Improved System for Bulk Meal Storage[1]

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ABSTRACT

A system was installed for the bulk storage of soybean meal and operated in a manner designed to eliminate the problems commonly associated with such storage, such as hangups and damage to tanks due to dropping of arched meal. The final system design and operation was based upon the results of a study of a large number of operating soybean meal storage systems and their problems. The primary consideration in successful storage of meal was found to be the condition of the meal itself and its tendency to consolidate when stored fresh from production. When the meal stored in this system was disturbed at regular intervals, this tendency was overcome; and the meal moved freely and uniformly without arching. The design and operating features of the system are described.

INTRODUCTION

Many soybean processors wish to store freshly produced ground soybean meal in large bulk storage tanks to provide surge capacity for their plant and allow for storage over weekends. There are many operating problems commonly associated with removal of meal from such storage. Under certain conditions, the meal will arch; and the arched meal may hangup, requiring poking, or the arch may fall with explosive force, damaging or knocking out the bottom and imploding the top of the tank. Over the years, processors have devised many different methods for avoiding these problems, some of which have improved the situation; but none have succeeeded in eliminating the arching and obtaining uniform removal of the meal. Most processors have resigned themselves to having storage problems and living with them the best they can, controlling conditions to avoid losing a tank.

We wished to establish design and operating conditions for a bulk meal storage system which would operate free of the serious problems previously experienced. We conducted a detailed study of ca. 25 operating soybean meal storage systems by mailed questionaires, by phone, and finally by visits to obtain first hand plant experience with mechanical designs and operating controls. From these studies, conclusions were drawn as to the nature of the problem; and we then proceeded with the design and installation of the improved system. Detailed operating procedures were established, and a test run carried out under carefully controlled conditions established the workability of the design. System operation has continued since July 1972 without serious problem and with no evidence of meal hangup and dropping.

INDUSTRY EXPERIENCE

The methods used by processors to solve their meal storage problems can be divided into three general categories: limiting size of tanks, controlling meal conditions, and using mechanical aids and additives.

Limiting Size of Tanks

Some processors do not store meal in tanks larger than 10 ft diameter. Other processors stretch this to 15 ft in diameter. Tanks this size rarely experience hangup problems but are limited in storage capacity. This investigation concentrated on 26 ft diameter tanks to provide the larger storage capacities desired.

Controlling Meal Conditions

It is recognized by most processors that moisture and temperature are the two most important conditions controlling storageability. The more cool and dry the meal, the easier to store without hangup. One processor with extensive experience reported the no-problem limit of moisture and temperature to be a maximum of 10% moisture and 80 F. Meal stored under these conditions would flow out with no problem; but, in his opinion, any departure from these conditions would aggravate the storage problem.

Cooling to 80 F can be done by water tube cooling, but it is not common in the industry. Most processors cool with air to 100 F, at best, during hot humid weather. Because shipping moisture is 12%, control of moisture at this level is economically important. However, water added to the meal prior to storage aggravates the problem of storage; and water added during load-out encourages meal set-up in the cars. Therefore, the moisture level is best controlled not by water addition but by regulation of the toaster or dryer operation, as uniformly as possible, to avoid swings in moisture to 13% or over. Most plants do experience these swings in moisture and when they do, they experience the most serious trouble in their storage tanks.

High level of fat from inefficient or upset extraction operation, adding back of gums, and presence of fines in the meal all contribute to the severity of problems with hangups and arching.

The severity of the problem greatly increases with the length of time in undisturbed storage.

Using Mechanical Aids and Additives

Mechanical aids and additives used to promote flow include mechanical unloading devices and other mechanical devices.

Mechanical unloading devices: These include (A) live bottom bins which are multiple screws unloading a large percentage of the tank diameter, (B) Harvestore straight wall, glass lined bins with unloaders which are screws rotating around the full tank periphery and discharging to center drag chains, and (C) Vibra Screw bin activators which are vibrating hopper bottoms covering ca. one-half tank diameter.

Other mechanical devices and additives: These include (A) external vibrators arranged in various patterns, (B) smooth tank linings, such as epoxy coatings; (C) aeration systems to ventilate the tank and its contents; and (D) additives, such as kaolin clay or bentonite.

None of these aids or additives eliminated arching or hangups if the meal physical condition was not good or if the meal remained in undisturbed storage for more than 10-12 hr.

Further insight into the behavior of meal during storage resulted from a study of two different piles of meal in flat storage, neither of which was adjacent to a tank wall, so there was no wall effect. Both were 50% meal; the first was fresh from production but had cooled on standing, and the second was older meal aged in a tank for several hours, then moved out to flat storage. The first contained vertical cliffs of meal that could be undercut substantially before

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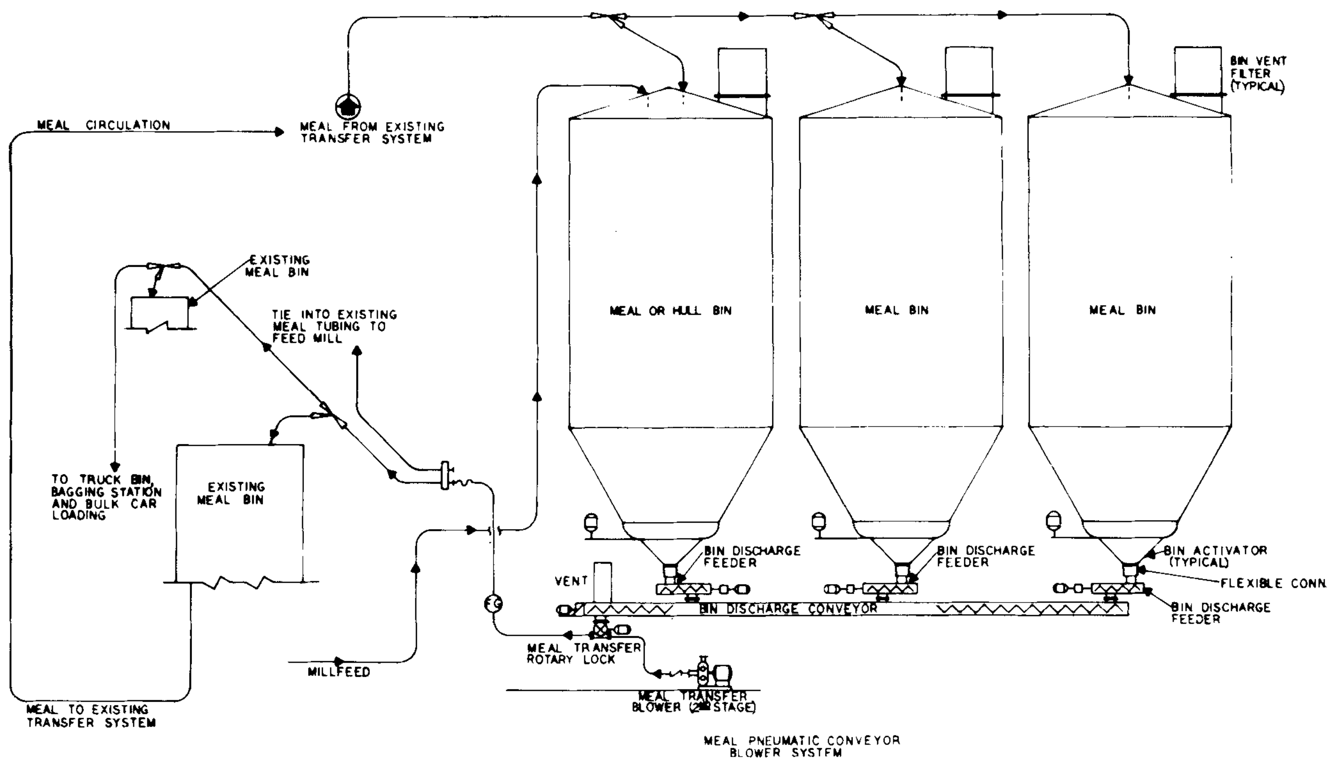

FIG. 1. Flowchart of meal storage and blending system.

collapsing, leaving large chunks of meal that disintegrated easily. The cliffs had a spongy resistance when pressed with the palm but were penetrated easily with the finger. These cliffs exhibited a cohesiveness resulting from the interlocking and slightly adhesive surface condition of the meal. The second pile was cone shaped with no evidence of cohesiveness; it behaved exactly as a pile of dry sand. We also examined meal particles under high magnification and found they were flake shaped and not granular, contrary to our expectations.

RESULTS

Analysis of the evidence and data obtained led to development of the theory, discussed below, to explain why fresh meal will hangup.

The flaky shape of the particles tends to promote orientation of the particles in layers rather than a random pile; and they will, like shingles, interlock and wedge if they cannot move freely upon one another.

Any tendency to develop surface adhesion between the layers of flat meal particles will strengthen the interlocking tendency and cause the meal to assume a structural rigidity that appears to be caking but is, instead, the development of many sites of locally small increases in frictional resistance to flake-on-flake sliding. Taken together, this results in the mass of meal developing sufficient overall strength to assume a stable form and resist shearing and flow. This development is defined as consolidation of the mass of meal and results in stable arches.

This consolidation can be aggravated by several means, and preliminary evidence indicates its development within freshly produced meal in the first 10-12 hr of storage. Warm, moist meal placed in bulk storage will orient itself as theorized above. During the 12 hr setting period, some cooling will occur; and moisture in the meal voids will condense, resulting in a slight surface stickiness which increases the frictional resistance to sliding flow. Higher moisture content, higher temperature, high fat content, presence of gums, or high fines content will act in the same manner.

We then concluded that the cohesive structure of the entire mass of stored meal could be destroyed by moving out only a small quantity of meal at regular intervals. This procedure, called breaking down, could prevent consolidation of the mass and eliminate arches. If the meal condition is good, it could be allowed periods of undisturbed storage of up to 12 hr before breaking down. If the meal condition is poor, because of high temperature, moisture, fat, or gums, it should be broken down more frequently and in some extreme cases should be moved continuously until well blended with good meal or aged 12 hr. This conclusion agreed with the opinion of several processors who had tried periodic breaking down but whose systems were not designed for systematic operation in that manner. We finally decided on breaking down every 4 hr to simplify procedures and allow for handling of poor condition meal.

NEW SYSTEM DESIGN AND OPERATION

The final design of the new system was based upon these conclusions and the following considerations: we considered the entire storage system to be a process in itself and not an isolated group of equipment and we wished to take advantage of the latest improvements in mechanical design to promote flow and to provide adequate tank strength.

The resulting system design is shown in Figure 1. Three tanks were provided, each capable of storing 600 tons of 50% meal. They are each 26 ft in diameter by 45 ft straight side, with a 30° roof and a 60° cone bottom. A Vibra Screw bin activator is flexibly connected to the hopper bottom of each tank. The walls, roof, and cone bottom are strengthened and reinforced; and four large vents are provided in each tank top. The tanks are loaded fresh from production from a process surge bin by a high pressure pneumatic system with diverter valves. They are unloaded by the Vibra Screw bin activator through a variable speed screw feeder which discharges to a collecting and blending screw conveyor, which, in turn, feeds a rotary valve discharging into a load-out high pressure pneumatic system. This pneumatic system can recycle back to the process surge bin or the bagging station. There is no aeration system, nor is any additive clay used because of its adverse effect upon the capacity of cloth air filters. No external vibrators are used.

The essential feature of the system is that meal in any one tank is not allowed to remain undisturbed for more than 4 hr at any time. Every 4 hr on a regular schedule, meal is pumped out of each meal tank at a 50 ton/hr rate for 6 min, for a total of 5 tons. This meal is pumped back to the process surge bin from which it recirculated back to the tanks. We believe that this frequent breaking down of the tank contents is responsible for the successful operation of the system, because it disrupts the developing frictional forces before the mass is consolidated and can form a stable arch. The flow of meal out of the tank was observed during these breaking down periods from an open manhole in the top. The meal surface developed numerous cracks, with large caps sliding around and down the upper cone. The meal flow out was uniform across the entire tank cross section; no inverted funnel was formed, nor did the meal angle of repose change. The pile of meal was broken up and agitated and its cohesive structure destroyed by pulling out only 5 tons.

We know that, without the regular break down, the use of the Vibra Screw by itself, or any other unloading device, would not prevent development of stable arches, hangups, and damaging falls of arched meal. We determined, by successful operation for almost a year, that regular breaking down and recirculation, combined with the use of the Vibra Screw Bin activator, apparently has solved the problem of bulk soybean meal storage in the present installation. We consider it to be a significant improvement in meal storage technique.

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