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ENGINEERING AND GINNING

Seed Cotton Unloading Systems

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ABSTRACT

The objective of this article is to review the literature and describe the current technology used by U.S. cotton gins for seed cotton unloading. Unloading systems supply the gin with raw material. Their essential functions are 1) to remove non-cotton materials such as protective covers used during transport and storage and large foreign objects such as dirt clods and rocks; 2) to break apart modules, which are compacted for transport and storage, so seed cotton is in small, loose clumps that can be dried more easily and cleaned; 3) to remove green bolls and some soil; and 4) to supply the gin with a steady, controlled flow that can be interrupted if there is a problem. Changes in the way harvested cotton is packaged in the field have resulted in significant changes in unloading systems in recent years. Current recommendations and best practices are presented.

RECENT DEVELOPMENTS

Innovations during the past 40 years have changed the way seed cotton arrives at cotton gins. At present, cotton gins in the U.S. receive almost all of their seed cotton in the form of rectangular and round modules. Only a small amount of seed cotton is presently unloaded from trailers, most is unloaded from module trucks. The word "unloading" distinguishes this first part of the ginning process from subsequent systems that dry and clean seed cotton.

The transition from trailers to modules was motivated by a need to de-couple harvesting from ginning. By the end of the 1960s a combination of short-season varieties and harvesters with increased capacities had greatly increased harvest rate. Cotton gins could not economically increase their processing rate to match because the total volume processed remained about the same (Wilkes and Jones, 1973). De-coupling harvesting from ginning was beneficial to growers. Ending the harvesting bottleneck of waiting on trailers freed growers to harvest quickly, minimizing fiber degradation and yield loss from exposure to weather.

De-coupling harvesting from ginning also was beneficial to ginners. Gins that had modules on their yards were free to operate independently of weather. The module system contributed to increased ginning capacity, which lowered labor and energy inputs per bale. And installing module feeding systems in some cases made it possible to eliminate the suction unloading fan. The average module-feeder energy consumption measured in a series of audits between 2009 and 2011 (Funk et al., 2013) was less than 1.0 kWh per bale. This represents a significant potential savings over the suction unloading or elevator fan energy consumption associated with trailer systems, which was greater than 4.0 kWh per bale in audits from the early 1960s (Wilmot and Alberson, 1964).

Unloading System Functions. Seed cotton unloading systems supply the gin with raw material. Their essential functions are 1) to remove non-cotton materials such as protective covers used during transport and storage and large foreign objects such as dirt clods and rocks; 2) to break apart modules, which are compacted for transport and storage, so seed cotton is in small, loose clumps that can be dried more easily and cleaned; 3) to remove green bolls and some sand and dirt; and 4) to supply the gin with a steady, controlled flow that can be interrupted if there is a problem.

Legacy Seed Cotton Unloading Systems. Pneumatic suction pipes have been in use for more than a century (Munger, 1893). Most of them are between 15 and 18 in (38-46 cm) in diameter (Stuller, 1992). Typically a concentric pair of pipes is arranged with the smaller diameter pipe mounted to a suction head, a flexible junction overhead that can move along a track, and with the larger diameter pipe sliding down

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from it, like a telescope. Because only a small fraction of seed cotton is still delivered in trailers, many gins have removed their suction telescope pipes and no longer accept trailers. However, trailers are still used where conventional (basket-type) harvesters operate to collect cotton harvested in quantities too small to make a module, either from small fields or the remainder of a larger field.

Pneumatic suction telescopes operated by hand limit the processing rate of a gin. As ginning capacities increased in the mid 1970s, power-assisted and remote controlled telescopes were developed. A remote controlled system has a cab above the unloading area where an operator uses a joystick to manipulate the suction pipe, typically powered by hydraulics (Fig. 1). It is important to follow the manufacturer's instructions when setting up the operating speed of each component. This is done through adjustments at the hydraulic valve bank, usually located on the suction head or track frame. The low speed setting is for when the telescope is extended beyond halfway. If the telescope end moves too fast there would not be time for the airstream to break seed cotton loose from the trailer or module. A flared tip helps direct the airflow into the pipe without jamming it with large wads. If made of flexible material, it also can help to minimize trailer damage (Stuller, 1992).

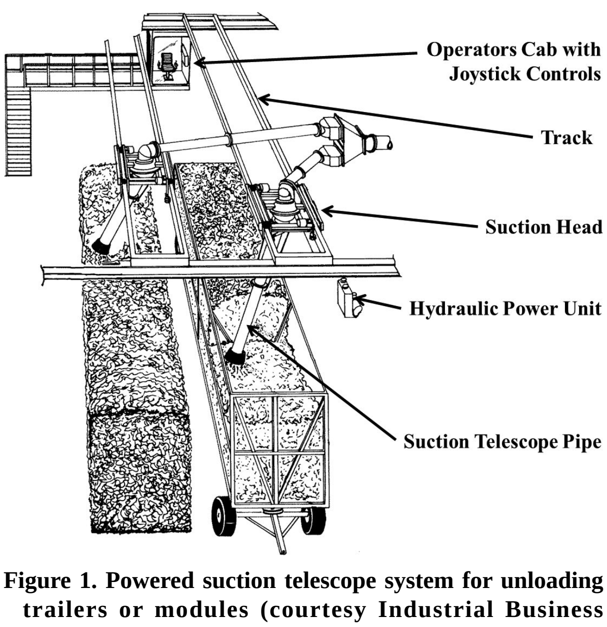

Figure 1. Powered suction telescope system for unloading trailers or modules (courtesy Industrial Business Consultants, Inc.).

Another technology that is passing from the scene is the traveling, mobile, or moving head module feeder. Their advantage was that they could unload modules that were on pallets. There are a number of them still in use, but they are no longer being installed in the U.S. Traveling head module feeders were introduced shortly after the stationary version (Condarco et al., 1978). Bi-directional versions overcame the liability of cotton flow to the gin being interrupted briefly while the traveling head returned to its start position (Prather, 1980).

Traveling head module feeders (Fig. 2) require a concrete staging area typically 25 ft (7.6 m) wide. The staging area holds two to six conventional modules, and most commonly is covered by a roof, especially in areas of high rainfall. Tracks on one or both sides of the staging area guide the dispersing head as it slowly moves through each module. A cable trolley supports electric wires that provide power to the traveling head. As it approaches the end of the last module a door is lowered to contain the collapsing wall of seed cotton. Its forward motion is powered by a variable speed motor that is controlled to match its dispersing rate to the gin's processing rate. If the traveling head has only one feed side, a high speed motor returns it to the starting end of the track. At the same time, a module truck should be backing up to place its load as soon as the traveling head reaches its start position and the operator has opened the containment door (Laird et al., 1994). Like the more common stationary head module feeder, the traveling head module feeder has from six to eight shafts supporting rollers with spikes or triangular teeth that tear tightly packed seed cotton from the module. A transverse conveyor drops this loose seed cotton onto a parallel conveyor belt running alongside the staging area. Seed cotton on the parallel conveyor belt typically is picked up with a suction duct using atmospheric or heated air. The suction duct usually includes a gap for separating rocks and green bolls (Fig. 3).

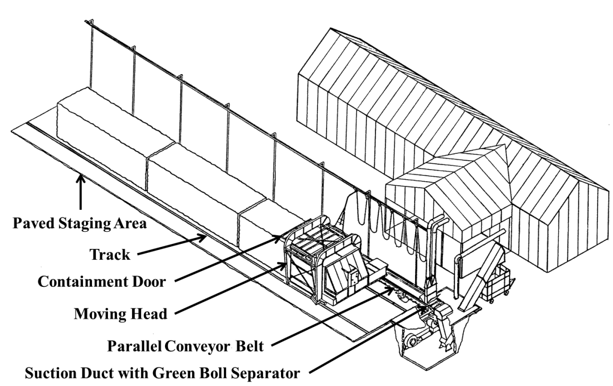

Figure 2. Traveling head module feeder (courtesy Beltwide Industrial and Gin Supply Co.).

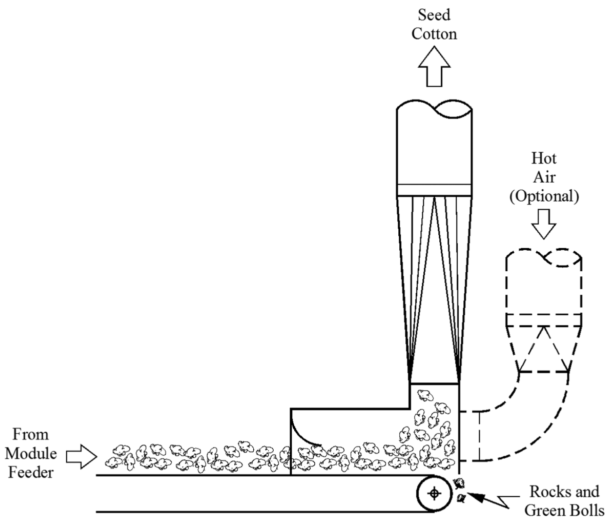

Figure 3. Suction or hot air pick up with green boll separation (courtesy Samuel Jackson, Inc.).

CURRENT TECHNOLOGY

Conventional Modules. U.S. cotton gins now receive almost all seed cotton in three distinct packages. In the early 1970s Lambert Wilkes at Texas A&M University and J.K. (Farmer) Jones at Cotton Incorporated led the development of technology for packaging harvested cotton into freestanding modules containing 18,000 to 22,000 lb (8000-10,000 kg) of seed cotton (Wilkes and Jones, 1973). They were also involved in developing a stationary module feeder (Jones et al., 1975). Modules are typically formed near the edge of the field using tractor-powered module builders. The module builder is filled directly from the harvester basket, or by a tractor-pulled boll buggy carrying seed cotton from one or more harvesters to the module builder. A decreasing, but still major, portion of cotton arrives at U.S. cotton gins in conventional modules that are 32 ft (9.75 m) long and between 7.25 and 7.54 ft (2.21-2.30 m) wide (ASABE, 2005). Modules are at most 8.5 ft (2.59 m) tall.

Harvester Modules. The motivation for the adoption of harvester or onboard module builders is limited labor availability, especially at harvest time. Labor is required to drive the harvester and boll buggy, operate the module builder, cover the completed module, and clean up dropped cotton. Two conventional harvesters in operation with ancillary equipment will generally require a crew of eight to 10 workers (van der Sluijs et al., 2015). Harvesters that form modules on board eliminate the need for boll buggies, module builders, and associated tractors and workers (Martin and Valco, 2008). The Case IH 625 and 635 Module Express harvesters make half-length (16 ft or 4.88 m long) rectangular modules 8 ft (2.44 m) wide and tall, weighing from 12,000 to 13,800 pounds (5443-6260 kg). Two Case IH modules are roughly the same package as one conventional module, and they can be handled with equipment designed to handle conventional modules.

The John Deere 7760 harvester and its upgrades, the CP690 and CS690, make the other package: round modules weighing approximately 4500 to 5500 lb (2040-2500 kg) that are 8 ft (2.44 m) wide and 7.5 to 8 ft (2.29-2.44 m) in diameter. Round modules are wrapped in a plastic film that provides structure for the module and protects the seed cotton from weather. Special equipment, typically a tractor of approximately 360 hp (265 kW), with forks, clamps, one or more spears, or a specialized grappling device, is needed to stage and load round modules. This operation can be done after the harvest (John Deere Des Moines Works, 2013a).

Round Modules. Harvesting into round modules allows the harvester to operate continuously (a completed round module can be carried to the edge of the field while the harvester begins forming the next round module). Because the harvester automatically wraps the module, no ground crew is required for tarping. Up to eight round modules can be carried on a flatbed semitrailer, or up to 10 round modules can be carried on a set of double semitrailers, without special permits, allowing cotton to be economically transported over greater distances. These advantages led to a transition starting in 2009 that resulted in 22.5% of U.S. cotton being harvested by this method in 2013 (Valco et al., 2015). The 2014 introduction of the John Deere CS690, a cotton stripper with the ability to form round modules on board, portends more round modules in future.

Round module staging and transporting. When staging round modules, it is recommended that they be staged end-to-end, and that there be a 6 to 8 in (15-20 cm) gap between each for loading purposes. If module trucks are used to handle wrapped (round) modules, the chains should be equipped with puncture-resistant or rounded lugs (John Deere Des Moines Works 2013b). For more information, see the article in this series by T.D. Valco, S.L. Simpson and E.M. Barnes titled “Seed Cotton Storage and Handling” to be published in a future issue of this journal.

Round modules in the gin. Round modules that were harvested at the correct moisture content and stored properly will tend to have more consistent moisture content than conventional modules, allowing the gin to run smoothly and in some cases at a higher capacity. However, round modules do not blend cotton from several parts of a field together as conventional modules do, so in nonhomogeneous fields there might be greater variability in fiber quality between bales (van der Sluijs et al., 2015). This liability could be mitigated with module averaging or with a blending system that combines seed cotton from multiple modules. To prevent contamination, wrapped modules should never be conveyed using chains that have sharp-edged lugs, and should never directly pass over rock or debris removing rollers (Fig. 4) (John Deere Des Moines Works, 2013b).

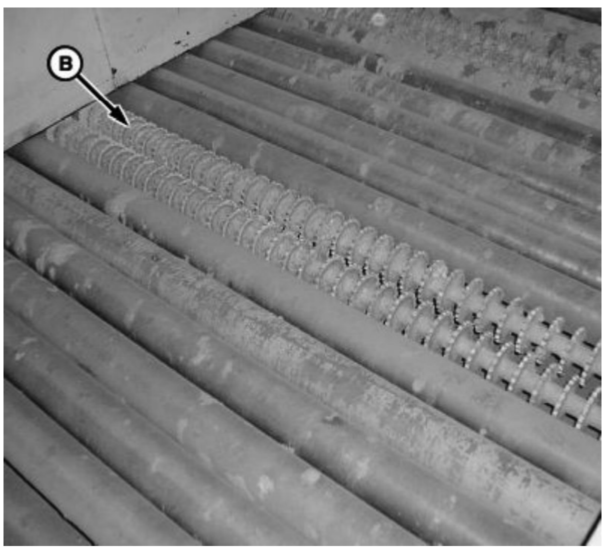

Figure 4. Prevent wrap punctures and tears by ensuring that wrapped modules do not directly pass over rock or debris removing rollers, "B" (courtesy John Deere Des Moines Works).

Removing round module wrap. Round module wrap is a potential contaminant if it gets entrained with seed cotton. To avoid inadvertently creating small pieces of wrap that might flow into the gin, it is critical to cut the wrap as directed by the manufacturer: make only one axial cut along the entire length of the module, make a clean cut, and cut the wrap on the side of the round module opposite the inner tail. Module wrap is manufactured with four individualized RFID tags that can be used by automated equipment to locate the safe cutting zone. The wrap on a full-sized module (7.5 ft [2.3 m] in diameter) can be cut directly opposite of the end of the outer tail without cutting through the loose inner tail (Fig. 5) (John Deere Des Moines Works, 2013b). Extreme care should be taken when removing the wrap from smaller round modules, as the desired cut location will vary and a loose piece of plastic might be unavoidable with small modules. A compactor should be placed close to the unwrapping process location to contain all plastic. Round module wrap is LLDPE film and can be recycled. Approximately 9 lb (4 kg) of plastic wrap is on each round module. For spindle-picked cotton, this represents approximately 2.2 lb (1 kg) of marketable plastic per bale ginned. For stripped cotton, 2.6 to 3 lb (1.2-1.4 kg) per bale could be available.

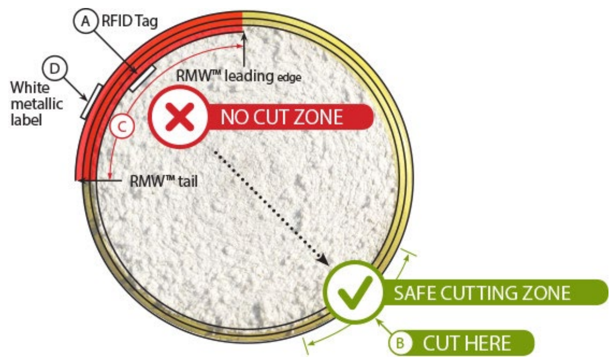

Figure 5. Safe cutting zone for round module wrap (courtesy Tama/Ambraco Inc.).

As round modules have proliferated, so have commercial solutions for unwrapping them. The simplest (and initially least expensive) solution is to stand the round modules upright by discharging them from a module truck that is 20 in (50 cm) above the feed bed. The wrap is cut with a box knife and removed by hand. This method has been adequate when ginning a limited number of modules, provided the feeder bed had side walls and was wide enough to convey the seed cotton as the modules broke apart. It helps if some form of surge bin (feed control-type storage hopper) is present to meter a steady flow of seed cotton into the ginning system. With increasing numbers of round modules, gins have invested in increasingly automated solutions to increase throughput and reduce their labor cost and risk of worker injury. Some of these systems slit the wrap as the module is unloaded from the yard truck, placed on the feed bed by a loader, or as it advances along the feed bed. Other unwrapping systems hold the modules on a tipping floor to one side of the roller bed or pick them up with arms equipped with belts or rollers, so the wrap can be cut by hand and more easily removed. And some automatically position the round module using its integral RFID tags and cut the wrap with a powered knife. There also are unwrapping systems that upend the module to dump the cotton out, as from a sack, instead of cutting the wrap. In most cases, a worker gathers the wrap by hand and stuffs it into a dedicated compactor for baling.

Regardless of the system used to remove plastic wrap from round modules, gin owners and managers should make employees aware of the potential plastic contamination problem and train them to make every effort to keep plastic wrap from entering the ginning system. Employees must check the module-feeder dispersing cylinders for contamination during every shift. They also need to be trained on the proper methods of handling modules both in the gin yard and at the feeder floor entrance (Cotton Incorporated, 2016).

The following recommendations were published to provide guidance to the ginning industry when round modules began to appear (Valco, 2012):

- Select an unwrapping system with enough automation to feed the gin without limiting ginning capacity and with considerations for the feeder design and gin yard layout.
- Select an unwrapping system that (1) locates the RFID tag embedded in the plastic wrap and makes cuts at the recommended location to prevent a loose piece of wrap remaining with the module or (2) an unwrapping system that dumps cotton from the wrap without cutting the wrap.
- Have additional well-trained personnel on the module feeder to handle the smaller rounds and plastic wrap in a safe and effective manner.
- Conduct training for workers on the importance of keeping plastic wrap from entering into the feeder and the gin.

Feeding round modules. There are three possible orientations for round modules. The orientation is determined largely by which unwrapping system is selected. Round modules can be oriented on the feeder bed with the axis of the modules parallel to their direction of travel (like sausages), the most common method; standing upright (like cans), or with the axis of the modules perpendicular to the direction of travel (like wagon wheels).

The smoothest feed rate occurs when the axis of the round modules is parallel to their direction of travel. Unwrapped round modules oriented with their axis parallel to their travel direction might need increased friction between them and the feed-bed rollers. To increase friction, some gins have welded small diameter steel rods to alternate feed-bed rollers and other gins have used nonskid or nonslip paint (John Deere Des Moines Works, 2013b). Module feeder roller beds, and some walking floors, are typically 1.5 to 3.5 conventional module lengths, or 48 to 112 ft (15-34 m) long. Prior to 2009, module feeders were designed to convey rectangular modules up to 7.54 ft (2.3 m) wide. Conventional and Case IH modules retain their shape up to the point where they contact the spiked cylinders in the dispersing head. Round modules, on the other hand, tend to break apart after the wrap is removed, increasing their width. To handle round modules that have their axis parallel to their direction of travel, or standing upright, gins might need to install wider module feeder roller beds or walking floors, and side walls up to 5 ft (1.52 m) high. Gins with traveling head module feeders need to place round modules with their axis perpendicular to the head travel direction, so seed cotton does not spill onto the traveling head track.

When the axis of the round modules is perpendicular to their direction of travel there is less spreading, reducing the need for side walls and/or a wider feed bed. Round modules that have their axis perpendicular to their direction of travel, or standing upright, present the dispersing cylinders with alternating amounts of material as they approach the maximum diameter and then move past it (peaks and valleys). Module feeders with automatic control systems that handled rectangular modules exclusively were able to provide gins with a reasonably steady flow of seed cotton, leading some gins to remove old surge bin (steady flow or feed control-type storage hopper) systems. Round modules with their axis parallel to the direction of travel can be fed fairly smoothly, too. However, round modules in vertical and perpendicular orientations could require an accumulator (steady flow) system with a surge bin, variable speed spiked rollers, and feed rate control to meter seed cotton at a constant rate into the next stage of the gin.

Uncovering Rectangular Modules. Rectangular modules placed on the roller bed or walking floor of a stationary feeder or on the staging pad of a traveling feeder need to have their cover removed. There are two focus areas bearing on final fiber quality that require management effort to provide adequate employee training and supervision. The first focus area impacts the price that the gin customer gets for his cotton; covers with pin holes in them will let moisture into the modules, degrading seed and fiber quality (ASABE, 2013). Covers must be handled gently and stored appropriately; away from the degrading influences of rodents, moisture, and sunlight (National Cotton Council, 2004). Powered tarp rollers are hard on tarps, and they are a hazard to personnel. The other focus area impacts the reputation of a region, and ultimately the price growers in that region can command in future years; every effort must be made to prevent contamination from module cover tie-downs. Gin management must educate growers to never use baling twine or other plastic materials as tie-downs. If approved module tape is used to hold down covers in high wind regions, the tape should be placed under the module before it is formed, and not through the module. Gin employees must carefully remove every piece of tie-down material.

Feeder Options. Several manufacturers have designed module feeders to pick apart the densely packed seed cotton that comes in modules. Stationary feeder dispersing heads typically are mounted at the end of a variable feed rate roller bed or walking floor. Roller beds usually are elevated above ground level to match the height of a module truck bed, whereas walking floors more often are at floor level. Roller beds are powered by 5 to 15 hp (4-11 kW) motors per section. Walking floors are normally powered by 40 hp (30 kW) hydraulic units.

The dispersing head might be over a pit that contains a surge bin (steady flow or feed control-type storage hopper), with metering rollers for feed rate control (Fig. 6). Construction costs for the associated pit might be partially justified if doing so eliminates the operating cost of a pneumatic conveying fan. A benefit of replacing this pneumatic conveying system with gravity is eliminating a significant source of emissions; unloading system cyclones are among the gin's highest in $PM_{2.5}$ and PM_{10} emissions per bale (Buser et al., 2013). The alternative is to have a conveyor belt, usually perpendicular to the feeder bed, or one or more screw conveyors beneath the dispersing head, to convey cotton to a hot box pick up.

Feeder details. Feeder dispersing heads typically contain six to eight shafts in a line inclined to remove the top part of the module first (Fig. 6). Each shaft has spiked cylinders or rollers with triangular teeth to tear open the tightly packed module. Dispersing heads typically are powered by motors from 30 to as much as 75 hp (22-56 kW).

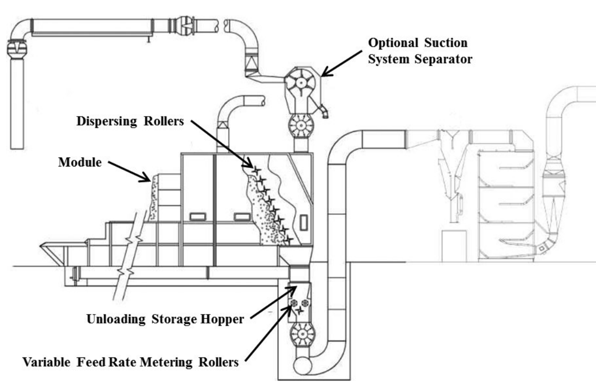

Figure 6. Stationary module feeder with a feed control system beneath (courtesy Lummus Corp.).

Feed rate control. Whether the surge bin is beneath the dispersing head or located separately (Fig. 7), it will have a pair of cylinders with welded flights powered by a variable speed motor from 1 to 3 hp (0.7-2.2 kW) to meter seed cotton into the ginning system at a rate selected by the ginner. Immediately beneath the feed rollers there usually is a high speed spiked cylinder, powered by a motor from 5 to 7.5 hp (3.7-5.6 kW), to break up clumps, further dispersing the seed cotton. This motor also powers the vacuum dropper, because at this point seed cotton is fed into a pneumatic conveying line. Normally a sensor in the surge bin provides feedback to the walking floor or roller bed, automatically adjusting the module feed rate to match the gin's processing rate. Seed cotton that has been opened and entrained in an air line settles at a density of 2 to 3 lb ft^{-3}(32-48 kg m^{-3}) when it is dropped into a container such as the surge bin. Cotton compresses from its own weight and density increases to 4 to 6 lb ft^{-3}(64-96 kg m^{-3}) at a depth of 6 to 8 ft (1.8-2.4 m). The surge bin normally needs to contain approximately a 30 sec. supply of seed cotton to avoid running out of cotton during momentary lapses in feeding from the unloading system. Under most conditions, lapses can be avoided by providing a surge bin volume of approximately 5 to 8 ft^{-3} (0.14-0.23 m^3) for each bale per hour ginned. The rollers in the bottom of the feed control hopper that feed cotton to the gin can choke if the depth sensors are adjusted to allow a depth of more than approximately 6 to 8 ft (1.8-2.4 m) of cotton to accumulate. Feed roller and vacuum dropper speed can be adjusted over a wide range, but the normal maximum feed rate is approximately four to five bales per hour for each foot (0.3 m) of surge bin width. Unloading system maintenance should be done with careful consideration of basic safety principles. Consult with the manufacturer or personnel experienced in unloading system design before making modifications.

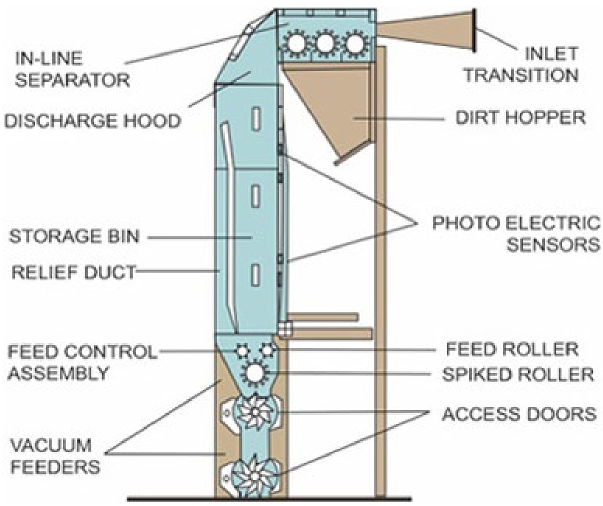

Figure 7. Free-standing feed control system (courtesy Bajaj ConEagle LLC).

Seed Cotton Conveying. Picking up seed cotton with hot air allows for drying while it is being conveyed. This can be done with a parallel-flow or cross-flow blowbox (blow plug), or with a Belt-Wide Hi-Slip dryer (Fig. 8). A hi-slip dryer is a shallow duct as wide as the feeder that forms a Venturi. Seed cotton drops into high velocity hot air at the Venturi. A slowly rotating shaft turns a cylinder with lugs to hold the seed cotton so air flows through it, in an attempt to increase drying time. Both of these devices are located under the feed rate control. Alternately, a hot-air pickup box can be installed over the conveyor belt that runs under the module feeder dispersing head belt or screw discharge conveyor (Fig. 3). A hot-air pickup is supplied by a pull-through burner, usually located nearby. Systems with a blow box or hi-slip can have a push fan, if necessary, to overcome greater pressure drops in the drying system. In either case, there must be enough air volume to convey seed cotton at 4500 ft/ min (23 m/s) or more. For more information about burners and drying systems, see the article in this series by M.G. Pelletier, R.K. Byler, R.G. Hardin IV and S.E. Hughs titled "Moisture Control"; for more information on conveying, see the article in this series by D.P Whitelock, M.D. Buser, J.K. Green, R.G. Hardin IV, G.A. Holt, D.B McCook and J.C. Fabian titled "Pneumatic Systems." Both articles will appear in a future issue of this journal.

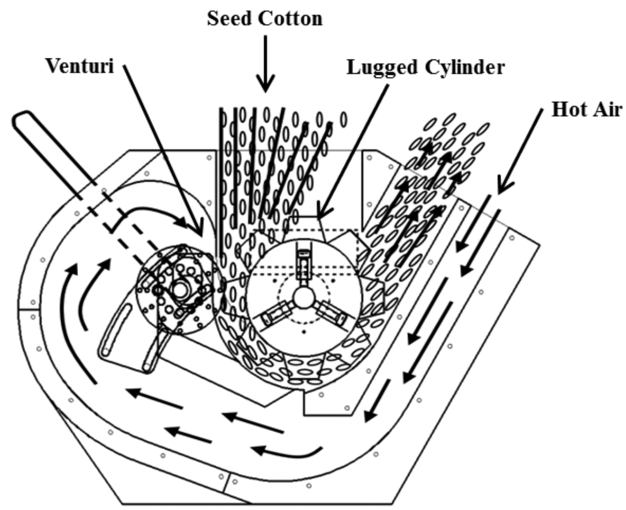

Figure 8. Belt-Wide Hi-Slip dryer (Mangialardi Jr. and Anthony, 2003).

Foreign Object Removal. Spindle pickers and machine strippers can pick up rocks, dirt clods, metal scrap, roots, and other heavy objects in the field. These contaminants must be removed before the cotton reaches the gin's processing machines or they will damage the machines and possibly cause chokes and fires. The hood of the hot-air pickup over a conveyor belt can be designed to let rocks and green bolls pass through, providing cleaning (Fig. 3). Otherwise a rock and green boll trap is installed in-line in the pneumatic conveying system, before any other seed cotton cleaners or dryers, to protect them from damage (Fig. 9). A green boll trap separates objects based on their density. An adjustable deflector in a hopper provides a decrease in air speed and a change in material flow direction that allows more dense green bolls to fall from the conveying air, while the less dense seed cotton remains suspended. An adjustable opening admits reclaimed air from the room (or warm air from the pull-through burner) to control the degree of separation. This trap might have a vacuum dropper, but the more common arrangement is a pair of doors in series powered by a pneumatic cylinder that alternately open, dropping green bolls onto the floor or into a container. Removing large foreign objects at this early stage reduces damage to ducts and machines later in the process.

Gins in areas with sandy soil, and especially gins processing stripper-harvested cotton, might have a sand cleaner (or sand separator) as part of a separator combination before the surge bin and feed control. These devices typically have three cylinders scrubbing seed cotton horizontally over a close-spaced grid. An alternative to pneumatic conveying from the module feeder is to use up to two dozen cylinders arranged in an incline to remove sand while conveying seed cotton to an above-ground flow control. For more information, see the article in this series by R.G. Hardin IV and C.B. Armijo titled "Seed Cotton Cleaning and Extracting" and the article by D.P. Whitelock, M.D. Buser, J.K. Green, R.G. Hardin IV, G.A. Holt, D.B. McCook and J.C. Fabian titled"Pneumatic Systems." (Both of which will be published in a future issue of this journal.) Once the tarps or wrap and large foreign objects have been removed, and seed cotton is in small, loose clumps at a steady, controlled rate of flow then the unloading portion is complete and the seed cotton is ready for drying and cleaning.

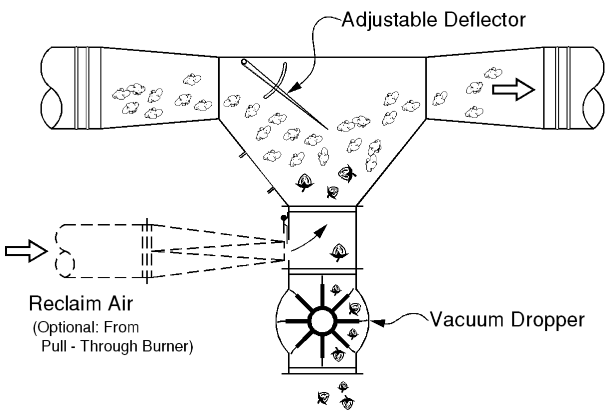

Figure 9. In-line green boll trap or rock catcher.

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