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Corn Drying

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CORN DRYING

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CORN DRYING

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Modern power units and corn harvest machines have brought both increased speed of harvest and greater choice in harvest methods. Corn picker-huskers, both pull type and tractor mounted, are made in one- and two-row sizes. Corn picker-shellers are made in one- and two-row sizes with some adapter sheller components to be used with the picker-husker basic machine. Lastly, the large combine, pull type or self propelled, has been fitted with gathering points for the corn crop and can be used (with reduced cylinder speeds) for a picker-sheller.

In two out of the three above instances, it is possible to combine two operations in one. This is a definite trend in harvest machinery. These self-propelled combines have been fitted with 2-row, 4-row, and, in a few cases, 6-row gathering heads.

Corn harvest, for a given farm, can now be accomplished in a very short time, and if done early in the season the corn will have a high moisture content. It can also be shelled in the field and go into weather-tight, rodent-proof structures for storage (provided that moisture is reduced). The shelled corn is a more suitable form for mechanized feed handling machinery to meter and deliver to the feed bunk.

CORN DRYING BECOMES NECESSARY

New and improved methods of harvest have left the farmer with three choices, none of which are without some added costs or hazards: (1) late or delayed corn harvest to secure dry corn, (2) early harvest with corn drying, and (3) early harvest with wet storage in gas-tight structures. This publication will deal only with drying corn as it is received from the picker-sheller, together with some of the field tests of several kinds of picker-shellers.

Early corn harvest allows longer periods for livestock to pasture the fields and retrieve machine losses. Machines have never been built to retrieve ears that have fallen to the ground, so early harvest is desirable from the low field loss viewpoint.

Picker-shellers work nicely and do a satisfactory job of shelling the corn when at 25% or lower moisture content. Some tests have been successfully run at the 30% moisture level, but kernel breakage increases considerably. At 35% or more, the work is definitely not satisfactory. Much corn is broken, the wetter kernels are mashed, and there is no way of measuring such loss, since it is neither delivered to the wagon, nor left on the ground in recoverable form.

FIELD LOSSES

In South Dakota, one should seldom plan to run the picker-sheller before October 10 or 2 weeks after a hard frost. Seasons vary a great deal and during the 1953-60 seasons there have been two where the corn was still 30% moisture on November 15. The ideal situation is to begin picker-sheller work at the 25% moisture level and before any ears have dropped to the ground or before any stalks have broken over.

In several seasons (1958 and 1959), pregleaning in connection with field loss studies showed essentially no loss from fallen ears. Dry weather, high winds, and corn borer damage all contribute to fallen ears.

Pregleaning is defined as the picking up, weighing, and recording of ears on the ground and unattached to any stalk, over a measured test run distance. Postgleaning is the total corn found on the ground of the test-run distance after the machine has passed over and includes whole ears not retrieved by the machine, broken ear parts damaged in the process, and shelled corn on the ground. This last is an indication of how well the snapping rollers, gathering chains, and gathering points can gather in the bent and fallen stalks with ears attached. The steering, adjustments, and general operation of the machine partly determine this type of field loss. Higher field speeds usually mean higher losses.

In the 1954 field tests, an end of season average showed: pregleaned ears on the ground, 1.7%; postgleaned ears, 3.0%; sheller loss on the ground, 4.2%; and other shelled corn on the ground, 2.2%. Total machine loss was 9.4% and total field loss was 11.1%. This netted 62.2 bushels per acre harvested from a total yield of 69.8.

During the 1956 and the 1957 season, field loss records were kept at various times from October 1 to November 30 and three different machines were used in the tests. In the 1956 season, most of the picking was done with 20% or less moisture in the corn. Of 20 tests on three machines, the machine losses averaged 10.2%, with individual tests as low as 1% and as high as 22%. This indicates the part careful steering plays and also the part wind and weather can play. Postgleaned ear loss was the major machine loss that year because of stalks blown to the ground yet still retaining their ears but out of reach of the gathering mechanism.

Years with low yield corn, such as 1957, do not necessarily mean low losses. Here the pregleaning checks of 20 tests showed several with 0% loss, with a few going to .75 bushel per acre. Postgleaned ears of the same tests showed .60 bushel per acre to 7.5 bushels per acre. Additional sheller losses varied from .85 bushel per acre to over 3.0 bushels per acre.

The beginning of the 1961 season was an exceptional one. Corn had good growth, high placement of well matured ears, and very few stalks were down. The field losses were very low.

The most extreme field losses were experienced in the 1956 season. After October 20 a severe wind storm put 15% of the corn on the ground or beyond the ability of the machine to pick it up. Such a situation is the best single argument for early harvest.

VARIOUS TYPES OF MACHINES USED

Field picker-sheller machines were selected to include a range of types, both single row and double, complete machines versus conventional picker with sheller attachment (an early model), and conventional corn shelling cylinder versus that of the grain combine type of cylinder. The field machines used in the test are shown in figure 1.

It was not the purpose of the project to compare field performance of one machine versus another, but rather to prepare the corn for the drying tests. A given machine that was best at the snapping roll was not necessarily best at the shelling cylinder. Many variations in ease of handling, speed of work, and thoroughness of work developed. Seasons and size of the corn also caused changes in performance. The cylinder built especially for shelling showed less crackage and broken kernels than the combine cylinder in most tests.

DRYING CORN WITH UNHEATED AIR

Corn harvest seasons such as 1955 make unheated air drying possible. By October 14, field picked and shelled corn was brought in at 14% and 15%. This corn was placed in a standard steel grain bin into which a sheet metal duct system had been placed. The system had one main air duct, three laterals, and the duct work was held 6 inches off the floor. The bottoms of the ducts were screened, but formed the only air opening for the system. Air was delivered to this bin by a 3 HP electric motor and a radial type fan with backward slanted blades.

Eight wagon or trailer loads were picked and shelled and placed in the bin over a period of 7 days. The fan delivering unheated air was started after the third load covered the ducts. The fan operated continuously for 14 days, at which time the grain was tested at various parts of the bin and showed an average moisture content of 12%. There were 31,690 pounds of the 12% corn (566 bushels) and it covered the bin floor to a depth of 4 feet. Excellent drying conditions for the field meant excellent drying conditions at the bin.

This illustrates how trouble-free unheated air drying can be under favorable conditions. Corn at 14%-16% moisture is very near to favorable storage condition. (A few days of cooling with below zero air would probably keep it safe for the winter months.) However, if such corn is kept through the sum-

Figure 1. Field picker-sheller machines used in the tests.

mer or for longer periods, it should be reduced to a 12% moisture content. One need only to know the moisture content as the corn enters and test periodically. When the desired moisture content is reached, the fan is turned off.

The slow evaporation keeps the grain cool. Relative humidity in the aerated grain is kept low, and mold growth is not a hazard. The fan can run continuously unless perhaps for extremely rainy days of high humidity; and this is not normal for early fall weather in South Dakota.

It does little good to have the fan operating in subzero weather in late fall or midwinter. Such air has no moisture carrying capacity and it cannot dry the grain, although the low temperature is not detrimental.

The 1954 season was similar to 1955, but picking started on October 18 with 23% corn, and due to higher moisture corn and a colder season, the fan was operated 28 days before the moisture was reduced to 14%. Only the very early picked corn of the 1956 crop season needed drying, as corn from the field was below 15% after October 11, very easy to shell, with no drying problems to consider. The costs of such an operation will be given in a later table.

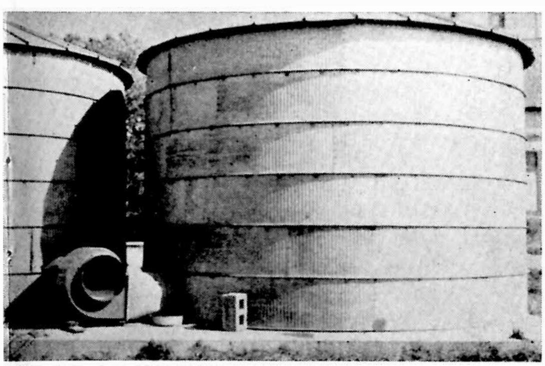


Figure 2. Drying grain with unheated air.

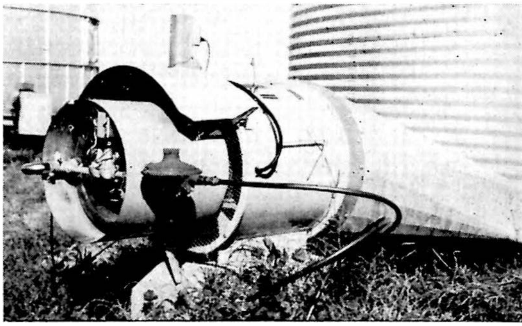
Figure 2 shows the bin and fan system used in 1954-55. A flat floor of perforated steel with open space beneath for air entry, like the cross-section drawing of figure 3, is easier to load and unload than bins with a duct system.

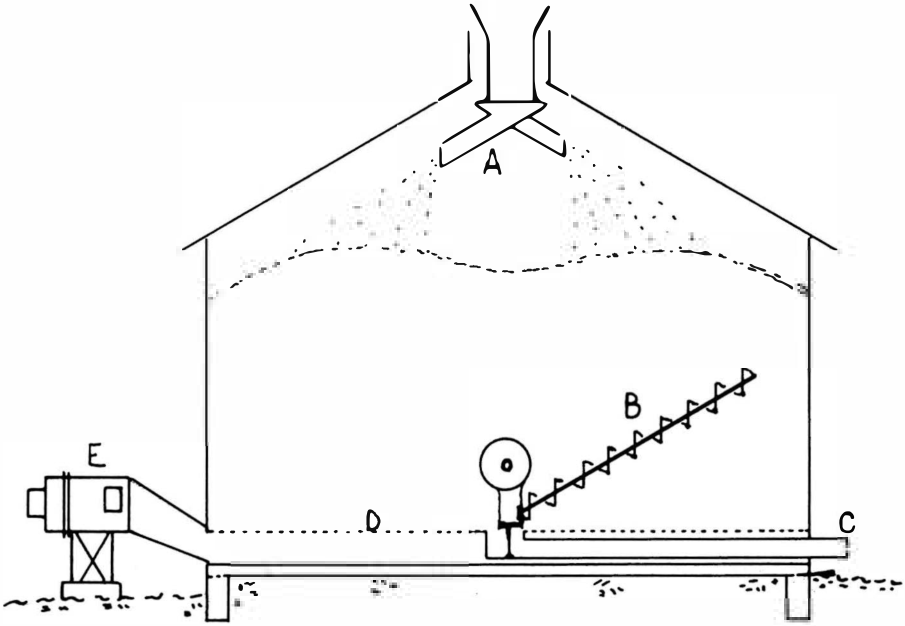
BIN MANAGEMENT WITH UNHEATED AIR

Unheated air drying usually means equipping a bin for drying corn, then leaving the grain in the same bin for storage. Drying air rates of 2, 3, or 5 cubic feet per minute (cfm) per bushel are recommended, depending on the moisture content reduction and the time allowed for doing the work.

Since 8 feet is the usual maximum depth for economical movement of air, such bins need not be high, but there should be enough of them to store the season's crop. More uniform air flow will result with a grain spreader device that will keep the bin level and keep the dirt and fine particles from dropping all in one place (see figure 3 at "A"). Unloading aids are also available to be installed with the perforated floors. These are: (1) a portable sweep auger to bring grain to the center of the bin (see figure 3 at "B") and (2) the horizontal auger installed

Figure 3. Supplemental heat, fan, burner, and bin combination. Line drawing shows cross section of round steel bin equipped with (A) grain spreader, (B) sweep auger, (C) tube for auger, (D) perforated floor, (E) fan and burner.





under the floor (see figure 3 at "C") for taking the grain from the center of the bin to the outside.

CONTROLS CAN SAVE POWER COSTS

While the unheated air drying may go on continuously, there could be some fan power cost saving accomplished by automatic controls. The most common control is that of the thermostat, whose switch points could control small motors, say ¼ HP, directly, or large motors through heavy duty relays. Since little drying is accomplished at below 0°F temperatures, the thermostat is set to turn the motor off during low temperature periods.

The humidistat control, since it

is sensitive to the drying ability of the air, is of more value than the thermostat. By setting the humidistat control to turn the fan off when humidity of the air rises above the 70% to 80% relative humidity level, the fan would then run only during the most favorable drying weather. Both temperature and humidity controls could be used to control the same motor relay if control components were properly matched. Such controls are desirable for unheated air drying, and they become a necessity at any time that heat is added to the drying process.

SUPPLEMENTAL HEAT DRYING

Much the same equipment is used in supplemental heat drying as in unheated air drying. The same type of bin is used and can be the 1,000 to 3,000 bushel circular steel bin with its perforated steel floor and air chamber beneath. Large diameter bins with correspondingly large floor areas are more desirable than the small ones. The lower bins are suitable and adequately accommodate the 8-foot depth of grain for the lower air pressures. The taller bins may be used with the upper parts unfilled unless dry corn is placed there after drying has been completed on the lower part. For pressure drop, air flow, grain depth relations, see figure 9.

Similar fans can be used as for unheated air drying, but the more popular fan type is the propeller fan, directly connected to the electric motor to eliminate all but two bearings, and running at 3,450 R.P.M. to reduce the weight and size of the motor to its minimum. This choice has been made to reduce size and cost of the overall installation. To the fan and tube is added the burner, and when direct fired, L-P gas is a "clean" and nearly odorless type of heat. Many variations are available, as to motor, fan, heater, controls, and general arrangement of the same. Figure 3 shows one such installation.

More care and watching is needed for supplemental heat drying than in unheated air drying. This calls for more careful bin management and more thorough understanding of the drying process. Drying air evaporates moisture from grain, taking the heat of vaporization from the air, which will show a temperature drop whenever vaporization goes on.

Generally speaking, air, and grain will arrive at a hygroscopic balance when brought together. Moisture will slowly move from the one which has the higher vapor pressure to the one with the lower vapor pressure. This means that the vapor pressure of the surrounding air, after a sufficient time, will come to equal the vapor pressure of the grain at its specific temperature and moisture content. Figure 10 gives these data.

Since heat is added to the incoming air, it can hold more moisture, and will dry the grain more rapidly. But the temperature will fall, and as the air moves on through the grain, it may cool to the point of reaching a saturated condition or near 100% relative humidity. This may cause one part of the grain to be suitable for mold growth, while another part is drying. Still more extreme conditions may cause the air to redeposit moisture near the air outlet which it first took up near the inlet. On cold steel bin sides or roof, water will condense from the moisture-laden air and trickle down the bin sides to the grain.

The above-mentioned extremes are, therefore, prevented to a substantial degree by "layer type of filling." The bin can be filled by 2-, 3-, or 4-foot layers of grain, depending on moisture, with the wetter grain being placed in a thinner layer. Drying takes place fastest at the bottom of the layer, but the "drying front" gradually moves on up. When the drying has reached the top, the next layer can be added etc. Each layer added will mean more back pressure and reduced air flow, so drying of the upper layers will be slower and they probably should be reduced in thickness.

Some typical fan outputs according to their static pressures are given in table 2. One should consult the manufacturer's ratings for a given type of fan.

The layer method of filling at once suggests a retarded filling pattern and brings up the chief obstacle of the method. Slow filling procedures either delay the field harvest or call for several bins each with their fan and heater systems. The farmer with his own field machinery can adjust the field rate to the drying rate. The custom operator is usually not situated to let his machines stand idle part of the time.

The rather slow, layer by layer filling, is a "must" with the supplemental heat method whenever the moisture content is a few percent above 12. However, an advantage is that with careful "layer management" one can successfully dry grain that is as high as 30% moisture. Such wet corn was successfully dried during the fall of 1960. These conditions tax the supplemental heat system to the limit and call for careful bin management and frequent inspection. Much of the time the relative humidity of the air leaving the grain was near 100%.

The grain was exposed to air that was 10° to 20° F. above the normal fall weather. Conditions for mold growth were favorable. Molding in serious proportions was prevented by reducing drying time. This in turn was accomplished by placing thin layers of the wet grain in the bin at a given time.

BIN MANAGEMENT UNDER SUPPLEMENTAL HEAT DRYING

Management and loading a supplemental heat drying bin depends on four principal variables. The first is fan size, which determines C.F.M. delivery against a given back pressure. The second is bin floor area (or total floor area of several bins connected to the fan). The third is the grain depth, which due to back pressure, will modify the C.F.M. of the fan. The fourth variable is the drying ability of the air itself — a combination of temperature and relative humidity and the new temperature and relative humidity after the air passes the burner.

Air flow into a bin can be stated as to C.F.M. per square foot of entry or C.F.M. per bushel. In unheated air drying, one usually deals with C.F.M. per bushel where the bin is filled rapidly and dried over a long period. Recommended C.F.M. per bushel is 2, 3, or 5, depending on the moisture content.

Typical supplemental heat dryers and their fans are designed for much more air movement. A 7,000 C.F.M. fan (at ½ inch static pressure) would deliver near 40 C.F.M. per square foot of entry on a 15-foot round bin. If the same fan were delivering to two such bins, the C.F.M. per square foot of entry would be something above half, or 22-23 C.F.M. For the major drying layer of 1¼ feet, this means 40 or 22 C.F.M., respectively, per bushel. If the drying layer were 2½ feet deep, the C.F.M. per bushel would become 20 and 11, respectively. There are endless combinations of bin size, fan size, grain depth, and moisture content.

By trial, one can soon tell how deep a layer of grain can be dried in a 24-hour period. One plans his loading schedule to get the maximum layer dried per day. This calls for careful observation and testing. Grain in the drying layer of the bin completes its initial drying below 13 to 15%, after which the other successive layers may be added. The grain in this former layer will continue to dry and will not retard the initial rapid drying of the new top layer. The bottom layer will finally get "too dry" or 8%-10% moisture content if a continuous heat is used.

Efficiency and economy in drying is brought about by having a minimum rise in temperature, say 10 to 15°F., and by longer drying periods before adding a new layer. Also, by using a humidistat control which will turn off the burner in favorable drying weather, some economy on fuel will be noted, but it will prolong the drying period.

Excessively dry layers of corn in the bin bottom can be somewhat corrected or "normalized" by allowing the fan to blow through the bins for several days with unheated air only at the end of the drying period.

DRYING CORN ON THE WAGON

There are occasions where corn may need to be dried on a given farm, but where there are no drying bins or batch dryers immediately available. Some sort of transportation of the newly shelled corn must be used from field to the farm storage place. It is here where the wagon drier might be a versatile and temporary solution to the problem. Wagons and trailers can be equipped with false floors and connected to a portable heater-dryer by canvas duct for the drying period. When dry, the corn from these wagons can be dumped and elevated into permanent storage.

Such an assembly of machines was used in the drying seasons of 1958 and again in 1959. Figure 4 shows one of the wagons, end-gate

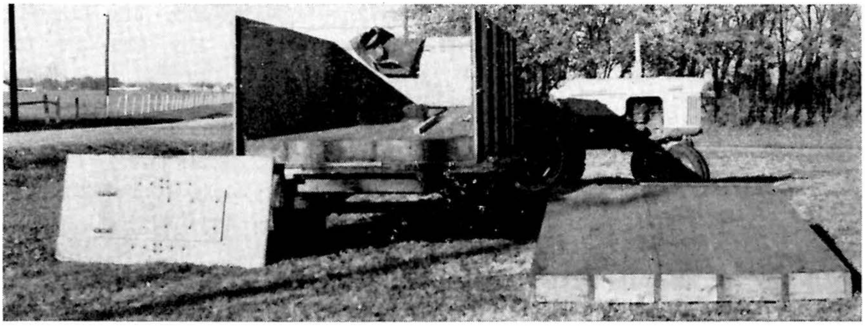


Figure 4. Wagon with false floor for grain drying.

removed. Beside the wagon is the false bottom. Three wagons were equipped with these sloping false bottoms, made of 2-inch framing lumber and covered with steel perforated bin flooring.

A small perforation was selected so the floors would hold small grain as well as shelled corn. The front end-gate of all of the wagons was replaced with a special one which provided an opening to which the canvas duct was attached, which in turn was attached to the dryer. One "Y" shaped tube was fabricated, which allowed two loads to be dried simultaneously, usually over night.

The schedule of picker-sheller field work was fitted to the drying rate. Under favorable conditions 400 to 600 bushels of shelled corn was processed per day. Rate of operation depends on many coordinated procedures, such as field work, hauling and hauling distances, and availability of an extra tractor for hauling. Hydraulic dumps on the wagons are desirable for aid in emptying the wagons, and adequate elevating machinery from wagon to permanent storage is an important part. Three wagons should be the minimum number available, except for very slow harvesting and drying operations.

For drying the corn, the portable dryer used for earlier tests in drying ear corn was used. This was an oil burning, heat exchanger type and is shown in figure 5. It is one with a 27-inch fan and a 3 HP electric motor. The drying process is similar to that of batch drying, in that high temperature air is used for rapid drying. The drying layer may be deeper, however, being 24 to 30 inches with the wagons used. The drying moves up in typical "drying front" fashion. The grain is very accessible for observation, sampling, and testing.

Since the drying process is reduced to a matter of a few hours, a moisture tester that will give an immediate answer is desirable. The problems in connection with moisture testing will be discussed in a separate section. The initial costs are high for the volume of work accomplished, but the dryer, elevator, and wagons are useful for many other farm jobs and can be used with more permanent arrangements for drying at a later date.

BATCH DRYING FOR FIELD SHELLED CORN

The "batch-dryer" process is designed for the operator who wishes to harvest high-moisture grain, dry it at the same rate as harvest goes on, and load it into permanent storage structures which are not equipped for drying. Such equipment concentrates some high priced, unusually large equipment at the farmstead and necessitates double loading elevators.

Many batch dryers have the dryer loading elevator built in as part of the unit. The fans are designed to move a large C.F.M. per bushel capacity, and the heater units are designed to give a very high rise in temperature with some going above the 200°F. range. Most have a short air passage between plenum chamber and outside of 12 to 24 inches or more, but the latter are usually built on the recirculation principle. With recirculation the elevator runs during the drying cycle, moving grain from bottom to top and repositioning it.

The advantage of such movement of the grain is to get uniformity of drying (to reblend so that the corn next to the plenum chamber is not over dried while that near the outside wall is less than properly dried). Recirculation does not guarantee absolute uniformity, although much progress has been made with feeder mechanisms and baffles to aid recirculation. As the path of travel of the air through the corn becomes shorter, recirculation becomes less necessary. When the batch is unloaded at the end of the drying period, the corn is well mixed in the bin and high and low moisture kernels will gradually adjust to near uniformity.

Batch dryers are built in sizes to handle 100 bushels per batch up to and larger than 600 bushels. A major problem is to select a batch dryer that will keep up with the field output of the picker-sheller or combine. The smaller sizes have the advantage of handling a small batch for trial periods and end periods. Many of the larger dryers are partitioned so that these small batches can also be handled. The large dryers have the obvious advantage of large capacity of drying, and although the first cost is high, the cost per bushel capacity

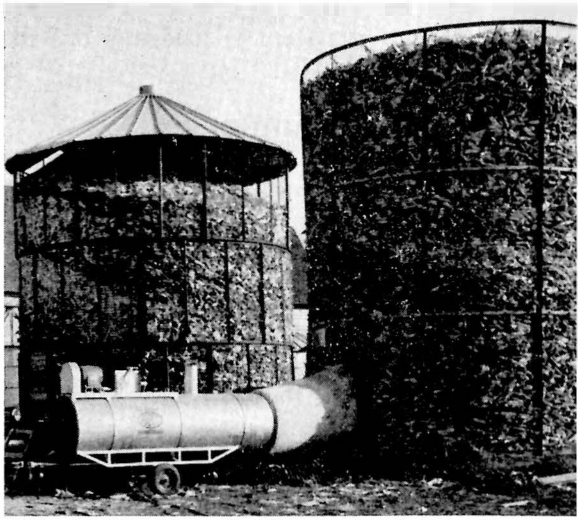


Figure 5. Portable oil burning dryer.

is lower. The custom operator who wants the corn processed as fast as his field machinery can operate will need one of the larger portable models.

The batch dryer must be fitted to various locations, some of which are temporary or "make-shift." A dumping pit or receiving bin large enough to dump a complete load and allow the vehicle to be on its way would be ideal. Under temporary arrangement the receiving bin may become just a "pile" on a canvas spread on the ground. Figure 6 shows this arrangement and the machine used in tests during the 1959 and 1960 seasons.

An ideal installation would be an arrangement where there was a dump pit or holding bin for wet corn, all-weather access road, and where only the unloading elevator need be moved from one bin to the next. This would call for a semi-circular bin arrangement, a very large single bin, or a distribution system to load any one of several bins.

MANAGEMENT OF THE BATCH DRYER

The mechanical management of the dryer will range from chiefly manual control by the operator to full automatic. A full automatic machine will load itself from a wet corn holding bin, keep itself loaded after drying and settling, dry the corn for a preset time or condition, cool the corn, and then unload. Such a machine will immediately reload itself and repeat the cycle, eliminating much of the watching and most of the manual labor. Wet corn does not "flow" like dry grain, and some work may still be needed for wagon and truck unloading.

Figure 6. The batch dryer.

There are many variables to corn drying, such as corn moisture content, weather, temperature setting of the burner, and drying time. The operator's job is to match these things so that his finished corn comes out at the desired moisture content of 12-14%. A typical operating run of the dryer (pictured in figure 6) for the 1960 season was as follows: October 27—100 bu. fill.

Drying time—4 hours less 12 minutes filling
Cooling time—20 minutes
Unloading time—6 minutes
Beginning moisture
By quick test—29.6%
By oven test—25.5%
Finished moisture
By quick test—14%
By oven test—13½%
Temperature setting — 140°F. — with burner cycling on and off occasionally to maintain the same.
Propane fuel—direct fired system
Rated fan delivery—8,000 C.F.M. —2HP.

These figures will show the importance of moisture testing. Test-

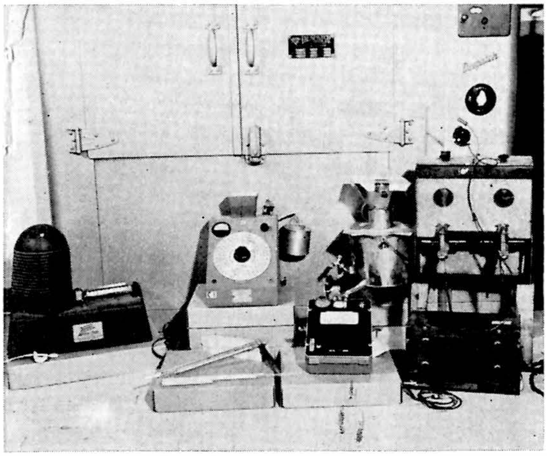


Figure 7. Moisture testers — Dispatch oven (background), heat lamp and scales (front, left), electrical 115 V., electric portable, Brown-Duval.

ing at time of unloading, or even before the major portion of the batch load is elevated is a good policy. Operations can be halted long enough for a quick test if the instrument can be operated on the site. Such quick tests should be verified by a more accurate test occasionally and the differences noted. Testing of the grain at the start of the run is equally as important, for it will allow the operator to adjust either the time period, the drying temperature, or both.

Drying temperatures should be watched carefully. The Agricultural Research Center at Beltsville, Maryland, states that: (1) heat in excess of 110°F kills the viability of seed corn and (2) corn dried at temperatures over 140°F is damaged for the wet milling process. However, South Dakota State College research shows that the nutritive value of corn in a complete diet is not lowered until visible damage is evident.

GRAIN MOISTURE TESTING

Accurate moisture tests should be the basis on which all grain drying management decisions are made. Initial moisture of a sample must be made to predict the time and temperature settings for any fast-dry process. Unheated air drying is slow enough so that tests can be made every few days to check the progress, and excess drying seldom occurs. To take the guesswork out of drying, one needs a moisture measuring instrument, and the best one that he feels his drying activities warrant. Figure 7 shows some grain moisture testing devices.

Official moisture testing methods are based on oven drying of grain samples. Some of these methods are briefly stated:

(a) **Air-oven method**—grind grain sample and dry at 266°F for 1 hour.

(b) **Water jacketed oven**—use whole grain and heat in oven at 212°F for 72 to 96 hours.

(c) **Vacuum oven**—grind grain sample and place in oven at 212°F, maintain the oven vacuum at 40 mm of mercury, and continue for 5 hours.

These are excellent methods, but they fail to yield an immediate answer as is sometimes needed. All substitute methods should be checked against these standards occasionally so that corrections in their readings can be made.

The distillation method by Brown-Duval testers is reliable and this equipment is available at most commercial grain elevators. The grain sample is "boiled in oil," driving off the water as vapor, and this is recondensed and measured. The apparatus pictured in figure 7 (left lower) is a distillation apparatus with electric heater elements and automatic shutoff. Such a test takes about 1 hour.

Some testers heat the sample by heat lamp and allow it to be weighed in place, figure 7—left. Most rapid testers are the electrical ones which test a certain conductance of the grain, which relates to a corresponding moisture content. Temperature corrections need to be applied to these readings. The more accurate have different scales that are used for a narrow range of moisture content. Such testers are shown in figure 7—front center.

The electrical testers give the immediate answer which is so necessary in running a batch dryer. Two precautions must always be kept in mind, however. First, sampling must represent a whole batch. All parts of a bin or batch do not dry at the same rate. Secondly, one must allow a correction for grain that has been dried rapidly. Moisture moves from the central part of the grain kernel outward to the drying surface, but a time element is involved. Fast-dried grain may appear to the electric or "surface contact" tester as quite dry just as it comes from a dryer. Several hours later it may "test" higher in moisture, for the moisture moves out from the still wet central part to the fast-dried surface.

Figure 8 shows in graphic illustration how this moisture movement takes place. Much of the trouble of wet spots and hot spots in permanent storage of grain dried by the batch method can be traced to faulty moisture tests or from the operator going by the "dry feel" of the grain as it comes from a batch drier.

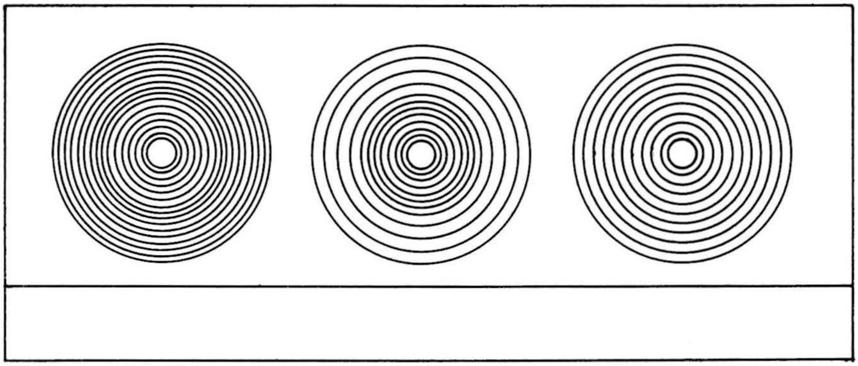


Figure 8. Graphic illustration of a problem in moisture testing—(left to right) wet kernel of grain; partially dry kernel with wet center (tests dry); kernel with uniform moisture, but surface shows more moisture.

METHODS OF CALCULATING MOISTURE

Practically all of the farm moisture tests are on a "wet basis," or express the moisture content as a percentage of the total sample weight. As grain is handled on the farm, sold and purchased on an "over the scale" weight basis, the "wet basis" moisture calculation is most practical. Unfortunately, however, any change in moisture content, means a new weight for the sample and a new base weight for the moisture calculation.

In research work, the moisture-free weight is sometimes used as the base. This means moisture is expressed as a percentage of the dry weight. The dry base never changes during a test, and the change in moisture can be recorded at various stages of the operation by a curve.

COSTS INVOLVED IN CORN DRYING

Corn drying can seldom be separated from the entire process of corn harvest and final storage. A more valid approach is to find the costs of each component part of the entire series, even though such things as hauling from field to storage are approximately the same regardless of the method of drying. Operation of the picker-sheller is essentially the same for any type

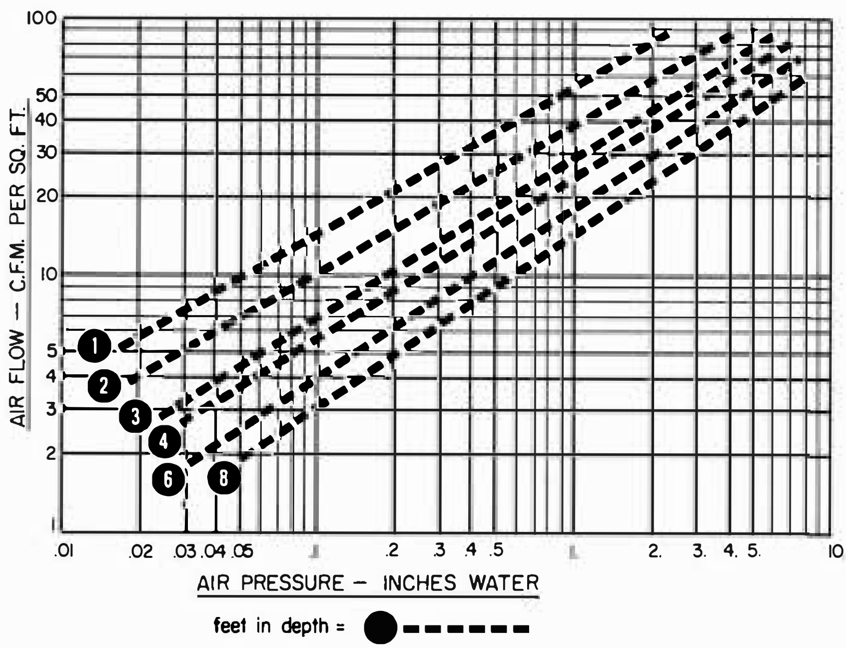


Figure 9. Flow of air through clean shelled corn (from A.S.A.E. Data Sheet #1, A.E. Index 11.732).

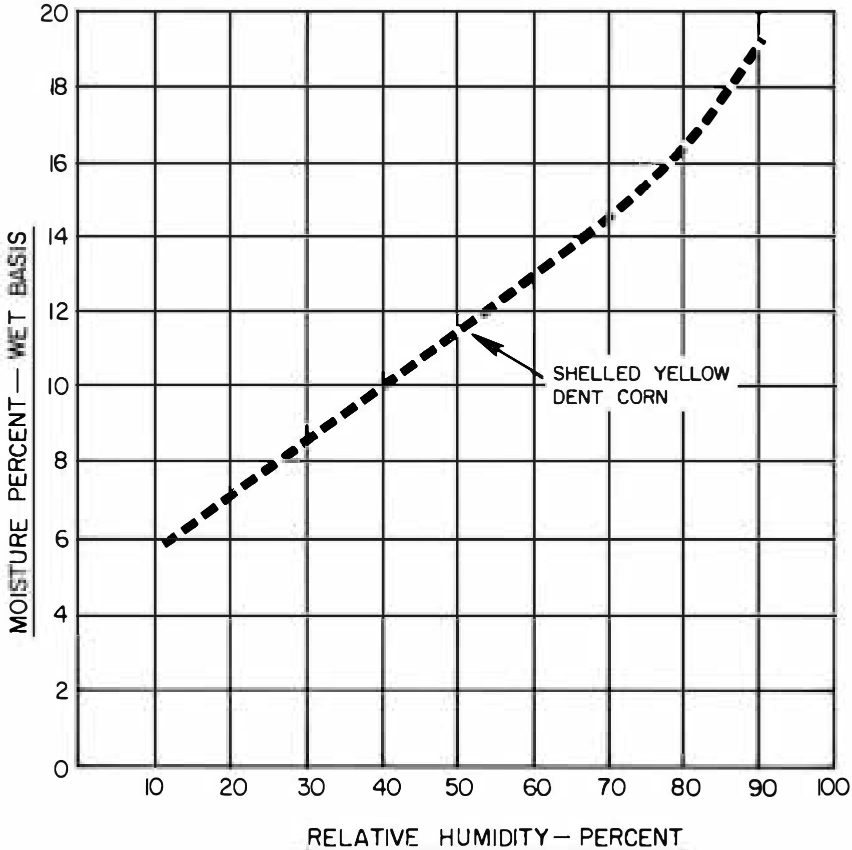


Figure 10. Moisture equilibrium in 77° F. air (from A.S.A.E. Data Sheet #1, A.E. Index 11.732.

of drying, provided the drying method does not restrict the rate of field operation.

The research work done by the Agricultural Engineering Department of the South Dakota State College Agricultural Experiment Station was not always typical of actual farm operations. Distances in hauling far exceeded the normal and intermittent work periods reduced labor efficiency. The smaller sizes of bins and dryers were excellent for repeated tests but were not as efficient as larger sizes when placed in the environment of normal farm operations.

The results obtained from the many research tests have, therefore, been translated to two hypothetical situations—a 5,000-bushel-per-year crop and a 10,000-bushel-per-year crop. Proper bin storage and proper fan or dryer sizes were selected for each of the two cases. Cost of drying with (1) unheated air, (2) supplement heat, and (3) the batch dryer have been calculated for the two quantities. The six variations are tabulated and summarized in table 1.

Much more detailed work sheets were used to arrive at the various summary figures, but these work sheets are not included in this publication. However, the basic assumptions made before setting out to calculate costs for a given situation are presented.

Before yearly costs of machinery can be calculated, assumptions must be made on the life of the machine. These assumptions then rule out the part which acreage or quantity might play in the life of the machine. This results in the situation where cost per bushel for the 5,000-bushel crop is nearly twice as high as for the 10,000-bushel crop (see "field-harvest" column, table 1). There are some arguments for using a specified "years of service" regardless of acreage or quantity in that after a given period, machines deteriorate or become obsolete.

The goal for the compilation of figures in table 1 was to give exact comparative figures for the different methods of drying. The batch dryer is used on 30% corn and the unheated air system on 20% corn. It is also recognized that an individual operator would start with different basic assumptions, costs, acres, etc. and arrive at different answers, which could be more accurate for his situation.

Table 1 gives in turn the total cost and the cost per bushel for: (1) field harvest with the picker-sheller; (2) hauling by tractor and wagons; (3) handling at the bins for dumping and one elevation, common to all methods; (4) bin costs of the major portion of the bins needed for annual storage of the crop; and (5) drying machinery costs, fuel and power costs, and bin accessory costs for a given drying procedure.

Part (5) was divided to show the three drying methods: (5) the unheated air drying for 20% moisture corn, (5A) for the supplemental heat drying of 25% moisture corn, and (5B) for the batch drying at 140°F air for the 30% moisture corn. Each drying method was used in its logical situation, although it must be kept in mind that the final figures of drying costs per bushel are not directly comparable.

Table 1. Costs of Harvesting and Drying

	First cost	Annual cost	Labor cost	Fuel, power	5,000 bu. Total	5,000 bu. $/bu.	10,000 bu. Total	10,000 bu. $/bu.
1. Field harvest—50 HP tractor	$2,600.00	—	5,000 bu.— 6 da.	—	—	—	—	—
Pull type 2-row picker-sheller	3,500.00	—	10,000 bu.—12 da.	—	—	—	—	—
5,000 bu./year	—	$542.35	$ 60.00	$ 48.00	$650.35	.130	—	—
10,000 bu./year	—	542.35	120.00	96.00	—	—	$758.35	.076
2. Hauling costs								
5,000 bu. {1 tractor	2,600.00	74.32	30.00	19.20	123.52	.025	—	—
5,000 bu. {2 wagons and dump	1,450.00							
10,000 bu. {1 tractor	2,600.00	79.52	60.00	38.40	—	—	177.92	.018
10,000 bu. {3 wagons and dump	2,050.00							
3. Handling at the bins								
5,000 bu. {1 elevator	800.00	73.40	15.00	0.44	88.84	.017	—	—
5,000 bu. {3 HP motor	225.00							
10,000 bu.-Grain spreader*	50.00	73.40	30.00	0.88	—	—	104.28	.010
4. Bin costs								
5,000 bu.—2 bins, 22′9″ x 9′	2,860.00	257.20	5.00	—	262.20	.053	—	—
10,000 bu.—4 bins, 22′9″ x 9′	5,720.00	514.40	10.00	—	—	—	524.40	.052
Subtotal parts 1, 2, 3, 4						**.225**		**.156**
5. Unheated Air Drying (20%-12%)								
5,000 bu.—Duct work, 2-floor, 1 fan	540.00	73.80	4.00	77.50	155.30	.031	—	—
10,000 bu.—Duct work, 4-floor, 2 fans	1,080.00	147.60	8.00	155.00	—	—	310.60	.031
Total 1, 2, 3, 4, 5						**.256**		**.187**

5a. **Supplemental heat drying** (25%-12%)								
5,000 bu.— Same as for unheated air plus burner (500 gal. tank)	1,580.00	200.00	18.35	141.50	359.85	.072	—	—
10,000 bu.—Same as for unheated air plus burner (1,000 gal. tank)	3,080.00	387.80	26.80	283.00	......	......	697.60	.070
Total 1, 2, 3, 4, 5a						**.297**		**.226**
5b. **Batch drying**—5 HP fan (30%-12%)								
5,000 bu.—150 bu. batch size	3,900.00	494.00	15.00	215.20	724.20	.146	—	—
10,000 bu.—255 bu. batch size	4,400.00	375.00	30.00	377.05	......	......	982.05	.098
Total 1, 2, 3, 4, 5b						**.371**		**.251**

*Plus equipment for 5,000 bushels.

Table 2. Some Manufacturers' Ratings of Grain Drying Fans

Fan description					C.F.M. of air at static pressure of:							
Type	No. blades	R.P.M.	Diam.-eter	HP of motor	0	¼	½	¾	1	1½	2	3
Vane axial	4	3,450	18″	1½	—	—	5,460	—	5,060	4,640	4,180	2,770
Vane axial	4	3,450	18″	3	—	—	7,860	—	7,450	7,000	6,560	5,580
Vane axial	4	3,450	22″	5	—	—	11,130	—	10,650	10,190	9,650	8,460
Propellor	4	Belted*	30″	5	18,800	—	17,600	—	15,400	11,200	7,000	—
Tube axial	7	3,450	16″	1½	4,100	3,700	3,560	3,400	3,250	2,920	2,480	1,420
Tube axial	7	3,450	21″	3	8,630	8,325	8,000	7,675	7,325	6,575	5,850	4,100
Tube axial	7	3,450	24″	5	12,900	12,600	12,250	11,950	11,600	10,900	19,050	8,000

Assumptions for Cost Analysis

1. Field operations based on 60 bu./A. yield, 2½ MPH operating speed, 42″ rows, 6½ hr./day actual operating time, 13.8 acres/day, 50 HP tractor.
2. Fuel costs, tractor belt HP x .8 x $.20 x days.
3. Estimated years life of machine and equipment.
   Tractors, picker-sheller, fans, and batch dryers—15 years
   Steel bins, hydraulic dump—20 years
4. Percentage of year's work charged to corn harvest.
   Tractors—1/10 year
   Elevator—½ year
   Wagons—⅕ year
   Bins—full year
   Picker-sheller—full year
   Dryers—full year
5. Moisture reduction for corn.
   Unheated air drying ...... 20% to 12%
   Supplemental heat drying ...... 25% to 12%
   Batch drying ...... 30% to 12%
6. Assumptions for probable dryer operating conditions.
   Unheated air—600 hrs. operation—5 HP/fan, 45° F. air@75% R.H.
   Supplemental heat—16 to 20 days, 5 HP/fan, 45° F. air, 15° F. rise.
   Batch dryers—drying period 4 hrs., 140° F. temperature. 12 min. load, 12 min. cool, 6 min. unloading.

SUMMARY

1. Picker-sheller machinery for field harvest of corn has proven satisfactory for corn harvest in South Dakota and probably will be used in increasing numbers. All stalks, husks, and cobs are left in the field and grain alone is hauled to the farmstead. Thus it fulfills the "once-over" completion of corn harvest which is a goal to work for in any harvest machine.

2. Shelled corn needs less bin space than ear corn and fosters storage in tighter structures that, ideally, are weather proof and bird and rodent proof.

3. The shelled corn is in a semi-fluid form that is well suited to move through conveyors and machines enroute to and through automatic feed yard machines.

4. The picker-sheller allows for early and rapid corn harvest, although it has no monopoly in this respect, for the other kinds of machines will also do this. The picker-sheller does an acceptable job with corn at 30% moisture and an excellent job with corn at 25% moisture or less. This is assuming the corn was fully matured before frost.

5. Unheated air drying of corn is a satisfactory and trouble-free way to dry corn that is placed in the bin at near 20% moisture or less. Late October, most of November, and some of December provide satisfactory weather conditions for unheated air drying in South Dakota. It does little good, with respect to drying, to blow below 0°F air through the grain. No harmful effects are caused by this cold air, however. Unheated air drying is slow and the fans may need to run from 2 to 5 weeks.

6. Supplemental heat drying can be done with the same bin and fan equipment as unheated air drying, with the addition of the burner and fuel storage facilities. Corn that is 25% moisture or less is workable with such a drying system. Corn must be added in 2 to 4 foot layers, and when drying is approaching completion the next layer is added. Such a necessity may retard field work unless multiple bins and fans are used. Drying periods are shortened as compared to unheated air drying, but fuel costs and equipment costs are added.

7. The batch dryer, using drying temperatures of 140°F or higher will dry corn in 1 to 4 hours, depending on its moisture content. Grain above 30% moisture content could be dried, but, since it does not shell satisfactorily, this is not recommended. No special bin arrangements are needed since the batch dryer is a self-contained unit. The high initial cost, and its effect on total cost of drying, indicate it is best suited for the large operator, for joint ownership arrangements, or for the custom operator.

8. An accurate, low-cost, portable moisture tester is by far the greatest aid to the successful operation of any crop dryer. Such a tester takes the guesswork out of drying and helps one plan his proper bin management