

Methods of test for

Drying performance of agricultural grain dryers

**Part 1. General procedures and limited
requirements for wheat**

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Committees responsible for this British Standard

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- AFRC Institute of Engineering Research (now Silsoe Research Institute)
- Agricultural Engineers Association
- British Agricultural and Garden Machinery Association Ltd.
- Health and Safety Executive
- Ministry of Agriculture, Fisheries and Food
- National Farmers' Union
- Royal Agricultural Society of England
- Scottish Centre for Agricultural Engineering (SCAE)
- Silsoe College

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Summary of pages

The following table identifies the current issue of each page. Issue 1 indicates that a page has been introduced for the first time by amendment. Subsequent issue numbers indicate an updated page. Vertical sidelining on replacement pages indicates the most recent changes (amendment, addition, deletion).

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Change of identifier

Wherever BS 3986 appears in this standard, it should be read as BS 3986 : Part 1 : 1998.

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Foreword

This British Standard has been prepared under the direction of the Agricultural Machinery and Implements Standards Policy Committee. It supersedes BS 3986 : 1966 which is withdrawn. The initial draft was prepared by AFRC Institute of Engineering Research under the Department of Trade and Industry consultancy drafting scheme. This new metricated edition has been fully revised in the light of current practice.

Machines used in agriculture for drying grain are made to a wide variety of designs and in many sizes to cover the diverse requirements for drying capacity and cost. Such machines are tested as part of their design and development and in order to provide a basis of comparison of their performance with user's requirements and with the performance of other dryers.

Although the function of a grain dryer is simply the removal of excess moisture from grain without loss of quality, the accurate measurement of dryer performance calls for a technique based on considerable understanding of the grain drying process. The object of this British Standard is the description of methods of test which the committee considers necessary to define dryer performance with reasonable accuracy.

Since the first issue of this British Standard there has been considerable advance in methods of calculation of the grain drying process so that the method of correcting results from tests of conventional convective dryers to standard atmospheric conditions, and to a standard reduction of moisture content, has been much improved.

The same advances in calculation methods that have enabled improvement in prediction of the performance of heated-air grain dryers have increased knowledge of in-storage dryers and shown the complexity of the effects of control methods on their performance. Therefore the specification of methods of test for on-floor dryers, envisaged in the foreword to the first issue, has not been attempted.

The use of the test for resistance to heat damage, (5) of A3 in BS 3986 : 1966, otherwise known as the 'Normality' test, for the selection of the test grain, has also been omitted from this edition. Although technically sound, it proved to be too slow for practical use.

Wheat, the grain on which the methods are based, is not entirely representative of the many other grains in which users of dryers are interested, but provides a useful guide to the performance with other grains. The prediction of the dryer's performance when drying other materials by comparison with its performance when drying wheat is likely to be improved as research into drying proceeds. However, some other grains have widely different thermal and mechanical characteristics from wheat, and it should not be assumed that a dryer tested with wheat is capable of handling other crops. Care has to be taken that comparison between different dryers is based on tests using like material.

It is envisaged that many grain dryer tests will be carried out by independent bodies, either to help manufacturers in development work or for specification of performance to the 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 this British Standard includes procedures to make such measurements.

Amendment 1 is issued to take account of a further Part of BS 3986 which has been developed and which is published as Part 2 *Additional procedures and crop specific requirements*. This new Part 2 widens the application of the procedures specified in BS 3986 : 1991 to cover a broader range of drying conditions for wheat and also to cover other crops that are commercially dried. The title of Part 1 now recognizes that BS 3986 : 1991 covers general procedures and specific requirements applicable to the drying of rewetted wheat over a limited moisture content range of 20 % to 15 % wet basis and limited range of drying conditions. At the same time, the opportunity has been taken to correct some errors found in the 1991 edition. Amendments and corrections to the text are identified by vertical lines in the margins.

NOTE. AFRC Institute of Engineering Research is now the Silsoe Research Institute.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Methods

1 Scope

This Part of BS 3986 describes general procedures for evaluating the drying performance of continuous-flow and batch grain dryers and specific procedures for rewetted wheat over a moisture content range of 20 % to 15 % wet basis. The methods specified are for determining the evaporation rate which the machines concerned are able to achieve when drying wheat under the steady state conditions prevailing during the tests. Methods for correcting observed performance to other input and standard ambient conditions are described.

NOTE 1. BS 3986 : Part 2 specifies additional procedures and requirements for testing and evaluating dryer performance for other crops, including barley, oats, maize, rice, sorghum and rape, and for wheat over a wider range of conditions than those specified in Part 1.

NOTE 2. The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this British Standard the following definitions apply.

2.1 continuous-flow dryer

A dryer in which the material being dried moves through the machine in a substantially continuous stream and is discharged without being recirculated.

2.2 batch dryer

A dryer in which the drying chamber is completely emptied between the drying of separate batches of grain.

2.3 automatic batch dryer

A batch dryer in which the whole drying cycle including intake of damp grain, cooling (if any) and output of dried grain may take place without intervention by a human operator.

2.4 recirculating batch dryer

A batch dryer in which the grain is recirculated continuously during the drying and cooling cycles.

2.5 ambient air temperature and relative humidity

The mean dry bulb temperature and mean relative humidity of the atmosphere measured as close as possible to the main air intake(s) of the dryer, but without their being affected by the dryer. 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.

2.6 standard ambient conditions

The ambient conditions of temperature, pressure and relative humidity to which the results of a dryer test are corrected, namely temperature 15 °C, pressure 101.325 kPa, relative humidity 80 per cent.

NOTE. 101.325 kPa has been adopted as the pressure of the International Standard Atmosphere.

2.7 steady state

For a continuous-flow dryer, the period during which both the moisture content of discharged grain and the temperature of the exhaust air are assumed stable and no variation is made to airflow, drying air temperature or discharge rate.

2.8 stabilisation period

The period during which a continuous-flow dryer is operated with no alteration of any settings and is supplied with grain at a substantially constant moisture content so that it approaches steady state.

2.9 test period

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

2.10 residence time

For a continuous-flow dryer, the mean time taken for the grain to travel from the inlet to the outlet.

2.11 input moisture content

The mean wet basis moisture content of the grain entering the dryer during the period of time equal to a test period and beginning one residence time prior to the start of the test period.

2.12 output moisture content

The mean wet basis moisture content of the grain leaving the dryer during a test period.

2.13 input

The mean mass flow rate of damp grain at the input moisture content into a continuous-flow dryer during a test period.

2.14 output

For a continuous-flow dryer: the mean mass flow rate of dried grain at the output during a test period.

For a batch dryer: the mass of the dried grain batch divided by the sum of the test period and the time between the end of one drying and cooling cycle and the start of the next.

2.15 dryer holding capacity

The mass of grain at the input moisture content required to fill the dryer for proper operation.

2.16 drying air temperature

The 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.

2.17 cooling air temperature

The 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.

2.18 exhaust air temperature

The mean temperature of the air exhausting from the dryer.

2.19 discharged grain temperature

The temperature of grain immediately after discharge from the dryer.

2.20 evaporation

The total mass of water evaporated during a test period.

2.21 evaporation rate

The mean rate of evaporation measured over the test period for a continuous-flow dryer or over the drying time of a batch dryer.

2.22 specific evaporation

The mass of water evaporated per unit mass of heating fuel, corrected to specified input and standard ambient conditions.

2.23 specific total energy consumption

The total thermal, electrical and mechanical energy used per kilogram of water evaporated, corrected to specified input and standard ambient conditions.

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

2.24 specific thermal energy consumption

The thermal energy used per kilogram of water evaporated, corrected to specified input and standard ambient conditions.

2.25 specific fuel consumption

The mass of fuel used per kilogram of water evaporated, corrected to specified input and standard ambient conditions.

2.26 rating test

A test to establish the throughput of a dryer operating at standard ambient conditions and input conditions recommended by the manufacturers of the dryer for the specified grain, e.g. milling wheats.

2.27 nominal capacity

The output achieved by the dryer under standard ambient and specified input conditions while drying specified grain.

2.28 indirect heating

If a heat exchanger is used to heat the air for drying, the dryer is of the indirect heating type.

2.29 direct heating

If the fuel is combusted in the air which is passed through the crop, the dryer is of the direct heating type.

3 Principle

For continuous-flow drying the basis of the test is to monitor the dryer during a relatively short period with steady state conditions fully established, rather than over a long period with fluctuating conditions. For batch dryers the basis is to monitor the dryer during a full cycle of operation. This approach allows the dryer to achieve an evaporation which is maximum for the test conditions, allows comparison of results between different dryers and enables the results to be corrected to specified input and standard ambient conditions.

4 Symbols and units

Symbol	Quantity	Units
<i>A</i>	total quantity of grain required for test	kg
<i>B</i>	rated output	kg/s
<i>E</i>	water evaporation	kg
<i>E'</i>	water evaporation rate	kg/s
<i>F</i>	fuel consumption	kg/s
<i>G</i>	holding capacity of dryer	kg
<i>H</i>	net calorific value of fuel	J/kg
<i>I</i>	electrical current	A
<i>J</i>	specific fuel consumption	kg/kg
<i>K</i>	factor for correcting evaporation (defined in 9.4.3)	
<i>M</i>	moisture content of grain, wet basis (m.c.w.b.)	%
<i>N</i>	anticipated number of test periods	—
<i>P</i>	power	W
<i>Q</i>	specific heat consumption	J/kg
<i>R</i>	specific ideal gas constant R = 287 for dry air R = 461 for water vapour	J·kg ⁻¹ ·K ⁻¹
<i>S</i>	specific energy consumption	J/kg
<i>U</i>	electrical voltage	V
<i>V</i>	volumetric capacity of dryer	m ³
<i>W</i>	energy consumption	J
<i>X</i>	moisture content of grain, dry basis (m.c.d.b.)	kg/kg
<i>Z</i>	mass of water per unit of energy produced by combustion of fuel	kg/J
<i>a</i>	air volume flow rate	m ³ /s
<i>b</i>	air mass flow rate	kg/s
<i>c_{pa}</i>	specific heat of air at constant pressure	kJ·kg ⁻¹ ·K ⁻¹
<i>c_{pw}</i>	specific heat of water vapour at constant pressure	kJ·kg ⁻¹ ·K ⁻¹
<i>d</i>	depth of grain bed	m
<i>f</i>	face area at point of air entry to grain bed	m ²
<i>h</i>	specific enthalpy	J/kg
<i>i</i>	constant for crop (see A.1)	kg/kg
<i>j</i>	constant for crop (see A.1)	
<i>k</i>	constant for crop (see A.1)	
<i>m</i>	mass of grain in a single batch or passing through a continuous-flow dryer in a test run	kg
<i>m'</i>	mass flow of grain	kg/s
<i>p</i>	pressure or pressure drop in appendix A	Pa
<i>r</i>	proportion of air recirculation	decimal fraction
<i>t</i>	duration of test period	s
<i>u</i>	air superficial velocity	m/s
<i>w</i>	mass of water to be added to grain	kg