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HEATED-AIR GRAIN DRYERS

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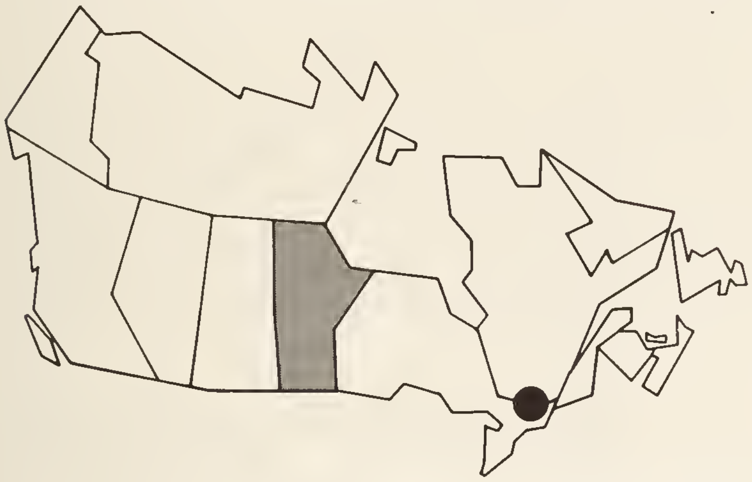

CANADA/MANITOBA

HEATED-AIR GRAIN DRYERS

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Contents

HEATED-AIR GRAIN DRYERS

This publication discusses the principles and problems of heated-air grain drying, and the characteristics of common types of grain dryers. It does not give specific operating instructions for different makes and models of dryers. Operating instructions and information on specific control and safety features are contained in the operator's manual. Read the manual carefully, and make sure the dryer meets all required federal and provincial safety standards. The dryer should have either Canadian Standards Association (CSA) or Canadian Gas Association (CGA) approval, or a special acceptance from your provincial department of labor.

ADVANTAGES OF GRAIN DRYING

Grain drying has become more common across the Canadian prairies. Instead of drying only during very wet harvest seasons, many farmers now use a dryer as part of their normal grain-harvesting system. There are a number of advantages to doing this:

Longer Harvest Season—Extra hours of harvesting in the morning and evening of each day and several extra harvest days each year are possible when a grain dryer is used. The number of available harvesting hours is increased substantially in most areas, which could reduce the overall investment in machinery. A smaller combine plus a dryer could be used instead of buying a second combine or trading up to a large one. For a farmer relying on custom harvesting, a grain dryer can be helpful in getting his harvesting done early. In any case, every combine can be used to harvest more grain if a dryer is included in the harvesting system.

Earlier Harvesting—Earlier harvesting is possible when a grain dryer is used. Wheat, oats and barley can be threshed at 20% moisture content (MC) and then dried without loss of quality, grade or germination. When compared with harvesting at 14%, there may be a difference of only 1 or 2 days in mid-August, but by mid-September it may be 4 days or more. If a wet spell occurs, the differences could be much greater. Early harvesting may allow a farmer to harvest nearer to the maximum 'dry' moisture content, which results in the highest weight of grain for sale. Harvesting early also allows a farmer to do a better job of weed control through timely chemical application and tillage practices.

Reduced Field Losses—Weather damage and losses caused by wildlife can be reduced by harvesting at the tough[1] or damp[2] stages. A loss of one grade may mean a 5% loss in price and a 5% loss in weight, for a total loss of 10%. Harvesting before, instead of after, a rainy spell can therefore result in a considerable saving. Overdrying of crops in the field, which leads to shattering and crop loss, can also be prevented by earlier harvesting. Straight combining of some crops, such as sunflowers and corn, is a necessity and if these crops are harvested damp, field losses are greatly reduced. A dryer in the system may also make it feasible to straight combine other crops. Replacing a windrower with a dryer is therefore an alternative that should be considered.

Eliminate Spoilage in Storage—When tough or damp grain is harvested and not dried, long-term storage frequently results in grain spoilage. Moisture migration within grain bins can make slightly tough or even dry grain unsuitable for storage. Spoilage problems caused by hot spots and insect infestations can be reduced or eliminated by proper drying and aeration in storage.

The initial cost of a grain dryer is one of the major deterrents to grain drying. Where only small amounts of grain are to be dried each year, the initial cost of the dryer should be a primary consideration (see *Drying Costs*). Where large amounts of grain are dried, fuel efficiency becomes a more important factor.

The labor and inconvenience of drying are also deterrents on many farms where no centralized grain-storage facility exists. To obtain maximum benefits from a grain dryer, it is necessary to set up a well-organized system for grain handling and storage.

Because of climatic variations, not all areas have the same need for grain dryers. Figure 1 shows prairie areas of equal net evaporation for the month of September. This is based on long-term data obtained from the Atmospheric Environment Service, Environment Canada. Values for individual years may vary slightly from the long-term averages. The physical features of an area, such as lakes, hills and woods, may also cause notable variations from the general pattern. In general, however, the need for grain drying on the prairies increases from the southwest to the northeast. In the driest areas, a dryer may be needed only 1 year in 10 for wheat, oats and barley, while in the northernmost areas it could be needed as often as 9 out of 10 years. If grain corn is grown for commercial sale, a dryer is essential in all areas. Sunflowers, rapeseed, and several other crops should also be harvested damp every year in order to minimize field and harvesting losses.

[1] Tough = MC values between those given in Table 1 and 17% for cereal grains or 13% for oilseeds
[2] Damp = MC above 17% for grains and above 13% for oilseeds

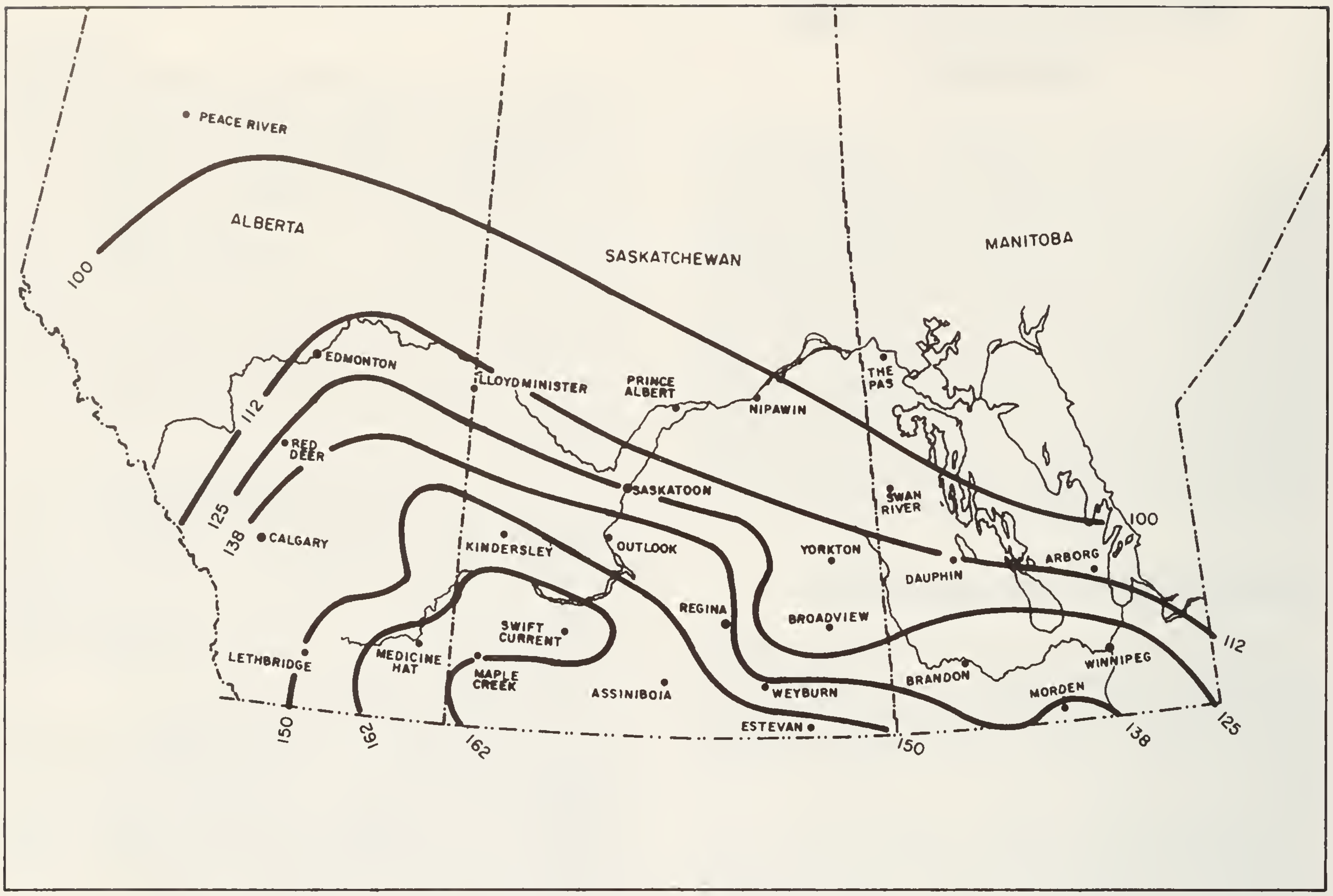


Figure 1. Long-term average net evaporation (mm) during September.

GRAIN MOISTURE RELATIONSHIPS

Maximum Storage Times for Damp Grain

The length of time that damp grain can be stored before drying depends on the grain temperature and moisture content. Figures 2, 3 and 4 give estimated allowable times for various crops and conditions. It should be noted that when heating starts, spoilage due to mold growth and insect infestation proceeds rapidly. Therefore, the temperature of damp grain must be monitored closely to ensure safe storage, even when air temperatures are well below 0°C.

Maximum Storage Moisture Contents

Maximum moisture contents for safe storage over the first winter are shown in Table 1.

Grain put into a bin on a hot day or grain containing green material could heat even at the moisture levels given in Table 1. Longer-term storage or processing of special crops may require lower moisture contents than those shown.

Moisture Migration

Grain that is placed in storage at or near the maximum 'safe' moisture content may develop localized high-moisture zones because of moisture migration. This is caused by changes in outdoor air temperatures which set up convection air currents in the bin (Figure 5). This may lead to grain spoilage near the top center of the bin in winter, or near the bottom center in summer. Moisture migration is more severe if the grain is hot when binned, and if the grain is stored in large bins. An aeration system can prevent these problems by maintaining a uniform temperature and moisture content throughout the bin. Any bin to be used for cooling grain or any bin of 100 m^3 or larger should be equipped with an aeration system (see *Aeration*).

Moisture Testers

There are various types of moisture testers on the market, with widely varying degrees of accuracy and repeatability. Some of them are reasonably accurate only near the 'dry' range and become progressively more inaccurate as the moisture content increases. Some are quite accurate for one type of grain and very inaccurate for others. A few are very accurate for most grains, and for a wide range of moisture contents. Detailed information on various testers is available from the Prairie Agricultural Machinery Institute, Humboldt, Sask., and the Canadian Grain Commission, Winnipeg, Man.

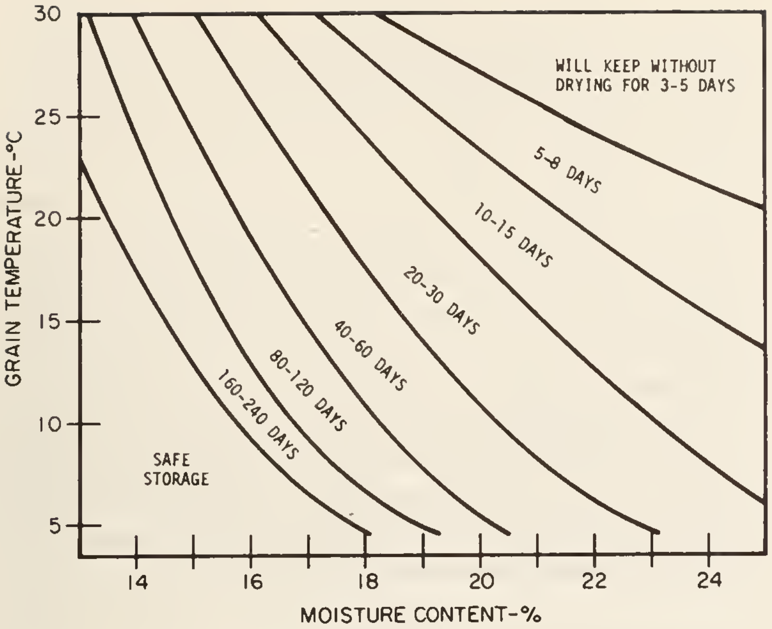


Figure 2. Effect of temperature and moisture content on allowable storage time of wheat, oats and barley.

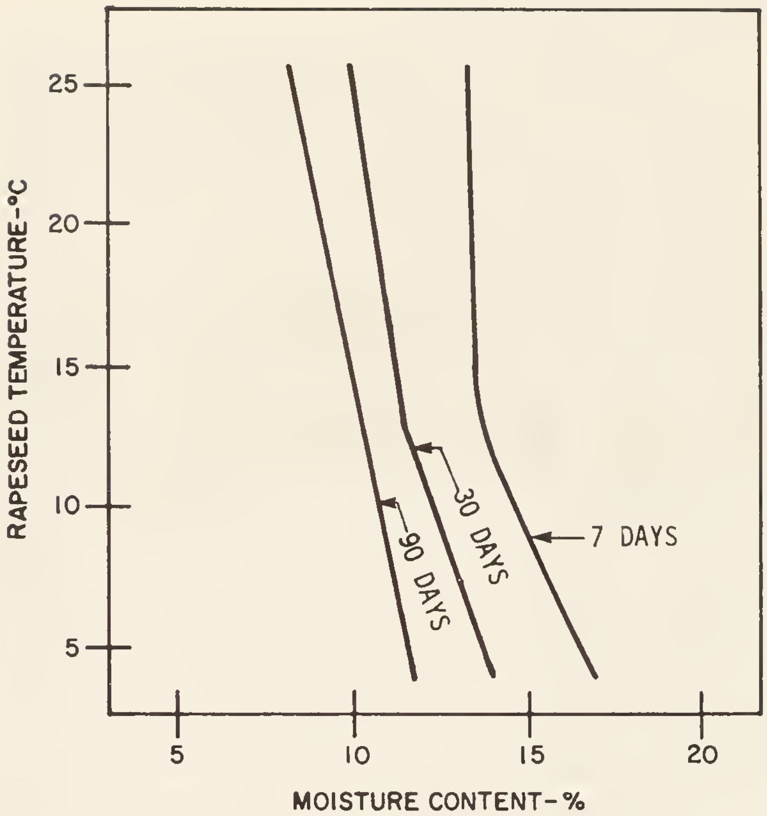


Figure 3. Effect of temperature and moisture content on allowable storage time of continuously ventilated rapeseed.

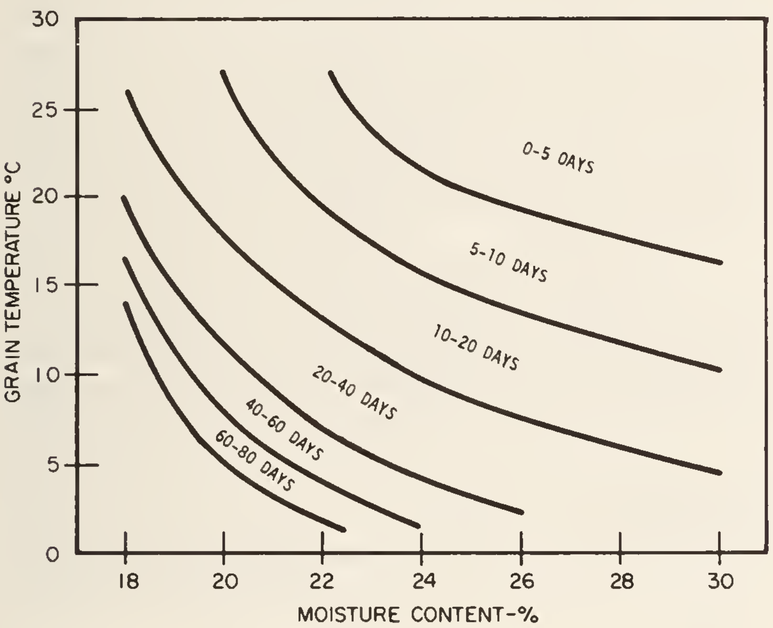


Figure 4. Effect of temperature and moisture content on allowable storage time of corn.

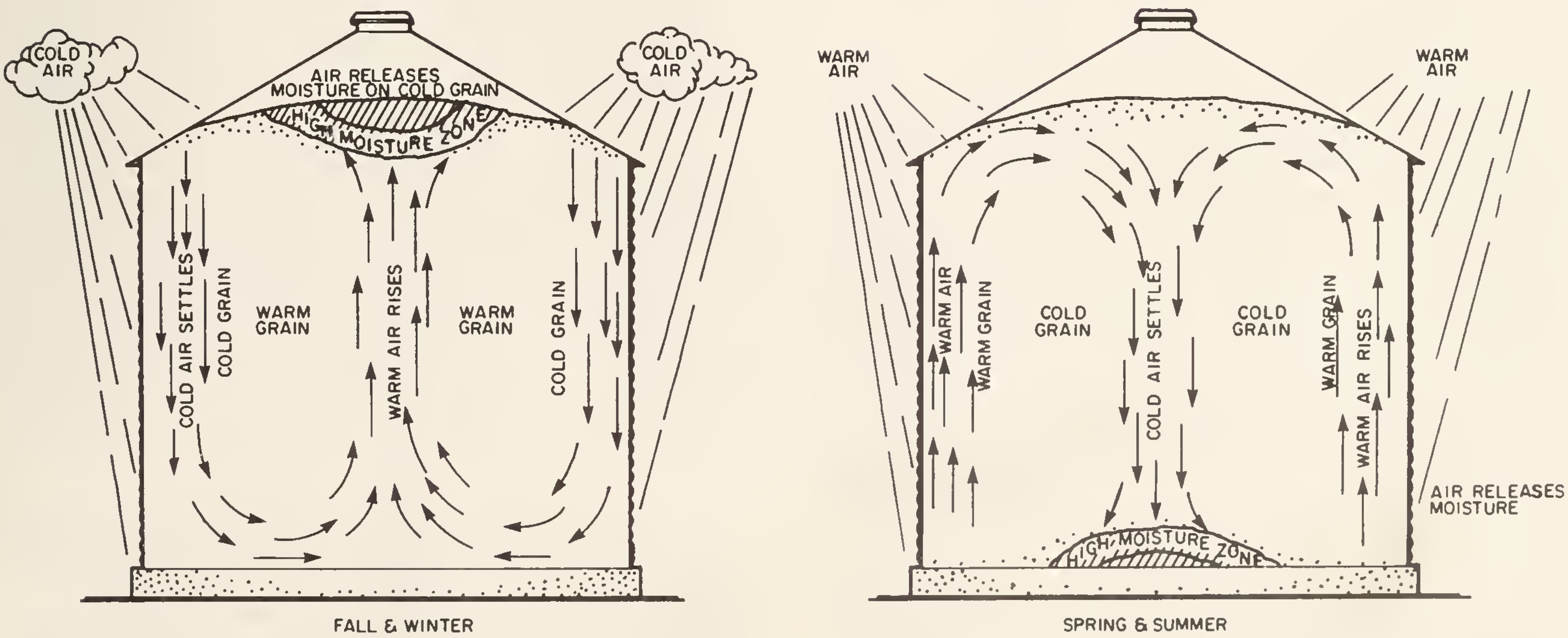


Figure 5. Moisture migration.

Moisture Rebound

When grain is dried rapidly (for example, a 6% drop in 2 hours or less) in a heated-air dryer, it is common to experience a moisture rebound. Grain coming out of the dryer may test dry, but after a few days of storage it may test 1% or even 1.5% higher. This is caused by the difference in moisture content within the grain kernels and the type of tester used. The outer part of the kernel dries faster and gives a lower moisture reading immediately after drying. When the moisture content becomes uniform, the tester will give a somewhat higher reading than it did earlier. Problems of this nature are usually solved by initially overdrying the grain by about 1%. Extreme care should be taken to not overdry the grain in total. The lower the moisture content, the more susceptible is the grain to heat damage. Also, overdrying requires more time and fuel, and results in an unnecessary loss in grain weight. Overdrying by 2% means a loss of 2.5% in weight and sale value.

When testing hot grain from a dryer, the sample should be placed immediately in a plastic bag to prevent moisture loss, and it should be allowed to cool to ambient temperature before testing.

WEATHER EFFECTS ON DRYING

Relative Humidity

Natural drying of grain occurs when the relative humidity (RH) of the air is below the equilibrium moisture content of the grain. When the relative humidity is above the equilibrium level, the grain takes on moisture. The approximate equilibrium moisture contents for cereal grains and oilseeds are given in Table 2.

If unheated air is used for drying, the RH of the air has a substantial effect on the drying rate. However, when air is heated the RH drops rapidly, and if the air is heated 30°C or more, the initial RH can be practically ignored. Air at 15°C and 100% RH, when heated to 65°C, will have only 7% RH. Even if 15°C air is heated to only 45°C, the RH will not be over 20%. Only when fairly high initial air temperatures (over 20°C) are combined with high RH and low drying temperatures (below 40°C) does the RH act as a noticeable deterrent to drying.

Wind and Sun

To understand the effects of wind and sun on grain drying, it is necessary to understand the operation of the dryer controls. With most continuous-flow dryers and batch dryers with automatic shut-offs, the drying time is regulated by a thermostat located near the outside of the grain column. When the grain temperature reaches the preset value, the unloading mechanism is started, or in a batch dryer the heat is shut off.

Unshielded thermostats located on the outside of a dryer can be affected by wind or sunshine. A cold wind blowing against the thermostat will delay its activation and, therefore, can cause overdrying at a setting that was previously satisfactory. In a

TABLE 1. MAXIMUM STORAGE MOISTURE CONTENTS

Wheat	14.5%	Rapeseed	8.5%
Barley	14.8	Corn	15.5
Oats	14.0	Peas	16.0
Rye	14.0	Sunflowers	9.5
Flax	10.5	Mustard	11.0
Buckwheat	16.0	Canary seed	12.0

TABLE 2. EQUILIBRIUM MOISTURE CONTENT OF CEREAL GRAINS AND OILSEEDS

Relative humidity of air	Cereal grains		Oilseeds	
	at 25°C	at 10°C	at 25°C	at 10°C
58%	12%	13%	7.5%	8.5%
65	13	14	8.4	9.4
71	14	15	9.3	10.3
76	15	16	10.2	11.2
80	16	17	11.2	12.2
83	17	18	12.2	13.2
85	18	19	13.2	14.2

two-column dryer, with each column controlled by its own thermostat, equal settings will result in one grain column moving faster than the other if a wind is blowing against one of them. This is often interpreted to mean that the windward side is drying much slower. However, this is not the case since the pressure created by the wind is insignificant compared with the pressure inside a dryer (dryers frequently operate at a static pressure of 750 — 1000 Pa whereas a 30 km/h wind creates a pressure of only 50 Pa). The column on the windward side can become seriously overdried as a result of the wind's effect on the thermostat, and grain damage is more likely. This can be prevented by (1) shielding the thermostat from the wind; (2) running both discharge augers from the leeward thermostat, or (3) mechanically operating the windward discharge auger at a speed equal to the leeward discharge auger.

The wind itself has little or no detrimental effect on the operation of a dryer and it is not necessary to shield the dryer from the wind. Shielding may, in fact, be detrimental because it may cause moist air to be drawn back into the dryer, and may also increase operator discomfort from swirling moist air and debris. Completely satisfactory drying has been obtained with many dryers operating without shielding in winds up to 50 km/h.

The effect of sunshine striking a thermostat will be the opposite to that caused by the wind. The thermostat on the sunny side will allow a higher grain-flow rate than will the one on the shady side. As wind and sun conditions change, unshielded thermostats may have to be readjusted to prevent underdrying or overdrying. However, the effects of wind and sun on the actual performance of the dryer are insignificant.

Ambient Air Temperatures

Differences in ambient air temperatures have little effect on drying rates if the temperature of the drying air is kept constant. However, the ambient air temperature does have a very significant effect on fuel consumption. Table 3 shows the relative fuel consumption in maintaining a drying temperature of 65°C.

Early fall drying is much less expensive than winter drying and allows a farmer to take advantage of more of the benefits of grain drying. When ambient air temperatures are high, the initial grain temperatures are also high and this further reduces fuel costs and drying times. Some dryers may have insufficient burner capacity to produce high plenum temperatures at very low outdoor temperatures.

MAXIMUM DRYING TEMPERATURES

The rate of grain drying is increased as the temperature of the drying air is raised. However, the grain will be damaged if the temperature is too high. Damage is more likely to occur when the grain is dry or nearly dry. Damp grain remains relatively cool due to the evaporative cooling that occurs when moisture is released. As the grain becomes drier, the moisture release slows down and the grain temperature increases. By the time the grain is dry, it is possible that some of it will have reached the same temperature as the drying air. To prevent grain damage, it is important that the maximum air temperature does not exceed the maximum allowable temperature of the grain being handled. The maximum drying temperatures for various cereal grains and oilseeds are given in Table 4.

The temperatures given in Table 4 are conditional on drying to not more than 1% below the safe storage moisture content (Table 1), and on the removal of not more than 6% moisture in one pass through a high-speed dryer. With dryers where the grain is exposed to heat for long periods (such as in non-recirculating bin dryers), it is advisable to use temperatures 5 — 10°C lower than those listed for commercial use. This is particularly important when drying rapeseed since the oil quality is affected by long exposure to high temperatures.

Air temperatures higher than those shown in Table 4 are safe under some conditions. If the grain is very damp, air temperatures 20°C above those indicated can be used safely during the early drying stages since evaporative cooling keeps grain temperatures low. As the grain approaches the 'tough' stage it is important that the temperatures be reduced to those shown in Table 4, or even lower. This can be done either manually or by the use of timers in any batch dryer. Continuous-flow dryers with the crossflow design (a crossflow dryer is one in which the airflow is perpendicular to the grain flow) and a single heating section should not use temperatures above those given in Table 4. Other types of continuous-flow dryers may be able to use slightly higher temperatures, but the dried grain should be checked for damage.

Temperature Sensing

A common problem in grain drying is inaccurate temperature sensing. Thermometers may become damaged, or sometimes they are improperly located and don't indicate the highest temperature in the air plenum. This often results in damaged grain, even though the temperature reading is within the specified limits. The best insurance against this problem is to use extra thermometers in the hot-air plenum and/or check the temperature of the grain nearest the plenum with a temperature probe. Various types of temperature indicators are available, although gas-filled thermometers are most commonly used in dryers. These may be obtained from dealers selling dryers or from thermometer suppliers in the larger cities.

If grain temperatures are being measured it is very important to know the exact location of the sensing bulb in the grain column. Typical temperature and moisture variations in a stationary batch or continuous-flow dryer are shown in the following

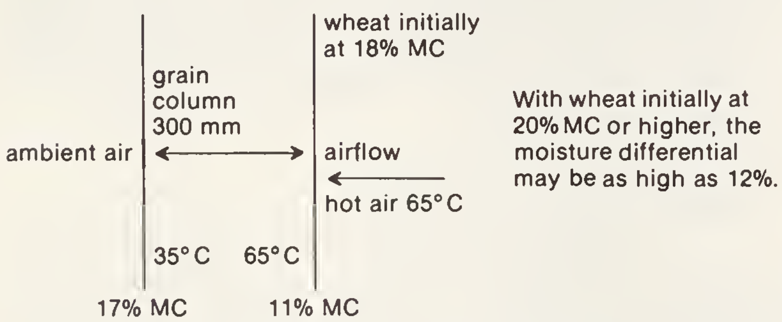
TABLE 3. RELATIVE FUEL CONSUMPTIONS AT VARIOUS AMBIENT TEMPERATURES

Ambient air temperature	Relative fuel consumption
15°C	1
-7°C	1.5
-30°C	2

TABLE 4. MAXIMUM DRYING TEMPERATURES

	Seed or malting	Commercial use	Feed
Wheat	60°C	65°C	80 - 100°C
Oats	50	60	80 - 100
Barley	45	55	80 - 100
Rye	45	60	80 - 100
Corn	45	60	90 - 100
Flax	45	80	80 - 100
Rapeseed	45	65	—
Peas	45	70	80 - 100
Mustard	45	60	—
Sunflowers	45	50	—
Buckwheat	45	45	—

diagram. A temperature-sensing bulb could give a reading of anywhere between 35 and 65°C depending on its location in the grain column.



The temperature and moisture differentials in recirculating batch dryers are normally less than in stationary batch or non-mixing continuous-flow dryers. Lower air speeds (such as obtained with rapeseed or flax) increase the differentials, and higher air speeds reduce them. Since the grain-temperature indicators on dryers may be located at various places across the grain column, these temperature readings should not be taken as indicators of safe drying temperatures.

Testing for Heat Damage

Various tests may be conducted to find the highest acceptable drying temperatures for a particular grain and dryer. If the grain is to be used for seed, a germination test should be used. In addition, a sample of the grain should be taken before drying for testing to help determine whether there was any change in the germination rate during the drying process. Other commercial grains (milling wheat, malting barley and oilseeds) are tested free of charge for heat damage by the Canadian Grain Commission. Two samples (minimum of 500 g each), one taken before and one after drying, should be sent to the Grain Research Laboratory, Canadian Grain Commission, Winnipeg, Man. The samples should be representative of the grain going in and coming out of the dryer. If the grain quality is unchanged, a higher temperature can be tried and two more samples sent in for testing. Several companies that purchase oilseeds, corn, and grain for seed also conduct tests for heat damage. Check with the purchaser at the start of drying to ensure that the dried grain meets their standards.

GRAIN-HANDLING SYSTEMS FOR DRYERS

A convenient grain-handling system is one of the most important factors in grain drying. If drying grain during harvest creates bottlenecks, inconvenience and labor problems, then drying will tend to be used only as an emergency procedure. Many of the potential benefits of drying are lost in such a situation. The grain-handling system should be arranged so that there is an absolute minimum of extra work involved in using the dryer. It should be only a matter of minutes to change back and forth between drying and not drying. The drying and storage system should be set up in such a way that the grain coming from the dryer can be transferred directly to a cooling bin or storage without having to be loaded into a truck. All large storage bins should have aeration systems to help ensure safe storage.

Continuous-flow dryer and semicircular storage layout.

Damp grain coming from the field will normally need to be placed in a surge bin to allow the truck to unload quickly and return to the combine. The damp grain is then fed as required into the dryer from the surge bin. The bin should be large enough to hold about half a day's harvesting volume. This is adequate for a system in which the dryer dries at half the harvesting rate and operates twice as many hours per day as the combine. Depending on the drying procedure and dryer capacity selected, a damp-grain surge bin may not be required if a bin dryer is used.

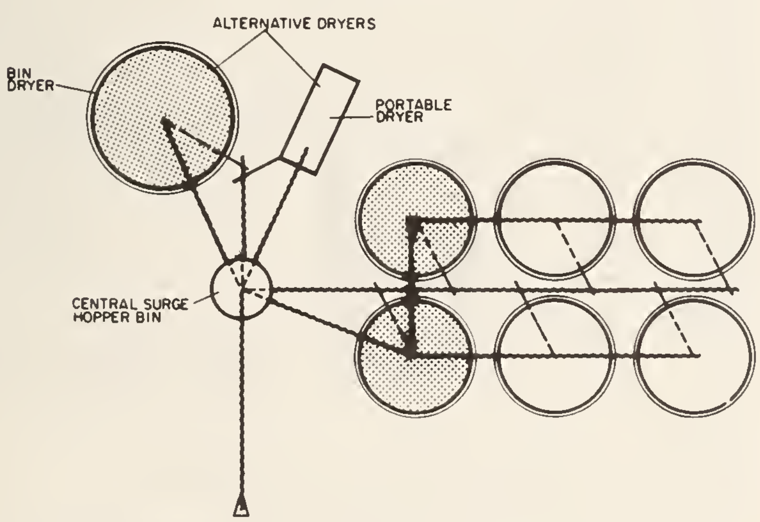


Figure 6. Grain drying and storage system with augers.

There are several bin arrangements that allow easy transfer of grain from the dryer to storage with a minimum of cost and inconvenience. Figure 6 shows one such arrangement using augers. Another arrangement, using a bucket elevator, is shown in Figure 7. Both systems can be built up in stages, starting with just a few bins. Detailed plans for these and other arrangements can be obtained from your provincial Department of Agriculture engineer, or from agricultural engineering consultants. Equipment details and other planning information can be found in the publication *Grain Storage and Handling Systems*, available from Communications Branch, Agriculture Canada, or the information may be obtained from your local engineer.

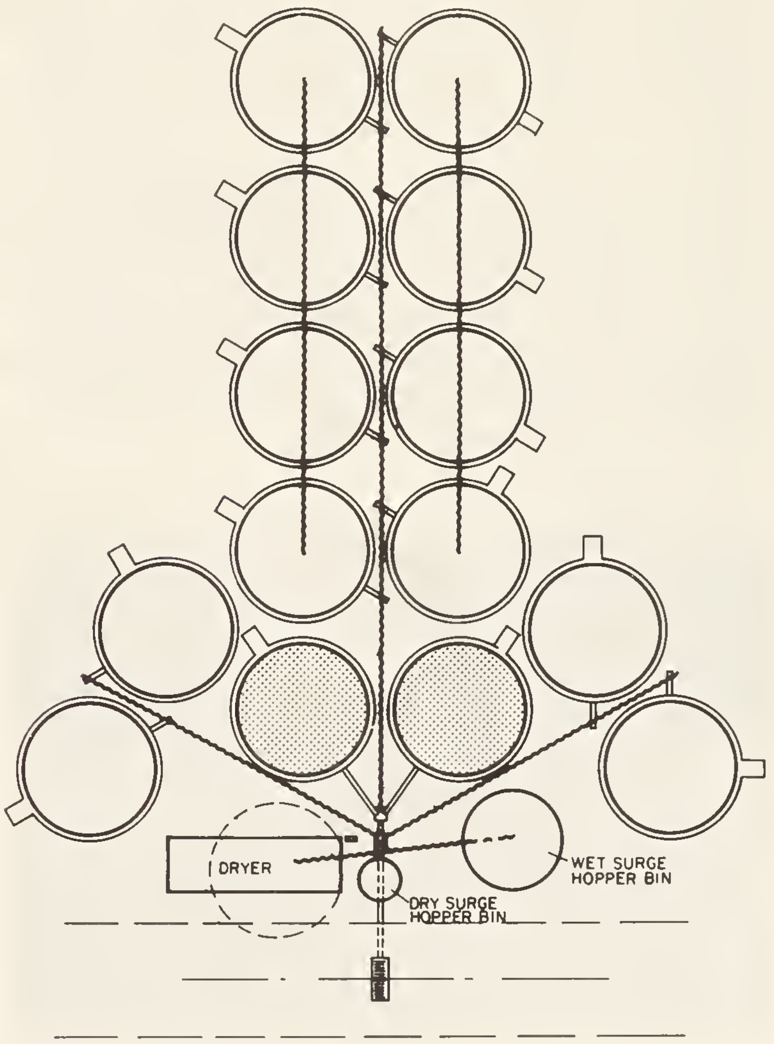


Figure 7. Grain drying and storage system using bucket elevator.

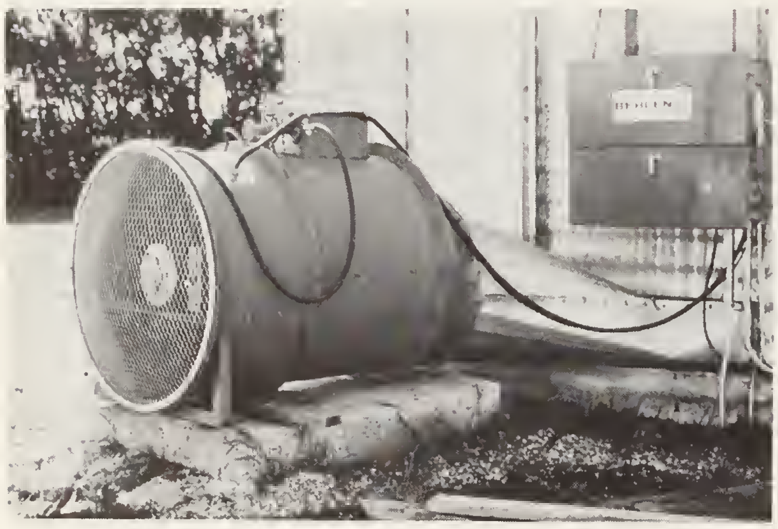
A special problem to be considered in planning is the possibility of fire when drying certain crops (particularly sunflowers). A convenient water supply and avoidance of combustible materials near the dryer can keep this hazard to a minimum.

DRYER TYPES

There are three major types of dryers: the non-recirculating batch type where the grain is loaded as a batch and remains stationary in the dryer throughout the drying period; the recirculating batch type where the grain is loaded as a batch and is constantly mixed while drying; and the continuous-flow type where the grain is loaded and unloaded continuously or intermittently. The three types are available for stationary bins and as portable dryers. The drying characteristics of the three types vary according to the grain depth and the rate of airflow. The individual characteristics, operational procedures and problems of each type are discussed in the following sections.

Bin Dryers

Bin dryers are available in many sizes and capacities, and can be operated in different ways to obtain various drying rates. They normally have lower airflow rates than other dryer types, resulting in slower drying but lower fuel consumption. Since bin dryers usually contain a greater volume of grain than other types, the amount of grain dried in a day can equal that with a 'high speed' dryer. A bin dryer should be sized to dry as much grain in 24 hours as will be harvested in a normal day. Manufacturers of bin drying equipment can provide detailed information on drying capacities with various bins, heaters and auxiliary equipment. An example of such information is given in the Appendix. A bin dryer setup can begin with a simple batch process, and if more capacity is desired, stirring augers or a continuous-flow device can be added later.



Bin dryer.

Batch-In-Bin Process

The lowest-cost setup uses the batch-in-bin process. A bin with a fully perforated floor, a grain spreader, fan and heater, sweep auger and under-floor unloading auger make up the basic equipment needed (Figure 8). The heater and fan unit is started up as soon as the first load of damp grain is dumped into the bin, and continues to operate as long as required to get the average moisture content of the grain to the desired level. Additional grain is loaded into the bin as harvesting progresses. By selecting an appropriate final depth of grain, based on dryer capacity and grain moisture content, a batch can be dried in 12, 24 or any other convenient number of hours. There can be substantial differences in the airflow resistance of different batches of grain depending on the filling method used, the size of seeds, and the amount and type of foreign material in the grain. For this reason the recommended depths given in the literature should be taken as a guide only. The best depth for a particular batch can be determined with the aid of a manometer or U-tube to measure the static pressure under the floor (Figure 9). The actual airflow rate can then be determined by using the charts supplied with the fan unit. Airflows of about 125 litres per second per cubic metre of grain (L/s·m^3) are recommended for efficient drying. Figure 10 shows the effect of grain depth on airflow rate for a typical fan and bin size. Typical grain depths for wheat, oats and barley are 1.5 — 2 m at moisture contents below 20%. Flax and turnip-type rapeseeds use depths of about 0.5 — 1 m. Lower moisture contents and lower temperatures permit greater depths (which result in lower airflows), while higher moisture contents and temperatures require the use of shallower depths (which result in higher airflows).

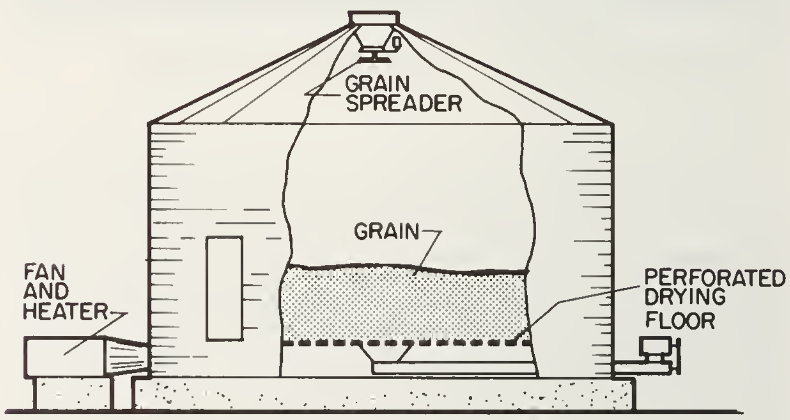


Figure 8. Typical batch dryer bin.

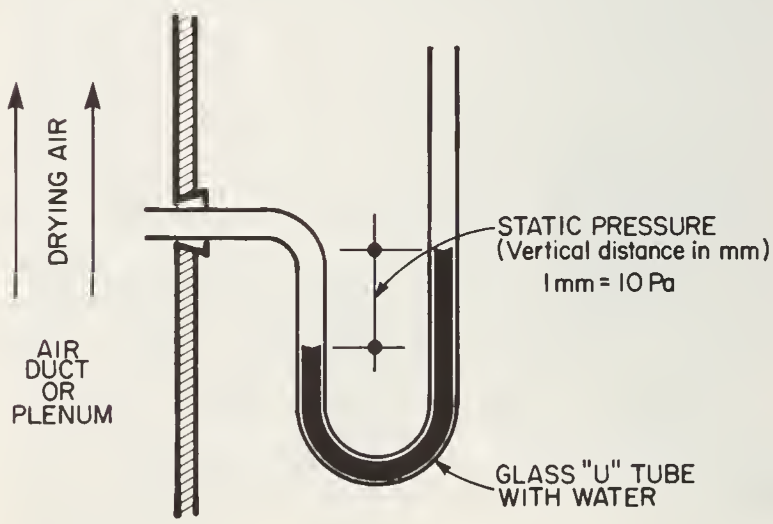


Figure 9. Static pressure measurement with manometer.

It is essential for the grain to be the same depth over the entire floor to ensure a uniform airflow and drying rate. Proper adjustment of the grain spreader should minimize or eliminate the need for manual leveling.

The grain nearest the floor will dry first and the 'drying front' will then move up through the grain. The location of this front will give an indication of the additional drying time needed. The use of higher air temperatures will speed drying somewhat, but will also increase overdrying near the floor.

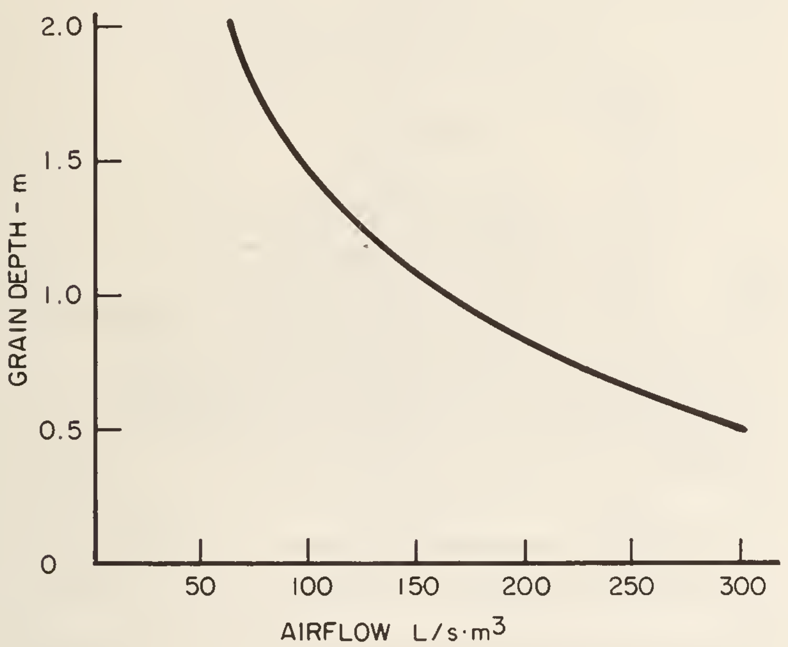


Figure 10. Airflow vs. depth of wheat for a particular fan-bin size combination.

With a bin dryer, the best way to hasten drying is to reduce the depth of grain. This increases the airflow and also provides more-uniform drying. A common tendency is to put too much grain in each batch. This reduces the number of times that the bin must be unloaded, but seriously reduces the overall drying capacity. The unloading of the dryer bin and the transfer of the grain to storage should be able to be carried out as quickly and conveniently as possible, so that several smaller batches can be dried each day when there is need for more drying capacity. The sweep auger should be at least 150 mm in diameter and have a backshield to clear the bin in one pass. The underfloor auger on all except fairly small bins should be at least 200 mm in diameter and have an exposed flighting of at least 300 mm, and preferably 500 mm, at the hopper intake. Adequate power for the augers is also essential. If several batches are to be dried in one day, a damp-grain surge bin may be needed. Another approach is to position the heater and fan unit to alternately serve two bins. This allows one bin to be filled and emptied while the other is being dried, thus eliminating dryer downtime and the possible need of a surge bin.

Some experience is required to determine when to turn off the heat and begin cooling. Usually the heat can be turned off when the drying front is about 150 mm from the surface. Some moisture will be removed during the cooling process, so it isn't necessary to dry the batch completely with hot air. The amount of moisture removed during cooling will depend to a large extent on the decrease in grain temperature. If the grain is cooled 40 — 50°C, it could lose between 1 and 2%, while a smaller decrease would reduce the moisture content by a smaller amount. Very high ambient air temperatures, together with high relative humidities, might result in no moisture being removed, or even a slight increase in the moisture level if the fan is run too long.

Cooling may be done with the dryer fan, or if aerated storage is available the grain can be transferred hot to the storage bin and cooled by an aeration fan. In either case, the grain should be cooled to within 5°C of ambient air or 2°C, whichever is higher, to prevent condensation or moisture migration. Since the grain does not have a uniform moisture content when it is removed from the dryer, and since complete mixing is not ensured, it is recommended that grain from a batch-in-bin dryer be placed in aerated storage to level out any moisture variations.

Drying in cold weather may result in condensation on the underside of the roof or on the walls of bin dryers. Troublesome wet spots may be created if this water is allowed to drip onto the grain. On some bins, a continuous opening can be provided around the bin eaves to allow water to run along the underside of the roof and drip down outside. With any drying bin, the total exhaust opening should be at least 3% of the floor area to allow easy exit of the moist air. The addition of an exhaust fan may be helpful in increasing the airflow through the bin. The fan must not be placed in any of the existing exhaust openings since this could cause a decrease in total airflow rather than an increase. Insulating the bin roof is another method of reducing condensation when drying in cold weather.

Drying small oilseed crops may create a problem on some perforated floors if the seeds block the openings. If this occurs, a shallow layer of larger-seeded grain, such as barley or oats, may be placed on the floor and the oilseed crop placed on top of it. The grain acts as an air diffuser and allows a greater airflow as well as preventing leakage of small seeds through the perforated floor. When removing a batch, the sweep auger is set so that it doesn't remove the large seeds on the bottom. Should some mixing occur, it is not difficult to separate the small seeds from the larger ones. The sweep augers in bin dryers do not completely clean the drying floor, so a seed grower would likely find a bin dryer unsuitable because of the extra work required for cleaning. The small amount of mixing when changing grain types is not usually a problem in the case of commercial grain sales. Sweep augers tend to accumulate fines near the bin center, so periodic cleaning of the perforated floor is required to prevent uneven airflow through the floor.

There are a number of variations of the basic batch-in-bin drying procedure. An alternate heating and cooling cycle may be used to reduce the moisture differential between the top and bottom of the batch. A cycle time of 3 or 4 minutes is used, with 75% of the time spent in heating and 25% in cooling. During the cooling part of the cycle the heat from the grain nearest the plenum is carried to the cooler grain and this results in a more-uniform temperature and moisture content throughout the batch. In a comparison with continuous heat drying, the moisture differential in a 1 m depth of grain was only about half as great with cycled drying. Slightly higher air temperatures can be used with this method to compensate for the reduced heating time.

Overhead Drying Floors

Some bin dryers use an overhead cone-shaped drying floor supported about 1 m below the roof (Figure 11). The heater and fan unit is mounted just below the drying floor. When the grain is dried it is dropped to a perforated floor below where an aeration fan is used to cool the grain while the next batch is loaded and dried on the floor above. Additional batches are dropped on top of the cooled grain until the bin is filled to the level of the heater unit. The dried grain is then transferred to another storage bin. With this system, drying can continue while the grain is being cooled and transferred. Unloading of the drying floor requires only about a minute.

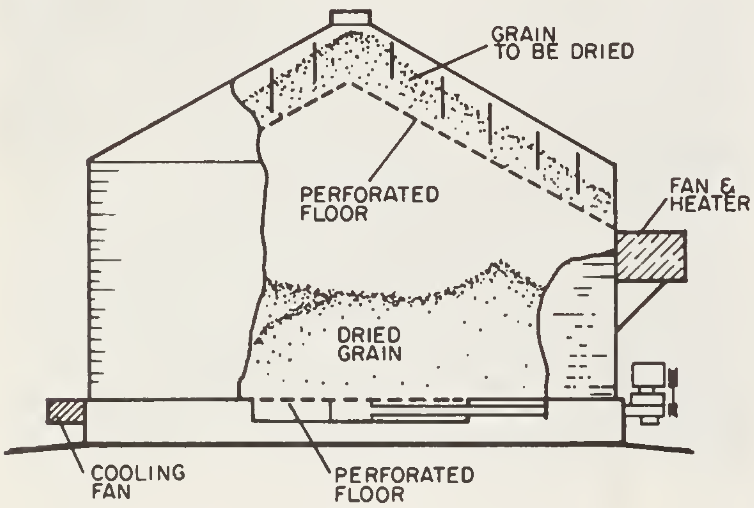


Figure 11. Bin dryer with overhead drying floor.

Stirring Augers

Vertical stirring augers can be added to a bin dryer to increase the allowable depth of grain and to provide more-uniform drying (Figure 12). The augers transfer dry grain from the bottom up through the grain mass. Stirring also fluffs up the grain which increases the airflow substantially. This normally permits slightly higher drying temperatures which, together with the increased airflow, result in significantly higher drying rates (see Appendix). Grain depths of 2 — 4 m may be used with wheat, oats or barley depending on the initial moisture content. Small oilseeds may use depths of 1 — 2.5 m. The use of stirring augers may result in slightly higher fuel consumption, but this is outweighed by the increased drying rate, the reduction in overdrying at the bottom, and the larger batch size.

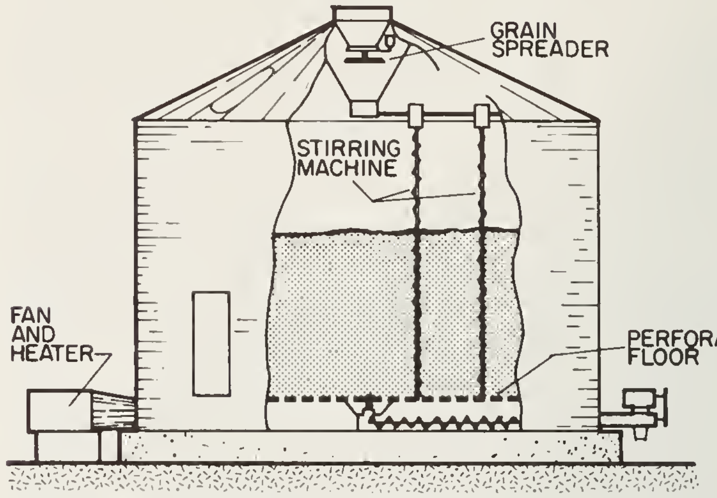


Figure 12. Bin dryer with double-auger stirring device.

Bin dryer with overhead drying floor.

Recirculating and Continuous-flow Devices

There are a number of other devices that can be added to bin dryers, either to recirculate the grain or to provide a more or less continuous flow through the bin. Figure 13 shows a bin dryer equipped as a recirculating batch dryer. The perforated floor is sloped towards the center so that the grain flows into a central chamber where it is picked up by a vertical auger and delivered to the top of the grain bin. The grain is mixed continuously as it is dried, and the drying is more uniform than in a non-recirculating batch dryer.

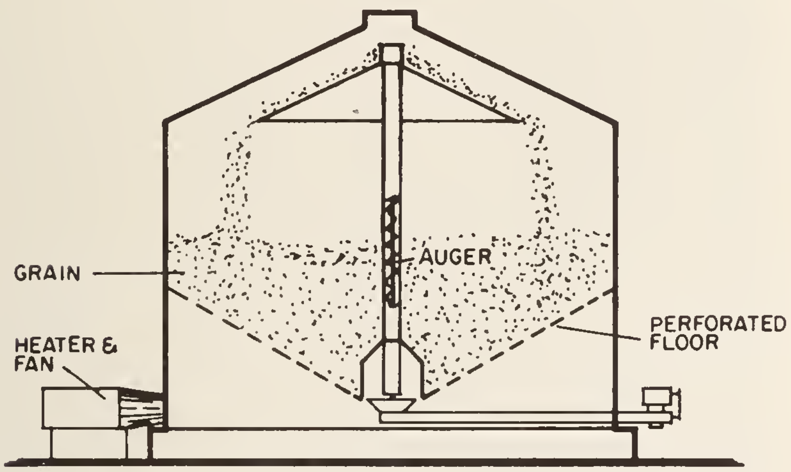


Figure 13. Recirculating batch bin dryer.

Figure 14 shows another unit that can be used either to recirculate the grain or to provide a continuous flow. A sweep auger is used to move the dried grain to the center of the perforated floor where it is picked up by a vertical auger and carried to an inclined transfer auger which takes the grain to a cooling bin. The operation of the sweep auger is controlled by a thermostat. The grain can also be recirculated by augering it up to the grain recirculator instead of to the transfer auger. When the unit is operated as a continuous-flow dryer the cooling must be done elsewhere, so this system needs at least one more aerated bin to complete the cycle. Dryeration or combination drying is normally used with this type of system. Excessive grain depths in recirculating and continuous-flow dryer bins will

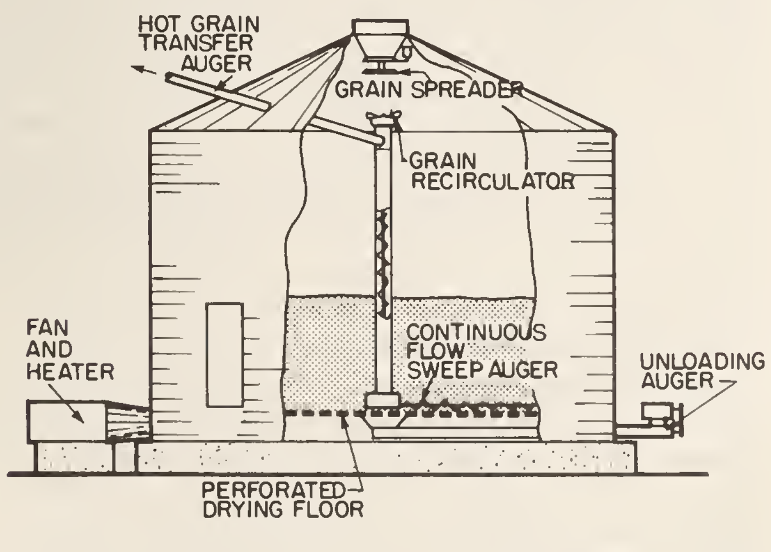


Figure 14. Continuous-flow or recirculating drying bin equipment.

reduce drying rates substantially. Grain depths should be the same or only slightly greater than those used in the batch-in-bin process.

Other drying procedures, such as multistage drying, are frequently used in bin dryers. Since these procedures can also be used with any other type of dryer, they are discussed later (see *Multistage Drying*).

Portable Dryers

Batch Dryers

There are two basic types of portable batch dryers available—the recirculating and non-recirculating types. These dryers are equipped with wheels to make them portable, but once they arrive at the farm it is essential that they be placed in a permanent position in a well-planned grain-handling system if drying is to be done efficiently and conveniently. The initial attraction of a portable dryer is usually to a farmer who has grain bins scattered around in various locations or does custom drying off his farm. While this may fill an immediate need in an emergency situation, a portable dryer without a proper grain-handling system will normally not be used in situations where drying would be beneficial but not absolutely essential. Many of the potential benefits of a dryer will be lost if it is not convenient to use at a moment's notice. The selection of a dryer should not be made on the basis of portability unless it is to be sold again immediately after the crisis is past.

Most batch dryers must be operated with a full or nearly full batch of grain. If the top of the air plenum is covered with only a few centimetres of grain, most of the air will escape through the top and most of the heat will be wasted.

When batch dryers are used to remove only a few points of moisture from grain, their 'time efficiency' is greatly reduced. Filling, cooling and unloading times are unchanged but the heating time is reduced. The actual drying time therefore becomes a lower percentage of the total operating time.

Considerable variation in drying rates and fuel efficiencies can be expected with batch dryers on different types of grain. Since the grain depth remains the same regardless of seed size, the airflow will be much lower for small oilseeds than for coarse grains and corn, particularly where an axial flow fan is used. This results in a reduced rate of moisture removal for crops such as flax and rapeseed, but also a substantial increase in fuel efficiency. Since it remains in contact with the grain longer, the air has more time to pick up moisture and is expelled at a higher RH. Increases of over 25% in fuel efficiency have been observed in batch dryers when drying flax as compared with wheat. A corresponding reduction in rate of water removal normally accompanies the increased fuel efficiency.

When comparing different batch dryers, fan capacity and column width are important variables. Higher fan capacity and narrower column widths will produce higher drying rates, but lower fuel efficiencies. Fan type is also important. A centrifugal fan will normally produce a more-constant airflow with different types of grain and will usually be quieter in operation than an axial flow fan.

Problems with temperature measurement, as discussed previously, are common in batch dryers as well as in other types. Malfunctions of sensors, and their improper location in the hot-air plenum and grain columns can result in misleading temperature information. Extra thermometers should be installed in the plenum and in the grain column next to the plenum to reduce these dangers.

Samples taken from batch dryers for moisture checks must be representative of the grain throughout the entire thickness of the grain column or bed. Careless sampling can result in seriously overdried or underdried grain.

Substantial improvements in both drying rate and fuel efficiency can be obtained by removing the hot grain from a batch dryer before the grain is fully dried and using unheated air to complete the process. This is discussed in more detail under *Multistage Drying*.

Batch dryers have some advantages over other types where relatively small amounts of different grains are to be dried. Start-up and changing from one type of grain to another is relatively easy compared with a continuous-flow dryer, and unloading and cleaning operations are usually easier than with a bin dryer. However, most batch dryers have much higher airflow rates than bin dryers and, consequently, use considerably more fuel to do the same amount of drying.

It is essential to have high-capacity loading and unloading equipment for a batch dryer to keep downtime to a minimum. An auger size of 150 mm or larger should be used to transfer grain into and out of the dryer. A damp-grain surge bin is also essential for efficient operation of a batch dryer.

Non-Recirculating Type—There are several variations of non-recirculating batch dryers, but most are of the fully enclosed, two-column type (Figure 15). The damp grain is loaded into the dryer from the top until it is filled and then the hot air is forced through the grain until it is dry. The grain does not move inside the dryer, so the inside layer becomes overdried while the outside layer remains underdried. After the heat cycle, the grain is cooled inside the dryer by shutting off the heat, or it is transferred to an aeration bin for cooling. As the grain is unloaded, the wetter and dryer grain is mixed and if safe temperatures were used and the grain was sufficiently dried and cooled, a satisfactory product results.

There are a number of automatic controls and safety devices available for these dryers. As the grain dries it shrinks, so with the use of a pressure switch and timer the dryer can be refilled from the surge bin. The dryer may also be set to operate at a higher temperature for the first part of the drying cycle if the grain is very damp, and then at a lower temperature for the latter part. A thermostat or timer may be used to regulate the heat shutoff control. The cooling time may also be controlled by a timer and the unloading augers started automatically after cooling. A batch dryer equipped with all of these controls is commonly referred to as an automatic batch dryer. If all of the controls are set and working properly, a batch dryer can fill, dry, cool and unload one batch after another without manual supervision or control. As grain conditions change, timers and thermostats have to be reset, and manual correction is needed in the case of a malfunction. A totally mechanized grain-handling system is essential for such a system to operate and get the grain into storage.

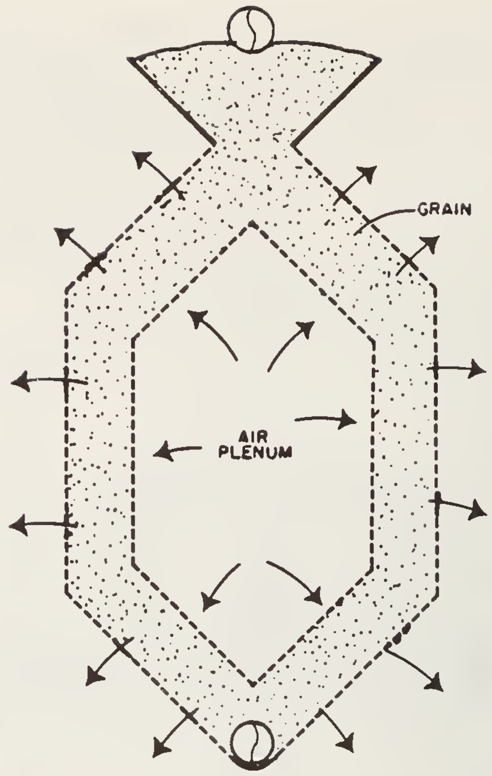
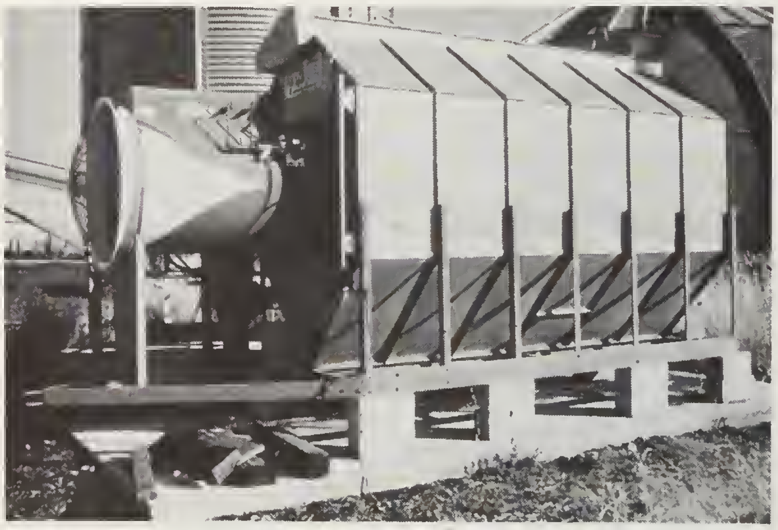


Figure 15. Non-recirculating batch dryer.



Non-recirculating batch dryer.

There are also other types of non-recirculating batch dryers such as wagon or truck-box dryers. A heater and fan unit, similar to those used for bin drying, is connected to a main plenum which is connected to smaller ducts inside the truck box. These ducts may be located on the floor or suspended at mid-height of the box. If they are suspended, exhaust ducts must be provided at the floor of the box. Capacities vary with the fan and burner capacity, and size of the truck box.

Recirculating Type—Recirculating batch dryers have one central air plenum surrounded by grain, and operate in the same sequence as non-recirculating batch dryers. The main difference is that the grain is constantly recirculated throughout the heating and cooling cycles. The dryer is usually circular in shape to accommodate the vertical auger in the center of the dryer (Figure 16). The auger picks up the grain at the bottom of the dryer and deposits it at the top. It is also used to unload the dryer. A complete recirculation of the grain occurs about every 15 minutes, which is the same as the unloading time. The constant mixing results in a more uniformly dried batch of grain than in a non-recirculating batch dryer. However, the constant augering can cause damage to certain seeds (including beans, peas and malting barley), particularly when they are nearly dry.

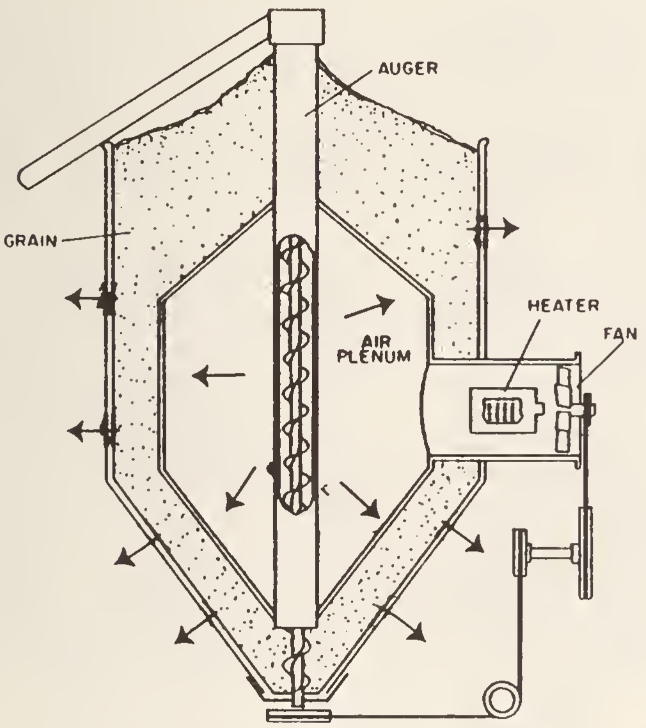


Figure 16. Recirculating batch dryer.

Recirculating batch dryer.

Drying temperatures 20°C higher than those given in Table 4 can be used while the grain is damp, but when the grain gets into the tough range the temperatures should be reduced to the levels indicated.

Automatic controls, such as those described in the section on the non-recirculating types of batch dryer, can also be used with recirculating batch dryers to reduce the amount of labor and supervision required.

Continuous-flow Dryers

There are many types of portable continuous-flow dryers. One of the more common types uses two or four vertical grain columns, with the air passing through the grain at right angles to the grain flow (Figure 17). The grain is loaded into a hopper on top of the dryer, flows down on both sides of the hot-air plenum, then past the cold-air plenum, and is removed by augers. The grain-flow rate is normally controlled by a thermostat located near the outside of the grain column. The rate of flow may also be controlled manually on most dryers. The grain is not mixed as it flows downward and, as a result, the grain next to the hot-air plenum becomes overdried, while the outside grain is underdried. Moisture differentials across a 300 mm grain column may be as high as 6 — 12% when the average moisture content is dry. The grain is mixed as it is unloaded and an acceptable product is produced if safe temperatures were used.

The moisture differential across the grain column depends on initial and final moisture content, air temperature, flow rate, and the column width. In a comparison of two dryers with 150 and

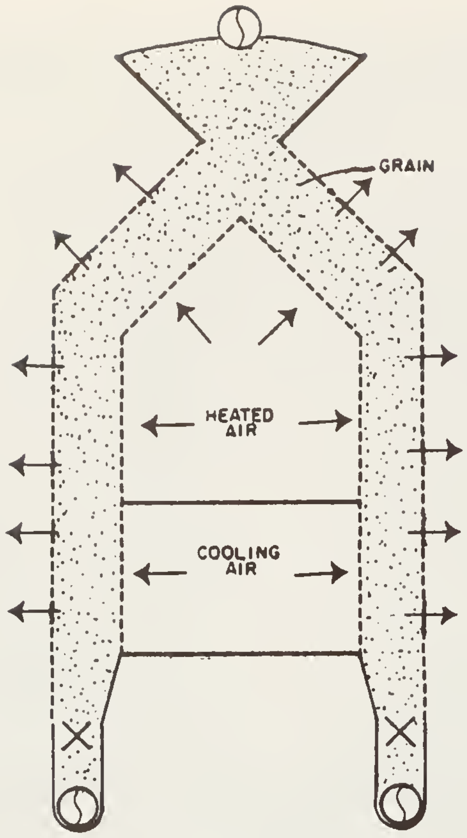


Figure 17. Continuous-flow dryer.

300 mm grain columns, using fans of the same type and size, the moisture differential was about 3.5% and 6% respectively. There was less resistance in the 150 mm column and the fan output was almost 50% greater than with the 300 mm column. Fuel consumption was also increased by about 50%, with very little difference in drying rates. As fan capacity is reduced or width of grain column increased, more efficient use of the heat results, but moisture differentials are increased.

Some continuous-flow dryers use three fans and plenums, each with individual temperature controls. The dryers can be run with two heating sections and one cooling, or with heat in all three, in which case the grain would be cooled in an aerated bin. The top section is normally run at a higher temperature since this air is in contact with the wettest grain. The dryer can also be operated as a continuous batch dryer, where the grain is dropped one section at a time instead of in a continuous flow.

Some continuous-flow dryers draw the cooling air through the grain and then pass it through the fan and heater unit into the hot-air plenum. This reclaims heat given up in cooling the grain and reduces the air-grain temperature differential as the grain passes from the heating to cooling sections. Some moisture is also picked up and sent through the heater unit, but there is still a net gain in fuel efficiency. Chaff and fine material picked up in the cooling section will accumulate on the inside of the hot-air plenum and, because of this, frequent checking and cleaning of the plenum may be required. The construction of this type of dryer may make it unsuitable for use in a dryeration system because it may not be possible to use the entire dryer for heating.

Another type of continuous-flow dryer is shown in Figure 18. It also has two vertical grain columns, but the airflow is parallel to the grain flow. This provides a uniform drying rate across the column because the entire width is subjected to the same air, and the grain is mixed as it passes through the dryer. Since this design reduces the danger of heat damage, slightly higher temperatures can be used than with the two-compartment crossflow dryer. This type of dryer has no screens; consequently, depending on quality of construction, small-seeded crops may be dried without leakage and cleaning may be easier. The dryer can be operated as a batch type, with both top and bottom sections receiving either hot or cold air. This feature, which is also available on some other continuous-flow dryers, is useful in start-up or when small batches of grain are to be dried.

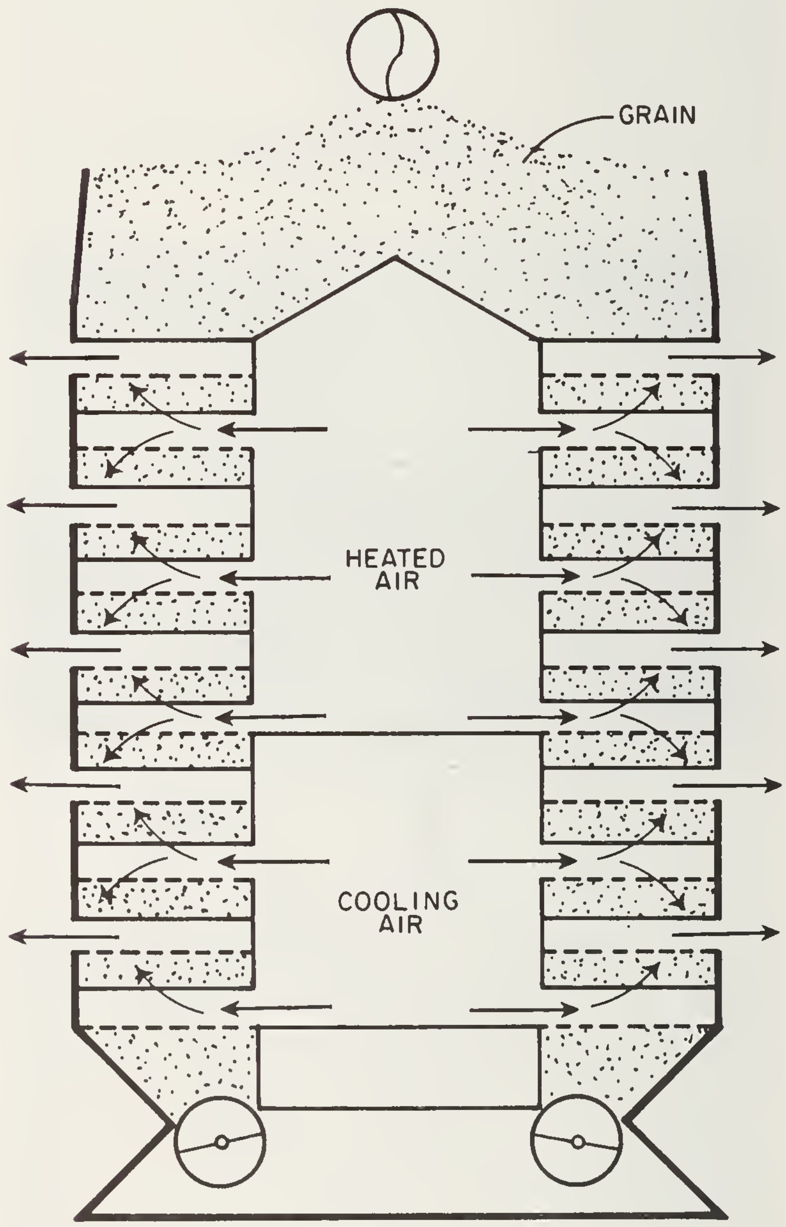


Figure 18. Parallel continouous-flow dryer.

Continuous-flow dryers are generally not well suited for drying small volumes of grain since starting and emptying them is quite inefficient, and accurate moisture control is difficult to achieve until a uniform flow is established, usually requiring a couple of hours. They are best suited to drying large

Drying system with continuous-flow dryer and parallel airflow.

volumes of grain without frequent changes from one type of grain to another.

Moisture controls on continuous-flow dryers are frequently affected by the sun and wind (see *Weather Effects on Drying*). Temperature sensors in hot-air plenums may be improperly located or may be inaccurate. Extra sensors should be placed in the plenum to get an accurate reading in the hottest part. Temperature sensors installed in the grain column next to the hot-air plenum can also be used to help guard against grain damage. Gas-modulating valves should allow the dryer to be operated at temperatures as low as 40°C.

Airflows in continuous-flow dryers are normally in the same range as those in batch dryers, and both types of dryer have similar fuel efficiencies. Drying rates will vary according to seed size, which has an effect on the rate of airflow. Faster drying rates can be obtained by using auxiliary cooling, dryeration or combination drying.

Large continuous-flow units can dry grain quickly when only a few points of moisture are being removed, so augers and surge bins must have considerable capacity. Augers of at least 150 mm diameter should be used.

Many different automatic controls and safety shutoffs are available for these dryers, allowing their operation without constant supervision. However, because controls need to be readjusted as grain conditions change, and because malfunctions can occur, frequent checks of their operation must still be made.

MULTISTAGE DRYING

Dryeration

Dryeration, or two-stage drying, is a process that uses both a grain dryer and a high-capacity aeration system. It consists of removing hot grain from the dryer at moisture levels about 2% above 'dry' and completing the drying and cooling process in a storage bin with airflows of 5 — 10 L/s·m^3 (Figure 19). Aeration is begun 6 — 12 hours after the grain is binned. This allows time for moisture to move from inside of the kernels to the outside for easier removal. There are a number of advantages to this process as compared with using a grain dryer only:

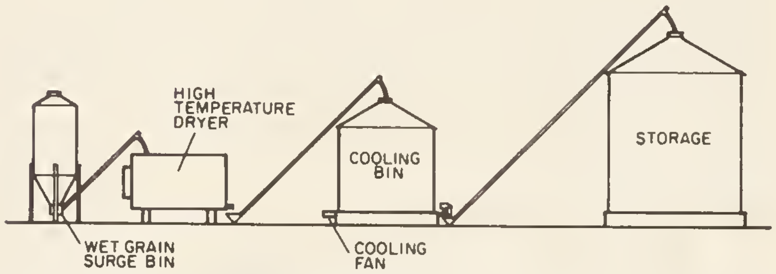


Figure 19. Dryeration process.

•Slightly higher drying temperatures can be used since the grain isn't completely dried in the dryer.

•The need for cooling time in a batch or bin dryer, or for a cooling section in a continuous-flow dryer, is eliminated. The use of higher temperatures, coupled with the elimination of the cooling time and a reduction in the drying time in the dryer, can result in an increase of 50% or more in dryer output.

•Fuel savings of 20% or more are common. The last few points of moisture are the most difficult and costly to remove in a heated air dryer so by removing them in the bin using the heat contained in the grain, much less fuel is required.

•Grain quality may be improved since rapid cooling of hot grain, which could cause stress cracks, is avoided. There is also less chance of heat damage.

Low-capacity aeration systems are inadequate for dryeration cooling. Larger fans and duct sizes are required to achieve airflows of 5 — 10 L/s·m^3. A fully perforated floor is desirable for the cooling bin since this will eliminate excessive pressure drops and produce a more-uniform airflow through the grain as compared with aeration ducts. It also eliminates the need to move the grain again for final storage.

Because a considerable amount of moisture is removed during cooling, condensation on the roof and walls of the bin is often a problem if the air is blown up through the grain. This means that the grain must be transferred from the cooling bin to another storage bin to mix any wet grain with the dry grain if a fully perforated aeration floor is not used. The extra grain transfer is the main disadvantages of this process.

Pulling the air down through the grain will reduce the condensation on the roof but will reduce the effectiveness of the dryeration cooling since the last grain in is the first to be cooled. Another way to eliminate the transfer is to begin cooling the grain just as soon as it comes from the dryer. This prevents most of the condensation by having a continuous airflow through the bin right from the start of filling. The grain can then be left in the cooling bin for storage. A disadvantage of this method is that some of the benefits of the 'heat soak' are reduced since the grain has less time to attain internal moisture equilibrium. This would mean that slightly less moisture (about 1%) would be removed during the cooling stage. Because of this, the grain would need to remain in the dryer a little longer.

Combination Drying

Combination drying is an extension of the dryeration process. It is used primarily when grain with a very high moisture content (above 25%) is to be dried. A high-temperature dryer is used to lower the moisture content to 19 — 23%, then the grain is transferred to a bin dryer for completion of the drying, either with or without supplemental heat. This makes use of the most efficient operating ranges of both types of dryers. The output of the high-temperature dryer is increased by two or three times compared with its use for complete drying. Dryer fuel requirements are reduced by about 50%, depending on the amount of moisture removed in each stage. There is also an improvement in grain quality as compared with completing the drying in the high-temperature dryer.

Airflows for the bin drying portion of combination drying are in the range of 10 – 25 L/s·m³. Fully perforated floors must be used. The grain may be put through a 'heat soak' dryeration process before the final bin drying or it may go directly from the high-temperature dryer to the bin dryer for immediate cooling and final drying.

The choice of using dryeration or combination drying will depend on the amount of grain and its initial moisture content, the cost of energy, and the capital investment required. Where small amounts of grain are involved and the moisture content is relatively low, the investment in equipment for combination drying would not be warranted. Higher initial moisture contents, larger grain volumes and higher fuel prices make dryeration and combination drying more attractive. In all cases, however, where bins of 100 m³ or larger are built, aeration ducts should be provided, even for grain that is brought in dry from the field. Building the aeration ducts large enough for airflows of at least 10 L/s·m³ is recommended so that future options are left open to accommodate some type of multistage drying. Because it allows the greatest variety of options, a fully perforated floor should be seriously considered when a large storage bin is being planned. Every grain storage system should contain at least one and preferably two or three bins with perforated floors.

AERATION

In aeration, unheated air is passed through a grain mass to cool it, or to equalize the temperature or moisture content throughout the bin. Aeration normally involves moving small amounts of air (about 1 – 2 L/s·m³) through dry or nearly dry grain. This is done to lower and equalize the grain temperature in the bin and prevent moisture migration (Figure 5), and to cool warm grain coming from the field. Small amounts of air such as this will do very little drying unless the weather is very dry and the fan is run for a long time. Grain that is put into storage with varying amounts of moisture can benefit from aeration since it will assist in the transfer of moisture from the wetter to the drier grain. Higher airflows (7 – 13 L/s·m³) are needed to maintain damp grain in condition while it is waiting to be dried. If outdoor temperatures become very warm, even these airflow rates may not ensure safe storage. Damp grain should be aerated continuously until it is dried or its temperature is reduced to near 0°C, especially at night when air temperatures are normally lower. When using aeration to cool dry, hot grain coming from a dryer, the fan should be operated continuously until the grain is within 5°C of the average outdoor temperature. At 1 L/s·m³, this may require up to a week of operation. Care should be taken to avoid overdrying of the grain by excessive aeration during very dry weather.

It is important to select ducts, perforated areas and fans of adequate size when setting up any aeration system. The required information and design assistance is available from your local agricultural engineer.

DRYING RATES AND EFFICIENCIES

The design and operation of grain dryers is frequently a compromise between drying rate and fuel efficiency. Increasing the airflow will speed drying but will also increase fuel consumption. Increasing the grain depth or column width will give better fuel efficiency but slower drying rates. If a fixed column width or depth of grain is used for large- and small-seeded crops, fuel efficiency and drying rates will vary greatly. Smaller seeds have a higher resistance to airflow and therefore reduce the fan output. This increases the amount of water that is absorbed by the air before leaving the dryer. Therefore, a dryer will give higher fuel efficiency with flax than it will when wheat or barley is being dried. Reducing the fan speed on batch and continuous-flow dryers will increase fuel efficiency, but will also reduce the drying rate.

Several practices contribute to both improved fuel efficiency and faster drying rates. The elimination of overdrying will do both as well as reduce the chance of grain damage. The drier the grain gets, the more time and fuel are required to remove moisture.

The effect of initial moisture content on drying rates and fuel efficiencies is shown in Table 5.

Removing fine weed seeds and broken kernels will also improve drying rates and reduce the total amount of drying required. Running the grain through a precleaner or screened auger before drying can help to speed up the drying and to reduce variations in drying rates.

Differences in initial grain temperatures have a slight effect on the drying rate and fuel consumption. A difference of 30°C in the initial temperature results in a difference of about 10% in the time and fuel requirements. Changes in temperature occur very slowly in grain unless air is being blown through it, or heating is taking place.

Outside air temperatures have a very significant effect on fuel consumption. With a 25°C temperature rise (e.g., 15°C ambient air and 40°C dryer temperature) a change of 1°C in ambient air temperature changes the fuel consumption by 4%. With a 50°C temperature rise, a 1°C change in outdoor temperature changes the fuel consumption by 2%. Drying rates are not affected by the outdoor air temperature as long as the dryer and grain temperatures remain constant.

Passing the cooling air from a continuous-flow dryer through the burner and into the heating section results in a net improvement in fuel efficiency. The heat that is salvaged from the cooling process more than offsets the moisture gained and can yield fuel savings of 10 — 15%. The fan must have slightly increased capacity to move the same amount of air through the dryer.

Dryer Capacities

Dryer capacity is best expressed in terms of water removal rates, such as kilograms per hour (kg/h). Dryers used on prairie farms have widely varying rates, from less than 100 kg/h to over 1000 kg/h. Table 6 gives typical water removal rates and fuel usages for some of the common farm dryers when drying wheat from 18% to 14% at 15°C ambient air temperature.

Water removal rates with wheat, oats and barley are approximately the same if the same drying temperatures are used. Water removal from flax and rapeseed is about 20% slower at the same temperatures. Since wheat is commonly dried at a somewhat lower temperature than flax, oats and

TABLE 5. EFFECT OF INITIAL MOISTURE CONTENT (MC) ON DRYING RATES AND FUEL EFFICIENCIES

Dryer	Grain	Initial MC %	Water removal kg/h	Fuel usage kJ*/kg of water
A	Wheat	18.0	480	3050
		16.4	425	3200
B	Corn	26.2	530	3550
		22.9	510	3700
		18.7	465	4200
C	Corn	26.6	1110	3000
		22.7	850	3400

*kilojoules (assuming a net heat production of 20'000 kJ per litre of propane).

TABLE 6. TYPICAL WATER REMOVAL RATES AND FUEL USAGES

Dryer	Water removal kg/h	Drying rate t/h	Fuel usage kJ/kg of water
Recirculating batch, 13 m^3 volume	125	2.5	4000
Non-recirculating batch, 4.5 m^3	125	2.5	4500
Continuous-flow, 16 m^2 perforated dryer area	300	6.0	4000
Bin, 9.1 m dia overhead drying floor	500	10.0	3000

barley, the actual drying rates (in kg/h) are normally about equal for wheat and flax, and about 15% higher for oats and barley.

The amount of water that must be removed from grain to dry it is given in Table 7.

A dryer removing 200 kg/h would therefore dry about 2 t/h of grain from 22% to 14%.

Dryer Efficiencies and Costs

Fuel efficiencies are measured in terms of the amount of energy required to remove water. The units are kilojoules of energy per kilogram (kJ/kg) of water removed. A litre of propane will produce about 20 000 kJ of energy with good burner efficiency. A kilowatt hour (kWh) of electricity is equal to 3600 kJ. Typical fuel efficiencies for continuous-flow and batch dryers are approximately 4000 kJ/kg for wheat, oats, barley and corn. Some dryers with high airflows may require as much as 6000 kJ to remove a kilogram of water. Bin dryers normally use about 3000 kJ/kg.

Table 8 gives the fuel costs for removing water for dryers with various fuel efficiencies, and with various propane prices.

The cost of drying a tonne of grain, using a dryer with an efficiency rating of 3500 kJ/kg, is determined in the following example:

Grain being dried from 22% to 14%
Fuel price 20¢/L
Dryer fuel usage 3500 kJ/kg
Fuel cost = 103 kg/t (Table 7) x 3.50¢/kg (Table 8) = $3.60/t

If the dryer in the above example used 5000 kJ/kg, the fuel cost would be $5.15/t. If 200 tonnes per year are dried, the difference in total fuel cost would be only $310 per year. This amount would need to cover any additional capital costs (if any) for the more efficient dryer. If a dryer is to be used for drying large amounts of grain, fuel efficiency would become a more important factor. A more expensive dryer does not necessarily use less fuel. Some dryers with a low initial price are also the most fuel-efficient.

Once a dryer is purchased, the fixed costs (interest and depreciation) occur whether or not the dryer is used. The decision on whether or not to use the dryer in a particular year should, therefore, be based primarily on the operating cost rather than on the total cost.

Where a substantial increase in grain drying is anticipated, consideration should be given to the addition of a dryeration or combination drying process rather than to increasing the dryer size. Besides increasing the drying rate, this would decrease fuel costs and improve grain quality.

FIRES IN DRYERS

With any crop, fires can occur in dryers if dirt and residue accumulate in the burner area. However, fires are not common, except when sunflowers are being dried. Sunflower seeds often have fuzz attached to them which is released in the drying process (particularly with recirculating batch dryers). If this material is drawn through the fan and burner, it can ignite and start a fire in the dryer. Anything that will reduce the chances of the material being drawn through the burner will help to reduce the risk of fire. This includes cleaning to remove any light or fine material from the seed before drying, and the provision of wind deflectors

TABLE 7. AMOUNT OF WATER REMOVED WHEN DRYING GRAIN

Final MC	kg/t* removed from grain with an initial MC of 16%	18%	20%	22%	24%	26%	28%	30%
14%	24	49	75	103	132	162	194	229
10%	71	98	125	154	184	—	—	—

*tonne of grain at the final moisture content

TABLE 8. FUEL COST FOR REMOVING WATER (¢/kg)

Fuel usage (kJ/kg)	Fuel price (¢/L) 18	20	22	24
2500	2.25	2.50	2.75	3.00
3000	2.70	3.00	3.30	3.60
3500	3.15	3.50	3.85	4.20
4000	3.60	4.00	4.40	4.80
4500	4.05	4.50	4.95	5.40
5000	4.50	5.00	5.50	6.00
5500	4.95	5.50	6.05	6.60
6000	5.40	6.00	6.60	7.20

to prevent airborne material from being drawn through the burner. Also, dust and fuzz should not be allowed to accumulate on the walls and other parts of the dryer.

The chance of fire will also be lessened by ensuring that the seed is not overdried and that the temperature of the drying air is not too high. Hot and overdried seeds are more easily ignited by the burning fuzz. High air temperatures by themselves are not usually the cause of fires when drying sunflowers. Even where drying temperatures were below 40°C, fires have occurred when fuzz particles were drawn through the burner and ignited.

In spite of all precautions, it is advisable to remain near the dryer and to be alert for signs of fire whenever sunflower seeds are being dried, especially near the end of the heating cycle. If a fire occurs, shut off the heat and fan. The fire may snuff itself out in a recirculating dryer if the auger is left running, but it is often necessary to use some water to extinguish it.

A number of fires have also occurred when drying rapeseed and other crops. Precautions similar to those recommended for drying sunflowers should be followed.

Nearly every fall there are a number of warm, dry days when drying is possible without the use of heat. On such days, putting sunflowers or rapeseed through a dryer without starting the burner can result in very low cost drying, and eliminate any chances of burner-induced fires.

APPENDIX

Drying Charts for Bin Drying
(Tables courtesy of Westeel Rosco)

FLAX, MUSTARD AND RAPESEED (Final moisture 10%)

Dryer size	Initial moisture %	Flax Depth m	Flax Volume m^3	Flax Time h	Mustard or rapeseed Depth m	Mustard or rapeseed Volume m^3	Mustard or rapeseed Time h
5.8 m DIA BIN			40°C			40°C	
3.75 kW motor	22	0.45	12	19	0.6	16	17
	20	0.6	16	21	0.9	24	21
	18	0.9	24	23	1.2	32	26
	16	0.9	24	21	1.35	36	25
	14	0.9	24	17	1.5	40	22
5.4 kW motor	22	0.6	16	19	0.9	24	19
	20	0.6	16	17	1.05	28	20.5
	18	0.9	24	21	1.2	32	21
	16	0.9	24	19	1.5	40	25
	14	0.9	24	13	1.8	48	23
9.3 kW motor	22	0.9	24	21	1.05	28	21
	20	0.9	24	19	1.2	32	20
	18	0.9	24	18	1.5	40	23
	16	1.2*	32	21	1.8	48	21
	14	1.2*	32	17	2.1	56	19
5.8 m DIA BIN (With twin-screw stirring devices)			55°C			45°C	
3.75 kW motor	22	0.9	24	23	1.5	40	36
	20	0.9	24	23	1.8	48	32
	18	0.9	24	22	2.25*	60	30
	16	1.2*	32	19	2.25*	60	45
	14	1.2*	32	15	2.25*	60	20
5.4 kW motor	22	0.9	24	23	1.5	40	32
	20	0.9	24	21	1.8	48	28
	18	1.2	32	24	2.4	64	30
	16	1.2	32	18	2.7*	72	34
	14	1.2	32	14	2.7*	72	32
9.3 kW motor	22	1.35	36	25	1.65	44	31
	20	1.35	36	24	1.95	52	30
	18	1.5	40	23	2.4	64	26
	16	1.8*	48	21	3.0*	80	29
	14	1.8*	48	19	3.0*	80	22

*Depths shown are maximum recommended because of static pressure limitations of the fan.

WHEAT, BARLEY AND OATS (Final moisture 14%)

Dryer size	Initial moisture %	Wheat Depth m	Wheat Volume m^3	Wheat Time h	Barley or oats Depth m	Barley or oats Volume m^3	Barley or oats Time h
½-day fill							
5.8 m DIA BIN			55°C			55°C	
3.75 kW motor	24	0.6	16	7.5	0.9	24	10.5
	22	0.9	24	9.5	1.2	32	11.5
	20	1.2	32	10.0	1.5	40	11.5
	18	1.5	40	9.5	1.8	48	10.0
	16	1.6	48	8.0	2.1	56	7.0
5.4 kW motor	24	0.6	16	6.5	0.9	24	9.5
	22	0.9	24	8.5	1.2	32	10.0
	20	1.2	32	8.0	1.5	40	10.0
	18	1.5	40	8.5	2.1	56	9.5
	16	2.1	56	8.0	2.4	64	8.0
9.3 kW motor	24	0.9	24	9.0	1.2	32	10.0
	22	1.2	32	9.5	1.5	40	9.0
	20	1.5	40	9.0	1.8	48	9.5
	18	1.8	48	9.0	2.1	56	8.5
	16	2.4	64	7.5	2.7	72	7.0
1-day fill							
5.8 m DIA BIN			40°C			40°C	
3.75 kW motor	24	0.9	24	19	1.2	32	23
	22	1.2	32	21	1.5	40	22
	20	1.5	40	22	1.8	48	22
	18	2.1	56	21	2.7	72	25
	16	3.0	80	18	3.6	96	18
5.4 kW motor	24	1.05	28	21	1.2	32	21
	22	1.35	36	23	1.5	40	20
	20	1.65	44	22	2.1	56	23
	18	2.25	60	21	2.7	72	22
	16	3.3	80	17	3.9	104	18
9.3 kW motor	24	1.2	32	23	1.35	36	21
	22	1.5	40	24	1.65	44	22
	20	2.1	56	23	2.4	64	24
	18	2.7	72	25	3.0	80	25
	16	3.6	96	18	4.2	112	19

WHEAT, BARLEY AND OATS (with twin-screw stirring devices; final moisture 14 %)

Dryer size	Initial moisture %	Wheat Depth m	Wheat Volume m^3	Wheat Time h	Barley or oats Depth m	Barley or oats Volume m^3	Barley or oats Time h
5.8 m DIA BIN			55°C			55°C	
3.75 kW motor	24	1.65	44	23	1.9	50	23
	22	1.9	51	22	2.25	60	22
	20	2.4	64	21	2.8	75	22
	18	3.1	82	22	3.7	99	22
	16	3.3	88	15	4.35	116	17
5.4 kW motor	24	1.8	48	22	2.1	56	24
	22	2.1	56	21	2.25	60	22
	20	2.55	68	21	3.05	82	21
	18	3.3	88	21	4.05	108	22
	16	3.9	104	16	4.35	116	15
9.3 kW motor	24	1.95	52	23	2.3	61	24
	22	2.3	61	22	2.7	72	22
	20	2.75	74	21	3.3	88	22
	18	3.6	95	20	4.3	114	22
	16	4.35	116	17	4.35	116	14

SHELLED CORN (Final moisture 13 %)

Dryer size	Initial moisture %	60°C Volume m^3	60°C Depth m	75°C (use stirring device) Volume m^3	75°C (use stirring device) Depth m
5.8 m DIA BIN					
5.4 kW motor	30	35*	1.3	43	1.6
	25	45	1.7	62	2.3
	20	70	2.65	96	3.6
9.3 kW motor	30	35	1.3	49	1.8
	25	48	1.8	66	2.5
	20	78	2.9	107	4.0

*Based on 21 hours drying time. All other capacities based on 18 hours drying and 2 hours cooling time. At drying temperatures over 60°C, a stirring device should be used. For more-even drying it may be used at temperatures of 60°C or less. Drying rates are based on outside air of 10°C—65 % RH. These rates may vary under other conditions.

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