The *Journal of Cotton Science 25:213–221 (2021)*
http://journal.cotton.org, © The Cotton Foundation 2021

NOTE

ENGINEERING AND GINNING

A Module Feeder Inspection System For Plastic Contamination – Updated System Design

John D. Wanjura*, Mathew G. Pelletier, and Greg A. Holt

ABSTRACT

This note describes the updated design and operation of an inspection system that provides ginners an instantaneous view of the dispersing cylinders in a cotton gin module feeder. Images are provided by network cameras installed in the back wall of a module feeder using a new adjustable housing design that allows for easier installation into various module feeder designs. We observed that when these systems are installed and operated, accumulation of plastic and other contaminants on dispersing cylinders is detected and removed more quickly than when the cylinders are manually checked between work shifts or during other pauses in gin operation. Gin crews are more responsive to plastic accumulation on the dispersing cylinders because they can see when it occurs and quickly remove the contaminants, thereby reducing the risk of plastic contamination in lint bales.

Cylindrical or "round" modules formed by John Deere cotton harvesters (7760, CP/CS690, and CP/CS770, Deere and Company, Moline, IL) are wrapped in multiple layers of linear low-density polyethylene (LLDPE) plastic film prior to in-field storage (TamaWrap™, Tama USA Inc., Dubuque, IA). The plastic material serves to protect the cotton inside the module from environmental effects such as wind and rain while restraining the seed cotton in cylindrical form. With the increased adoption of these harvesters has come an increase in the occurrence of plastic contamination in lint bales. Bales with plastic contamination receive substantial price discounts from merchants and mills as reflected in the -4000 point per pound spot quotation discount for United States Department of Agriculture Agricultural Marketing Service (USDA-AMS) plastic designations 71 and 72 (USDA-AMS, 2020). The consistent discount for plastic contamination on spot market quotations has increased the Commodity Credit Corporation (CCC) Loan discount for 71 and 72 designations to -3130 and -3240 points per pound, respectively (USDA-CCC, 2021). Moreover, the increased presence of plastic contamination in United States (US) lint bales has eroded the premium once received by US cotton on the world market for its long-standing reputation as one of the cleanest sources of natural fiber. This has continued so that now instead of trading on international markets with a premium, US cotton now often trades at a discount relative to other growths of similar quality (Pelletier et al., 2021). Thus, it is of keen interest to the US cotton industry to minimize the occurrence of plastic contamination.

Damage to module wrap prior to unwrapping at the gin increases the risk of plastic contamination. Although efforts are taken by growers and ginners to protect the integrity of module wrap during handling in the field, transport, and handling at the gin, the plastic can still be damaged by contact with the harvester during the ejection process, improper engagement by staging equipment, abrasion from exposure to cotton stalks or other sharp debris, and mishandling during loading or unloading from transport vehicles (Wanjura et al., 2020; Iqbal et al., 2021).

Handling and unwrapping techniques that result in plastic remaining in the seed cotton after the unwrapping process also increase the risk of contamination. Often, large pieces of plastic remaining in the seed cotton after unwrapping accumulate on the dispersing cylinders of the module feeder. If not removed by the gin crew, this material frays into small pieces over time potentially contaminating many bales. To mitigate this risk of contamination,

J.D. Wanjura*, M.G. Pelletier, and G.A. Holt, USDA-ARS Cotton Production and Processing Research Unit, 1604 E. FM 1294, Lubbock, TX 79403
*Corresponding author: John.Wanjura@usda.gov

a camera-based inspection system was developed that provides ginners a periodic view of the back side of the module feeder dispersing cylinders (Pelletier et al, 2020). The system was tested under commercial conditions and helped gin crews to quickly see when plastic accumulated on the dispersing cylinders. The objective of this work is to document improvements to the original camera-based inspection system described by Pelletier et al. (2020) and provide details on the design, implementation, and performance of the new system.

MATERIALS AND METHODS

Original System Overview. The basic module feeder inspection system consists of internet-protocol (IP) cameras, camera mount assemblies, light emitting diode (LED) lights, and software to view the video stream data from the cameras. Multiple cameras are typically installed across the width and/or height of the module feeder back wall to enable viewing of the full width/height of the module feeder dispersing cylinders. Network IP cameras can be connected directly (via ethernet cables) to a personal-computer (PC) running the viewing software or they can be connected to a network (through a network switch or router) to which the PC is also connected in cases where enough ethernet ports are not available on the PC to allow direct connection. The cameras are powered from either an external direct-current (DC) power supply or by a power-over-ethernet (POE) connection which conveniently transfers data and power through the same network cable. Independent from the cameras, LED lights are used to provide necessary lighting inside the module feeder dispersing cabinet to properly illuminate the dispersing cylinders. The software used to view the video data from the network cameras will often come with the camera from the manufacturer. Alternatively, free-ware software packages available on the internet can be used to view the video stream from most modern network IP cameras. In any case, the simple viewer software displays the live video stream from the network IP cameras. Thus, the ginner must manually pause the module feeder floor briefly to allow the cotton to fall away from the back of the dispersing cylinders to obtain a clear view of any accumulation of contaminants on the cylinders (figure 1).

Figure 1. Image captured by module feeder inspection system at a commercial gin testing location showing plastic accumulation on bottom dispersing cylinder.

Updated System Design Overview. In 2020, a custom written software package was developed to help automate the operation of the basic module feeder inspection system. The same hardware components used in the original module feeder inspection system with respect to network cameras and LED lights were used with the new automated system. The automated system software was designed to sense the operational status of the module feeder floor and execute a programmed pause before capturing and displaying still images of the module feeder dispersing cylinders. The programmable logic controller (PLC) program controlling the module feeder was modified by the equipment provider (at the request of the gin) to include a pause routine which, when enabled, would automatically pause the feeder floor for a preset period (~10 sec) on a preset interval (every 15 to 30 minutes). When the PLC program paused the feeder floor, a dry-contact relay (RPM12F7, Schneider Electric, Andover, MA) was actuated signaling the automated module feeder inspection system software through an ethernet connected data acquisition device (T4, LabJack Corp., Lakewood, CO) that the feeder bed pause event had begun. The inspection system software then executed a pre-programmed pause period (~ 9 sec) to allow cotton to fall away from the back-side view of the dispersing cylinders before capturing still images of the cylinders. Once the bed pause period elapsed in the module feeder PLC program, the feeder bed resumed normal operation. The automated module feeder inspection system software user interface is shown in figure 2 and displays the live (left-hand side) and still images (right-hand side) captured by the network cameras monitoring the upper and lower cylinders, respectively. A machine-vision algorithm was built into the automated module feeder inspection system software to facilitate automatic detection of plastic on the dispersing cylinders. Additional information on the design and performance of the automated module feeder inspection system machine vision algorithm will be provided in a later report.

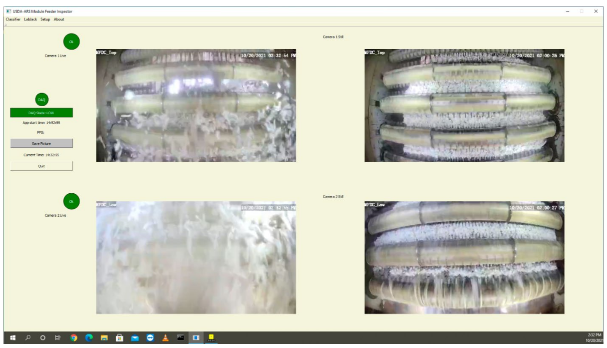


Figure 2. Automated module feeder detection system software user interface displaying most recently captured still images (right-hand side images) and live video feed images (left-hand side images) from the network cameras monitoring the top and bottom dispersing cylinders at a commercial gin testing location.

Adjustable Camera Mount – Design and Installation Details. The network IP cameras used in the updated module feeder inspection system are installed into the back wall of the module feeder dispersing cabinet using adjustable mount assemblies (Figure 3a and 3b). Each assembly requires a 17.8 cm x 17.8 cm (7 in x 7 in) opening to be cut into the back wall of the module feeder and 4.76 mm (3/16 in) diameter holes drilled to mount the hinge at the base of the mount assembly and the toggle clamps which hold the mount in operating position. The mount assemblies provide +/- 30 degrees of elevation adjustment allowing the camera to be positioned more conveniently on the rear wall of the feeder while maintaining the desired view of the dispersing cylinders. Each camera is held in place by a "ball-faced" sleeve made from ultra-high molecular weight (UHMW) plastic that pivots on two steel plates welded to the front face of the mount. A replaceable lens protector made from scratch and impact resistant clear acrylic is installed in front of the camera lens to protect the camera from airborne debris in the feeder.

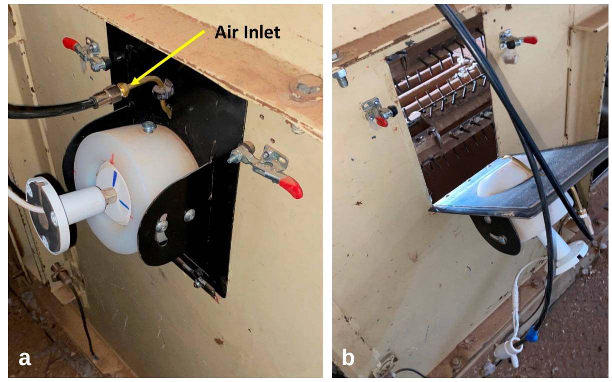


Figure 3. Adjustable mount for network IP camera installed on the back wall of a module feeder. The camera is held to the back side of the module feeder by quick release toggle clamps (figure 3a) and a hinge at the base that allows the camera to be tilted out of operating position for maintenance (figure 3b). Supplemental compressed air is provided through the air inlet (figure 3a) to help clear dust and debris from the lens protector.

An optional air nozzle is included in the camera mount design to direct compressed air over the face of the lens protector and help clear accumulation of dust and debris. A push-to-connect fitting is used to attach the compressed air supply line to the nozzle so that the air line can be easily disconnected when the assembly is pivoted away from the module feeder back wall for periodic cleaning and maintenance.

Light emitting diode lights are installed adjacent to the cameras to provide supplemental light. To avoid 60 Hz cycling of the images, DC powered lights were selected. We observed that a minimum of 2500 lux (232 ft-candle) illuminance is needed at the dispersing cylinders to produce a clear image. It is important that the lighting coverage is uniform across the back side of the dispersing cylinders to produce clear images that are free from dark areas. Installation of the LED light bars used in the module feeder inspection system require a rectangular opening to be cut in the rear wall of the module feeder and housing clamps provided by the manufacturer are used to fix the lights in place. The LED light bars are powered by an external driver that converts 120 VAC to 12 VDC power (one driver per light bar).

A view of the adjustable camera mount from the inside of the module feeder dispersing cabinet is shown in figure 4. The smooth shape and minimal protrusion inside the module feeder back wall of the ball-faced camera sleeve and polished air inlet nozzle provide minimal resistance to cotton moving down the back wall of the feeder. At maximum elevation adjustment (i.e. the camera angle adjusted all the way up or down), the camera sleeve extends approximately 29.2 mm (1.15 in) inside the back wall of the module feeder. With the camera lens parallel to the feeder back wall, the camera sleeve extends inside 19.3 mm (0.76 in).

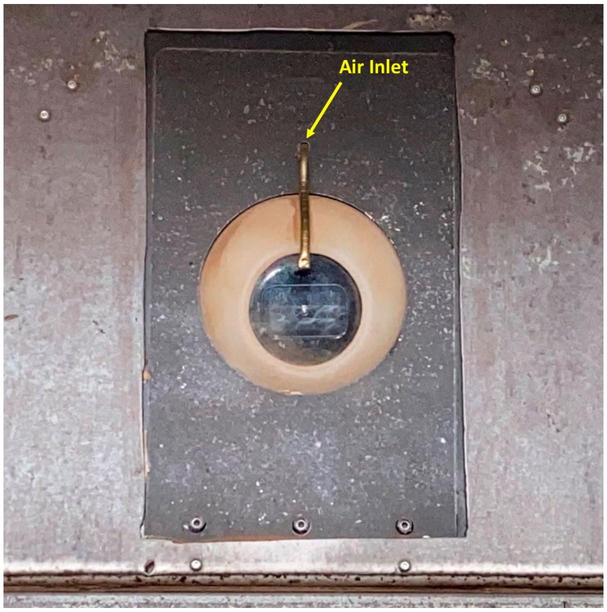


Figure 4. Internal view of the adjustable camera mount installed on the back wall of a module feeder. The smooth shape and minimal protrusion of the camera sleeve and air nozzle provide minimal resistance to cotton moving down the back wall of the feeder.

The cameras and lights should be positioned on the back wall of the module feeder to capture a complete view of the dispersing cylinders. This may require the installation of multiple cameras that provide images that slightly overlap one another. The camera and light positions are determined based on the optical imaging angle for the lens, the distance between the back wall of the feeder and the dispersing cylinders, and the slope of the back wall relative to the dispersing cylinders. Best practice is to connect the cameras to the PC and viewing software and manually hold the cameras on the inside back wall of the feeder. The camera position is adjusted until the image coverage is suitable. Two possible camera and light position scenarios are shown in figure 5. The placement scenario shown in figure 5a can be used when there is adequate distance between the back wall and dispersing cylinders to provide complete view of the top and bottom cylinders. The images from the cameras installed as shown in figure 5a will overlap in the center of the dispersing cylinders. The camera and light position schematic shown in figure 5b can be used in situations where the distance between the back wall of the feeder and dispersing cylinders is not adequate to provide a complete image of the top and bottom cylinders. In figure 5b, the top and bottom cameras are spaced vertically to provide full cylinder length images of the upper and lower dispersing cylinders, respectively. The images from cameras installed as shown in figure 5b will overlap on a portion of one of the middle dispersing cylinders. An example of the vertical camera installation from the outside and inside of the feeder dispersing cabinet at one commercial gin testing location is shown in figure 6a and 6b, respectively. Another alternative camera/light location to consider is the roof of the module feeder due to clearance issues. In any case, light placement and illuminance levels are critical to providing clear, bright images that clearly show accumulation of plastic or other contaminants on the dispersing cylinders. Placement of additional lights over those shown in figure 4 may be needed to provide a minimum illuminance value of 2500 lux.

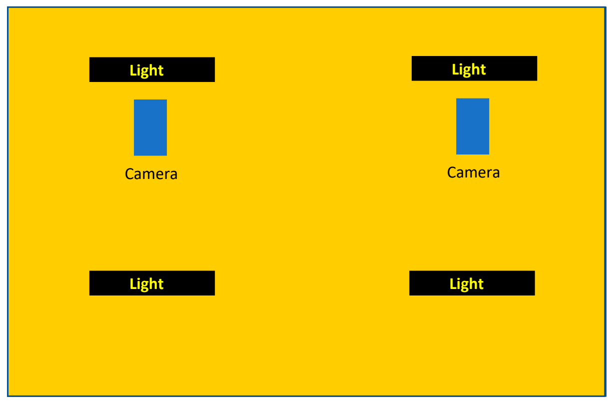


Figure 5a. Placement of camera and light components on the back wall of a module feeder when sufficient distance between the back wall and cylinders exist, for the cameras to provide an image of all cylinders from top to bottom. Black boxes indicate placement of lights, blue boxes indicate placement of camera housings.

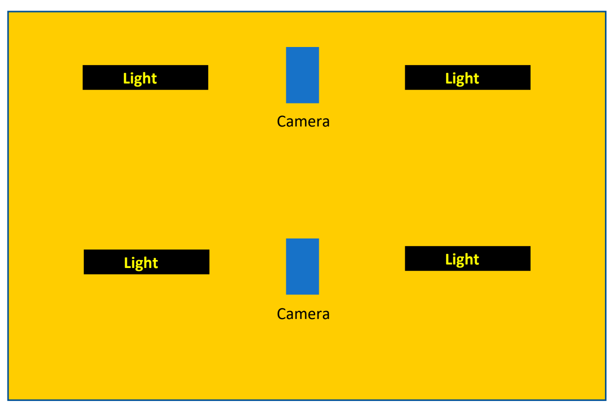


Figure 5b. Placement of camera and light components on the back wall of a module feeder when the distance between the back wall and cylinders is not sufficient for the cameras to provide an image of all cylinders from top to bottom. Black boxes indicate placement of lights, blue boxes indicate placement of camera housings.

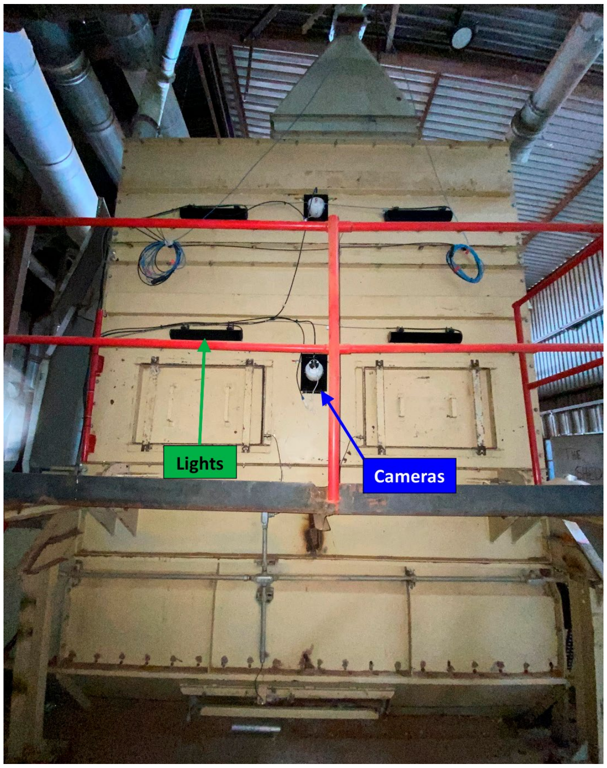


Figure 6a. Exterior photo of module feeder inspection system cameras and lights installed on the back wall of a module feeder.

Figure 6b. Interior photo of module feeder inspection system cameras and lights installed on the back wall of a module feeder.

RESULTS AND DISCUSSION

The following points provided improved performance of the updated module feeder inspection system during testing at commercial gins:

- Use of the optional supplemental air nozzle provided some cleaning of the lens protector but two potential issues were observed with its use: 1) mud may accumulate on the lens protector if the air supplied to the nozzle is not free of oil and water, and 2) when dust and other particles inside the feeder mix with the compressed air from the nozzle, the surface of the lens protector can be abraded and become cloudy thus blocking a portion of the camera view. It was often observed that the lens protectors were kept adequately clean without the use of the supplemental air nozzle through the scrubbing action of the cotton falling away from the dispersing cylinders.
- While use of the lens protectors is not mandatory, their use is highly encouraged to extend the life of the cameras. The lens protectors functioned well during the 2020 ginning season and required replacement only once, about mid-way through the season, due to abrasion from the supplemental air nozzles. The lens protectors remained clear after replacement and discontinued use of the supplemental air nozzles. None of the cameras installed failed due to broken lenses or damage caused by impact (no camera failures were experienced in 2020).
- During installation, the lens protectors were sealed to the face of the cameras using thin film tape. This helped to keep dust from collecting between the lens protector and the camera lens.
- Placement of reference marks on the back housing of the camera and camera sleeve helped to ensure that the camera was returned to the same rotational position after removal for service/ maintenance.
- If the back wall to dispersing cylinder distance is adequate to allow for camera and light positioning according to figure 5a, placing the cameras higher on the back wall of the feeder will reduce maintenance requirements.
- Supplemental light with uniform coverage in the lower dispersing cylinder area is critical to obtaining clear images. Additional lights may be needed in some module feeder configurations to provide adequate lighting. Hand placement of lights while determining camera positions before final installation will provide insight as to the amount of extra light that may be needed and help to provide more uniform light coverage.
- The module feeder inspection system was not installed on module feeders with cleaning cylinder/grate sections at the back of the dispersing cabinet because this design does not allow for an unobstructed view of the dispersing cylinders. Different camera mounting locations and/or use of more sophisticated camera lens technologies and optical techniques may allow for monitoring of the dispersing cylinders in this type of module feeder.

It was observed that the gin crew could often see plastic accumulation on the dispersing cylinders between programmed feeder bed pause events when the module feeder bed slowed down or stopped briefly to allow the rest of the ginning system to overcome intermittent periods of overload. These naturally occurring intermittent pauses were long enough to allow the cotton to fall away from camera view and reveal a clear image of the dispersing cylinders. It was noted that the amp load on the dispersing cylinder drive was far below the level observed when the cylinders are dispersing cotton into the ginning system (e.g. approximately 10% of max rated motor load). Thus, future development of this system may consider control of the image capture routine of the automated module feeder inspection system software using a dispersing cylinder drive motor power monitor or zero-speed proximity relay installed on the feeder bed drive to facilitate more frequent image captures, thereby taking advantage of the natural pauses in the ginning process, and avoiding the need to introduce intentionally programmed pauses to capture images of the dispersing cylinders.

SUMMARY AND CONCLUSIONS

The module feeder inspection systems installed for testing in 2019 and 2020 provided significant benefits to the gin staff at each gin by improving their ability to see and quickly act to remove potential contaminants from the dispersing cylinders. The updated system discussed herein, provides additional installation flexibility allowing for easier installation into different feeder designs. In all cases, the gins experienced a significant drop in the number of plastic calls after installation of the systems compared to prior years.

Component and assembly drawings for the adjustable camera mount and bill of materials table are shown in figures 7 – 14 and table 1, respectively. Additional details on LED light bars and power supply units are shown in table 2.

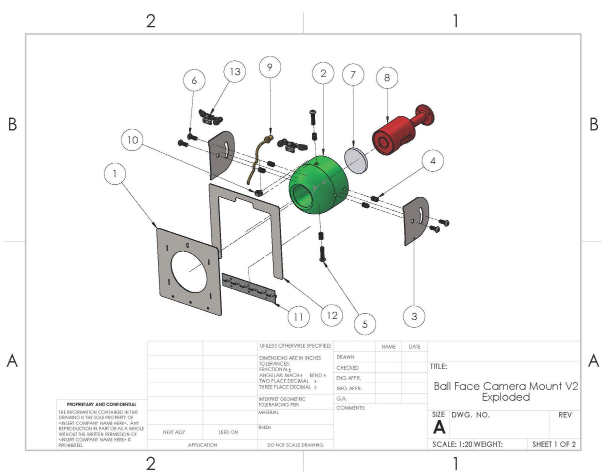


Figure 7. Exploded view of the adjustable camera mount.

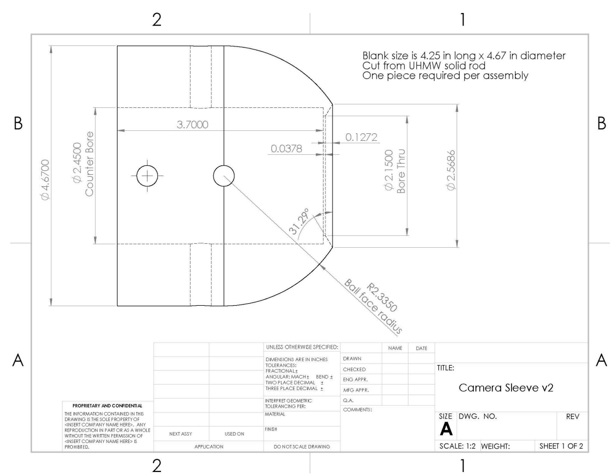


Figure 9a. Camera Sleeve V2 component drawing (item 2, table 1).

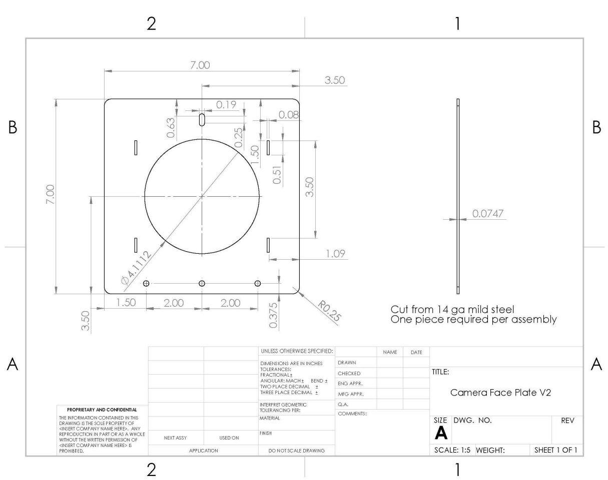


Figure 8. Camera Face Plate V2 component drawing (item 1, table 1).

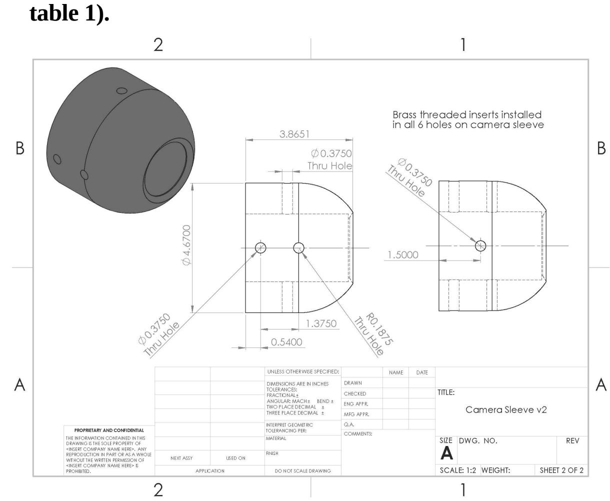


Figure 9b. Camera Sleeve V2 component drawing (item 2, table 1).

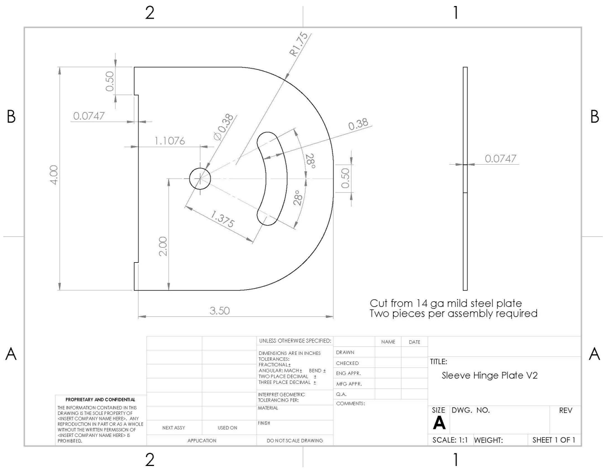


Figure 10. Sleeve Hinge Plate V2 component drawing (item 3, table 1).

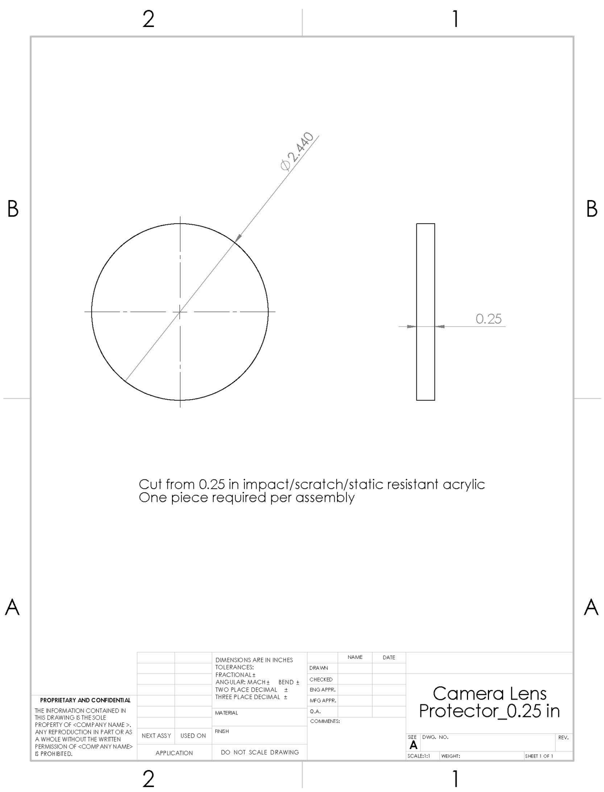


Figure 11. Camera Lens Protector_025 component drawing (item 7, table 1).

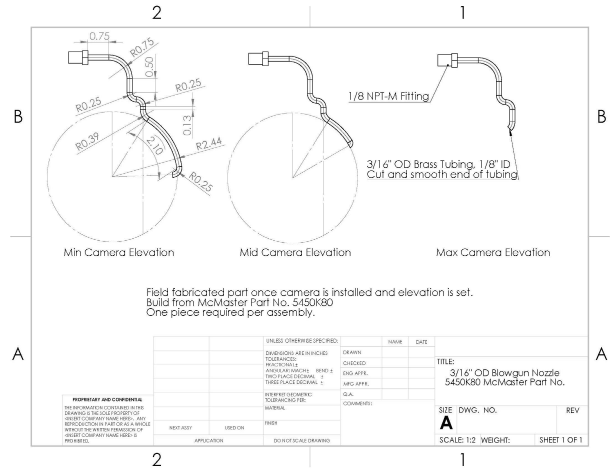


Figure 12. 3_16 OD nozzle - Mid Cam Elevation component drawing (item 9, table 1). Part is field-fit to match specific camera elevation when installed.

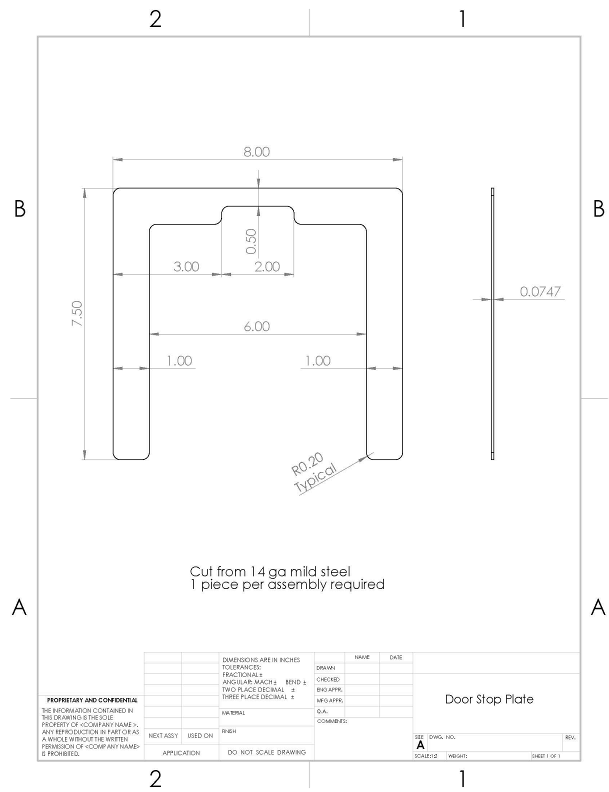


Figure 13. Door Stop Plate component drawing (item 12, table 1).

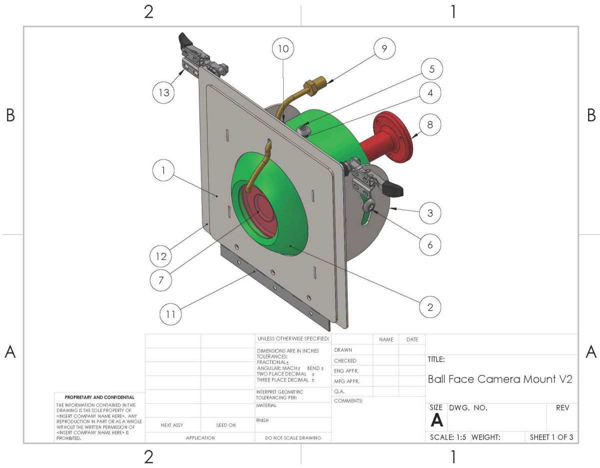


Figure 14a. Assembly details for adjustable camera mount.

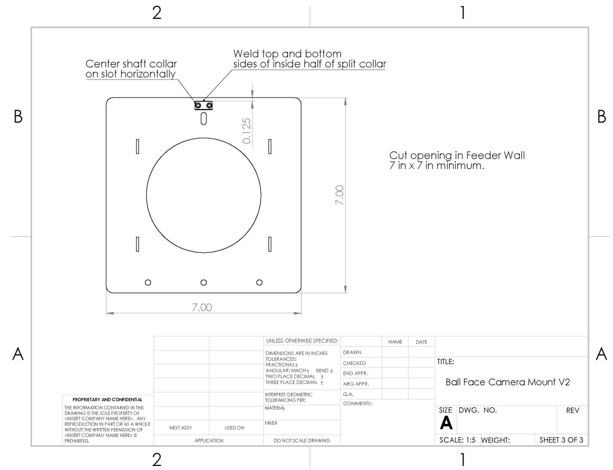


Figure 14c. Assembly details for adjustable camera mount.

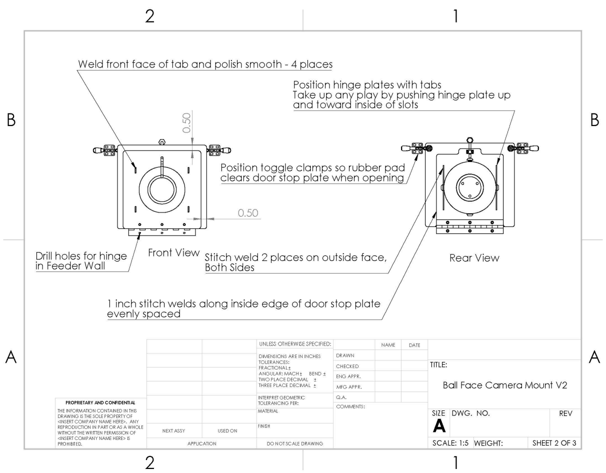
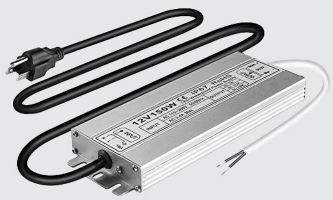


Figure 14b. Assembly details for adjustable camera mount.

Table 1. Bill of materials for the adjustable camera mount used in the module feeder inspection system.

Item No.	Part Description	Quantity per Assembly	Estimated Unit Cost	Source/Material Link
1	Camera Face Plate V2	1	$ 15.00	Shop Fabricated, 14 ga mild steel
2	Camera Sleeve v2	1	$ 156.17	Shop Fabricated, https://www.mcmaster.com/8701K63/
3	Sleeve Hinge Plate V2	2	$ 8.00	Shop Fabricated, 14 ga mild steel
4	92395A030 - Threaded insert, 5/16 - 18 thread	6	$ 0.70	https://www.mcmaster.com/catalog/127/3568
5	91306A404 - 5/16 - 18 x 1.25 in - Button Head Hex Drive Screw, Zinc Plated	2	$ 0.45	https://www.mcmaster.com/catalog/127/3240
6	91306A387 - 5/16 - 18 x .75 in - Button Head Hex Drive Screw, Zinc Plated	4	$ 0.34	https://www.mcmaster.com/catalog/127/3240
7	Camera Lens Protector_0.25 in	1	$ 13.17	Shop Fabricated, https://www.mcmaster.com/8536k164
8	IP Camera (Dahua, N42BD32)	1	$ 109.00	https://www.amazon.com/Dahua-Technology-N42BD32-Outdoor-Connection/dp/B08MQS664M
9	3_16 OD nozzle - Mid Cam Elevation	1	$ 7.88	Shop Fabricated, https://www.mcmaster.com/catalog/127/2923
10	6436K6 - 3/16"Split shaft collar	1	$ 5.00	https://www.mcmaster.com/catalog/127/1338
11	1569A391 - Piano Hinge	1	$ 2.72	https://www.mcmaster.com/catalog/127/3178
12	Door Stop Plate	1	$ 12.00	Shop Fabricated, 14 ga mild steel
13	5128A620_Low-Profile Hold-Down Toggle Clamp	2	$ 10.18	https://www.mcmaster.com/catalog/127/2789

Table 2. LED light and driver components for module feeder inspection system.

Part ID, Picture	Product Description	Price
	**Nilight – ZH006** **LED Light Bar, 20 Inch, 126w LED, 10,000 Lumens** https://www.amazon.com/Nilight-ZH006-20Inch-Harness-Warranty/dp/B06XQGQTXQ/ref=sr_1_3_sspa?dchild=1&keywords=led+light+bar&qid=1619027350&sr=8-3-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUExRVBSSUFGRzQ1SEUmZW5jcnlwdGVkSWQ9QTA4NDM5NDI2SkEwWlk2WFlQTzUmZW5jcnlwdGVkQWRJZD1BMDIyMzYwODFGQ0U4VDdXQlA4SDImd2lkZ2V0TmFtZT1zcF9hdGYmYWN0aW9uPWNsaWNrUmVkaXJlY3QmZG9Ob3RMb2dDbGljaz10cnVl	**4 @ $40 each**
	**Idealy 150W DC 12V Ip67** **Waterproof LED Power Supply Driver Transformer** https://www.amazon.com/Idealy-Waterproof-Transformer-Adapter-Lighting/dp/B08CRQ45BD/ref=sr_1_1?dchild=1&keywords=Idealy+150W+DC+12V+Ip67+Waterproof+LED+Power+Supply+Driver+Transformer&qid=1619027531&sr=8-1	**4 @ $34** **(1 per light)**

ACKNOWLEDGMENT

The authors gratefully acknowledge the financial support of Cotton Incorporated in this work and the cooperation of the commercial gin partners.

DISCLAIMER

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the USDA-ARS. USDA is an equal opportunity provider and employer.

REFERENCES

Iqbal, Z., R.G. Hardin, T. Wang, J.K. Ward, J.D. Wanjura. 2021. Round Modules: Handling Logistics and Cover Damage, 2nd Year. Proc. 2021 Beltwide Cotton Conf., Virtual. 5 – 7 Jan. 2021. pp. 623-629. Natl. Cotton Counc. Am., Memphis, TN.

USDA-AMS. 2020. Cotton Price Statistics 2019-2020. mp_cn830. 101(13). 21 p. Memphis, TN. USDA Agricultural Marketing Service Cotton and Tobacco Program. Available online: https://www.ams.usda.gov/mnreports/cnaacps.pdf (accessed 24 May 2021).

USDA-CCC. 2021. 2021 Commodity Credit Corporation (CCC) loan schedule of premiums and discounts for upland and ELS cotton. Washington, D.C.: USDA-CCC. Available online: https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/Price-support/pdf/2021/2021%20Cotton%20%20Premiums%20and%20Discounts.pdf (accessed 24 May 2021).

Pelletier, M.G., Holt, G.A., Wanjura, J.D., 2020. A Cotton Module Feeder Plastic Contamination Inspection System. AgriEngineering 2, 280–293. https://doi.org/10.3390/agriengineering2020018

Wanjura, J.D., M.G. Pelletier, J.K. Ward, R.G. Hardin, and E.M. Barnes. 2020. Prevention of Plastic Contamination when Handling Cotton Modules. 10 p. Raleigh, NC., Cotton Incorporated. Available online: https://cottoncultivated.cottoninc.com/research_reports/prevention-of-plastic-contamination-when-handling-round-modules/ (accessed 24 May 2021).

Pelletier, M.G., G.A. Holt, J.D. Wanjura. 2021. Cotton Gin Stand Machine-Vision Inspection and Removal System for Plastic Contamination: Software Design. AgriEngineering 3, 494–518. https://doi.org/10.3390/agriengineering303003