INTERNATIONAL STANDARD

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Second edition
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Storage of cereals and pulses —

Part 2: Practical recommendations

Stockage des céréales et des légumineuses —

Partie 2: Recommandations pratiques

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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.

Attention is drawn to the possibility that some of the elements of this part of ISO 6322 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 6322-2 was prepared by Technical Committee ISO/TC 34, A*gricultural food products*, Subcommittee SC 4, *Cereals and pulses*.

This second edition cancels and replaces the first edition (ISO 6322-2:1981), which has been technically revised.

ISO 6322 consists of the following parts, under the general title *Storage of cereals and pulses*:

— *Part 1: General recommendations for the keeping of cereals*

— *Part 2: Practical recommendations*

— *Part 3: Control of attack by pests*

Introduction

The most important factors affecting the storage of grain are:

a) initial grain temperature and moisture content;

b) condition of the ambient air (with daily and seasonal variations in relative humidity and temperature);

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

d) attack by microorganisms (mainly moulds);

e) condition of the storage building and the means and methods of handling.

In general, the condition of grain changes slowly while in storage; the extent of any change depends on ambient conditions at harvest. 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 is ventilated. Heavy infestations of insects, however, may cause a rise in temperature in the grain mass, possibly due to the development of fungi. The temperature gradients produced may cause sufficient migration of moisture to cause damage; i.e. sprouting and damage by enzymatic and chemical actions.

It is therefore important that sound, dry, clean grain, free from infestation, is stored in sound, clean storage containers free from infestation and that subsequent deterioration is prevented by keeping the grain as cool and as dry as possible.

Grain may be stored either in the open, or in a specially constructed store or other container. The choice of the method of storage is often dictated by different criteria: the state of the grain at harvest; transport, labour and materials costs; duration of storage; and other technical and economic 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 (flat bottom storage) where it has a larger surface area exposed in relation to its volume, and grain stored in silos (vertical storage), where it has a smaller area exposed in relation to its volume.

Storage of cereals and pulses —

Part 2:
Practical recommendations

1 Scope

This part of ISO 6322 gives guidance on the choice of a method of storage of cereals and pulses, and on the practical recommendations 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 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 6322. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 6322 are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 6322-1, *Storage of cereals and pulses — Part 1: General recommendations for the keeping of cereals.*

ISO 6322-3, *Storage of cereals and pulses — Part 3: Control of attack by pests.*

3 Handling

Any storage system requires a means for moving the commodity into and out of the store. These should be selected to minimize damage to or deterioration of the grain and the storage containers. As far as is practical, these means should limit dust emissions in the building or its immediate environment.

4 Storage in the open

4.1 General

Storage in the open is the cheapest but the least satisfactory method. There is high risk of attack by birds, rodents, insects and mites (see ISO 6322-3), development of fungi, damage by bad weather, theft and other mishaps. Generally, such storage should be for short periods only. Open storage may be used for bumper harvests when other stores are full. It should be in a dry, cool place.

4.2 Uncovered storage

Uncovered storage is less undesirable in dry countries, where a short, sharp shower will only affect the surface (to a depth of up to 5 cm) and subsequent sunshine will dry out the grain again. Such exposure, however, may result in damage by bleaching. Storage under snow or in cold climates 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 should, if possible, be on a "hard standing" surface or another prepared smooth surface, preferably raised 0,5 m above ground level, and featuring an insulating system giving protection against running water and moisture rising from the ground, and allowing a complete removal of the grain.

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

4.3 Covered storage

Sometimes, a temporary roof, for example 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 or tarpaulins may be used to give additional protection against the weather.

Alternatively heaps of grain (bulk or bagged) may be covered with waterproof tarpaulins provided that suitable precautions are taken against sun and consequent sweating. It is good practice to fold back these tarpaulins on dry days to allow any condensed moisture to evaporate. The cover should be tightened by heavy objects (tyre, sandbag, breeze-block, etc.) placed at the foot of heaps.The cover should overlap at least 50 cm taking account of the direction of the dominant wind.

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. It is essential to cover the open-sided cribs, to avoid rain getting into the cereals and to restrict mould growth. 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 (flat stores)

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, easy access and safe working 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 waterproof. "Tamped" earth is not recommended. A wooden floor has cracks and crevices which can harbour rubbish, insects and mites. A smooth and hard surface usually means concrete of good quality treated with a hardener to prevent dust. A walled construction joined to the ground by a curved, smooth profile without projections eases cleaning. The water barrier should be carried through to the damp-proof course in the walls; usually it is "sandwiched" in the concrete.

The foundation of the stock should be constructed above ground level or, where it is downstream, above the highest water level in order to avoid flooding.

5.2.3 Walls

The walls should be sound and smooth, and, if permitted by local regulations, light in colour (usually white) 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 may be constructed of different materials in accordance with local availability and practice: timber (not recommended), clay bricks or blocks, bricks or masonry. They should be covered on the interior with a coating. They can also be in galvanized iron, aluminium, poured-on-site concrete or reinforced concrete. Hollow concrete blocks are not generally recommended (unless filled in) as they can harbour rodents and insects.

It is important that the construction be strong enough to withstand the pressure exerted on the walls by the grain.

5.2.4 Roof

The roof should be sound, waterproof and, if permitted by local regulations, light in colour (usually white) on the outside. Girders and supporting pillars should be avoided as far as possible. Supporting pillars do not present problems on the side of stores, however in the middle they cause obstructions to the loading/unloading, cause grain stacking and decrease the store capacity. Grain shall not be stacked around pillars because of fumigation problems. If the roof is flat, it should have a slight slope so that rainwater runs off. In the tropics a pitched roof with wide eaves helps insulation. The roof should be a good thermal insulator, not affected by condensation, and give protection against attack by pests and moulds. It should be designed so as not to provide harbourage for insects and mites. These measures require attention to the sealing between walls and roof, and protection of all possible openings with a finely meshed grill. An internal ceiling is not advised, as it may provide harbourage for predators. Roofing materials include tiles, slates, bituminized felt and galvanized iron or aluminium sheet.

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. All external water and drain pipes should be fitted with sheet metal rat guards to prevent rats gaining access to the store eaves. Pipes should also have mesh baffles fitted inside their lower open ends.

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. Permanent natural ventilation is not desirable, as it may let in moist air. However, a certain degree of ventilation shall be possible at certain times of day to obtain the required coolness. This coolness can be helped by shading by slatted windows, provision of wide eaves, etc.

Ventilation apertures are vital for the circulation of air. They should be small but suitable for the size of the building and positioned in the upper part of the walls. These apertures should be fitted with an anti-bird grille on the outside and with a mesh on the inside.

A suitable meshed ventilation duct should be placed in each gable so that warm air accumulating under the roof can escape.

Roof lights and windows should be kept to a minimum or avoided. They should be left open as little as possible. Windows should be protected by mesh grilles to keep birds out when the windows are open.

Store doors should close tightly and should, if possible, be made of metal. If they are made of timber, the lower part of both the door and the frame should be covered by a steel strip protecting them against attack by rodents. In certain areas, it is useful to protect them with a canopy against rain.

The number of doors will depend on the required frequency of access to the stored product. The size of the doors depends on loading/unloading operations (e.g. if trucks need to enter the store). The design of loading doors should take into account the difficulties in maintaining them rodent-proof in service.

5.2.6 Proofing

Insofar as possible, every precaution should be taken against the entry of insects, rodents, birds and bats to the building.

When the building needs to be fumigated, it should be sealed. Sealing shall be complete before the store is filled. If the building cannot be sealed, fumigation can be carried out under gas-proof sheeting.

5.3 Storage of bagged produce in buildings

5.3.1 Cleanliness

Cleanliness and good hygiene are essential. The store shall be perfectly sound, i.e. cleaned and treated prior to any storage operation. During storage, frequent cleaning is absolutely essential.

5.3.2 Provision of spacers

The use of spacers (pallets) avoids the sacks being in direct contact with the ground, and is therefore vital when the ground is not perfectly watertight. As a precaution, it is recommended that spacers be used in humid areas. Their main role is to enable ventilation, avoid localized falling temperatures, prevent humidity leading to condensation or rising from a badly constructed floor. It is desirable that spacers be standard pallets, of manageable size, and therefore easy to lift. They should be treated with pesticides and stacked neatly when not in use.

However, in dry areas and when stores have been correctly constructed, it is not essential to use palettes.

5.3.3 Stacking

Stacking should be such that the stacks are geometric, well constructed and mechanically strong so that handling and pesticide treatment are possible. The use of a regular stacking pattern will allow the bags to be easily counted.

Stacking around pillars or against walls should be avoided, as this makes inspection and fumigation difficult, and it can damage the building.

Gangways should be wide enough (at least 1 m) to allow proper inspection and spraying. An inspection walkway shall always be left between stacks and the store walls.

The retention of impermeable sheets after fumigation prevents re-infestation but is not advised because of condensation problems.

5.4 Bulk storage in “flat stores”

5.4.1 Cleanliness

It is essential that the interior of premises and their surroundings and all handling equipment be cleaned and treated with pesticide.

5.4.2 Equipment

Bulk flat storage is a cost-effective solution, but difficulties in handling and application of pest control measures may arise. It is therefore important to provide all equipment required for good storage and quality control: an appropriate handling system, fumigation equipment, sampling equipment, and means for testing the grain temperature.

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

5.4.3 Disposition of the grain

In some stores grain is stored against the walls of the building. These should be strong enough to resist lateral pressure exerted by the grain.

Storage may be between partitions which compensate for the lack of wall strength and enable batches to be separated. These partitions may be made of concrete elements, timber or metal partitions. However, grain handling becomes much more difficult.

It is recommended that a space between the top of the bulk and the roof be left to enable a person to pass to test the grain, if the original construction of the storage does not permit this.

Where a ventilation system can be used, it is recommended that the surface of the bulk be levelled to improve the air movement.

6 Silo storage

According to the level of technical development of the country, different containers may be used.

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 in excess of 1 000 tonnes each. These large grain silos are convenient but costly to install. The large terminal silos at ports are really handling installations and are not cost-effective for long-term storage. For storage, the main requirement is simplicity, with the minimum of mechanization, and mass-produced unit systems are ideal.

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

a) in the tropics, locally available "holding" bins may be made of clay, basketwork, etc.; old oil drums may be used, after thorough cleaning;

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, bituminized paper, polyethylene, polyvinyl chloride, butyl rubber, etc.);

c) very large silos may be made of corrugated steel or cast concrete.

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.

Fumigation facilities, and cleaning, sampling, temperature control and monitoring, as well as ventilation systems, should be included when the installation plans are drawn up. Some of the bin constructions in b) above cannot be fumigated unless completely covered by gas-proof sheeting.

Whilst automatic mechanized handling arrangements are not necessary for small silos, they are desirable for large installations.

7 Special systems of storage

7.1 Airtight storage

7.1.1 General

Storage in airtight structures may be used to control and to prevent insect and mite infestations in dry grain and prevent development of moulds in grain which is too damp. 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 result is achieved mainly by allowing the respiration of the grain and of other organisms. Purging with nitrogen, carbon dioxide or other inert gases can speed up the process but is not essential, and can be difficult in practice.

NOTE Killing insects in a commodity depends on the concentration of carbon dioxide (CO_2) used. With a concentration of CO_2 of more than 35 % over a period of 10 days, 99 % mortality of insects has been achieved.

In practice, grain respiration will reduce the concentration of oxygen in an airtight container to about 2 % over a period of between several days and 3 weeks, thus killing insects which were initially present. If the re-entry of oxygen per day, through slight leakage, is less than about 0,5 % of the free space above the grain, including intergranular air, 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.

Airtight storage is ideally suited to control insect and mite infestations in dry grain, without the use of pesticides. It is particularly suitable for long-term famine reserves in warm countries, where an upper limit for moisture content of 13,5 % (wet mass basis) 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 consumption. It is advisable, however, not to store seed grain in a sealed container for more than one cropping season.

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 of grain with a moisture content greater than 16 % (wet mass basis), changes resulting from the activity of naturally occurring enzymes may occur. There may also be activity of semi-anaerobic micro-organisms. The grain undergoes certain changes which affect its milling and baking properties, leading to subsequent unsuitability for these commercial uses.

If humid grain is stored in an airtight artificial housing, the moisture content of the grain should ideally be in the range 18 % to 22 % (wet mass basis). Above this value, problems relating to grain coagulation and compaction arise to such a point that at moisture contents above 25 % (wet mass basis) a special unloading system is required.

If air tightness is not sufficient, harmful microorganisms may develop, especially if suitable means are not available to reduce the entry of oxygen to a minimum.

7.1.3 Types of airtight stores

7.1.3.1 Underground stores

These have the advantage of ensuring a relatively stable temperature, thus avoiding risks of moisture migration.

The site should be chosen with care in order that the water table is below the bottom of the store. Ground water and rain water should not be able to enter. The walls of the store should be watertight; the concrete may be covered with a protective layer. The roof should be watertight.

7.1.3.2 Above-ground structures

Above-ground silos are also used for the storage of high-moisture grain. The silos may be constructed of sheet steel, which may be painted, galvanized or vitreous-enamelled. The plates are usually bolted together against a special mastic. Arrangements for the release of pressure and for emptying with minimum entry of air are essential. Emptying should be carried out at a predetermined rate to minimize the development of toxic microorganisms in the surface grain.

Airtight silos generally of up to 500 t capacity may be made by supporting a 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.

7.2 Cool storage

7.2.1 General

Ventilation may be used to keep grain at temperatures lower than the limits of development of insects and spread of moulds. To avoid warming during the day, stores should be insulated.

7.2.2 Cooling ventilation with ambient air

By lowering the temperature to below 12 °C, the development of most insects becomes so slow that infestations are prevented. For example, in temperate countries, ventilation with ambient air with an airflow of approximately 1,66 l/s to 5,0 l/s (0,1 m^3/min to 0,3 m^3/min) per cubic metre of grain for a total ventilation period of 50 h to 200 h, which may be spread over several weeks, is usually adequate. Ventilation should be confined to periods when air temperature is 5 °C to 7 °C lower than that of the grain. Grain cooling by ventilation with ambient air is now a well-established practice in temperate countries where single bulks of more than 50 000 t are so treated.

When the moisture content exceeds the safety level, cooling ventilation prevents the growth of moulds as it lowers the temperature of the grain. When the moisture content exceeds 18 % (wet mass basis), a musty smell appears after 2 to 6 months depending on the temperature, and moulds develop.

NOTE In this case, continuous ventilation at a high flow rate (approximately 10 times the volume of that for cooling alone) enables slow drying if the precaution is taken to increase the air temperature by a maximum of 4 °C or 5 °C at night and during periods of rain. However, this technique is only economically viable for stocks which are not piled high and for small quantities.

7.2.3 Chilling with refrigerated air

The grain has to be brought to the desired temperature rapidly if mould and insect damage are to be prevented. This temperature depends on the moisture content and should not be higher than 10 °C for grain with a moisture content of 15 % (wet mass basis). Artificially refrigerated air ventilation enables rapid cooling which will limit the development of insects. This may even kill them and will, in particular, enable grain to keep very well. The energy costs involved can be significant compared with ambient air cooling systems.

8 Storage of grain during transport

8.1 Short-term transport

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

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

8.2 Long-term transport

Long-term transport is usually carried out by sea. Normal voyages can extend to a period of 4 to 6 weeks but may possibly 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. Many voyages involve movement between different climates. There is, therefore, a danger of moisture movement within the cargo due to heating or cooling during transport.

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, the hold of a ship may be considered as a store or silo. The same storage principles should be applied as have been outlined in the previous clauses. Hence it is necessary to ensure that the cargo hold is clean, dry and free from infestation before loading. In addition any bags used, for example, to stabilize the cargo, should also be clean and free from infestation by insects and mites. No infestation of the cargo itself should be detectable, except if fumigation is provided for in transit. Various exporting countries employ differing criteria for acceptable levels of infestation in export cargoes due to be fumigated in transit. Where regulations are laid down, cargoes of cereals or pulses should conform to these regulations. Where such regulations do not exist, two living adult insects

per kilogram of stored grain should be the maximum level of infestation (see ISO 6322-3). The detection and measurement of hidden infestation within grain is also desirable.

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, the recommendations given in ISO 6322-1 shall be considered. 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 depends on the conditions of the voyage, the 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 Particular problems relating to shipping

NOTE The technical considerations given above are valid but particular factors occur in shipping cargoes.

8.3.1 Temperature variations and moisture migration

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. This is a particular problem when sailing from one climate to another; changing external temperatures can lead to moisture migration.

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 or identical to those stated in the report "International Conference on Safety of life at Sea 1960", published by the International Maritime Organization (IMO), 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 Fumigation in transit

CAUTION — Fumigation should only be performed by an accredited company as the fumigant gases are highly toxic to all animals.

Bulk transport in ships or "carriers" which do not feature a ventilation device is the most frequently used method of transport.

A ventilation system is only advantageous if it is designed at the same time as the fitting-out of the ship's hold, so as to be used to clear gas from the hold before the cargo arrives at its destination, when the latter has been fumigated during transit.

In order for this fumigation operation to be possible, it is necessary that gas can be introduced into different points of the hold, particularly at floor level. Rigid conduits designed to withstand the pressure exerted by the grain may be fitted at the bottom of the hold with exhaust pipes against its walls for connection to the gas extraction system. Fumigation of vessels in transit (at sea) shall comply with IMO Regulations.

Bibliography

[1] ISO 6639-1, *Cereals and pulses — Determination of hidden insect infestation — Part 1: General principles.*

[2] ISO 6639-2, *Cereals and pulses — Determination of hidden insect infestation — Part 2: Sampling.*

[3] ISO 6639-3, *Cereals and pulses — Determination of hidden insect infestation — Part 3: Reference method.*

[4] ISO 6639-4, *Cereals and pulses — Determination of hidden insect infestation — Part 3: Rapid methods.*

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