# Animal and Plant Health Inspection Service

# Harvest Equipment Inspection Training Module

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This module is provided “as is” without warranty of any kind, either expressed or implied. In no event shall the producers of this module be liable to you for any damages including lost profits, lost savings or other indirect, incidental or consequential damages arising out of the use or inability to use this module. This module is intended to train inspectors and mentions some but not all locations where residual grain and biomaterials may reside.

Not every piece of equipment or every type of combine is covered. The operation manual from the manufacturer should be consulted for specific instructions. No endorsement is intended by the producers of this module of the products mentioned, nor is criticism implied in similar companies or their products not mentioned.

## Acknowledgments

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## Background

With the advent of field testing in the United States of Federally regulated genetically engineered (GE) plants in 1987, the importance of proper harvest equipment clean-out and subsequent government compliance inspection has gained national and international importance. The adventitious presence (AP) of regulated GE plant material or seed, unintentionally introduced through harvest equipment, in the Nation's food or feed supplies and channels, would create significant negative domestic use and trade impacts. Such a regulatory calamity could have financial and trade implications measured in the billions of dollars and devastate the long-term survivability of the affected agricultural production sectors. For example, in 2000 the unintentional introduction into human foods of a Federally regulated (Environmental Protection Agency) GE corn line known as StarLink™, which was not approved for human consumption resulted in millions of dollars worth of food products being pulled from the store shelves and dramatic and immediate negative responses by our trading partners.

Animal and Plant Health Inspection Service's (APHIS) experience with high risk GE pharmaceutical-containing plants has demonstrated that one of the most critical points in the prevention of the inadvertent introduction of GE plant material into the environment and the potentially damaging subsequent AP of such material in the food chain and feed supply is crop harvesting equipment. In order to effectively and efficiently manage this complex regulatory compliance issue, APHIS has contracted Iowa State University (ISU), to produce this valuable training aid. ISU is one of the world's preeminent agricultural universities and a leader in seed identity preservation through proper harvest machinery clean-out.

## Introduction

With the introduction of value-added traits, identity preservation programs, Federal organic standards, and the advent of field testing of federally regulated genetically modified plants, harvest equipment clean-out has become a production, marketing, and regulatory imperative. New federal regulations by United States Department of Agriculture (USDA) agencies under Marketing and Regulatory Programs, in the areas of certified organic production, plant protection and quarantine, and biotechnology require that harvesting equipment be cleaned of seed and biomaterial before use, interstate transport, or return-to-service in a growing number of cases.

Traditionally, 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. APHIS' regulatory concerns and practices are best exemplified by its quarantine program for Karnal Bunt disease of wheat. In order to effectively contain this serious fungal disease and prevent its spread, combines were 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 the last several growing seasons BRS has seen the appearance of two new classes of GE plants, one class that expresses traits for the synthesis of pharmaceuticals and the second class expresses traits for synthesis of industrial compounds. The Agency'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. Combines used to harvest these high-risk traits must be dismantled, cleaned and inspected prior to return-to-service for harvesting of traditionally bred crops. The need for a trained cadre of compliance inspectors with both knowledge and experience in the area of harvest equipment clean-out and inspection is an Agency imperative.

## Harvest machine considerations

To know where to clean and inspect for residual crop material in harvest equipment, it is important to understand basic operation of the machine, particularly flow paths of crop through the equipment. Grains and oilseeds (e.g. corn, soybeans, wheat, rice, oats, beans, flax, and rye) are usually machine-harvested with a combine. Cotton is machine-harvested with a cotton picker or stripper. Other specialty machines are used for harvesting crops such as sugar beets, potatoes, tobacco, peanuts, fruits, and vegetables. Common components of such machines gather the crop into the machine, separate the part of the crop to be harvested from other biomaterial coming into the machine (e.g. separating wheat grain from straw), collect what is desired of the crop, and expel remaining crop material to be left in the field. Throughout this process there are often conveyors (e.g. auger, chain, belt, pneumatic (air)) to carry the material from one part of the machine to another. Usually during processing by the harvest equipment, parts of the plant material will be broken into smaller pieces. These smaller pieces along with dirt and other debris are often termed foreign material. Although foreign material may have little or no viable seed, in some cases the transfer of even small amounts of unwanted biomaterial by the harvest equipment can be a problem.

Because of equipment size and number of different processes involved, it is important to be able to recognize safety hazards that may be present when cleaning and inspecting equipment. For example, when inspecting underneath a gathering head, make certain it is not supported only by a hydraulic cylinder, but it is mechanically locked or blocked (figure 1) so the head will not fall unexpectedly in the event of a sudden hydraulic system leak or failure. Processing of crop by the machine involves many pinch or crush points such as between auger flighting and housing. The machine should not be operated during inspection and because tension on a drive might unexpectedly release, fingers and hands should stay out of potential pinch and crush areas during inspection. Safety shields and access doors are commonly opened for inspection, but should be closed before subsequent machine operation to avoid flying projectiles hitting bystanders and to protect

 

against contact with drive mechanisms and processing equipment. Those cleaning the machine should strongly consider a dust mask, safety glasses, a hard hat, gloves, and hearing protection (figure 2) as dust levels will be high, spaces cramped, and equipment such as compressed air wand or shop vacuum noisy. Although cleaning equipment may not be operating during an inspection, an inspector should consider the use of such personal protective equipment, particularly a hard hat when inspecting in areas without overhead clearance and gloves to protect hands from abrasive surfaces.

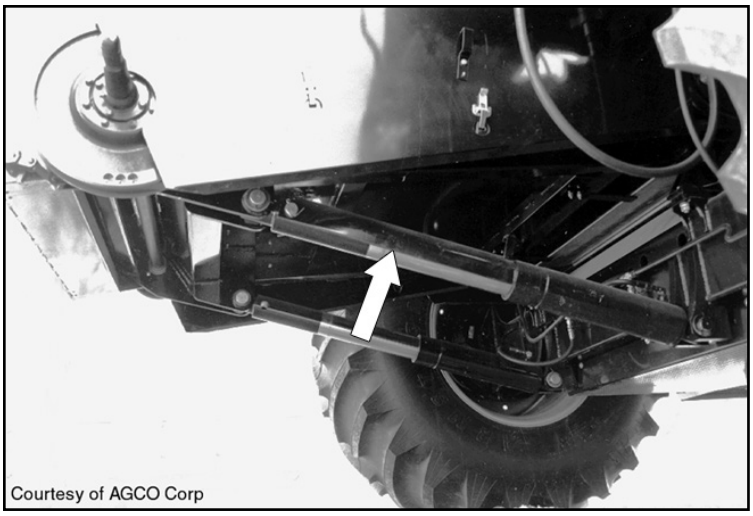


**Figure 1. Feederhouse blocked up by cylinder stop**


**Figure 2. Personal protective equipment**

The array of potential harvesting machines for inspection is broad. This module will concentrate on combine harvesting equipment for grains and oilseeds. The objective is to show common locations of grain and other biomaterial residual entrapment inside the equipment. It is beyond the scope of this module to highlight every possible location that biomaterial may

become trapped. Rather, a goal is to develop increased understanding of machine operation and material flow paths so the inspector may be able to assess the need for areas of inspection depending on circumstances. Keep in mind that accessibility of the machine interior has been primarily designed for material flow and maintenance. Long sections of conveying equipment between entry and exit may be relatively inaccessible without major disassembly. For safety reasons, equipment manufacturers generally limit accessibility to that required for proper machine operation and maintenance. Harvesting equipment is divided into commercial combines and plot combines used for smaller harvested areas.

# Commercial combines

## Combine operation and flow path of crop

The upper part of the plant including grain or seeds is initially gathered into the machine by a gathering head. For most crops (e.g. soybeans, small grains, rice and sunflowers) this is usually a grain platform and for corn it is a cornhead with individual row units operating in each row. Crop material is delivered by the gathering head into a feederhouse to transport material into the threshing area. Threshing or breaking the bond of the grain or seeds from the rest of the plant is done in the rotor or cylinder area. From this point on material is separated into two streams. Grain is transported to the cleaning shoe area for further cleaning of grain before being transported by elevator to an upper clean grain tank. Small amounts of unthreshed grain that is too heavy to be blown from the rear of the cleaning shoe is transported as tailings in a return elevator and sent back to the threshing area. Larger material (stalks, stems, etc.) exits the threshing area for further separation of any remaining grain in the rear sections of the rotor or on straw walkers following the cylinder. This larger residue is often chopped and spread at the rear of the combine. General areas within cylinder and rotor combines are shown in figures 3 and 4, respectively.

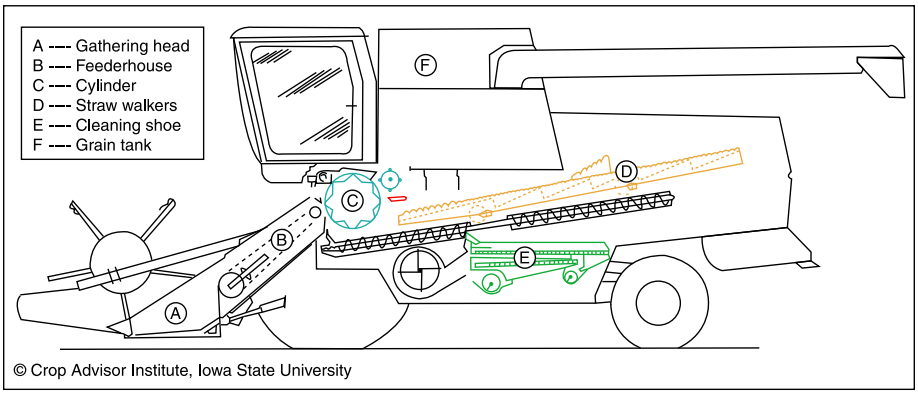



**Figure 3. Cylinder combine**

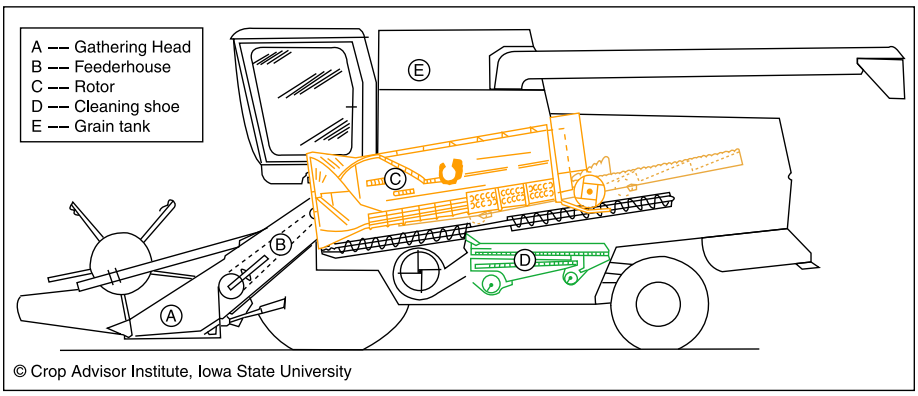



**Figure 4. Rotary Combine**

Combines are most efficiently cleaned from top-to-bottom and front-to-back. This ensures dislodged material that falls has an opportunity to be subsequently removed and also follows material flow paths through mid-level areas of the machine (head, feederhouse, threshing, and separating areas). During inspection, it is assumed that most or all material will have been cleaned from a combine so that order of inspection is not as important as systematically checking all important areas. Following are more detailed descriptions of various areas of commercial combines and common areas where grain and biomaterial may accumulate.

## Gathering unit or head

The grain platform (figure 5) consists of a cutterbar to cut the crop, reel to push the crop into the head, and cross-auger to bring material to the feederhouse. Visually inspect all areas including along the cutterbar; reel bats, fingers, and end sections, as well as underneath and behind the cross-auger. Inspect the underside of the head and, if attached to the combine, make certain it is mechanically locked or blocked before getting underneath it. Shielding is commonly used on one or both sides of the grain platform to protect drive components. Open shields and inspect drive areas and ledges for material. If the platform cross-auger has access panels, consider opening them for inspection if tolerance for commingling is particularly low.


**Figure 5. Grain platform**

The cornhead (figure 6) used when harvesting corn consists of individual row units with snapping rolls (that remove ears from stalks) shielded by individual stripper plates with gathering chains operating on top of these plates to pull ears into the head (figure 7). Plastic or sheet metal shields with protruding snouts cover equipment between the row units. It is important to raise these shields (typically by loosening a latch and pivoting upward) when visually inspecting the individual row units (figure 8). Considerable amounts of material accumulate underneath these shields during harvest. Other areas to inspect such as the cross-auger and rear of the head are similar to the grain platform (figure 9). Inspect the underside of the head, making sure it is mechanically locked and blocked before getting underneath it. Inspect

 

the sides of the cornhead if access shields are present. If the cross-auger has access panels, consider opening them for critical inspections. Occasionally, a head with individual row units will be used for soybean harvest. Follow a similar strategy of opening shields between rows to inspect for material accumulated in gathering mechanisms.

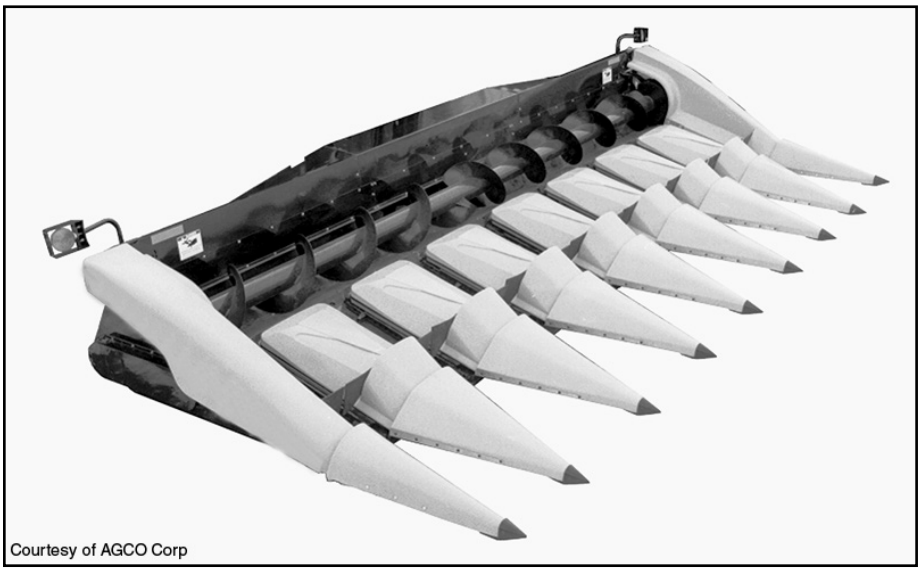


**Figure 6. Cornhead**

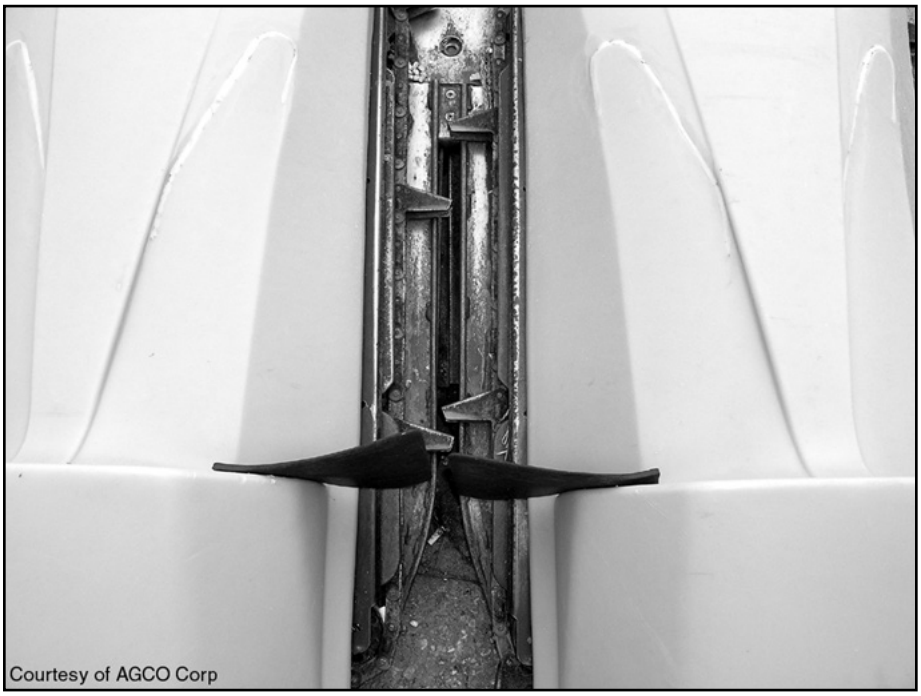


**Figure 7. Shielded snapping rolls on cornhead row unit**


**Figure 8. Corn residue underneath shields on cornhead**


**Figure 9. Opening into rear of cornhead showing cross-auger**

## Feederhouse

To inspect the feederhouse (sometimes simply called feeder), have the gathering head removed if possible. This allows much easier access to the front of the feederhouse and further inspection of the rear of the gathering head. The typical mechanism is a slatted chain mounted on front- and rear-drums that pulls crop to the threshing area. On some combines, one or more pre-processing rolls or cylinders are at the rear of the feederhouse before crop enters the main threshing area. Besides inspecting from the front opening into the feederhouse, one or more access doors are often present in the top of the feederhouse for further inspection (figure 10). Because the front of the feederhouse is lower than the rear, material commonly accumulates inside the front, lower corners.

 


**Figure 10. Inspecting feederhouse through top access doors**

## Rock trap

At the rear of the feederhouse, just before crop enters the main threshing area, many combines have a rock trap. The trap consists of a cavity into which rocks may fall before being forced through the threshing area and causing significant damage to the machine. This cavity fills with significant amounts of material during harvest that should be cleaned prior to inspection. An access door (figure 11) is present to allow removal of rocks and should be opened for machine inspection (make sure the feederhouse is mechanically locked/blocked before getting underneath it to access this door).


**Figure 11. Rock trap opened underneath feederhouse (corn residue visible)**

## Threshing rotor or cylinder

Two major types of threshing mechanism, rotor and cylinder, are commonly used. Both utilize rasp bars fastened to a rapidly rotating rotor or cylinder. A single rotor or cylinder is typical, but a twin rotor design is also common and other designs use multiple cylinders. A rotor is typically longer than a cylinder with threshing in the front section of the rotor and additional separating of grain from other biomaterial as crop passes to the rear of the rotor. For rotary threshing, crop flow spirals around the outside of the rotor next to the concave with the general flow path parallel to the axis of the rotor.

For cylindrical threshing, the cylinder is aligned perpendicular to crop flow. Crop material passes underneath the cylinder and above the concave. Most threshed grain falls through openings in the concave with the rest of the material (mostly non-grain at this point) removed at the rear of the cylinder by a rotating beater and then onto oscillating straw walkers for further separation of grain remaining in the mat of biomaterial.

In both designs loose grain, seeds, and other smaller material threshed from the rest of the plant fall through openings in a concave wire cage around the rotor or bottom of the cylinder. Stalks, stems, and larger material either continue to be spun in later sections of the rotor for further separation or is removed from the cylinder by a counter rotating beater for further separation on oscillating straw walkers.

Search for access openings on both sides of the machine to inspect the threshing area. Residual material often gets caught between and around the bars or wires of the concave cage (figure 12) or along projecting points (e.g. rasp bars and fasteners) or cavities of the rotor or cylinder. On some rotor machines, material accumulates on the concave surface above the rotor so be sure to check there. Below the concave is usually a bed of several augers that push grain rearward to the cleaning shoe area. Visual access to these clean grain augers (figure 13) is usually from the threshing region. Inspect as possible for material caught underneath these augers and particularly toward the front of the machine (if access doors are in the front of this area, make sure the feederhouse is mechanically locked before getting underneath it). The threshing access area is also typically used to inspect the front of the cleaning shoe area.

 


**Figure 12. Wire concave area that wraps around the rotor**

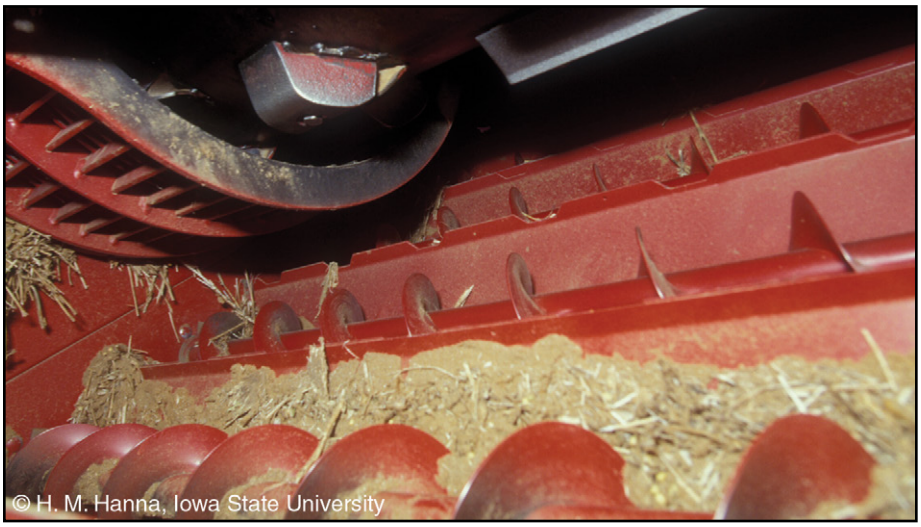


**Figure 13. Clean grain augers below the concave**

## Separating area

For rotor-type combines, access to rear sections of the rotor allows inspection for material in remaining portions of the rotor and corresponding concave sections. For cylinder-type combines, a separate straw walker area extends from behind the cylinder to the rear of the combine where straw is expelled. Straw walkers (figure 14) consist of oscillating sieve sections with projecting sides to help lift straw. Physical access to this area for maintenance and cleaning is usually from the rear of the combine, however spreader or chopper mechanisms may need to be at least partially removed. Access doors may be present on either side or top of the combine for inspection. If the combine has been properly cleaned, little residual crop material remains

in this area, and the proportion of it that is whole grain is quite low. If it is required to get onto the straw walkers, protect legs, knees, hands, and elbows as well as the walker surface by using material such as a rubber mat or carpet to protect surfaces.


**Figure 14. Straw walkers**

## Cleaning shoe

The cleaning shoe consists of two or more adjustable sieves (figures 15, 16, and 17) in the lower rear part of the combine. Grain, smaller foreign material, and unthreshed pieces are transported by the conveying augers under the threshing area onto an upper sieve sometimes termed a chaffer. Sieves oscillate and openings are adjusted to allow clean grain to drop below to a cross-auger that conveys the grain to the clean grain elevator on the side of the combine. A fan near the front of the cleaning shoe is adjusted to blow lighter small foreign material on the sieves out the rear of the machine. Material that is too large to fall through the sieve openings and too heavy to be blown from the shoe area falls into a small cross-auger at the rear of the shoe which transports this material (typically unthreshed grain) to a tailings elevator on the side of the combine that sends the grain to the threshing area for rethreshing.

 

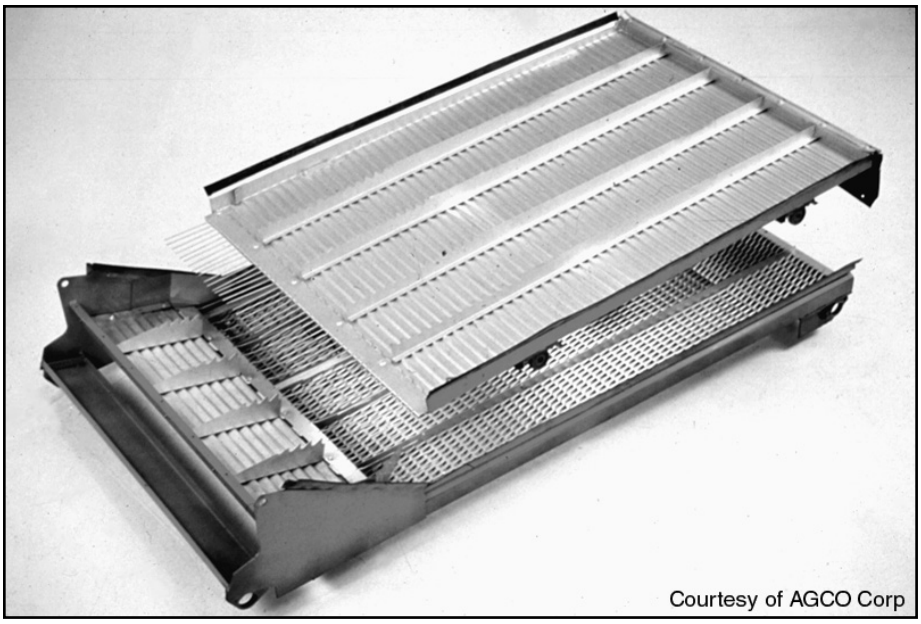


**Figure 15. Cleaning shoe sieves located in lower rear of combine**


**Figure 16. Corn at edge of sieve**


**Figure 17. Soybeans at front of sieve**

Access for inspection in the cleaning shoe area is from the lower rear of the combine (figure 18) and also any access panels near the front of the shoe that are also used to access the lower threshing area and clean grain augers. Adjusting the sieves to wider openings may increase visibility from the rear.


**Figure 18. Vacuuming in the rear of the cleaning shoe**

## Grain elevators

Both the clean grain and tailings elevators are located on the side(s) of the combine. They are commonly flight-type chain conveyors. Clean-out doors hinged at the bottom of the elevator (figure 19) are often the only convenient access points for inspection inside the elevator itself. Check the housing

 

of the clean grain cross-auger underneath the combine carrying grain to the elevator to see if it is easily opened for cleaning and thus also inspection.

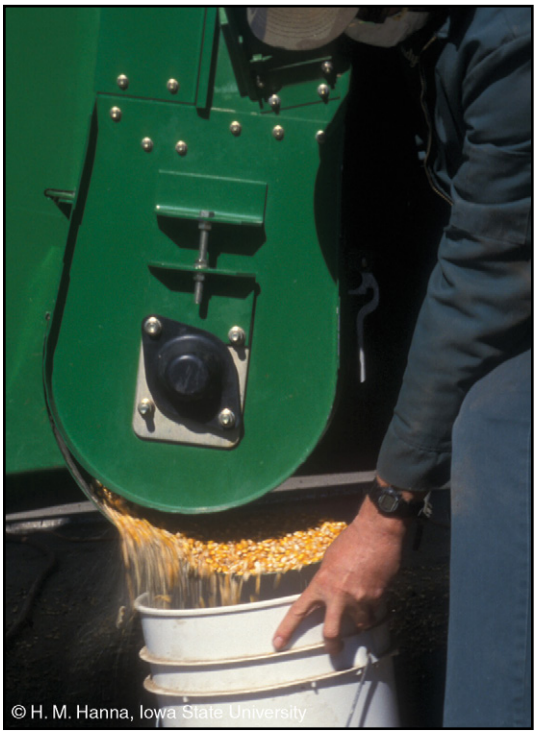


**Figure 19. Opening door at bottom of grain elevator**

If the clean grain elevator is equipped with a grain moisture sensor, investigate the ability to open it and check for grain trapped inside. A yield sensor may be mounted at the top of the clean grain elevator. Calibration can be affected by mounting position of this sensor, and as material is not likely to stay at the top, opening this sensor location is usually avoided unless inspection conditions are extraordinary.

## Grain tank

Access to the grain tank is from the top of the combine. As with other inspection procedures, before climbing into the tank for inspection make certain that power is disengaged, the engine is shut off, and that no one will be able to restart power exposing you to moving parts. All ledges should be inspected as well as the bottom cross-auger(s) and "bubble-up" auger for incoming grain (figure 20). Closely inspect the sump area in the grain tank where grain exits to the unloading auger. While atop the combine, check the roof of the cab (operator's station) for residual material that may fall into the grain tank.


**Figure 20. Augers in the grain tank. Note corn spilled on the cab roof in background.**

## Unloading auger

Turret-style unloading augers usually have one or more access panels or doors at the incoming flow base of the auger (figure 21). These should be opened for inspection. The area at the exit point (end) of the auger between auger flighting and housing should also be inspected. Figure 22 shows a spring-loaded door to keep residual grain inside the auger that may need to be opened. Check for other access points (figure 23) along the auger housing. If excessive grain residual is found inside the unloading auger, check to see if flushing with a suitable material (e.g. wood chips) was done during cleaning or would be appropriate.


**Figure 21. Open access door at base of turret-style unloading auger**

 


**Figure 22. Exit of unloading auger with spring-loaded door folded down**


**Figure 23. Access panel removed on unloading auger housing**

## Rear-axle and chopper/spreader area

Biomaterial, mostly non-grain, being expelled from the rear of the combine tends to hang up on surfaces (figure 24). This material is unlikely to be deposited in the grain tank during the current season's harvest, but seeds and other biomaterial may be spread off site if not cleaned. Check for material wrapped on rotating spreaders, chopper hammers (figure 25), and on interior ledges. If the combine has manually adjustable rear-axle width, check for cleaning in and around adjustment holes.


**Figure 24. Cleaning the rear of the combine**


**Figure 25. Chopper at rear of the combine**

## Engine compartment and operator's station (cab)

Although biomaterial residuals found in these areas are not likely to enter the clean grain tank, they may be transported to another field location. The amount of material in these areas is typically much less than other areas where crop readily passes through. In the engine compartment (figure 26), inspect particularly regions of higher air flow and dust accumulation such as around the radiator and upper engine surfaces. Inside the cab, check the floor areas, near operator controls, and any place grain or foreign material/dust may enter the cab (e.g. a tailings return inspection door, ventilation entry into the cab). If not already done, carefully inspect the combine chassis, frame, and tires.

 


**Figure 26. Engine compartment**

## Plot combines

This section details specific inspection points for a plot combine that are different from those mentioned previously for commercial combines. Plot combines are divided into two major categories, larger commercial-type combines that have been modified for plot harvesting and smaller combines produced specifically for plot harvesting (figure 27). The objective of plot combines is primarily to harvest information (e.g. yield, moisture) and only secondarily to harvest bulk grain. Because it is in the harvester's best interest to keep cultivar information segregated, such equipment or portions of it is often cleaned with greater frequency and precision than are commercial grain harvesting combines.


**Figure 27. Small plot combine harvesting soybeans**

### Commercial combines modified for plot harvest

In instances such as corn yield trials, where cultivars from small plots can be aggregated after weight and grain moisture are recorded for the plot, it is common to use a commercial combine with some modification. Cleaning and inspection practices for much of the combine are detailed in the previous section on commercial combines. The major modification difference inside these machines is that the flow path of the grain near the top of the clean grain elevator is diverted into a small hopper so that grain can be weighed and sampled for grain moisture before being transferred into the grain tank. A common scheme is to divert flow with a movable flap at the top of the elevator (figure 28) into a smaller hopper using a load cell to measure and record weight (figure 29). Pneumatic tubes may also be used to take a small sample of grain for moisture content, dropping the sample into a bag. If the weighing hopper is outside the grain tank, a conveyor such as a small auger is used to transfer the sample back into the grain tank. Otherwise, the small hopper dumps directly into the grain tank.

 


**Figure 28. Top of a grain elevator with the access door open to expose the diverter flap to redirect grain to an in-cab weighing hopper**

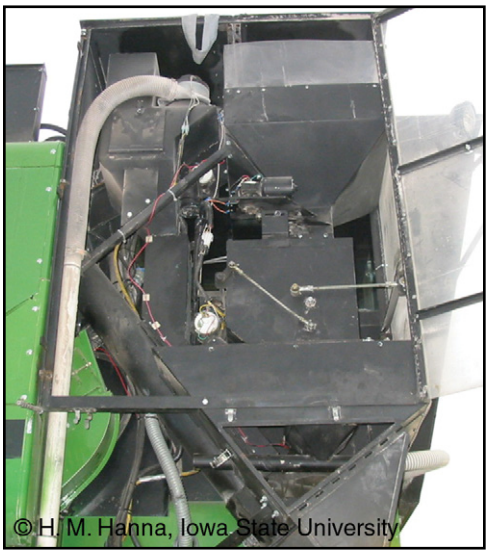


**Figure 29. Modification on commercial combine (right of the cab) to weigh grain samples**

Areas to inspect in this modified part of the combine include the diverter flap near the top of the grain elevator and smaller weighing hopper. If the hopper is outside the grain tank so that a transfer auger is required to move grain back into the grain tank, the auger area should be inspected. If a moisture sampling system is present (typically pneumatic air tubes) it should also be inspected. As with other areas of the combine, accessibility may be limited but is often present at points in the system where material may plug or maintenance is needed. Look for access panels, removable hose clamps on air tubes, and access at the lower end of transfer augers. Material is more likely to rest in lower parts of the system. Also inspect areas where errant grain may fall or bounce during the bagging of moisture samples (e.g. floor of the cab).

## Smaller combines built specifically for plot harvest

Small plot combines are used to harvest and contain specific cultivars for seed selection in small grains and oilseeds. Row-type heads (figure 30) may be used as well as small grain platforms. Small plot combines have similar corresponding functional areas as larger commercial combines. Common

exceptions are the absence of a rock trap, the use of cleaning sieves for material separation (i.e. no straw walkers), and pneumatic conveyors for transfer of grain after sieve separation. The smaller size of the combine limits the volume of cavities where grain and other material can hang up inside the machine. Because of the need for frequent field clean-outs to maintain cultivar purity, there is more open access. A straight-through flow path of material inside the machine is desirable for letting the machine mechanically "clean" between plots. A cylinder-type threshing mechanism is common for simplicity and open architecture in the interior. The inside of high-speed air transfer tubes are generally not accessible; however, air velocity makes them self-cleaning for most "non-zero" clean-out criteria. Because small volumes are harvested but not aggregated on the combine, no grain tank or unloading auger is present.


**Figure 30. Two-row head on a small combine used for soybean harvest**

Common areas for residual material to collect in the combine include the cylinder, sieves, and gathering mechanisms on the head. Check for removable shields around the head and inspect underneath them. If the head is a row-crop style with two or more rows, shielding on the hinged snout(s) should be lifted for inspection around gathering mechanisms (figure 31). After securely mechanically locking or blocking the head, check the underside of it. Inspect the feeder area and front of the cylinder. Look for an access door to open for easier inspection at the cylinder front (figure 32). The rear of the machine should be easily accessible, perhaps after opening a rear access panel. Sieves (often two; figure 33) should be removed and inspected (figure 34). The rear cavity behind the cylinder and including the grain transfer tube at the bottom should be inspected while sieves are out of the combine. Although sections of the pneumatic grain transfer tube are generally inaccessible, check bends and elbows (figure 35) for the presence of panels that might be opened. Grain or seeds discharge from the pneumatic conveyor in the upper part of the combine near the operator's station through a cyclone separator. The cyclone is usually clean and free of ledges to catch residual, but may be opened at the top or inspected through the bottom exit. Inspect carefully below the bottom of the cyclone where collection bags are placed. Grain missing the bag may spill into and around the operator's

 

station and engine compartment (figure 36). If not already done, carefully inspect the combine chassis, frame, and tires.


**Figure 31. Gathering mechanisms on the head exposed after the center shield was lifted**

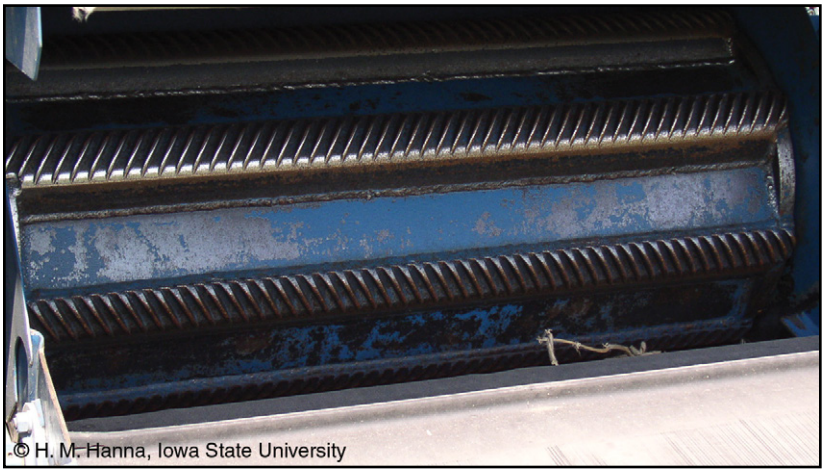


**Figure 32. Front of the cylinder**


**Figure 33. Two sieves in the rear of combine**

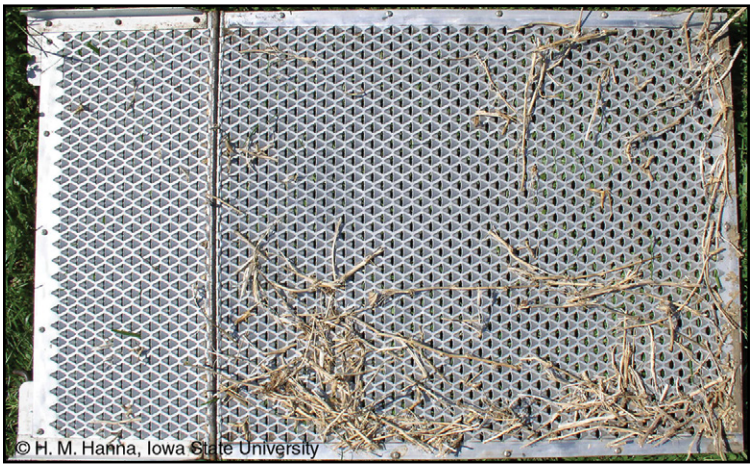


**Figure 34. Soybean material on sieve surface**


**Figure 35. Pneumatic air tube as it bends from fan to collection area underneath combine**

 

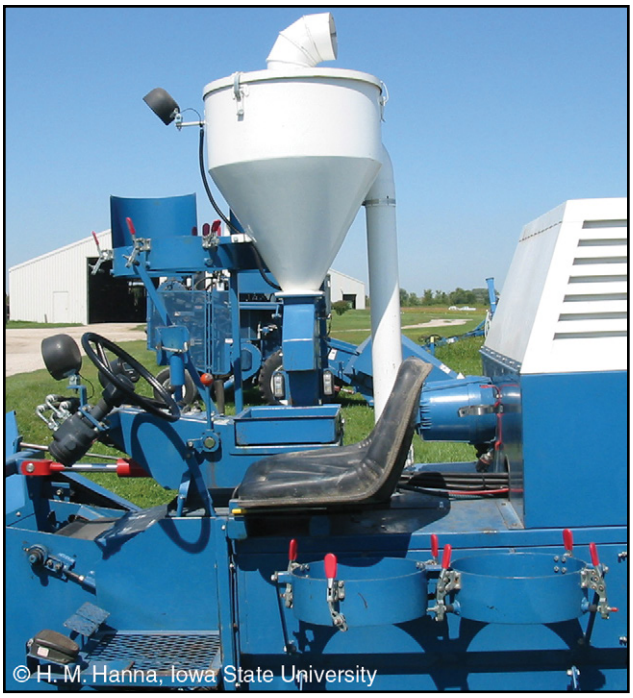


**Figure 36. Operator's station just ahead of the engine compartment**

## Other plot combine items

Some larger commercial combines with twin rotor threshing mechanisms have been modified so that two separate streams of crop flow through the machine. Flow paths are similar to those described in a commercial combine; however, there are separate but parallel regions to check inside the machine. The two flow streams are separately diverted for weighing and moisture sampling before being re-aggregated in the grain tank (similar to the modification described previously for commercial combines used for plot harvest). Smaller combines built specifically for plot harvest and using a four-row head also have been fabricated using two separate, parallel flow streams. Cleaning and inspection would proceed as described above, only for two separate flow paths on a single combine chassis.

Control of seeds harvested from plots is important. In most instances grain is removed from the field. However, because information is the most important thing harvested and grain/seed is secondary, some plot harvest combines have a device attached to destroy the ability of the grain to later germinate as seed. Grain is simply expelled into the field after such processing. Such a device may consist of crushing rolls, a hammermill and screen, or other processing apparatus to destroy seed viability. If such a device is present, inspect the area for residual biomaterial.

Thoroughness of harvest equipment inspection depends on the inspector's ability to carefully assess areas of the machine that may hold residual crop and biomaterial. Knowledge of common material flow paths and machine operation along with careful assessment of the level of inspection required for the risks involved are key inspection elements.