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EVALUATION OF AIR MOVEMENT IN EQUESTRIAN FACILITIES
AND ON EQUINE ATHLETES

THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in Biosystems and
Agricultural Engineering the Colleges of Agriculture and
Engineering at the University of Kentucky

By

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Lexington, Kentucky

2019

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ABSTRACT OF THESIS

EVALUATION OF AIR MOVEMENT IN EQUESTRIAN FACILITIES AND ON EQUINE ATHLETES

Ventilation and air movement are important aspects of animal agriculture and is frequently neglected in equine facilities. This paper discusses three different studies that examine different components of ventilation and air movement. One is a fan orientation study which examines how fans impact the stall environment, the second is a cooling study questioning whether forced air speed across a horse increases the rate of cool out after intense exercise, and the last is a survey examining ventilation, air quality, and health concerns in indoor arenas.

The stall fan study took place over two summers with the goal of determining how the placement and orientation of different fans impacted the temperature within the stall, the air movement around the stall, and if the fans could provide fly control. Two barns with vastly different designs and natural ventilation properties were used. The barn in the first year had good natural ventilation, while the barn in the second year did not. Overall, the fans had little to no effect on reducing the temperature within the stalls, providing air movement throughout the stall, and did not produce sufficient air movement for fly control.

After intense exercise such as a running a race, cross country, or participating in an endurance race, it is necessary to cool the horses and bring their vital signs back to resting ranges. The predominant method for this is hand walking or drenching and scraping the horses until the heart rate, respiration rate, and rectal temperature have returned to an acceptable level. The cooling study sought to examine whether providing forced air speed across the horses increased their rate of cool out through placing a Bannon Tilted Belt Drive 42 in drum fan around the horses during the drenching period of their cool out process. Heart rate, respiration rate, and rectal temperature were all monitored throughout the cool out process and the rate of return to resting values of the vital signs was used to determine the effectiveness of the cooling techniques. The presence of the fan and the air speed across the horses tended to increase their rate of cool out after exercise with the fan blowing from the hindquarters towards their head provided the greatest increase.

Finally, the indoor arena study included an online survey and site visits with the purpose of gathering information regarding indoor arenas. As this is an under-researched topic, the goal of this study was to establish common characteristics, identify problems or issues within the facilities, and any health concerns for the horses and humans who use the facilities. The information gathered in this study covered a multitude of topics including arena construction and design, arena usage, footing type, maintenance practices, environmental concerns, and potential health issues within the facilities. This study will serve as the framework to build future research studies to examine and rectify issues within the facilities and, ultimately, provide design recommendations for building or retrofitting indoor arenas to mitigate or eliminate concerns.

KEYWORDS: Equine, Equine Facilities, Air Movement, Cooling, Fans, Indoor Arena

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EVALUATION OF AIR MOVEMENT IN EQUESTRIAN FACILITIES
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CHAPTER 1. INTRODUCTION

1.1 The Horse Industry

Each spring the rolling hills of Central Kentucky are dotted with newborn foals sleeping, grazing, and romping next to their dams. It's an idyllic image that only allows for a glimpse into this robust and diverse industry. According to the American Horse Council's Economic Impact Survey, \$50 billion of the United States total Gross Domestic Product (GDP) with a total economic contribution of \$122 billion is attributed to the equine industry (American Horse Council Foundation, 2018b). The total economic contribution accounts for direct, indirect, and induced effects. Direct effects are those that are generated within the industry itself, indirect effects are those generated from the other services necessary for the industry to function, and induced effects are the ripples felt from the spending habits of the industry labor force (American Horse Council Foundation, 2018b). In addition to the momentary impacts, the horse industry contributes over 1.7 million jobs to the work force due to the 7.2 million horses within the United States (American Horse Council Foundation, 2018b). While there are still communities such as the Amish that use horses for the purpose of labor, most horses are used for sport, competition, or recreational purposes (American Horse Council Foundation, 2018b). The impact to land usage cannot be understated as over 80 million acres, roughly the size of New Mexico, is owned or leased for the express purpose of keeping horses (American Horse Council Foundation, 2018b). While horses may not be the main source of transportation as they were 100 years ago, their importance within the United States has not diminished.

As the self-proclaimed "Horse Capital of the World", Lexington, KY states the importance of the horse industry to the state. Between Keeneland, Churchill Downs, the

Land Rover Three-Day Event, and the multitude of shows and events held each year, it is unsurprising that the horse industry directly contributes \$1.6 billion to Kentucky's GDP with a total economic impact of \$5.2 billion (American Horse Council Foundation, 2018a). Again, this accounts for the direct, indirect, and induced effects of the industry. The industry's total impact on the job sector within the state is over 60,000 jobs. The total horse population within Kentucky is estimated to be just over 238,000 horses with 831,000 acres being owned or leased for the purpose of raising or housing them (American Horse Council Foundation, 2018a). Though many of the horses within Kentucky are used for competition or sport purposes, the Amish population within the state still use them for transportation or for farm labor. Each of these facts contributes to the how the horse industry is influential to the economy and image of Kentucky.

1.2 Equine Facilities Research

Much of the equine research to date has focused within the disciplines of nutrition, physiology, or veterinary science, but little research has been completed from an engineering perspective. In fact, much of the information regarding equine structures and facilities is as extension publications or as pamphlets. Multiple universities including Iowa State, Clemson University, and Pennsylvania State University have all published extension articles over the last few decades on this subject. More often than not, these publications focus on the stable design exclusively or with a short mention to the other types of facilities that are commonplace on farms such as indoor arenas. Clemson University released a publication in the early 1990s focusing on the different stable designs and plans for barn configurations, specifically, based on the number of horses that needing to be housed ("Horse Barns and Equipment," 1991). The design options available for facilities are as

varied and unique as the industry itself and how the aisle way is devised is a fairly common method for changing the use and feel of the barn. Two of the most common aisle way options are a center aisleway with stalls on the outside and an outer aisle way with stalls in the center of the building ("Horse Barns and Equipment," 1991).

In addition to the design of the aisle way, the roof line and, consequently, the presence or absence of a hayloft is a major factor in determining the overall layout of the barn (Wheeler, 2005). Haylofts provide a location to store any hay as well as infrequently used items such as blankets above the horses in what can be considered a dead space within the barn (Wheeler, 2005). Unfortunately, they typically are placed over the top of stalls and, consequently, pose challenges to adequate ventilation (Fabian, 2002). Of the research and information available regarding equine facilities, one of the most frequent topics is proper ventilation. Ventilation in its most basic form is providing fresh air to the horses and removing stale air from the facility, however it can also include providing air distribution to all areas of the barn (Fabian, 2002). Equine facilities tend to rely solely on natural ventilation techniques which include thermal buoyancy and wind (Fabian, 2002). Thermal buoyancy relies on stale air rising out the top of the barn and fresh air entering through openings along the walls and wind is only effective if it can move through the facility to push stale air out of the barn (Fabian, 2002). In order for this air exchange to happen through natural ventilation, there must be sufficient inlets and outlets in the barn. Often these include windows and doors which are opened or closed depending on the weather conditions, but sidewall openings and ridge vents should also be present in order to allow ventilation to occur through all seasons (Fabian, 2002). During colder weather conditions, windows and doors tend to be closed more than open to preserve heat in the

facilities, which can restrict or eliminate the introduction of fresh air to the facility and the removal of stale air. Not having adequate inlets and outlets is only one obstacle to proper ventilation, as the presence of solid walls and haylofts above stalls trap stale air within the stalls and around the horses (Fabian, 2002).

The Alberta Agriculture, Food, and Rural Development published an information guide to horse handling facilities in 1997 covering a wide array of topics. Unsurprisingly they discussed stable design considerations, but they also included discussion on fencing options, outdoor feeding stations, and arenas (Kidd, Winchell, & Burwash, 1997). The discussion of arenas included a short section on indoor arena facilities, but was essentially a general overview of them rather than an in-depth discussion about how they should be designed (Kidd et al., 1997). This trend to only provide a cursory amount of information about indoor arenas is found in almost every publication that discusses more than just the stable design. One of the most widely used sources of information is Eileen Wheeler's *Horse Facilities Handbook* and the section on indoor arenas discusses in broad strokes the necessary considerations, such as adequate dimensions for being able to work horses and ensuring necessary eave and ridge clearance especially for facilities where horses will be jumping. Indoor arenas serve an important role within the equine industry as they allow horses to be worked and trained in all weather conditions.

In recent years, emphasis has been placed on the importance of proper footing within arenas to provide the best surfaces for horses to work and train on. The International Federation for Equestrian Sports (Fédération Équestre Internationale or FEI) published the *Equestrian Surfaces – A Guide* by Lonnell and Hernlund and the *Equine Surfaces White Paper* by Hobbs et al. in 2014 and 2015 respectively. Both publications highlighted the

considerations necessary for determining appropriate footing when building arenas, including the biomechanics of how horses move and impact the ground, the different types of footing available, and how the planned arena usage dictates many of the aspects of the arena such as dimension, necessary maintenance, and footing additives (Hobbs et al., 2015). Once again, there is a cursory mention of the indoor arena, but no substantial discussion other than to state that more research is necessary to provide a better understanding of these facilities (Lonnell & Hernlund, 2014).

1.3 Overview

The three studies discussed in this thesis examine different components of ventilation and air movement within the equine industry. All three studies were designed to be applicable within the industry and with the goal of being implemented on farms or in training programs. The first is a fan orientation study which examines how fans impact the stall environment. The ultimate goal was to determine if current industry fan practices are fulfilling the needs of the farms using them. The second study is a cooling study questioning whether forced air movement across a horse increased the rate of cool out after intense exercise. Finally, the third is a study of indoor arenas with two sections: an online survey and site visits. This study examines ventilation, air quality, and health concerns in indoor arenas. As there is little research regarding indoor arenas, this study will serve as frame work for future research to be designed and allow for the development of design recommendations.

CHAPTER 2. FAN PLACEMENT IN HORSE STALLS

2.1 Introduction

Providing good ventilation in horse barns and stalls is imperative to maintaining healthy and happy horses. Challenges in horse barns include managing temperature, humidity, ammonia, and dust (Fabian, 2002). Proper ventilation can help to alleviate some of the concerns for horse health like extreme heat and high concentrations of ammonia and moisture, which can become particularly unsafe during hot summer months. Using fans to increase air movement within stalls is a method frequently used by horse owners to cool horses in stalls and facilitate air moving through the barn. Often facilities believe that placing mixing fans to blow into stalls serve to create an air exchange within the stalls even if they are only circulating stall air. Few studies have been conducted to determine whether these fans are effective at reducing horse stall temperature, ammonia concentrations and, areas of stagnant air. Fans can be considered a form of mechanical ventilation; ventilation that is driven by fans that either exhaust air or force air into a barn. The mixing fan orientation may allow fresh air to enter a stall acting as a pseudo-mechanical ventilation for the stall specifically. In cases where the aisle ventilates while the stalls are stagnant, fans can provide fresh air into the stalls or if the fan pulls air from the stall, an eave, or sidewall inlet it may also provide fresh air.

The other main technique used to achieve air exchange and combat the issues within barns is natural ventilation (Fabian, 2002). Natural ventilation relies on wind and thermal buoyancy to move the air through and out of the facility. Thermal buoyancy is achieved through the design and construction of the barn with the use of eave openings, sidewall openings, and ridge vents in combination with a higher temperature inside the barn than

the temperature of the outside air. This temperature difference serves to drive the hot, stale air out while bringing cooler, fresh air into the barn. This process is often assisted by wind moving over the roof as well as through wall openings of the facility itself.

Many agricultural ventilation systems are a hybrid of the two methods, with equine facilities relying heavily on wind and mechanical ventilation, though thermal buoyancy can often be found through the use of cupolas rather than ridge vents (Fabian, 2002; Wheeler, 2005). Fans are often placed on the sides of stalls along the aisle to blow in or in the eaves to blow down into the stalls and then at the end of aisle ways. The intention is to circulate and move fresh air into the stalls. Decreasing the temperature in the stall, improving convective cooling for the horse, and acting as a fly deterrent are commonly cited reasons for having the fans present, but little evidence exists as to whether fans placed to blow into the stalls achieves any of these results. In Year 1, this study sought to examine whether fans placed on the side of the stall and in the eaves of stalls affect the temperature and ammonia within the stalls and whether the airspeeds created by the fans were great enough to deter flies. During Year 2, a facility with less natural ventilation was selected and fans were placed on the doors of the stalls, however with the same goal of examining whether fans affect the temperature within the stalls and whether the fans could serve as a fly deterrent.

2.2 Materials and Methods

This study took place over two summers in Lexington, KY at two different farms. Year 1 used two different types of fans a 20 inch 3 speed box fans on their second speed setting and a 20 inch high velocity fan with a 110 degree pivoting head. Year 2 only used the 20 inch 3 speed box fans on the second setting. According to the manufacturers, the 20

inch 3 speed box fan has the capabilities to move up to 2500 CFM, while the 20 in high velocity fan has the capabilities to move up to 3460 CFM ("Floor Fan Hv 20", 2019; "Lasko 20 in. 3-Speed Box Fan," 2019). During both summers the wind primarily came from the South or Southwest (NOAA/FAA/DoD: Automated Surface Observing System (ASOS)/Automated Weather Observation System (AWOS) hourly data obtained from the Midwestern Regional Climate Center, cli-MATE (MRCC Application Tools Environment, on /CLIMATE/").

Each of the farms had a very distinct facility design for the barn, which is discussed more in section 2.2.1 and 2.2.2. However, Table 2.1 details the volume of the barns and the stalls as well as the area of the openings to allow air into and out of the barns and stalls. The barn in Year 1 was slightly larger by volume than the barn in Year 2, but had a smaller area of openings to allow air to move into the barn itself. In contrast, the stalls within Year 1 had a larger area of openings to facilitate air movement through the stalls. Overall, this indicates that the stalls were the limiting factor for ventilation in Year 2; based on the movement through the stalls.

Table 2.1 Volume of the barns and stalls from both years in cubic feet. Areas of openings in the barns and stalls from both years in square feet. Note Year 2 has 4 roof wind turbine vents reported in cubic feet per minute.

		Volume (ft ³) of Spaces	Total Opening Area (ft ²)
Year 1			
Barn		125,452	
	Door (x2)		240
	Cupola		64
	Ridge Vent		10
	Eave Opening		74.67
Stall		1,728	
	Door (x2)		64
	Grate Wall (x2)		96
	Ceiling		144
Year 2			
Barn		119,000	
	Door (x4)		400
	Windows (x10)		60
	Roof Wind Turbine Vent (x4)		*6800 cfm at 4 mph*
Stall		1,848	
	Door		32
	Ceiling Opening		48

2.2.1 Year 1

The barn chosen for year 1 of the study is designed to take advantage of natural ventilation techniques. There are eave openings serving as air inlets and three fully functional cupolas that allow stale air to escape. In addition, each stall has a grate front door and grate back door with wooden Dutch doors that can be fully opened as well as grate half walls on the aisle and one side of the stalls. The aisle had large 10 x 12 foot doors that allowed fresh air to move into the barn. All doors were kept open except for cases of bad weather when it was necessary to close the doors. In order to most accurately determine whether the fans had an impact on the temperature, ammonia, air movement, and fly control within the stalls, the two stalls chosen for the study were located along the east sidewall to limit the impact of wind increasing air exchanges in these stalls and therefore were the

stalls most susceptible to experiencing stagnant air. This barn was well ventilated naturally so the fans were augmenting the normal air movement through the facility even in these selected stalls.

Data was collected from July 7th until September 29th. The facility had ultimate control over the use of the fans and, subsequently, there were days they felt it was necessary to utilize both fans as well as days they didn't use the fans at all. Those days were excluded from the study data. The fans were placed in one of two locations: at the back eave of the stall angled toward the floor or on the stall wall facing the aisle to the right of the door. The fan on the wall either blew into the stall or blew out of the stall through the metal grate. There were four fan orientations: overhead blowing down, on the wall blowing in, on the wall blowing out, and no fan. The dates each stall experienced each fan orientation is displayed in Table 2.2. As each stall did not experience every fan orientation combination, statistical analysis was only completed for the orientations that both stalls experienced. This would be the Fan Out and Fan In and the Ceiling Fan and No Fan.

Table 2.2 Start dates for each of the treatments. Ceiling Fan refers to the fan placed in the eaves, Fan Out refers to the fan placed on the stall wall blowing out, Fan In refers to the fan on the stall wall blowing into the stall, and No Fan is when no fan was being used.

	Stall 1	Stall 2
7/7/2017	Ceiling Fan	Fan Out
7/26/2017	Fan Out	Fan In
8/3/2017	Fan In	Ceiling Fan
8/26/2017	Fan In	Fan Out
9/5/2017	Ceiling Fan	No Fan
9/20/2017	No Fan	Ceiling Fan

In addition to the fans, each stall was outfitted with two HOBO MX 2301 sensors which recorded temperature, relative humidity, and dew point every five minutes, though the temperature was the main focus of this study. The sensors were placed under the feed

bin and above the door into the aisle. The ammonia sensors (BW Honeywell GasAlert Extreme Single Gas) were placed under the feed bins in each of the stalls and recorded data every minute to examine any differences in the ammonia levels with the different fan orientations.

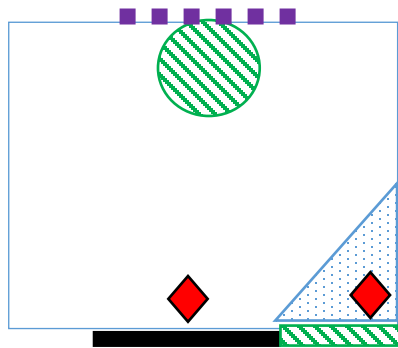


Figure 2.1 Top view of 12ft x 12 ft (3.65m x 3.65m) stall layout. Green striped figures are the possible fan locations, black rectangle is the aisle way door, purple/dotted line is the exterior door, blue spotted triangle is the feed bin, and the red diamonds are the sensors. The one sensor was placed below the feed bin and the second was above the door. Door opening 4ft x 8 ft (1.21m x 2.44m).



Figure 2.2 Overhead fan in the eaves blowing down into the stall.



Figure 2.3 Stall wall fan that blew into and out of the stall.

To determine the air speed around the stall due to the use of the fans, a hot wire anemometer (Dwyer, 471B-1) was used. Measurements were taken in 9 locations at two different heights, 4 inches (10.16 cm) and 60 inches (152.4 cm). Anemometer was oriented to measure air speed along the axis between the exterior wall and aisle wall parallel to the floor.

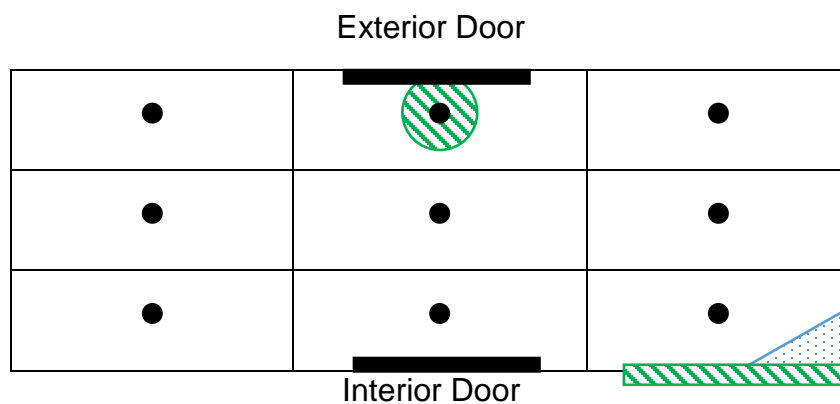


Figure 2.4 Locations of anemometer/air speed data collection. Green/striped shapes are the fans, black rectangles are doors, blue/dotted triangle is the feed bin and the black dots are the locations the air speed data was collected.

2.2.2 Year 2

The barn chosen for year 2 of the study was selected due to its lack of natural ventilation. The stalls are in the interior of the barn and the aisle way is around the outside of the stalls. There are large 10 x 10 ft doors at each end of the aisles to potentially allow fresh air to enter the barn. In addition, the stall walls are concrete block with a metal grate door. Most of the ceiling of the stall is covered by a hay loft, but a portion of it was removed to allow air movement to occur. Three stalls were chosen for the study and they were along the west side of the barn in the center of the aisle to reduce the effects of any natural ventilation that may have occurred. The fans would serve as the main source of air movement in the stalls. The main aisle way doors were left open allowing air to move down the aisle ways as wind allowed.



Figure 2.5 Layout of barn for Year 2. Aisle way along the outside of the barn with the stalls in the center of the barn and concrete block walls. The aisle way door (closed in this image) that can be opened to allow air to move down the aisle is at the far end of the image.

Data was collected from May 27, 2018 to August 25, 2018. Any days that the stalls were not in use were excluded from the study data. The fans were placed on the outside door of the stalls. During Year 2, five fan orientations were used oriented around the center of the door: upper half blowing in, lower half blowing in, upper half blowing out, lower half blowing out, and no fan. The fan locations are depicted in Figure 2.6 and Figure 2.7. The study period was broken down into ten blocks with a block lasting 5 days. Each stall experienced each orientation twice throughout the study period. Table 2.3 displays when the stalls experienced each treatment. Statistical modeling was used to analyze the data as each stall had received all treatments multiple times. The general linear model was used in SAS to determine if the treatment had a significant effect on the stall environment. It was necessary to set up a correlation between the days within a block going back three days. This means that what the stall experienced on the first day of the block was impacting what was happening in the second, third, and fourth day of the block. It was assumed there was no correlation between the blocks therefore each block was treated as an individual unit.

Table 2.3 Dates of each treatment. Low Fan Blowing In (LFBI), Low Fan Blowing Out (LFBO), Upper Fan Blowing In (UFBI), Upper Fan Blowing Out (UFBO), No Fan (NF).

	Stall 1	Stall 2	Stall 3
5/27/18 – 6/2/18	LFBO	UFBI	UFBO
6/10/18 – 6/15/18	LFBI	LFBO	UFBO
6/25/18 – 6/30/18	UFBI	LBFO	NF
7/2/18 – 7/6/18	LFBO	LFBI	UFBI
7/9/18 – 7/14/18	LFBI	UFBI	NF
7/16/18 – 7/20/18	UFBO	NF	UFBI
7/23/18 – 7/28/18	UFBO	NF	LFBI
7/30/18 – 8/3/18	NF	UFBO	LFBO
8/6/18 – 8/10/18	NF	LFBI	LFBO
8/14/18 – 8/17/18	UFBI	UFBO	LFBI



Figure 2.6 Position of fan for upper fan placements.



Figure 2.7 Position of fan for lower fan placements.

As in Year 1, each stall was outfitted with a HOBO MX 2301 to collect the temperature, relative humidity, and dew point every five minutes. Only one HOBO MX 2301 was placed in each stall and it was located in the front right hand corner in the rafters of the stalls. This location was selected so the horses would not be able to disturb them as well as to eliminate the impact of any drafts from potential air movement through the stall. The main difference for Year 2 was the decision to not test for ammonia. This decision was made because no ammonia data of interest was collected the first year and the facility being used for year 2 exhibited similar stall management.



Figure 2.8 Openings in the ceiling of the stalls and location of the temperature and relative humidity sensor in the front left corner of the ceiling of the stall (Circled in red).

The air speed around the stall was determined using a hot wire anemometer (Dwyer, 471B-1) in the same configuration as in Year 1. Nine locations around the stall were selected forming a grid and the air speed was measured at 4 in (10.16 cm) and 60 inches (152.4 cm). The anemometer was oriented to measure the air speed along the axis between the interior wall and aisle wall parallel to the floor.

2.3 Results and Discussion

2.3.1 Temperature and Ammonia Control

The first question explored with this fan study was whether the fans impacted the temperatures within the stall using the sensors placed above the interior door and the feed bin. The fan orientations compared were the overhead fan vs no fan and the stall wall fan blowing in vs the stall wall fan blowing out. In order to compare the temperature difference between the two different fan orientations, the average outside air temperature was subtracted from the average stall temperature. This was completed for both the overhead fan vs no fan and stall wall fan blowing in vs stall wall fan blowing out (figures 2.9 and 2.10). Interestingly, there was little to no difference in the temperature between the stalls no matter the fan orientation. In both instances, the temperature differences within the stalls were less than 0.5°F (0.25°C). This lack of a temperature difference between the different fan orientations suggests that the use and direction of the fans do not impact the temperature within the stalls.

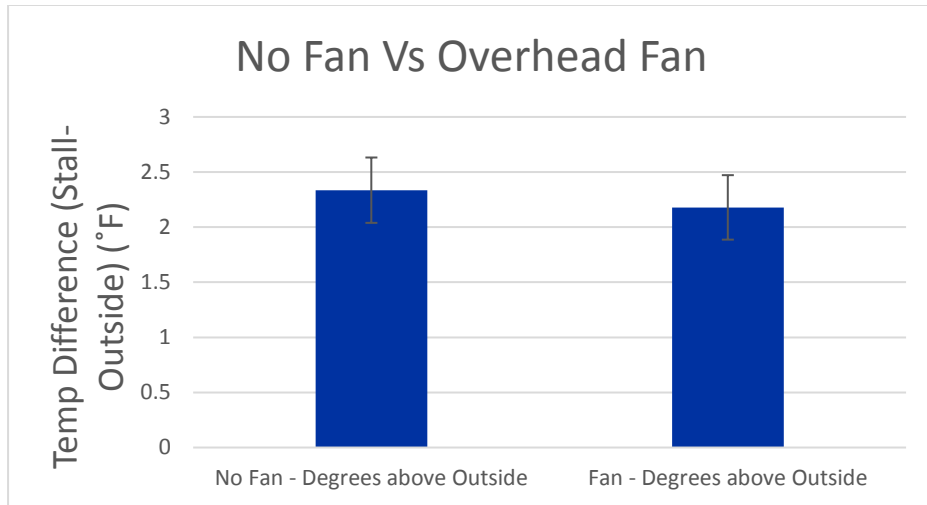


Figure 2.9 Fan orientation temperature comparison between no fan and overhead fan; temperature difference represents outside temperature subtracted from stall temperature error bars show ± 1 SD.

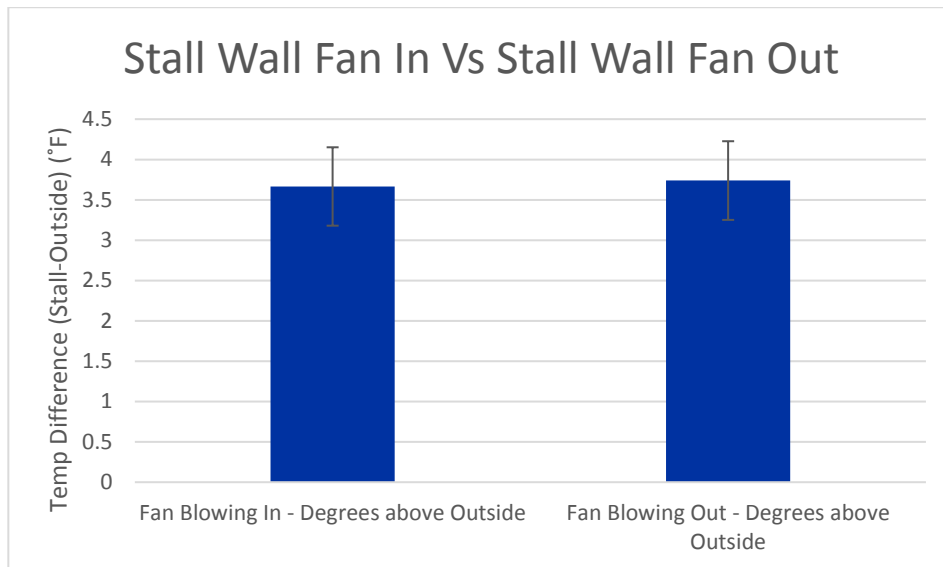


Figure 2.10 Fan orientation temperature comparison between stall with wall fan blowing in and stall wall fan blowing out; temperature difference represents outside temperature subtracted from stall temperature error bar show ± 1 SD.

In conjunction with the potential impact of the fans on temperature within the stalls, ammonia levels within the stalls was collected to examine whether the fans helped keep ammonia levels low. The ammonia levels observed were very low or below detection limits

for the majority of the time. Average ammonia concentration measured was less than 1 ppm and the maximum measured during the study was 6 ppm. This could be a result of the natural ventilation and air exchanges within the facility as well as the thorough removal of any urine saturated bedding each day.

As Year 2 was a continuation of Year 1 simply in a different facility, the same questions regarding temperature control were examined through the placement of temperature sensors along the ceiling of the stall. In this case, a linear regression model was used to examine whether the different fan treatments had an impact on the stall temperature as each stall received each treatment. As in Year 1, the fans and the different fan orientations had no significant impact on the stall temperature when compared to the outside temperature ($p\text{-value} = 0.57 > 0.05$). The model for statistical analysis accounted for the mean outside temperature as well as the wind speed. Both of the mean outside temperature and the wind speed had a significant impact on the stall temperature ($p\text{-value} < 0.001$ and $p\text{-value} = 0.01$ respectively). A comparison of the average temperature of each fan type between the outside temperature was completed. The most noticeable difference between the two years of data collection was the stall temperature difference from the outside air was slightly lower in Year 2 than the difference between the outside temperature and the stall temperature in Year 1. Except for the Upper Fan Blowing Out all the fan orientations were within $0.75\text{ }^{\circ}\text{F}$ ($0.38\text{ }^{\circ}\text{C}$) of each other. The difference in the Upper Fan Blowing Out is most likely due to the weeks that orientation was used in the stalls, with cool night time temperatures those weeks allowing the barn to remain cooler later into the day. The Year 1 and Year 2 differences could also be attributed to weather or possibly

to the barn design and material differences between the two farms.

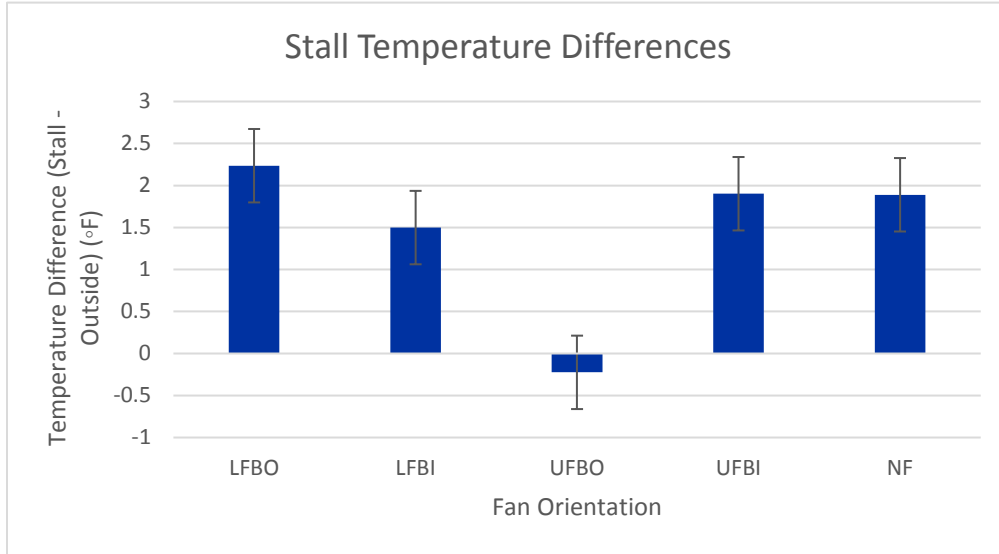


Figure 2.11 Year 2- Fan orientation temperature comparison; temperature difference represents outside temperature subtracted from stall temperature error bar show ± 1 SD.

2.3.2 Fly Control and Air Movement

The anemometer data was divided into three air speed ranges; 0-50 ft/min (0- 0.25 m/sec), 50-100 ft/min (0.25-0.51 m/sec), and over 100 ft/min (0.51 m/sec) and corresponded to stagnant air, slight air movement, and air movement, respectively. In Year 1, the overhead fan produced the largest amount of air movement across the entire stall while the wall fan blowing in produced the fastest air speeds immediately in front of the fan. The location of the highest air speed within the stall when the overhead fan was on depended greatly on the angle of the fan. If the fan was pointed down more, the air speeds were concentrated on the floor at the 4 in (10.2 cm) height, while if the fan was angled more shallowly, the air speeds were concentrated at the 60 in (152.4 cm) height (figures 2.12 and 2.13). The ability to adjust where the air movement is in the stalls based on the angle of the fan means that horse owners can decide where they want to concentrate the

air; they can choose to direct it to the floor and the bedding or across the horse's back depending on their desires. In comparison, the aisle wall fan registered stagnant air across the entire stall when the fan was blowing out and when the fan was blowing in, the air speeds were immediately in front of the fan and stagnant air was found throughout the rest of the stall. The orientation blowing air out is not ideal for cooling effect, but may still provide value for winter air movement if the goal is to not create air speed across the horse.

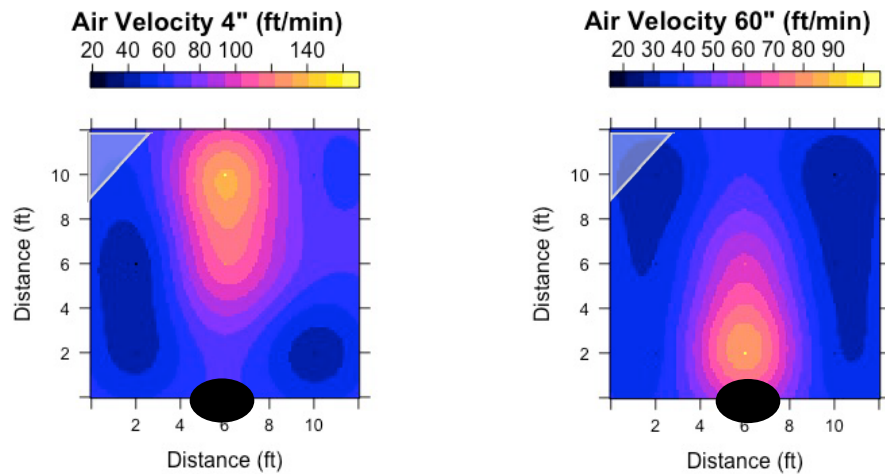


Figure 2.12 Year 1 Stall 1 Air Speed Measurements: At 4 in (10.16 cm) air speeds from overhead fan blowing down into the stall. Stall 1 was angled further down while Stall 2 was angled further out. Triangle is the feed bin and the black oval is the fan.

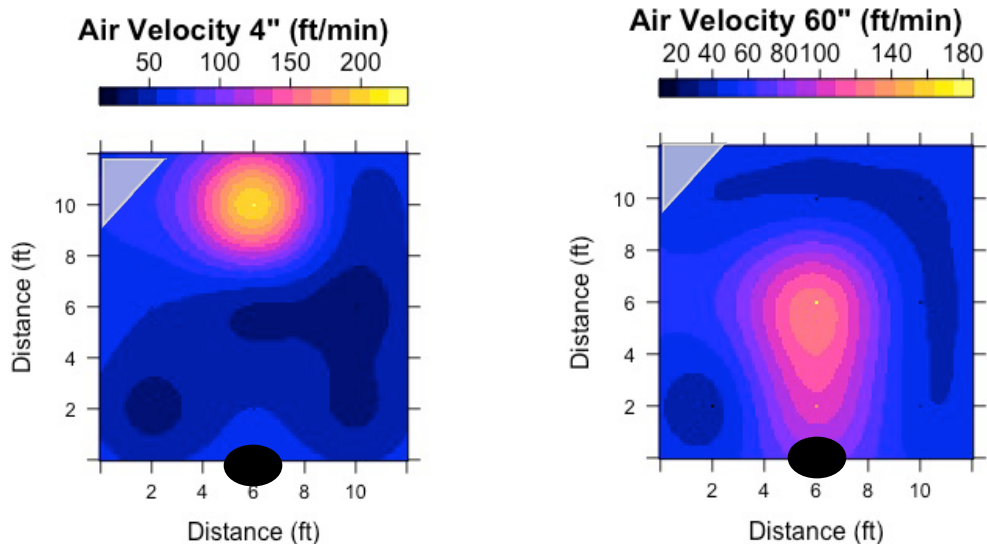


Figure 2.13 Year 1 Stall 2 Air Speed Measurements: At 60 in (152.4 cm) air speeds from overhead fan blowing down into the stall. Stall 1 was angled further down while Stall 2 was angled further out. Triangle is the feed bin and the black oval is the fan.

During Year 2, air speeds were collected using the same procedure in Year 1. Only two of the fan orientations reached air speeds above 100 ft/min (0.51 m/sec): Lower Fan Blowing In and Upper Fan Blowing Out. Those air speeds were only observed in the 60 in measurements. In all the other orientations, the air speeds in the stalls most consistently were in the stale air range. Once again, the fan being angled differently due to attaching it to the stall door appears to dictate the regions of greater the air movement in the stall. The Lower Fan Blowing In fan orientation more evenly distributed the air across the stall, but at slower air speeds. In contrast, the Upper Fan Blowing In Orientation concentrated the air movement to one side of the stall at faster air speeds, but left a spot of stale air on the opposite side. The overall lack of air movement through the stalls is an interesting development especially considering the average temperature difference between the stall temperature and outside temperature in the barn in Year 2 was not as large as the difference

in Year 1. As stated previously, the temperature differences could be contributed to a number of different factors including weather variations or facility design differences.

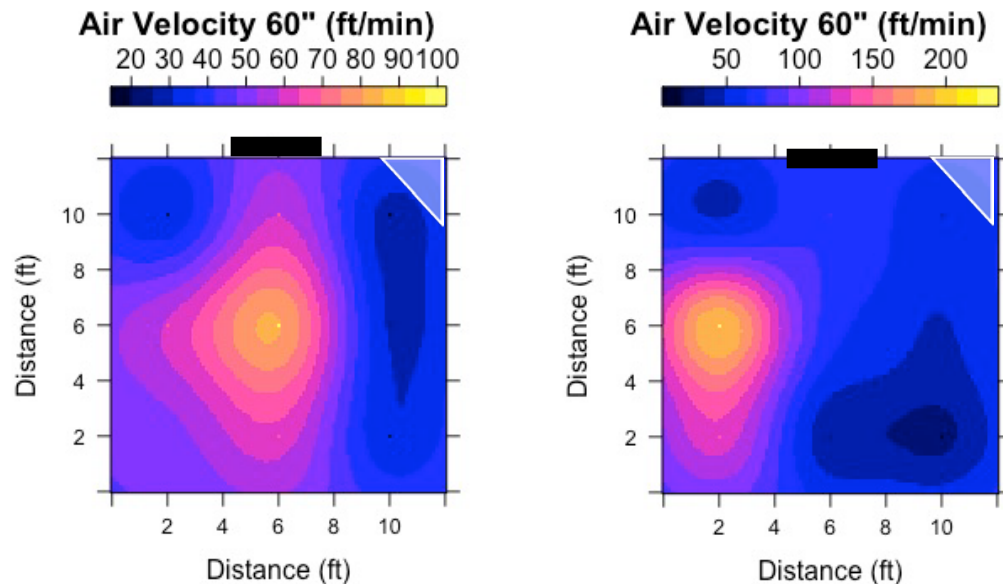


Figure 2.14 Year 2 Stall Fan Airspeeds: The left figure is the Lower Fan Blowing In air speeds measured at 60 in (152.4 cm). The right figure is the Upper Fan Blowing In air speeds measured at 60 in (152.4 cm). The position and angle of the fan determines where air movement is directed. The triangle is the feed bin location and the black rectangle is the fan location.

Air speeds for fly control need to be between 196.85 – 590.55 ft/min (1 – 3 m/sec) (Lühe, Mielenz, Schulz, Dreyer-Rendelsmann, & Kemper, 2017). During Year 1, the only fan orientation that achieved air speeds over 200 ft/min (1.01m/sec) was the fan on the stall wall when it was blowing in and this air speed was only achieved directly in front of the fan (figure 9). As in Year 1, there was only one fan orientation during Year 2 which achieved speeds over 200 ft/min (1.01 m/sec) and that was the Upper Fan Blowing In. This indicates that the fans used in this study do not produce sufficient air speeds to be used for fly control purposes. Since fly control is often referenced as a reason to run fans in stalls, this certainly raises questions about the fan requirement for sufficient air speeds and providing recommendations for horse owners about how to manage flies in their barns.

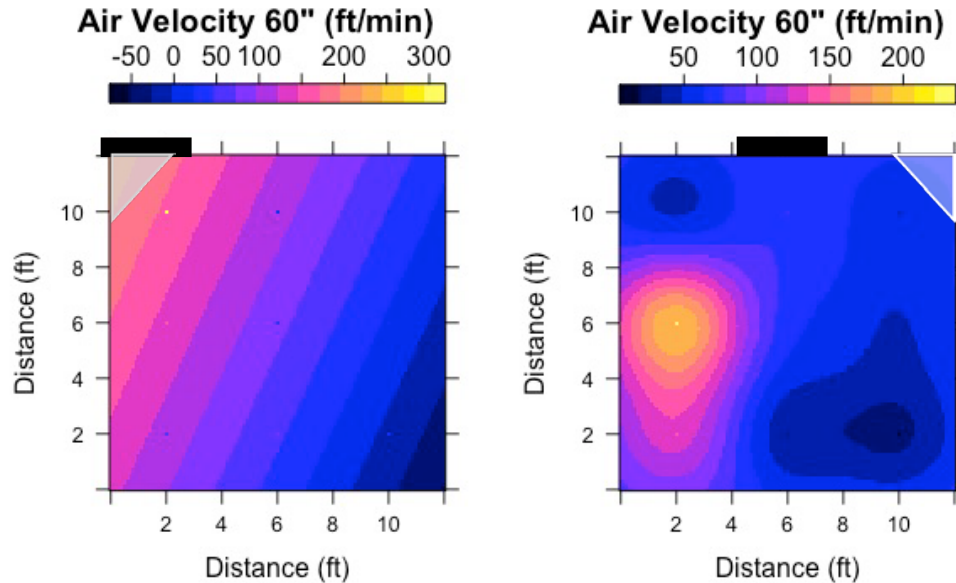


Figure 2.15 Fly Control Air Speeds: Right is 60 in (152.4 cm) air speeds form stall wall fan blowing into the stall from Year 1. Left is 60 in (152.4) air speeds from upper fan blowing in from Year 2.

2.4 Conclusion

This study examined whether different fan orientations impacted the temperature, air movement, and fly control within horse stalls in a well naturally ventilated barn and a poorly naturally ventilated barn. Through temperature and relative humidity sensors, it was shown that the fans created no discernable difference in the temperatures of the stalls in either barn. The lack of temperature difference due to the fans indicates that supplemental air is not being provided with mixing fans. Instead, designing barns appropriately to allow the natural air movement through the facility and, specifically, to the stalls would be more effective in increasing total air movement and, therefore, increase the fresh air within the barn. In addition, the different fan orientations had little impact on controlling the fly populations within the stalls. Overall, the overhead fans in Year 1 provided more air movement around the stall and, as well as, an ability to target where the air was needed, but there were still stagnant locations within the stall. Fans in Year 2 provided little to no

air movement within the stalls. The data collected from this study indicates that the design of the barn and the ability for air to move naturally through it without becoming stale can limit the need for supplemental fans in the stalls. If fans are being used for other purposes like fly control, fans with greater capacity for air speed are required. More research into how fans impact the temperatures within stalls that are in a poorly naturally ventilated barn is necessary and would allow for more recommendations on how to best provide for the health of the horse while they are in their stalls.

CHAPTER 3. AIR SPEED TO INCREASE RATE OF COOL OUT FOR HORSES AFTER INTENSE EXERCISE

3.1 Introduction

Three-day eventing and racing are two of the many equine sports which require horses to expend a tremendous amount of energy in a short amount of time resulting in massive heat production. In the immediate aftermath of running cross country or a race, it is imperative that the horse's vital signs be brought back within a resting range as quickly as possible (Guthrie & Lund, 1998). The heat produced during exercise is exacerbated by hot, humid conditions which can cause the rate of heat storage to be more than twice that of the same intensity exercise in cool, dry conditions (Lindinger, 1999). With the increase in heat storage during hot, humid conditions, it becomes even more important to cool horses following bouts of intense exercise to prevent complications due to heat stress and heat exhaustion. While horses have the ability to create incredible amounts of sweat, their low surface area to body mass ratio can inhibit their ability to effectively cool themselves (Hodgson, Davis, & McConaghy, 1994). The conventional method of cool out in the industry involve drenching horses with cool water, scraping the water off, and repeating until the horses are cool (Marlin et al., 1998). This process has been shown to cool horses out faster than walking them until they are cool which is another common method of cool out (Marlin et al., 1998).

The goal of this study was to determine whether forced air movement across the horses increased the rate of cool out after intense exercise. By increasing air speed across the skin of the horses, more heat should be lost through convection and the evaporation process and, therefore, more heat can be moved to the surface of the horse. Increasing the rate of cool out and bringing the horse's vital signs back to resting faster, ideally reduces

the risks of overheating and allows the horses to recover more quickly from the physically demanding sports in which they compete.

3.2 Literature Review

Horses regulate their own body temperature using thermoregulation to maintain appropriate body temperatures. The main methods of temperature regulation at high ambient temperatures are evaporation of water from the respiratory system and off the skin as sweat (Guthrie & Lund, 1998). These thermoregulatory techniques efficiently manage body temperature at moderate temperatures and moderate exercise intensity when approximately 80% of the energy expended is in the form of heat (Guthrie & Lund, 1998). The problem comes in when temperatures are high or exercise is at high intensity. In these instances, and especially when they are combined, the thermoregulatory mechanisms can fail and cause muscle and respiratory fatigue and ultimately lead to more extreme reactions such as heat stroke and hyperthermia. If these responses begin to happen, the best solution is to change and, ultimately, reduce the exercise performance required of the horse (Lindinger, 1999).

The majority of the early research in high temperature (30°C) and high humidity (80%) conditions focused on acclimation and adjusting competition requirements necessary to keep the horses safe. These focused on the physiological side of the discussion and were conducted by veterinarians beginning around the Atlanta Olympic Games in 1996. In the lead up to the Atlanta Olympic Games in 1996, there was concern about horses being able to safely compete in the high heat, high humidity conditions. Marlin et al. (1996) completed a study in the years immediately prior to the Atlanta Olympic Games to help gauge how non-heat acclimated horses would fair in cool conditions, hot dry conditions,

and hot humid conditions. All horses were able to complete the training regimen in the cool and hot dry conditions but only one was able to complete all the phases in the hot humid conditions. This led to the determination that measures needed to be taken during the Games to ensure the horses maintained temperatures and physiological response levels that are not considered dangerous (Marlin et al., 1996).

While Martin et al (1999) published “Physiological responses of horses to a treadmill simulated speed and endurance test in high heat and humidity before and after humid heat acclimation” after the games, it strove to quantify whether an acclimation period was necessary for the horses to be able to safely compete and work in these climate conditions. Overall, the study produced results indicating their resting body responses (right arterial temperature, oxygen uptake, and heart rate) were lower after the acclimation period and they were able to complete more of the prescribed exercise program, but all horses were still stopped while completing phase D at the 30°C and 80 % humidity level (Marlin et al., 1999). Hargreaves, Kronfield and Naylor (1999) examined the effect of climate on the physiological responses of horses in three different climates – a hot, humid climate, a hot, dry climate, and a cold dry climate. The responses examined were heart rate, rectal temperature, respiration rate, total cell volume, and packed cell volume. Regardless of acclimation, horses have higher heart rates, respiration rates, and rectal temperatures in the hot, humid climate than either of the other climates (Hargreaves, Kronfeld, & Naylor, 1999).

To further determine the necessity of an acclimation period, McCutcheon and Geor tested some short term training programs on the thermoregulatory and sweat responses. For horses that must be able to complete intense amounts of work in a short amount of time

such as eventers or racehorses, fitness is a major component of their training regime (2010). To this end, this study sought to determine if a short-term training regime would help horses better handle a hot condition that might be experienced in competition. Unlike previous studies that used an acclimation period, this study showed that a short-term training program in cool temperatures can result in a better capability to handle a hot condition (McCutcheon & Geor, 2010).

Many researchers also began to try and determine a temperature monitoring system to better determine when the conditions would overly stress the horses. The most common method for determining whether the temperature and humidity condition is safe for the horse to train or work is a Comfort Index. This index is based on adding the temperature and the relative humidity and their combined values can help determine if it is appropriate to commence normal work or if the work load needs to be lightened for the day. The Comfort Index is not an accurate system and fails to completely capture the necessary measurements for determining horse comfort in a high heat, high humidity climate (Schroter, Marlin, & Jeffcott, 1996). To more accurately determine if horses can deal with hot conditions; convection, radiation, and evaporation must be considered. Overall, an index of the climatic conditions would best serve to determine the environmental heat load and its impact on the horse. But since there is little evidence of how well horses work in high heat situations, it is difficult to determine how exercising in heat will impact the horse (Schroter & Marlin, 1995). The Wet Bulb Globe Temperature (WBGT) Index is a more effective way to quantify the heat load a horse will be experiencing. The WBGT takes into account temperature and humidity and also considers wind strength and radiation. It does

this by basing the calculations on the true psychrometric wet bulb temperature and the black globe temperature through the equation.

$$WBGT = 0.7 T_{wb} + 0.3T_g$$

In 1998, Marlin et al. completed a study to determine if there were temperature differences within the different body compartments of the horse after a prescribed exercise routine on a treadmill. The pulmonary artery temperature, tail-skin temperature, rectal temperature, muscle temperature, and heart rate and respiratory functions were all monitored; in addition, thermography was utilized. They determined that immediately following exercise there was a slight increase in muscle temperature immediately following exercise, but after the first couple of minutes the heat was redistributed and the rectal temperature began to increase. The skin temperature also increased immediately after the exercise period. There were rapid fluctuations in the pulmonary temperature which they interpreted to indicate the local skin cooling was transferred quickly to the blood stream for circulation. The skin thermography images showed large fluctuations in temperature between applications of the cold water treatment (Marlin et al., 1998).

A similar cooling study was done by G. Bradbury and K. Allen in 1994. The purpose of the study described by Bradbury and Allen was to examine the effectiveness of a fan misting system in the cool down phase after the conclusion of the endurance phase at the 1993 Young Rider Championships. They constructed an area at the event containing eleven 36" fans each with brass nozzle misting kits. A survey distributed to competitors yielded an overall positive response to the cooling area regarding the rate their horses cooled out. The data supported the rider observation further stating that the decrease in ambient air temperature in conjunction with the air movement across the horses produced a faster cool

out rate than a cool out period without air movement added (Bradbury & Allen, 1994). The most notable statement made in this study was that airspeed across the horses provided faster cooling and that the horses actively moved toward the fans rather than away. While this study didn't provide any specifics on the effectiveness of the misting and air speeds, it does suggest that they are worth investigating.

3.3 Materials and Methods

3.3.1 Study Design

The purpose of this study was to examine if air speed applied to horses after intense exercise would increase the rate of cool out. Heart rate, respiration rate, and rectal temperatures, in addition to thermal images and visual clues (nostril flaring and chest temperatures through touch) observed by the horse handler, were all used to follow the horses through their cool out process. A Vicks digital readout thermometer was used for collecting the rectal temperatures and an Acousta Deluxe Stethoscope was used for monitoring heart rate. A 42 in Bannon Tilting Belt Drive drum fan was used to provide the air speed across the horse (Table 3.1). Seven Thoroughbreds in full race training ranging in ages from 5 to 15 years with body condition scores averaging a 4-4.5 were studied. Each horse was trotted for 1 mile and then galloped in hand (not breezed or galloped at max speed) for a mile or a mile and a half by a jockey in training. There were three different treatments used for the study: no fan, fan blowing at the posterior of the horse, and fan blowing at one of the horse's lateral sides. In addition, each horse was subjected to the industry standard cool out of drenching and scraping. Five of the horses experienced each

treatment twice, while the other two only received each treatment once; both horses were removed from the study early, due to non-study related issues.

Table 3.1 Air speed in feet per minute of the 42 in Bannon Tilted Belt Drive drum fan used through the cooling study. Air speed measurements were taken with 0” being the center of the fan (COF) for the column headings. The row headings are the number of diameters from the fan and the corresponding distance measurement in inches.

Distance From Fan (Diameters(in))	Distance From The Center of Fan(COF) (inches (left of COF negative, right of COF positive))								
	-63”	-42”	-21”	-10.5”	0” COF	10.5”	21”	42”	63”
0 (0”)	15.7	15.3	811.4	1105.9	275.1	593.5	299.4	15.7	14.9
1(42”)	15.2	18.5	248.5	514.2	122.1	118.6	706.8	55.9	15.2
2 (84”)	37.8	50	495.7	480.4	112.2	91	1817	550.1	15.2
3 (126”)	125.3	387.2	384.3	288.8	80.1	118.3	82.5	203.7	414.3
5 (210”)	361.3	185.7	186.1	120.9	76.3	96.9	98.6	130	271.2
7.5 (315”)	169.7	112.2	99.2	115.2	98.8	134.1	106.4	135.1	153.7
10 (420”)	119.6	80.9	50.1	44.1	47.8	67.8	105.6	108.4	150

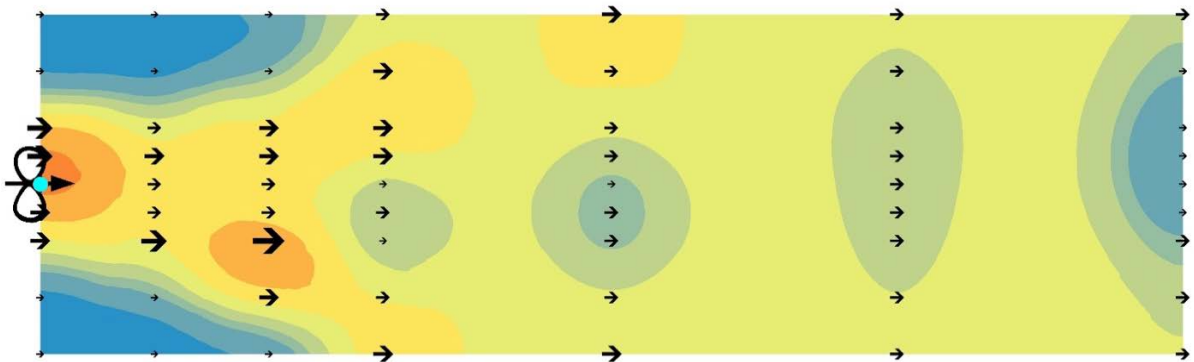


Figure 3.1 Visual representation of air speeds from Table 3.1 from the 42 in Bannon Tilted Belt Drive drum fan. Fan is located at the center left side of the figure.

3.3.2 Study Procedure

Following training the horses were walked up to the barn and returned to their stall which took approximately a minute and a half to two minutes. At no time from when they

entered the barn after training were the horses subjected to direct solar radiation and solar heat load as they were drenched, scraped, and walked inside the barn. Immediately following the removal of their tack, their heart rate, respiration rate, and rectal temperature were taken. The horses were walked a lap around the barn which was approximately 475 ft before being brought into the wash stall. Once inside the wash stall, the fan treatments were applied and the horses were drenched with water that was approximately 55°F (12.8°C) for 45 seconds and then the excess water was scraped from their bodies. The horses stood between 3 and 5 diameters away from the fan. The horses received one treatment for the entire cool out period each day they participated in the study. After the drenching, vital signs (heart rate, respiration rate, and rectal temperature) were taken as well as thermal images of various body parts. The horses were then walked a lap around the barn and once they returned to the wash stall the entire process was repeated until they were completely cooled down. Completely cooled was defined as when their heart rate dropped below 50 beats per minute, respiration rate dropped below 30 breaths per minute, and rectal temperature was below 101.5°F (38.6°C). All three of the vital sign thresholds needed to be met in order for the horses to be considered cooled down. The rectal temperature was taken with an over the counter thermometer in accordance with what most vets, barn managers, and horses owners use to determine temperature and the respiration rate and heart rate were recorded for 15 seconds and multiplied by 4 to determine the rate per minute (King & Ecker, 2019).

3.3.3 Statistical Analysis

Once all the data were collected, a slope of the cool out for each vital sign was calculated using a linear regression model. For most of the horses, at least one of the vital

signs dropped below the threshold before the other two. Due to this occurrence, two slopes were calculated for each of the vital signs; one that included all the data points collected and one where the extra data points recorded after the vital sign was considered cool were excluded from the slope calculations. Also, the rectal temperature slopes were calculated from the maximum temperature recorded. It is documented that rectal temperatures in horses will continue to increase after they finish exercising (Marlin et al., 1998). Analysis was completed using the SAS statistical software and a MANOVA or multivariate analysis of variance for each of the vital signs. The variables accounted for in the analysis were individual horse, ambient temperature, furlong speed, and treatment to determine if any were significant.

3.4 Results and Discussion

Examining the impact on heart rate for both the original slope and the adjusted slope showed that the individual horse (p-value = 0.0003) and outside ambient temperature (p-value <0.0001) had a significant effect on the cooling rate, while the furlong speed (p-value = 0.52) did not have a significance impact. The treatment p-value for the adjusted slope was 0.44 in contrast to the original slope for heart rate which was 0.11. For respiration rate, in the original slope analysis only the individual horse (p-value = 0.0019) and the outside ambient temperature (p-value = 0.033) had a significant impact on the cooling rate of the horses. Individual horse (p-value = 0.036), outside ambient temperature (p-value = 0.023), and furlong speed (p-value = 0.039) all were significant for the adjusted slope of respiration rate, while the p-value for the treatment was 0.17. Finally for rectal temperature, the individual horse was the only factor significant for both the original slope and the adjusted slope (0.0001 for both). The p-value for the original slope was 0.108 for rectal temperature.

Throughout the cooling process, the horse handler was asked when they thought the horses were cool based on their normal process of checking the horses breathing rate and how cool the horses' chests felt. On average, the horse handler stated the horse was cool at least two drenching cycles before all three vital signs were considered cool by the thresholds established for the study. One of the other pieces of information examined was the average number of times the horses were drenched for each of the treatment types. They were drenched on average more times for the no fan treatment than when being drenched in front of the fan, but they tended to be drenched less times during the back fan treatment than the side fan treatment.

Table 3.2 Average number of times horses were drenched and average rate of cool out for the original and adjusted slopes. Format is Mean \pm Standard Deviation. * indicates p-value of 0.1, ** indicates p-value of 0.05.

	No Fan	Fan Side	Fan Back
Average Number of Times Drenched	5.25 \pm 1.9	5 \pm 1.7	4.9 \pm 1.9
Average Original Slope of Heart Rate Cool Out*	-4.18 \pm 1.52	-4.96 \pm 2.65	-5.86 \pm 3.61
Average Adjusted Slope of Heart Rate Cool Out	-8.29 \pm 5.11	-8.97 \pm 5.89	-10.68 \pm 6.11
Average Original Slope of Respiration Rate Cool Out	-11.54 \pm 6.13	-11.42 \pm 5.17	-11.77 \pm 5.24
Average Adjusted Slope of Respiration Rate Cool Out*	-21.05 \pm 11.66	-15.25 \pm 8.33	-16.81 \pm 10.23
Average Original Slope of Rectal Temperature Cool Out*	-0.28 \pm 0.17	-0.37 \pm 0.21	-0.33 \pm 0.14
Average Adjusted Slope of Rectal Temperature Cool Out	-0.28 \pm 0.17	-0.40 \pm 0.34	-0.35 \pm 0.167

While the p-value varied some between the adjusted slope and the original slope for all of the vital signs, unfortunately, none of the p-values for the treatments were statistically significant with a significance level of 0.05 or less. It should be noted that all of the vital signs were trending towards the treatments having a significant effect on the rate of cool out for the horses with a p-value of 0.1. This trend towards significance is important

considering the small sample size of the study which is difficult to avoid while doing equine research. Additionally, the horses only spent about a third of their cool out period in front of the fan during the back and side fan treatments. The owners of the horses dictated a cool-out protocol where the horses were walked frequently throughout the cool out period so as not to deviate too far from the horses' normal cool out process of walking until they were demeaned cool and then receiving a bath. This is a common process for the racing industry, but other equestrian sports such as eventing prefer to drench and scrape horses until they are cool with minimal walking breaks. In addition, the entire experiment added an element of stress to the horses they would not normally experience. Their normal routine was changed as little as possible, but the fan itself was a potentially stressor. Most of the horses seemed to enjoy standing in front of the fan through their cool out, though at least one of the horses was more stressed with the addition of the fan and the change to their routine. It was evident the horse was stressed to due to an elevated heart rate. The horse's heart rate dropped close to 50 beats per minute and then went back up while all of the other vital signs stayed low. After the first two days of being included in the study, the horse's heart rate stayed below the threshold considered for resting heart rate as he adjusted to the new cool out process.

3.5 Conclusion

The purpose of this study was to examine whether or not adding forced air movement across the horses would impact, ideally increase, the rate of cool out of horses after intense exercise. While the data was not statistically significant, it did show that there were trends toward an increased rate of cooling with the addition of the air movement across the horses. Overall, the fan placed behind the horses and blowing forward increased the rate of cool

out more than the side fan did as indicated by the average number of times the horses were drenched for each treatment. If further work were to be done, a larger sample size and more time spent in front of the fan with less walking would be the main changes to the study as it was performed initially. In addition to the vital signs that were recorded, thermal images of the horses throughout the cooling process were taken. These images are still being analyzed to ensure that all the useful and important information in them can be properly utilized. One notable trend that has been seen is the difference in skin temperature of the horses on their body cavity between the side exposed to the fan compared to the side not exposed to the fan during the side fan treatment. The analysis of the thermal images is planned for summer of 2019 with a publication likely to follow.

CHAPTER 4. CHARACTERIZATION OF INDOOR ARENAS THROUGH A SURVEY AND SITE VISITS

The equine industry contributes a total of \$122 billion dollars a year to the United States' economy and this indicates that large amounts of money is spent on the facilities the horses utilize (American Horse Council Foundation, 2018b). Not only are farms building stables for the horses to live in, but facilities are required to train and work horses (Kidd et al., 1997). Many of these facilities have outdoor arenas, but inclement weather can inhibit the ability to train in the outdoor arenas so indoor arenas are built. An indoor arena affords trainers and riders the ability to keep their horses exercising and training even in inclement weather. These facilities potentially receive high amount of use and yet there is no information on common characteristics, environmental control features, or potential health hazards within these spaces.

Due to the lack of research into indoor arenas, a survey was designed and distributed to help begin to identify concerns. This study had two components: a written online portion to gather basic information from the facility owners or managers and a site visit component intended to build a framework within which future research could be completed. The main objectives of the survey were to begin to characterize building dimensions, footing, and indoor climate, define typical maintenance procedures and practices, and explore the potential health issues created in these facilities due to dust, moisture, and ventilation design.

4.1 Literature Review

Publications of design recommendations and considerations has been centered in extension publications and, primarily, regarding the barns or stables where horses live. Clemson University (1991), the Alberta Agriculture, Food, and Rural Development (1997),

Pennsylvania State University (2002), and Iowa State University (2005) are the most notable institutes to publish information on the best design practices. Clemson University's booklet focuses on different plans for stables based on the number of stalls required ("Horse Barns and Equipment," 1991). In contrast, the Alberta Agriculture, Food and Rural Development discussed many aspects of the horse facilities including barn design, fencing considerations, feed containers, and arenas (Kidd et al., 1997). The *Horse Facilities Handbook* by Eileen Wheeler is also a more comprehensive discussion of equine facilities. Finally, the Pennsylvania State University extension publication focus entirely on the ventilation and the designs that facilitate appropriate and necessary ventilation (Fabian, 2002). The common theme among mentioned publications is the lack of information about indoor arenas. The two publications that discuss them, *Horse Handling Facilities* and *Horse Facilities Handbook*, briefly mention them and provide cursory recommendations about dimension, construction materials, and suggest using principles similar to the ones used to build outdoor arenas (Kidd et al., 1997; Wheeler, 2005).

In 2014 and 2015, the International Federation for Equestrian Sports (Fédération Équestre Internationale or FEI) published the *Equestrian Surfaces – A Guide* and the *Equine Surfaces White Paper*, respectively. Both publications focus on important considerations for arena footing, such as the biomechanics of footfall of the horses, the differences in footing types, and how the usage of the arena impacts all aspects of the arena design and building process (Hobbs et al., 2015; Lonnell & Hernlund, 2014). The *Equine Surfaces White Paper* recognizes that many environmental factors must be taken into consideration, such as the potential issues due to the presence of organic materials and the footing creating dust, and acknowledges that more research is necessary to fully understand

the potential impacts. Spending substantial amounts of time within indoor arenas has been linked to higher occurrences of self-reported respiratory conditions in equine instructors (Kollar, Swinker, Swinker, & Irlbeck, 2005). The percentage of instructors who reported incidence of bronchitis symptoms was actually higher for instructors considered as indoor workers than those who reported to be smokers (Kollar et al., 2005).

The connection between the exposure to inhalable dust and immune response has also been documented in the literature. Endotoxins and $\beta(1\rightarrow3)$ glucans have been reported within the horse stables in amounts higher than normal recommended exposure levels, but little research has been conducted on the exposure within indoor arenas (Elfman, Riihimäki, Pringle, & Wålinder, 2009; Samadi et al., 2009). In addition, the increase in ventilation rates within stables has been shown to decrease the inflammatory markers present within horse stable workers in conjunction with a reduction in overall allergens, such as ammonia and ultrafine particles (Wålinder et al., 2011). Kentucky Equine Research published a short article detailing that arena dust may have an impact on the lung health of horses (Kentucky Equine Research Staff, 2017). This article cited a 2017 study conducted in Germany examining the changes in dust dispersed in indoor arenas with the addition of horses working in the arena. Overall, the addition of a working horse substantially increased the amount of dust present in the indoor arena environment (Lühe et al., 2017). The research conducted thus far states that dust within horse facilities is a potential hazard to human and horse health and indicates a need for further research into the impacts of dust and other exposures within indoor arenas.

4.2 Materials and Methods

4.2.1 Study Design – Survey

In order to best capture the varied experiences of those in the horse industry, the online survey was designed to have different questions for people who owned, managed, or rode regularly at facilities with indoor arenas. The survey was completely voluntary, and the participants could opt out of the survey at any time. If the participant was under 18 or did not ride in an indoor arena on a regular basis, they were unable to participate. This was done to ensure that all answers obtained were from individuals who could provide the most useful information.

The survey was constructed using the Qualtrics survey software that is used for all official University of Kentucky surveys and what the Internal Review Board encourages researchers to use. Using this software allowed for the questions to be presented to the participant based off the answers to the initial questions, such as do you own, manage, or ride in a facility with an indoor arena. For instance, riders were asked questions regarding their riding habits and general questions about the farm where they ride, the arena design and size, the footing, and the arena environment. Managers answered similar questions to the riders, but also included questions about the arena construction, its orientation, eave and ridge height, arena maintenance and the farm occupancy. Finally, the owners were asked questions regarding the cost to build and operate the indoor arena in addition to all the questions the riders and managers were asked. All three of the groups were also asked a series of health-related questions to begin to identify any health concerns in the horses and humans that use the arena. The survey in its entirety can be found in Appendix B.

Distribution of the survey was done through multiple different news outlets and organizations. The organizations shared them on their websites, in their publications, and on their social media pages depending on how they reach their members. The goal with the selection of the various organizations and media outlets was to reach as many people as possible from a multitude of different disciplines. The organizations can be found in Table 4.1. There were other organizations and individuals that chose to share the survey on their own, but the ones who wrote letters of intent that were filed on the IRB are listed.

Table 4.1 The organizations listed on the IRB that shared the survey.

United States Equestrian Federation	Mid-south Eventing and Dressage Association
Paulick Report	Eventing Nation
Jumper Nation	American Horse Publications
UK Equine Programs	Bluegrass Equine Digest
Appaloosa Horse Club	Kentucky Horse Council

The survey was open for a 12 week period from the beginning of May 2018 to the end of July 2018. In this time, 455 people took the survey from 9 different countries. Of the 455 participants, 339 results were used for the analysis as they had completed 80% or more of the survey. Demographics for the survey participants are included in Table 4.2. The survey consisted of 154 questions, though some questions were specifically for owners, managers, or riders, so no one answered all of the questions. Questions were either multiple choice, select all that apply, or open-ended questions with some of the multiple choice questions having an option for a text answer. All analysis was completed on the aggregate data and no one individual or facility could be identified from the survey questions and results. The goal of the study is to characterize and identify issues within indoor arenas not to damage the reputation of any facility or individual.

Table 4.2 Demographics of the survey participants.

Age N=352	18-24	20.7%
	25-34	29%
	35-44	18.1%
	45-54	13.6%
	55-64	12.8%
	65+	5.1%
	Choose Not to Answer	0.5%
Gender N=352	Male	4.3%
	Female	95.4%
	Choose Not to Answer	0.28%
Race/Ethnicity N=353	American Indian or Alaska Native	0.57%
	Asian	0.85%
	Black or African American	0.57%
	Hispanic	0.57%
	Other	0.57%
	White	93.5%
	Choose Not to Answer	3.4%
Own, Manage or Ride in a Facility with an Indoor Arena N=353	Own	13.3%
	Manage	10.2%
	Ride	76.5%

4.2.2 Study Design – Site Visit

In addition to the online survey, this study includes visits to 30-50 farms in and around central Kentucky. These facilities were identified by the researcher with the help of the University of Kentucky Equine Extension Specialist, Dr. Bob Coleman. Initially over 100 farms were identified as having indoor arenas, but the list was narrowed to arenas that had unique designs, would provide beneficial data for the study, or were known to be potentially problematic or have issues. As with the survey, the site visit data was be examined as the aggregate data and not the individual facilities. In accordance with the IRB protocol, the farms were assigned random identifying numbers in order to de-identify the farms and only the IRB approved members of the research team would have access to the list of farms. Each farm was required to sign an informed consent form which detailed

all the information of the study and that participating in the study presented a minimal risk to the farm.

Not only did visits include collecting data within the indoor arena, but they also included interviews with trainers, managers, and riders who use the facility. Those interviewed were asked questions regarding the age of the arena, if any updates had been completed, general information about the farm such as number of horses, how much use the arena gets, arena maintenance, the arena environment, whether any health impacts had been noticed in the people or horses, and for any information they felt was important for the research team to know. These interviews augmented the collection of measurements regarding temperature, relative humidity, light distribution, and air movement. All of the measurements were taken at 15 different locations around the arena which can be seen in Figure 4.1. Footing samples and depth measurements were taken at 9 locations around the arena. Footing samples were stored in individual plastic bags and placed in 34 °F (1.1°C) cool storage.

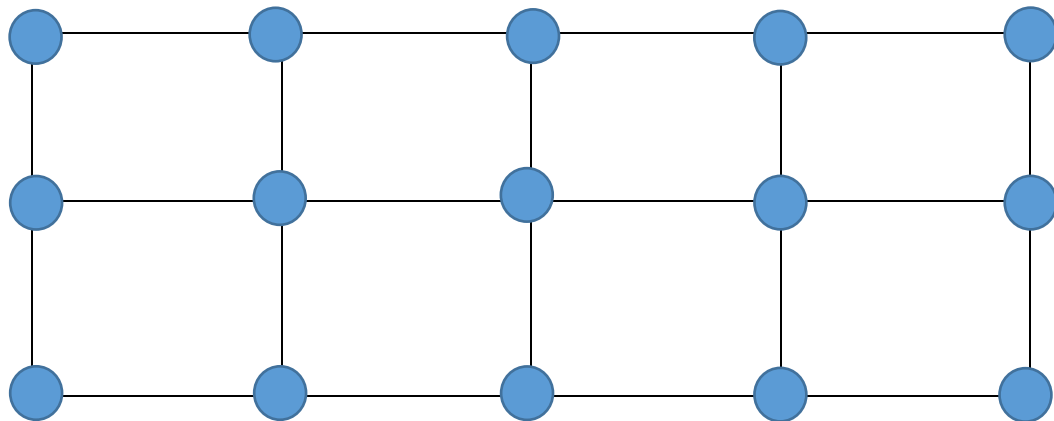


Figure 4.1 The points around the arena where the measurements, excluding footing samples, were collected.

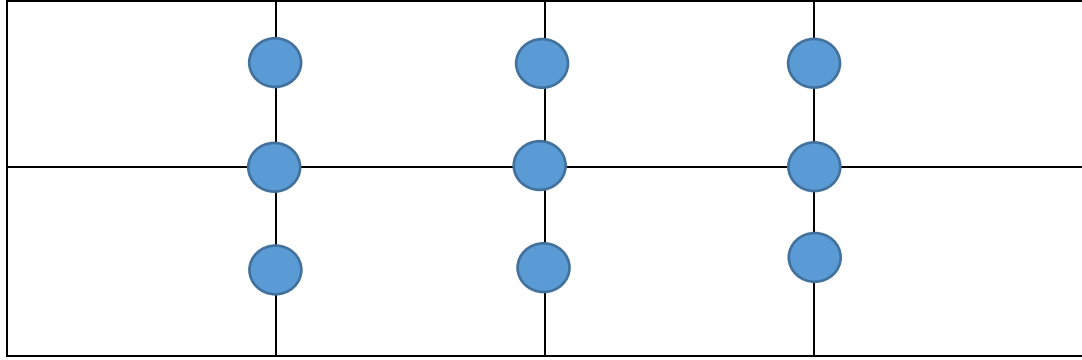


Figure 4.2 The locations around the arena where the footing depth measurements and the footing samples were collected.

4.2.3 Statistical Analysis

Analysis of the data was completed using the JMP software. Based off of the topics and questions asked of the participants, information to gather from the data was determined. The questions asked of the survey data were designed to examine the effect of characteristics such as age, region, cost to build the arena, and environmental concerns on traits such as lighting, footing type, number of windows, size of the arena, and the definition of an indoor arena.

Due to the large and varied distributions of the some of the answers, it was necessary to recode them. For instance, the question regarding which state the participants owned, managed, or rode in an indoor arena were recoded into regions of the United States. The regions used were the Northeast, South, Midwest, Kentucky, Southwest, West, and outside the US. Kentucky was left as its own region as it had the largest number of participants and was the location of most interest in conjunction with the site visits. Other questions recoded included the disciplines the participants rode, arena construction materials, arena size, footing contents, environmental concerns, and footing treatment methods. All the recoding information can be found in Appendix 5.

The most notable recoding was for the footing within the indoor arenas. The footing was divided into two different categories: the primary component and any secondary components found in the footing. Primary components included sand, waxed sand, washed sand, crushed rock, dirt, dirt and sand and wood chip, while the secondary components were clay, crushed rock, fiber, fiber and rubber, none, rubber, and wood chip. Crushed rock and wood chip were included in both categories because there were arenas that indicated the only footing found was crushed rock or wood chip, but there were also arenas which indicated it was included with other footing types such as sand or dirt.

Once the recoding was complete, contingency tables examining the relationships between answers to different questions were completed. By examining the relationships between the answers, trends present within the data can be explored within the different categories. For example, the relationship between the age of an indoor arena and the type of lighting present could be examined to determine whether the age of the arena had any effect on the lighting used in the facility. As all the data was categorical, all plots created were mosaic plots and not scatter plots as scatter plots are used for continuous data. P-values were included in the contingency tables and p-values less than 0.05 were considered significant, while p-values between 0.1 and 0.05 were considered trending towards significant.

The analysis of the site visit data was completed using pie charts to examine the percentages of different aspects of the indoor arenas. Currently, only 25 arenas have been evaluated so the analysis will be completed on those with plans to visit more facilities in the future. Future publications will include all facilities visited. The topics analyzed included whether the footing and building dimensions were the same, the square footage,

the main disciplines, and the different footing types. Due to the small number of arenas visited currently, it was unrealistic to complete statistical analysis using the same techniques as the survey. Though, the ultimate goal will be to examine both the survey data and the site visit data using the same software and to compare the trends amongst the two data sets.

4.3 Results and Discussion

4.3.1 Survey

4.3.1.1 Age of Arena

Owners and managers reported the age of the arena. This was used to determine the relationship between the age and the lighting, the primary component of the footing, any secondary components of the footing, and the square footage or size of the arena. By combining the answers of the owners and managers, the sample size averaged 83 answers for the questions regarding the age of the arena. The p-value for the likelihood ratio of the relationship between age and the lighting within the indoor arena was 0.08 which indicates a trend towards significance (n=81, DF=6). Metal halide/high pressure sodium lights and fluorescent lights were most prevalent in arenas older than 5 years. Most interestingly, LED lights were seen most in the 1-5 year old arenas and the arenas over 15 years old. One reason this could be is that the older arenas are being retrofitted with newer, more energy efficient lights as the metal halide or high pressure sodium or fluorescent lights died or became too difficult to maintain. While LED lights are more expensive to install than fluorescent lights, they are ultimately more economical considering maintenance and operating costs.

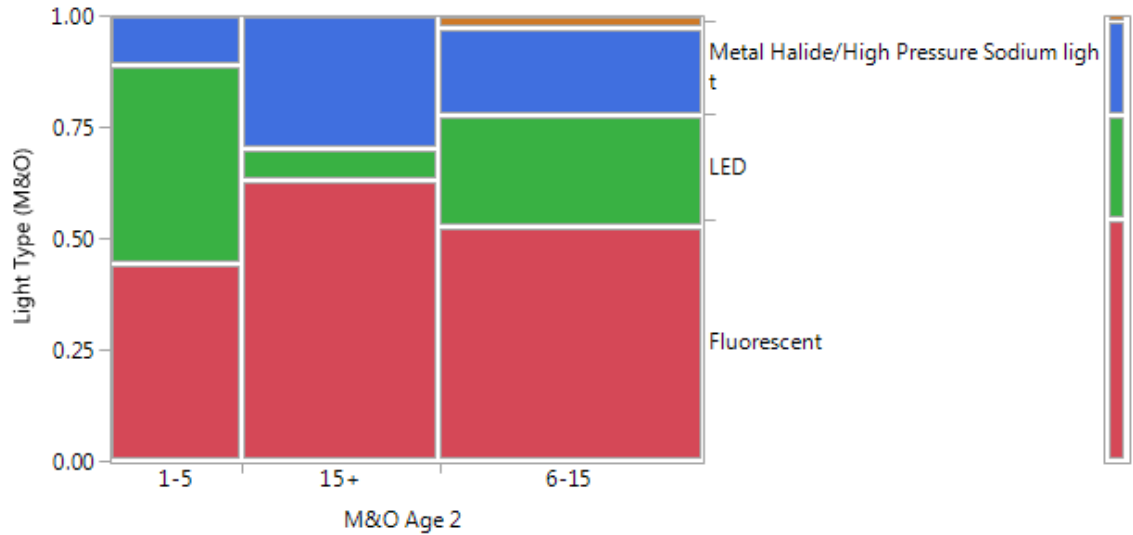


Figure 4.3 Mosaic plot for the relationship between the age of the arena and the lighting type.

Examining the primary and secondary footing components did not yield a significant relationship between the age of the indoor arena and the footing ($n=82$, $DF=12$ and $n=82$, $DF=12$, respectively). The only notable trend was the primary component of the footing which found that no arenas under 5 years old contained any primary footing component other than sand, while the arenas that were 6-15 years or older than 15 years had the most variability in the primary footing component. The most common secondary footing type was none meaning that there wasn't anything added to the primary footing component while the second most common secondary footing component was fiber. The arenas under 5 years old did have a higher amount of fiber as a secondary footing component than the 6-15 years old or older than 15 years arenas.

Finally, the last relationship examined with the age of the arena was the square footage of the arena. The square footage was broken down in less than 10,000 square foot, 10,000-15,000 sq ft, and over 15,000 sq ft. Similar to the relationship with the lighting, the relationship between the age of the arena and the size of the arena were trending towards

significance (p-value = 0.08, n=83, DF=4). The arenas that were over 5 years old were more likely to be less than 10,000 sq ft, the arenas between 6-15 years old were more likely to be 10,000 – 15,000 sq ft or less than 10,000 sq ft, and then the newer arenas, those under 5 years old, were more likely to be over 15,000 sq ft. This indicates a trend that the more recently the arena was built, the larger it tends to be.

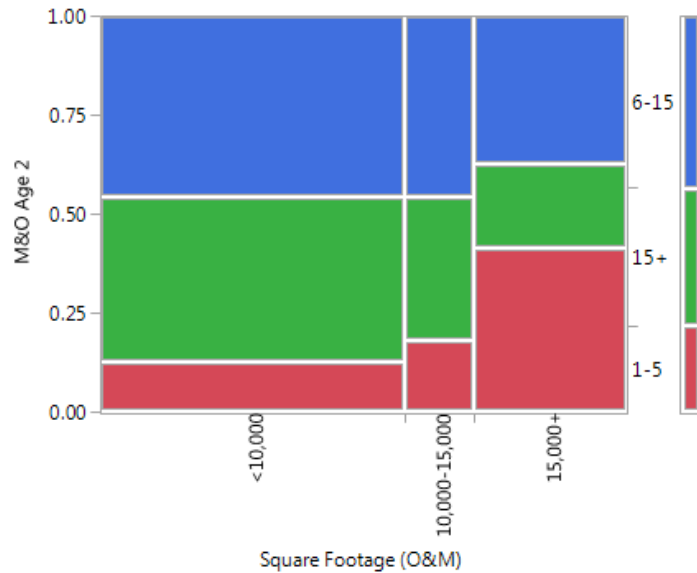


Figure 4.4 Mosaic plot for the relationship between the age of the arena and the square footage of the indoor arena.

4.3.1.2 Cost to Build the Arena

Unlike the questions regarding the age of the arena, only the owners were asked the cost to build the arena and this led to a reduction in the number of answers to the question of cost as only 47 of the participants were owners of facilities with an indoor arena. Interestingly, the cost to build the arena did not have a significant relationship with the lighting type, either the primary or secondary footing component, or the main discipline of the farm. This is potentially due a lack of information because of the relatively small sample size or because there are no trends associated with the cost of the arena and the examined

arena traits. As expected though, the square footage of the arena and the cost to build the arena was a significant relationship (p-value=0.01, n=47, DF=6). The most expensive arenas which were over \$1,000,000 were also some of the largest, though there were arenas that were over 15,000 sq ft that also cost between \$100,000, and \$250,000 to build. This indicates that the most expensive arenas incurred costs in other areas such as being wider rather than longer, using more expensive building materials, having the ability to heat or cool the space, or something else entirely. The most significant trend that was seen is that most of the arenas built were less than 10,000 sq ft and cost less than \$250,000 to build. This trend could be indicative of the owners wanting to have a way to work horses during inclement weather, but not needing a large indoor arena or not having or wanting to invest the resources on an indoor facility.

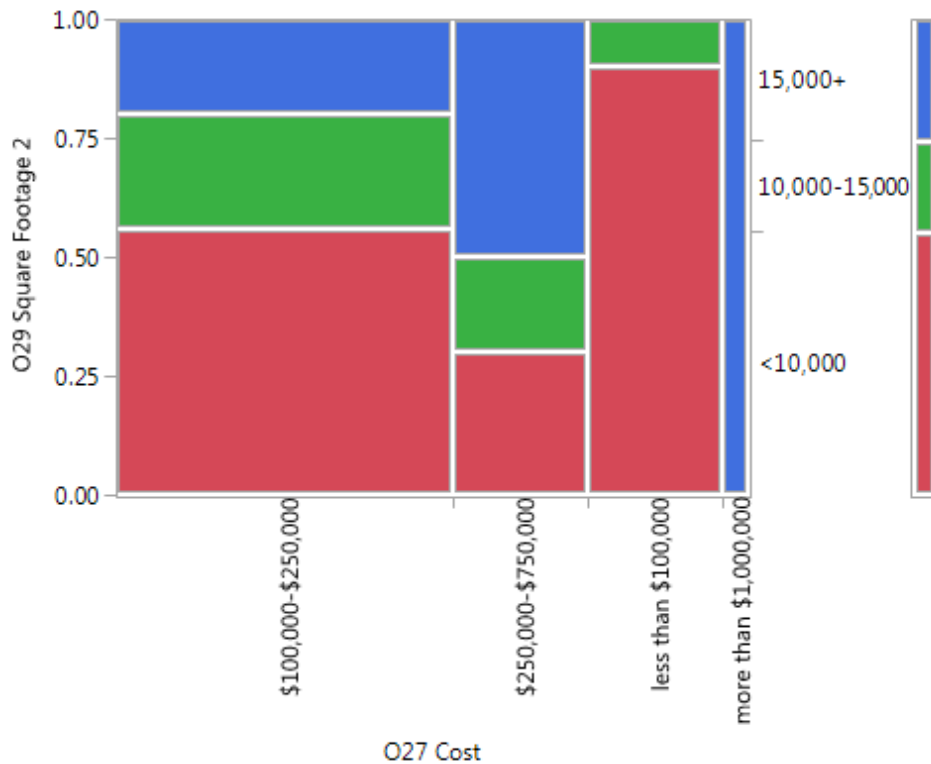


Figure 4.5 Mosaic plot of the relationship between the cost to build the arena and the square footage of the arena.

4.3.1.3 Region

The relationship of the region where the indoor arena was located combined the answers from questions asked of all three groups: the owners, managers, and riders, leading to 339 participants included in this analysis. The number of lights in the indoor arena and the primary footing component were not significant, but also didn't display any interesting or notable tendencies with the data. However, the relationship between the region and the secondary footing component was highly significant (p-value <0.001, n=324, DF=36). The most prevalent answer was no secondary components in Kentucky, the Northeast, and outside the US. In comparison, fiber was the most common additive in the South, but with an almost equal amounts of arenas in the South and Northeast containing fiber in their footing. When coupled with the significance of the relationship between the regions and the main disciplines of the farms (p-value = 0.01, n=336, DF=24), this trend of secondary footing components is even more interesting. Dressage was most prevalent in the Midwest region, but the highest number of farms were classified as a flat emphasis and a fence and flat emphasis. Kentucky had the highest percentage of eventing farms over the other disciplines. The Northeast, the South, and outside the US actually contained the highest numbers of eventing farms, but both the South and the Northeast had a fairly even distribution of eventing farms, flat emphasis, and flat and fence emphasis. Outside of the US only differed in that flat emphasis was not as large a percentage of the disciplines reported.

Examining the relationship between the discipline and the secondary footing indicates that disciplines with a jumping or jumping and flat emphasis have a higher prevalence of fiber in the footing. Fiber is added to footing to increase shear strength,

stability, and to reduce maintenance requirements while increasing the grip of the footing in combination with a sand footing (Lonnell & Hernlund, 2014). The addition of fiber is a common occurrence for the sport horse disciplines (show jumping, dressage, and eventing), but the effect on the horses has not been greatly studied (Lonnell & Hernlund, 2014). Fiber as a secondary footing component is more prevalent in the South and Northeast and the disciplines that tend to use fiber in their footing are more prevalent in those regions of the United States as well.

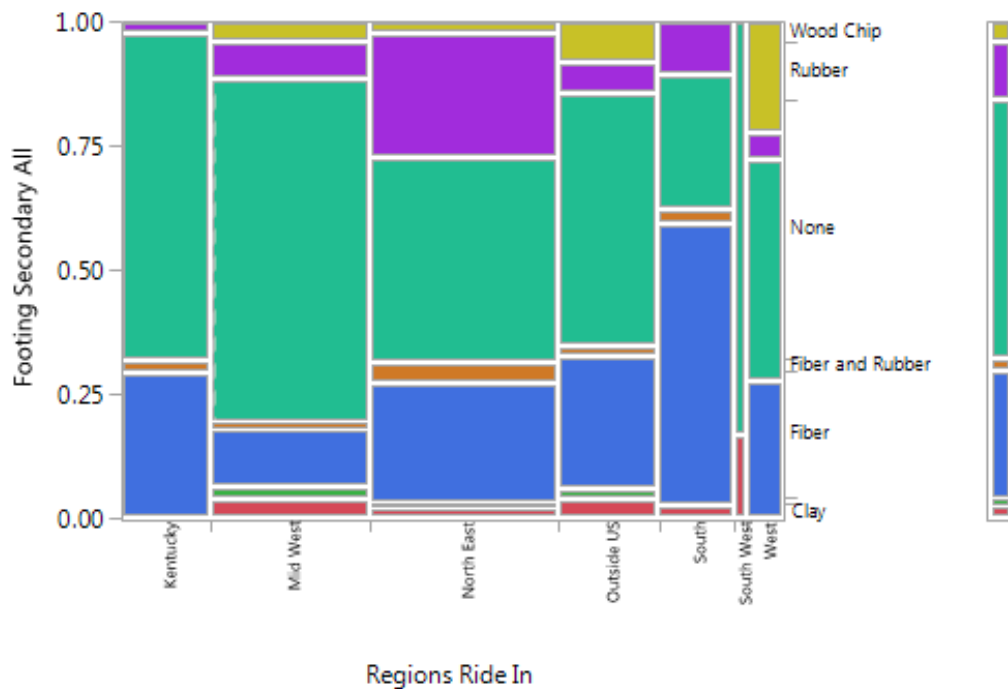


Figure 4.6 Mosaic plot of the relationship between the region participants ride in/where the arena is located and the secondary footing component.

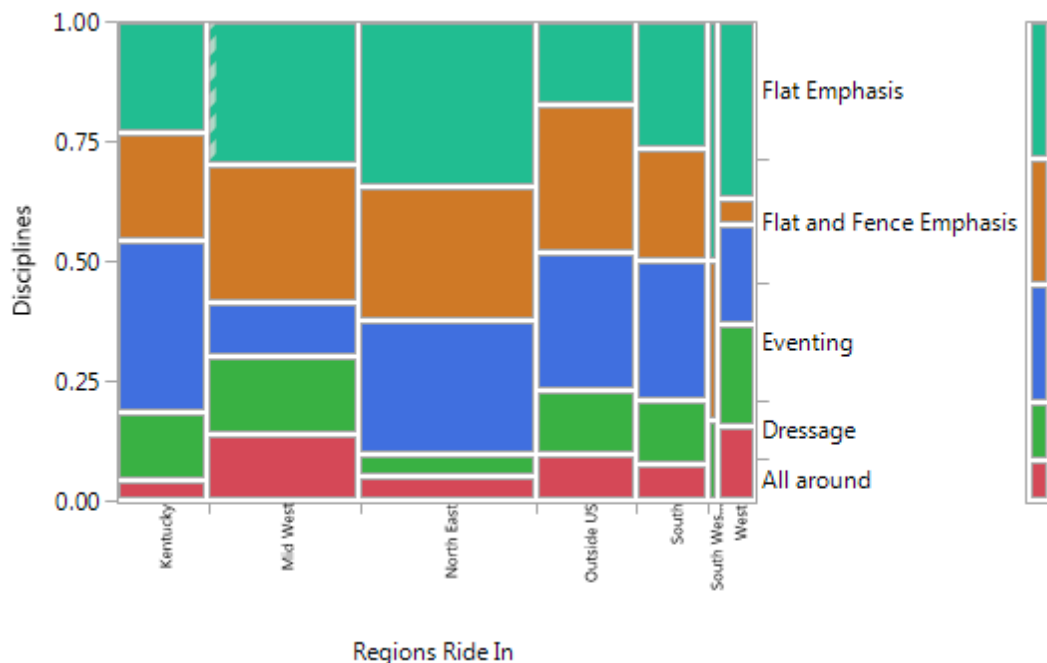


Figure 4.7 Mosaic plot of the regions participants ride in/where the arena is located and the discipline the participants ride.

While the relationship between the region and the square footage of the arenas was not significant, there was an interesting trend in the data (n=322, DF=12). Overall, the arenas tended to be either less than 10,000 sq ft or more than 15,000 sq ft. There were some that were in the range from 10,000-15,000, but it was a much smaller percentage. In addition to the square footage relationship, whether the indoor arena was attached to the barn was not significant though Kentucky and the Midwest trended towards more facilities being attached, while the Northeast trended towards more facilities not being attached. Arenas and barns were considered attached if the horses could walk from one location to the other without going outside. Both of these relationships warrant more research in an effort to understand why they are not significant.

The number of windows in the facility were also examined in relation to the region the arena was located and there was a significant association between the two (p-value =

0.005, n=324, DF=18)). Facilities in Kentucky, the Northeast, the Midwest, the West, and outside the US all tended not to have windows. Having fewer than 5 windows was the second most frequent answer for all of the afore mentioned regions except for the West. Understandably, the South tended to have windows, but was pretty evenly distributed between less than 5 windows, 5-10 windows, and more than 10 windows. Considering that the weather in the South tends to be hotter and more humid than other regions, windows that can facilitate air movement may be more regularly included in indoor arena designs.

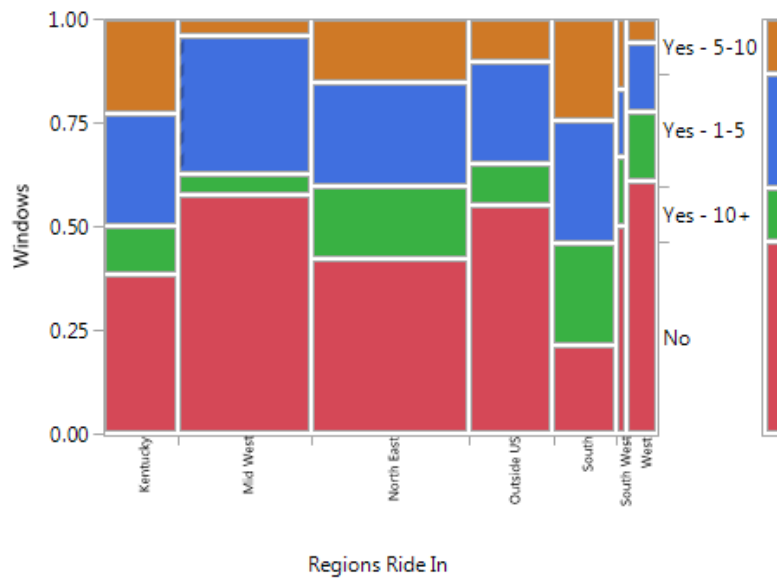


Figure 4.8 Mosaic plot of the relationship between the number of windows in the indoor arena and the regions the participants ride in/where the indoor arena is located.

The final relationship examined for the regions where the indoor arenas were located was what the participants of the survey considered the definition of an indoor arena. This was also a significant relationship (p-value = 0.0045, n=341, DF=24). For Kentucky, the Northeast, the Midwest, and outside the US, the definition of an indoor arena was ‘four walls and a roof’ for the majority of participants, but for the South, Southwest, and West, four walls and a roof was closely matched by or less than ‘any configuration of walls and

a roof.’ Overall the third most common answer was any space that can be used in all weather. The division between the more northern states and the southern states is quite striking for this question. Areas of the United States which experience colder and more inclement weather tended towards needing four walls and a roof to be considered an indoor arena, while the regions that require more air movement due to hotter conditions or which receive less inclement weather, indicated an arena was any configuration of walls and a roof. This seems to indicate that the different regions have different requirements for their indoor arenas and, therefore, have different overall ideas of what an indoor arena looks like.

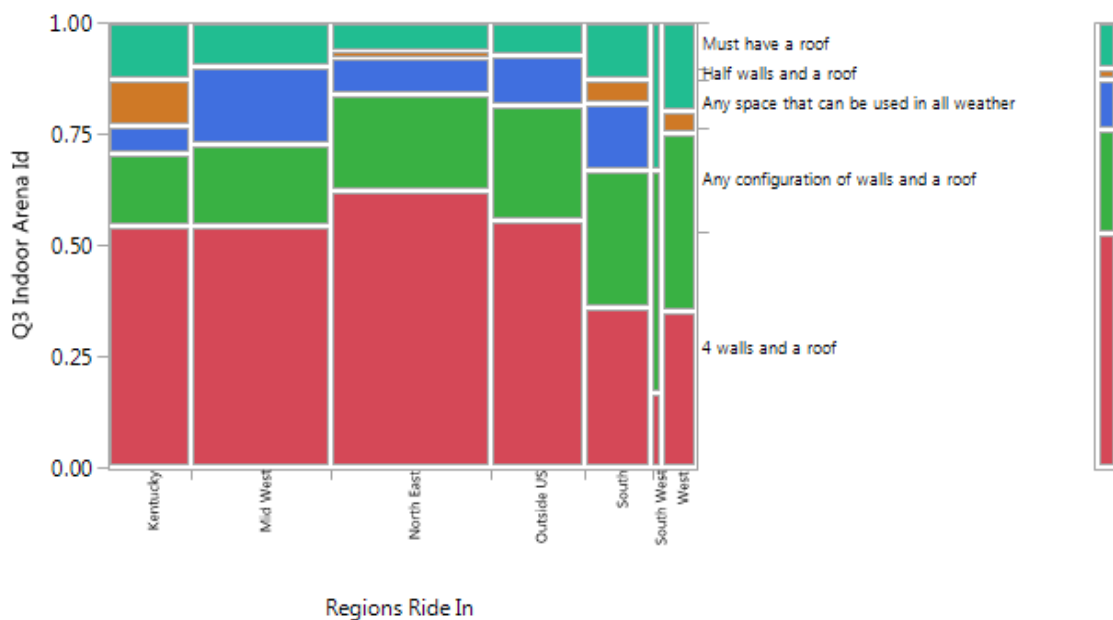


Figure 4.9 Mosaic plot of the relationship between the region participants ride in/where the arena is located and how participants define an indoor arena.

4.3.1.4 Environmental Concerns

Of the 335 participants of the survey, 71.34% or 239 participants reported having concerns about the environment within the indoor arena. The participants were allowed to select all of the environmental concerns that they had for their arena so someone could

have selected dust, moisture, and lack of air. Due to this, the percentages were calculated based on the total number of participants who selected a specific set of concerns. Dust was anecdotally discussed and therefore expected to be a problem within indoor arenas, but having 84.51% of participants with environmental concerns choose dust strongly reinforced that dust was an issue. In addition to dust being a concern, lack of air movement was a concern for 65.27% of those who had concerns regarding the environment. It is possible that both of these concerns are because of a lack of appropriate ventilation within the facility. By changing the indoor arena's ventilation system, it might be possible to help eliminate some of the concerns with dust and a lack of air movement. These changes may be as simple as having appropriate inlets and outlets for air to move through the indoor arena. One other possibility for these issues is due to arena maintenance practices. The most common method for controlling dust is by distributing water on the footing. Too much water could be contributing to the moisture issues that 27.2% of participants stated was a concern. Many of these environmental concerns may be interrelated and could be mitigated through similar methods. For instance, increasing the numbers of windows, doors, and translucent panels in the indoor arena, could mitigate the concerns regarding lack of air movement, temperature issues, and not having enough light within the arena. In addition, it is possible that while a solution may mitigate one concern it could exacerbate another. Many arenas treat footing with water in order to keep dust down, but this could potentially cause problems with increased moisture in the arena environment. Ultimately, managing environmental concerns is a balancing act of addressing one problem without creating another.

Table 4.3 Percentage of environmental concerns within the indoor arenas. The percentages are based on the number of participants who reported having environmental concerns.

Environmental Concern	Percent
Dust	84.51
Moisture	27.20
Lack of air movement	65.27
Too much air movement	1.67
Not enough light	25.10
Temperature	36.82

The goal of asking about the environmental concerns was to examine the relationship between the environmental concerns and different aspects such as footing components, footing treatment practices, whether the barn is attached to the indoor arena, and the average number of horses working in the arena at one time. Unfortunately, the design of the question regarding the indoor arena environment concerns complicated this goal. The participants were able to select all of the environmental concerns that they felt were present which included dust, moisture control issues, too much air movement, not enough air movement, too much light, not enough light, and temperature concerns. A better solution for this question would have been to break it down into individual questions about the potential environmental concerns. This is vital information for any future surveys that may be designed and distributed with the goal of gathering this information.

It was hypothesized that a higher average number of horses in the arena at one time would increase environmental concerns within the indoor arenas. This hypothesis was determined to be false, but that could be due to issues with the survey design which made it problematic to actually test this hypothesis. Not only did the environmental concern questions inhibit the ability to test the hypothesis, but the questions regarding the average number horses did as well. 95% of the participants answered less than 5 horses for the

average number of horses in the arena at one time. This issue could have potentially been resolved if there had been a large number of participants in the survey or through designing the question differently. For example, instead of grouping the answers into 1-5 horses, 6-10 horses, 10-15 horses and more than 15 horses, allowing for the selection of 1 horse, 2 horses, 3 horses, etc. through a slider bar would allow for a more precise number and could influence the analysis of how the average number of horses potentially impacts environmental concerns. The differences and variability in the number of horses and the use of the indoor arena is still potentially an important aspect to examine and, therefore, warrants more research to fully understand its impact.

4.3.1.5 Discipline Specific Needs

The relationship between the different disciplines and the primary footing component was significant (p -value = 0.007, $n=336$, $DF=28$). Regardless of discipline, sand was the most common primary footing component. An interesting trend within the fence and flat emphasis and the flat emphasis was the second most common primary footing component was a dirt and sand mixture. In contrast, the secondary component of the footing and its relationship with discipline was only trending towards significance (p -value = 0.09, $n=336$, $DF=24$). Once again, the most prevalent answer was not having any secondary components in the footing. Fiber was the second most prevalent answer of possible secondary footing components with dressage, eventing, flat emphasis, and flat and fence emphasis being the disciplines that reported more than 20% of the arenas of that discipline type containing fiber. This trend is consistent with the previous survey data regarding the disciplines and footing components that was observed examination of the relationship between regions and disciplines and footing components.

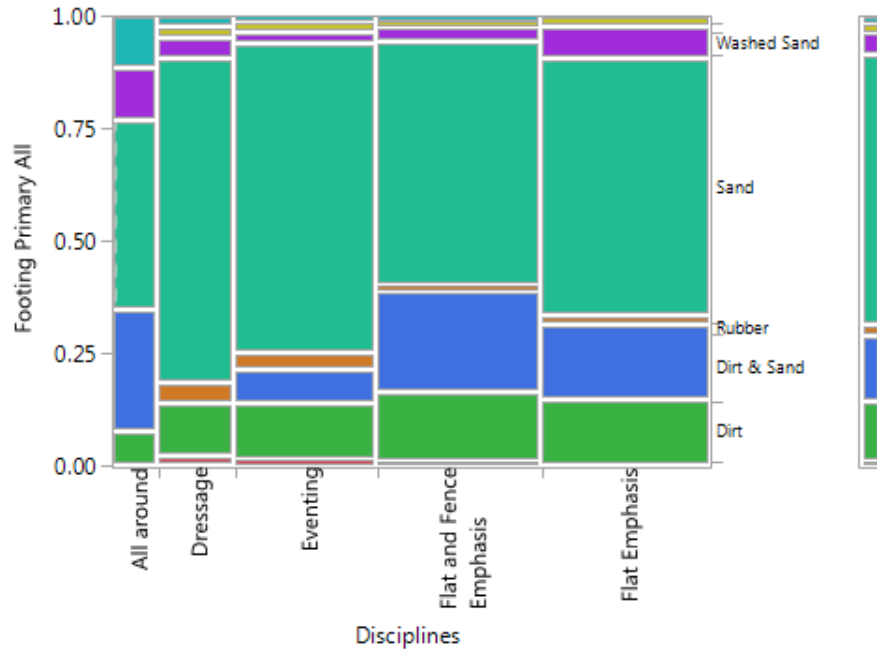


Figure 4.10 Mosaic plot of the relationship the discipline participants rode and the primary footing component.

Once again, the square footage or size of the arena was not significantly correlated with the different disciplines ($n=334$, $DF=8$). While there were not any trends in the data with respect to disciplines, the majority of the indoor arenas split between being less than 10,000 sq ft and more than 15,000 sq ft. This split has been seen in other relationships where arena size has been examined such as in the discussion regarding the regions where the indoor arenas were located.

4.3.1.6 Building Dimensions

The relationship between the length and the width of the arenas was significant (p -value = 0.0002, $n=82$, $DF=4$). Most of the data was concentrated into the mid-range length and width: between 100-200 ft long and 80-120 ft wide. Understandably, none of the arenas less than 100 ft long were over 80 ft wide. This relationship is expected with the general rule of thumb that arenas are longer than they are wide. Comparing width and length with

the eave height did not result in any significant relationships. This is not necessarily unexpected, but is still an interesting observation.

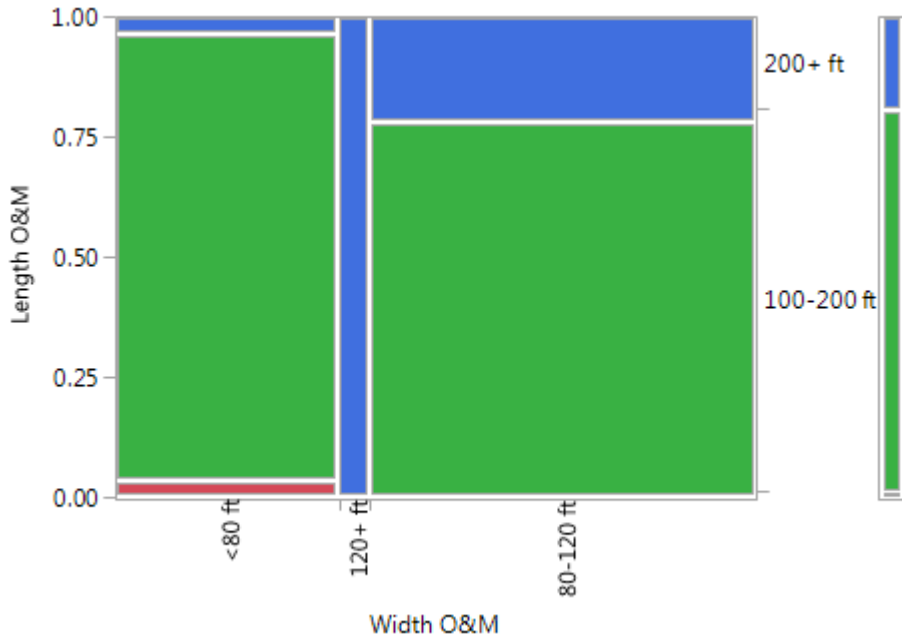


Figure 4.11 Mosaic plot of the relationship between the length of the arena and the width of the arena.

4.3.1.7 Translucent Panels

There was not a significant relationship between the number of translucent panels present in the indoor arena to let in natural sunlight and the number of lights present in the indoor arena ($n=333$, $DF=9$). Even though there was no relationship, most of the arenas did not have translucent panels. Overall, most of the arenas had less than 20 lights. This lack of relationship is potentially due to wanting an even distribution of light across the arena when there is no natural sunlight filtering through the translucent panels. Many boarding facilities have people who work during the day and, therefore, may be riding after dark during at least some of the year so it becomes important to have even supplemental light when it is needed.

4.3.1.8 Maintenance Costs

The annual maintenance costs of the arenas were not significantly correlated with the square footage or the primary footing component. The small sample size was an issue with examining this particular relationship as only the owners were asked about the maintenance costs ($n=19$, $DF=6$). A larger sample size wouldn't necessarily result in a significant relationship, but it would allow for confirmation of the lack of significance that was observed. Interestingly, the secondary footing component relationship to maintenance costs was recorded as significant ($p\text{-value} = 0.016$, $n=19$, $DF=9$), but this is suspect, as much of the contingency table did not actually have data present. Once again more information would be necessary to confirm the significance of the relationship between the maintenance costs and the secondary footing components.

4.3.1.9 Incidence of Rust

The final hypothesis for the survey data was that the presence of insulation reduced the incidence of rust and "raining" in the indoor arena. Unfortunately, it was not possible to confirm this hypothesis as there was not enough information about the presence of insulation in the arenas. This is an area of particular interest, especially for examining how the construction of indoor arena impacts the environment within the arena. It is possible that the structure of the question regarding the construction materials of the indoor arena contributed to the lack of response regarding the presence of insulation. This question was a select all that apply with a list of the possible construction materials and as such it is possible the participants did not select insulation even if insulation was present. Reworking this question in future surveys would be necessary to increase the likelihood of collecting the desired data.

4.3.2 Site Visit

4.3.2.1 Disciplines

During the interviews conducted on the site visits, the owners or managers of the facilities were asked to identify the main discipline or purpose of the facility. The categories used for data aggregation purposes matched those used for the survey data with the addition of event facility for indoor arena facilities used for shows or other events. In some cases, the facilities hosted not equine related events which dictated a name inclusive of the variety of activities hosted. Both the show/multi-use facilities and the flat and fence emphasis facilities each represent 36% of the indoor arenas visited. Dressage and all around facilities have been visited the least and each make up 8% while eventing facilities comprise 12% of facilities. This distribution is represented in Figure 4.12. There are plans to increase the number of facilities and the variability of disciplines as well.

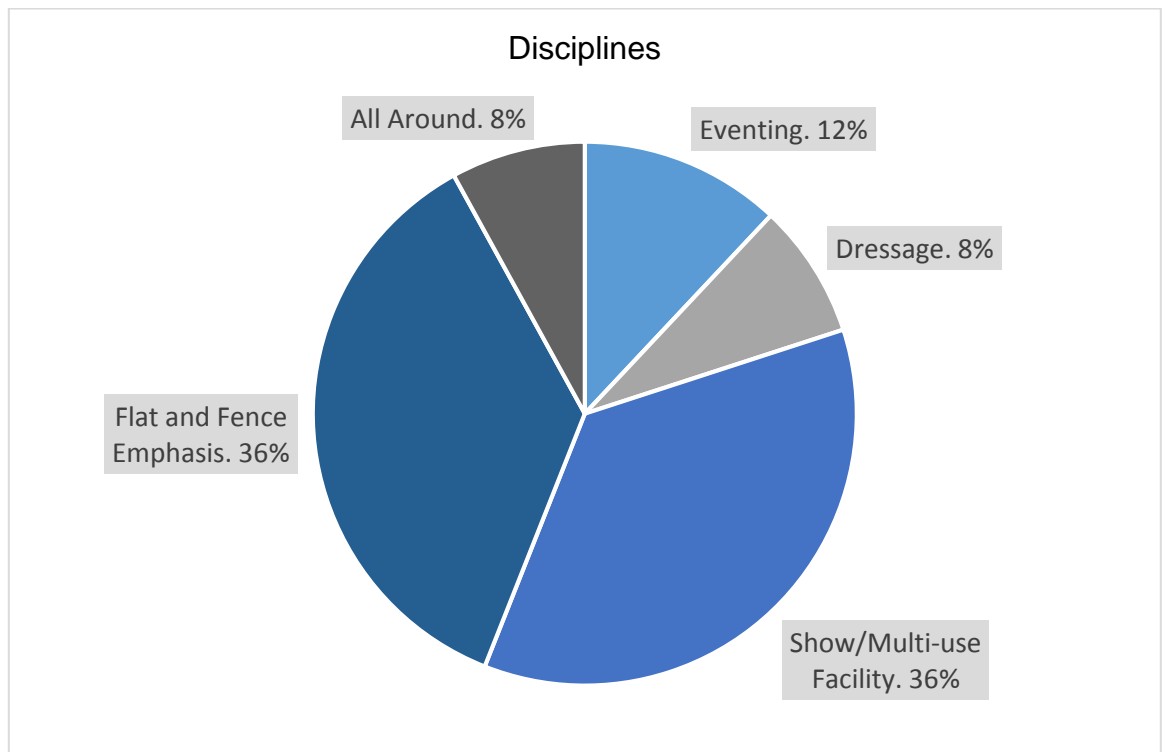


Figure 4.12 Percentages of the disciplines from the facilities for the site visit evaluations.

4.3.2.2 Size of Arenas

Over 70% of the facilities visited for the site visit have had building square footages over 15,000 sq ft, with the 10,000-15,000 sq ft being the second most prevalent building size at 20%, and only 8% of the buildings being less than 10,000 sq ft. Interestingly, the preliminary site visit differs slightly from the survey data as most of the arenas reported in the survey were either below 10,000 sq ft or above 15,000 sq ft. As more indoor arenas are evaluated in the site visits, the trend towards the sizes may be more similar to the survey data as the sample size for the site visits is still quite small.

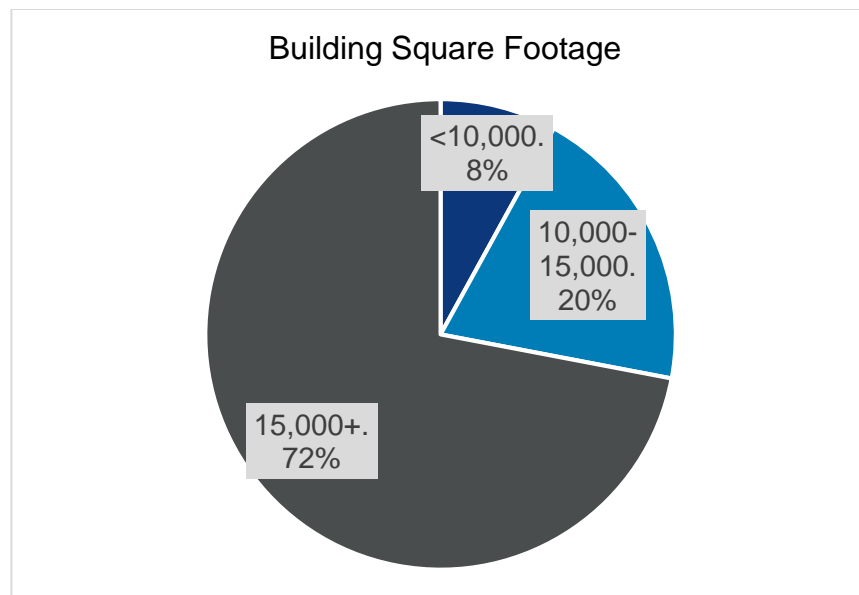


Figure 4.13 Percentage of building square footage which housed the indoor arena.

The similarities between the footing and building dimensions were also of interest to the research team and 80% of the facilities footing dimensions were different than the building itself. In all cases, the footing dimension were smaller than the building dimension which follows the logic of the purpose of walls and buildings. This loss of space was due to stalls, storage areas, kick walls, stands or, in some cases, climate controlled viewing

areas. The square footage of the footing only differed slightly from the building square footage. Less than 10,000 square foot and 10,000 – 15,000 sq ft both increased slightly to 12% and 24% respectively. Consequently, the arenas bigger than 15,000 sq ft decreased to 64%. Overall, the trend was maintained in the footing square footage that was observed in the building square footage. Considering the vast array of building arrangements possible for barns and arenas, it is unsurprising to see facilities that contain more than just the indoor arena. It should also be noted that many of the arenas the loss of footing square footage was concentrated in the length of the arenas rather than in the width. The width of the arenas seemed to more closely follow the building exterior and the owners or facility designers were more apt to add extra length for the viewing areas, storage areas, or bleachers.

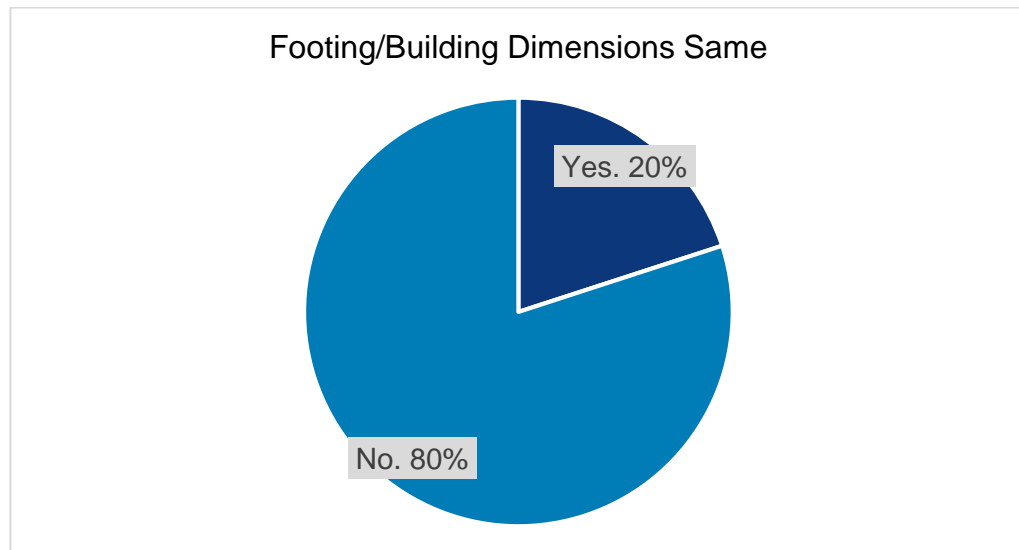


Figure 4.14 The percentages of whether the footing square footage was the same as the building square footage.

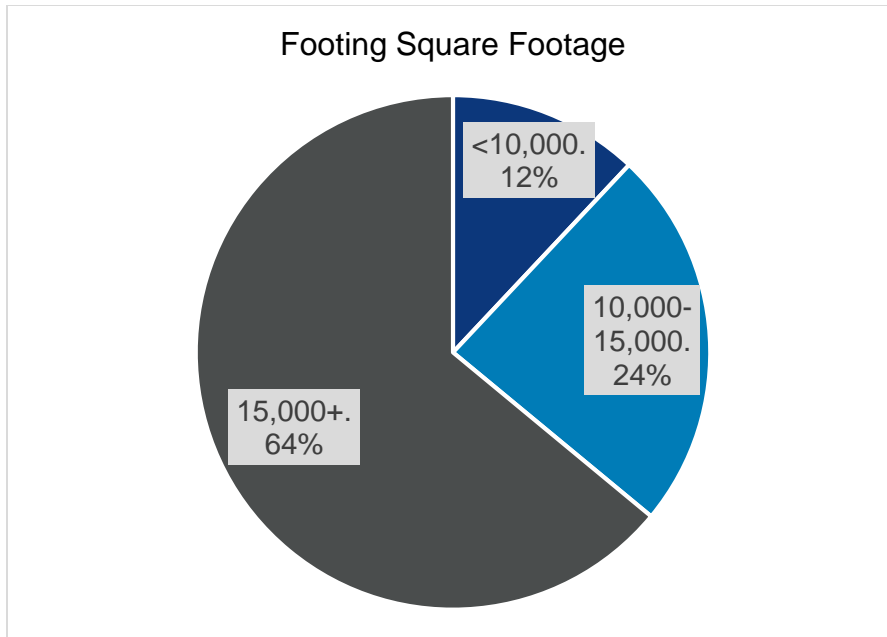


Figure 4.15 Percentage of square footage for the footing within the indoor arenas.

Finally, the footing dimensions themselves were analyzed. The footing width was fairly evenly distributed between the three widths: less than 80 ft, 80-120 ft, and more than 120ft. In contrast, just over half of indoor arenas for the site visit had a length between 100-200 ft, 40% were longer than 200 ft, and only 8% were less than 100 ft. This is a notable difference in the distributions as, logically, it would seem the width and length divisions would be fairly similar. Again, as more indoor arenas are evaluated the distributions could change and the length and width distributions may more closely align with the addition of more data.

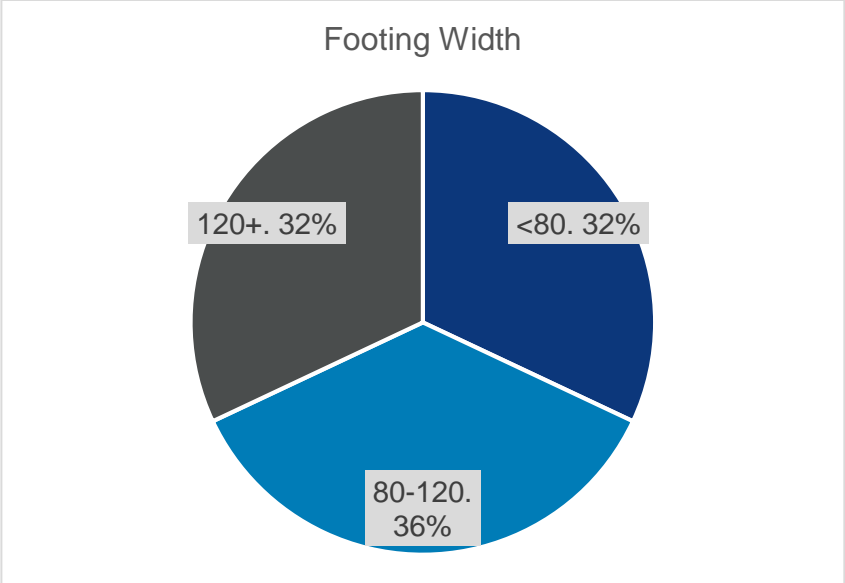


Figure 4.16 Distribution by percentage for the site visit indoor arena footing widths (ft).

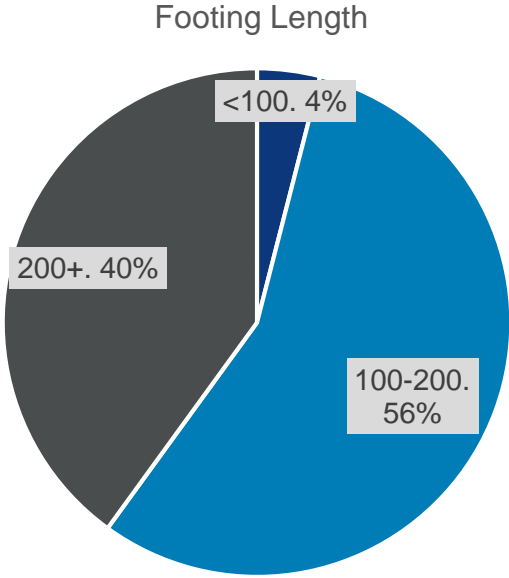


Figure 4.17 Distribution by percentage for the site visit of the indoor arenas footing lengths (ft).

4.3.2.3 Footing

Only two primary footing components were observed in the arena site visits: sand and rubber. The primary footing component were reported based on what the farm owner or manager stated the primary footing component to be and not what the research team

observed. Overwhelmingly, the majority of the arenas were sand arenas at 96%, while only 4% of the arenas contained rubber as the primary component. More interesting was the fact that the most common secondary footing component was fiber at 60%, followed by no secondary component at 36%, and, finally, a fiber and rubber mix being third at 4%. Once again, the trend in the site visit evaluation is different from the trends seen in the survey data. The most common secondary footing component reported in the survey was nothing, while fiber is the most common response in the site visit data. Any additional data from the site visits planned for the future will potentially impact the distributions. Some of the deviation from the survey data is potentially from the types of facilities that have been visited thus far. An increase in the variability of the main disciplines of the farms will likely influence the type of primary and secondary footing components observed.

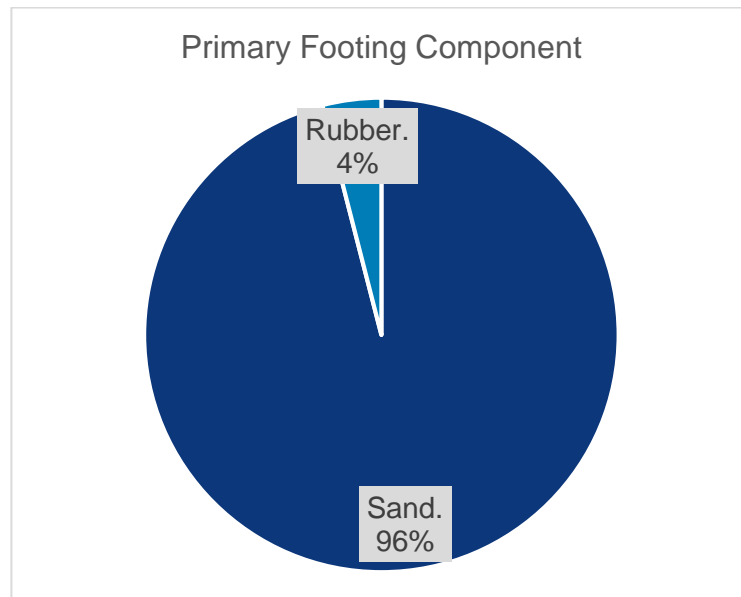


Figure 4.18 Site visit primary footing components.

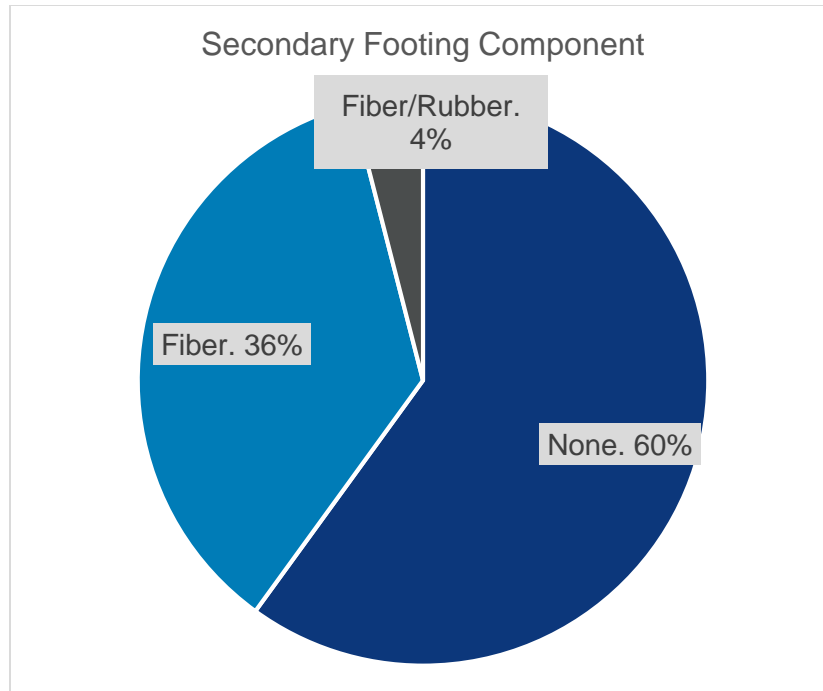


Figure 4.19 Secondary footing components from the indoor arena site visits.

4.4 Conclusion

The indoor arena survey and site visits were designed to begin to fill in the gap within the academic research regarding indoor arena facilities. They are an important aspect of the horse industry that allows for horses to continue to work and train all year and no matter the weather conditions. Due to this potential for high usage, it is important to gather information regarding these facilities and to understand the environment within them. In addition, any problems within the arenas or health concerns about them need to be addressed to ensure that both the horses and humans are benefiting from using the facility. The relationships between the different topics such as age of the arena and the lighting choices, the region where facilities are located and the footing components, and number of translucent panels and number of lights all paint a picture of how arenas have been built and the usage patterns within the facilities. The multitude of information collected through

this study will provide the frame work for future research as well as lay the foundation for publishing design recommendations for building or retrofitting indoor arenas.

CHAPTER 5. CONCLUSION

5.1 Fan Placement in Horse Stalls

Providing fresh air within stalls and barns is vital to ensuring the respiratory health of the horses who live and work in the facilities (Fabian, 2002). Adequate ventilation allows for the necessary fresh air to enter, while stale air exits the barn. In many cases, facilities rely on natural ventilation techniques, such as thermal buoyancy or wind, to provide the necessary air changes in the facility, but during the summer months many owners add supplemental fans to the stalls in an effort to improve ventilation (Fabian, 2002). Temperature control, increased air movement across the horses, and fly control are oft cited reasons for placing fans in or around the stalls and the fan placement and orientation study sought to determine whether the goals of the fans were being met. This was tested through the use of 2 different fans, a fan in the eaves blowing down into the stall and a box fan placed on the outside of the stall. The box fans either blew into or blew out of the stall depending on which orientation was being tested.

Overall, the fans did not actually fulfill any of the purposes which are typically cited by people within the horse industry. During the two summers of research conducted, only one of the fan orientations experienced temperatures below the outside ambient temperature. This reduction in stall temperature is likely due to environmental factors, such as the barn design and construction, and not due to the fan itself. For all other fan orientations, the stall temperature was higher than the outside temperature with little to no difference observed between the various orientations. The air movement observed throughout the stalls was highly influenced by the angle and direction of the fan. Every fan orientation and placement produced areas of stale or stagnant air within the stalls. For

this study, less than 50 feet per minute (0.25 m/sec) air speed was considered stale air, while good air movement was more than 100 feet per minute (2.54 m/sec). Finally, only the box fans placed on stall walls blowing in produced air speeds at great enough speeds for fly control. Unfortunately, those air speeds were only achieved directly in the path of air movement from the fan.

Ultimately, proper facility design and construction with the intention of facilitating good natural ventilation serves to provide better air movement through and within the facility. Currently, the fans favored within the industry do not actually address the issues they are intended to address. Other animal agriculture industries have successfully used mixing fans to increase convective cooling and discourage fly nuisance within their facilities. If horse and farm owners and managers wish to continue to use fans as a means for providing air movement and ventilation within facilities, it is necessary to complete further research into what fans will produce sufficient air speeds and how they should be placed to be most effective.

5.2 Air Speed to Increase Rate of Cool Out in Horses

Horses have an incredible capacity to regulate their body temperatures through thermoregulation techniques inherent in their physiology (Hodgson et al., 1994). Evaporation through the respiratory system and by sweating are the main ways they regulate their body temperature, but increasing the amount and intensity of exercise can inhibit the horse's natural ability to dissipate heat. This study examined the effect of adding forced air speeds across the horses during the drenching process of the cool out period after increase exercise.

Overall, the horses had an increased rate of cool out with the addition of air speed and the back fan position blowing from the hindquarters to the front of the horse provided the greatest increase in the rate of cool out. The horse's heart rate, respiration rate, and rectal temperature were all monitored throughout the cool out process. Their heart rate and rectal temperatures were both observed to be most impacted by the presence of the fan and the forced air speed across them. In agreement with other studies conducted examining acclimation to different climates and how horses cool out after exercise, the respiration rate rates of cool out were not a good indicator for the overall cooling process of the horses.

Due to the small sample size and the limited amount of time the horses spent in front of the fan, there was only a trend (p -value = 0.1) towards statistical significance for the increase in the rate of cool out, but it is still meaningful. By increasing the amount of time in front of the fan from about $\frac{1}{3}$ of the cool out process to over $\frac{1}{2}$, we speculate the rates of cool out would increase even more. While all horses could potentially benefit from the addition of forced air speed across them as they cool out, the horses competing in the racing industry, at horse trials in three-day eventing, and at endurance races could benefit the most. Both three-day eventing and endurance races require horses to be monitored through their cool out process before being released to the next phase or to go back to the barn. The faster their vital signs can return to resting rates, the faster they can begin to fully recover from the intense exercise required of them and be ready for the next phase of competition or event they are entered.

5.3 Characterization of Indoor Arenas

Indoor arenas allow trainers and riders to work and train their horses no matter the season or the weather outside. They serve an important purpose within the industry that

relies heavily on consistency of being able to train so the horses can compete and, therefore, generate profits for their owners and trainers. As a whole, very little is known about these facilities outside of knowing they exist on farms as almost no research has been completed on them. With these considerations in mind, the indoor arena study was conducted with two parts: an online survey and site visits in and around Central Kentucky. The goals of the study were to characterize building dimensions, footing, and indoor climate, define typical maintenance procedures and practices, and explore the potential health issues created in these facilities due to dust, moisture, and ventilation design.

One of the overall goals of the survey was to begin to formulate how people within the horse industry define an indoor arena. Interestingly, the participant's definition of what they consider an indoor arena was specific to the region they ride in. For those in the South and Southwest, an indoor arena was any configuration of walls and a roof. In contrast, participants in Kentucky, the Northeast, the Midwest, and outside the US stated an indoor arena must have four walls and a roof. These delineations are in line with trends in weather patterns; areas which need more protection from the elements define indoor arenas to be facilities that are more closed, while the areas which need less protection from the elements and more air movement through the facility consider facilities that have a more open design to be indoor arenas.

The most important information collected from the survey data is the environmental concerns that were recorded by participants. 71% of respondents stated there were environmental concerns within the arenas they owned, managed, or rode in. Of those that reported concerns, 84.5% reported dust being a concern, with lack of air movement being second at 65%, and temperature third at 37%. These findings indicate that there are serious

issues and environmental concerns within indoor arenas and that future research needs to be targeted to the best ways to address them.

The site visits completed for the indoor arena study has allowed for a more comprehensive evaluation of indoor arena facilities in and around Central Kentucky. More site visits need to be completed to develop a more complete picture of indoor arenas. In addition to the data discussed in this thesis, more analysis needs to be conducted on the air movement, temperature, relative humidity, and light data that has also been collected. This data in conjunction with the survey data will allow for future research to be designed within the framework of issues that have been identified by the industry.

5.4 Future Work

The stall fan placement and orientation study and the indoor arena study are the two main areas of interest for future work. For the stall fan study, future work can focus on fans that actually address the issues farm and horse owners want them to address and how the building design and construction impacts the ventilation within the facility. The small study completed for this thesis began to illuminate how building design can highly impact the environment within the stalls. The barn in the second year was not as well naturally ventilated, but experienced temperatures that were not as high above the outside temperature as those in the well naturally ventilated barn in the first year. Second, the fans used within the study are the most commonly used fans in the equine industry at this time. By highlighting their lack of effectiveness, more research into fans that are more effective is necessary to provide horse and farm owners with alternative fans if they still wish to use them.

Finally, the indoor arena study has barely begun to explore the indoor arena and the complexity of managing and working within the facility. Future work will focus on examining the environmental concerns that were reported in the survey results and ways building design and ventilation can help address them without creating new concerns. Currently, there is not a single resource facility owners can use to help with the design and building process of their indoor arenas and they, instead, rely on personal experiences and guidance from the construction company. With that in mind, ultimately, the goal of the indoor arena study work is to create and publish facility design recommendations for people who are looking to build or retrofit an indoor arena. Throughout the development of this resource, more work will be done into dust, moisture, and temperature management within the facilities and how all of those components impact the health of the horse and humans who use the indoor arenas.

APPENDICES

APPENDIX 1. COOLING STUDY – STANDARD OPERATING PROCEDURES

Each horse will undergo a training exercise prescribed by the trainer. This may be galloping a mile on the track, galloping for 15 min in the field. Each horse will undergo the same training regime for every treatment it receives. The treatment will be recorded for each horse.

After exercise – Just drenching/rinsing:

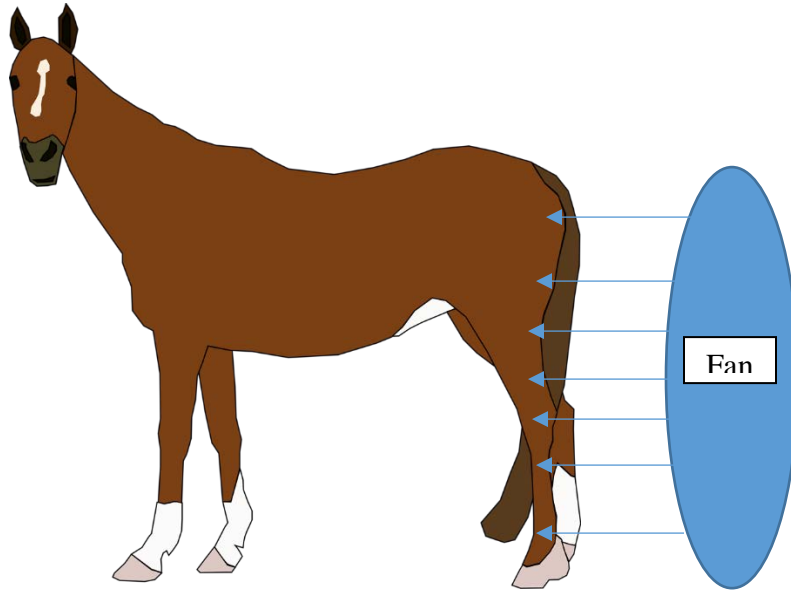
1. As soon as the horse is untacked, vital signs (heart rate, respiration rate, and rectal temperature) will be taken and recorded. A thermal imaging picture will be taken as well.
2. Time will be started as soon as the horse's tack has been removed and vital signs have begun to be taken.
3. The horse will be offered water. The horse will walk a lap to begin cool out.
4. Horse will be drenched/rinsed with water and scrapped for 45 seconds. Vital signs and a thermal image will be taken during this process.
5. The horse will be offered water. Horse will be walked a lap.
6. Horse will be drenched/rinsed with water and scrapped for 45 seconds. Vital signs and a thermal image will be taken during this process.
7. The horse will be offered water. Horse will be walked a lap.
8. This process will continue until all vital signs have returned to normal. Heart rate less than 50 beats per minute, respiration less than 30 breaths per minute, and temperature below 101.5 °F.

After exercise – Drenching/rinsing and air from behind:

A fan will be placed behind the horse, blowing air from hind end up the body while they are being drenched/rinsed. The fan will already be running when the horse comes into the wash area.

1. As soon as the horse is untacked, vital signs (heart rate, respiration rate, and rectal temperature) will be taken and recorded. A thermal imaging picture will be taken as well.
2. Time will be started as soon as the horse's tack has been removed and vital signs have begun to be taken.
3. The horse will be offered water. The horse will walk a lap to begin cool out.
4. Horse will be drenched/rinsed with water and scrapped for 45 seconds.
5. The horse will be offered water. Horse will be walked a lap.
6. Horse will be drenched/rinsed with water and scrapped for 45 seconds.
7. Horse will be walked a lap.

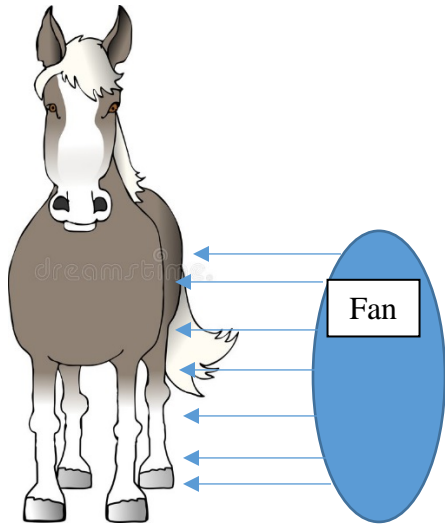
- This process will continue until all vital signs have returned to normal. Heart rate less than 50 beats per minute, respiration less than 30 breaths per minute, and temperature below 101.5 °F.



After exercise – Drenching/rinsing and air from the side:

A fan will be placed to the side of the horse, blowing air towards the side of the horse while they are being drenched/rinsed. The fan will already be running when the horse comes into the wash area.

- As soon as the horse is untacked, heart rate, respiration rate, and rectal temperature will be taken and recorded. A thermal imaging picture will be taken as well.
- Time will be started as soon as the horse's tack has been removed and vital signs have begun to be taken.
- The horse will be offered water. The horse will walk a lap to begin cool out.
- Horse will be drenched/rinsed with water and scrapped for 45 seconds.
- The horse will be offered water. Horse will be walked a lap.
- Horse will be drenched/rinsed with water and scrapped for 45 seconds.
- The horse will be offered water. Horse will be walked a lap.
- This process will continue until all vital signs have returned to normal. Heart rate less than 50 beats per minute, respiration less than 30 breaths per minute, and temperature below 101.5 °F.



Cooling Study Barn Layout:

- The barn was 100 ft. by 250 ft.
- White area is the aisle ways of the barn
- Gray are stalls or storage areas
- Orange rectangles represent the entrances and exits of the barn
- Wash stalls are repressed by the blue rectangles
- Main walking path from the two wash stalls are represented by the red dashed line
 - Horses walked into the center aisle way wash stall and walked a complete lap to enter into the wash stall from the outside aisle way
 - Every effort was made to ensure amount walked was as similar as possible

APPENDIX 3. COOLING STUDY – HORSE RECORD SHEET

Horse Number:			Exercise:		Stop Time:
Treatment:			Start Time:		
Initial Vitals	Heart Rate		Post 6th Administration	Heart Rate	
	Respiration Rate			Respiration Rate	
	Temperature			Temperature	
Post 1st Administration	Heart Rate		Post 7th Administration	Heart Rate	
	Respiration Rate			Respiration Rate	
	Temperature			Temperature	
Post 2nd Administration	Heart Rate		Post 8th Administration	Heart Rate	
	Respiration Rate			Respiration Rate	
	Temperature			Temperature	
Post 3rd Administration	Heart Rate		Post 9th Administration	Heart Rate	
	Respiration Rate			Respiration Rate	
	Temperature			Temperature	
Post 4th Administration	Heart Rate		Post 10th Administration	Heart Rate	
	Respiration Rate			Respiration Rate	
	Temperature			Temperature	
Post 5th Administration	Heart Rate		Post 11th Administration	Heart Rate	
	Respiration Rate			Respiration Rate	
	Temperature			Temperature	

APPENDIX 4. INDOOR ARENA STUDY – SURVEY

Questions beginning with a “Q” are general questions every participant was asked.

Questions beginning with an “O” were asked of owners of indoor arenas.

Questions beginning with a “M” were asked of managers of indoor arenas.

Questions beginning with a “R” were asked of riders who frequently use an indoor arena.

Questions beginning with a “H” were health related questions asked of every participant.

Start of Block: Informed Consent

Q1 Informed Consent - Indoor Arena Survey

You are being invited to participate in a voluntary research survey about indoor arenas and health exposures associated with indoor arenas. This survey is for my master’s thesis research at the University of Kentucky.

There has been little research done on indoor arena environments. The goal of the survey is to gather information regarding common characteristics about indoor arenas in order to better make recommendations for future designs. The survey includes questions for owners, managers, and riders who have or use an indoor arena facility. The questions cover a multitude of topics such as arena design and construction, footing, maintenance, arena environment, and your perceptions of health outcomes associated with arena environments. Although you will not get personal benefit from taking part in the research study, your responses will help us be able to make better recommendations for the design and construction of new indoor arenas.

You have a choice about whether or not to complete the survey. Should you want to participate you may also choose to skip any questions or discontinue the survey at any time. The survey will take about 15-20 minutes to complete. If you start the survey and must complete it at a later time, your answers and place within the survey will be saved for a week after you first start it.

Your response to the survey is anonymous; no names will appear on research documents, or be used in presentation or publications. Participation will not be tracked unless you volunteer information in open comments sections to be contacted.

Please be aware, while we make every effort to safeguard your data once received from the online survey/data gathering company, given the nature of online surveys, as with anything involving the Internet, we can never guarantee the confidentiality of the data

while still on the survey/data gathering company's servers, or while en route to either them or the University of Kentucky.

The person in charge of this study is Staci McGill of the University of Kentucky, Department of Biosystems and Agricultural Engineering. If you have questions, suggestions, or concerns regarding this survey her contact information is: staci.mcgill@uky.edu or (859) 218-4360. Staci is a student and she is being guided in this research by Morgan Hayes (hayesmorgan@uky.edu) and Kimberly Tumlin (kimberly.tumlin@uky.edu). There may be other people on the research team assisting at different times during the study.

If you have any questions, suggestions or concerns about your rights as a volunteer in this research, contact staff in the University of Kentucky (UK) Office of Research Integrity (ORI) between the business hours of 8am and 5pm EST, Monday-Friday at 859-257-9428 or toll free at 1-866-400-9428.

If you would like to retain this page for future reference, you must print it now as you will not be able to access it once you continue.

By continuing with this study, you are consenting to participate in the study and that you understand the above information.

Thank you in advance for your assistance with this important project.

The survey will remain open for 12 weeks.

End of Block: Informed Consent

Start of Block: 18 or older

Q2 Are you 18 or older?

- Yes (1)
- No (2)

Skip To: End of Survey If Are you 18 or older? = No

End of Block: 18 or older

Start of Block: Intro questions

Q3 What do you consider an indoor arena to be?

- 4 walls and a roof (1)
 - Half walls and a roof (2)
 - Any configuration of walls and a roof (3)
 - Must have a roof (4)
 - Any space that can be used in all weather (5)
 - Other (Please Specify) (6)
-

Q4 Do you own or manage a facility with an indoor arena?

- Own a facility (1)
 - Manage a facility (2)
 - Own and manage a facility (3)
 - I do not own or manage (5)
-

Display This Question:

If Do you own or manage a facility with an indoor arena? = I do not own or manage

Q5 Do you actively use or ride at a facility with an indoor arena more than once a month?

Yes (1)

No (2)

Skip To: End of Survey If Do you actively use or ride at a facility with an indoor arena more than once a month? = No

End of Block: Intro questions

Start of Block: Default Question Block

Q6 Please select your age range:

18 - 24 (1)

25 - 34 (2)

35 - 44 (3)

45 - 54 (4)

55 - 64 (5)

65 - 74 (6)

75 - 84 (7)

85 or older (8)

Choose not to answer (9)

Q7 What is your gender?

- Male (1)
 - Female (2)
 - Choose not to answer (3)
-

Q8 Please select the ethnicity/race that you feel best describes you:

- White (1)
 - Hispanic (2)
 - Black or African American (3)
 - American Indian or Alaska Native (4)
 - Asian (5)
 - Native Hawaiian or Pacific Islander (6)
 - Other (7)
 - Choose not to answer (8)
-



Q9 In which country do you currently reside?

▼ United States of America (1) ... Zimbabwe (972)

Q10 In which state do you currently reside?

▼ I do not reside in the United States (1) ... Wyoming (53)

Q11 In which state do you currently own a facility, manage a facility, or ride at a facility with an indoor arena?

▼ I do not own, manage or utilize a facility in the US (1) ... I do not reside in the United States (54)

End of Block: Default Question Block

Start of Block: Owner Questions - Farm questions

O12 Select the discipline(s) that best describe the main riding discipline on your farm:

- Dressage (1)
- Show Jumping/ Hunter Jumper (2)
- Eventing (3)
- Reining (4)
- All around (5)
- Gymkhana/Games (6)
- Gaited (7)
- Endurance (8)
- Racing (9)
- Fox hunting (10)
- Driving (11)
- Western Performance (12)
- Other (Please specify) (13)

O13 Where do most of your riders prefer to ride? (if weather is not a concern)

- Indoors (1)
 - Outdoors (be it field, arena, etc) (2)
-

O14 Do you also ride?

- Yes (1)
 - No (2)
-

Display This Question:

If Do you also ride? = Yes

O15 How often do you typically ride?

- Multiple times a day (1)
- Once a day (2)
- A few times a week (3)
- Once a week (4)
- A few times a month (5)
- Once a month (6)
- Less than once a month (7)

Display This Question:

If Do you also ride? = Yes

O16 What is the typical length of each ride?

- less than 30 min (1)
 - 30 min - 1 hour (2)
 - 1-2 hours (3)
 - 2-4 hours (4)
 - More than 4 hours (5)
-

O17 What best describes the main classification of the riders who utilize your facility?

- Recreational riders (1)
 - Professional riders/trainers (3)
 - Personal use (4)
 - Open for public events (2)
-

O18 What type of business do you consider your facility/farm?

- It is not a business/recreation only (1)
 - Non-Profit (2)
 - Not for Profit (3)
 - For profit (4)
 - Other (Please specify) (5)
-

Display This Question:

If What type of business do you consider your facility/farm? != It is not a business/recreation only

O19 Please select the answer(s) that best describe the business?

- Training/rehab facility (1)
 - Boarding facility (2)
 - Sales (3)
 - Breeding (4)
-

O20 What are the total number of horses on the farm?

- 1-5 (1)
 - 6-10 (2)
 - 11-15 (3)
 - 16-20 (4)
 - 21-25 (5)
 - 26-30 (6)
 - 31-35 (7)
 - 36-40 (8)
 - 40+ (9)
-

O21 Which months generally have the maximum number of horses on the farm? (Select all that apply)

Does not vary (1)

January (2)

February (3)

March (4)

April (5)

May (6)

June (7)

July (8)

August (9)

September (10)

October (11)

November (12)

December (13)



O22 Which months generally have the least number of horses on the farm? (Select all that apply)

Does not vary (1)

January (2)

February (3)

March (4)

April (5)

May (6)

June (7)

July (8)

August (9)

September (10)

October (11)

November (12)

December (13)



O23 What is the maximum number of horses in the indoor area at one time?

- 1-5 (1)
 - 6-10 (2)
 - 11-15 (3)
 - 16-20 (4)
 - 21-25 (5)
 - 26-30 (6)
 - 30+ (7)
-

O24 What is the average number of horses in the indoor arena at one time?

- 1-5 (1)
 - 6-10 (2)
 - 11-15 (3)
 - 16-20 (4)
 - 21-25 (5)
 - 26-30 (6)
 - 30+ (7)
-

O25 What is the typical number of horses worked in the arena each day?

- 1-5 (1)
 - 6-10 (2)
 - 11-15 (3)
 - 16-20 (4)
 - 21-25 (5)
 - 26-30 (6)
 - 30+ (7)
-

O26 What time of day does the facility get the most use?

- 6am-9am (1)
 - 9am-12pm (2)
 - 12pm-3pm (3)
 - 3pm-6pm (4)
 - 6pm-9pm (5)
-

O27 What was the cost to build your indoor arena facility?

- less than \$100,000 (1)
- \$100,000-\$250,000 (2)
- \$250,000-\$500,000 (3)
- \$500,000-\$750,000 (4)
- \$750,000-\$1,000,000 (5)
- more than \$1,000,000 (6)

End of Block: Owner Questions - Farm questions

Start of Block: Owner Questions Arena Design

O28 How old is the indoor arena?

- less than 5 years old (1)
 - 5-10 years old (2)
 - 10-15 years old (3)
 - 15-20 years old (4)
 - more than 20 years old (5)
-

O29 What most accurately represents the dimensions of your area? (width x length)

- 60 ft x 100 ft (1)
 - 80 ft x 120 ft (2)
 - 100 ft x 200 ft (3)
 - 150 ft x 300 ft (4)
 - Other (Please specify) (5)
-

O30 What is the eave height of your indoor arena? (i.e. height of your walls/height of trusses)

- Under 16 ft (1)
 - 16-18 ft (2)
 - +18 ft (3)
 - Unknown (4)
-

O31 What is the peak/ridge height of your indoor arena?

21-25 ft (1)

25-30 ft (2)

+30 ft (3)

Unknown (4)

O32 Select the picture that most accurately represents how your indoor arena is oriented:
(Rectangle represents the arena)

Image:East west orientation (1)

Image:North south orientation (2)

O33 What are the main wall building materials for your indoor arena? (Select all that apply)

- Metal siding (1)
 - Fabric siding (2)
 - Vinyl siding (3)
 - Exterior reflective paint (4)
 - Exterior wooden shingles/walls (5)
 - Interior wooden half walls (6)
 - Interior wooden walls (7)
 - No interior wall covering (8)
 - Wood studs/column (9)
 - Metal column (10)
 - Insulation (11)
 - Other: (Please Specify) (12)
-
-

O34 What are the main roof building materials for your indoor arena? (Select all that apply)

- Wood truss (1)
 - Metal truss (2)
 - Wood (laminated) arches/rafter (3)
 - Metal (I-beam) arches/rafter (4)
 - Metal roofing (5)
 - Shingles (6)
 - Fabric roofing (7)
 - Reflective paint (8)
 - Other: (Please Specify) (9)
-

O35 Do you have any opaque or transparent roofing panels or any other methods of natural light? (not from windows or doors)

- No (1)
- Yes - 1-5 panels (2)
- Yes - 5-10 panels (3)
- Yes - more than 10 panels (4)

O36 What type of lighting do you have?

- Fluorescent linear/bar light (1)
 - Fluorescent high bay (2)
 - Fluorescent round light (3)
 - LED linear/bar light (4)
 - LED round light (5)
 - Metal Halide/High Pressure Sodium light (6)
 - Other (Please specify) (7)
-

O37 Number of lights:

- 1-5 (1)
 - 6-10 (2)
 - 10-15 (3)
 - 15-20 (4)
 - 20+ (5)
-

O38 Do you have solar panels or other renewable energy sources?

- No (1)
 - Yes - solar panels (2)
 - Yes - other (please specify) (3)
-

O39 Do you collect, store, and use rain water as a water source for the farm?

- Yes (1)
 - No (2)
-

O40 Is there a ridge opening or cupola?

- Yes - ridge opening (3)
- Yes - cupola (4)
- No (5)

O41 Are there windows that can be opened to allow air to move through the arena?

- No (1)
- Yes - 1-5 (2)
- Yes - 5-10 (3)
- Yes - 10+ (4)

Display This Question:

If Are there windows that can be opened to allow air to move through the arena? != No

O42 What type of window do you have?



- Vertical sliding (1)
 - Horizontal sliding (2)
 - Swinging door (3)
 - Other (Please specify) (4)
-

Display This Question:

If Are there windows that can be opened to allow air to move through the arena? != No

O43 What are the typical opening dimensions of the windows? (in feet)

0 1 2 3 4 5 6 7 8 9 10

Height (1)	
Width (2)	

O44 Do you have curtains or sidewalls that can be opened?

- Yes - can open the entire wall (1)
- Yes - can open half the wall (2)
- Arena only has half/partial walls (3)
- No (4)

O45 What is the number of doors opening to the outdoors?

1 (1)

2 (2)

3 (3)

4 (4)

5+ (5)

O47 Are horses stabled under the same roof as the arena?

No (1)

Yes - horses are in the same space as arena (2)

Yes - a door can be closed (3)

Yes- doorway is open constantly (4)

O46 Do any of the doors open into the barn or an enclosed space?

- No (1)
- Yes - 1 door (2)
- Yes - 2 doors (3)
- Yes - more than 2 doors (4)

End of Block: Owner Questions Arena Design

Start of Block: Owner - Footing

O48 What best describes the footing in the indoor arena? (Select all that apply)

- Dirt (1)
- Sand (2)
- Washed sand (3)
- Waxed Sand (4)
- Poly/Synthetic (5)
- Clay (6)
- Crushed Rock (7)
- Wood Chip/Sawdust (8)
- Textile/fiber - low proportion (9)
- Textile/fiber - high proportion (10)
- Rubber (11)
- Other (Please specify) (12)

O49 What type of maintenance is required? (Select all that apply)

- Dragging (1)
 - Harrowing (2)
 - Rolling (3)
 - Aerating (4)
 - Other (Please specify) (5)
-

O50 How many hours per week are spent maintaining the footing?

- 1-5 hrs (1)
 - 5-10 hrs (2)
 - more than 10 (3)
-

O51 How often do you have to add or replace footing?

- Yearly (1)
 - 1-5 years (2)
 - 5-10 years (3)
 - Never done it (4)
-

O52 Do you treat the footing with anything? (Select all that apply)

- Wax (1)
 - Mineral Oil (2)
 - Water (3)
 - Other (Please specify) (4)
-

Display This Question:

If Do you treat the footing with anything? (Select all that apply) = Water

O53 If you water your arena, how do you water it?

- Water tank and tractor (1)
 - Overhead sprinklers (2)
 - Sprinklers attached to the sidewalls (3)
 - Movable garden type sprinkler (4)
 - By hand with hose and spray nozzle (5)
 - Do not water arena (6)
-

O54 How often do you treat the footing with the most commonly used treatment?

- Once a year (1)
- Once a month (2)
- Once a week (3)
- Multiple times per week (4)
- Daily (5)

End of Block: Owner - Footing

Start of Block: Owner - Arena Environment

O55 Are there rust spots on the walls, roof, or supports?

Yes (1)

No (2)

Unknown (3)

O56 Does it ever "rain" in the arena?

Yes (1)

No (2)

O57 Is the roof insulated?

Yes (1)

No (2)

Unknown (3)

O58 Are there temperature control methods in the indoor arena? (Select all that apply)

- Heaters (1)
 - Fans (2)
 - Central air system (3)
 - None (4)
-

Display This Question:

If Are there temperature control methods in the indoor arena? (Select all that apply) = Heaters

Q59 How many heaters do you utilize?

- 1-3 (1)
 - 4-6 (2)
 - 6-9 (3)
-

Display This Question:

If Are there temperature control methods in the indoor arena? (Select all that apply) = Fans

O60 How many fans are there?

- 1-3 (1)
 - 4-6 (2)
 - 6-9 (3)
-

Display This Question:

If Are there temperature control methods in the indoor arena? (Select all that apply) = Fans

O61 What type of fans are they? (ie ceiling/panel fans, exhaust fans) Please provide diameter and brand if possible

O62 Do you have any concerns about the environment within your indoor arena? (ie is it dusty? Is it hot? Is there little air movement? etc)

- Yes (1)
 - Maybe (2)
 - No (3)
-

Display This Question:

*If Do you have any concerns about the environment within your indoor arena? (ie is it dusty? Is it h...
!= No*

O63 Do your concerns fall into any of these categories?

- Lack of air movement (1)
- Too much air movement (2)
- Temperature (3)
- Dust (4)
- Moisture control (5)
- Not enough light (6)
- Too much light (7)

End of Block: Owner - Arena Environment

Start of Block: Owner - Cost Questions

O64 What is your gross household income?

- less than \$50,000 (1)
 - \$50,000-\$150,000 (2)
 - \$150,000-\$250,000 (3)
 - More than \$250,000 (4)
-

O65 How much on average do you spend in operating costs for your farm each year?

- less than \$10,000 (1)
 - \$10,000-\$25,000 (2)
 - \$25,000-\$50,000 (3)
 - more than \$50,000 (4)
-

O66 What is the yearly gross income for the farm?

- \$0-\$50,000 (1)
 - \$50,000-\$150,000 (2)
 - \$150,000-\$250,000 (3)
 - More than \$250,000 (4)
-

O67 How many tractors do you have on the farm?

- None (1)
- 1 (2)
- 2 (3)
- 3 or more (4)

O68 How many farm vehicles does your farm have?

- None (1)
 - 1 (2)
 - 2 (3)
 - 3 or more (4)
-

O69 How much do you spend on fuel each year for the farm equipment?

- Less than \$500 (1)
 - \$500-\$2500 (2)
 - \$2500-\$5,000 (3)
 - More than \$5,000 (4)
-

O70 How much do spend on electricity each year?

- Less than \$1,000 (1)
 - \$1,000-\$3,000 (2)
 - \$3,000-\$5,000 (3)
 - \$5,000-\$7,000 (4)
 - More than \$7,000 (5)
-

O71 How much do you spend on water each year?

- None - I collect rain water (1)
 - None - I use a well or spring (2)
 - less than \$1000 (3)
 - \$1,000-\$3,000 (4)
 - \$3,000-\$5,000 (5)
 - \$5,000-\$7,000 (6)
 - More than \$7,000 (7)
-

O72 How much do you spend on indoor arena maintenance and operation each year?
(including water, electricity, fuel for tractors, any other treatment or repair, etc)

- Less than \$1000 (1)
 - \$1000-\$3000 (2)
 - \$3000-\$5000 (3)
 - \$5000-\$7000 (4)
 - More than \$7000 (5)
-

O73 What percent of your yearly operating costs are spent on maintenance for your indoor arena?

0 10 20 30 40 50 60 70 80 90 100



End of Block: Owner - Cost Questions

Start of Block: Manager Questions - Farm Questions

M74 Select the discipline(s) that best describe the main riding discipline on your farm:

- Dressage (1)
 - Show Jumping/ Hunter Jumper (2)
 - Eventing (3)
 - Reining (4)
 - All around (5)
 - Gymkhana/Games (6)
 - Gaited (7)
 - Endurance (8)
 - Racing (9)
 - Fox Hunting (10)
 - Driving (11)
 - Western Performance (12)
 - Other (Please specify) (13)
-
-

M75 Where do most of your riders prefer to ride? (if weather is not a concern)

- Indoors (1)
 - Outdoors (be it arena, field, etc) (2)
-

M76 Do you also ride?

- Yes (1)
 - No (2)
-

Display This Question:

If Do you also ride? = Yes

M77 How often do you typically ride?

- Multiple times a day (1)
- Once a day (2)
- A few times a week (3)
- Once a week (4)
- A few times a month (5)
- Once a month (6)
- Less than once a month (7)

Display This Question:

If Do you also ride? = Yes

M78 What is the typical length of each ride?

- Less than 30 min (1)
 - 30 min - 1 hour (2)
 - 1-2 hours (3)
 - 2-4 hours (4)
 - More than 4 hours (5)
-

M79 What are the total number of horses on the farm?

- 1-5 (1)
 - 6-10 (2)
 - 11-15 (3)
 - 16-20 (4)
 - 21-25 (5)
 - 26-30 (6)
 - 31-35 (7)
 - 36-40 (8)
 - 40+ (9)
-

M80 Which months generally have the least number of horses on the farm? (Select all that apply)

Does not vary (1)

January (2)

February (3)

March (4)

April (5)

May (6)

June (7)

July (8)

August (9)

September (10)

October (11)

November (12)

December (13)

M81 Which months generally have the maximum number of horses on the farm? (Select all that apply)

Does not vary (1)

January (2)

February (3)

March (4)

April (5)

May (6)

June (7)

July (8)

August (9)

September (10)

October (11)

November (12)

December (13)

M82 What is the typical number of horses worked in the arena each day?

- 1-5 (1)
 - 6-10 (2)
 - 11-15 (3)
 - 16-20 (4)
 - 21-25 (5)
 - 26-30 (6)
 - 30+ (7)
-

M83 What is the maximum number of horses in the indoor area at one time?

- 1-5 (1)
 - 6-10 (2)
 - 11-15 (3)
 - 16-20 (4)
 - 21-25 (5)
 - 26-30 (6)
 - 30+ (7)
-

M84 What is the average number of horses in the indoor arena at one time:

- 1-5 (1)
 - 6-10 (2)
 - 11-15 (3)
 - 16-20 (4)
 - 21-25 (5)
 - 26-30 (6)
 - 30+ (7)
-

M85 What time of day does the facility gets the most use?

- 6am-9am (1)
- 9am-12pm (2)
- 12pm-3pm (3)
- 3pm-6pm (4)
- 6pm-9pm (5)

End of Block: Manager Questions - Farm Questions

Start of Block: Manager - Arena Design

M86 How old is the indoor arena?

- less than 5 years old (1)
 - 5-10 years old (2)
 - 10-15 years old (3)
 - 15-20 years old (4)
 - more than 20 years old (5)
-

M87 What most accurately represents the dimensions of your area? (width x length)

- 60 ft x 100 ft (1)
 - 80 ft x 120 ft (2)
 - 100 ft x 200 ft (3)
 - 150 ft x 300 ft (4)
 - Other (Please specify) (5)
-

M88 What is the eave height of your indoor arena? (i.e. height of your walls/height of trusses)

Under 16 ft (1)

16-18 ft (2)

+18 ft (3)

Unknown (4)

M89 Select the picture that most accurately represents how your indoor arena is oriented:
(Rectangle represents the arena)

Image:East west orientation (1)

Image:North south orientation (2)

M90 What are the main building materials for the indoor arena? (Select all that apply)

- Metal siding (1)
 - Fabric siding (2)
 - Vinyl siding (3)
 - Exterior wooden shingles/walls (4)
 - Exterior reflective paint (5)
 - Interior wooden half walls (6)
 - Interior wooden walls (7)
 - No interior wall covering (8)
 - Wood studs/column (9)
 - Metal Column (10)
 - Insulation (11)
 - Other (Please specify) (12)
-
-

M91 What are the main roof building materials for the indoor arena? (Select all that apply)

- Wood truss (1)
 - Metal truss (2)
 - Wood (laminated) arches/rafter (3)
 - Metal (I-beam) arches/rafter (4)
 - Shingles (5)
 - Fabric roofing (6)
 - Reflective paint (7)
 - Other (Please specify) (8)
-

M92 Do you have any opaque or transparent roofing panels or any other methods of natural light? (not from windows or doors)

- No (1)
 - Yes - 1-5 panels (2)
 - Yes - 5-10 panels (3)
 - Yes - more than 10 panels (4)
-

M93 What type of lighting do you have?

- Fluorescent linear/bar light (1)
 - Fluorescent high bay (2)
 - Fluorescent round light (3)
 - LED linear/bar light (4)
 - LED round light (5)
 - Metal Halide/High Pressure Sodium light (6)
 - Other (Please specify) (7)
-

M94 Number of lights:

- 1-5 (1)
 - 6-10 (2)
 - 10-15 (3)
 - 15-20 (4)
 - 20+ (5)
-

M95 Are there solar panels or other renewable energy sources?

- No (1)
 - Yes - solar panels (2)
 - Yes - other (please specify) (3)
-

M96 Do you collect, store, and use rain water as a water source for the farm?

- Yes (1)
 - No (2)
-

M97 Is there a ridge opening or cupola?

- No (1)
 - Yes - ridge opening (2)
 - Yes - cupola (3)
-

M98 Are there windows that can be opened to allow air to move through the arena?

- No (1)
- Yes - 1-5 (2)
- Yes - 5-10 (3)
- Yes - 10+ (4)

Display This Question:

If Are there windows that can be opened to allow air to move through the arena? != No

M99 What type of windows are there?



- Vertical sliding (1)
- Horizontal sliding (2)
- Swinging door (3)
- Other (please specify) (4)

Display This Question:

If Are there windows that can be opened to allow air to move through the arena? != No

M100 What are the typical opening dimensions of the windows? (in feet)

0 1 2 3 4 5 6 7 8 9 10

Height (1)	
Width (2)	

M101 Are there curtains or sidewalls that can be opened?

- Yes - can open the entire wall (1)
 - Yes - can open half the wall (2)
 - Arena only has half/partial walls (3)
 - No (4)
-

M102 What is the number of doors opening to the outdoors?

- 1 (1)
 - 2 (2)
 - 3 (3)
 - 4 (4)
 - 4+ (5)
-

M103 Are horses stabled under the same roof as the arena?

- No (1)
 - Yes - horses are in the same space as arena (2)
 - Yes - a door can be closed (3)
 - Yes- doorway is open constantly (4)
-

M104 Do any of the doors open into the barn or an enclosed space?

- No (1)
- Yes - 1 door (2)
- Yes - 2 doors (3)
- Yes - more than 2 doors (4)

End of Block: Manager - Arena Design

Start of Block: Manger - Footing

M105 What best describes the footing in the indoor arena? (Select all that apply)

- Dirt (1)
- Sand (2)
- Washed sand (3)
- Waxed Sand (4)
- Crushed Rock (5)
- Wood Chip/Sawdust (6)
- Textile/fiber - low proportion (7)
- Textile/fiber - high proportion (8)
- Rubber (9)
- Clay (10)
- Other (Please specify) (11)

M106 What is the type of maintenance required? (Select all that apply)

- Dragging (1)
 - Harrowing (2)
 - Rolling (3)
 - Aerating (4)
 - Other (Please specify) (5)
-

M107 How many hours per week are spent maintaining the footing?

- 1-5 hrs (1)
 - 5-10 hrs (2)
 - more than 10 (3)
-

M108 How often does the footing have to be added or replaced?

- Yearly (1)
 - 1-5 years (2)
 - 5-10 years (3)
 - Never been added or replaced (4)
-

M109 Is the footing treated with anything? (Select all that apply)

- Wax (1)
 - Mineral Oil (2)
 - Water (3)
 - Other (Please specify) (4)
-

Display This Question:

If Is the footing treated with anything? (Select all that apply) = Water

M110 If the arena is watered, how do you water it?

- Water tank and tractor (1)
 - Overhead sprinklers (2)
 - Sprinklers attached to the sidewalls (3)
 - Movable garden type sprinkler (4)
 - By hand with hose and spray nozzle (5)
 - Do not water arena (6)
-

M111 How often is the footing treated with the most commonly used treatment?

- Once a year (1)
- Once a month (2)
- Once a week (3)
- Multiple times per week (4)
- Daily (5)

End of Block: Manger - Footing

Start of Block: Manager - Arena Environment

M112 Are there rust spots on the walls, roof, or supports?

- Yes (1)
 - No (2)
 - Unknown (3)
-

M113 Does it ever "rain" in the arena?

- Yes (1)
 - No (2)
-

M114 Is the roof insulated?

- Yes (1)
 - No (2)
 - Unknown (3)
-

M115 Are there temperature control methods in the indoor arena? (Select all that apply)

- Heaters (1)
 - Fans (2)
 - Central air system (3)
 - None (4)
-

Display This Question:

If Are there temperature control methods in the indoor arena? (Select all that apply) = Heaters

M116 How many heaters do you utilize?

- 1-3 (1)
 - 4-6 (2)
 - 6-9 (3)
-

Display This Question:

If Are there temperature control methods in the indoor arena? (Select all that apply) = Fans

M117 How many fans are there?

- 1-3 (1)
 - 4-6 (2)
 - 6-9 (3)
-

Display This Question:

If Are there temperature control methods in the indoor arena? (Select all that apply) = Fans

M118 What type of fans are they? (ie ceiling fans, wall fans) Please provide diameter and brand if possible

M119 Do you have any concerns about the environment within the indoor arena? (ie is it dusty? Is it hot? Is there little air movement? etc)

- Yes (1)
 - Maybe (2)
 - No (3)
-

Display This Question:

*If Do you have any concerns about the environment within the indoor arena? (ie is it dusty? Is it ho...
!= No*

M120 Do your environmental concerns fall into any of these categories?

- Lack of air movement (1)
- Too much air movement (2)
- Temperature (3)
- Dust (4)
- Moisture control (5)
- Not enough light (6)
- Too much light (7)

End of Block: Manager - Arena Environment

Start of Block: Rider Questions

R121 Select the discipline(s) that best describes your main riding interest:

- Dressage (1)
 - Show Jumping/Hunter Jumper (2)
 - Eventing (3)
 - Reining (4)
 - All around (5)
 - Gymkhana/Games (6)
 - Gaited (7)
 - Endurance (8)
 - Racing (9)
 - Fox Hunting (10)
 - Driving (11)
 - Western Performance (12)
 - Other (Please specify) (13)
-
-

R122 Do you prefer to ride indoors or outdoors? (if weather is not a concern)

Indoors (1)

Outdoors (2)

R123 What are the typical number of horses present in the indoor arena when you ride?

1-3 (1)

4-6 (2)

6-9 (3)

More than 9 (4)

R124 How often do you typically ride?

- Multiple times a day (1)
 - Once a day (2)
 - A few times a week (3)
 - Once a week (4)
 - A few times a month (5)
 - Once a month (6)
 - Less than once a month (7)
-

R125 What is the typical duration of your rides?

- less than 30 min (1)
 - 30 min - 1 hour (2)
 - 1-2 hours (3)
 - 2-4 hours (4)
 - more than 4 hours (5)
-

R126 On average, how many times a week do you ride in the indoor arena?

- less than 1 (1)
 - 1-2 (2)
 - 3-4 (3)
 - 5 or more (4)
-

R127 What time of day do you typically ride?

- 6am - 9am (1)
- 9 am - 12 pm (2)
- 12 pm - 3 pm (3)
- 3 pm - 6 pm (4)
- 6 pm - 9 pm (5)

End of Block: Rider Questions

Start of Block: Rider - Arena Design

R128 What most accurately represents the dimensions of the area? (width x length)

- 60 ft x 100 ft (1)
 - 80 ft x 120 ft (2)
 - 100 ft x 200 ft (3)
 - 150 ft x 300 ft (4)
 - Other (Please specify) (5)
-

R129 Are there windows that can be opened to allow air to move through the arena?

- No (1)
 - Yes - 1-5 (2)
 - Yes - 5-10 (3)
 - Yes - 10+ (4)
-

R130 Do you have any opaque or transparent roofing panels or any other methods of natural light? (not from windows or doors)

- No (1)
 - Yes - 1-5 panels (2)
 - Yes - 5-10 panels (3)
 - Yes - more than 10 panels (4)
-

R131 How many lights are there in the indoor arena?

- 1-5 (1)
 - 6-10 (2)
 - 10-15 (3)
 - 15-20 (4)
 - 20+ (5)
-

R132 What is the number of doors opening to the outdoors?

1 (1)

2 (2)

3 (3)

4 (4)

4+ (5)

R133 Are horses stabled under the same roof as the arena?

No (1)

Yes - horses are in the same space as arena (2)

Yes - a door can be closed (3)

Yes- doorway is open constantly (4)

R134 Do any of the doors open into the barn or an enclosed space?

- No (1)
- Yes - 1 door (2)
- Yes - 2 doors (3)
- Yes - more than 2 doors (4)

End of Block: Rider - Arena Design

Start of Block: Rider - Footing

R135 What best describes the footing in the indoor arena? (Select all that apply)

- Dirt (1)
 - Sand (2)
 - Crushed Rock (3)
 - Wood Chip/Sawdust (4)
 - Textile/fiber - low proportion (5)
 - Textile/fiber - high proportion (6)
 - Rubber (7)
 - Clay (8)
 - Other (Please specify) (9)
-

End of Block: Rider - Footing

Start of Block: Rider - Arena Environment

R136 Does it ever "rain" in the arena?

Yes (1)

No (2)

R137 Are there temperature control methods in the indoor arena? (Select all that apply)

Heaters (1)

Fans (2)

Central air system (3)

None (4)

R138 Do you have any concerns about the environment within the arena? (ie is it dusty? is it hot? Is there little air movement? etc)

Yes (1)

Maybe (2)

No (3)

Display This Question:

*If Do you have any concerns about the environment within the arena? (ie is it dusty? is it hot? Is t... !=
No*

R139 Do your environmental concerns fall into any of these categories?

- Lack of air movement (1)
- Too much air movement (2)
- Temperature (3)
- Dust (4)
- Moisture control (5)
- Not enough light (6)
- Too much light (7)

End of Block: Rider - Arena Environment

Start of Block: Health Questions

H140 Do you notice your horse(s) or other horses tripping frequently in the indoor arena?

- Yes (1)
 - No (2)
-

H141 Does your horse(s) cough during the warm up period of your ride in the indoor arena?

Yes (1)

No (2)

H142 Does your horse(s) cough after your warm up when you ride in the indoor arena?

Yes (1)

No (2)

H143 Do you cough while you're riding in the indoor arena?

Yes (1)

No (2)

H144 Is smoking allowed in the indoor arena?

Yes (1)

No (2)

H145 Do you smoke tobacco?

Yes (1)

No (2)

Display This Question:

If Do you smoke tobacco? = Yes

H146 How often do you smoke tobacco?

Multiple times a day (1)

Once a day (2)

Few times a week (3)

Once a week (4)

Few times a month (5)

Once a month (6)

Less than once a month (7)

Display This Question:

If Do you smoke tobacco? = Yes

H147 Do you smoke in the indoor arena?

Yes (1)

No (2)

H148 Have you experienced any other health issues while riding in the indoor arena?
(Select all that apply)

No (1)

Yes - Allergies (2)

Yes- Shortness of breath (3)

Yes - Frequent headaches (4)

Yes - Lightheadedness (5)

Yes - Skin issues/rashes (6)

Yes - Other (please specify) (7)

H149 Have you experienced any health issues while observing or teaching in the indoor arena? (Select all that apply)

- No (1)
 - Yes - Allergies (2)
 - Yes - Shortness of breath (3)
 - Yes - Frequent headaches (4)
 - Yes - Lightheadedness (5)
 - Yes - skin issues/rashes (6)
 - Yes - other (please specify) (7)
-

H150 Is it every excessively hot or cold for your horse(s)?

- No (1)
 - Yes - Hot (2)
 - Yes - Cold (3)
 - Yes - Both (4)
-

H151 Is it ever excessively hot or cold for you?

- No (1)
- Yes - Hot (2)
- Yes - Cold (3)
- Yes - Both (4)

End of Block: Health Questions

Start of Block: Final Thoughts

H152 Name two things you would change about your arena:

H153 Name two things you like about your arena:

H154 Any final thoughts you feel should be discussed about your indoor arena?

End of Block: Final Thoughts

APPENDIX 5. INDOOR ARENA SURVEY – RECODING

Original Question	Original Answers	Recoded Answers
In which state do you currently own a facility, manage a facility, or ride at a facility with an indoor arena?	All 50 states and Outside the US	Kentucky, Northeast, South, Southwest, West, Midwest, and Outside the US
Select the discipline(s) that best describe the main riding discipline on your farm or you participate in:	Dressage, Show Jumping/Hunter Jumper, Eventing, Reining, All around, Gymkhana/Games, Gaited, Endurance, Racing, Fox hunting, Driving, Western performance, Other (please specify)	All Around, Dressage, Eventing, Flat and Fence Emphasis, Flat Emphasis
What was the cost to build your indoor arena facility?	Less than \$100,000, \$100,000-\$250,000, \$250,000-\$500,000, \$500,000-\$750,000, \$750,000- \$1,000,000, more than \$1,000,000	Less than \$100,000, \$100,000-\$250,000, \$250,000-\$750,000, more than \$1,000,000
How old is the indoor arena?	Less than 5 years old, 5-10 years old, 10-15 years old, 15-20 years old, more than 20 years old	1-5 years old, 6-15 years old, 15+ years old
What most accurately represents the dimensions of your arena? (width x length)	60 ft x 100 ft, 80 ft x 120 ft, 100 ft x 200 ft, 150 ft x 300 ft, Other (please specify)	Width: less than 80 ft, 80 – 120 ft, more than 120 ft
		Length: less than 100 ft, 100-200 ft, more than 200 ft
		Square Footage: less than 10,000 sq ft, 10,000-15,000 sq ft, more than 15,000 sq ft

What type of lighting do you have?	Fluorescent linear/bar light; Fluorescent high bay, Fluorescent round light, LED linear/bar light, LED round light, Metal halide/high pressure sodium light, Other (Please specify)	Fluorescent, LED, Metal halide/high pressure sodium light, Spotlight
Are horses stabled under the same roof as the arena?	No, Yes - horses are in the same space as the arena, Yes – a door can be closed, Yes- doorway is open constantly	No, Yes
What best describes the footing in the indoor arena? (Select all that apply)	Dirt, Sand, Washed Sand, Waxed Sand, Poly/Synthetic, Clay, Crushed Rock, Wood Chip/Sawdust, Textile/fiber – low proportion, Textile/fiber – high proportion, Rubber, Other (Please specify)	<p>Primary Footing Component: Crushed Rock, Dirt and Sand, Sand, Washed Sand, Waxed Sand, Wood Chip</p> <p>Secondary Footing Component: Clay, Crushed Rock, Fiber, Fiber and Rubber, None, Rubber, Wood Chip</p>

APPENDIX 6. INDOOR ARENA – SITE VISIT INTERVIEW QUESTIONS

Arena Construction:

Dimensions?

How much did the arena cost to build?

When was the arena built?

Have there been any recent changes to the arena and has that affected its usability/environment?

Footing:

What type of footing is in the arena?

What is the type of maintenance required? (dragging, rolling, etc)

How many hours per week spent maintaining the footing?

Do you ever treat it with anything? (ex: water, mineral oil) If so, how often is it treated?

Do you use any material to maintain moisture content of the footing?

On average, how much do you spend each year to maintain footing?

Arena Environment:

Does it “rain” in the arena?

Do you have any environmental concerns? (ex: air movement or lack of, temperature, dust etc)

Is it ever excessively hot or cold for your horse?

Is it ever excessively hot or cold for you?

Do you regulate the temperature in the arena? If so, how?

Are there fans for ventilation and circulation? If yes, what are the number, type and dimensions of the fans?

Farm Operation:

How would you classify the main riding discipline on your farm?

As a whole, do most of the riders on the farm prefer riding indoors or outdoors?

What is the total number of the horses on the farm?

What is the maximum number of horses in the indoor arena at one time?

What is the average number of horses in the indoor arena at one time?

What is the typical number of horse worked in the arena each day?

Which months of the year have the maximum horse populations?

Which months of the year have the least horse populations?

What time of day arena receives the most use?

Health Questions:

Do you notice your horse(s) or other horses tripping frequently in the indoor arena?

Does your horse(s) cough during the warm up period of your ride in the indoor arena?

Does your horse(s) cough after your warm up when you ride in the indoor arena?

Do you cough while in the indoor arena? If so, what were you doing?

Is smoking allowed in the indoor arena?

Do you smoke? If yes, how often do you smoke? Do you smoke in the indoor arena?

Have you experienced any health issues while in the indoor arena such as allergies, shortness of breath, frequent headaches, lightheadedness, or skin issues or rashes? If so, what were you doing?

Final Thoughts:

Is there anything else you feel we should know about the indoor arena?

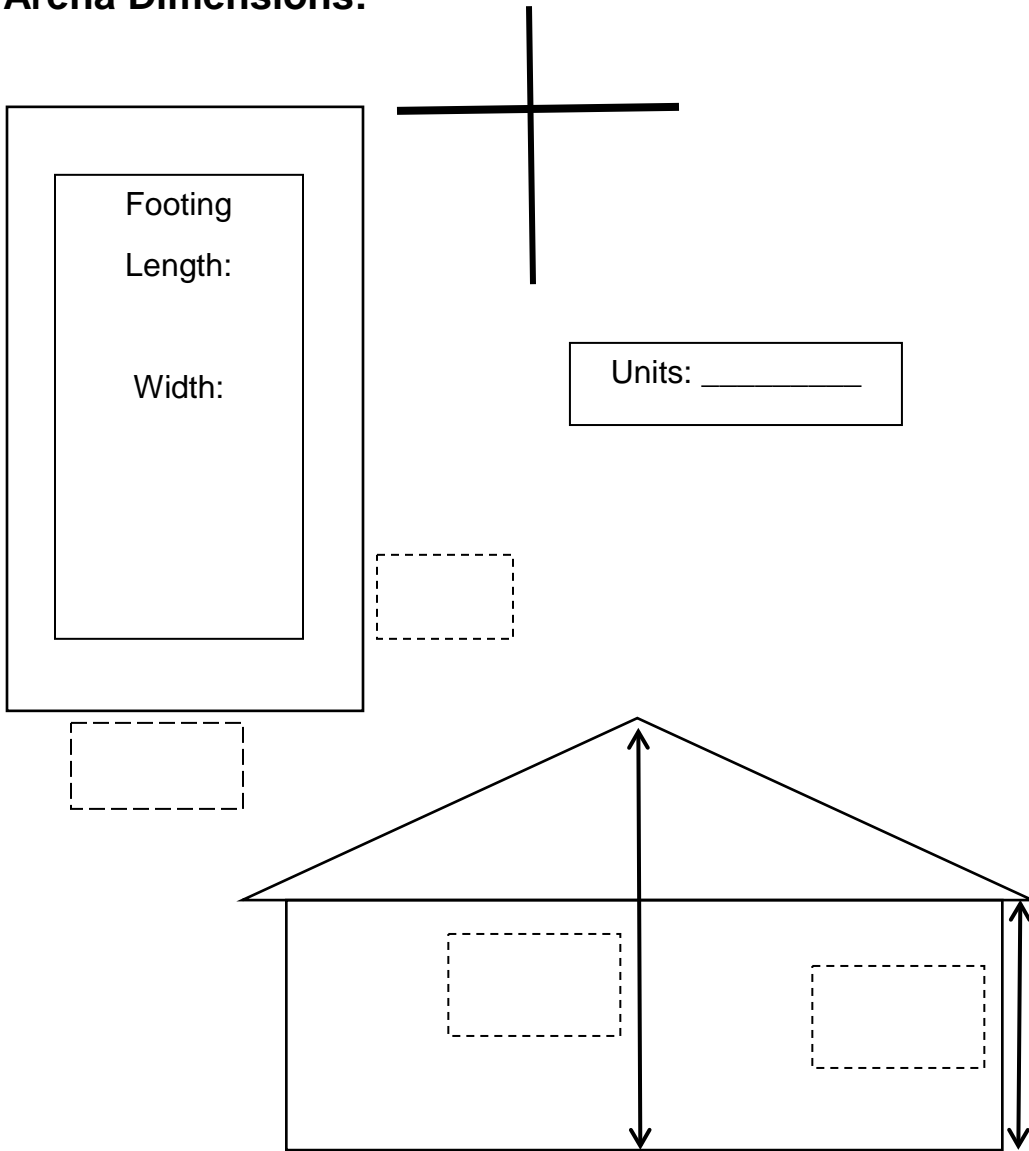
APPENDIX 7. INDOOR ARENA SURVEY – SITE VISIT DATA COLLECTION

SHEET 1

Farm Number:

Date:

Arena Dimensions:



Footing Dimensions same as building dimensions: Y N

Construction/Building Materials:

Trusses or Rafters:

Walls (description (ie open sided, curtains etc) and material):

Roof:

Insulation:

Lighting (number and type):

Windows (number and dimensions):

Doors (number and dimensions):

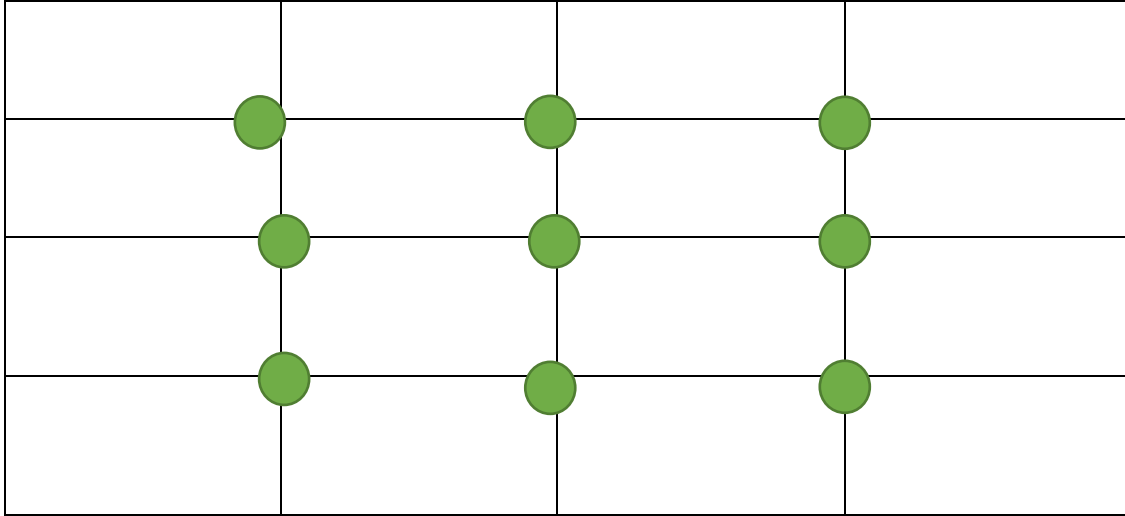
Ridge opening/Cupola: Y N Dimensions –

Footing:

Sample Taken: Y N

Type:

Depth:



Base type and Depth:

Maintenance (manure removal, dragging etc):

Type of Drag:

Treatment/Additive Type and Frequency:

pH:

Arena Environment

Rust spots: Y N Where?

Fans:

Heaters:

Arena/Farm Usage:

Main riding discipline (ex: reining, jumper, eventing, dressage, barrel racing):

Outdoors Arenas: Y N

Total number of the horses on the farm:

Maximum number of horses in the indoor arena at one time:

Average number of horses in the indoor arena at one time:

Typical number of horse worked in the arena each day:

Time of day arena receives the most use:

Recent changes:

Health questions

Horses tripping:

Horses coughing:

People coughing:

Smoking allowed:

Any health issues experienced while in the indoor:

Final Thoughts

Anything else we should know:

APPENDIX 8. INDOOR ARENA STUDY- SITE VISIT DATA COLLECTION SHEET 2

Air Movement Data

Farm:

	1	2	3	4	5
A					
B					
C					
D					
E					

A1:

X:

Y:

Z:

Temp R:

Light:

G:

C1:

X:

Y:

Z:

Temp R:

Light:

G:

E1:

X:

Y:

Z:

Temp R:

Light:

G:

A2:

X:

Y:

Z:

Temp R:

Light:

G:

C2:

X:

Y:

Z:

Temp R:

Light:

G:

E2:

X:

Y:

Z:

Temp R:

Light:

G:

A3:

X:

Y:

Z:

Temp R:

Light:

G:

C3:

X:

Y:

Z:

Temp R:

Light:

G:

E3:

X:

Y:

Z:

Temp R:

Light:

G:

A4:

X:

Y:

Z:

Temp R:

Light:

G:

C4:

X:

Y:

Z:

Temp R:

Light:

G:

E4:

X:

Y:

Z:

Temp R:

Light:

G:

A5:

X:

Y:

Z:

Temp R:

G:

Light:

C5:

X:

Y:

Z:

Temp R:

G:

E5:

X:

Y:

Z:

Temp R:

G:

Light:

Light:

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