Building the SpoonFeeder

Prototype Development
Final Presentation

Spring 2009

April 27th

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2.0 SUMMARY

Following a tragedy with a particular family show horse, the sponsor has challenged Corp 3 to design a device to be attached to the wall of a barn stall that will slowly and constantly feed a certain amount of hay and grain to a horse throughout the day. Several commercial products exist which dispense feed two or even six times a day, but the sponsor has expressed interest in a device designed to be loaded once daily and dispense feed fairly continuously, providing for both hay and grain feed.

Keeping cost, safety, and durability factors in mind, the group has developed and analyzed several concept designs for the feeding device. One concept idea was selected and is recommended by Corp 3, and proof-of-concept models have been built to determine the feasibility of the chosen concept idea. The concept has been modified and re-engineered to address the sponsor concerns that arose during the Midterm Presentation. The concept analysis and proof-of-concept processes are discussed in detail in the report.

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4.0 INTRODUCTION

In its natural environment, a horse habitually grazes slowly and constantly throughout the day on hay and grass. This constant feeding is important because a horse's stomach produces digestive juices in small amounts continuously, and a horse has difficulty digesting large amounts of feed at one time. There is a concern that race horses and show horses, which are often housed in barn stalls and fed several times a day, may suffer digestive problems if too much hay and grain is ingested in one sitting. If a horse consumes too much too quickly, the horse may colic and suffer what is known as gastric distension, which is often fatal.

Following a tragedy with a particular family show horse, the sponsor has challenged us, Corp 3, to design a device to be attached to the wall of a barn stall that will slowly and constantly feed a certain amount of hay and grain to a horse throughout the day. Several commercial products exist which dispense feed two or even six times a day, but the sponsor has expressed interest in a device designed to dispenses feed fairly continuously and can provide for both hay and grain feed.

Keeping cost, safety, and durability factors in mind, the group has developed and analyzed several concept designs for the feeding device. Proof-of-concept models have been built to determine the feasibility of the chosen concept ideas. The concept analysis and proof-of-concept processes are discussed in detail.

Distribution of Tasks: Tasks were distributed based on the skills and strengths of the team members. The team later divided into two groups: pellet feed device and hay device.

Mission Objective: *"To develop a feeding device for a horse which imitates a horse's natural feeding patterns as closely as possible."*

5.0 MAIN BODY

5.1 Sponsor Requirements and Constraints

The following requirements were provided to the team by the sponsor:

Function Requirements:

- Device will be loaded daily
- Will feed: 2 scoops of pellet food
  8 to 10 flakes in small amounts all day
- Will constantly distribute small portions throughout the day
- Device should hang outside or may rest inside the stable wall
- Must be cost efficient and affordable
- The hay may be distributed up to the bars so that the horse may pull it through to feed

Health and Safety Requirements:

- Device must be “virtually indestructible” and waterproof
- Able to be cleaned out or rinsed off
- Must contain no parts that can cut or get caught, snagged, trapped, etc.

Preferred Requirements:

- Portable device
- Adjusts to attach to different types of stalls
- One system could feed on both sides of an adjacent stable wall

Spatial/Stall Requirements:

- Stalls are 12 by 12 feet, device must not be space intrusive
- Most stalls have “prison type” bars to which a device may be clamped

Design Constraints:

- Device needs to be affordable, designed and built in an economic manner
- Device must not in any way be able to injure the animals
- Device must not take up excessive space in the barn stall
- Device must accommodate for several different types of pellet feed
- Device must have the capability of tearing up hay flakes

5.2 Engineering Specifications

The engineering team has calculated quantitative values to meet sponsor device requirements.

Function Specifications:

- Device will be loaded one time every 24 hours
- Device must accommodate for 2 gallons of feed and a 28" X 24" X 24" hay block
- Small portions: Less than 1/20th of full capacity per serving.
- Device will accommodate for grain feed and sweet feed materials
- Device must hang onto the bars outside or rest inside the stable wall
- Device cost will try to be kept less than $1000.

Health and Safety Specifications:

- Device must be made of structurally sound and weatherproof materials such as steel and hard plastics.
- Sharp edges must be rounded to at least 1 mm radius

Spatial/Stall Specifications:

- Device should be no wider than 4 feet, and is desired to be 30" X 30" X 24"
- Device will accommodate for bars that are 3 ½" apart.

Other Engineering Design Criteria

Manufacturability

- It is desired that the device may eventually be produced in mass quantities. Therefore, all parts should be able to be made in automated machining and casting processes
- Initial concept that is developed for the final presentation will be produced in a different manner than the device that is to be produced in mass quantities. Manufacturing plans will be developed for both the concept and the mass quantity device

Environmental

- Device should consist of materials that are safe to use in an environment around animals
- Feeding devices should default to a closed position to eliminate the possibility of overfeeding
- Device should not contain any caustic, corrosive or harmful chemicals or materials since it is to be used outdoors and around animals
- It is desired that parts chosen for the device be recyclable or cleanly disposable

Economic

- The designed device must be cost efficient and affordable
- All materials chosen for the device should be of comparable strengths and toughness to ensure that device will not fail at the junction of bolts, screws, etc. Therefore, cost of material will be moderated to fit its function with a reasonable factor of safety

Ergonomic

- Device must be easily accessible to a person for loading and cleaning, thus it will be no higher than 6-7 feet off the ground
- One person must be able to load or clean the device, so the door must not need more than 15-20 pounds force to load
- It is desired that the device be light enough to be installable and portable by two or three people, thus the entire device should not weigh more than 80 pounds unloaded

5.3 Project Deliverables Overview and MPCOD

The device will distribute eight to ten flakes of hay and about two gallons of pellet feed throughout the day in a safe, secure device which may be installed outside the barn stall for the type of stall which has straight vertical bars at 3 ½" separation. Device will be able to function for an entire day with only one human interaction of loading per day. The overall function of the device is to imitate a horse's natural feeding patterns as much as possible.

Manager's Project Contract of Deliverables (MPCOD)

What the device will deliver:

Function Requirements:

- The developed device will be a fully functioning, full-size prototype model
- The device will be capable of running for a 24-hour period
- The device will be assembled in accordance with the assembly drawings that were posted in the final report
- The device will be able to contain at least 2 ½ gallons of pellet feed and can store and distribute eight to ten flakes of hay
- The unit will be capable of hanging on the outside of the stall and will accommodate, at minimum, stall models that have vertical bars that are 3 ½" apart. The device requires vertical stall bars for proper functioning
- The hay may be distributed up to the bars so that the horse may pull it through to feed

What the team will deliver:

A functioning prototype device will be developed and built that, to best efforts, will produce the desired output of grain and hay feed distribution

- The device outputs will be tested and controllers will be adjusted for smooth distribution over a 24-hour period
- The device will be available to the sponsor for observation later in the Spring 2009 semester at Auburn University location
- The team will pursue licensing through the university and will initiate intellectual property process

Health and Safety Requirements:

- The team will perform evaluations and tests in effort to ensure that the device is “safe” and meets the all the necessary health and safety concerns
- The unit will be able to be cleaned out or rinsed off
- The unit, to the best of our design, will contain no parts that horses may in any way access that can cut or get caught, snagged, trapped, etc.
- The device will be user-friendly and completely safe for the animals

Optional Features of Prototype Model:

- Multiple settings or control dials will be available in the final model for users to adjust the feed rates

Prototype Design Restrictions

- This prototype device will not incorporate any molded pieces due to the cost and time frame of the class project
- The molded prototype parts will instead be constructed out of either sheet metal or wood material
- The system will be able to run on a standard 60 Hz / 120 Volts.
- This prototype will not be intended for production due the need for pre-manufactured parts
- This delivered device, constructed purely as a prototype, is not rated for nor intended for actual use in a stable around live animals.

5.4 Concept Presentation

5.4.1 Commercial Products

Introduction: Several commercial products exist which dispense feed two or even six times a day, but the sponsor has expressed interest in a device designed to be loaded once daily and dispense feed fairly continuously, providing for both hay and grain feed. Commercial automatic horse feeders were found, but all had shortcomings that are to be addressed in the current design.

Advantages: The recommended device will be able to accommodate for both hay and grain, will be very sturdy in structure and will be relatively easy to load and maintain.

Disadvantages: The device will be larger and heavier than commercial products because it must accommodate for eight to ten flakes of hay and two gallons of grain feed. Device may be cost more than commercial products because of the multiple motors, sensors, and solenoids required.
Note: *More comparison information can be found in the Decision Matrices section of the report.*

rcial models are discussed

Some, like the "StableGrazer" shown above on the left, feed less than six times a day and do not tear the hay into small portions for feeding. No hay-feeding devices were found that also accommodate for grain feed

Others, like the "Quick Feed" shown above on the right, only distribute grain and do not accommodate for hay. These devices were often not sturdy enough to place inside the stall with the horse and also were very expensive.

5.4.2 Concept Generation Sketches

Concept Generation Sketches

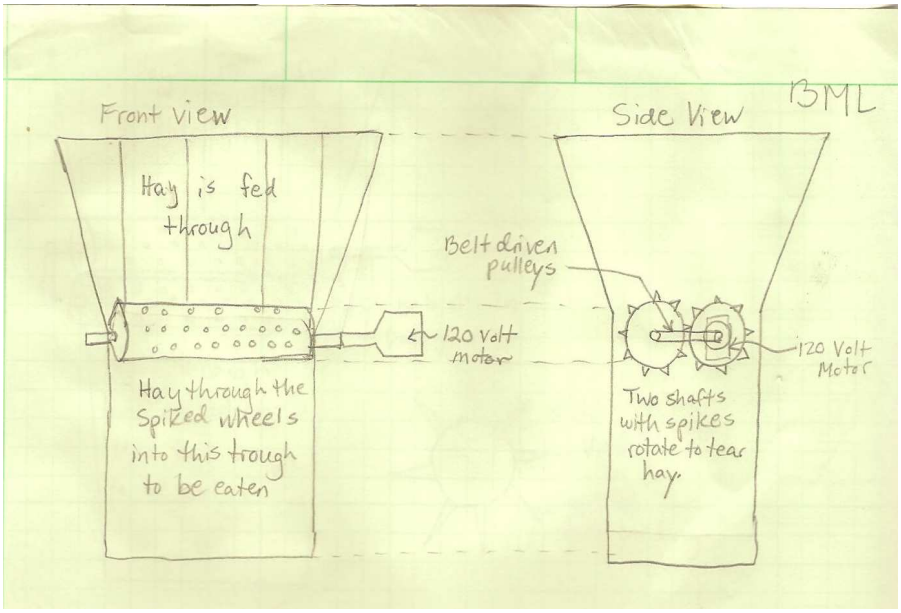


Figure 2: Hay feed Concept by Liles

--Hay dispensing device

In the first concept, hay is fed from the top of the device through two rotating rollers. Rollers contain spikes that tear apart the hay.

Advantages: The hay is efficiently torn apart; relatively simple function

Disadvantages: Two rollers may get wound up in hay or may grind against each other; danger of sharp spikes in the design.

In the second concept, hay flakes are loaded individually into eight different shelves. Shelves drop one-by-one throughout the day based on a timer.

Advantages: Very simple design

Disadvantages: Lots of moving parts, reloading difficult. Hay is not torn apart effectively.

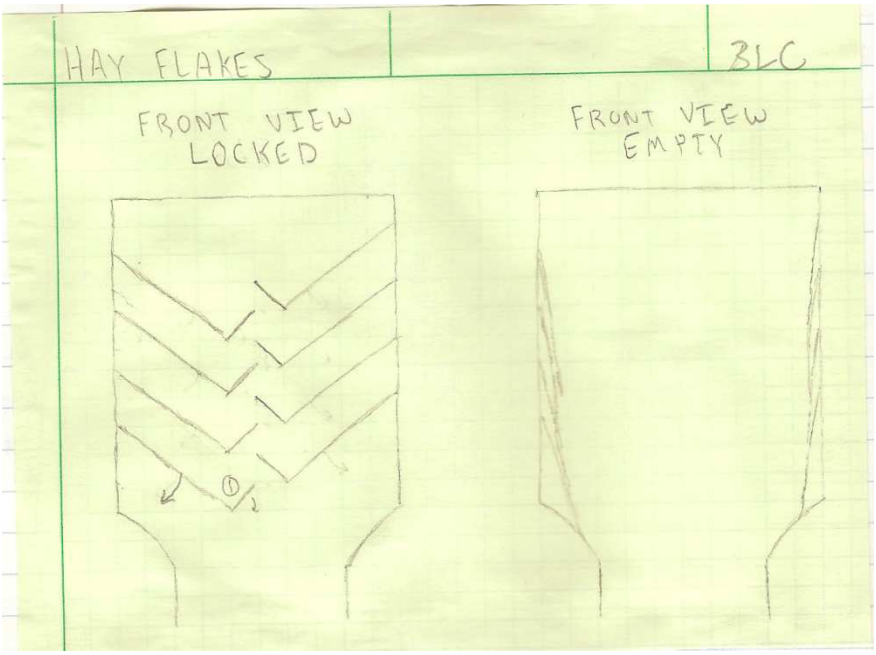


Figure 3: Hay feed Concept by Collins

In the third concept, hay is loaded from the top of the device and is put under pressure by a weight. The bottom opens up and the spikes grab and drop a small amount of hay, on a timer.

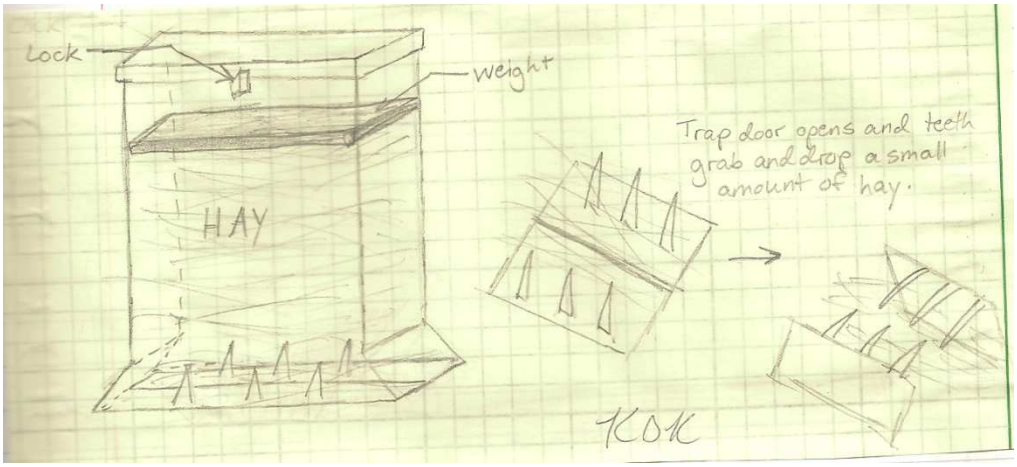
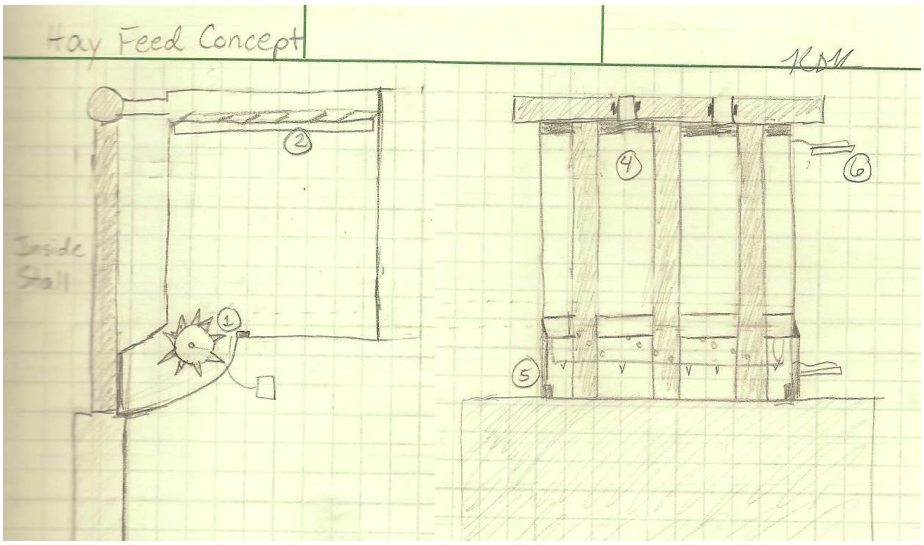


Figure 4: Hay feed Concept by Kirk

Advantages: Simple design, few moving parts.

Disadvantages: Loading would be difficult with the weight; trap door may get caught.

Final Concept Sketch:



1. Roller with pins
2. Gravity-driven plate pushes hay downward
3. A stop holds plate when hay is loaded
4. Device bolts to bars
5. Hay falls into chute
6. Pin holds door in loading

In the final concept, hay is loaded from the side and held under pressure by a spring-forced plate. Hay is torn by a horizontal shaft with spikes, and hay is dropped down a chute to rest against the bars

Advantages: Device may hang outside of the stall, parts are safely stored away from the horse

Disadvantages: Hay may not necessarily fall into the stall to ground level. Some stall doors of peculiar shape may not be accommodated for in hanging this device

Concept Generation Sketches (2)

--Grain dispensing device

In the first concept, grain is poured in from the top of the device. A stainless steel shaft with turning teeth disturbs and drops feed.

Advantages: Very protected components; easy loading process

Disadvantages: No stopping process for feed; multiple moving parts. Device, if in failure, might remain open overfeeding horse

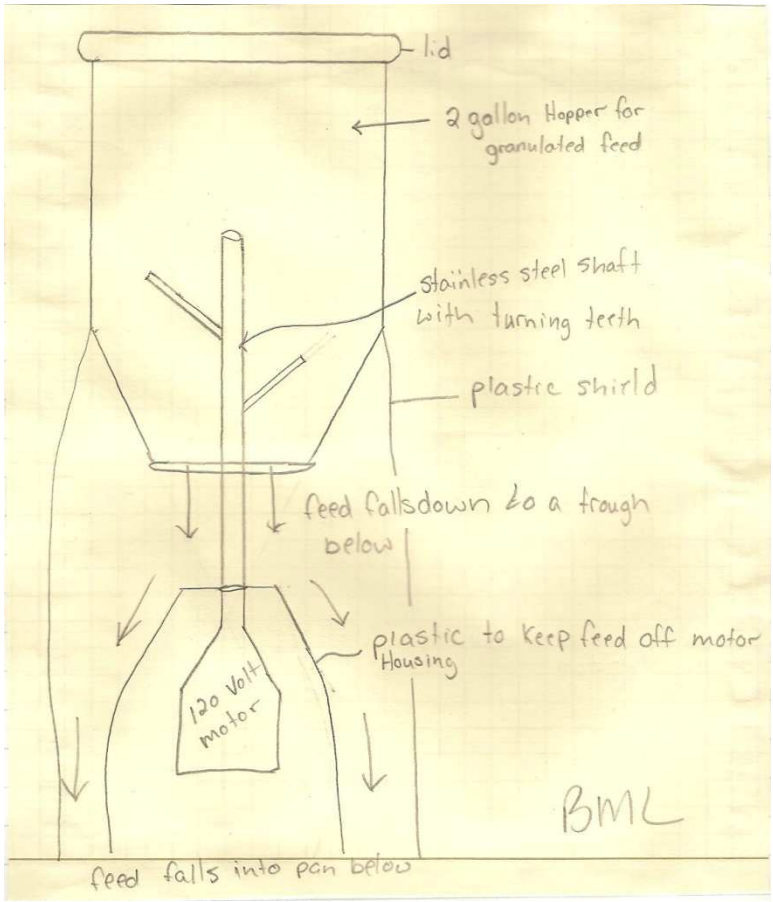


Figure 5: Grain feed Concept by Liles

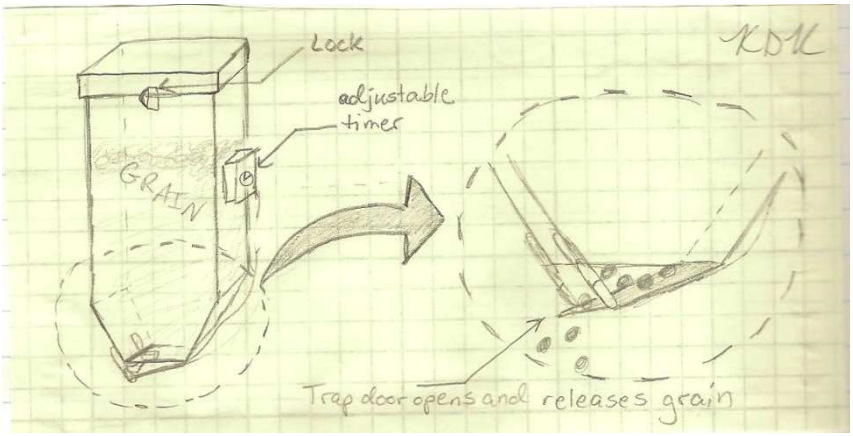


Figure 6: Grain feed Concept by Kirk

In the second concept, grain is poured in from the top of the device. A trapdoor, guided by a timer, opens for a short amount of time to release grain.

Advantages: Very protected components; easy loading process and easy cleaning

Disadvantages: Multiple moving parts, complicated trap door design.

In the third concept, grain is poured in from the top of the device. Thin agitators lining the walls of the device rotate to disturb and distribute grain.

Advantages: Easy loading process and easy cleaning of components

Disadvantages: No "closed" option for function, no secure lid for device

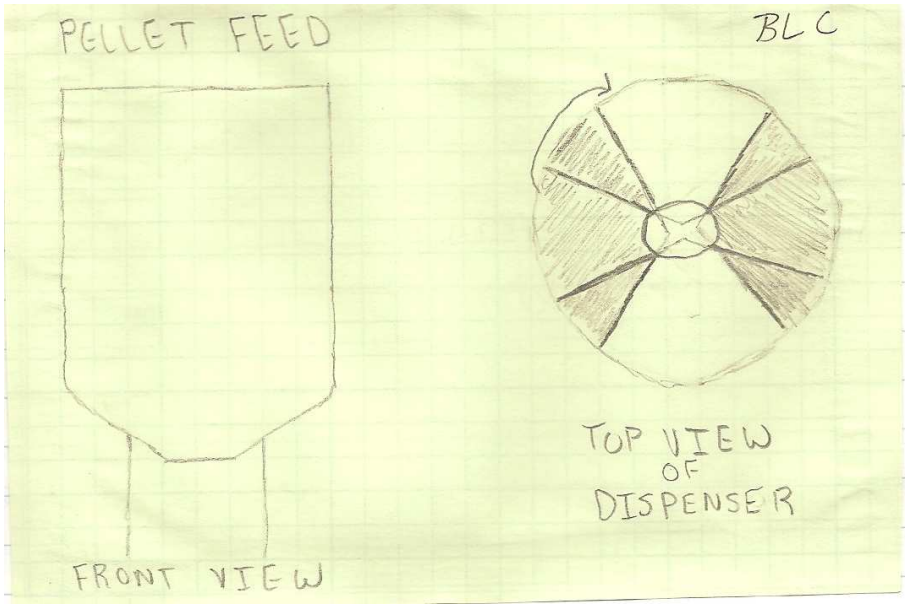
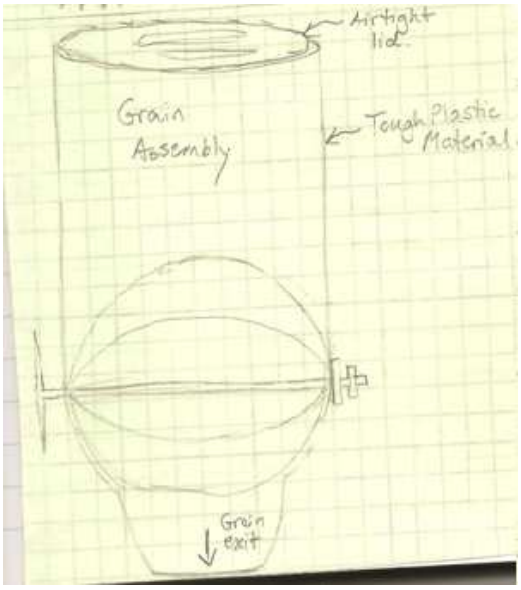


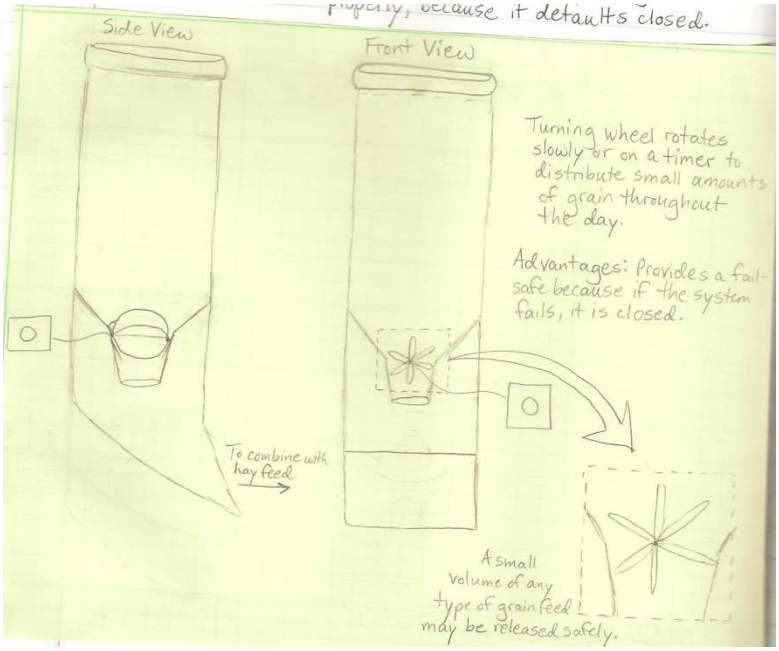
Figure 7: Grain feed Concept by Collins

Final Concept Sketch: The final concept is top-loaded, and the grain is dispensed with the help of a rubber paddle wheel that is spun by a small motor.

Advantages: Device fails in a "closed" position, simple design and easy loading

Disadvantages: Plastic and rubber materials must be incorporated into the design





5.4.3 Decision Matrices/Reasoning

Decision matrices are used to describe a multi-criteria decision analysis. It consists of establishing weighted criteria based upon the importance of each, and the different concepts or ideas are quantitatively compared for making a "best" solution recommendation. Alternatives are compared to a "Datum" design, so that a ranking may be done for the best three devices in consideration.

Hay Dispensing Device

	Criteria	Importance	Alternatives		
			Final Concept	**Concept 1**	**Concept 2**
1	**Stability**	10	D	-	+
2	**Affordability**	15	A	S	_
3	**Easy Installation**	5	T	S	_
4	**Easy to manufacture**	1	U	+	S
5	**Easy to maintain/clean**	6	M	+	_
6	**Attractive**	3	D	S	S
7	**Safe to Horse**	30	A	S	S
8	**No noticeable temperature effect**	4	T	S	S
9	**No noticeable dirt effect**	3	U	S	S
10	**Easy to load**	8	M	_	_
		Total +	----	2	1
		Total -	----	2	3
		Overall Total	----	0	-2
		Weighted Total	----	-11	-24

Figure 8: Decision matrix for Hay Device

Decision matrix comparisons proved that the datum, the recommended hay dispensing device concept, was the best choice considering the criteria described in the figure above. Concept 3 was eliminated by the team before analysis. The more negative the number, the less satisfactory the design is for specifications and requirements.

Grain Dispensing Device

	Criteria	Importance	Alternatives		
			Concept 1	**Final concept**	**Concept 2**
1	**Stability**	10	S	D	S
2	**Affordability**	15	-	A	S
3	**Easy Installation**	5	S	T	S
4	**Easy to manufacture**	1	-	U	-
5	**Easy to maintain/clean**	6	-	M	-
6	**Attractive**	3	S	D	S
7	**Safe to Horse**	30	S	A	S
8	**No noticeable temperature effect**	4	S	T	S
9	**No noticeable dirt effect**	3	S	U	S
10	**Easy to load**	8	S	M	S
		Total +	0	----	0
		Total -	3	----	2
		Overall Total	-3	----	-2
		Weighted Total	-22	----	-7

Figure 9: Decision matrix for Grain Device

Decision matrix comparison for the grain device also proved that the datum, which is the recommended grain dispensing device, was the best choice because the other designs considered were less satisfactory (negative in comparison). Once again Concept 3 was eliminated by the team before this analysis.

House of Quality

Horse Owner	Horse Show Stables	Automatic Horse Feeder	How								Now
			# of modules	Users having injury to horse	Assembly Time	# of flakes able to feed per day	Energy required to load	# of tools needed to install	Energy required to transport	Gallons of feed able to dispense per day	Δ StableGrazer O SpoonFeeder ◊ The QuickFeed
		Direction of Improvement	↓	↓	↓	↑	↓	↓	↓	↑	Bad → Good
		Units	#	%	min	#	lbs	#	lbs	gal	1 2 3 4 5
10	15	Stability		O	Δ		Δ	Θ	Δ		Δ◊O
15	16	Affordability	Δ		Θ			Δ			Δ ◊ O
3	1	Portable	O					O	Θ		◊ O Δ
5	3	Easy Installation	Θ					Θ			◊ O Δ
1	1	Easy to manufacture	O		Θ			O			◊ O Δ
6	8	Easy to maintain/clean	Δ	Δ		Δ					Δ◊ O
3	2	Attractive			Δ						◊ Δ O
30	25	Safe to Horse		Θ		Δ		O		Δ	◊ΔO
4	5	No noticeable temperature effect	Δ	Δ							◊ΔO
3	4	No noticeable dirt effect	Δ	Δ							◊ΔO
8	10	Easy to load				O	O			O	Δ ◊O
12	10	Dispenses both hay & grain		O		Θ	Θ			Θ	Δ◊ O
		StableGrazer	1	0	20	6	50	2	100	0	
		SpoonFeeder	1	0	30	10	40	2	200	2	
		The QuickFeed	1	0	40	0	20	3	50	2	
		Target(delighted)	1	0	30	10	20	2	25	2	
		Target(disgusted)	5	10	60	4	100	10	500	1	

The House of Quality describes many different factors and criteria of a device, in this case the Automatic Horse Feeder compared to several other models. Symbols are used to rate each different design, and the factors are weighted with numerical values. Target values are discussed at the very bottom of the chart, and it is desirable that delighted values are high

5.5 Engineering Analyses

A Gantt Chart construction schedule has been developed for the Spoonfeeder.

	January			February				March				April					May
								Week Number:									
Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Order/obtain parts																	
Construct hay shaft																	
Cast paddle wheel																	
Cast plastic container																	
Construct sheet metal housing/parts																	
Assemble grain feeder																	
Assemble hay feeder																	
Attach parts to frame																	
Wire the electronics																	
Test motor for grain																	
Test motor for hay																	
Assemble final parts																	
Finishing touches																	

Table 1: Gantt Chart- Construction Schedule

The engineering team developed a schedule for construction of the design project, to be completed in May of next year.

Sections in black indicate that work is being done on the task listed to in the left-most column during the week numbers (listed above in the third row).

Design for Environment, or green design, has been addressed for the SpoonFeeder's components. Four guidelines were followed as the design was considered.

- *Guideline 1: Be aware of environmental effects of materials used in products.*
  Since aluminum is a natural substance, parts should not break off and harm the environment.
- *Guideline 2: Design the Product with high separability*
  All fasteners are easily accessed and none obstruct access of others. No lamination or adhesives are used. No electrical wiring is used.
  Each component is very easily broken into blocks of an individual material.

- *Guideline 3: design components that can be reused or recycled The five steps of recycling are retrieval, separation, identification, reprocessing, and marketing.*
  All of the aluminum can be melted and recast; the stainless steel bolts may be reused or recast as well. For retrieval, separation, and identification, all of the materials are aluminum except for the steel cables and the hinges. These material changes can be specified in the owner's manual.

- *Guideline 4: be aware of environmental effects of material not reused or recycled.*
  All aluminum components can be melted down and remolded into something else.

5.5.1 Flow Rate Testing

Table 2: Initial Flow Rate Testing Results: Grain Feed Dispenser

Type: Sweet Feed

Trial Run	Volume (cups)	Time (s)	Flow Rate (cups/s)
1	22	13.78	1.59651669
2	22	13.27	1.65787491
3	22	14.17	1.55257586
Average Flow Rate			1.60232249
			Flow Rate (cups/s)
1	11	8.06	1.36476427
2	11	6.85	1.60583942
3	11	6.88	1.59883721
4	11	6.99	1.57367668
Average Flow Rate			1.59278444
			Flow Rate (cups/s)
1	4.5	2.75	1.63636364
2	4.5	2.52	1.78571429
3	4.5	2.63	1.71102662
Average Flow Rate			1.71103485

Average for all heights: 1.63538059

Type: Grain Feed

Trial Run	Volume (cups)	Time (s)	Flow Rate (cups/s)
1	20	13.19	1.51630023
2	20	12.85	1.55642023
3	20	12.97	1.54202005
Average Flow Rate			1.53824684
			Flow Rate (cups/s)
1	10	5.99	1.66944908
2	10	6.57	1.52207002
3	10	6.16	1.62337662
Average Flow Rate			1.60496524
			Flow Rate (cups/s)
1	5	2.97	1.68350168
2	5	3.17	1.57728707
3	5	3.2	1.5625
Average Flow Rate			1.60776292

Average for all heights: 1.58365833

Type: Sweet Feed: Round 2

Trial Run	Volume (cups)	Time (s)	Flow Rate (cups/s)
1	20	13.54	1.47710487
2	20	12.83	1.55884645
3	20	13.7	1.45985401
Average Flow Rate			1.49860178
			Flow Rate (cups/s)
1	5	2.58	1.9379845
2	5	2.68	1.86567164
3	5	2.7	1.85185185
Average Flow Rate			1.88516933

Average for all heights: 1.69188556

Time for 2 gallons of Sweet Feed to fall:

19.2350107 seconds

Time for 2 gallons of Grain Feed to fall:

20.2063787 seconds

Flow Rate Testing (Continued)

Flow Rate Testing Parameters:

It has been proven that flow rate of granulated materials through an orifice depends on several factors:

- Orifice shape (round, square, etc)
- The hydraulic diameter of the orifice
- The bulk density of the material
- The diameter of the granulated material
- The height of the column of material used

In-depth mass flow calculations showing the relations and importance of these factors could be made for the grain feed material, but these calculations would prove rather inappropriate for the application at hand. Horse owners typically measure out grain feed by volume with cups or buckets, so volumetric flow calculations would be more appropriate. Volumetric calculations have been done in the table shown above.

Experimental Procedure:

Flow rate testing was done in the following manner:

- Cone device was placed in the grain feed storage cylinder to "stop" the flow
- Cups of feed were poured into the top of the device
- The cone was dropped simultaneously with the beginning of a stopwatch timer
- Time recording was stopped exactly as the last pieces of feed passed the orifice
- Grain was collected into a bucket below the storage cylinder

Discussion of rate testing results:

The flow rates were expected to *decrease* with the decrease in quantity (cups) due to the fact that less pressure would exist above the orifice as quantity was reduced.

The overall trend, however, showed that this was not the case for the two materials under experiment. Flow rates for smaller grain heights (or cup amounts) tended to be faster than those for taller grain heights. This could be due to the added pressure clogging up in the funnel rather than increasing the rates as expected.

After finding that the flow rates for the lowest volume of Sweet Feed (4.5 cups in the first trial) were inconsistent, more experiment was done to ensure that the results were repeatable. Assuredly, in "Sweet Feed: Round 2" testing, the flow rate turned out to be significantly faster for the shorter grain heights.

Flow Rate Testing (Continued)

Effect of Water on Flow Rates:

The Sweet Feed and storage tube were lightly dampened (3 sprays from a spray bottle in the feed before loading) to determine the effect of water on flow rate. The added water had negligible effect on the flow rate of the grain.

Then the feed and storage tube were highly dampened with water (about 15 sprays from a spray bottle) for a "worst case" scenario and flow rate tests were run. When the cone was first released, the grain did not flow smoothly. After reinserting and removing the cone, however, the grain was stirred and flowed quickly and freely, proving that the device can function even in poor water conditions.

A moderate amount of hay was poured in with the grain feed to ensure that the device still functioned properly. The hay had negligible effect on flow rate, showing that if grain feed were to be contaminated by a small amount of hay, the device would still function well.

Conclusions from rate testing results:

Calculations of the time it would take for two gallons of feed to flow from the device were calculated using the average flow rates found in experiment. Sweet Feed, at about 19.2 seconds, would be released slightly faster than the grain feed at 20.2 seconds. These results were as expected because the grain feed pellets are larger than the average Sweet Feed pellets (by visual inspection).

Because the flow rates were so similar for the two very different grain types, the need for multiple feed type settings may be eliminated for this device.

Also, since the flow rates were very similar for the different grain heights (or different volumes), the need for a timer that increases the flow intervals with decreasing grain height may also be eliminated.

For the Newest Grain Concept

Manufacturing specifications for a device that was purchased with a similar paddle wheel to that of the newest grain concept help describe the flow rate of the concept. The purchased device has a turning paddle wheel that distributes about 1/35 of a gallon of cereal with each 1/6 of a turn. Using both the Sweet Feed material and the grain feed material in the device, experimental testing proved that the manufacturing information continued to prove accurate. More in-depth testing will be done in the construction portion of the course.

5.5.2 Hazard Analysis

Hazard analysis was performed on the SpoonFeeder concept to ensure that no unacceptable hazards exist within the design.

Hazard	Frequency	Consequence	Hazard category
Horse kicks the exterior of the device	E, Improbable Device is located outside the stall	IV, Negligible Interior parts are safely inaccessible	Acceptable without review
Sensors or timers stop functioning	D, Remote	IV, Negligible	Acceptable without review
Power is cut off from device	D, Remote	III, Marginal	Acceptable with review
Device is dislodged from stable wall and falls	E, Improbable Device is bolted to stable wall in four locations	III, Marginal	Acceptable with review
Water or other elements get into the SpoonFeeder	C, Occasional	IV, Negligible Interior electrical parts are in weather-proof storage	Acceptable without review
Interior hay shredding apparatus is exposed	E, Improbable Apparatus is entirely sealed in a protective plastic coating	II, IV Critical or Negligible (whether device is in- or out-side stall)	Acceptable with review
Loader closes door on a hand or finger	D, Remote	IV, Negligible Minor cuts or bruises	Acceptable without review

Table 3: Hazard Analysis for the SpoonFeeder

In the hazard analysis, each possible hazard is given a frequency rating and a consequence rating that are both combined to produce the acceptability rating (fourth column).

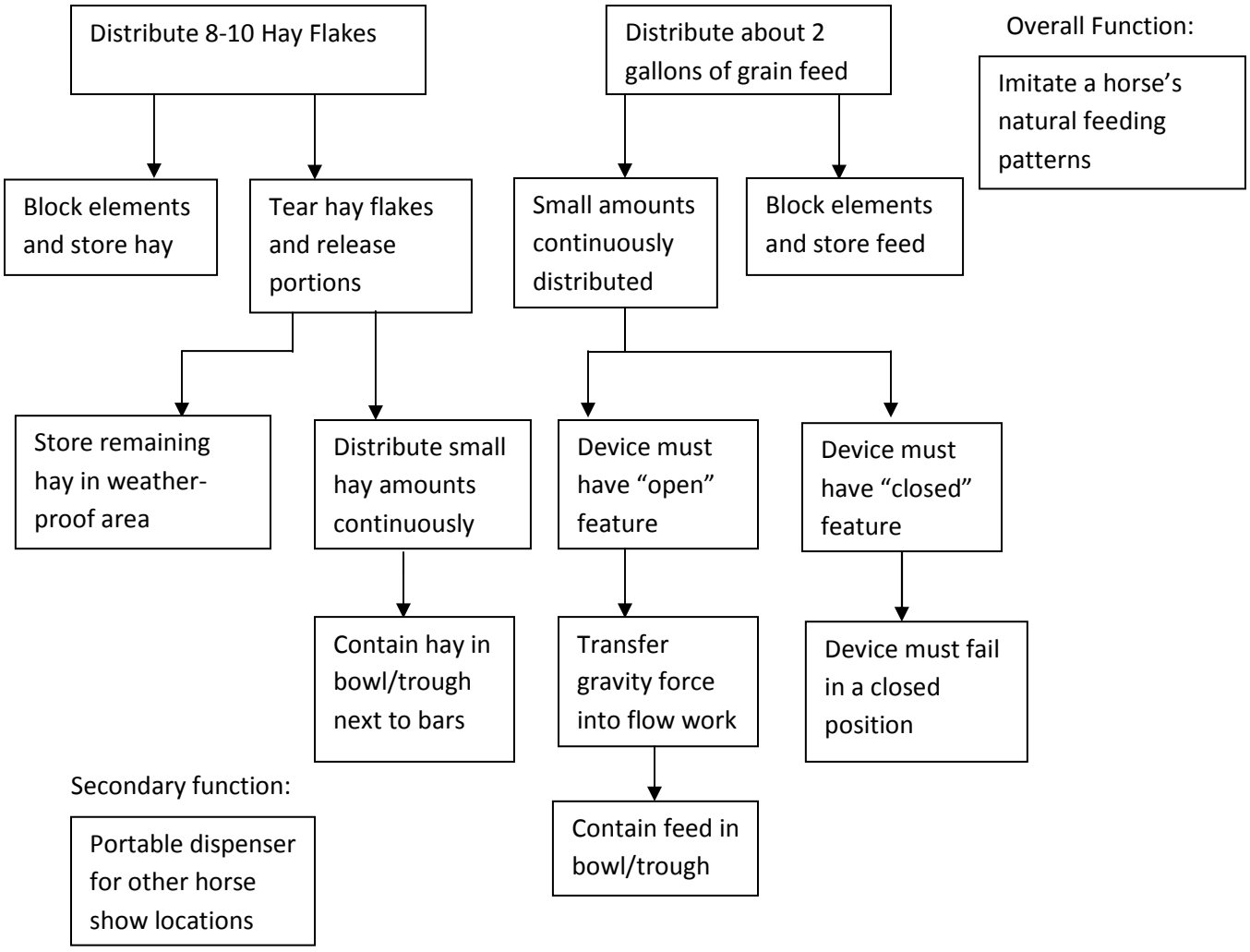
From the analysis done, the team has determined that there are no unacceptable hazards associated with the device.

5.5.3 Discussion of Project Deliverables (In Depth)

FUNCTIONAL DECOMPOSITION FOR THE SPOONFEEDER

The SpoonFeeder device was broken down into smaller functions so that each function may be addressed and solved individually during the design process

Figure 10: Functional decomposition of the SpoonFeeder device



The functional decomposition of the SpoonFeeder device shows the breakdown of the larger functions of the device. The overall function is shown in the top right square, and an alternate function of the device (beyond functions specifically intended for the device) is shown at the bottom left.

5.6 Economic Analysis

5.6.1 Complete Parts List

The following components have been purchased and incorporated in the design of the SpoonFeeder prototype device.

Table 4: Bill of Materials for the SpoonFeeder

Item Description	Item No.	Company	Quantity	Cost ea.	Cost
Taper Pins 3/8 - 24 X 4	2UHD8	Grainger	8	14.18	113.44
Mounted Ball Bearing	6X235	Grainger	2	29.56	59.12
Gearmotor 1.1 RPM 50 Torque	1MBF3	Grainger	1	44.03	44.03
Relay with Single-Timing Function	7630K23	McMaster	2	66.85	133.70
Relay Socket, 8-pin Circular	7122K19	McMaster	2	3.96	7.92
Gearmotor 6 RPM 600 torque	1LPP7	Grainger	1	257.04	257.04
QT Acetone Crown	206558	Lowes	1	6.98	6.98
Butt splice 16-14 20 Pk	135676	Lowes	1	2.48	2.48
11" Black Cable Ties 20 Bag	220871	Lowes	2	2.58	5.16
12 Oz Auto Gloss Black sp	283714	Lowes	4	4.97	19.88
10.2 Oz Universal Adhesive	236670	Lowes	1	9.97	9.97
Rivets, Fittings	79055008286	Lowes	1	15.45	15.45
Material - 1/8 Alum. tread 2pc	Alum 3003	DMW	1	162.00	162.00
Material - 1/8 Aluminum tread	Alum 3003	DMW	1	55.00	55.00
Single Dry Food Dispenser	541489	Target	1	25.79	25.79
Charger DCW	76607759030	Home Depot	2	4.47	8.94
14" Roll Flash	99137153208	Home Depot	1	11.44	11.44
3 Pc PRK Set	81243890825	Home Depot	1	10.46	10.46
Strait Snip	37103136442	Home Depot	1	12.97	12.97
GE Clear	77027050400	Home Depot	2	5.97	11.94
HCS 1/4-20 X 2	115013	Fastenal	20	0.3156	6.31
1/4-20 YZ8 NE Nylock	1137183	Fastenal	20	0.19	3.80
SAE Thru-Hard 1/4	1133813	Fastenal	40	0.0934	3.74
Angle 3 x 3 x 3/16	AS33316	Southern Stl	1	55.00	55.00
Square tube 1	TS112112120	Southern Stl	2	27.00	54.00
Angle 2 x 2 x 1/8	AB2218	Southern Stl	1	19.80	19.80
HR Strip 3/16 X 1	HRS3161	Southern Stl	1	8.9	8.90
HR Round 1 6'	HRR1	Southern Stl	1	8.9	8.90
Welding Supplies, Assort.	-------	Dixie Welding	1	34.4	34.40
5/16"-18 Pk	1133416	Fastenal	8	0.3678	2.94
SAE Thru-Hard 1/2	1133861	Fastenal	9	0.403	3.63
HCS 1/2-20x2	1187187	Fastenal	4	0.75	3.00
1/2-18 Nylock	115219	Fastenal	4	1.11	4.44
				Total $:	**1182.57**

Note: Another parts list detailing the exact quantities of materials present in the prototype device is available in the Appendix.

5.7 Prototype Device Discussion

5.7.1 Addressing Sponsor Concerns

Following the midterm report there were some concerns from our sponsors based on a few areas involving our design concepts. The following are the concerns and how we plan to accommodate them.

- The need for the hay feeder to be installed on the outside of the stall so that the horse has ample room to move around. This will also help prevent any harm to the horse by the SpoonFeeder.
    - We have now designed the SpoonFeeder so that it can be hung on the outside of a standard barn door with bars 3 1/2" apart. We are aware that there are many different types of barn doors, but since it would be extremely difficult to accommodate every type, we have made the product also available to be hung inside of the barn if needed. The SpoonFeeder will also be made out of a plastic composite material so that it will not cause any harm to the horse if hung inside.
- If in fact our grain feeder motor were to fail, it is very important that all of the remaining feed not be distributed all at once to the horse.
    - In the event that all of the grain was dispensed at once, the horse's health would be in serious jeopardy. Since the safety of the horse is our utmost concern we have installed a failsafe device. This device in the event of a fail would fail closed which means that no grain would be dispensed. We accomplished this by using a paddle wheel design that dispenses the same amount of grain each partial turn.
- Another concern is that our product could possibly be too bulky.
    - We have addressed this problem by contacting our sponsor and finding the desired dimensions of the SpoonFeeder. The dimensions we received were 30" X 30" X 24". We believe we will be able to meet these dimensions by having the hay feeder and grain dispenser attached closely within the frame.

5.7.2 User Documentation

The manufacturing plan, user assembly instructions, and the operating instructions were formulated for the SpoonFeeder device.

Safe Operating Instructions:

I. Assembly/Mounting Instructions

- The device has been delivered to the customer fully assembled and is designed to attach to the OUTSIDE of the stall so that hay and grain may be safely dispensed into the barn stall.
- To mount, first adjust the U-bolts width by sliding to the appropriate spacing for the particular stable
- Tighten bolts into the slots provided.
- Place SpoonFeeder against the bars from the outside and tighten U-bolts.
  Note: The majority of the device weight must be supported from the U-bolts and NOT the bottom hay chute. The Lexan chute is not designed to support the full system weight.

II. Operating Instructions

A. Hayfeeder operation

- Open the loading door by unlatching the two hinges
  Note: Before loading the Hayfeeder, be sure that the power is disconnected from the motor, either by unplugging the device or by switching the "On-Off" switch to the "off" position.
- Load in the desired amount of hay, laying the hay quantity directly on top of the spikes
- Close and latch the loading door
- Turn the Hayfeeder "On-off" switch to the "On" position.
- To adjust the proportion and lengths of On and Off times, open the wirebox front door and adjust the appropriate relay knobs.

Important Note: This device has NOT been designed for safe use inside a barn stall.

B. Grainfeeder operation

- Open the grain storage container by pulling up (while slightly twisting) the lid
  Note: Before loading the Grainfeeder, be sure that the power is disconnected from the motor, either by unplugging the device or by switching the "On-Off" switch to the "off" position.
- Load in the desired amount of grain. Sweet feed and pellet feed are two types of feed that have been found compatible with the device

- Replace the top of the grainfeeder with a snug fit
- Turn the Grainfeeder "On-off" switch to the "On" position.
- To adjust the proportion and lengths of On and Off times, open the wirebox front door and adjust the appropriate relay knobs.

Important Note: This device has NOT been designed for safe use inside a barn stall.

III. Safety Precautions

- The prototype device model is not designed nor intended for prolonged use.
- Do not try to load the SpoonFeeder device while it is in operation.
- The SpoonFeeder system is rated for 120 V, 60 Hz electricity.
- Both motors for the device are safely grounded and wired through a fuse. Do not compensate the capacities of the fuses and do not tamper with the grounds. Burnt fuses must be replaced with the appropriate equivalent
- Mount the SpoonFeeder only to secure fixtures. Serious injury could occur if device is not securely fastened.
- Do not allow children to play with or around the SpoonFeeder
- All parts that are designed to come into contact with the stable bars are smoothed, rounded or covered for horse safety. For the safety of the horse, do not improperly install the device within the stable stall for any reason.

IV. Maintenance Instructions

- The motors have already been lubricated for satisfactory turning. Lubrication can be applied if necessary.
- The hayfeeder may be rinsed off with clean water. Allow to dry completely before reloading hay into the bin
- The grainfeeder may also be rinsed off with clean water. Do not take the grain feeder motor cover off, as the grain feeder motor is not covered properly by itself to be waterproof. Allow the grainfeeder to dry completely before reloading grain into the device.

V. Troubleshooting

Problem: The system runs for too long or too short of a time period
Solution: Adjust the respective knobs for the hay feeder and grain feeder to the desired dispensing length.

Problem: One of the motors has stopped turning
Solution: First check to make sure that the switches are turned on to the motors and the fuses are intact and functioning. Then make sure that all wires are properly joined.

Problem: The grain feeding motor shaft stops turning
Solution: If the grain feeder motor becomes locked up, remove the motor and gently turn the motor shaft manually (NOT the gearbox shaft) with a pair of pliers until the shaft becomes dislodged

Problem: The hay becomes trapped in the back of the Lexan chute.
Solution: Turn off the power to the hay feeder, make sure that all components have stopped rotating, and remove the hay from the back of the chute.

Manufacturing Plan

For the SpoonFeeder device, mass prototyping manufacturing should be feasible

- Construct the frame from a lightweight aluminum square tubing. 6061 Aluminum would be a reasonable choice
- Cut and fit the diamond plate metal housing into the aluminum frame. The door may be constructed out of a different, clear material if desired.
- Construct the grain feeder, in an injection molding process or a sand casting process
    - If injection molding, melt the acrylic – 10 minutes in a large crucible and inducting furnace
    - If sand casting – 1 part to cast: Grain feeder hopper – 4 minutes per part for total of 4 minutes in a sand casting machine
    - Allow materials to cool and set – 48 hours
- Machine the hay shaft, laying the holes into it as described in the computer modeling. Attach the bearings and shaft.
- Attach both motors to interface with the motor shafts
- Install the outsourced wire box and attach power to the motors
- Install the spikes in the hay shaft and along both sides of the hay feeder bin bas, as shown in the drawing
- Construct the rounded Lexan hay chute and attach it as shown in computer model
- Mount the SpoonFeeder device securely using U-bolts into the main frame, being sure that the majority of the system weight is supported by means other than the Lexan chute.

5.7.3 Dimensioned Part and Assembly Drawings

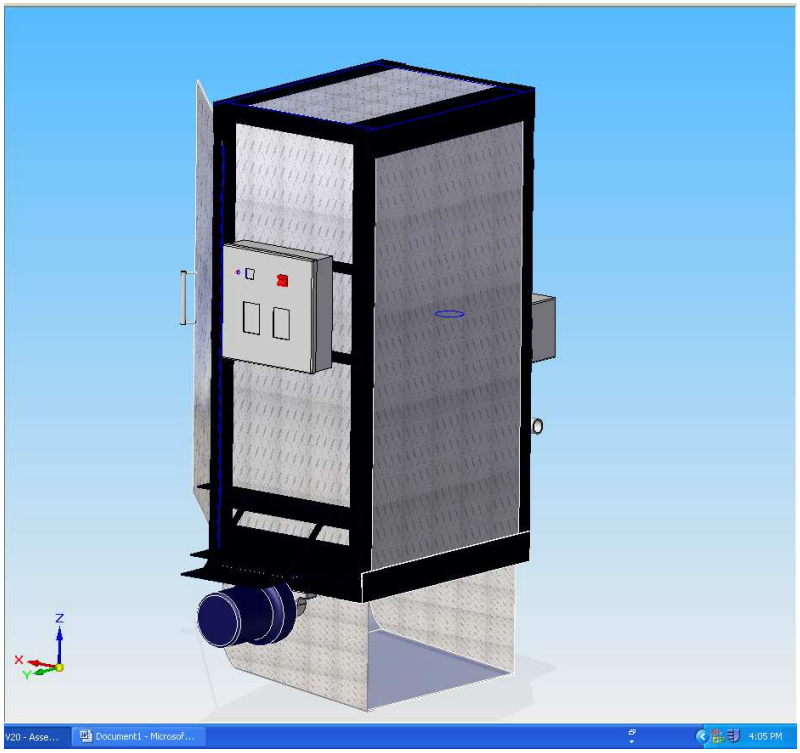


Figure 11: Full timing-box view of the SpoonFeeder

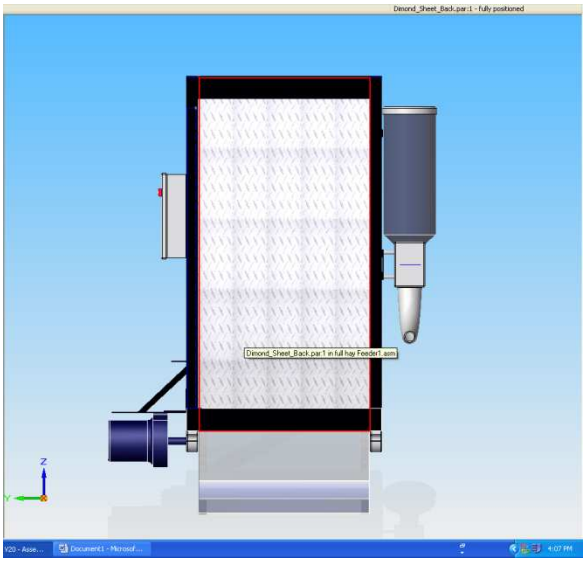


Figure 12: Full front view of the SpoonFeeder

All Dimensioned Part and Assembly Drawings can be seen in Appendix C

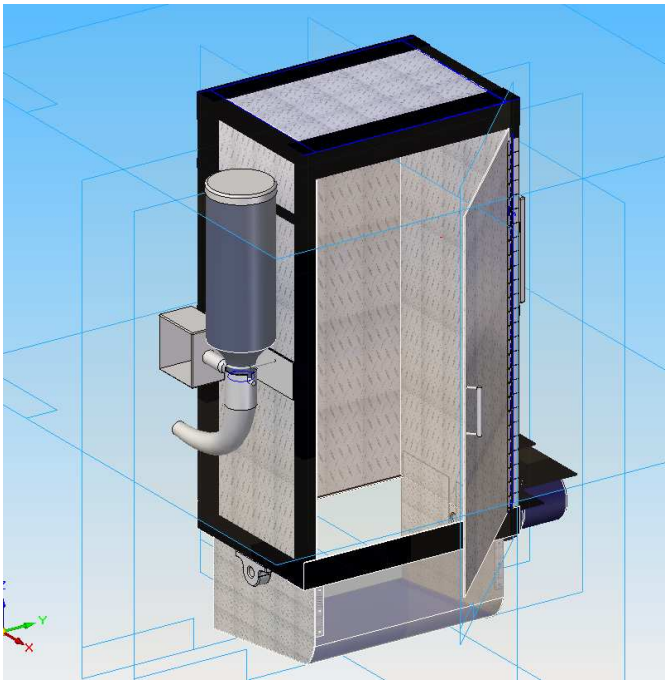


Figure 13: Full back (loading) view of the SpoonFeeder

The recommended concept is a device that the team believes meets the design criteria specified by the sponsor.

- The device effectively tears and distributes hay down a chute and into a bin container on the ground.
- The device may be installed outside the walls of the stable stall and is relatively unobtrusive space-wise.
- The device is designed with a protective covering on components that make contact with the bars to ensure animal safety and protection of the interior components of the device.

The hay shredding device consists of a roller with pins that spins to tear hay. The hay is released down the chute to the bars so that the horse may safely eat from it.

5.7.4 Design Presentation

All Dimensioned Part drawings for the SpoonFeeder device are presented in Appendix C.

Selected Motors:
For the hay feeder – AC Parallel Shaft Gearmotor
Model number 1LPP7 - $257.04

Figure 14: Hay motor

Specifications
AC Gearmotor
Parallel Shaft
Single Output Shaft,
Nameplate RPM 6
Input HP ¼
Gear Ratio 286:1
Voltage Rating 115
Full Load Amps 5.7
Overhung Load 300 Lb
Full Load Torque 600 In-Lbs
60 Hz, Open Dripproof
Ambient 40 C
Thermal Protection None
Insulation Class B
Split-Phase Motor Type
Rotation CW/CCW

For the grain feeder – AC Parallel Shaft Gearmotor
Model 1MBF3 - $60.00

Figure 15: Grain motor

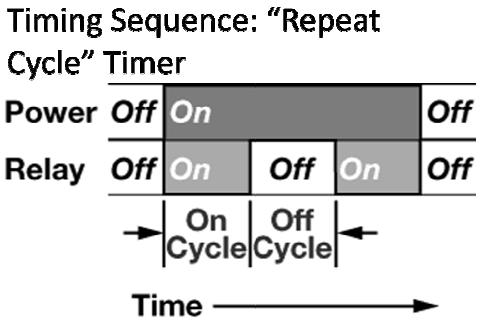
Specifications
AC Gearmotor
Parallel Shaft
Nameplate RPM 1.1
Input HP 1/670
Gear Ratio 3231:1
Voltage Rating 115
Full Load Amps 0.38
Overhung Load 41 Lb
Full Load Torque 50 In-Lbs
60 Hz
Open
Ambient 40 C
Thermal Protection None
Insulation Class B
Motor Type Shaded Pole
Rotation CW

System Relays/Timers

The selected timer and relay system incorporates the device shown in the figure below. The device has two knobs for separate adjustment of “on” and “off” times, within the given timing range. The timing system (seen on the right in the figure) repeats until power is disconnected from the timer.

McMaster Carr
Model # 7630K23

Relay with Single-Timing Function Repeat Cycle



- Mechanical life: 10 million cycles.
- Size: is 2.9" Ht. x 1.7" Wd. x 2.4“
- Control Voltage: 120 VAC
- Power Consumption: 25 mA
- Timing: 18 to 1800 seconds

Figure 16: Relays/Timers for the SpoonFeeder

The device is rated for 10 amperes at 240 VAC and 100 milliamps at 12 VDC. The relay is connected in an 8-pin circular pin style. The components are UL recognized and CSA certified.

The relay system has an initiation time of 20 mS, and is connected to a separate socket for integration with the rest of the electrical system.

Control Systems Schematics

The Electrical Schematic for the Spoonfeeder is shown in the figure below. The power source runs directly through fuses, and simple "On-off" switches are available for easy "pausing" of the motors. A red lamp has been installed to indicate when power is supplied to the motors, and the timer is connected to the neutral. Each motor is powered from the corresponding relay, and both motors have been safely grounded.

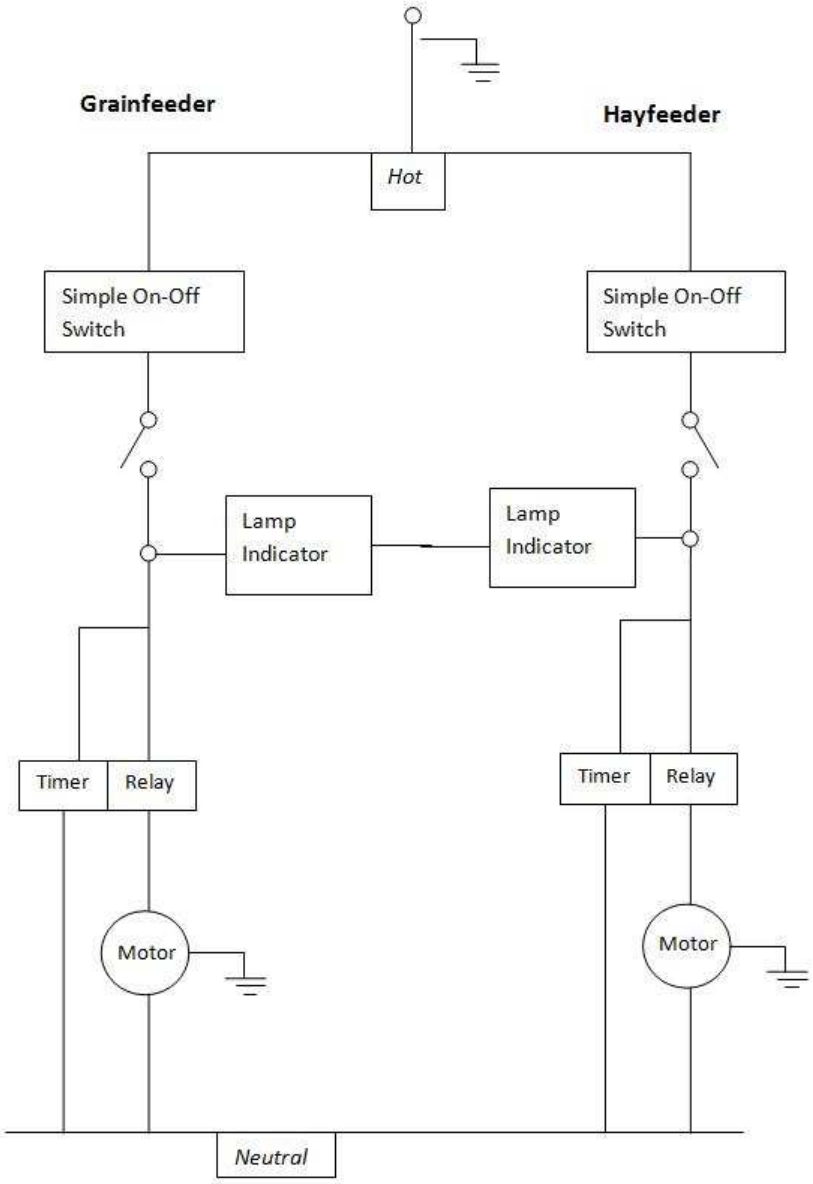


Figure 17: Control System Schematics

6.0 Conclusion

Prototype Development

In the current semester, the team has developed a prototype model which demonstrates the processes required to meet the design problem. Criteria such as health and safety, economic, ergonomic, and manufacturability have been taken into consideration in design. Information gathered from speaking with the sponsor about the concerns of the original recommended design was incorporated into the design of the new device as well. Data and results from most recently updated proof-of-concept models helped verify the feasibility of the design and aided in device development. Using a systematic method of manufacturing, the full-scale prototype model was constructed by the team.

The chosen device accommodates for both grain and hay feed to be distributed in small amounts throughout the day. The grain device consists of a paddle-wheel assembly attached to a motor, placed inside a vertical grain storage cylinder. The device "turns out" small portions of grain and defaults to a closed position. The hay device consists of one roller with spikes embedded in it, attached on a spinning shaft horizontally. Hay is loaded from the top and the device is spun with a motor so that hay is gradually torn and released down a chute. Both types of feed may be distributed into low containers or troughs on the ground. The entire assembly has been designed to attach to the outside of the barn stall, for the safety of the horse.

Mass-Production Recommendations

The prototype model has been designed to satisfactorily demonstrate the function of the Spoonfeeder design. However, the device is to be made with mass-production methods eventually. To address this task, the design team has made recommendations about design "adjustments" for successful mass production of the device. Such recommendations include design changes that will reduce weight, decrease production time, and improve the aesthetic qualities of the device.

For example, the main frame of the device can perhaps be made out of a lighter aluminum if the proper welding tools are available. If the grain feeding component can be made in an injection molding process, it may be quicker to assemble and integrate it into the system. Also, it is recommended that the electrical components be outsourced for efficiency and cost reduction.

Appendix A: References

Fehringer, Dan. "Products/Guides." Stable Grazer: Automatic Horse Feeder. 2008. HayDay LLC. 29 Oct 2008 <http://www.stablegrazer.com>.

"Linear Solenoids, Intermittent Duty." GlobalSpec - Engineering Search Engine. 2008. GlobalSpec. 29 Oct 2008 <http://www.globalspec.com>.

"Quick Feed Automatic Horse Feeders and Automatic Pet Feeders." Quick Feed. 2007. Nolan Engineering Inc.. 29 Oct 2008 <http://www.quickfeed.com>.

CustomPart.net. 2008 CustomPartNet. 7 Dec 2008. <http://www.custompartnet.com/estimate/injection-molding>

Grainger Industrial Supply. 2008 W.W. Grainger, Inc. 7 Dec 2008. <http://www.grainger.com>

Appendix B: Contract of Deliverable Samples

CONTRACT TITLE: Selection of Motors for the SpoonFeeder
TEAM: Corp _3 Doctor
STUDENT NAME: Karen Kirk
TODAY'S DATE: 01/20/2009

TASKS: The task for this contract is to select, order, and monitor the shipment and delivery of the two gear motors to be used in the SpoonFeeder device.

- The grain feeder motor will be selected as a small, AC parallel shaft gear motor. A reputable company will be selected as the distributor.
- The hay feeder motor will be selected as a larger, strong AC parallel shaft gear motor. A reputable company (preferably the same as the grain feeder motor) will be selected as the distributor. Both motors will be selected based on the torque and rotation requirements specified in the product design.
- Manufacturing specifications for both motors will also be obtained and delivered to the team manager, so that the motors may be incorporated under proper recommended use.
- A copy of the motor receipts will be delivered to the Mechanical Engineering office
- Both motor timers will also be selected

Final Deliverables: Two AC parallel shaft gear motors and timers

INTERFACING PLAN: The gear motors must interface with the timer and either the grain feeder paddle wheel via a fitted pin or the hay feeder shaft via a connecting rod. Motors will not contain the connecting devices, those will be made separately. The main potential cause of delay in the deliverable will be the rate at which the motors are shipped by the distributor.

MEASURE OF PERFORMANCE: Motors will be delivered to the team manager in a state ready for interfacing, and will be accepted or rejected by the team manager.

DELIVERY DATE: March 31, 2009

Student Signature: Manager's Signature: Instructor's Signature:

_____ _____ _____

Appendix B: Contract of Deliverable Samples

Selection of Motors and Timers for the SpoonFeeder

Two motors and two timing systems for the motors were selected for the SpoonFeeder device. This document will explain the reasoning behind the selection of the SpoonFeeder components and will conclude with our future planned work with the motors.

To dispense hay, a fairly large motor that is capable of starting rotation from rest with a full loading weight of 8-10 flakes of hay is needed. Preliminary torque tests were performed on the prototype machine that was built last semester, and the resulting required "start-up" torque value was found to be slightly below 600 in-lbs. This value proved to be the main "sizing" factor for the hay-feeder motor. A professional sales representative from Grainger Industrial Supply was consulted, and the recommended motor was the AC Parallel Shaft Gearmotor 1LPP7 (shown on pages 2 and 3) with a single output. The motor runs on 115-120 V, which will be available in the barns of most consumers.

The dispensing of grain feed calls for a smaller motor than that required for hay-feeder. The motor needs to have the capability of turning a paddle wheel on the grain-feeder dispenser, and it will be automating a process that is usually performed by the human hand with a knob. Preliminary torque tests were also run on the grainfeeder using the knob of the actual device, and the appropriate motor was selected with recommendation from a professional sales engineer. The selected motor is the AC Parallel Shaft Gearmotor 1MBF3 (shown on pages 4 and 5). This motor produces 50 in-lbs of torque and also runs on 115-120 VAC.

To control the two selected motors, the same Repeat-Cycle Relay model was chosen for both. It is a Relay with Single-Timing Function Repeat Cycle by Macromatic (shown on page 6) and has two dials, one which controls the "On" time in minutes and one that separately controls the "Off" time in minutes. This relay was chosen for many reasons. First, it is very user-friendly and easier to set up for proper timing than other models such as percentage timers or single-dial models. Second, the device is rated for 10 Amps at 240 VAC (although it runs on 120 VAC which is desired) and was recommended by a McMaster-Carr sales professional. Third, the device has timing capabilities from 18-1800 seconds which is adequate for both motors and is set on a convenient 8-pin relay socket for straight-forward wiring by our team.

A wiring diagram for both motors has been provided at the end of the report (on page 7). All wiring done by the team will be inspected by a professional before release and presentation as a prototype.

Appendix B: Contract of Deliverable Samples

Print *printed* April 20, 2009

Gearmotor,1.1 RPM,50 Torque,115,Open

AC Gearmotor, Parallel Shaft, Nameplate RPM 1.1, Input HP 1/670, Gear Ratio 3231:1, Voltage Rating 115, Full Load Amps 0.38, Overhung Load 41 Lb, Full Load Torque 50 In-Lbs, 60 Hz, Open, Ambient 40 C, Thermal Protection None, Insulation Class B, Motor Type Shaded Pole, Rotation CW

Grainger Item #	1MBF3
Price (ea.)	**$78.00**
Brand	DAYTON
Mfr. Model #	1MBF3
Ship Qty.	1
Sell Qty. (Will-Call)	1
Ship Weight (lbs.)	3.65
Usually Ships	Today
Catalog Page No.	97

Price shown may not reflect your price. Log in or register.

Additional Info

- 115VAC Shaded Pole Parallel Shaft Gearmotors

- Gearcase: die-cast zinc
- Lubrication: grease filled
- Gears: heat-treated cut steel and acetal
- Bearings: porous bronze sleeve on both case and motor
- Mounting: all-position
- 60 Hz
- Rotation: CW facing output shaft

Appendix B: Contract of Deliverable Samples

GRAINGER
FOR THE ONES WHO GET IT DONE

Print *printed* April 20, 2009

Gearmotor,6 RPM,600 Torque,115V,ODP

AC Gearmotor, Parallel Shaft, Single Output Shaft, Nameplate RPM 6, Input HP 1/4, Gear Ratio 286:1, Voltage Rating 115, Full Load Amps 5.7, Overhung Load 300 Lb, Full Load Torque 600 In-Lbs, 60 Hz, Open Dripproof, Ambient 40 C, Thermal Protection None, Insulation Class B, Split-Phase Motor Type, Rotation CW/CCW

Grainger Item #	1LPP7
Price (ea.)	**$376.75**
Brand	DAYTON
Mfr. Model #	1LPP7
Ship Qty.	1
Sell Qty. (Will-Call)	1
Ship Weight (lbs.)	23.77
Usually Ships	Today
Catalog Page No.	107

Price shown may not reflect your price. Log in or register.

Additional Info

- 115VAC Split Phase Parallel Shaft Gearmotors

- Enclosure: pen dripproof
- Gearcase: die-cast zinc
- Lubrication: grease filled
- Gears: cut steel and phenolic
- Bearings: porous bronze sleeve on case; ball on motor
- Mounting: all-position
- 60 Hz
- Rotation: reversible
- Thermal protection: none
- Ambient: 40 DegreeC
- UL Recognized and CSA Certified

Appendix B: Contract of Deliverable Samples

Contract of Deliverables #3

CONTRACT TITLE: Construction and Wiring of Grain feeder timing system
TEAM: Corp _3 Doctor
STUDENT NAME: Karen Kirk
TODAY'S DATE: 03/05/2009

TASKS: The task for this contract is to properly wire and power the motor timing system for the grain feeding device of the SpoonFeeder

- A timing system has been purchased and developed to perform the controlling necessary for the grain feeder motor
- The system may be run on a 120V outlet and will be compatible with the chosen 1.1 rpm AC parallel shaft gearmotor
- The timer will be able to turn the motor on and off sequentially
- Timing of the system will be fine-tuned to be adequate for the distribution of grain

NOTE: Integration into the rest of the system (including the coupling junction with the paddle wheel) is NOT included in this Contract of Deliverable

Final Deliverables: A functioning timing system plus any required circuitry schematics or block diagrams

INTERFACING PLAN: The timing system must be able to control the grain feeder motor, which integrates with the paddle wheel via a fitted pin. The timing system will be mountable so that it may be attached to the SpoonFeeder device. The main potential cause of delay in the deliverable will be compensating for how much power is needed based on the grain load.

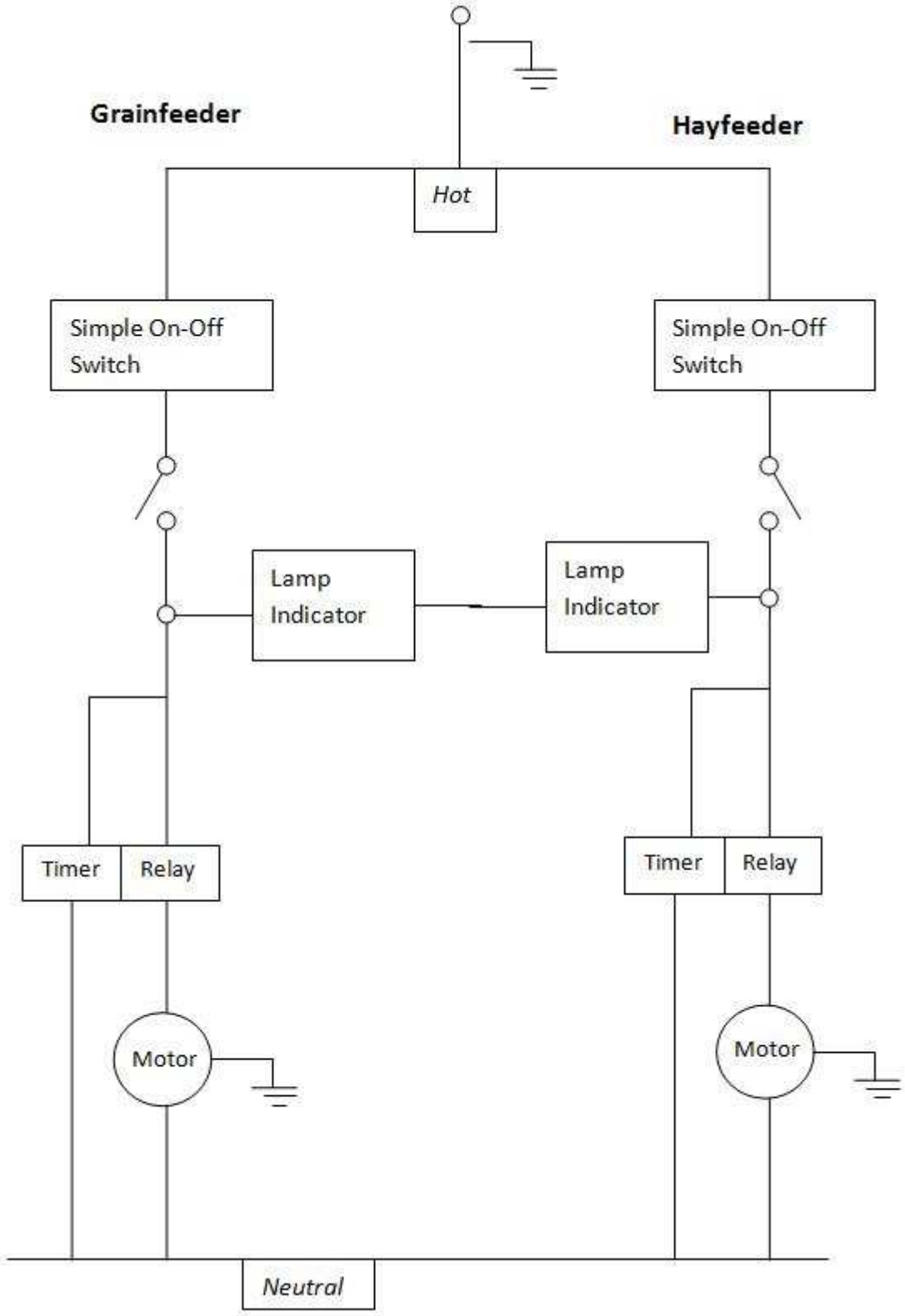
MEASURE OF PERFORMANCE: The timing system will be delivered to the team manager in a state ready for integrating into the SpoonFeeder, and will be accepted or rejected by the team manager.

DELIVERY DATE: April 16, 2009

Student Signature: Manager's Signature: Instructor's Signature:

_____ _____ _____

Appendix B: Contract of Deliverable Samples



Appendix C: Computer Modeling