A CLOSED LOOP PNEUMATIC CONVEYING SYSTEM FOR COTTON

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Abstract

Pneumatic suction unloading systems for cotton gins can be constructed as a closed loop without the high volume exhaust air discharge that causes difficulty in meeting air quality standards. Tests comparing a closed loop suction unloading system with a standard open exhaust suction unloading system showed that the closed loop system can be operated at a performance level equal to the standard suction system using 110 horsepower compared to 250 horsepower for a 30 bale per hour system. This is a substantial savings that demonstrates a big advantage of the closed loop system that would justify it even if it did not eliminate exhaust emissions. Returning the exhaust into the fan inlet eliminated the energy cost associated with entry and exit losses experienced in conventional systems. The cost savings would quickly pay for the installation and provide the gin with reduced operating expenses thereafter. The closed loop suction unloading system helps solve the air quality problem that is currently critical for cotton gins and helps to attain the air quality goals of the clean air act because it totally eliminates one major emission source.

Introduction

Meeting increasingly rigorous air quality standards has become a serious problem for most agricultural operations including cotton gins. Substantial research and development effort has been expended to devise efficient economic systems for cleaning up cotton gin exhausts. Research has developed very efficient cyclone exhaust cleaning systems which are expensive to install and operate and may overload air handling equipment. In some instances the cyclones must be supplemented with even more expensive final air cleaners. The cotton ginning industry continues to face the prospect of more stringent air quality standards. Some gins have had to close down or move because of dust emission problems. An alternative solution to meeting emission standards is to use the closed loop principle to eliminate the external air exhaust and with it the regulatory problem.

Objective

We designed and tested a closed loop suction unloading system for a cotton gin to evaluate the feasibility of this method in a gin handling machine-stripped cotton. The closed loop system used principles similar to the monoflow system (Leonard and Gillum, 1968, 1973) developed for the later stage pneumatic transport systems in cotton gins. An opportunity for testing a closed loop suction unloading system for a cotton gin arose in a cooperative demonstration project for a belt conveyor dryer system for seed cotton that was installed at Terry County Coop Gin in Brownfield, Texas in March of 1992. This closed loop experiment was done as a subsidiary activity within the cooperative project between the USDA Agricultural Research Service, Texas Tech University Department of Industrial Engineering, and Terry County Coop Gin company to demonstrate a new belt conveyor-dryer system for seed cotton. In that demonstration project the belt dryer needed to be installed parallel to an existing unloading/drying system, leaving the original system intact. This required a second parallel suction unloading line from the module feeder to the separators delivering the cotton to the belt conveyor dryer. We designed the added parallel suction system for the belt dryer demonstration as a test system for the closed loop concept.

Methods and Materials

The original seed cotton unloading system consisted of a split-stream with two 18-inch diameter hot air suction pipes that picked up the cotton from a hot air box at the end of a flat belt conveyor delivering the cotton from a module feeder. Each suction streams was routed from the seed cotton pickup through a rock and green boll trap, an airline cleaner, Lummus Thermo dryer, and a separator that dropped the cotton into one of two auger conveyor dryers. These auger conveyors carried the cotton into the first incline cleaners of a split-stream double overhead seed cotton cleaning system. The two pull lines from the separators were connected through pairs of 1D3D cyclones to two 125 hp suction fans. The bottom of the cyclones were equipped with rotary air locks for sealing and trash removal. Inclusion of the cyclones in the system ahead of the fan alleviates the high wear problem due to the trash and dirt passing through the fan.

The experimental closed loop seed cotton suction unloading system that was added for the belt dryer demonstration utilized two 16 inch diameter sheet metal suction pipes in a split stream that carried the cotton from the pickup at the end of the flat belt conveyor up to two 6 foot wide suction separators that fed the belt dryer, figure 1. The suction line from each of the two separators was connected to twin cyclones. The exhaust from the top of the cyclones was picked up by involute hoods and piped back into the fan inlet. The exhaust from the fan was routed through a single 24-inch pipe to the pickup point. This closed the loop and gave a system without an external exhaust that could produce air pollution problems We developed a crossflow air jet cotton pickup device to recieve cotton for the closed loop suction after the end of the belt conveyor downstream from the

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standard vertical hot air box suction pickup of the original suction.

The crossflow pickup provided an open inlet for the cotton with the necessary negative pressure characteristic required to properly entrain the cotton in the air stream. The crossflow jet forced the cotton falling off the end of the flat belt conveyor into the suction inlet for the two 16-inch suction lines. Adjusting air velocity and volume in the jet allows it to serve as a rock and green boll separator. Additional air to boost the velocity up the suction lines was directed through two jets in the sides of the pickup box. Excess air not needed for the jets was returned into the top of the suction pickup box. A slide valve in the excess air line was used to regulate pressure and volume in the lines to the jets. The belt conveyor dryer received the cotton directly from the two suction separators and transported it into the two auger conveyor dryers.

Limited funding was available so we decided to build the experimental system with used equipment that the gin company had on hand. Four available cyclones that fit a 0.7D-1.2D description with D being 42 inches were renovated to provide a 10-inch by 14-inch rectangular inlet and 23-inch diameter outlet with the internal tube 0.7D long. The gin company also had two Continental 72-inch rotating drum separators which were reconditioned and used. We connected two of the cyclones downstream from each separator with 18-inch pipe. We installed involute hoods on the top of the cyclone pairs and connected them into the intake of a used Lummus size HF 238 straight blade exhaust fan. The fan was powered with a used 60 horsepower electric motor. The fan exhaust was connected by a 24-inch diameter pipe to the crossflow air jet suction pickup box.

Results

Because this experiment was a sideline to the primary belt conveyor dryer demonstration project we only collected a limited amount of data. We measured air pressure in both of the suction systems during ginning operations near the end of a 52,000 bale ginning season. The two original suctions were stronger than the experimental closed loop system, since they utilized two 125 horsepower fans compared to the single 60 horsepower fan on the closed loop system. The closed loop system worked well on dry cotton but gave problems at operating rates greater than 28 bales per hour on high moisture cotton. Occasional heavy wet cotton lumps choked the pickup nozzle.

Static pressures in the two original suction lines were typical of modern high negative pressure suction unloading systems, Table 1. The west suction line appeared to be stronger and pressure drops across the rock traps, air line cleaners and Thermo dryers were inconsistent. Inconsistencies were due to the equipment being used. The equipment had defects that resulted in leaks. The two new high efficiency fans were quite strong and unloading capacity was adequate with the original suction systems. Velocity pressure in the original suction lines running empty was 2.8 and 3.1 inches of water for the east and west line respectively. This provided 6108 and 6426 feet per minute velocity up the 18-inch diameter pipe which is in the upper end of the recommended range for an effective unloading system. Air volume flow was 10,793 and 11,357 cubic feet per minute in the east and west suction lines. Adding about 30 % estimated for leakage into the system gives 14,031 and14,764 cubic feet per minute through the fan. The fan chart indicated that a fan running at about 1870 rpm should require 115 to 120 horsepower. Current readings of 145 to 149 amps measured in the 3 phase 460 volt supply lines for the motors indicated that this was the case.

Static pressure in the experimental closed loop system was at a lower level than the original suction system and was negative from the pickup box to the fan and positive from the fan through the jets at the pickup box, Table 2. There was good balance between the east and west legs mainly because the equipment was newly reconditioned or new and well sealed. Also the two sides were interconnected entering the fan and all the air went through a single 24-inch diameter pipe on the positive side until it was split into the crossflow pickup device. Total pressure across the fan was 12.5 inches of water, which was less than half of the pressure across either of the two fans in the original suction. The experimental system used the positive pressure side to feed the negative pressure side thus reducing the pressure level within the system and across the fan compared to a conventional system. The smaller negative pressure reduces inefficiency caused by leakage into high negative pressure systems.

Air velocity in the two legs of the experimental closed loop system was 3998 and 3828 feet per minute in the east and west legs respectively (1.2 and 1.1 inches of water velocity pressure). This is below that recommended for a suction system but worked adequately on dry cotton because of the crossflow jet to accelerate the cotton (which had been opened and fluffed up by the module feeder) into the suction inlet. It was not enough conveying velocity for wet cotton at high processing rates so the ginners backed off from the normal 28 to 30 bales per hour ginning rate to about 20 to 22 bales per hour when they encountered wet modules. They preferred to do this rather than switching over to the original system because the belt conveyor dryer was more effective than the conventional dryers.

The fan was handling about 13,660 cubic feet per minute at 12.5 inches of water fan total pressure in the closed loop system. We calculated volume through the fan by adding the 5583 and 5345 cubic feet per minute measured in the east and west suction lines and increasing the total by 25 percent for leakage through the separators. Current readings of 72 to 76 amps in the 460 volt three phase motor leads indicated that the 60 horsepower motor was operating at a slight overload. The fan chart available for the used Lummus HF238 fan indicated that it should use 45 brake horsepower at the estimated airflow condition of 13,660 cfm of standard air at 1150 rpm against 12.5 inches of water total pressure. The current measured in the motor leads showed the fan actually was using slightly over 60 horsepower. A rebuilt wheel in the used fan with different blades and tip diameter may explain the discrepancy.

The recommended velocity for an effective suction system is 6,000 feet per minute velocity up the two 16-inch vertical suction pipes. Estimated values for higher performance for the closed loop system were obtained by modifying the measured data using Ginners Handbook tables and the fan chart. A recommended system would have 2.7 inches of water velocity pressure, (6000 ft/min), 8375 cubic feet per minute in each 16-inch diameter suction pipe for a total of 20,938 cubic feet per minute through the fan after adding 25 % for leakage through the separators. Assuming this would increase fan total pressure to 15 inches of water, the fan chart shows that 85 brake horsepower at 1490 rpm would be needed. Adding 25 horsepower to cover the discrepancy noticed previously between chart values and measured power level gives 110 horsepower for the fan.

These calculated estimates show that the closed loop system can be operated at a comparable performance level with the original suction system using 110 horsepower compared to the 250 horsepower on the original system. This is a substantial savings that demonstrates a big advantage of the closed loop system that would justify it even if it did not eliminate exhaust emissions.

Not all of the difference in fan total pressure between systems was due to closing the loop. The differences in cyclone design, pipe size, and velocity pressure also contributed to the differences in performance between systems. Also modern high efficiency separators for the experimental system would optimize operation and reduce pressure and flow losses.

There is the old adage that nothing comes for free. Such is the case for the closed loop system since it does not allow use of drying in the suction unloading step. The condition of the cotton dominates air conditions within the closed loop since the same air is continually recirculated within the system. We were concerned about possible buildup of dust loading within the loop because of increasing emissions from the top of the cyclones but saw no evidence that this occurred. We did find that a layer of fuzz and dirt would build up to form a pad that was hairpinned over the rounded nose of the splitters into the cyclone pairs (a 4-inch half round nose 14 inches tall). This pad would reach several feet in length and was cleaned out every few weeks. However it did not seem to create any problem. The used cyclones were a non-standard design that had spiral flanges about three inches high welded inside the cone from the top to the bottom. These caused buildup of large ropes of fiber and dust that eventually would break loose and choke up the rotary air lock outlet at the bottom of the cyclones.

Conclusions

The closed loop concept allows construction of suction unloading systems without the high volume exhaust air discharge that causes difficulty in meeting air quality standards. It also gives increased energy efficiency through reduced horsepower. Returning the exhaust into the fan inlet eliminated the energy cost associated with entry and exit losses experienced in conventional systems. Cyclone banks or other air cleaning devices can be positioned within the system to clean the air before it passes through the fan. The closed loop arrangement almost eliminated wear to the fan wheel and housings which is a major part of the annual maintenance costs for many suction systems. The closed loop system also results in about 50 percent reduction in operating energy costs for the suction unloading system. The cost savings would quickly pay for the installation and provide the gin with reduced operating expenses thereafter. Currently available emission control technology that is economically feasible has higher initial cost and results in increased annual maintenance and operating expenses and still may not give acceptable control of the dust emissions in some cases.

The closed loop suction unloading system helps solve the air quality problem that is currently critical for cotton gins and helps to attain the air quality goals of the clean air act because it totally eliminates one major emission source. The suction unloading system exhaust is reported to be the one that usually fails the grain loading standard in non-attainment areas. From another standpoint the closed loop concept allowed us to obtain satisfactory operation of the two pipe system on dry cotton with a fan setup that was barely adequate for one pipe of a suction system with an open exhaust. In retrospect the potential for increased efficiency and elimination of exhaust emissions justifies a much more extensive evaluation of the closed loop system than was done in this test. We are designing a new experiment at the gin lab for a more extensive evaluation of the closed loop system including measuring velocity and volumes throughout the loop as well as sampling for particulate loading at various stages in the air stream.

This closed loop pneumatic transport system has been patented by USDA-ARS, Patent number 5,727,909, dated March 17, 1998. It is available for licensing for commercialization by contacting the USDA-ARS Technology Transfer Coordinator at 301-504-5899.

The author is indebted to Kyle King and Tony Garibaldo of the Terry County Coop Gin company who assisted with installation and patiently coped with inefficiencies and interuptions caused by the experimental system to the ginning operations during this test.

Note: Trade names are used in this paper to give precise information and does not constitute endorsement or recommendation by USDA-ARS over other similar products.

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Table 1. Static pressure (inches of water) measured after each device in the two parallel legs of the original suction unloading system. All piping in these legs was 18 inches in diameter.

Measurement location	Static pressure east line	Static pressure west line
horizontal suction line	-4.8	-6.3
after rock trap	-10.3	-10.5
after air line cleaner	-13.0	-15.3
after Thermo dryer	-14.1	-17.0
after separator	-21.2	-21.5
after cyclones	-25.6	-26.0

Table 2. Static pressure (inches of water) measured in the experimental closed loop suction unloading system. Pipes from the suction box to the separators were 16 inch diameter and from the separator through the cyclones into the fan were 18 inch diameter. A single 24-inch pipe connected the fan exhaust to the suction box lines.

Measurement location	Static pressure east line		Static pressure west line
after separator	-3.5		-3.5
after cyclones	-6.0		-6.0
after fan (single 24-inch pipe)	--	+6.5	--
return leg (before slide valve)	--	+4.2	--
crossflow jet	--	+4.5 to 4.8	--
boost jets	--	+4.0 to 4.2	--

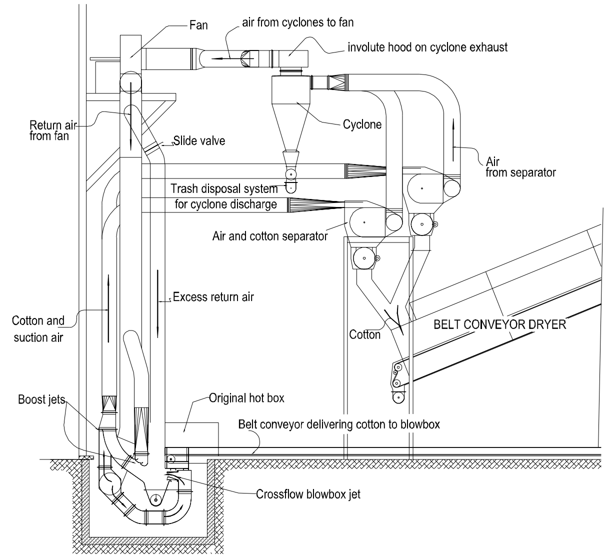

Figure 1. Schematic diagram of the closed loop seed cotton unloading system.