value in degrees Celsius.

7.3.1.1 Drying air temperature

Sensors shall be installed in the air stream as close as possible to the point where it enters the grain bed. To detect spatial gradients in air temperature as it enters the grain bed, a minimum of six sensors shall be installed, equally spaced on a two by three grid.

NOTE — Particular care should be taken to install additional sensors at the locations where the highest temperatures are likely, as these values will be important in assessing the reasons for any thermal damage to grain.

7.3.1.2 Cooling air temperature

At least one sensor shall be installed in the air stream as close as possible to the point where it enters the grain bed. However, sensors shall not be installed close to surfaces which will be hot during the test.

7.3.1.3 Temperature of air inlet(s) to heater

Install at least one sensor shielded from sources of radiant heat.

NOTE — This temperature is required to calculate the temperature rise of the air over the heaters.

7.3.1.4 Exhaust air temperature

Sensors shall be installed in the air stream as close as possible to the point where it leaves the grain bed. To detect spatial gradients in air temperatures at the point where air leaves the grain bed and to give overall exhaust air temperature, a minimum of six sensors shall be installed, equally spaced on a two by three grid.

Exhaust air temperatures indicate the progress of drying. For example in a continuous-flow drier, the approach to steady-state can be detected by steady values of exhaust air temperature from the whole drier, and particularly the exhaust air temperature at the end of the drying section. One of the sensors shall be installed at this point.

7.3.1.5 Fitted sensors

To check the placing and calibration of any temperature sensors supplied with the drier for monitoring or controlling temperature, place an additional sensor close to each one.

7.3.2 Sensors for humidity of inlet air (drying and cooling)

For driers not employing any recirculation of exhaust air, a single sensor shall be located in the air to be heated for the drying section.

7.3.3 Direct method for determining grain temperature

The direct method for determining grain temperature should preferably be used. In this method, for the measurement of ingoing and outgoing grain temperatures, sensors shall be installed in the buffer zone or discharge hopper of the drier.

Sensors installed in the grain bed to measure grain temperature shall not be subject to a flow of air, otherwise they will tend to register the air temperature. This is particularly so for a discharge hopper where there may be

— air leakage through the grain, and

— grain in the ventilated beds.

In these cases the sampling method given in 8.2.4.1 should be used.

7.3.4 Sensors for air static pressure

Sensors shall be installed to measure the difference in static pressure across the grain bed(s), and across the fan(s).

8 Grain sampling

8.1 Before the test

This procedure shall be carried out whether or not the grain is to be dampened.

Mentally divide grain bulk into approximate lots of 20 t each.

From each lot, take 40 samples of not less than 50 g each and bulk to provide one 2 kg sample.

For each 2 kg sample, mix by sample divider and remove, by sample reduction, 100 g. Determine the moisture content as specified in ISO 712.

Take a 200 g sample from the remainder of each 2 kg sample, seal each in a fine-mesh bag and dry with substantially unheated air prior to storage in a moisture proof container at 10 °C. Determine the mass of

1 000 grains in accordance with ISO 520 and the moisture content in accordance with ISO 712. Germination and purity are analysed as specified in ISTA (International Seed Testing Association) rules.

Bulk and mix the remaining grain from each 2 kg sample and reduce the whole by sample dividing to a 3 kg sample, seal in a netting bag and, if necessary, condition to a suitable moisture content for storage. Determine bulk density by a method in accordance with ISO 7971.

8.2 During the test

8.2.1 Choice of sampling points

If the average condition of outlet grain is required, sampling should be done after the grain has passed any device in the grain handling line which mixes the grain, e.g. a screw conveyor. If grain is discharged in batches from the drier or from a hopper, care should be taken that the samples taken are representative of the batch, as the properties of the first and last grain in the batch may be significantly different. The position of inlet sampling point, which should be downstream of devices such as grain cleaners, is less critical than that of the output sampling point as the grain conditions are not likely to vary greatly. Samples may be taken from the drier itself to determine the properties of the grain inside the machine.

8.2.2 Quantity per sample

For each sample, at least 50 g of grain shall be taken from an extracted volume of 1 l.

NOTE — Some analyses may be done on each individual sample, e.g. moisture determination, whereas others may be done on samples formed by bulking individual samples over a test period, if information on variations during the test period is not important.

8.2.3 Frequency of sampling for grain moisture content

8.2.3.1 Continuous-flow driers

The frequency of sampling from the outgoing grain stream(s) shall be such that a minimum of 12 samples are obtained, spaced evenly over a test period. The timing and frequency of sampling of the ingoing grain stream shall be such that

— the grain sampled corresponds with that which will leave the drier during the test period, and

— a minimum of 12 samples evenly spaced in time are obtained.

NOTES

1 This may mean that some input samples are taken but later found to be unnecessary.

2 During stabilization periods the sampling rate of outgoing grain can be reduced.

8.2.3.2 Batch driers

At least 12 samples from the batch of grain to be dried shall be taken, spread evenly over the loading period. At least 50 samples from the batch of dried grain shall be taken during emptying, spaced evenly over the unloading period.

8.2.4 Treatment of samples

8.2.4.1 Sampling method for determining grain temperature

Each of the 12 samples for temperature determination shall be tested immediately. Grain shall, within 5 s of sampling, be placed and held in a preconditioned insulated container until a temperature sensor in the container has reached a maximum. The temperature shall then be recorded.

NOTE — A vacuum flask of at least 500 g capacity is a suitable container and can be preconditioned by filling with a sample from the same source which is then discarded.

8.2.4.2 Moisture determination

Samples for moisture determination shall be placed in sealed containers until required for analysis. Because samples may be warm and moist when they are placed in the containers, some condensation may occur on the inside of the container. Care needs to be taken that all such moisture has been reabsorbed before the container is opened for analysis.

NOTE — Polythene (polyethylene) bags which are heat-sealed or polythene bottles with tightly fitting lids have been found suitable.

8.2.4.3 Other analyses

Samples for other analyses shall be bulked for subsequent analysis; as far as possible samples taken at adjacent intervals shall be bulked to accumulate sufficient grain for testing.

NOTE — This is to retain, even in the bulked samples, the time variation which may be important for later assessment of performance.

Care needs to be taken that each bulk is thoroughly mixed before subsequent use.

8.2.4.4 Germination

If samples for germination are taken, they shall be placed in air-permeable material and ventilated with air at a temperature of less than 30 °C until 15 % m.c.w.b. is reached.

8.3 Determination of grain mass

8.3.1 Timing

Where the output grain stream is continuous the flow shall be diverted for weighing during a timed period equal to the test period. The diverted grain shall be that material which left the drier during the test period, so the diversion may need to be delayed at the start and end of the test period depending on the time taken by the grain to be transported from the discharge of the drier to the diversion point. If the drier has an intermittent or cyclically varying discharge, the test period shall start and end at the same point in the discharge cycle.

8.3.2 Loss of material in exhaust airstream

Care shall be taken to ensure that amounts of grain removed in the exhaust airstream are small.

NOTE — If there are no grain leaks, the loss of mass of the grain on drying comprises the water evaporated and any particles lost in the exhaust air. If the grain is reasonably free of dust and small particles, the latter will be negligible unless grains are entrained in the airstream and carried out of the grain chamber.

9 Test procedures

The drier shall be connected to all required services as specified by the manufacturer and shall be in working order. The required proportion of cooling shall be set.

9.1 Continuous-flow drier

9.1.1 Start up

Fill the drier with damp grain.

Switch off any automatic control of discharge rate.