Feed Center Design

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Introduction

Feed is a significant cost in milk production. Generally over 50 percent of the production cost may be associated with meeting the nutritional requirements of the lactating cow. Dairies monitor feed cost through feed ingredient purchases, feed delivery records and weigh backs of refused feed. However, actual costs associated with shrink are often ignored. Shrinkage is the loss of feed ingredients that never have a potential for economic return. Generally, shrinkage includes not only storage losses but excessive inclusion rates in rations that are unnecessary to meet the nutritional needs of the animal. Dutton (1998) defined shrink as “the percentage of feed on a farm that is not accounted for by the rations by the animals for which it is intended.” Causes may include wind, wildlife (birds and rodents), moisture or spoilage. Brouk (2009) also included delivery weight errors, discarded feed, feed dispersed by tires and tracking, and mixing errors as other contributors to shrink.

Brouk (2009) indicated shrink may represent 15 to 20 percent of the total feed cost with wet and expensive ingredients representing the greatest concern. Dutton (1998) reported 6 to 8 percent shrink on one dairy but felt most of the shrink was due to overfeeding ingredients. He questioned the value of feeding cows more accurately in the northeast United States since many of the overfed ingredients were lower cost per ton. There are limited research reports on the actual shrink occurring on dairies. On-site dairy discussions tend toward considering shrinkage a non-issue or part of normal feed cost, and opportunities for improvement are considered limited. However, a willingness to understand true costs related to shrinkage and addressing these problems can lead to economic benefits.

Brouk (2010) determined the cost of a corn silage based ration equaled $5.49 per head per day assuming zero shrinkage. Daily feed cost increased to $6.05/head when typical shrink values were applied to each feed ingredient in the diet. If shrink losses were reduced by 50 percent for each ingredient, daily feed costs were reduced to $5.75/head. The difference in daily feed cost of $0.30/head due to reduced shrink results in an annual savings of $100 per dairy cow.

Impact of Facilities on Shrinkage

Data in Table 1 shows typical shrink values for different ingredients based on storage type. The storage options shown in Table 1 provide different levels of protection from weather. The minimum expected loss is 10 percentwhen ingredients are stored in uncovered open piles. Storage bins reduce storage losses to 2 to 5 percent. An 8 percent storage loss reduction of soybean meal reduces daily feed cost $0.095/head assuming a daily use of 6 lbs and $400/ton. Designing a feed center to minimize the impact of solar radiation, moisture and wind may have economic returns due to reductions in shrinkage.

Table 1 Percent loss of different ingredients based on type of storage facility

Ingredient	Uncovered Open Piles	Covered 3-sided Bay	Closed Bin
Whole Cottonseed	10 – 20 %	5 -15 %	-------
Dry Meal	5 – 10 %	3 – 8 %	2 – 4 %
Soybean Hulls	12 – 20 %	5 – 10 %	2 – 5 %
Dry Distillers	15 -22 %	7 – 10 %	3 – 5 %
Wet Distillers	15 – 40 %	15 – 40 %	-------

Kertz, 1998

Normal shrinkage for commodity buildings (3-sided bay) is 8 percent. There are many places to reduce shrink when storing ingredients in commodity buildings. Common areas where shrinkage occurs include the following:

- Unloading on concrete slab – wind movement of ingredients, failure to move 100 percent of an ingredient into a bay
- Ration preparation – accuracy of measuring individual ingredients with a bucket loader is limited to about 1 to 2 cubic feet, resulting in over or under feeding individual ingredients
- Weather – building is often oriented based on prevailing wind, leaving feed exposed to blowing precipitation, resulting in spoilage due to rain or snow
- Number of bays – failure to empty bays completely often results in spoilage of ingredient along the back wall due to the inability to use in timely manner
- Management - more emphasis on time or getting cows fed versus accuracy of feed ration
- Feed center layout – efficiency in procurement of ingredients

Table 2 illustrates the impact of shrink on feed cost. Feed is purchased at a given cost per unit weight or volume. However, the actual feed cost may be significantly higher depending on shrinkage. For example, a dairy may pay $30 per ton of silage however, if there are 20 percent losses, the actual cost per ton of silage used in the ration is $37.50. Reducing silage losses to 12 percent saves an estimated $3.43 per ton of silage fed. Realistically, there will always be some shrinkage and loss. Each dairy must have a realistic target and for most ingredients other than forages, 2 to 4 percent is a reasonable target. Fermented forages or grains will have some loss associated with the fermentation process. If this fermentation occurs at the dairy, the goal should be less than 10 percent for fermented forages and below 5percent for fermented grains. Hurbaugh and Moeching (1984) and Hurbaugh et al (1983) reported on and off farm facilities handling whole corn had a shrink of 1 percent or less.

Impact of Moisture on Shrinkage

Feed ingredients are often purchased on a wet basis but formulated into rations on a dry weight bases. The impact of moisture must be considered when evaluating shrink. Table 3 shows the impact on weight of a 1 percent change in moisture content for products at different initial moisture contents. An ingredient such as hay purchased and delivered at 15 percent initial moisture content but dries while in storage to 14 percent has 1.16 percent less moisture. This impacts feed formulation unless moisture content is monitored to ensure a ration contains appropriate ingredients on a dry weight bases. If moisture is not considered, then for every 1 percent reduction in moisture, there is a 1.16 to 2.78 percent increase in dry matter depending on the initial moisture content. Similarly if moisture increases 1 percent due to rain or snow, there is 1.16 to 2.78 percent decrease in dry matter if the diet formulation is not adjusted. Table 4 shows the increase in dry matter per ton of feed based on initial moisture content and moisture losses of 2, 4 and 8 percent.

Table 2 Impact of shrink on feed cost for various ingredient purchase cost

Purchased Feed Cost ($/ton)	Actual Feed Cost w/ 2 % Shrink ($/ton)	Feed Cost Based on Percent Shrinkage (%)				
		4	8	12	16	20
30	$30.60	$31.20	$32.40	$34.09	$34.80	$36.00
50	$51	$52	$54	$56.82	$58	$60
100	$102	$104	$108	$113.64	$116	$120
150	$153	$156	$162	$170.45	$174	$180
200	$204	$208	$217	$227.27	$232	$240
250	$255	$260	$270	$284.09	$290	$300
300	$306	$312	$324	$340.91	$348	$360
350	$357	$364	$378	$397.73	$406	$420
400	$408	$416	$432	$454.55	$464	$480

Table 3 Impact of 1 percent reduction in initial moisture content for ingredients at different initial moisture content

Initial moisture content (%)	15	25	35	45	55	65
Weight change with 1 % reduction in moisture content	1.16 %	1.32 %	1.52 %	1.79 %	2.17 %	2.78 %

Another moisture concern is rain or snow entering the open commodity storage sheds. Table 5 shows the amount of rain entering every linear foot of a commodity shed assuming 1 inch of moisture blows into a bay for different side wall heights. For example, for a commodity shed with a 24 foot high sidewall, 15 gallons of water per linear foot will enter a bay. If a curtain is dropped to reduce the opening to 8 feet (skid steer height), then 10 gallons of moisture are prevented from entering the bay, or a 67 percent reduction. A 50 percent reduction occurs if a curtain is dropped leaving a 12 foot (pay loader height) opening. Lowering a curtain or flexible door at night or upon completion of feeding may prevent significant ingredient losses due to rainfall and subsequent spoilage. Frequency of rainfall events would determine curtain management and frequency of lowering. Curtains also minimize the impacts of wind and potential movement of ingredients between bays without solid dividers. Buildings storing commodities delivered in live bottom trailers may be able to reduce the sidewall height to a 14 foot opening using permanent materials.

Table 4 Increase in dry matter concentration due to moisture loss at different ingredient moisture contents

Delivered Moisture Content (%)	Moisture Loss in Storage (%)	Delivered Dry Matter per Ton (lbs)	Impact of Moisture Lost	
			Weight (lbs)	Percentage Increase in Dry Matter concentration
15	2	1700	1,740	2.4%
	4		1,780	4.7%
	6		1,820	7.1%
25	2	1500	1,540	2.7%
	4		1,580	5.3%
	6		1,620	8.0%
35	2	1300	1,340	3.1%
	4		1,380	6.2%
	6		1,420	9.2%
45	2	1100	1,140	3.6%
	4		1,180	7.3%
	6		1,220	10.9%
55	2	900	940	4.4%
	4		980	8.9%
	6		1,020	13.3%
65	2	700	740	5.7%
	4		780	11.4%
	6		820	17.1%

Impact of Scales on Shrinkage

Table 6 shows the weighing accuracy of scales depending on the mixer capacity and scale accuracy. Producers adding small quantities of ingredients may reduce shrink by using a smaller stationery mixer with more accurate scales to pre weigh these ingredients prior to moving ingredients into a larger mixer. Table 7 shows the typical ingredients in a corn silage based ration. Assuming a 10-ton mixer with 1 percent scale accuracy, the potential error ranges from 2 percent to 195 percent of the ingredient inclusion weights. For example, if 1,230 lbs of almond hulls are added to a 10-ton mix (Table 7), a 1 percent scale accuracy allows for measurement of this amount to the nearest 200 lbs, meaning that the potential exists for a ±16 percent weighing error of this ingredient. There is a familiar expression that someone "measures to the nearest 1/10 of inch, marks with chalk and cuts with an axe." This occurs daily on most dairies as nutritionists formulate rations to the nearest pound, the weight readout may be to the nearest 10 lbs, and the fill mechanism into the mixer is a pay loader which may have an accuracy of 50 to 100 lbs depending on the operator.

Table 5 Amount of water entering a commodity shed per linear foot due to 1 inch rainfall blowing into the open bays

Height of Open Side (feet)	Gallons moisture entering the commodity shed at full opening	Impact of Reducing Opening to 8 feet		Impact of Reducing Opening to 12 feet	
		Reduction in gallons of moisture entering commodity bays	Reduction as compared to fully open side wall	Reduction in gallons of moisture entering commodity bays	Reduction as compared to fully open side wall
8	5.0	na	na	na	na
12	7.5	2.5	33%	na	na
16	10.0	5.0	50%	2.5	25%
20	12.5	7.5	60%	5.0	40%
24	15.0	10.0	67%	7.5	50%
28	17.5	12.5	71%	10.0	57%
32	19.9	15.0	75%	12.5	63%

Table 6 Potential weight (lbs) error depending on mixer capacity and scale accuracy

Mixer Capacity (tons)	Scale Accuracy (%)			
	0.1	0.5	1	2
1	2	10	20	40
3	6	30	60	120
5	10	50	100	200
10	20	100	200	400

Accuracy is not related to the precision with which the scale may be read or set. The scale accuracy is determined by the mechanism (load cells) use to weigh the mixer box not the digital display. A readout device on a mixer may read to the nearest 10 lbs but even with a 1 ton mixer with 1 percent accurate scale, the actual accuracy is only guaranteed to the nearest 20 lbs.

There are two other basic types of scale errors (Ross, 2005). The first type of error (Type 1) is inconsistency of the scale. This type of error occurs when a scale reading is incorrect by a consistent percentage across the range of the scale. With this error the digital display may read and print the correct weights for formulation, but is off by a consistent percentage. Thus the scale may add an extra 25percent to the weight of each individual ingredient. When this error occurs, the ration is still formulated correctly but each group of cows may be overfed by 25 percent. The weight of the proceeding ration may be adjusted down due to excessive weigh-backs, however the nutritionist never knows the exact quantity of feed being consumed by a pen of cows even if the percentage of individual ingredients may be at the right proportion. This can be problematic in part because expensive, low-inclusion ingredients (i.e. feed additives) may be formulated at higher concentrations in the diet in an attempt to achieve a desired intake on a per cow per day basis. The underestimation of feed intake therefore leads to excessive intake of these relatively expensive ingredients.

Table 7 Potential weighing error individual ingredients in a10 ton ration assuming the scale accuracy is 1 percent.

Feed Ingredient	Daily Feed lbs/hd	Ingredient Weight per 10 ton Batch (lbs)	Potential Weighing Error Assuming 1 % Scale Accuracy
Alfalfa Hay	12	2,460	8.1 %
Corn Silage	35	7,180	2.8 %
Flaked Corn	14	2,870	7.0 %
Almond Hulls	6	1,230	16.3 %
Canola Meal	4.5	925	21.7 %
Dry Distillers Grains	4	820	24.4 %
Whole Cotton Seed	3	615	32.5 %
Rumen By-pass Fat	0.5	105	195.0 %
Minerals and Vitamins	1.5	310	65.0 %
Liquid Whey	15	3080	6.5 %
Molasses	2	410	48.8 %

The other error (Type 2) is consistent weight addition or subtraction. The scale adds a fixed amount of weight to every ingredient added to the ration. For example, 25 lbs is added to one ingredient formulated at 500 lb inclusion rate and 25 lbs is added to a second ingredient formulated at a 4,000 lb inclusion rate. In this case, the nutritionist may not realize the ingredients at smaller inclusion rates are being over or under fed in the diet. This type of error may parallel health issues related to ingredients added at lower rates since the percentage of over or under feeding is much greater as compared to an ingredient such as corn silage.

Table 8 compares the impact of Type 1 and Type 2 scale errors. Type 1 shrinkage is uniform and independent of the ingredient inclusion rate. Type 2 shrinkage is inversely proportional to the ingredient inclusion rate; higher shrinkage occurs with lower inclusion rates.

Larger dairies may find it economically beneficial to install a stationery mixer where the operational conditions are more controllable and then use a feed delivery wagon to move feed to the bunks. The other advantage of a stationery mixer is automation and extra time available.

Automation reduces the number of employees actually adding ingredients to the mixer. This increases the accuracy and reduces the variability due to human error in adding ingredients to the mixer.

Automatic control systems may be used to weigh individual ingredients while another batch is being delivered. Many ingredients may be stored in hopper bins reducing shrink. The authors are familiar with one stationery feed system where 2 augers, 12 and 6 inch augers, are installed in the boot of a bin to decrease the fill time. Both augers are started simultaneously; however, as the desired ingredient weight is reached, the 12-inch auger is turned off, allowing more accuracy as the 6-inch auger adds the final quantity of product. This system overcomes the typical concerns with slow fill times using hopper bins.

Table 8 Impact of Type 1 and Type 2 scale errors on shrinkage

Feed Ingredient	Daily Feed lbs/hd	Ingredient Weight per 10 ton Batch (lbs)	Type 1 Error with 10 % extra		Type 2 Error with 30 lbs extra	
			Actual Weight (lbs)	% error	Actual Weight (lbs)	% error
Alfalfa Hay	12	2,460	2,710	10	2,490	1.2
Corn Silage	35	7,180	7,900	10	7,210	0.4
Flaked Corn	14	2,870	3,160	10	2,900	1.0
Almond Hulls	6	1,230	1,355	10	1,260	2.4
Canola Meal	4.5	925	1,015	10	955	3.2
Dry Distillers Grains	4	820	900	10	850	3.7
Whole Cotton Seed	3	615	675	10	645	4.9
Rumen By-pass Fat	0.5	105	115	10	135	28.6
Minerals and Vitamins	1.5	310	340	10	340	9.7
Liquid Whey	15	3080	3385	10	3,110	1.0
Molasses	2	410	450	10	440	7.3
TOTAL		20,000	22,000	10	20,330	1.7

Wind and Shrinkage

Wind breaks (Figure 1) can be used to reduce shrink around 3-sided commodity buildings. A wind break protects an area 10 times the height of the wind break. If the windbreak is 10 ft high, then the protected area is 100 ft. The snow dump area is 4 times the wind break height. The distance between the feed center and windbreak should be at least 4 times the height of the wind to prevent snow from piling in the feed center or covering traffic roads. Normally, it is recommended that windbreaks have 20 percent openings; however, around feed centers this is not as critical. A permanent wind break is recommended since shrink losses due to wind occur year round. Some opt to store hay or bedding around the perimeter of the feed center or pens.

This option limits wind protection to only to those periods when the hay or bedding is being stored.

Dairies located in areas with colder climates or excessive rainfall may benefit from placing the entire feed center under a roof to eliminate moisture and wind problems. Silage is delivered from the silage storage area daily and placed in a bay inside the building. Several bays are also available for ground hay. Hay storage remains in separate buildings until ground or immediately prior to usage. Working with the ingredient suppliers and trucking firms is critical prior to construction, since adequate room must be available inside the building to maneuver semi-trucks. More space is required if trucks are required to back into bays prior to unloading versus unloading on a slab (with the ingredients pushed into a bay).

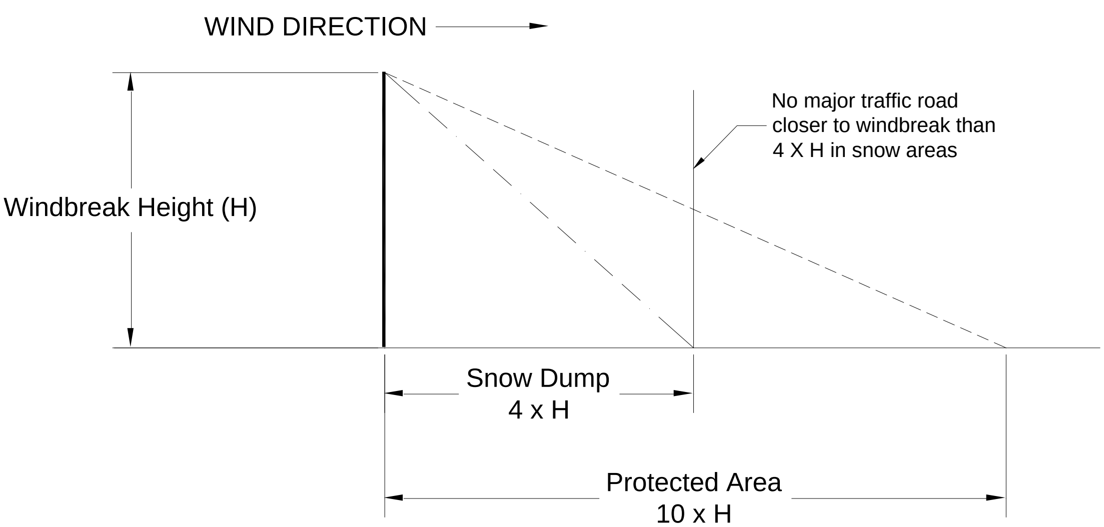

Figure 1 Illustration of impact of wind break on protecting a feed center

Low density feed ingredients should be delivered in self unloading trucks (walking floors) when ingredients are stored in open front commodity buildings. Many dairies have reported significant shrink when low density products are unloaded on an apron prior to transferring into a bay on windy days. If ingredients are unloaded on an apron, the shrink is minimized by immediately moving the materials into a bay.

Wind speeds of 6 mph may cause soil movement in highly erodible fields. Sand with a dry weight density 4 to 10 times that of most feed ingredients begins movement at 12 mph. Reducing wind speeds around the feed center is critical to minimize shrink as well as preventing deposits of soil from adjacent areas into the commodity bays. Assuming feed ingredients begin moving at wind speeds of 5 mph, Table 8 shows the impact of wind speed on potential losses assuming feed particles beginning blow away if stored in an open pile. The impact factor in Table 9 illustrates the potential increase in feed losses due to wind are 8 times greater at 10 mph than 5 mph. As wind speed increases, there is an exponential increase in potential losses due to the cubic relationship between wind speed and particle movement.

Table 9 Potential impact of wind speed on feed losses based on the assumption there are no feed particles losses at winds speeds of 5 mph or less.

Wind Speed (mph)	Potential increases in relative feed losses assuming no ingredient losses at wind speeds of 5 mph or less
5	No losses
10	8
15	27
20	64
25	125

Windbreaks also help minimize soil and foreign matter from accumulating in the feed center area. Feed centers surrounded by large crop acreages often serve as a windbreak, causing materials to settle out in commodity bays during wind storms. This foreign matter is included as part of individual ingredient weights, resulting in feed formulation errors. Average annual soil losses due to wind were reported at 2.5 tons per acre of land (Lyles, 1975). Wind erosion is higher from fields with less surface residue such as corn silage fields. An exterior windbreak causes this material to settle prior to entering the feed center area.

Designing Feed Centers to Minimize Shrinkage

Figure 2 provides an illustration of a windbreak around a feed center. The windbreak should be located at least 4 times the height of the windbreak away from the feed center. This space will serve as a snow dump area. If snow is not an issue, the windbreak may be located closer to the feed center. "L" shaped commodity sheds provide protection from the wind from multiple directions. Feed center protection is increased if the building is oriented such that the prevailing wind is perpendicular to the intersection of the two building sides (corner of "L") than along one side. A single row of commodity bays may be modified along one side to include a 2nd building to provide additional wind protection. Many dairies also need a place to store additional commodities, ground hay or daily silage needs prior to feeding.

Figure 3 provides an illustration of a totally enclosed commodity building. The advantage to this building is that weather related shrinkage losses are minimized. The overall building width is typically 60 to 80 feet wider than a 3-sided commodity building. This is necessary to provide room inside the building to maneuver semi-trucks delivering ingredients. The authors recommend consulting with trucking firms to make sure there is adequate room. Significant reductions in open space may increase feed loading time since feed loading equipment may not have free space to maneuver rapidly.

Figure 4 illustrates a feed center with a stationery mixer. There is room around the mixer to use micro ingredient tanks as well as liquid tanks. Stationery mixers enable more hopper bottom tanks with automated handling equipment to be utilized for low inclusion rate ingredients and liquids. Commodity bays are in close proximity of the stationery mixer, allowing adequate time to secure individual ingredients. Another advantage is minimum losses due to weather shrinkage.

Summary

Minimizing feed shrinkage can improve the bottom line of a dairy. Weather related shrinkage due to wind and moisture may be minimized with proper feed center design. Utilizing existing records can provide an opportunity to explore actual shrinkage on a dairy and the potential economic return to minimizing such losses. There are management opportunities to reduce shrinkage due to weather and spoilage in existing facilities, even without automation.

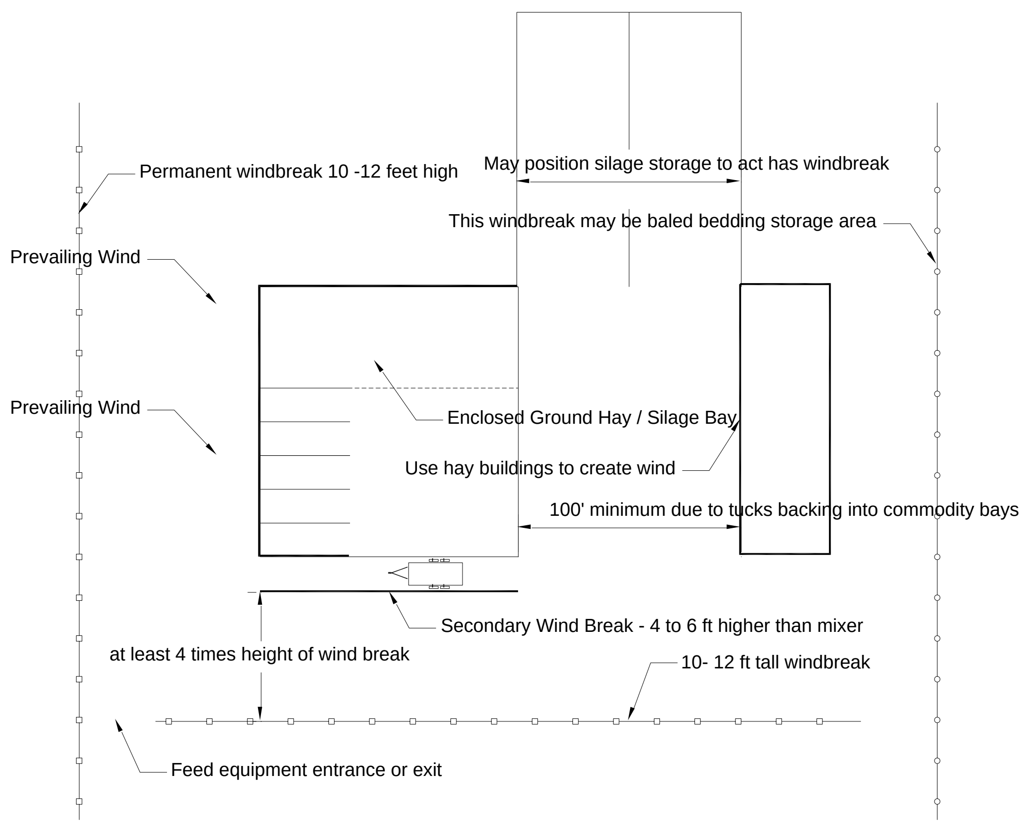

Figure 2 Utilization of buildings and windbreaks to minimize shrinkage due to wind

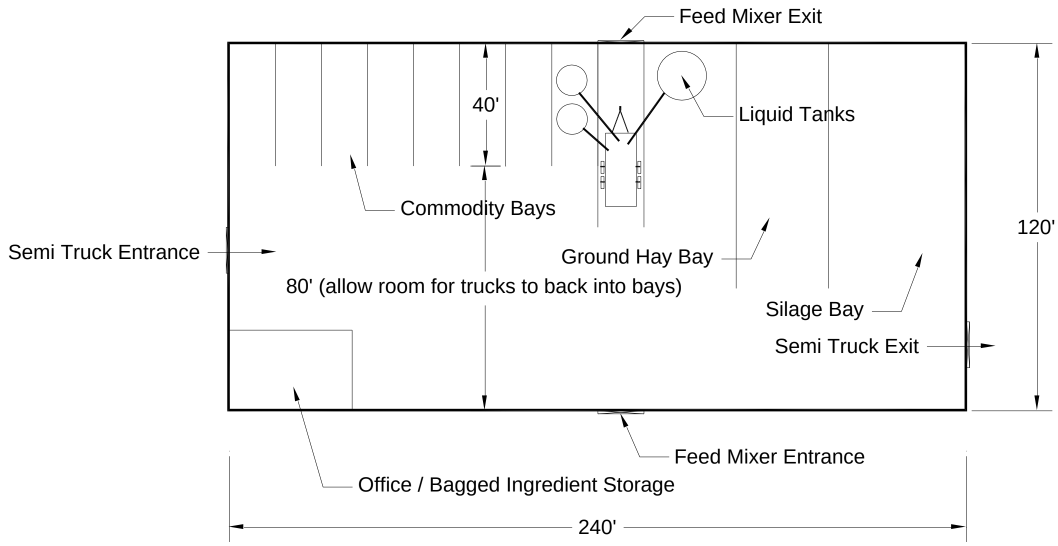

Figure 3 Illustration of totally enclosed commodity building using a portable mixer

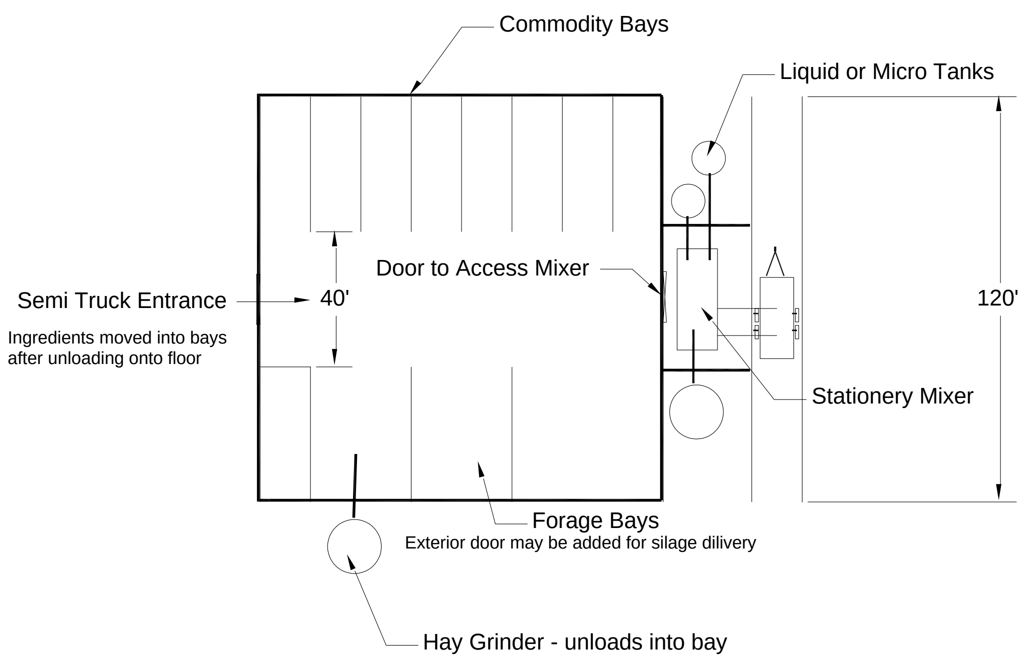

Figure 4 Illustration of a feed center with a stationery mixer

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