Animal and Plant Health Inspection Service

Storage and Handling Equipment Inspection Training Module

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Background

Since field testing of federally regulated genetically engineered (GE) plants began in the late 1980s, proper equipment clean-out and subsequent compliance inspection has gained national and international importance. Adventitious presence of regulated GE seed or plant material, unintentionally introduced through storage or grain handling equipment into food or feed channels could result in the loss of billions of dollars with long-term impact on survivability of affected market sectors. In 2000, unintentional introduction of StarLink™ corn, a federally regulated GE corn line not approved for human consumption, caused millions of dollars of food products to be pulled from store shelves and sudden negative responses by trading partners.

Experience with high risk GE pharmaceutical-trait plants by the Animal and Plant Health Inspection Service (APHIS) has shown that due diligence in equipment clean-out and sanitation, including storage and handling equipment, is a critical step in preventing inadvertent introduction of material into the environment and the potential for subsequent damage to the integrity of food and feed supplies. To aid in managing this complex regulatory issue this training guide on storage and handling equipment has been prepared by Iowa State University for APHIS.

Introduction of value-added traits, identity preservation programs, federal organic standards, and the advent of field testing of federally-regulated genetically-modified plants have resulted in storage and handling equipment clean-out and sanitation becoming a production, marketing, and regulatory necessity. In a growing number of cases, federal regulations by United States Department of Agriculture agencies under Marketing and Regulatory Programs, in the areas of certified organic production, plant protection and quarantine, and biotechnology regulatory services require that equipment be cleaned of seed and biomaterial before use, interstate transport, or return-to-service.

In the past, APHIS has been concerned with plant pest and disease pathway analysis and disease epidemiology related to the rapid spread of plant pests and diseases from one field location to another or to their introduction into the country via equipment. An example of APHIS's regulatory concerns and practices is its quarantine program for Karnal Bunt disease of wheat. In order to effectively contain this serious fungal disease and prevent its spread, interstate movement of grain elevators, equipment, or structures used for storing and handling wheat was regulated and this equipment cleaned of residue biomaterials, disinfected, and inspected prior to moving to another location.

Currently, APHIS Biotechnology Regulatory Services (BRS) annually issues permits and notifications for field testing of regulated GE crops at over 5,000 domestic field test sites. In recent years, two new classes of GE plants, one class that expresses traits for the synthesis of pharmaceuticals and the

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second class that expresses traits for synthesis of industrial compounds have appeared. BRS's regulation of pharmaceutical or industrial trait expressing plants is more rigorous than traditional GE crops containing agronomic traits such as herbicide or insect resistance. Storage for relatively smaller quantities of these crops may be dedicated bags, modular bins, or transport vehicles. Storage and handling equipment used to handle and store these high-risk traits must be cleaned, inspected, and opened up by dismantling as necessary prior to return-to-service for storage or handling of traditionally bred crops. The need for a trained cadre of compliance inspectors with both knowledge and experience in the area of storage and handling equipment clean-out and inspection is an Agency imperative.

Because of the need for more scrupulous clean-out and sanitation, identity-preserved markets are generally developed around on-farm bin-type storage with the grower delivering product to transport vehicles directed to the end-user with minimal or no intermediate storage. This strategy minimizes or eliminates storage and handling at commercial grain terminals. Because of this, more attention will be given in this module to smaller storage and handling systems typically found on-farm or as part of a smaller boutique grain terminal better able to segregate grain. The relative level of cleaning and inspection required will depend on the needs of the marketplace, end-use customer, suppliers, regulatory requirements, and the public good (e.g. disease prevention, integrity of food or feed chain).

Overview

A section describing basic concepts of storage, grain conditioning, and drying is included at the beginning for those less familiar with grain storage. This is followed by a brief description of tools for cleaning before sections on major specific functional areas found in storage systems (i.e. bins, bin dryers, and stand alone dryers). A section on handling equipment, augers, and other conveyors is included adjacent to a safety section at the end. Augers and conveyors serve to connect grain receiving, drying, storage, and load-out areas. Readers unfamiliar with the concept of augers mentioned in storage and drying sections may want to review the section on handling equipment first. Terms and phrases used for storage and handling equipment are described as they come up within these different sections. Although it has been attempted to eliminate technical jargon, readers may want to refer to the appropriate section to review unfamiliar terms. Safety information is included as appropriate within each section as well as at the end.

Seeds are an immense variety of shapes and sizes. Smaller seeds include grains such as wheat and rice as well as small and slippery oilseeds such as flax and canola. Most grass and clover seeds are small. Large seeds include corn, soybeans, and other beans. The term "grain" will be used to include all types of seeds. Although corn has been shown in many pictures, locations where grain may become trapped and reside are mostly independent of the size of seed as even small crevices can hold broken parts of larger seeds.

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Concepts of storage, maintaining grain condition, and artificial drying

To find locations where grain may reside, it is important to understand the major activities of grain storage, grain flow pathways into and out of storage, and what happens during storage. Following are descriptions of basic storage, grain conditioning, and drying concepts. Descriptions are to acquaint the reader with how grain flows and interacts with core storage and handling components in order to better anticipate areas that need to be inspected and cleaned. Readers are referred to other references (e.g. MidWest Plan Service 1988, 2004) for information on how to manage fans, drying equipment, and how to maintain grain condition. Those already well acquainted with grain storage, maintenance by aeration, drying, and suffocation safety hazards may only want to skim this concepts section.

Cylindrical storage loading and unloading

Grain is usually stored in a cylindrical structure, often a round metal bin (figure 1) on the farm or at country elevators (terminals initially receiving grain). At larger commercial elevators (local, intermediate, or export terminals) cylindrical storage is more likely to be a tall concrete silo (figure 2).

Figure 1. Grain bin on farm

Figure 2. Commercial grain silos

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Grain enters the bin by gravity drop forming a pile with a natural cone-shaped surface. The angle of the cone surface is determined by the amount of resistance of individual seeds sliding on each other. The steepness of the cone angle is affected by the type of grain as well as its moisture content. A grain spreader (figure 3) may be used as grain enters the top of the bin so that broken grain and smaller material do not accumulate below the entry. Adjusting the spreader so that grain does not hit the bin sidewall, but lands at least one to two feet short of it minimizes breakage of grain. Grain normally exits the bin through a sump opening in the center of the bin floor (figure 4). By exiting in the bin center, pressure on the cylindrical bin walls is maintained equally around the bin perimeter to maintain structural integrity. As the grain exits, the surface forms an inverted cone or cone-of-depression with the valley of the cone over the sump exit.

Figure 3. Grain spreader mounted in top of bin

Figure 4. Sump for unloading in center of bin floor

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Safety considerations around grain storage are many. Besides somewhat more obvious hazards such as overhead electrical wires, gas used for drying, and grain intakes on conveying equipment, there is the potentially fatal hazard of grain suffocation. Although a natural tendency is to think of grain as a solid, it can entrap like quicksand when it flows. Even a small conveyor unloading grain through the floor of a bin moves grain quickly enough to entrap someone standing on the surface during unloading. Each year people die in grain suffocation accidents as human strength is not enough to overcome the suction force of moving grain. If grain covers the floor of a bin, never enter the bin without making sure unloading equipment is electrically locked out. Automated controls or someone outside the bin could inadvertently start the unloading auger. Electrically locking out the unloading auger is usually done by manually shutting off power to the auger in the electrical service box and locking the box during entry to prevent accidental start-up. Make sure a second person outside the bin knows you are in the bin. If ever caught in flowing grain, try to get to the bin wall and keep walking along the perimeter trying to stay as far away from the valley of the cone-of-depression as possible. If pulled below the surface, cup hands over nose and mouth to give more time for rescuers.

Maintaining grain in storage

Grain is a living, perishable commodity or product. When harvested, it may have dried in the field to reasonable moisture content for storage or it may require artificial drying to extend the amount of time it may be safely stored. At typical storage moistures of 12% to 15% water content each bushel of grain holds about one gallon of water. Grain at these lower storage moisture contents can still deteriorate over weeks or months. To help prevent this in a bin where grain may be stored for months at a time, a fan is used to periodically move air through the grain and control grain temperature. The fan is usually located on the outside perimeter of the bin (figure 5). In many cases the fan pushes air under a false perforated floor in the bottom of the bin (figure 6). Air moves through the floor perforations, up through the grain mass, and out exit vents in the bin roof (figure 7). Variations of this scheme include using a perforated tube rather than full floor to distribute airflow and/or pulling air down through the grain mass.

Figure 5. Fan on outside perimeter of bin

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Figure 6. Perforated bin floor surrounding sump location

Figure 7. Exit air vent in bin roof near eave (vents may also be located nearer center of bin roof)

Grain that deteriorates and goes out of condition or spoils during storage is often due to small masses of grain that become wetter than required for safe storage. This may occur any place in the grain mass, but is more likely on perimeter walls or directly in the top center of the grain mass. Along perimeter walls moisture may enter through cracks or the perimeter roofline from rain or snow. If grain has been dried in the bin, water is more likely to be from moisture that condensed on the inside roof while drying and ran down the sidewalls into the grain.

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The likeliest spot for spoiled grain is at the top center of the grain mass. Moisture naturally migrates to this area during storage; however, this can be greatly reduced by controlling air temperature with a fan as previously described. Spoiled grain in this area can form a crust strong enough to temporarily support a person's weight. Grain underneath this area in the very center of the bin is the first to be unloaded as the cone-of-depression forms. Because of this, bridged and crusted grain can mask a large hollow cavity underneath it. Breaking of the crusted, bridged section with a person standing on it can result in a sudden avalanche of grain into the void, burying the person. This can occur even without the unloading auger operating at the time. Never enter or stand on a crusted grain mass if grain has been removed beneath it but the surface remains level or does not conform to the volume of grain previously removed. Each year grain workers are killed when crusted grain unexpectedly gives way releasing an avalanche of grain around them.

Drying grain

Although most small grains and soybeans dry in the field before harvest, corn may require artificial drying in some seasons when field weather conditions do not lower grain moisture content to a safe storage level before harvest. To maintain rice quality, it is also commonly harvested at wetter moisture content than suitable for storage and thus must be further dried before storing. Understanding the basic flow movement of grain through the drying process helps to know where leftover grain may reside. Figure 8 shows typical grain movement from field to commercial storage. Large capacity combine harvest equipment necessitates being able to move grain quickly away from the combine and into a dryer (if needed to dry wet grain) and then into storage. Although automated drying equipment can dry grain when the combine may not be harvesting (rain, night) it often cannot keep up with drying during daytime hours while the combine operates. Because of this backlog of harvested grain during the day, some capacity to hold wet grain before it goes into a grain dryer is often needed to receive grain from the field that is too wet to store for long periods. Such wet-holding capacity is often a small bin that later automatically transfers grain to the dryer, but wagons, grain carts, or other grain transport equipment may also temporarily hold grain for manual unloading into a dryer.

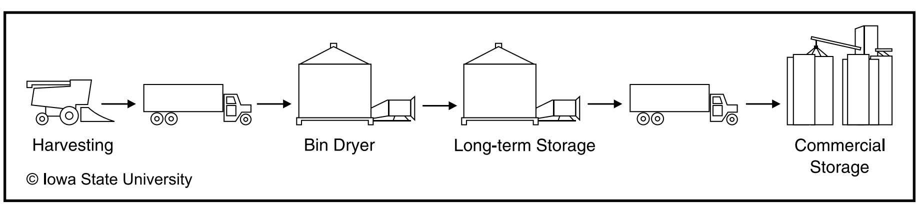

Figure 8. Typical grain movement from field to commercial storage. Arrows represent grain handling equipment

Drying can be categorized as either high temperature (e.g. > 120°F) or low temperature that uses ambient outside air. High temperature drying removes moisture from grain in a short period of time (minutes or hours) by blowing heated air through the grain mass. Some seeds quickly lose considerable

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moisture as their exterior surfaces come into equilibrium with air containing relatively little moisture. The entire grain mass is mixed as it leaves the dryer and a lower average moisture content is produced, making the grain safe for months of storage. Grain is often cooled with unheated air during the last phase in the dryer; however, some systems use a small bin for intermediate holding after leaving the hot dryer and before transferring the grain into storage with air cooling (a process called dryeration). If low temperature drying is used, grain is unloaded from the field into a storage bin with a large fan and a perforated drying floor. Air blowing continuously up through the grain mass slowly dries the grain over a period of weeks. Air flow amounts for successful low temperature drying are substantial (e.g. 1 to 1.5 cubic ft air/bu drying capacity) to remove moisture. Adequate fan capacity and roof vents for exit air are required. Air flow to remove moisture is important because the typical temptation is to simply increase drying temperature to a range near 85-100°F. Air in this temperature range increases grain deterioration faster than the drying rate increases and results in spoilage. Because of the slow drying rate, low temperature drying is not used at local country elevators receiving grain from the field but is an alternative for on-farm drying. Different high-temperature dryer types will be described in later sections. Faster, high temperature drying can impact grain quality, as small stress cracks created in the seed favor breakage and are entry points for mold or insect activity.

Tools for removing grain

Tools for removing grain, plant, and biomaterials include both functional tools to physically remove material and personal protective safety equipment (PPE). The amount and location of grain may affect whether a scoop or brush is more desirable to loosen, gather, and remove grain. A pick, such as a flathead screwdriver or chisel, can be used to dislodge grain stuck on surfaces or in cracks. Use a wet/dry shop vacuum (or a pneumatic grain handler for large amounts) to pick up grain and control dust flow. Pressurized compressed air may be more useful on the exterior surfaces outside of confined spaces if dust does not need to be contained. Pressurized water may also be used for cleaning exterior surfaces if water or wet biomaterial will not affect other components (e.g. auger bearings) and moisture will quickly evaporate before rust ensues. Water should be avoided when cleaning interior bin surfaces as excess moisture may collect underneath perforated bin floors and cause biomaterial underneath to "cake" and adhere to surfaces and itself. A head lamp, flashlight, or other portable lighting is useful for interior observation of darkened surfaces including ledges and crevices. Tools used for cleaning (e.g. vacuums, brooms, PPE) should be cleaned and inspected after cleaning to avoid cross-contamination with other cleaning activities.

Use a respirator or dust mask to protect lungs when cleaning interior confined spaces, using air, or if grain may have been moldy. Safety glasses keep dust out of eyes and are needed if sharp blows are used to dislodge grain. A hard hat or bump cap helps to protect the head inside enclosed spaces or working

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under equipment. Ear plugs may be used to help protect hearing in noisy areas. Safety equipment is shown in figure 9. The tops of storage areas are often many feet above the ground. Use protective hand rails and shoes with non-slip soles.

Figure 9. Safety equipment (dust mask, ear plugs, hard hat, safety glasses, and gloves)

Grain bin or silo

Grain is often stored in large circular steel bins on-farm or at country elevators which serve as grain storage and collection points. At commercial grain terminals (including country elevators) where grain must be rapidly moved to fill large transports such as railcars or barges, grain is stored in tall concrete silos for faster gravity unloading at the side of the structure. In both cylindrical bin and silo structures grain enters through a center opening in the top of the structure and forms a cone-shaped pile. Most grain falling through the top opening goes directly into storage; however, if the fill spout of the loading auger or conveyor was not able to be inserted inside the opening, small amounts of grain may have fallen on the exterior roof of the bin. This commonly occurs when a portable auger is used to fill an on-farm bin and wind carries some grain away from the opening. Grain usually falls down the sloping bin roof before dropping to the ground around the perimeter of the bin. In addition to checking around the bin perimeter, if needed check around the top entry area for residual grain as access conditions permit. Carefully evaluate accessibility before attempting to climb to the bin roof. Taller bins should have access stairs (figure 10) or ladders with guards (figure 11).

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Figure 10. Access stairs to bin roof

Figure 11. Ladder with safety guards to bin roof

The main exit sump for grain is in the bottom center of the bin (figure 4). One or more auxiliary sumps are usually located in a line over the bottom unloading conveyor (figure 12). These are used in case the main sump fails (e.g. bridged over with spoiled grain clumps) or for very large diameter bins. Due to the cone-of-depression effect, grain on the bin floor not directly above the unloading sump must be moved to the sump in the latter stages of emptying the bin. This is typically accomplished with a mechanical sweep auger that pivots around the center sump (figure 13). After sweeping with the auger, remaining grain is usually hand scooped and brushed into the unloading sump.

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Figure 12. Auxiliary unloading sumps in bin floor over bottom unloading conveyor

Figure 13. Mechanical sweep auger fastened to pivot around central sump (sweep auger is currently positioned over auxiliary sumps above unloading auger directly under bin floor)

Before entering the bin for inspection or cleaning, augers should be electrically locked out of operation so they cannot be started by automatic control or inadvertently by a bystander. Carefully inspect and clean the sump area. Grain may be caught around the opening at the edge of structural support flanges holding the entrance of the unloading auger below the floor (figure 4). Minor grain damage at the auger intake often results in smaller pieces of broken grain in the sump area below the floor. Consider removing the unloading auger from the outside if contamination standards are extremely tight.

In a tall concrete silo, a side exit (figure 14) is often used to allow gravity to quickly fill a transport vehicle. With a side gravity discharge, the silo floor is often sloped with a hopper bottom to the exit. Some residual grain requiring manual cleaning will likely be left in the silo since usually not all grain will be removed with a simple gravity discharge.

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Figure 14. Elevated side exit for gravity unloading from concrete silo

Areas to check inside the grain bin include any cracks or crevices where grain may hide. Small ledges may be present wherever two or more building materials or sections meet. Other areas to check besides the unloading sump(s) include the entry doorway, interior access ladder, floor, perimeter, and wall surfaces. Flanges present around the entry doorway add structural strength but will harbor residual grain, particularly on horizontal surfaces (figure 15). An interior ladder (to provide access from a bin roof opening into the bin) has several support points along the wall that should be cleaned and inspected (figure 16). Check for grain adhering along the interior bin sidewalls. Even without a ledge, grain that has become wet or gone out of condition may stick to vertical walls (figure 17). Grain may need to be mechanically dislodged with a brush or pick if air alone does not remove it.

Figure 15. Interior horizontal flange above bin doorway

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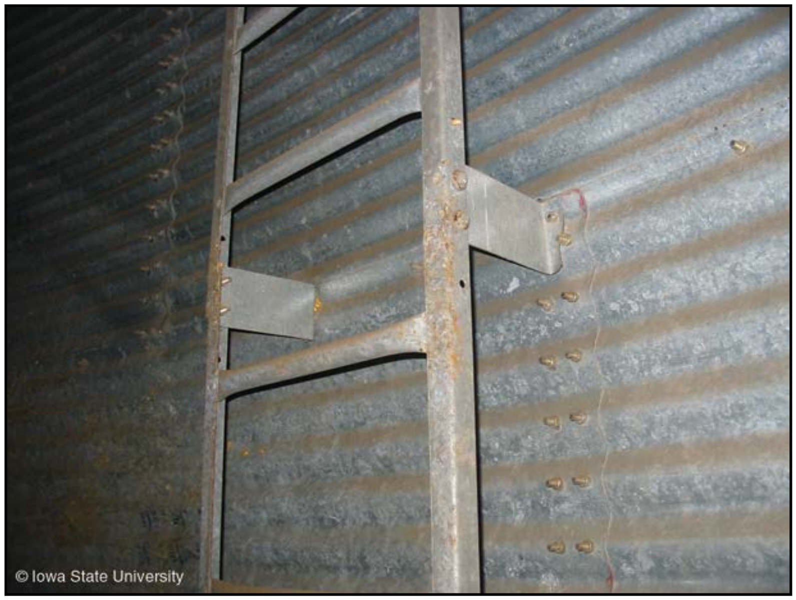

Figure 16. Support structure for interior bin ladder

Figure 17. Grain adhering to interior bin wall surface

Clean and inspect the floor and the inner perimeter where the floor meets the wall. Many bin floors are perforated to allow air movement by the fan for temperature control or grain drying. Perforations are natural places to trap broken grain and smaller foreign material (figures 18 and 19). Final floor cleaning may be done by pressurized or vacuum air or vigorous brushing. Over time the area under perforated floors becomes a repository for smaller

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pieces of broken grain ("fines") and other small foreign material (figure 20). Incoming stored grain is usually not contaminated from this source; however, in cases where all biomaterial must be removed before placing the bin back in service the floor may need to be removed and the area cleaned of debris beneath it.

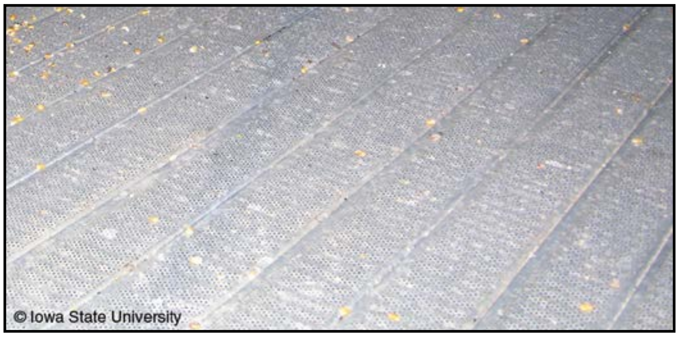

Figure 18. Grain on floor and grain pieces trapped in bin floor perforations

Figure 19. Partial bin floor showing open area and support sections underneath it

Figure 20. Small pieces of broken grain, dust, and dirt too small to be identified are termed foreign material

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Common locations to check for grain residue outside the bin include the unloading auger, fan/dryer housing, and around the bin perimeter. A horizontal unloading auger under the bin transfers grain into a vertical or inclined auger or conveyor for loading into a transport truck or other vehicle. Inspect and clean in and around the unloading spout (figures 21 and 22). As required, access the area at the bin perimeter where the horizontal auger feeds grain into the vertical auger. Where two conveyors meet (figures 23 and 24) is often a location that contains grain fragments from grinding and residual material is left behind.

Figure 21. Unloading spout from conveying system on side of grain bin (note safety shielding is missing on lower auger drive)

Figure 22. Inclined portable unloading auger to receive grain from horizontal unloading auger under bin floor

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Figure 23. Conveyor junction point where horizontal auger under bin floor delivers grain to vertical unloading auger on side of bin (safety shield missing around belt drive)

Figure 24. Grain at junction between horizontal unloading auger under bin floor and portable auger intake (on left, outside hopper)

Inspect and clean around the bin outside perimeter (figure 25). A special area to clean is located around a fan (figure 5). Be sure that the fan has been electrically locked out so that it cannot start by automatic control or a bystander. Check around the fan housing and transition and also visible inner parts. High air flow rates in the region on the output side of the fan tend to self-clean but the input or vacuum side may have grain dust and foreign material.

Figure 25. Outside bin perimeter

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Bin used for drying

Although stand-alone grain dryers are used at local country elevators and larger on-farm storage sites, smaller on-farm bins may be equipped to dry grain inside the bin. If the bin is used for high-temperature drying, a ring of burners will be located around the fan transition housing into the bin, heating air going into the bin (figure 26). LP or natural gas is usually used to heat the drying air. During initial heater operation (i.e. start up) for drying, frost may appear on vapor lines to the burner for 60 to 90 seconds (normal operation). If frost continues to increase, the heater should be immediately shut off and checked by a professional. For safety, be aware of the LP tank location (figure 27) and be alert for any gas odor around lines or fittings. If gas is detected, leave the area immediately and notify qualified repair personnel. While checking for grain around the fan and transitional duct into the bin, check this heater area too.

Figure 26. LP gas lines to dryer ring inside fan transition housing that supplies heat to airflow

Figure 27. LP gas tank to supply fuel to dryer

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A set of one or more vertical augers used to stir grain is likely to be found in a drying bin. Augers hang vertically from a track suspended in the top of the bin (figure 28). The augers slowly stir the entire grain mass by moving radially along the track from the bin center to the wall while the center-to-wall track very slowly pivots around the bin center. The infrastructure at the top of the bin to support and drive the auger(s) as well as the auger itself provide additional areas for residual grain to collect. In particular, horizontal surfaces on the track or structural support may hold residual grain. During drying, grain should remain below the level of the top track and supports. After drying, however, additional grain may have been added to "top off" the bin storage. Residual grain has an opportunity to be caught around horizontal surfaces and structural supports. To clean and inspect this area near the top of the bin, it likely will be necessary to rotate the support track for stirring equipment near the interior bin ladder or near a roof access door accessible by outside ladder or stairs. A low-temperature, natural-air drying bin may also have stirring equipment, particularly if a small amount of electric heat is added to the air stream from the drying fan (heating the air a few degrees).

Figure 28. Vertical stirring augers suspended from overhead track inside a drying bin

High temperature bin-drying often results in moisture condensation on the inside of the bin roof from hot air escaping the dried grain. Collected water runs to the eave and if it cannot escape, runs down the inner wall surface re-wetting grain and potentially causing spoilage. To allow for air circulation next to the wall and minimize this, a false-wall bin liner (figure 29) or vertical air tubes (figure 30) are often permanently mounted on the inner bin

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wall. Irregularities along the bin wall presented by these structures create additional opportunities to trap grain and should be inspected. In general, in a bin used for high-temperature drying, because of stirring equipment and a bin liner there is more structure with ledges and therefore more opportunity to trap residual grain.

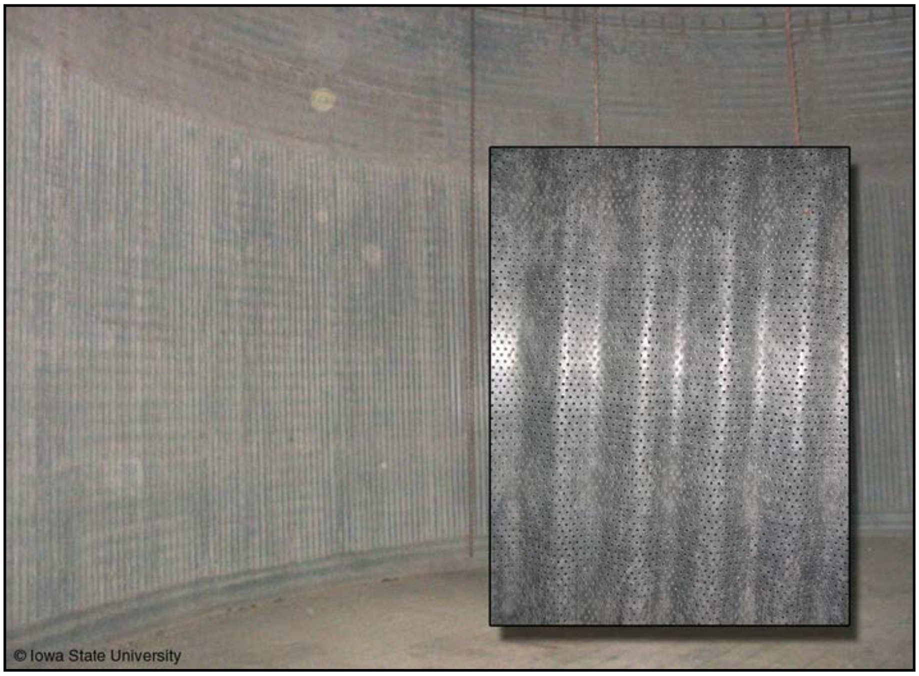

Figure 29. False-wall bin liner on lower part of grain wall. The inset is a close-up of the false-wall bin liner

Figure 30. Vertical air tubes along interior bin wall

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Another variation of high temperature drying inside a bin also uses a heater in the fan transition outside the bin, but no vertical-auger stirring equipment is present inside the bin to allow drying grain as a whole "batch." Instead, hot, dry grain on the bin floor is continuously removed by a sweep auger on the floor pivoting around the center to a central vertical transfer auger (figure 31) that lifts grain to another overhead auger transferring grain away from the drying bin and to a separate storage bin.

Figure 31. Floor sweep auger and vertical transfer auger inside high-temperature continuous-flow bin grain dryer

Dryer

A stand-alone artificial grain dryer (figure 32) is designed to dry grain with hot air and usually cool it before being transferred to storage. These dryers are more common in larger farm grain handling systems, and a large capacity dryer is required at commercial installations. To rapidly dry grain, either continuously or in batches, heated air is forced through a short segment of grain. Entry and exit points of grain into the dryer should be cleaned and inspected as well as any accessible points along the grain flow path. As with a bin, entry is usually at or near the top of the dryer. Grain drops by gravity through most dryers in the drying process with grain exiting near the bottom of the dryer. A conveyor such as an auger or gravity drop tube from a vertical grain elevator drops grain into the dryer. A second conveyor (e.g. auger or flight-type) carries grain away from the dryer. Air flow is typically horizontal (cross flow from inside to outside the dryer) across the path of the grain which moves vertically down through the dryer. High air flow rates and the vertical drop of grain through the dryer often help dryers self-clean; however, lighter material such as the red "bees wings" from corn often settle and stick on exposed surfaces.

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Figure 32. On-farm stand alone grain dryer

Handling equipment

To transfer bulk commodities such as grain between storage areas, or to load or unload from transport vehicles some type of handling or conveying equipment is required. A screw-type auger is commonly used (figure 33), but other conveying systems such as pneumatic, flat belt conveyor, gravity tube, flight-type conveyor, or bucket-type elevator are also used. Because grain must enter and exit the conveyor, access is relatively open at the entry and exit. To convey grain without spillage and for safety reasons intermediate parts of the conveyor are usually tightly enclosed. As the grain is aggressively grabbed at the entry point into the conveyor, a guard such as wire mesh will usually be over the entry point (figure 34). Before cleaning or inspection, make certain power is disconnected and locked-out so that a conveyor will not automatically start or be started by a bystander. If a guard is removed to access the entry point be certain to replace it immediately afterwards before the conveyor is operated.

Figure 33. Grain auger set up to fill bin

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Figure 34. Wire-mesh guard over grain auger entry that receives grain from gravity-flow wagon (note screw auger underneath guard)

An auger is simply an inclined, screw-type flighting spiraled around a center shaft and placed inside a tube. The powered shaft turns the flighting that forces material along the tube. To convey grain efficiently, flighting must be enclosed within the tube. Thus the only openings easily cleaned and inspected are at the entry and exit points of the tube. If flighting must be removed for cleaning and inspection, it usually must be pulled out of one end of the tube. Flighting is commonly made from steel or plastic, but flighting may be made of rubber or a brush to more gently handle grain. Most grain damage occurs at the intake section of the auger or if the auger is not running full. Steel edges on flighting may grind grain or puncture the seed coat. Softer material may be used throughout the auger or just at the intake section to more gently handle grain. Using brushes for flighting is gentle on grain, but residual grain and biomaterial is readily trapped in the brushes. Depending on the cleanliness required and the type of flighting, the auger may need to be pulled from within the tube for cleaning. If disassembly is not required, the auger is typically cleaned by operating empty for some period of time and perhaps flushing with a second suitable inert material (e.g. wood chips or a different type of grain) through the auger.

Pneumatic grain handling equipment (figure 35) uses an air-lock entry to introduce grain into a pressurized air stream from a large fan. At the discharge exit, grain is separated from the main air flow by centrifugal action in a cyclone separator before exiting by gravity and remaining airflow. Cleaning and inspection at the entry are limited by the closely fitting air lock without major disassembly. Conveying tubes with high air flow and the cyclone separator are relatively self-cleaning although tube sections may be disassembled relatively easily. A flat belt conveyor is likely to be more open at the entry and exit points for easier cleaning and inspection, but still may be partially or totally enclosed to reduce grain spillage along its length.

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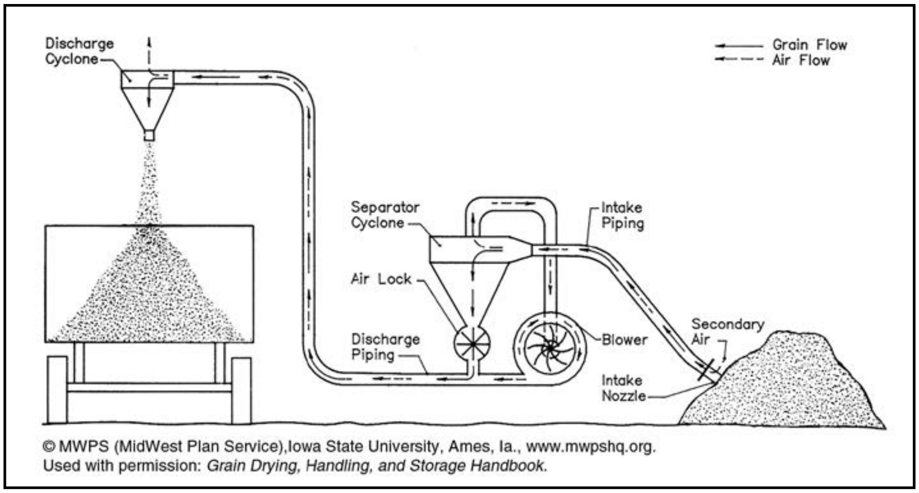

Figure 35. Pneumatic grain handling equipment

Both flight-type conveyors (figure 36) and bucket-type elevators (figure 37) use large link chains or belts. A flight-type conveyor has flat plates mounted periodically across one or two chains. The face of each plate is perpendicular to the direction the chain operates. The flights and grain they push are contained within a u-shaped trough that is often covered for safety and to reduce grain spillage between entry and exit. A flight-type conveyor is used for horizontal and vertically inclined grain conveying at moderate angles. A bucket-type elevator is used for high capacity vertical conveying of grain. Instead of flights, individual buckets or containers attached to chains on each side or alternatively attached on a belt scoop grain from a lower sump. Residual grain should be cleaned from the lower sump area and this area inspected. Buckets on the elevator carry grain upward, dumping it at the upper end, often into a gravity tube. A gravity tube is a hollow, open-chamber tube that allows grain to fall downward at a slope steep enough to ensure that it should be self-cleaning in almost all cases.

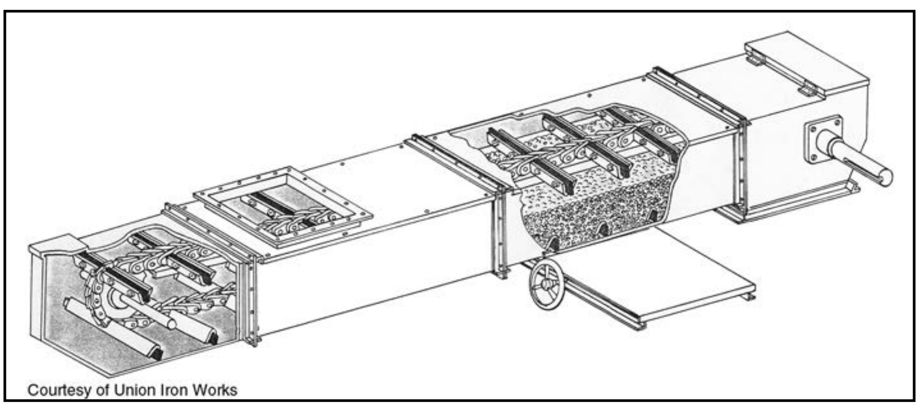

Figure 36. Flight-type grain conveyor

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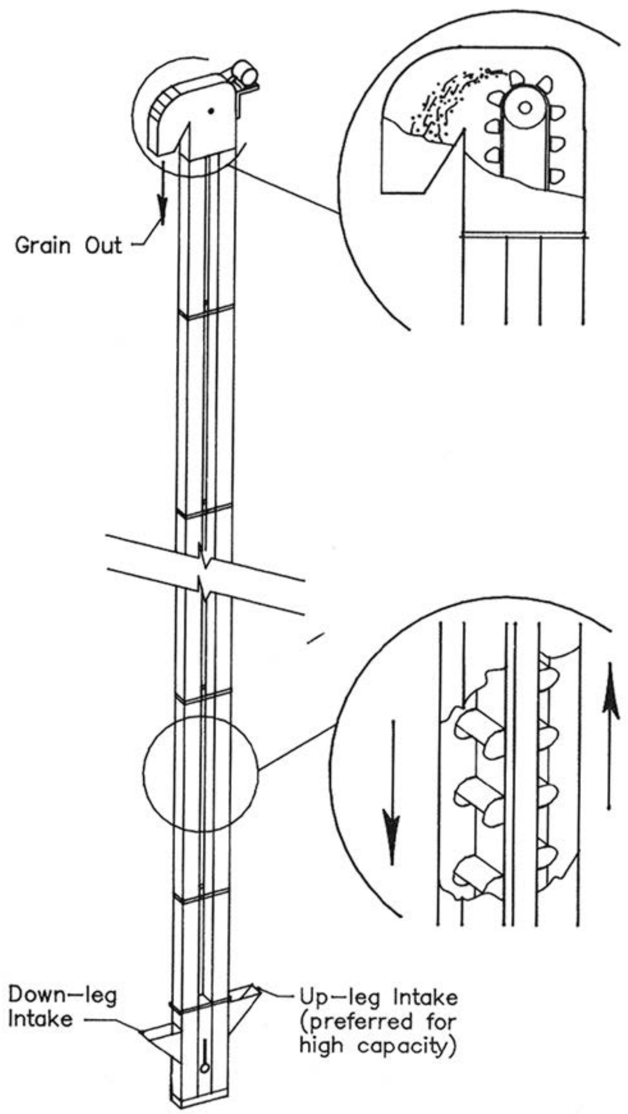

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Figure 37. Bucket-type elevator to vertically lift grain

A grain cleaner to separate whole grain from smaller foreign material may be used between conveyors or before grain goes into longer term storage to help avoid spoilage (foreign material present should be limited for long-term storage). An example would be an inclined screen below the top of a grain elevator to route smaller broken grain and foreign material into a small separate bin collection area (figure 38). Another type of grain cleaner is an inclined rotating screen (figure 39). As with conveying equipment, check entry and exit locations as well as screen openings for any build-up of residual materials.

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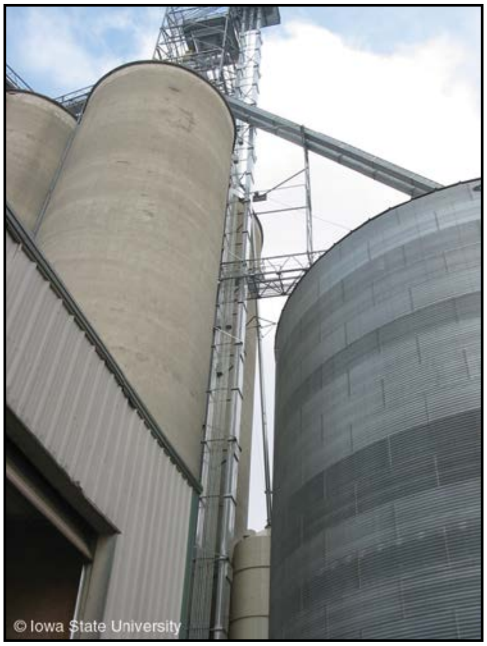

Figure 38. Cleaning screen system at a commercial grain elevator (cleaning screens are in metal transition high overhead)

Figure 39. Rotary grain cleaner

Safety

Safety issues around storage and handling equipment are particular to the equipment and often not readily apparent.

Grain suffocation

Grain suffocation, although not an issue during inspection if virtually all grain has been removed, can be fatal during unloading of grain or when cleaning large amounts of crusted, out-of-condition grain. Control systems can automatically start unloading conveyors.

- Never climb onto grain in a grain storage area without making certain that unloading equipment is turned off and the system electrically locked-out so it cannot be started automatically or by someone else outside the storage structure.

- As grain flows during unloading, a person can be rapidly trapped as in quicksand and pulled under at the center of the cone-of-depression (figure 40). If ever caught in flowing grain, try to get to the bin wall

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and keep walking along the perimeter trying to stay as far away from the valley of the cone-of-depression as possible. If pulled below the surface, cup hands over nose and mouth to give more time for rescuers.

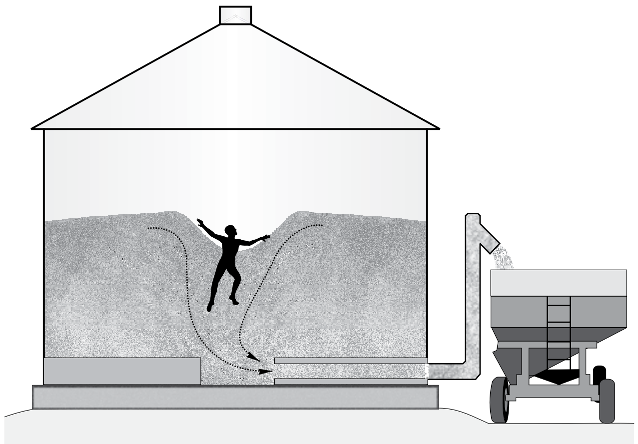

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Figure 40. Being pulled under the grain surface as the cone-of-depression develops during bin unloading

- Crusted and/or bridged out-of-condition grain can give way without warning (figure 41). Do not stand on grain surfaces where grain has been removed but does not show the corresponding volume removed on the surface. When cleaning, beware of large quantities of grain that may suddenly give way without warning when crusted grain breaks up.

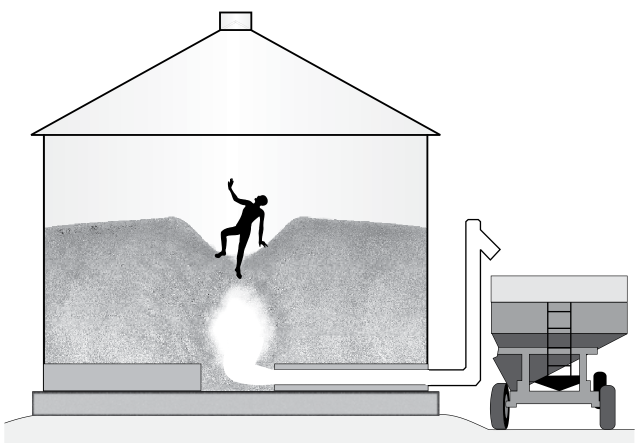

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Figure 41. Becoming trapped as a crusted grain surface gives way over a hollow area previously unloaded

Electrical lock-out of automatic controls

Control systems can automatically start augers or other conveyors, fans, and drying heaters. Automated controls should be shut-off and locked-out before cleaning, servicing, or inspecting grain storage and handling systems to

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prevent accidental start-up.

Falling from heights

Portions of grain storage and handling equipment are often many feet above the floor or ground. Falls are extremely hazardous and can be fatal. Use guardrails on stairs and ladders. Shoes should have non-slip soles. If using a portable ladder, make sure of its stability by checking its footing. The ladder should be one foot away from the wall for every four feet of height. Do not stand on the ladder's top three rungs.

Entrapment in grain conveyors

The intake area of any grain handling conveyor is necessarily aggressive during operation. Guards are present to keep clothing, fingers, hands, toes, and feet out of the intake area. If removed for cleaning and inspection, remember to replace before operation. Portable grain augers and other conveyors are usually powered by a rotating power-take-off (PTO) shaft from a tractor (figure 42). Make sure the PTO shaft is adequately guarded and do not work near the shaft when in operation. Any exposed rotating surface is a potential wrapping hazard. Permanently placed augers and other conveyors that are electrically powered often have drive belts with hazardous pinch points between belt and pulley. The speed at which augers, conveyors, drive belts, and drive shafts operate is too great for human reaction time to avoid an accident.

Figure 42. Power-take-off shaft on grain auger drive is attached to rear of tractor

Electrical and gas lines

Energy sources around storage sites include electricity to operate fans and conveyors, and LP or natural gas used for high-temperature artificial drying. Know the location of electrical lines and service entrances. On some older sites, electrical service lines are not buried, but instead are overhead. Beware of electrical shock from overhead lines or connections (figure 43). Electrocution can occur if a metal ladder used for inspection and cleaning touches an overhead power line or when a grain auger or conveyor is being moved. Portable augers and conveyors should be lowered to safety stops during transport to help avoid overhead power lines and to prevent a sudden

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fall. Human reaction time is not fast enough to avoid falling equipment. Gas connections, lines, and tank locations should be noted to avoid striking them. If any gas odor is noticed leave the area immediately and contact appropriate service personnel.

Figure 43. Overhead electrical lines at grain bin site

Other – fumigation, dust explosions, general inspection procedures

Always check with the local grain manager for potential safety hazards before inspecting storage areas. Third-party inspection may involve moving heavy doors, floor sections, conveying equipment, and so on. Inspectors should consult and defer to the grain manager for lifting or moving equipment as appropriate.

Insects may be attracted to stored grain, particularly if it contains significant broken grain or is older. Insecticides or even fumigants (requiring the storage to be sealed from human entry) may be used. Check with the grain storage manager before entering storage areas to see if chemical insect control has been used and if so, that re-entry is permitted.

Small particles of grain dust and oxygen present in the air can form an explosive mixture that may be ignited by a spark or hot surface of a grain conveyor bearing. Stirring dust by cleaning may temporarily suspend more dust particles in contact with air. Cleanliness and good housekeeping should minimize this hazard for inspection, but plan cleaning activities with the grain manager to have adequate ventilation and avoid suspending large volumes of fine dust particles in the air at one time.

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