International Standard ISO 6322/2

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Storage of cereals and pulses — Part 2 : Essential requirements

Stockage des céréales et des légumineuses — Partie 2 : Principales conditions requises

First edition — 1981-06-15

UDC 633.1 + 635.65 : 664.821 **Ref. No. ISO 6322/2-1981 (E)**

Descriptors : agricultural products, grains (food), leguminous plants, leguminous grains, storage, specifications, general conditions, transportation, silos.

Price based on 6 pages

Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 6322/2 was developed by Technical Committee ISO/TC 34, *Agricultural food products*, and was circulated to the member bodies in February 1979.

It has been approved by the member bodies of the following countries :

Australia	Germany, F. R.	Poland
Austria	Hungary	Portugal
Brazil	India	Romania
Bulgaria	Israel	South Africa, Rep. of
Canada	Kenya	Spain
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No member body expressed disapproval of the document.

Storage of cereals and pulses — Part 2 : Essential requirements

0 Introduction

The most important factors affecting the storage of grain are :

a) the conditions of the surrounding atmosphere (with daily and seasonal variation in relative humidity and temperature);

b) attack by pests (birds, rodents, insects and mites);

c) attack by micro-organisms (mainly mould fungi);

d) the condition of the storage building and method of handling.

In general, grain changes its condition only slowly while in storage, the extent of the change depending on the ambient conditions. Changes in moisture content and temperature are limited to the periphery of a bulk or to the outer bags of a stack, unless the storage period is prolonged or the grain mass is aerated. Heavy infestations of insects, however, cause a rise in temperature in a grain mass, and the temperature gradients produced may cause sufficient migration of moisture to cause mould damage, sprouting and damage by enzymic and chemical action. Mould development also causes grain to heat. The question of pests and their control is dealt with in ISO 6322/3.

It is therefore important when storing grain to put sound, dry[1], clean, uninfested material into a sound, clean and uninfested storage container and to prevent subsequent deterioration by keeping it as cool and dry as possible.

Grain may be stored either in the open or in a specially constructed building or other container. The choice of the method of storage is often dictated by harvest and transport conditions, labour and materials available, cost, duration of storage and other factors.

A distinction should be made between grain stored in sacks and grain stored in bulk. Furthermore, for bulk grain there is a difference between grain stored in heaps in buildings, where it has a larger surface area exposed in relation to its volume, and grain stored in silos, where it has a smaller surface area exposed in relation to its volume.

1 Scope and field of application

This part of ISO 6322 gives guidance on the choice of a method of storage of cereals and pulses and on the essential requirements for good storage, according to the method chosen. Other aspects of the storage of cereals and pulses are dealt with in ISO 6322/1 and ISO 6322/3.

2 References

ISO 6322/1, *Storage of cereals and pulses — Part 1 : General considerations in keeping cereals.*

ISO 6322/3, *Storage of cereals and pulses — Part 3 : Control of attack by vertebrate and invertebrate animals.*

3 Handling

Any storage system requires a means for moving the commodity into and out of the store. The means should be selected to minimize damage to or deterioration of the grain and the storage containers, and, as far as is practicable, should suppress dust.

4 Storage in the open

4.1 General

Storage in the open is the cheapest but the least satisfactory method. There is great danger of attack by birds, rodents, insects and mites (see ISO 6322/3), of attack by fungi, of damage by bad weather, of theft, of mechanical damage to bags and of other mishaps. Generally, such storage should be for short periods only.

4.2 Uncovered storage

Uncovered storage is less undesirable in dry countries, where a short, sharp shower will affect only the surface (to a depth of about 2 cm) and subsequent sunshine will dry out the grain again. Such exposure, however, may result in damage by

1) Except for special methods of storage (see clause 7).

"bleaching". Storage under snow is also practicable because the low temperature restricts insect and mould development. Even so, a few toxin-producing fungi can grow at near-freezing temperatures on grain wetted by the snow, and therefore great care is needed if this method of storage is used.

Storage in the open may be :

a) on the ground itself, in sacks or in bulk (storage of the unthreshed crop in stooks or ricks is becoming less common);

b) on a "hard standing" or other prepared surface, in which the incorporation of a water-vapour barrier is desirable.

With bulk grain, artificial ventilation of the heaps is sometimes desirable but not always practicable.

4.3 Covered storage

Sometimes, a temporary roof, for instance of corrugated iron on a wooden frame, may be erected over a stack of bagged grain or a heap of bulk grain; "walls" of hessian curtains may be used to give additional protection against the weather.

Heaps of grain may be covered with waterproof sheets, or straw and earth or both.

Unthreshed maize is commonly stored in open-sided cribs, for example with wire-mesh sides, to allow drying to take place where atmospheric conditions are favourable. Maize on the cob can be stored relatively easily and safely, as it has not suffered mechanical damage due to threshing. Special attention should be given to protecting maize from birds and rodents (see ISO 6322/3).

5 Storage in specially constructed buildings other than silos

5.1 General

The objectives of putting grain in buildings are protection from the weather, prevention of the entry of pests, and security. Ideally, such storage should permit some control of temperature and humidity, to keep the grain as cool, as dry and at as uniform a temperature as possible. The structure should be properly built to provide good storage conditions and should not provide harbourage for pests.

5.2 Construction of the building

5.2.1 Site and foundations

The orientation should be such that radiant heat gain from the sun is minimal, i.e. with the long axis north-south in the temperate zone, and with the long axis east-west in the tropics. The foundations should be of adequate strength to take the weight of the building and of the grain filling, and should be termite-proofed where necessary. The surroundings should be kept clear of vegetation, rubbish, flooding or water logging, etc. There should be direct access for appropriate forms of transport.

5.2.2 Floor

The floor should be sound, smooth, hard and water-vapour proof. "Tamped" earth is not recommended. A wooden floor has cracks and crevices which can harbour rubbish and insects and mites. A smooth and hard surface usually means concrete of good quality treated with a hardener to prevent dust. A coved construction at the walls makes cleaning easier. The water-vapour barrier should be carried through to the damp-proof course in the walls; usually it is "sandwiched" in the concrete.

5.2.3 Walls

The walls should be sound and smooth, and, if permitted by local regulations, light in colour (or with a highly reflective surface) on the outside to reduce the absorption of heat. In tropical countries, some insulation may be desirable. The construction should avoid having "dead spaces", and the interior plastering should be free from cracks. Walls of buildings are commonly made of timber (not recommended), clay bricks or blocks, asbestos-cement, galvanized iron, aluminium, bricks or masonry, poured-on-site concrete or reinforced concrete.

5.2.4 Roof

The roof should be sound, and, if permitted by local regulations, light in colour (or with a highly reflective surface) on the outside. It should be free from girders (a "shell" construction is ideal), and supporting pillars should be avoided as much as possible. If the roof is flat, it should have a slight (about 3 %) slope, so that rainwater runs off. In the tropics a pitched roof with wide eaves helps in insulation. The roof should be a good thermal insulator, not affected by condensation, and immune to attack by birds, rodents, insects, mites and moulds; it should not provide harbourage for insects and mites. An internal ceiling can give improved thermal insulation but should permit access to the intervening spaces, which may provide harbourage for pests. Roofing materials include tiles, slates, asbestos-cement tiles, bitumenized felt, galvanized iron or aluminium sheet, corrugated asbestos-cement sheets and rendered concrete.

All drain-pipes from roof gutters should be external; it is bad practice to have pipes running down the insides of buildings, as they act as a harbourage for insects and mites and as runways for rodents, and if defective can allow rainwater to damage the grain.

5.2.5 Doors and windows

Ventilation should be controllable. In a nearly full building, the grain itself largely controls the conditions in the store. "Natural" ventilation is not always desirable, as it may let in moist air. To obtain maximum coolness some ventilation may, however, be required, at a suitable time of day. This can be helped by the shade of trees, shading windows by canopies, provision of wide eaves, etc.

Gaps at the eaves should be avoided, especially where the prevailing relative humidity is high.

Doors and windows should be kept to a minimum, and they should be left open as little as possible. Roof lights are useful, but they should be small in number and size.

5.2.6 Proofing

The building should be proofed as far as possible against the entry of insects, rodents, birds and bats, and should be sealable for fumigation.

5.3 Storage of bagged produce in buildings

5.3.1 Cleanliness

Tidiness and good hygiene are essential, and routine cleaning is imperative.

5.3.2 Provision of spacers

The provision of proper spacers is important. The main function of spacers is to permit ventilation, to avoid local cooling and moisture migration leading to condensation, as much as to prevent "rising damp" from a badly constructed floor. It is desirable that spacers should be of standard pallets[1], of manageable size, and therefore easy to lift, treat with pesticides and stack neatly when not in use.

5.3.3 Stacking

Stacking should be by a good bonded system such that, firstly, the stacks are neat, well constructed and mechanically strong, and, secondly, pesticidal treatment is possible. Stacking around pillars or against walls should be avoided, as this makes inspection and treatment by fumigation more difficult. Gangways should be wide enough to allow proper inspection and spraying. The retention of impermeable sheets after fumigation prevents re-infestation but is not advised for stacks which have become heated, because of condensation problems resulting from moisture migration as the stack cools.

5.4 Bulk storage in buildings

5.4.1 Storage may be within bulkheads, which can be of bags, or within specially constructed grain-retaining walls. Sufficient space should be left for inspection and treatment.

5.4.2 In some stores, there is a bulk filling to the walls of the building, which, like the bulkheads, should be strong enough to withstand the lateral pressure of the grain.

5.4.3 In all bulks there is the danger of temperature gradients developing, leading to moisture migration and possible mould growth, especially in the 5 to 20 cm layer at the surface and against the walls and floor. This can be overcome by an aeration system for artificial ventilation through the bulk (see 7.2).

5.4.4 Bulk horizontal storage is cheap. There may, however, be difficulties in handling and application of pest control, although developments in mechanical handling and pneumatic machinery have overcome many of the problems formerly encountered.

6 Silo storage

The storage units may vary in size from small bins with a capacity of a few kilograms to large installations of many silo bins holding up to several hundred tonnes each. Large silos for storage are convenient but costly to install. The large port or terminal silos are really handling installations and are uneconomic for long-term storage. For storage, the main requirement is simplicity, with the minimum of machinery, and mass-produced unit systems are ideal.

Materials used for construction should be appropriate to the size of the bin, for example :

a) locally available "holding" bins, of small size, may be made of clay, basketwork, etc.; old oil drums may be used;

b) larger bins (more than 10 t) may be made of wood (plain or plywood), brick or concrete (slabs or cast), sheet metal (steel, corrugated iron, aluminium) or metal mesh (lined with hessian, bitumenized paper, polyethylene, polyvinyl chloride, butyl rubber, etc.).

As with other buildings, silos should be designed to be of adequate strength, and should be constructed so that there are no cracks or crevices.

When silos are constructed, fumigation and spraying systems, as well as cleaning and inspection facilities, should form part of the original installation.

Automatic mechanized handling arrangements are not necessary for small farm silos, but they are desirable for large installations.

7 Special systems of storage

7.1 Airtight storage

Storage in airtight structures may be used to control and prevent insect and mite infestations in dry grain and to prevent the growth of moulds in grain that is damp enough to allow their development in open storage. The principle of the method is the same in both applications, namely elimination of the oxygen that insects or moulds require for their growth. This is achieved mainly by the respiration of the organisms, but also by that of the grain. The carbon dioxide produced can also help to kill the pests. Purging with nitrogen, carbon dioxide or other inert gas can speed up the process but is not essential. Airtight storage is very suitable for structures which need relatively simple machinery for filling and emptying. It may be necessary to incorporate sampling facilities in this type of storage for the purpose of quality control, for example grading.

1) See the International Standards prepared by ISO/TC 51, *Pallets for unit load method of materials handling*.

7.1.1 Airtight storage to control insects and mites

Airtight storage is ideally suited to control insect and mite infestations in dry grain, without the use of pesticides. It is particularly applicable to long-term famine reserves in warm countries, where an upper limit for moisture content of 13,5 % (*m/m*) is recommended. Under these conditions there is little change in the properties of the grain, which may be used for almost all purposes, including human food. It might be advisable, however, not to store seed grain in a sealed container for more than one cropping season.

In practice, a moderate initial infestation reduces the concentration of oxygen in an airtight container to about 2 % in 2 to 3 weeks, thus killing the insects. If the re-entry of oxygen, through slight leakage, is then less than about 0,5 % of the free space above the grain plus intergranular air per day, any second-generation insects will be unable to survive, and the infestation will die out. If the leak is greater than this, insects may be able to grow and build up a slight infestation.

7.1.2 Airtight storage to prevent mould growth

Airtight storage to prevent mould growth in damp grain is more suited to temperate countries.

During airtight storage at moisture contents over 16 % (*m/m*), changes in the grain resulting from activity of naturally occurring enzymes may occur. There may also be activity by anaerobic micro-organisms. The grain undergoes certain changes which affect its milling and baking properties, and it suffers a loss in viability. Grain so stored is therefore suitable only for animal feed or industrial use.

For satisfactory storage of such grain, the moisture content of the grain should ideally be in the range 18 to 22 % (*m/m*). Above this, there may be problems of "bridging" and compaction of the rather soft grain. In tall silos at moisture contents above 25 % (*m/m*), a special system of unloading may be necessary.

If the store is not kept satisfactorily airtight, harmful micro-organisms may develop, especially if suitable means are not provided to reduce the entry of oxygen to a minimum.

The dangers can be reduced by careful management, and particularly by ensuring that the silo is empty by the time the temperature rises in the spring, in temperate countries. In tropical countries, where the temperature is at the optimum for mould growth throughout the year, airtight storage is not recommended for grain having moisture contents above 14 % (*m/m*).

7.1.3 Types of airtight stores

Airtight storage may be either below or above ground.

7.1.3.1 Underground stores

Pits have the advantage of providing a more or less even temperature and generally reduce the risk of moisture migration.

A suitable site should be chosen, with a water table below the bottom of the pit for most of the year. The entry of soil water and rainwater should be prevented. The pit walls should be water-vapour proof; concrete should have a bituminous barrier, but smaller pits may be lined with mud, bitumen and straw in combination, polyethylene or similar material. The roof, which may or may not be flexible (for example layers of roofing felt and wire netting), should also be water-vapour proof. The importance of a good, sound construction cannot be overstressed.

7.1.3.2 Above-ground structures

Above-ground bins are being increasingly used in temperate countries, particularly for the storage of high-moisture grain for animal feed. The bins may be constructed of sheet steel, which may be painted, galvanized or vitreous-enamelled; except in France, where a welded construction is common, the plates are usually bolted together against a special mastic. Arrangements for release of pressure, and for emptying with minimum entry of air, are essential. If top unloaders are employed, emptying should be at a predetermined rate to minimize development of toxic micro-organisms in the surface grain.

Portable airtight bins up to 2 500 t capacity may be made by supporting a flexible bag in a metal-mesh cage. The bag is commonly made of butyl rubber, but polyethylene and polyvinyl chloride of adequate thickness, or similar materials, may be used.

Thermal insulation is desirable.

7.2 Cool storage

In the airtight storage system, the grain and its pests largely control the atmospheric environment in the store, but in aerated storage systems the conditions are artificially controlled.

Aeration may be used to keep grain at temperatures below those at which increase in insect and fungal populations may occur.

7.2.1 Aeration with ambient air

By lowering the temperature to below 15 °C, the development of most insects, but not mites, becomes so slow that infestations are prevented. For example, in temperate countries, aeration with ambient air with an airflow of 1,66 to 2,5 l/s (0,1 to 0,15 m^3/min) per cubic metre of grain for a total aeration period of 120 to 170 h, which may be spread over several weeks, is usually adequate. Aeration should be confined to periods when the condition of the air is such that the moisture content of the grain is not raised above the safe level for storage and is kept as low as possible (see ISO 6322/1).

Grain cooling by aeration with ambient air is now a well-established practice in temperate countries, where single bulks of more than 20 000 t are being so treated.

In some farm installations, where the moisture content is above the safe level, rapid mould growth is prevented by aeration, which lowers the temperature of the grain to 5 to 10 °C in 2 to

3 months. At moisture contents over 18 % (m/m), a musty smell may appear after 5 to 6 months, and visible mould growth occurs on about 2 % of the grains when the moisture content is above 20 to 21 % (m/m) if the outside temperature is favourable. If the moisture content is above the safe level, continuous ventilation at a higher rate may achieve a slow drying during storage.

If the moisture content of the grain is above 17 % (m/m), the viability will be affected. Only temperatures close to freezing can prevent mite infestation, if the moisture content is above the safe level for normal storage.

7.2.2 Chilling with refrigerated air

This is a more severe process. The grain has to be brought to the desired temperature within a few days if mould damage is to be prevented. This temperature depends on the moisture content, and should not be higher than 5 °C for a grain moisture content of 20 % (m/m), the maximum recommended for chilled storage. Although mould growth is largely inhibited, mite infestation can develop slowly under such conditions.

In temperate climates, the advantages of chilling with refrigerated air as opposed to aeration with ambient air are marginal. Chilled storage of high-moisture grain is not practicable in tropical countries, although it may be feasible to use some refrigeration to lower the temperature of a bulk of dry grain to the level (15 °C) needed to control most species of insects.

8 Storage during transport

8.1 Short-term transport

Short-term transport is usually by road, rail or in lighters or barges. The grain may be held in the vehicle itself or in a transportable container.[1] The unit amount of grain carried is comparatively small. The vehicles and the containers should be clean, dry and free of undesirable odours and of infestation. Wetting by any form of precipitation should be prevented.

If the produce is unexpectedly held in vehicles or containers for prolonged periods, infestations may become a problem, and if the moisture content is excessive, microbiological activity may also be significant.

8.2 Long-term transport : general problems

Long-term transport is usually carried out by sea. Normal voyages can extend to a period of 4 to 6 weeks but may be prolonged by breakdown of the ship's engines, etc. In addition, there may be delays in the discharge of cargo due to port congestion, after the voyage has been completed. In certain ports, delays of several weeks are not uncommon and delays of up to 6 months have occurred. Such delays are particularly dangerous in ports in warm countries.

Cereals and pulses may be carried either in bags or in bulk, the latter form being the principal method for the carriage of cereals at the present time. Pulses are still mainly carried in bags. Many bagged commodities, and some bulk cereals, are carried in dry cargo containers.

In general terms, ships' holds may be considered as warehouses or silos. The same principles of storage should be applied as have been outlined in the previous clauses. Hence it is necessary to ensure that the cargo space is clean, dry and free from infestation before loading. Any bags used, for example to stabilize the cargo, should also be clean and free from infestation by insects and mites. The cargo itself should have a low level of infestation. Various exporting countries employ differing criteria for acceptable levels of infestation in export cargoes. Where regulations are laid down, cargoes of cereals or pulses should conform to these regulations. Where such regulations do not exist, two living adult stored-grain insects per kilogram should be the maximum level of infestation (see ISO 6322/3). The detection and measurement of hidden infestation within grain is also desirable (an International Standard on this subject is in preparation).

The cargo should be at a sufficiently low moisture content at the loading temperature to prevent the occurrence of significant microbiological activity prior to discharge. To ensure this situation, it is preferable to apply the criteria discussed in ISO 6322/1. However, for short voyages, cereals and pulses may be successfully shipped at moisture contents slightly above the maxima permissible for products which are to be stored for long periods. The tolerance acceptable is dependent on the conditions of the voyage, quantity of cargo carried in each cargo compartment, etc. The moisture content of the cargo may have to conform to regulations of the importing country or to the terms of commercial contracts.

8.3 Problems relating to shipping

Other factors occur in shipping such cargoes, which are not met with, or are less significant, in land storage.

8.3.1 Stowage

In loading a ship, it is necessary to consider not only the best method of protecting the cargo from damage, but also the safety of the vessel during the voyage. The latter requirement is paramount and thus a vessel may be stowed in such a way that under certain circumstances cargo damage could result, when this might have been avoided if the stowage were different. As an example, shipping regulations of countries adhering to the International Conference on Safety of Life at Sea require that bulk cereal cargo is stowed up into the hatch coamings which will act as feeders. This is to prevent cargo movement in the holds. However, such a stowage may result in the grain adjacent to the coamings being wetted as a result of moisture migration and condensation against the inside of the coamings.

1) See the International Standards prepared by ISO/TC 104, *Freight containers*.

Shipping regulations are strictly a nautical matter and are complex. Certain exporting countries require ships to be loaded in compliance with their own regulations, whilst others require loadings to be carried out in accordance with the regulations of the country of registration of the vessel. Generally speaking, however, all nautical regulations are either similar to or identical with those stated in the report "International Conference on Safety of Life at Sea 1960", published by the Inter-Governmental Maritime Consultative Organization, London. Frequently, cargoes are inspected during loading, by port authorities or marine surveyors to ensure that the quality of the produce is as stated or to ensure that the loaded ship is seaworthy.

8.3.2 Temperature changes and moisture migration

When cereals and pulses are carried in ships' holds, environmental temperatures of the sea water and external atmosphere can change quite rapidly. This in turn gives rise to changes in the temperature of the cargo on the periphery of the stow and hence moisture migration from the warmer to the cooler zones of the cargo. Temperature changes in the bulk, however, are quite slow.

Moisture migration can be very substantial, but is less in bulk grain than with other products; different commodities vary considerably in this regard.

Extraneous heat from ships' sources, such as engine-room bulkheads, steam pipes and fuel-tank tops, can cause moisture migration and encourage infestation which may lead to spontaneous heating.

NOTE — More detailed consideration of this aspect is contained in ISO 6322/3.

It is normal practice to insulate such sources of heat, wooden sheathings being used to cover bulkheads and tank tops, and various types of insulation being used on hot pipes.

8.3.3 Ventilation

Ventilation is considered by some authorities to be useful in minimizing damage resulting from moisture migration. However, virtually all vessels carrying cereals and pulses are equipped only with surface ventilation, which cannot be used to dry or cool a cargo. Hence ventilation can only be effective in minimizing surface damage. Even this function has been questioned in recent years on various grounds, and recent statistics indicate that bulk grain is best carried in tankers with no ventilating capacity.

When ventilation is practised, it should be carried out so that the dew point of the ventilating atmosphere is less than that of the atmosphere in the top layers and immediate vicinity of the cargo. Otherwise moisture from the ventilating air is absorbed by the cargo. In certain vessels special equipment is fitted to dry the ventilating air, but in most the air used is drawn from the external atmosphere. In these vessels it is essential that ventilation should be stopped if the dew point of the external atmosphere is too high.

With bulk stowage and complete loads, it is necessary for stability reasons to stow up into the deckhead beams, which severely restricts the airflow over the surface and hence the surface ventilation. Furthermore, unless bagged cargo is used to top off the centre of the stow, cargo has to be loaded into the hatch coamings which act as feeders. This further restricts surface ventilation.