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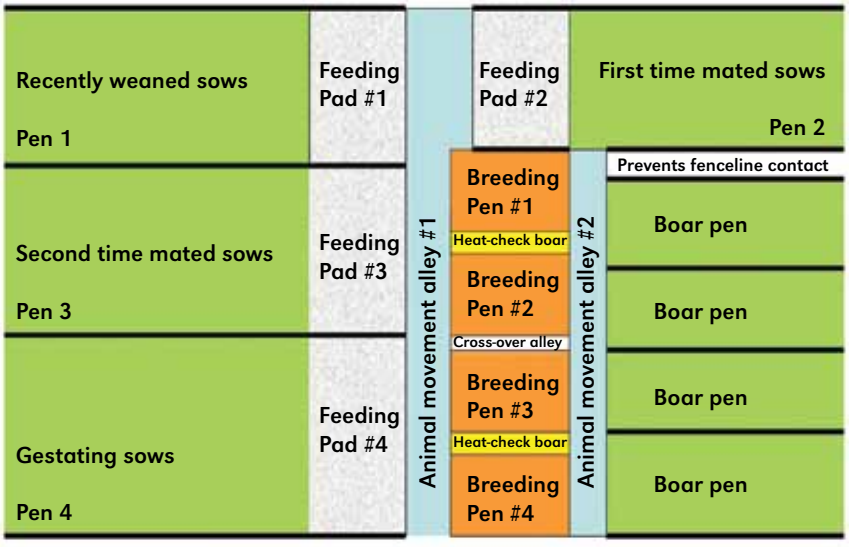
EC287

Hand-Mating Pigs on Small- and Medium-Sized Pork Operations
(Design and Management Principles)

Donald G. Levis, Professor Emeritus



Summary

Most small- and medium-sized swine operations have a diversified farm; thus, they cannot devote total time and management to the swine enterprise. The use of hand-mating helps to increase reproductive performance of the sow herd. Hand-mating involves the placement of an individual estrous female in a small pen where she is mated to an individual boar with supervision by a person working in the breeding area. The main factors that make hand-mating easy, fast and efficient include: (1) location of boars, sows, and gilts, (2) procedure for estrous detection of sows and gilts, (3) procedure for moving animals, (4) design of alleyways, (5) design of breeding pens, (6) functionality of gates and gate latches, (7) design of boar housing area, (8) provision of an adequate number of working boars, (9) method of feeding sows, (10) efficient use of labor, (11) use of an excellent record keeping system, (12) control of extreme weather conditions on boars, sows, and gilts, and (13) facility design whereby estrous sows can be mated by a boar. Regardless of the number of sows in the herd, these factors apply when hand-mating sows and gilts.

This publication discusses these factors and provides designs for hand-mating sows either indoors or outdoors. In addition, the publication discusses the importance of minimizing stress of sows after mating.

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Table of Contents

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List of Tables

Title **Page**

List of Figures

1. Introduction

During 2006, the USDA's National Animal Health Monitoring System conducted a survey in 17 states. These states accounted for 94 percent of swine operations with an inventory of 100 or more pigs. The survey gathered information about the type of mating technique used on the site. Artificial insemination was the predominate method of mating sows during first, second, and third matings (*Table 1*). Individual hand-mating with a boar or pen-mating with multiple females appear to be used on few sows during any mating. For swine enterprises that used hand-mating on the first mating, the second mating was accomplished by hand-mating on 11.2 percent of the farms, by artificial insemination on 2.1 percent of the farms, or by pen-mating on 1.1 percent of the farms (*Table 2*).

Most small- and medium-sized swine operations have a diversified farm; thus, they cannot devote total time and management to the swine enterprise. These pork producers seasonalize the production of pigs around their cropping plans. However, the breeding area is one of the most important elements of the swine enterprise. The use of hand-mating helps to increase reproductive performance of the sow herd. Hand-mating involves placing individual estrous female in a small pen where she is mated to an individual boar with supervision by a person working in the breeding area. An analysis of reproductive performance data from North Carolina State University's Swine Development Center revealed that the number of live pigs born per litter increased by 0.5 piglets per each 10 percent increase in farrowing rate (*Figure 1*). All sows at the Swine Development Center were hand-mated. An analysis of reproductive

Table 1. The percentage of sows serviced by mating technique used for first, second, and third or more matings (USDA, 2007).

	Percentage of sows mated		
Mating technique	**First mating**	**Second mating**	**Third or more mating**
Artificial insemination	91.6	90.0	51.0
Individual hand-mating naturally	2.4	7.5	0.2
Pen-mating	6.0	1.2	1.5
No second mating	N/A	1.3	N/A
No third mating	N/A	N/A	47.3
Total	100.0	100.0	100.0

Table 2. The percentage of sites and percentage of sows serviced by mating technique used for first and second mating (USDA, 2007).

Mating technique		**Number sites**	**Sows mated**
First mating	Second mating	(Percent)	(Percent)
Artificial insemination	Artificial insemination	76.1	89.8
Artificial insemination	Hand-mating	2.5	0.7
Artificial insemination	Pen-mating	3.6	1.1
Hand-mating	Artificial insemination	2.1	0.8
Hand-mating	Hand-mating	11.2	1.3
Hand-mating	Pen-mating	1.1	0.2
Pen-mating	Any other technique	3.4	6.1
Total		100.0	100.0

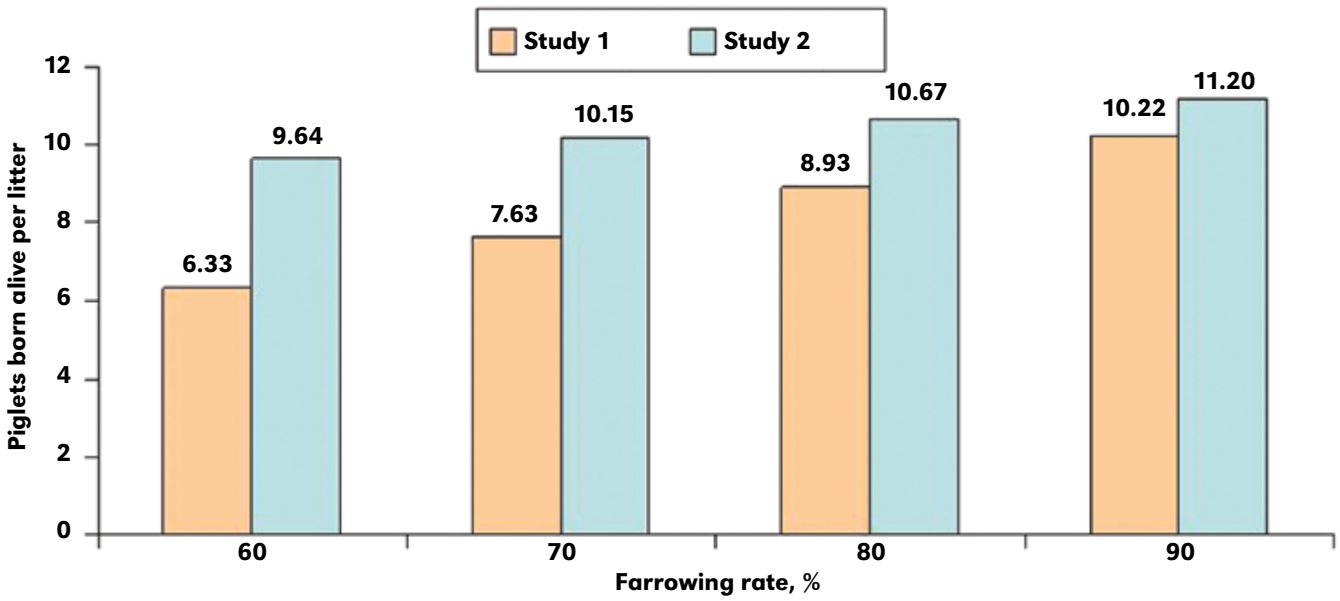

Figure 1. Relationship between farrowing rate and live piglets born per litter (data from Rasbech, 1969; North Carolina State University Swine Development Center Reports, 1972-1976).

Table 3. Reproductive performance on a commercial farm that changed from pen-mating to hand-mating (Levis – unpublished data).

Year	Method of Mating	Avg. number of sows on inventory	Number females farrowed	Litters per female per year	Number of pigs		Pigs per female per year
					Farrowed	Weaned	
1	Pen-mated 12 months	140	219	1.56	2061	1849	14.39
2	Hand-mated 4 months and pen-mated 8 months	140	246	1.76	2587	2145	16.69
3	Hand-mated 12 months	111	259	2.33	2809	2412	21.72

performance data gathered in England revealed that the number of live piglets born per litter increased by 1.3 piglets per each 10 percent increase in farrowing rate. All the sows were hand-mated.

Pork producers who have pen-mated sows and then changed to a correctly designed and managed hand-mating system for sows and gilts never consider returning to a pen-mating system. They do not return to pen-mating because of the increase in reproductive performance. Reproductive performance of a farm that changed from pen-mating to hand-mating is indicated in *Table 3*. This farm could observe the benefit from hand-mating because during a 12-month period they had pen-mated the first four months, hand-mated the middle four months, and pen-mated the last four months. When the reproductive data was summarized, the farrowing rate and litter size was lower for pen-mating compared to hand-mating. When a 12-month period of hand-mating was compared to an earlier 12-month period of pen-mating, the improvement in reproductive performance when hand-mating was:

- 0.2 percent increase in pigs weaned per litter
- 15 percent increase in pigs born live per litter
- 30.5 percent increase in total number of pigs weaned
- 36.3 percent increase in total number of pigs born live
- 49.4 percent increase in litters per female per year
- 51 percent increase in pigs weaned per female per year

The increase in reproductive performance when hand-mating was accomplished with a 20.7 percent decrease in the average number of females on inventory. Some factors that improved reproductive performance were: better control of boar fertility; a tighter production schedule due to knowledge of exact breeding dates; bred females were regularly heat-checked to identify open females; and females returning to estrus after their second mating were culled.

Hand-mating systems do not require a large financial investment. Many times an existing farmstead structure can be renovated into a highly efficient hand-mating facility. Other circumstances may only require the development of a boar housing area with breeding pens. The purpose of this publication is to discuss the advantages and disadvantages of hand-mating, discuss factors that make a hand-mating system work efficiently, and present a few designs that have been satisfactorily used by pork producers.

2. Advantages

Compared to pen-mating, numerous advantages are found when hand-mating sows and gilts. The main advantages are:

- Hand-mating has consistently resulted in a 15 to 30 percent increase in farrowing rate for sows that are mated within the first 21 days after being weaned on the same day when compared to pen-mating. Farrowing rate is defined as the number of sows farrowed when bred during the first 21 days after weaning divided by total number of sows bred during the first 21 days after weaning.

- Provided boars are housed individually, hand-mating controls the mating frequency (copulation rate) of boars. Therefore, farrowing rate and litter size are improved.

- Hand-mating ensures that sows are mated at least once or twice. Optimal fertility is enhanced when viable spermatozoa are present in the oviduct just prior to ovulation. Sows that are only mated once are at more risk to not become pregnant. A research experiment conducted by North Carolina State University evaluated the effect of double natural mating on reproductive performance. The sows were mated either one time when first detected in estrus during the morning or mated one time when first detected in estrus during the morning and a second time 24 hours later. The results indicated that double mating of gilts significantly increased farrowing rate 15.4 percentage points and the number of piglets born live by 1.8 pigs (*Table 4*). Double mating of multiparous sows did significantly increase the number of piglets born live by 1.3, and numerically increased farrowing rate by 11.9 percent. A good method to evalu-

Table 4. Effect of number of natural matings on reproductive performance of gilts and multiparous sows (Flowers and Alhusen, 1992).

	Gilts mated naturally			Multiparous sows mated naturally		
Item	**Once**	**Twice**	**Difference**	**Once**	**Twice**	**Difference**
Number of animals	61	67	6	100	95	5
Farrowing rate, %	56.3[a]	71.7[b]	15.4	75.4	87.3	11.9
Piglets born live per litter	8.0[a]	9.8[b]	1.8	9.0[a]	10.3[b]	1.3
Total piglets born per litter	9.0[a]	10.9[b]	1.9	10.1[a]	11.3[b]	1.2
Fecundity index for piglets born live[c]	450	703	253	679	899	220

[a, b]Means in the same row and within a category of gilt or sow with a different superscript differ (P < .05)
[c]Fecundity index = (Farrowing rate x litter size) x 100

ate reproductive performance is to calculate the fecundity index for piglets born live. The equation for fecundity index (FI) is: FI = (farrowing rate x number of piglets born alive per litter) x 100. In other words, the fecundity index provides a method to calculate the total number of live pigs born per 100 gilts and sows bred. Double mating increased the fecundity index by 253 piglets for gilt matings and 220 piglets for sow matings.

Another study to evaluate the effect of double natural mating on reproductive performance of multiparous sows was conducted in Australia. The scientists conducted two trials. The first trial was during the summer months and the second trial during the winter months. The time of matings was: (1) Double mating — first mating when first detected in estrus and a second mating 24 hours later; (2) Single mating — one mating when first detected in estrus, and (3) Single mating — one mating 24 hours after first detected in estrus. Sows that were double mated during the summer months farrowed significantly more live piglets per litter than either of the groups of sows which were mated once (*Table 5*). The farrowing rate tended to be greater in double mated sows (90.3 percent) than sows mated once when first detected in estrus (85.2 percent) or mated once 24 hours after first detected in estrus (84.4 percent). For sows mated during the winter months, there was no significant effect of double mating on litter size or farrowing rate. However, the overall average fecundity index for the two trials indicated that double mated sows produced 104 additional pigs per 100 sows bred.

A study conducted by the University of Minnesota evaluated the influence of mating frequency on sow reproductive performance. The study was conducted from May through September. The breeding schedule for each mating frequency was: Single mating — AM the first day of estrus; Double mating — AM the first day of estrus and AM the second day of estrus; and Three matings — AM the first day of estrus, AM the second day of estrus, and PM the second day of estrus. The absolute importance of having both a high farrowing rate and litter size

Table 5. Influence of single or double natural mating on farrowing rate and number of piglets born live per litter (Paterson and Mullan, 1994).

	Single mating (mated when first detected in estrus)		Single mating (mated 24 after first detected in estrus)		Double mating (mated when first detected in estrus and 24 hours later)	
Item	**Trial 1**	**Trial 2**	**Trial 1**	**Trial 2**	**Trial 1**	**Trial 2**
Number sows bred	176	152	141	164	113	149
Number sows farrowed	150	134	119	139	102	137
Piglets born live per litter	10.28[a]	10.31	10.27[a]	10.63	11.12[b]	10.67
Farrowing rate, %	85.2	88.2	84.4	84.8	90.3	91.9
Fecundity index[c]	876	909	867	901	1004	980

Average fecundity index: Double matings = 992, Single matings = 888; thus, a double mating produced 104 additional pigs per 100 sows bred.
[ab]In Trial 1 litter size was significantly greater (P < .03) for sows double mated.
[c]Fecundity index = (Farrowing rate x litter size) x 100

Table 6. Influence of hand-mating frequency on farrowing rate and litter size of gilts and sows (Xue et al., 1998).

Number matings[a]	Number of gilts		Farrowing rate, %[b]	Number of piglets[c]		Fecundity index, PBA[d]
	Bred	Farrowed		Total born per litter	Born live per litter	
1	85	65	76.5	8.6	8.2	627
2	72	47	65.3	9.7	9.3	607
3	56	45	80.4	9.5	9.0	724
Number matings	**Number of sows**			**Number of piglets**		
	Bred	**Farrowed**	**Farrowing rate, %**	**Total born per litter**	**Born live per litter**	**Fecundity index, PBA**
1	189	156	82.5	10.9	10.4	854
2	191	162	94.8	11.0	10.4	882
3	152	129	84.9	10.8	10.2	866

[a]1 = mated the day estrus was detected; 2 = mated day 1 in the morning and day 2 in the morning; 3 = mated day 1 in the morning, day 2 in the morning, and day 2 in the afternoon.
[b]Mating frequencies 1 (76.5, P = .06) and 3 (80.4%, P < .05) had a higher farrowing rate than did mating frequency 2 (65.3%).
[c]Gilts with mating frequency 2 during an estrus had greater (P < .03) total born (9.7) and born live (9.3) pigs than those having mating frequency 1 (8.6 and 8.2).
[d]Fecundity index = (Farrowing rate x number of piglets born live per litter) x 100

can be seen in *Table 6*. The farrowing rate for the gilts bred twice was very low (65.3 percent); however, these gilt had the highest number of piglets born live (9.3). Because of the low farrowing rate, the fecundity index for piglets born live was the lowest (607). The gilts that were bred three times had the highest farrowing rate (80.4 percent) and a litter size of 9.0. Thus, they had the highest fecundity index (724). Double mating of sows did not significantly increase farrowing rate or litter size. However, farrowing rate was numerically greater for sows double mated compared to single mated sows (94.8% vs 82.5%).

- Hand-mating helps determine exact breeding dates. Because exact breeding dates are known, the stockperson has a better estimate as to when the sows will farrow. Therefore, the stockperson spends less time observing sows to determine when they might farrow, the stockperson can make sure bedding materials are readily available for sows that farrow outdoors, and the stockperson can make sure the sows are in the farrowing area prior to arrival of the first piglet. When exact breeding dates are known, sows can be induced to farrow during a short period of time. The reasons for inducing farrowing include: (1) The direct supervision of farrowings helps reduce stillborns, (2) Supervision of the farrowing process helps limit the number of pigs born which have been hypoxic (deficiency of oxygen) during a prolonged farrowing process, (3) Supervision of the farrowing process helps enhance colostrum intake by all the piglets, (4) The sows are induced to farrow during daylight hours and during the week days, and (5) Inducing sows to farrow reduces the variation in the day of farrowing among sows within rooms; thus, there is less variation in age of piglets, cross-fostering is more easily accomplished, and operating the farrowing room(s) on an all-in-all-out basis is more easily accomplished. Sows should not be induced more than two days early to prevent the birth of immature piglets. The length of gestation can be quite variable (*Figure 2*); therefore, each farm needs to document the length of gestation for their farm.
- Hand-mating allows producers to maintain a tighter farrowing schedule. Thus, an all-in-all-out pig flow in the farrowing and nursery facility is more easily accomplished. The use of all-in-all-out flow allows the pigs to be exposed to the same pathogens as their pen mates. When a group of pigs is moved from any facility, the area needs to be fully cleaned, power washed, and properly disinfected.
- Hand-mating helps producers determine whether boars have an adequate level of sexual behavior, mounting ability, and dexterity for a successful copulation. The person supervising the mating can determine whether the boar is overly abusive to estrous sows.
- Hand-mating allows the person supervising the mating to control the body size difference between boars, sows, and gilts during mating.

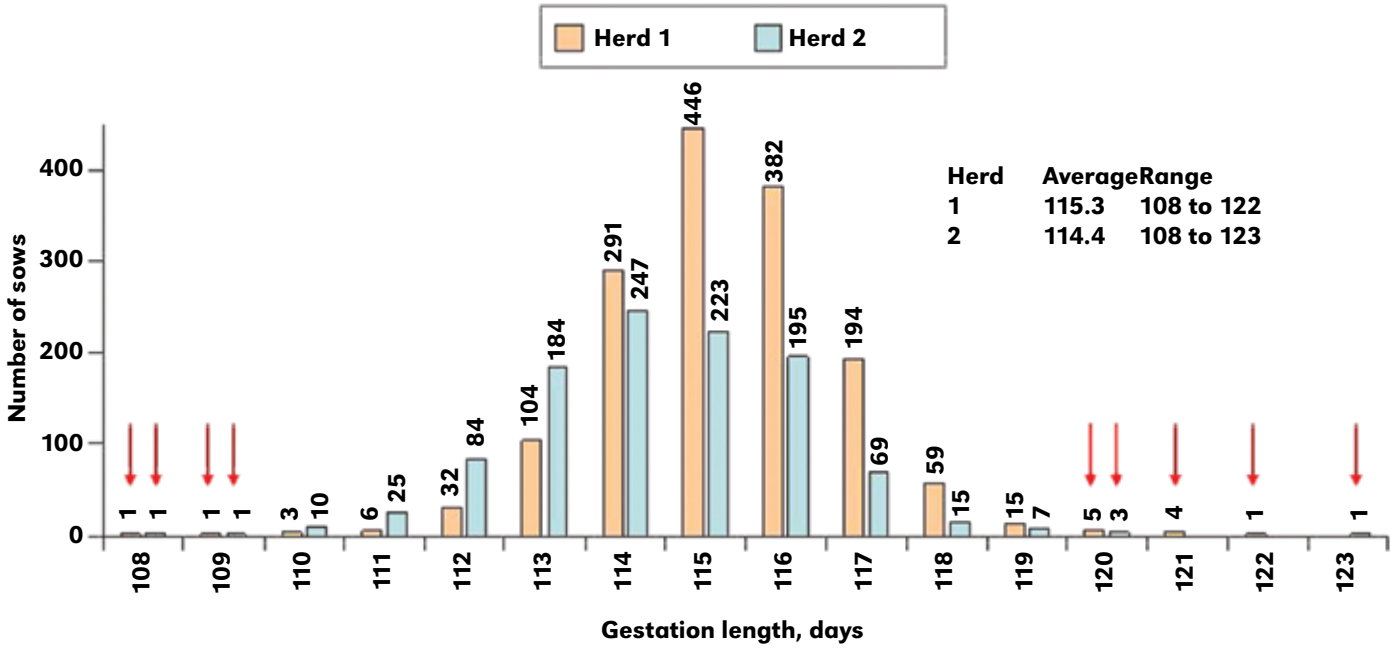

Figure 2. Frequency distribution for length of gestation in pigs (English et al., 1982; Stanislaw and Zering, 1984).

- Producers that hand-mate generally have their boars penned individually. Thus, there is less risk for injury of boars which increases their longevity in the breeding herd.
- Hand-mating helps control the number of sperm cells ejaculated by a boar during each mating, provided the boars are penned individually to prevent homosexual activity. Because some boars become sexually excited and ejaculate on their own when housed close to estrous sows, the boars should be housed out of the sight and sound of estrous sows.
- Hand-mating allows the stockperson supervising the matings to make specific matings.
- Hand-mating increases the reliability of meeting production goals because the exact number of matings accomplished is known.
- Hand-mating helps increase the accuracy of cash-flow estimates.
- Hand-mating allows the use of a better overall and accurate record keeping program.
- Hand-mating can increase the number of dollars generated from the pork enterprise.

3. Possible problems with hand-mating

If the breeding facility is not properly designed and managed, some of the problems that can occur when hand-mating sows and gilts include:

- frustration by the stockperson when moving animals and supervising the mating process.
- labor requirements may be greater because the breeding area is not designed for ease of handling animals.
- overuse of boars that are easy to handle and quickly mate sows.
- inadequate number of working boars.
- estrous detection is difficult to accomplish satisfactorily.

4. Factors that make hand-mating work

Newly constructed or remodeled facilities designed for individual mating should be planned with known benefits and limitations in mind. The main factors that make hand-mating easy, fast, and efficient include:

- **Location of boars, sows, and gilts** — It is very important that recently weaned sows and cyclic gilts do not have close contact with boars prior to the time of estrous detection and mating. Estrous sows and gilts become refractory to boar stimuli (sight, sound, and smell) within 5 to 10 minutes after exhibiting the standing response (*Table 7*). Estrous females exhibit a standing response periodically throughout the estrous period. Therefore, do not allow estrous females to receive boar stimuli for about one hour prior to estrous detection and mating.

Table 7. Proportion of gilts exhibiting the standing response at various times when continuously exposed to mature boars for 21 minutes (Levis and Hemsworth, 1995).

	Minutes after initiation of estrous detection (continuous fenceline contact with mature boars)					
Time of day	**0**	**5**	**10**	**11**	**16**	**21**
AM-Day 1	100	100	100	92.3	84.6	84.6
PM-Day 1	100	93.3	93.3	93.3	86.7	66.7
AM-Day 2	100	94.1	88.2	82.4	76.5	70.6
PM-Day 2	100	94.1	76.5	70.6	64.6	64.7

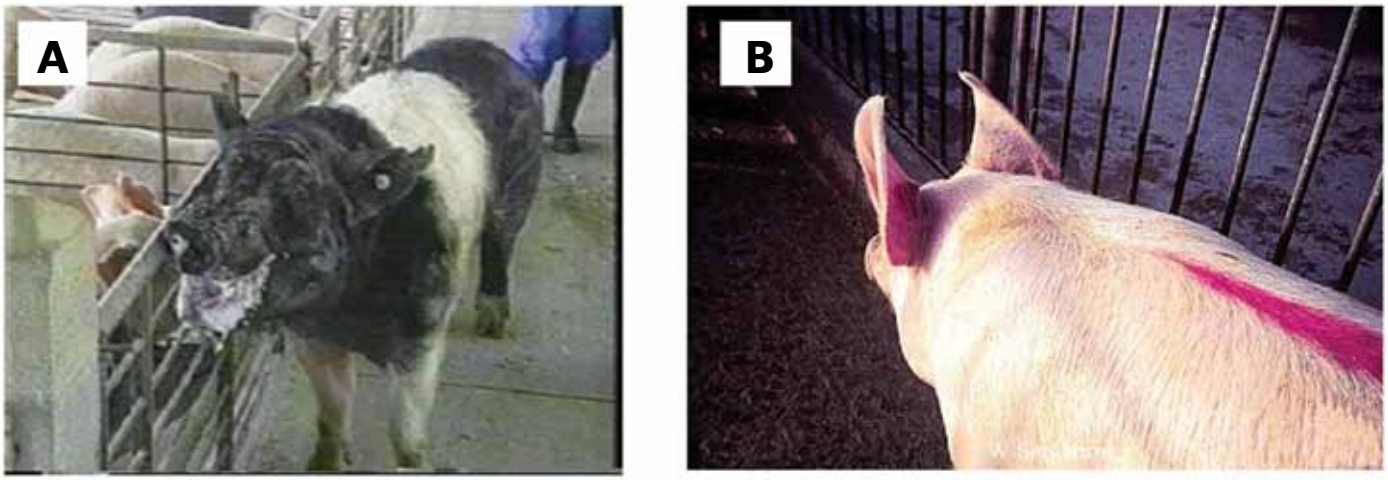

Figure 3. A. Excellent estrous detection boar. B. Ears lifted on estrous sow

Figure 4. Swollen and red vulva. Redness is more prominent in gilts.

- **Estrous detection procedure —** A key factor for successful hand-mating is the estrous detection procedure. The essential factors to stimulate the standing response are sight, sound, and smell of a mature boar; plus, the physical contact with the boar. The boars used for estrous stimulation and detection should be at least 10 months of age. Boars that chomp and produce saliva are the best heat-checking boars (*Figure 3A*). Physiological signs of estrus are swollen and red vulva (*Figure 4*). These signs are more prominent in gilts. Additional evidence of estrus is a sticky, viscous secretion at the vulva. Behavioral signs of estrus are increased vocalization, irritability, constant movement, nervousness, immobilization, and lifting of ears (*Figure 3B*). The most reliable sign an estrous sow is ready for mating is the solid standing response (*Figure 5*). The publication by Belstra et al.

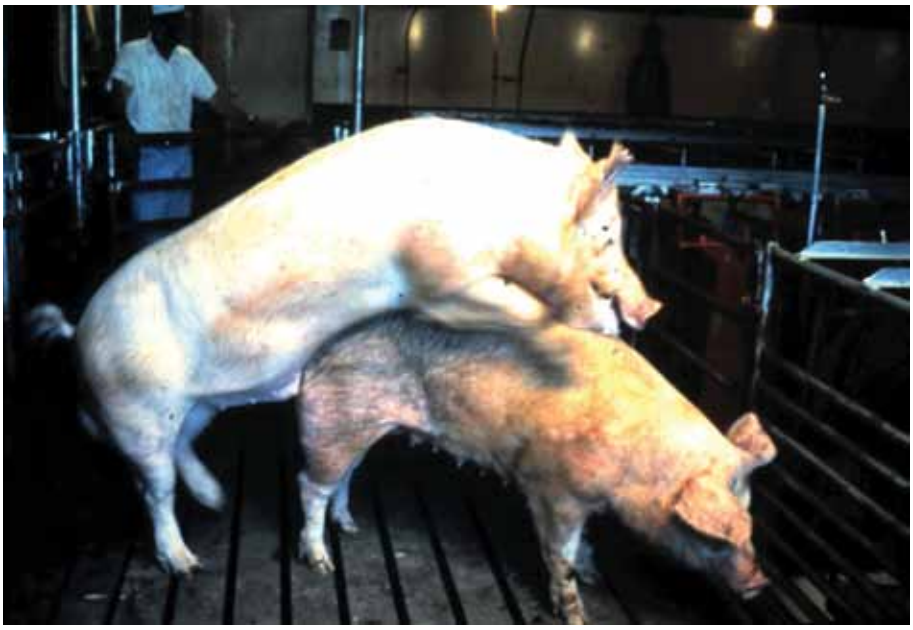

Figure 5. Estrous sow expressing a solid standing response to boar stimuli

Figure 6. Hand-held sorting panel

(2001), *Detection of Estrus or Heat*, does an excellent job describing how to effectively perform the task of estrous detection.

- **Animal movement —** Regardless of whether the estrous sows and gilts are being mated indoors or outdoors, it is critical that movement of boars, recently weaned sows, replacement gilts, and workers is quick, easy, and safe. Various hand-mating designs have given consideration only to the distance an estrous female had to be moved. Therefore, the designs placed sows and boars next to each other. Some of these designs contributed to a high level of worker frustration when mating females indoors, such as breeding sows on slick floors within the boar pen, estrous detection was not efficient due to close boar-sow contact prior to mating, workers had to climb over gates to operate the breeding pens, and workers were placed in a high risk zone for injury by aggressive boars and sows. A hand-mating breeding facility should be designed whereby: (1) It is easy to remove a sow or sows from a group of sows. (2) It is easy to move sows and gilts down an indoor or outdoor alley to the estrous detection and mating pen. (3) It is easy to handle sows and boars while they are in the breeding pen. (4) It is easy to move heat-checked or mated sows to a holding pen. (5) The entire alley is cutoff when the gate is open; thus, sows, gilts, and boars have to go where you want. In addition, make sure the gates can be easily locked open. (6) Animal movement should be continuous and never dead-ended. In addition, one person should be able to move an animal (boar, sow, or gilt) to any breeding pen without assistance. (7) Movement and handling of sows and boars is safe for animals and workers. During the mating process, it is important that all animals have a nonslippery surface. It is advisable to have readily available escape methods for workers. For safety purposes a handheld sorting panel should be used when handling boars (*Figure 6*).

- **Alleyways —** When sows and gilts are bred indoors, using of narrow alleys enhance the movement of animals. Narrow alleys prevent animals from turning around. Also, the alleys should be nonslippery, free of items that will distract pigs from moving, not have any shadows, and free of items that will cause injuries to animals or stockpeople.

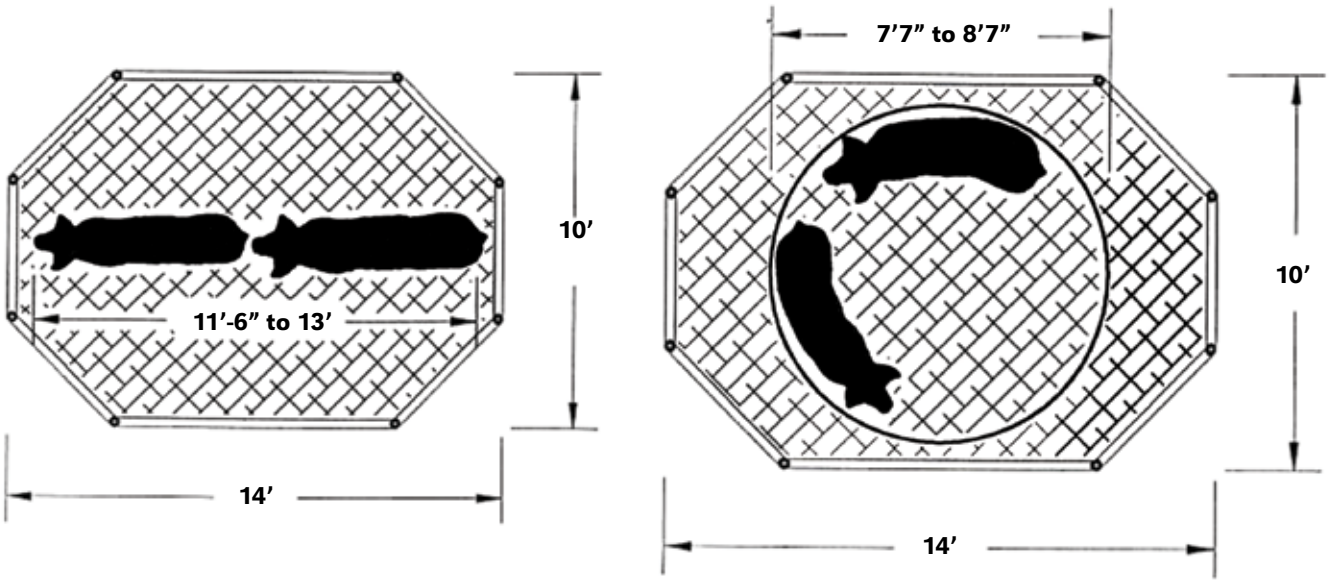

Figure 7. Octagonal shaped breeding pen. (Robert Borg, personnel communications)

- **Breeding pen —** Regardless of whether the breeding pen(s) is located indoors or outdoors, the functionality of the breeding pen is a key for making hand-mating successful. If properly designed, one worker can easily and efficiently supervise four breeding pens. Indoor breeding pens should be at least 8' x 8' with a slip-free surface that can be easily cleaned and kept dry. A larger breeding pen is preferred. The breeding pen should be designed for easy movement of a boar into and out of the breeding pen, easy movement of sows and gilts among breeding pens, and have an easy and quick escape method for workers.

  The design of an octagonal breeding pen is shown in *Figure 7*. As the boar follows the sow around the pen prior to mating, he needs room to walk forward without pivoting on his hind legs or arching his back. As the boar approaches the rear of the sow prior to mounting, the pen should be as long as the sum of the boar and sow nose to tail lengths. The use of breeding mats that provide drainage has been very beneficial (Appendix A). Placing the breeding mat on top of a totally slatted or woven wire floor allows the urine and some of the fecal matter to escape from the breeding pen. If the mats are used on a solid concrete floor, the mat and floor will need to be cleaned. Because of the weight of the mat, it is best to use a rubber mat when the mat has to be removed for cleaning. Small breeding pens and/or slippery floors contribute to worker frustration. The breeding pen should be used only for estrous detection and breeding process.

- **Gates and gate latch —** Another key factor for helping to make hand-mating successful is the design and functionality of the gate and gate latch. Regardless of whether the breeding pen(s) is located indoors or outdoors, all gate latches should be designed for quick and easy function. A gate latch should be designed so the latch can be released (or fastened) and the gate opened (or closed) with a continuous motion using only one hand. Various types of swine breeding pen gate latch designs are indicated in Appendix B. Breeding pen gates along the alley should be designed to cutoff the alley and lock open; thus, all sows and boars have to go into the designated breeding pen. If animals are entering the breeding pen from both directions down an alley, the gate latch indicated in Picture 3, 4, and 12 of Appendix B works very well. If the gate latch allows a gate to swing at only one end, two gates that swing at opposite ends should be installed on the alley side of each breeding pen. It is critically important that all corner posts are securely fastened in a manner whereby they will not move. Pictures 9 and 10 in Appendix B indicate how corner posts have been secured to prevent movement.

- **Boar housing —** During hand-mating, the greatest risk for worker injury occurs when working around boars. To minimize the risk of worker injury, boars should be individually housed and handled with a handheld solid panel. Individual housing increases longevity because it eliminates injuries resulting from fighting and mounting. Individual housing also allows control of feed intake

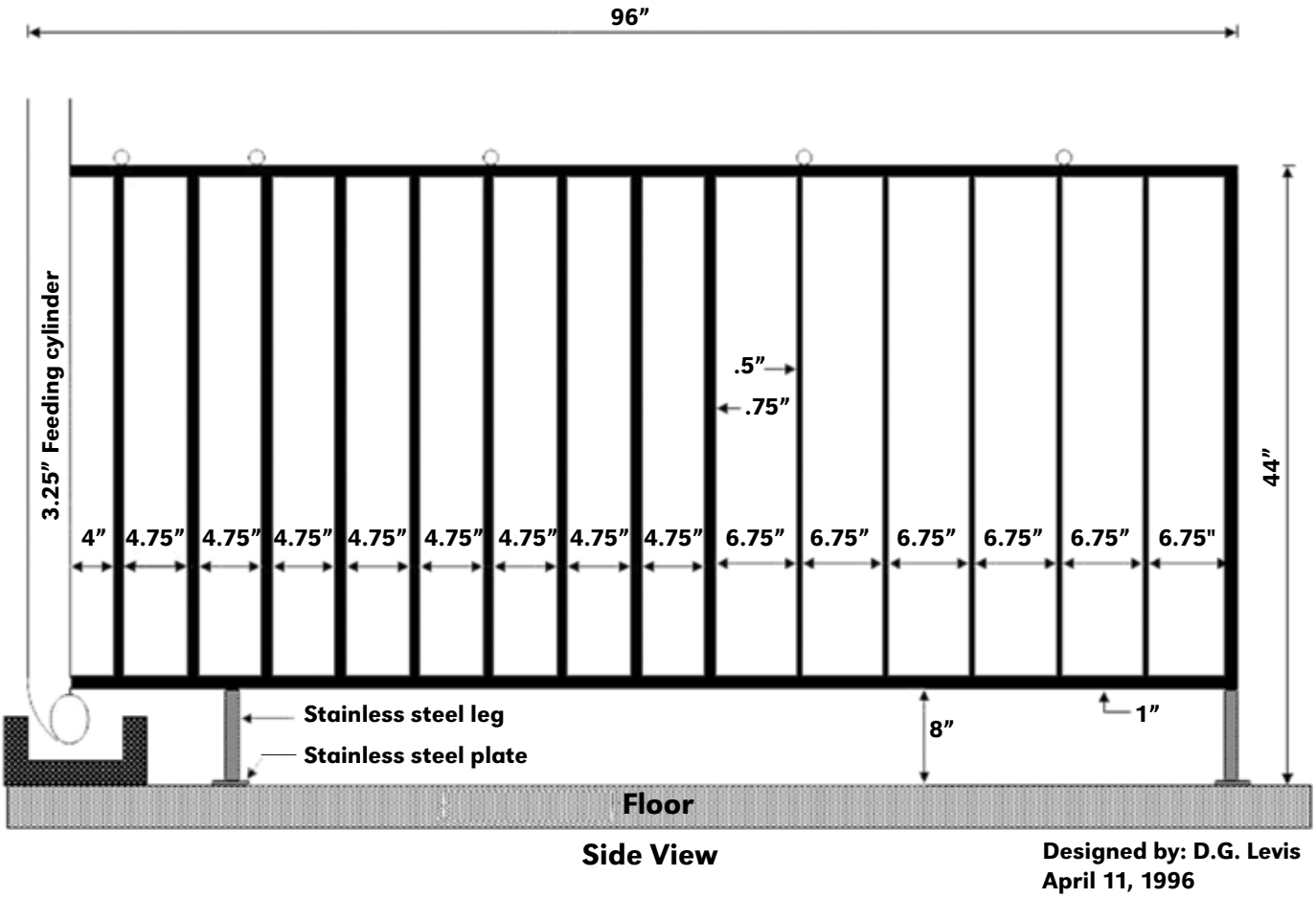

Figure 8. Schematic of side partition of a boar stall.

Table 8. Recommended minimum space for boars housed indoors (Harmon et al., 2001).

Size of boar	Boar pen Square feet	Boar stall Width	Length	Height
Large boar (greater than 500 lb)	70	28”	96”	46”
Medium boar (350 to 500 lb)	48	26”	84”	45”
Small boar (Less than 350 lb)	40	24”	84”	44”

and , therefore, size and body condition of boars. Ejaculation frequency is controlled because homosexual activity is eliminated. Controlling ejaculation frequency helps create a more consistent and predictable level of boar fertility. When housed indoors, boars are generally housed individually in small pens or stalls. Stalls are not recommended unless boars are used at least on a weekly basis. If boars are not used weekly, they must be turned out of their stall for exercise. The recommended minimum space for boars housed indoors is indicated in *Table 8*. *Figure 8* is a schematic of a side partition of a boar stall. The durability and spacing of vertical rods on the side partition is very important. The vertical side rods have to be strong enough to prevent bending. If the rods become bent, the boars can bite each other and cause injury.

- **Adequate number of boars —** The number of boars needed for hand-mating is a function of: (1) age of boar, (2) sperm output at the time of ejaculation, (3) desired number of ejaculations per boar per unit of time, (4) number of sows weaned on each day, (5) percentage of weaned sows cycling on each day, (6) the number of days between each sub-group of sows weaned (if split weaning), (7) percentage of boar inventory that is working, (8) desired number of matings per female per estrus, (9) estimated farrowing rate of group being bred, (10) desired utilization rate of the farrowing crates, and (11) possibly additional boars for a specific genetic line. The number of motile sperm required for good fertility will vary from boar to boar. It is believed that 3 to 9

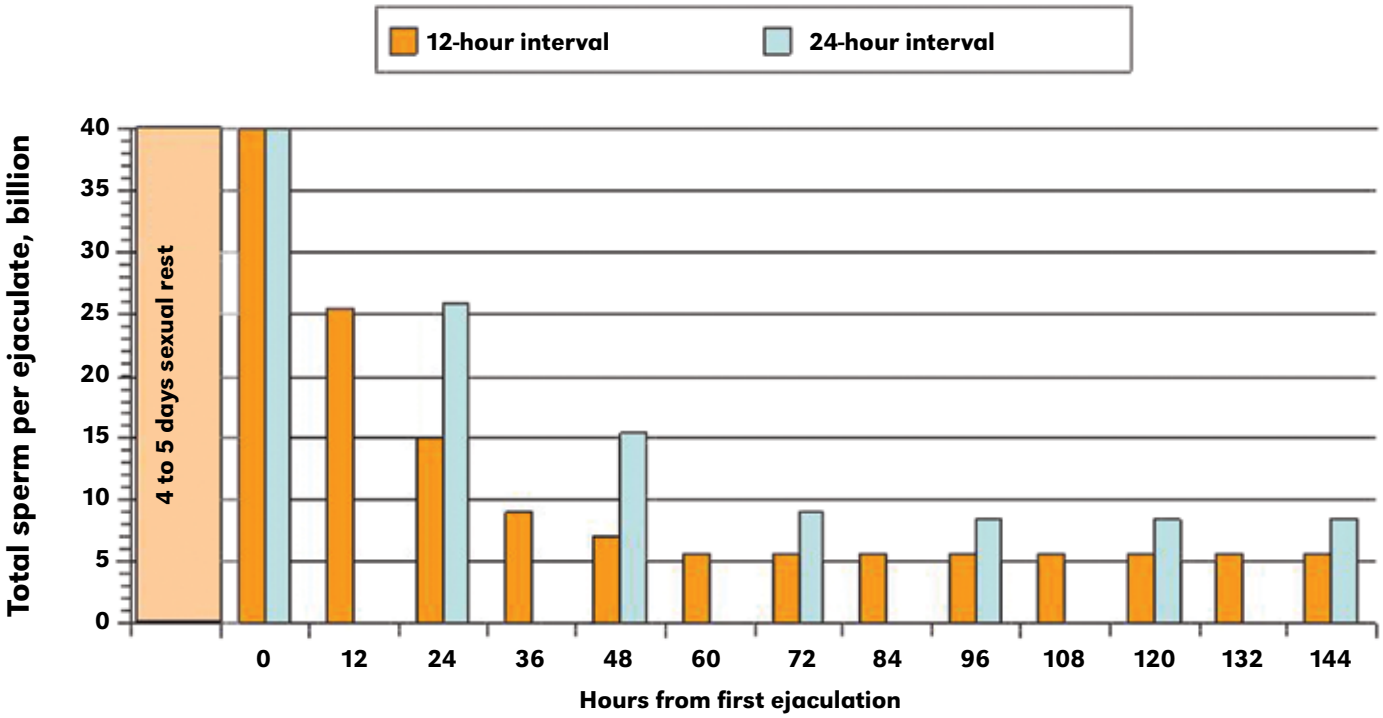

Figure 9. Sperm output at two ejaculation intervals (mature boars, 12+ months old) (Levis, 1997).

billion mature, motile sperm cells are needed for adequate fertilization of ova. Frequent and regular ejaculation will cause a decrease in total sperm output initially; however, a leveling out will result once epididymal sperm reserves have been stabilized (*Figure 9*). Generally, sperm output tends to stabilize at a low level after five or six consecutive ejaculations at an interval of 12 to 24 hours. *Figure 9* illustrates a boar's need for sexual rest after mating to allow sperm replenishment. The second time a boar mates on a 12- or 24-hour mating interval, he will ejaculate from 33 to 41 percent fewer motile sperm than were ejaculated at the first mating. The third time he mates there are from 59 to 66 percent less motile sperm than the first ejaculate. The decrease in sperm output at a 12- or 24-hour mating frequency occurs regardless of boar age. *Figure 10* illustrates that sperm output increases as the number of days between ejaculates increase.

Table 9. Equation to calculate the minimum number of boars required for individual hand-mating systems (Ruen et al., 1992)

MBI = ((NF ÷ FR) x MF) ÷ (MB x %AB)
Where:
MBI = Minimum number of boars on inventory
NF = Number of females desired to farrow per unit of time
FR = Estimated farrowing rate (expressed as decimal)
MF = Desired number of matings per service per female
MB = Ideal number of matings per boar per unit of time
%AB = Percentage of boar inventory active per unit of time (expressed as decimal)

Mating should be timed so the maximum number of viable sperm cells come in contact with the maximum number of viable ova. Sperm cells can remain viable for about 24 to 36 hours in the reproductive tract of the sow. However, the sperm cells require about five to six hours in the sow's reproductive tract after a natural mating to undergo biochemical and structural changes before they are capable of fertilizing ova. The life span of ova is eight to 10 hours after ovulation; thus, the ova should be fertilized as soon as they reach the site of fertilization (upper one-half of the oviduct). Because of the relationship between the time of ovulation, life span of ova and life span of sperm cells, the timing of mating is critical to the success of a hand-mating program. The time of ovulation is quite variable (*Figure 11*); thus, it is advisable to mate estrous sows twice.

If 20 sows are all weaned the same day, how many boars would it take to mate each sow twice? The equation in *Table 9* can be used to estimate minimum number of boars required for hand-mating systems. The assumptions are: 20 females to farrow, 83.3 percent farrowing rate, two matings per female, five matings per boar, and 90 percent of boars are working. Using this equation would indicate a minimum of 11 boars are needed.

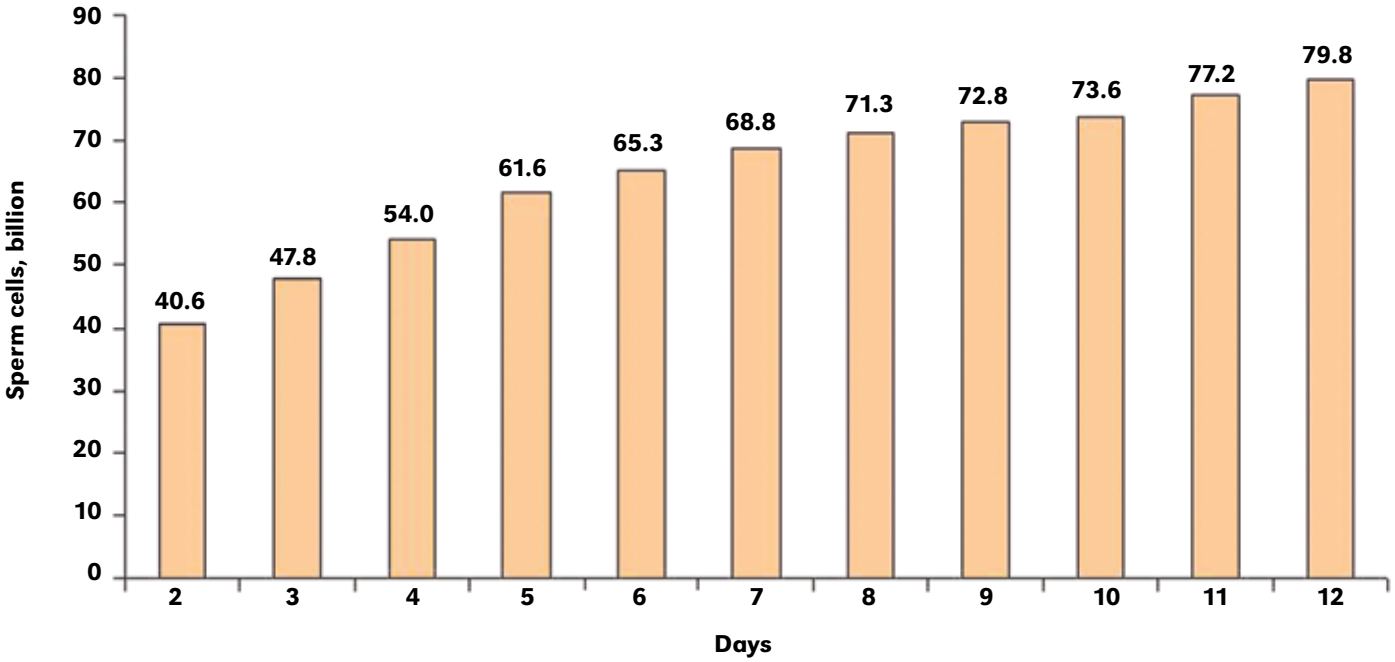

Figure 10. Influence of interval between ejaculations on total sperm cells per ejaculation (Kennedy and Wilkins, 1984).

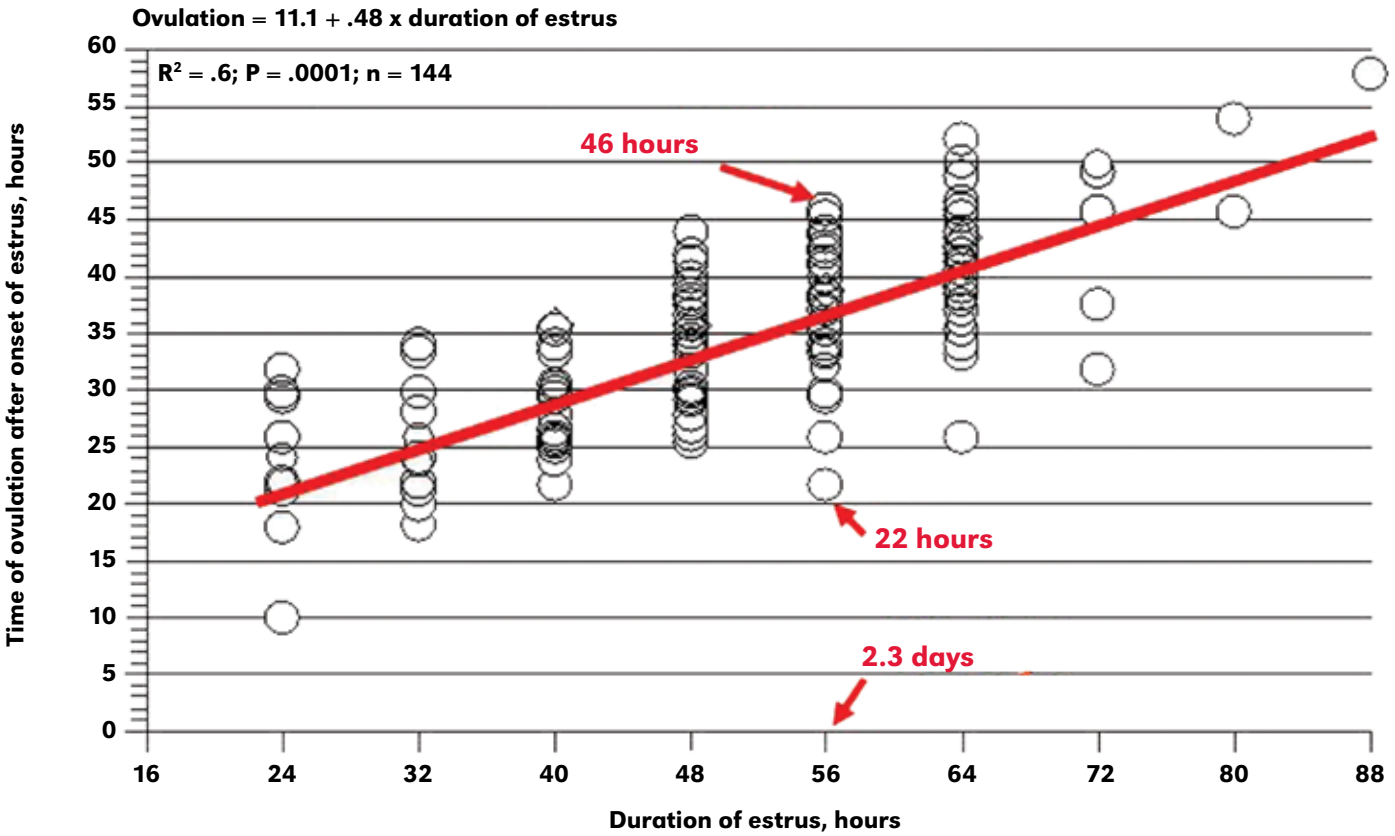

Figure 11. Relationship between time of ovulation after onset of estrus and duration of estrus (Soede, et al., 1995).

Table 10. Estimated number of boars required for hand-mating 18 sows and six gilts by natural service

	Hours after weaning 20 sows							
Sow ID	**72**	**96**	**120**	**144**	**168**	**192**	**216**	**Total matings**
1	A1[a]	B1						2
2		A2	B2					2
3		C1	A3					2
4		D1	C2					2
5		E1	D2					2
6		F1	E2					2
7		G1	F2					2
8			G2	A4				2
9			H1	B3				2
10			I1	C3				2
11			J1	D3				2
12			K1	E3				2
13			L1	F3				2
14			M1	G3				2
15				H2	A5			2
16				I2	B4			2
17					C4	B5		2
18						C5	D4	2
Number mated	1	7	13	9	3	2	1	36
Gilt ID[b]								
1				J2	L2			2
2				K2	M2			2
3					H3	J3		2
4					I3	K3		2
5						L3	H4	2
6						M3	I4	2
Number mated				2	4	4	2	12

[a]A is the boar ID and the number is the number of times the boar has mated (A1 means Boar A has mated 1 time during the current breeding period). Two different boars are used to mate each sow. The yellow box indicates young boars. The number of matings per boar is: A = 5, B = 5, C = 5, D = 4, E = 3, F = 3, G = 3, H = 4, I = 4, J = 3, K = 3, L = 3, and M = 3.

[b]Because only 90% of the weaned sows cycle during the first 8 days after weaning, a few replacement gilts will need to be bred to fill all the farrowing crates. It is assumed that the farrowing rate will be 83.3%. Therefore, six gilts will need to be bred (20 crates/.833 farrowing rate = 24 bred sows and gilts. 24 bred sows — 18 sows = 6 gilts).

When taking into consideration the weaning-to-estrus pattern, the number of boars needed may be more than calculated by the equation in *Table 9. Table 10* indicates that 13 boars are needed for mating 24 weaned sows when using the following assumptions: (1) the estimate number of sows in estrus on each day after weaning (*Figure 12*), (2) a farrowing rate of 83.3 percent to fill 20 farrowing crates, (3) 90 percent of weaned sows cycle (18 sows and six gilts are mated), (4) estimated sperm output of the boars is satisfactory for boars ejaculating once per day for five days (*Figure 13*), and (5) estrous detection and mating are performed once per day during the morning. In *Table 10* the sows are listed on the left side of the table and the hours after weaning the sows are presented on the top line. Each sow is mated to two different boars. The boar used to mate the sow is indicated with a capital letter. The number following the capital letter indicates the number of times the boar mated. The yellow box indicates younger age boars. This example assumes that all boars are working satisfactorily. In this example, the largest need for boars occurs 120 hours after the sows are weaned. All 13 boars are needed for mating the sows. If a farm only has 20 sows that farrow twice per year, then 13 boars appear to be excessive and costly. As discussed in the following section, an option would be to use a combination of hand-mating with artificial insemination.

- **Combination of mating techniques —** The number of boars needed to mate the sows and gilts is reduced when artificial insemination is used for the

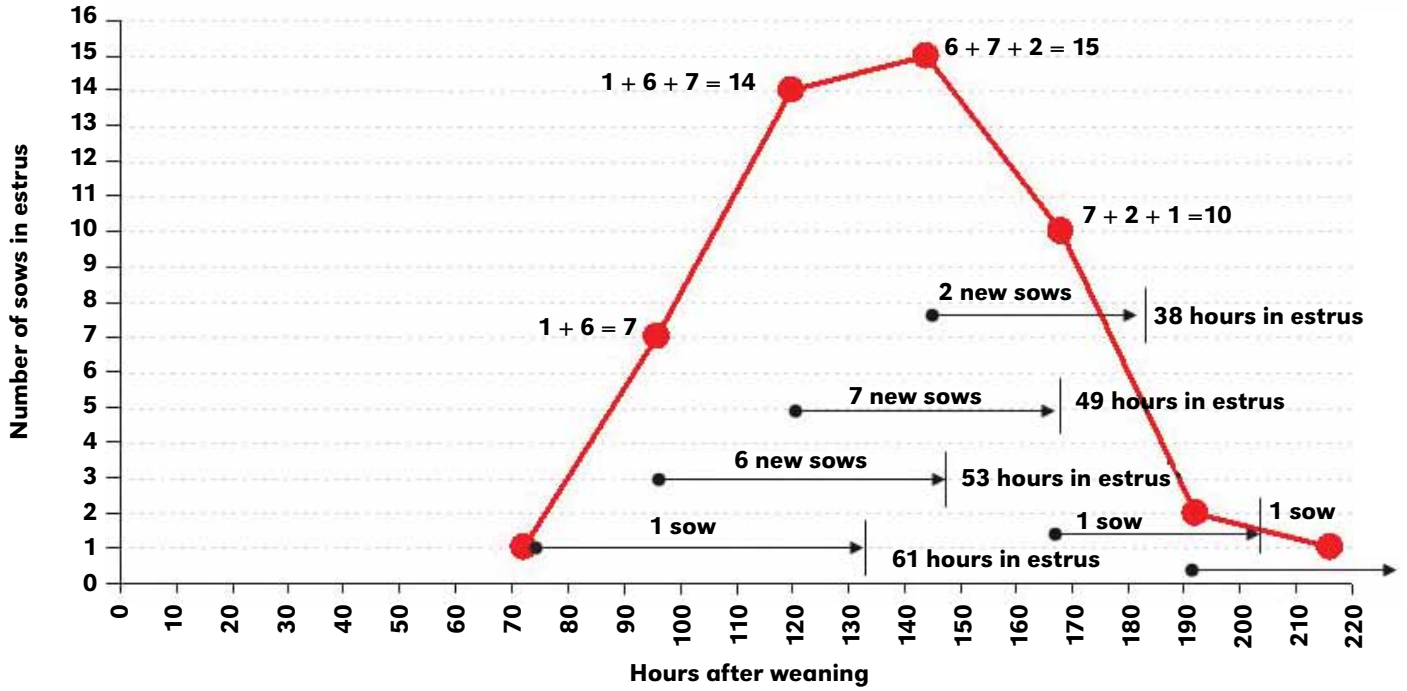

Figure 12. Estimated number of females in estrus on each day when twenty females are weaned the same day and 90 percent cycle within eight days after weaning.

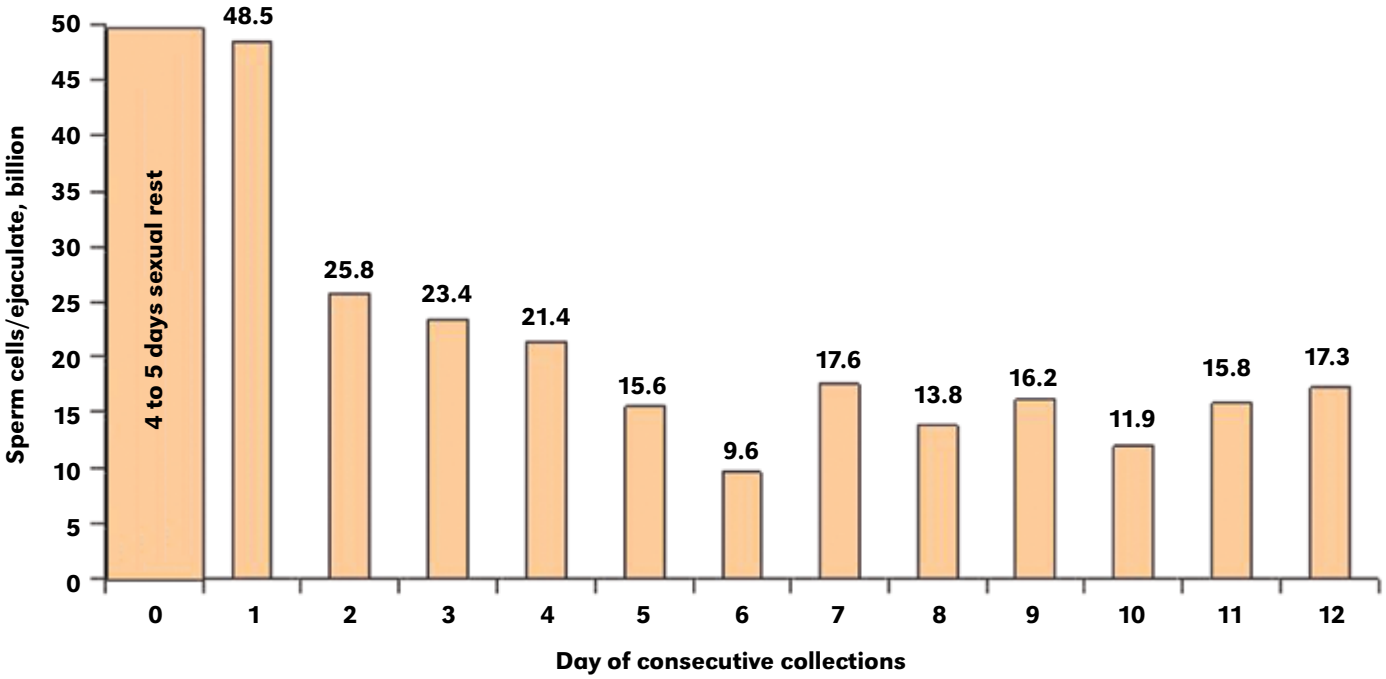

Figure 13. Sperm output when boars (13.6 months old) ejaculate every 24 hours (Johnson et al., 1969).

Table 11. Estimated number of boars required for hand-mating 18 sows and 6 gilts by a boar on the first mating and artificial insemination on the second mating.

	Hours after weaning 20 sows							
Sow ID	**72**	**96**	**120**	**144**	**168**	**192**	**216**	**Total matings**
1	A1[a]	AI[b]						2
2		A2	AI					2
3		B1	AI					2
4		C1	AI					2
5		D1	AI					2
6		E1	AI					2
7		F1	AI					2
8			A3	AI				2
9			B2	AI				2
10			C2	AI				2
11			D2	AI				2
12			E2	AI				2
13			F2	AI				2
14			G1	AI				2
15				A4	AI			2
16				B3	AI			2
17					C3	AI		2
18						B4	AI	2
Number mated	1	7	13	9	3	2	1	36
Gilt ID[c]								
1				D3	AI			2
2				E3	AI			2
3					F3	AI		2
4					G2	AI		2
5						G3	AI	2
6						D4	AI	2
Number mated				2	4	4	2	12

[a]A is the boar ID and the number is the number of times the boar has mated (A1 means Boar A has mated 1 time during the current breeding period). The yellow box indicates young boars. The number of matings per boar is: A = 4, B = 4, C = 3, D = 4, E = 3, F = 3, and G = 3.

[b]AI is artificial insemination

[c]Because only 90% of the weaned sows cycle during the first eight days after weaning, a few replacement gilts will need to be bred to fill all the farrowing crates. It is assumed that the farrowing rate will be 83.3%. Therefore, six gilts will need to be bred (20 crates/.833 farrowing rate = 24 bred sows and gilts. 24 bred sows – 18 sows = 6 gilts).

second mating instead of a boar (*Table 11*). When natural mating at first mating is combined with artificial insemination on second mating, seven boars are needed instead of 13. The value of using artificial insemination is: (1) the genetic merit of the AI boars can be greater than the boars used for natural mating, (2) less time will be required to artificially inseminate the sows and gilts on their second mating compared to using a boar, and (3) the cost to purchase doses of semen is less than the cost to purchase six boars. It is critical that the people performing artificial insemination of the sows and gilts be well trained on storing and handling semen, estrous detection, and performing artificial insemination procedure. A study at North Carolina State University found that farrowing rate was higher for sows that received a natural mating at first mating followed 24 hours later by an artificial mating at second mating compared to sows receiving two natural matings 24 hours apart or only one natural mating at first mating (*Figure 14*). All heat-checking occurred during the morning and matings/inseminations were done between 7:30 AM and 10:30 AM. Each dose of semen contained 7 billion sperm cells in a total volume of 60 milliliters. All semen was diluted with BTS and

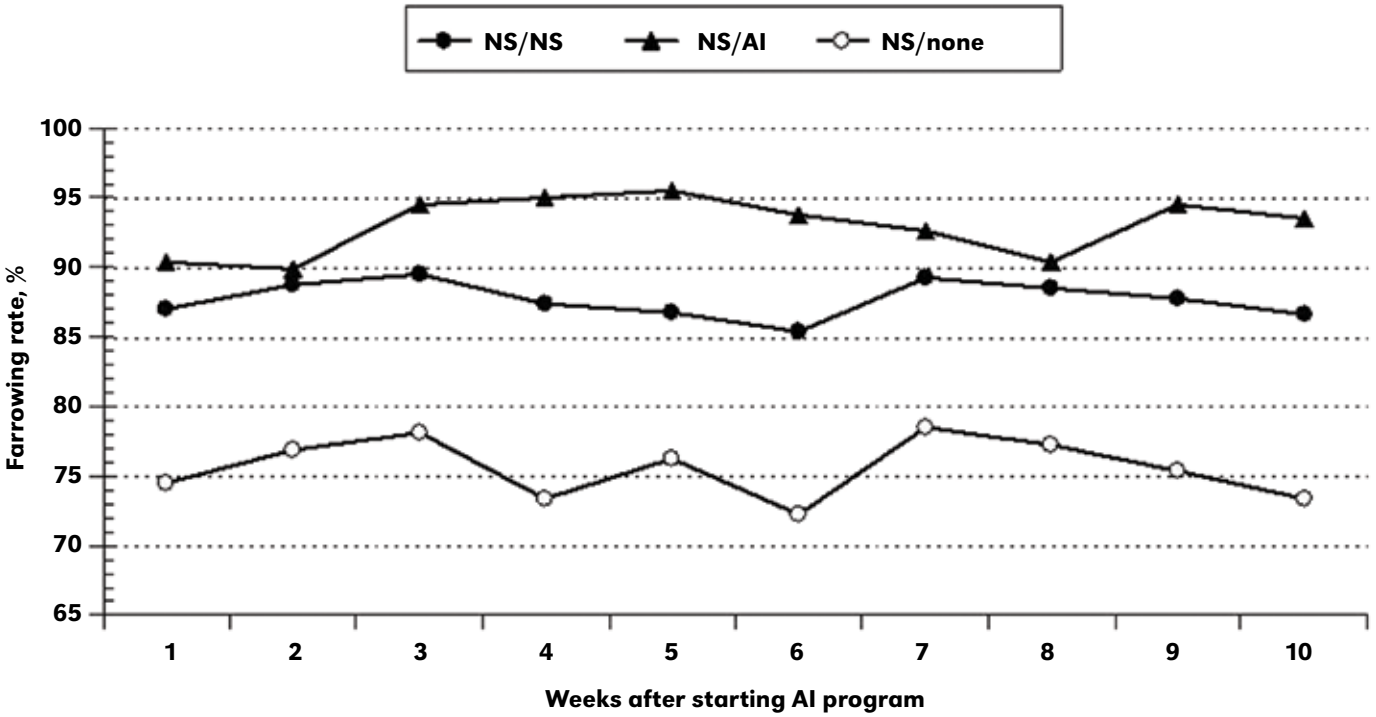

Figure 14. Farrowing rate when sows receive either two natural mating (NS/NS), a natural mating on first service and a second mating by artificial insemination (NS/AI) or only one natural mating at first service (NS/none) in multiparous sows (Flowers and Alhusen, 1992).

Table 12. Effects of mating combination of natural mating (NS) and artificial insemination (AI) on reproductive performance of multiparous sows (Flowers and Alhusen, 1992).

	Mating combination		
Item	**NS/NS**	**NS/AI**	**NS/none**
Farrowing rate, %	87.3	93.2	75.4
Piglets born alive per litter	10.3[x]	10.2[x]	9.0[y]
Piglets born dead per litter	1.0	1.0	1.1
Total number of piglets born per litter	11.3[x]	11.2[x]	10.1[y]
Fecundity index (piglets born alive)	899	951	679

[xy]Means in the same row lacking a common superscript letter differ (P < .05).

Table 13. Effects of mating combination of natural mating (NS) and artificial insemination (AI) on reproductive performance of gilts (Flowers and Alhusen, 1992).

	Mating combination		
Item	**NS/NS**	**NS/AI**	**NS/none**
Farrowing rate, %	71.7[x]	88.9[y]	56.3[z]
Piglets born alive per litter	9.8[x]	9.5[x]	8.0[y]
Piglets born dead per litter	1.1	1.4	1.0
Total number of piglets born per litter	10.9[x]	10.9[x]	9.0[y]
Fecundity index (piglets born alive)	761	845	450

[xyz]Means in the same row lacking a common superscript letter differ (P < .05).

used within two days of collection. The effect of mating combination on reproductive performance is indicated for multiparous sows (*Table 12*) and gilts (*Table 13*). There was no significant difference in the number of pigs born alive and the total number born between NS/NS and NS/AI. The fecundity index for the number of piglets born alive was 52 piglets greater for sows mated by NS/AI and 84 piglets greater for gilts mated by NS/AI. During natural matings, it has been suggested that many of the activities associated with the boar's courtship ritual are a form of stress for the sows and gilts.

- **Method of feeding sows —** Hand-mating systems should be designed whereby the feeding of boars, sows, and replacement gilts is easily and quickly accomplished. It is recommended that boars and sows be fed at least 30 minutes before mating. If feed has been

spilled in the alley, the boars and sows will have a tendency to stop moving and eat the spilled feed. Ideally, the feed spilled in the alley should be removed prior to moving animals down the alley to the breeding pen. If recently weaned sows are kept in large pens outdoors, a feeding pad enclosed with gates is recommended to hold the sows until they have completed eating, before they are moved to the breeding pens. The sows to be bred should be housed and fed close to the breeding pen area; thus, the time required for moving the sows to and from the breeding pen is minimized.

- **Labor requirement —** The amount of labor required per day to hand-mate sows and gilts during a designated breeding period depends on many factors. Some of the factors are distance to move sows to the breeding area, ease of separating estrous sows from non-estrous sows when heat-checking two or three sows in the same pen, ease of moving an estrous sow from one breeding pen to another breeding pen when heat-checking more than one sow simultaneously in the same breeding pen, distance to move boars to and from the breeding pen, amount of courtship behavior by a boar until he copulates with an estrous sow, duration of ejaculation of the boar, use of a holding pen for heat-checked sows that did not stand for breeding, use of a pen to house once bred sows until the second mating, number of breeding pens, ease of opening and closing gates, floor surface of the breeding pen, ease of worker to move between the breeding pens to supervise the mating activity in the multiple mating pens, mating dexterity of the boars, duration of time taken for estrous sows and gilts to respond to boar stimuli, number of sows to breed on a specific day, and number of workers involved with the mating process. If the breeding facility is designed correctly, one person can easily operate four breeding pens. Using four breeding pens allows one worker to keep busy and supervise the matings. The average duration of copulation per mating is about four minutes; however, the duration of copulation can range from two to 11 minutes. When using four breeding pens, 10 to 12 sows can be mated per hour.

- **Record keeping —** Hand-mating allows workers to record breeding dates, which boar(s) mated each estrous sow, and boar usage. If sows are mated indoors, some workers have used a 2' x 3' wall chart with an erasable surface to record how many times each boar has mated. Because there is little to be learned from a boar usage chart covering more than two weeks, it is recommended that a two week boar usage form be laminated to a board that can be easily cleaned (see Appendix C). The oldest date can be erased when appropriate. The boar usage chart is used by placing an "X" on the appropriate location each time the boar mates. A period of sexual rest is shown by drawing a line through the next few days he is to be rested. To help identify individual boars that are not satisfactorily copulating, some workers use sheets of plexiglass (8" x 13") attached to a wire line above the boar. An "X" is marked on the plexiglass each day that the boar is taken to the breeding pen. If the boar copulates, the "X" is circled. If the boar does not copulate, the 'X" is not circled.

- **Ambient temperature requirement —** It is essential to meet the needs of boars, sows and gilts throughout the year, especially during extreme weather conditions. Temperatures above 80 to 85 degrees Fahrenheit may cause lowered semen quality in boars, reduced farrowing rates and litter size, and increased embryonic death loss in females. Heat-stress can also cause anestrous in sows and gilts and decreased libido in boars. In most geographical regions, some method of cooling should be provided during the hot months of the year.

Less is known about the influence of low ambient temperatures on reproductive performance of boars, sows, and gilts; however, indoor breeding facilities should be maintained at a minimum of 55°F to reduce feed intake requirements of animals and to prevent water freezing problems. During winter months, the number of animals in the building may not be sufficient to generate adequate heat while allowing sufficient ventilation to control moisture levels. Therefore, some indoor breeding facilities may require supplemental heat for animal comfort and replacement of heat removed by ventilation.

5. Hand-mating designs

5.1. Outdoors. Hand-mating can be performed outdoors. However, the workers have to be very willing to work in the environmental conditions at the time, such as snow, ice, rain, mud, wind, extreme ambient temperatures, and excellent weather conditions. As described above, the basic principles are the same regardless of whether hand-mating is preformed indoors or outdoors. Various methods have been used to hand-mate sows that are housed outdoors.

5.1.1. Fence corner setup. This hand-breeding area requires a fence corner, four small gates, two panels to form the breeding pen, and two stub fences (*Figure 15*). In the schematic, "A" is the boar lot. The breeding pen (B) is built in the corner of the lot with two panels and a small gate ("1"). The

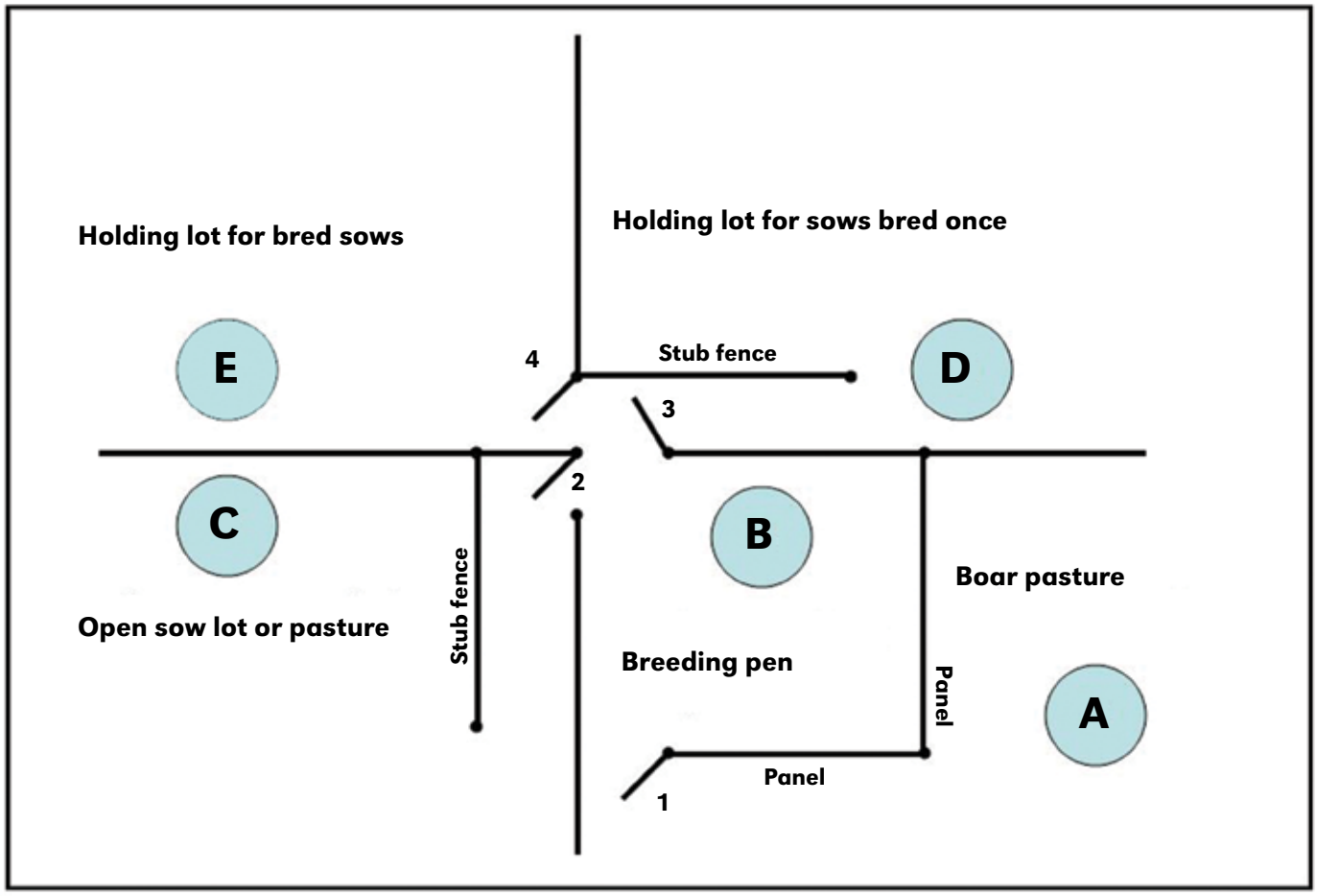

Figure15. Schematic of a fence corner setup for hand-mating outdoors (Hollandbeck, 1968)

open sows are kept in lot "C". Quite naturally, the sow in estrus comes to the boar lot fence. The sow(s) can be identified with a paint stick for breeding the next day.

Boars are easier to drive than a sow in heat. Gate 1 is opened the next day and the boar is driven into the breeding pen. The sow follows along the main fence to the corner. The stub fence makes it easy to sort out the identified sow to enter the breeding pen through gate 2. After mating, the sow is driven through gate 3 into lot D with other sows having been bred that day. The boar returns to lot A.

The following day, the sow(s) in lot D are rebred on the third day of her heat period. After the second mating, the sow is driven through gate 4 into lot E. Lot E is a holding lot until all of the sows in this group are bred. After all the sows have been bred, the entire group is moved to the gestation pasture.

Figure 16 is a modification of the fence corner hand-mating facility. The boar(s) is kept in a pasture and fed in a large pen. The sows in Pen A are heat-checked in Pen B. The sows are bred in either Pen B or Pen C. The sow(s) mated in Pen B or C is moved into Pen D after mating. On the third day of estrus each sow in Pen D is mated in Pen C. After the second mating the mated sows are moved into the pasture for bred sows.

There can be problems with the two designs that use a fence corner for hand-mating. The first problem is that nonbred sows have continuous exposure to boar stimuli in both designs. Thus, some of the estrous sows might be refractory to boar stimuli when the worker is present. Another problem is that all the boars are housed together. In *Figure 15* there is only one breeding pen. In *Figure 16* the gates are long; thus, there can be a problem of not being able to easily open and close the long and heavy gates. Also, the boar feeding area is very large. A possible solution to solving the hand-mating problems of the previous two designs is indicated in *Figure 17.*

Weaned Sow Pen. At the time of weaning, the sows are placed into Pen 1. Pen 1 has a concrete feeding pad. The feeding pad is designed to lock the sows on the pad during the feeding period. During the breeding period, the sows are moved to one of the four breeding pens.

Heat-check Boar Area. Prior to moving the sows to the breeding pens, a boar is placed in the heat-check boar

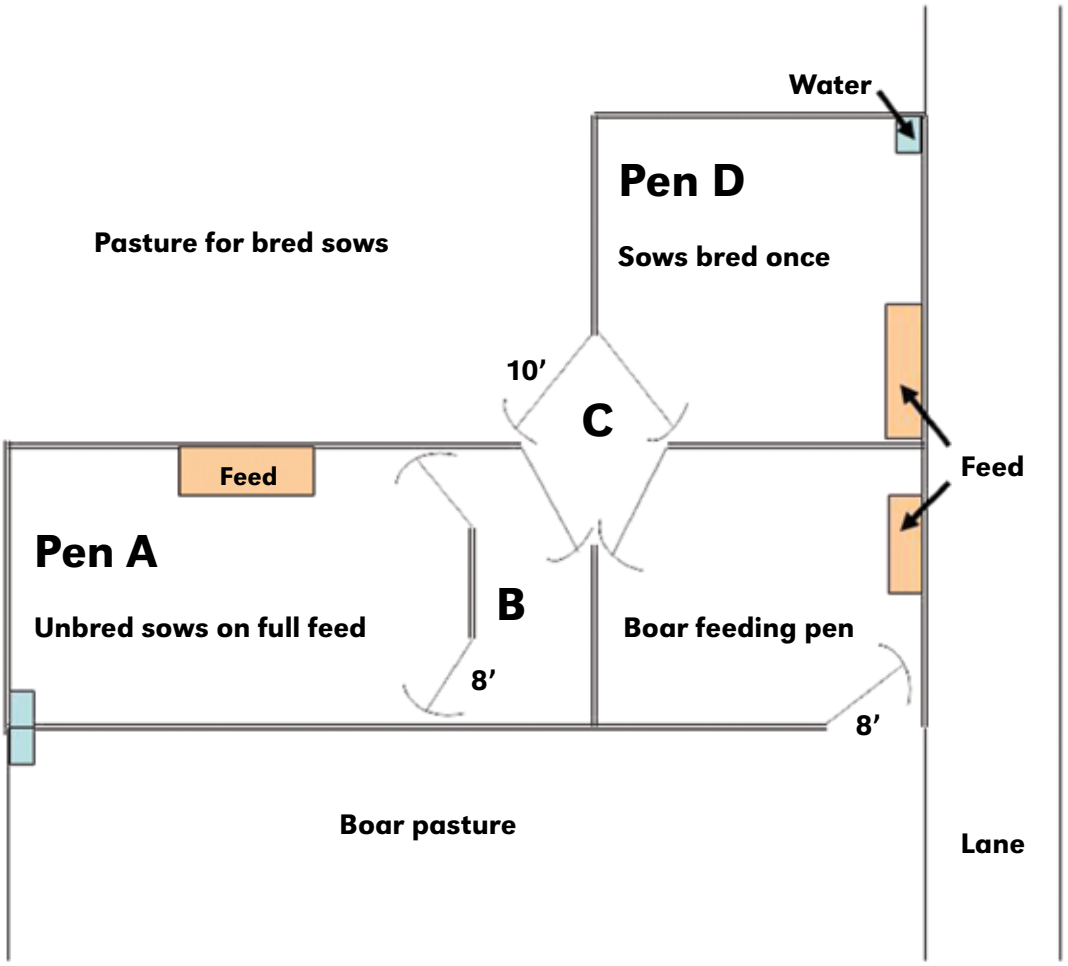

Figure 16. Schematic of a fence corner setup for hand-mating outdoors (MWPS-8, 3rd Edition, 1972).

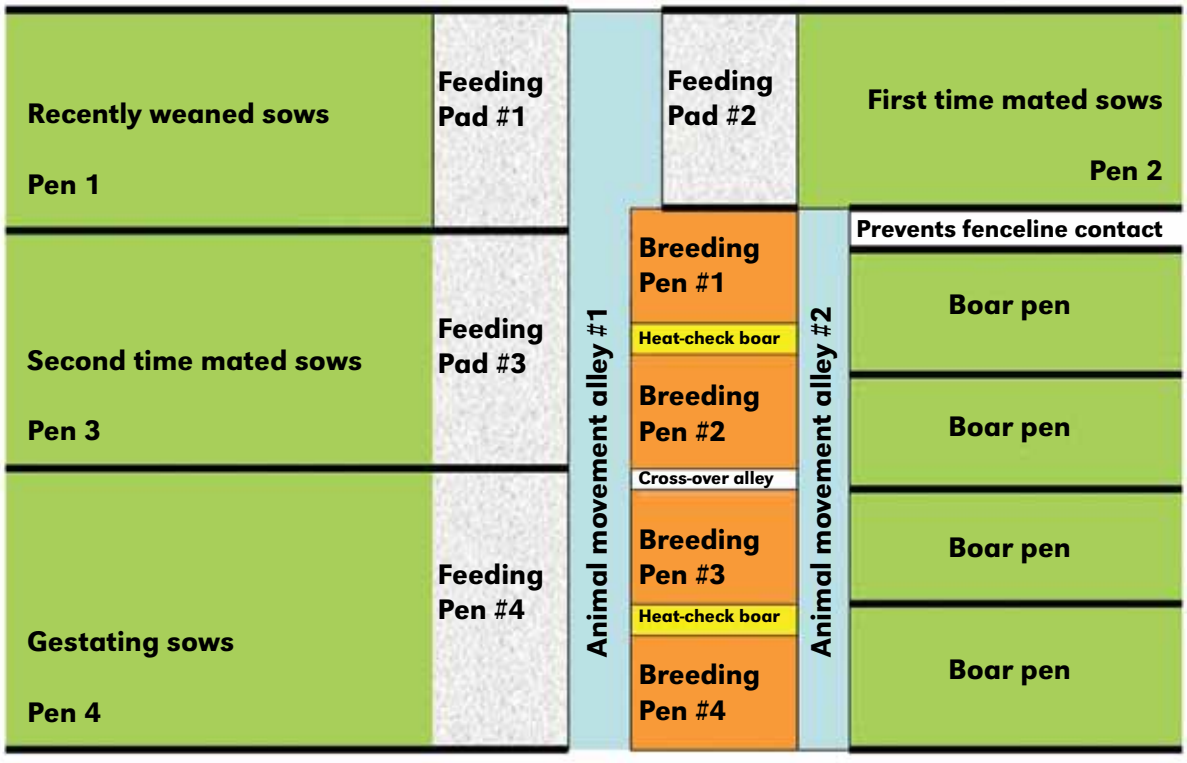

Figure 17. Schematic of an outdoor hand-mating system that separate sows to be mated and boars.

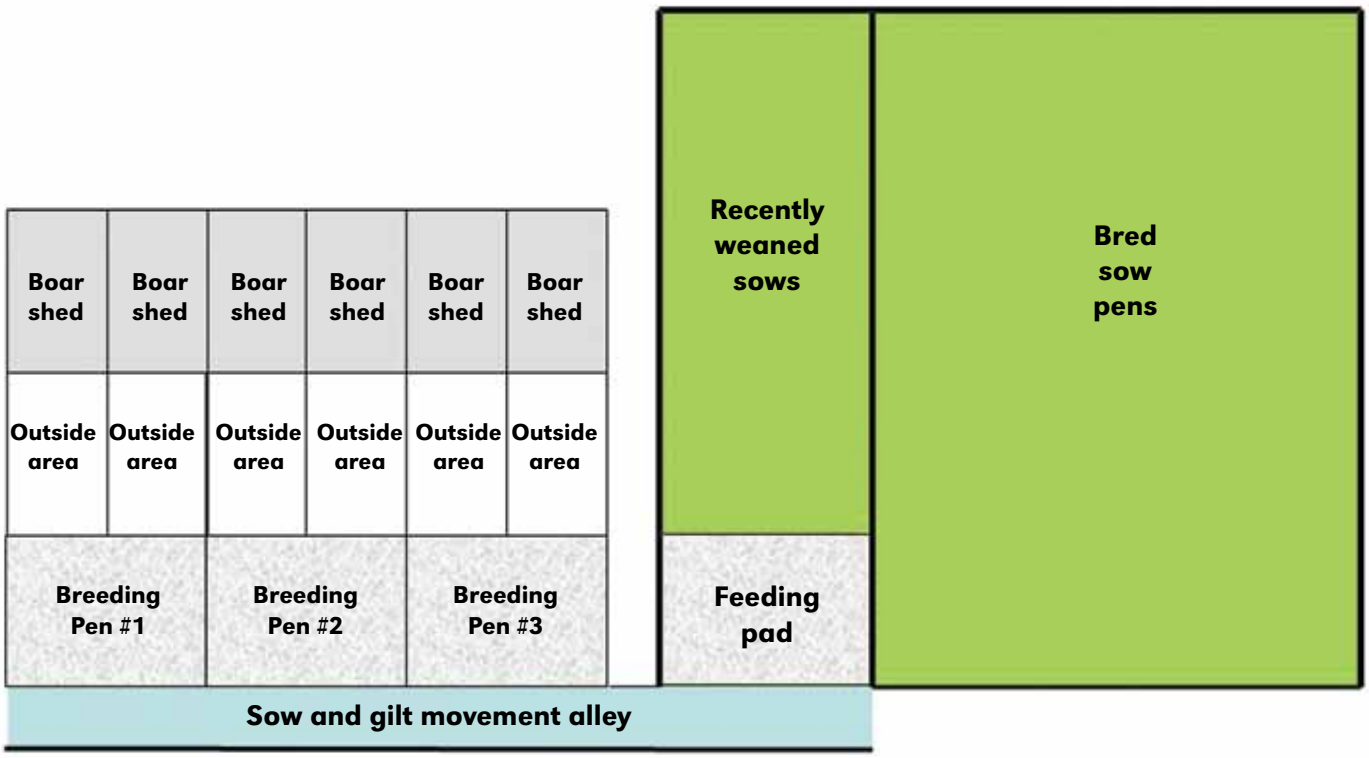

Figure 18. Schematic of a boar shelter and outdoor hand-breeding

area. The use of a heat-check boar area helps the stockperson detect estrus and to keep the estrous sow in the breeding pen while the gate is open for the boar to enter the breeding pen. The side partitions of the heat-check boar pen are designed to prevent fighting between the heat-check boar and the boar in the breeding pen.

Breeding Pen. Ideally, the breeding pen should have a concrete floor with a breeding mat. The corner posts can be placed in the concrete floor; thus, the gates can easily swing. A secure corner post also ensures that the breeding pen gates can be easily opened and locked. The breeding pen gates should be long enough to cut-off the alley when open. Ideally, there should be a mechanism in place to lock the breeding pen gate open. The size of the breeding pens should be at least 8' x 9'. Some pork producers have installed a roof over the breeding pens and adjacent alleys.

Crossover Alley. The crossover alley is designed whereby the stockperson can easily move between the sow area and boar area without having to walk through a breeding pen being used. To prevent the opening and closing of crossover alley gates, pork producers have used small step-over gates.

Animal Movement Alley. The animal movement alley should be no wider than the breeding pen gate. The breeding pen gate should cutoff the animal movement alley; thus, the animals have to enter the appropriate breeding pen.

Prevent Fenceline Contact. The area between the boar pen and first time mated sows (Pen 2) helps prevent fenceline contact between boars and estrous sows. This procedure helps sows from becoming refractory to boar stimuli prior to movement to the breeding pen.

First Time Mated Sow Pen. After the sows have received their first mating, they are moved down the alley on the boar side to Pen 2. On the second day of estrus, the sows are locked on the feeding pad; thus, they are moved to the breeding pen for their second mating. After their second mating, they are moved to Pen 3.

5.1.2. Boar shelter and outdoor hand-breeding. *Figure 18* is a schematic of a boar shelter with an outdoor hand-breeding area. The outdoor area is a small dirt lot. The boars are individually housed. Each breeding pen is used by two boars. The sows are maintained on dirt or pasture lots. The recently weaned sows are fed on a concrete pad. The concrete pad is designed whereby the sows are locked on the pad during feeding. Because the sows are locked on the feeding pad, they can be easily moved to the breeding pens for estrous detection and mating. If desired, a first time mated pen can be established. Thus, the sows are already separated and easily moved to the breeding pen for the second mating.

5.1.3. Boars and breeding pens are indoors with sows housed outdoors. *Figure 19* is a schematic drawing of a breeding facility with boars and breeding pens indoors. The sows

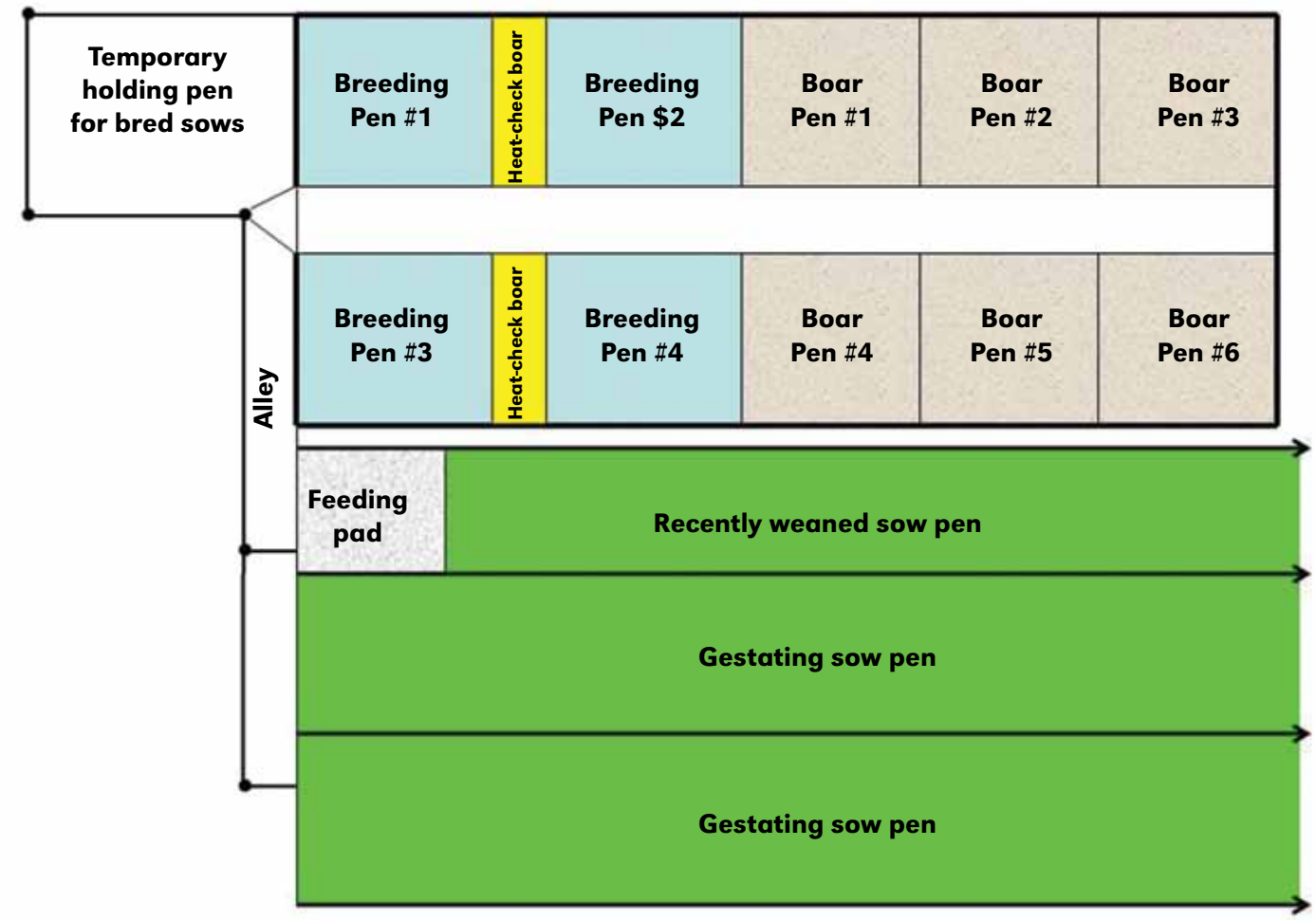

Figure 19. Schematic of a breeding facility with boars and breeding pens indoors

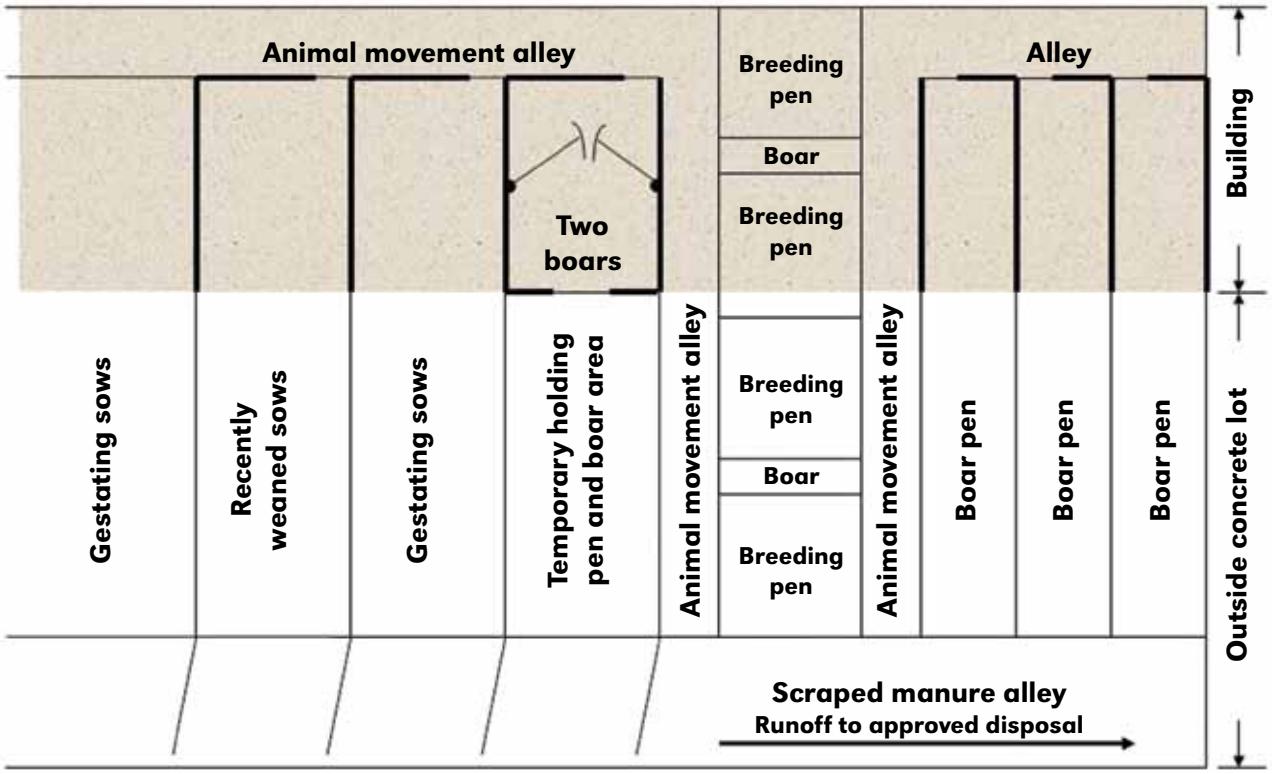

Figure 20. Open shed with concrete lot designed for hand-mating (Modified from Midwest Plan Service – 20, 1984).

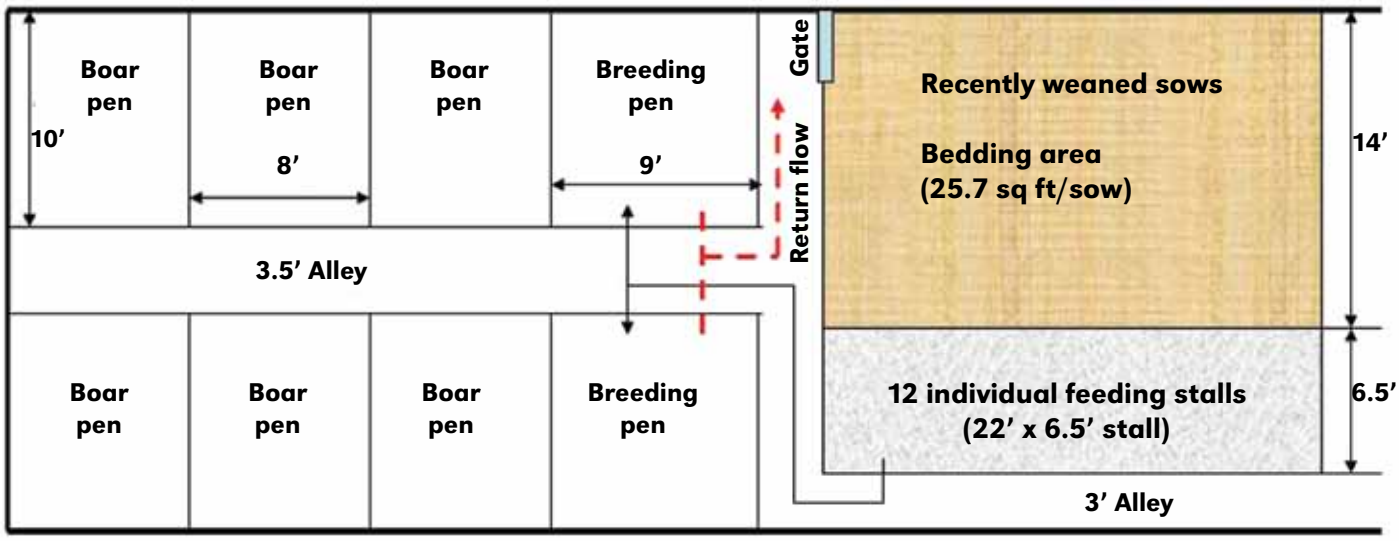

Figure 21. Schematic of a hand-mating system within a hoop structure.

are maintained outdoors in dirt or pasture lots. Because boars are not used on a weekly basis, they are housed in small pens. A heat-check boar is placed between the two breeding pens on each side of the building. The recently weaned sow pen has a feeding pad; thus, the sows are locked in the feeding pad during the time of estrous detection and mating. The sows are moved down an alley to the boar area. Sows not detected in estrus are moved outdoors and placed in the temporary holding pen. After estrous sows are mated, they are moved outdoors and placed in the temporary holding pen. An alternative to the movement of nonestrous sows is to: (1) move nonestrous sows from the boar area and briefly hold them in the alleyway while hand-mating estrous sows in the boar area, (2) install a narrow alley on the feeding pad of the recently weaned sow pen, and (3) move the nonestrous sows back to the recently weaned sow pen when the stockperson returns to the recently weaned sow pen for another group of sows. The bred sows are moved to the temporary holding pen. The estrous sows bred for the first time can be moved to an established first time mated sow pen. Sows that have received two matings can be moved to their gestation pen.

5.1.4. Open shed with concrete pad. *Figure 20* is a line drawing for a pole-frame open shed with an outside concrete lot. The original design has been modified for hand-mating. Additional construction details can be found in the 1984 Midwest Plan Service-20 handbook. Prior to moving sows to the breeding area, the two boars housed in the temporary holding pen are placed in the two heat-check boar stalls (2' x 9') in the breeding area. The heat-check boars keep estrous sows in the breeding pen while the breeding pen gate is open for moving the boar into the breeding pen. The breeding pens are 8'x 9'. All breeding pen gates should cutoff the alley when open. There should be a locking mechanism that easily locks the breeding pen gates open. The recently weaned sows are moved down the alley to the breeding area. Sows not detected in estrus are moved to the temporary holding pen. After estrous sows are mated, they are moved to the temporary holding pen. After all the sows in the recently weaned sow pen have been moved to the breeding area for heat-checking and breeding, the group is moved back to their home pen. If two boars are housed together, they should be used to mate sows at the same time. Thus, their sexual drive has been diminished which will help reduce homosexual and aggressive activity.

5.1.5. Hoop structure. In the United States, hoop structures have been successfully used to house breeding and gestating sows. A schematic of a hoop breeding-gestation facility is shown in *Figure 21.* Some of the factors involved with the design and management of hoop structures are briefly presented below.

Floor Design. A hoop structure is a "half-cylinder" shaped building with pony sidewalls 4 to 6 feet high made of treated wood posts and wood sides. In the United States, the typical outside dimensions of a hoop are 24 to 40 feet wide and 60 to 100 feet long. Pens should be at least 15 to 16 feet wide to reduce aggression. Tubular steel arches fastened to the tops or sides of the posts form a half-circle roof, which is covered with an opaque, UV resistant, polyvinyl trap. To reduce the cost of construction most swine hoop houses have a dirt floor except for a concrete feeding floor and watering pad. The Midwest Plan Service Publication, AED 44 – Hoop Structures for Gestating Swine, provide line drawings of floor plans and design information for gestating sows in a hoop structures with different feeding systems. *Figure 21* is a line drawing of a hand-mating

system within a hoop structure. All the boar pen partitions have to be designed to prevent fighting between boars. The boar pens are cleaned by hand. The sows are fed with lockable rear gates on the individual feeding stalls. During the period of time for estrous detection and mating, the sows are temporarily locked in their feeding stalls. Thus, the stockperson can easily move the sows out the front gate and take them to the breeding pen. The sows and boars can be placed in any of the breeding pens. After the sows have been checked for estrus or heat-checked and mated, they are returned to the bedded area of their home pen by moving them through the gate attached to the sidewall. The entry gate has to be designed whereby the gate is easily opened and closed. When artificially inseminating estrous sows, the sows are locked in a feeding stall. A mature boar is placed in the feed alley to stimulate the standing response. The boar should only be allowed to stimulate four sows at one time.

Space Requirements Per Animal. The amount of bedded area per sow in a hoop structure without a concrete slatted dunging area ranges from 24 to 27 square feet. The amount of additional space in the hoop will depend on the type of feeding system and other management procedures, e.g., space for boars and breeding pens.

Animals Per Pen. The number of sows housed in hoop structures in the United States ranges from 40 to 100 head. The number of sows housed varies according to the size of structure, method of feeding, and other management procedures, such as implementation of a hand-mating procedure.

Feeding System. Recently weaned sows are fed in individual feeding stalls (20 to 22 inches wide and 6.5 feet long) that have front and rear gates. Therefore, the sows can be easily moved to the breeding area. Gestating sows housed in hoops have been fed by the following methods: (1) individual feeding stalls (lockable and nonlockable rear gate), (2) floor fed, and (3) interval feeding with a self-feeder. A "centralized" feeding area has been used to feed sows; thus, the number of sows housed in a hoop is increased. Using of a centralized feeding system requires more time spent feeding sows, because sows have to be moved to and from the feeding area.

Ventilation. Hoop structures are naturally ventilated and take advantage of prevailing winds. Therefore, the longitudinal aspect of the structure is in the direction whereby air moves longitudinally through the facility. In the Midwestern section of the United States most of the structures are oriented in a north-south direction. In general, the hoop structure has a minimal volume of air entering from the sides.

Heating and Cooling Systems. A heating system is not used in a hoop structure because the deep-bedded material generates heat while decomposing. During high ambient temperature, the sows are generally cooled with a water sprinkling system.

Bedding and Manure Management. Most of the floors in hoop buildings are covered (14 to 18 inches deep) with deep-bedded oat/wheat straw or cornstalks (about 1.5 to 2.25 tons per sow per year); however, other types of bedding material have been used (prairie hay, corn cobs, barley straw). The influence of quality of bedding on welfare, health, and performance of the animals has not been extensively studied. All bedding materials should be free of molds to prevent reproductive problems during gestation. A skid-loader or a tractor loader equipped with a grappling fork is used to clean out the shelter about every three to four months. The quality of the solid manure for application on the land will vary greatly between the material removed from the sleeping area and the dunging area. The solid manure can either be hauled to the field directly or composted.

Labor Requirements. Scientific literature on the total amount of labor needed to operate a deep-bedded hoop breeding and gestation facility could not be located. It has been estimated that seven to nine hours of total labor is needed to clean the hoop structure and spread the material on nearby cropland.

Reproductive Performance. Canadian researchers have compared the reproductive performance between sows housed in a hoop structure and sows housed as a group in a conventional barn system. Sows gestating in a 731 square feet hoop structure were housed as a single group of 24 to 30 head and fed once daily in individual feeding stalls. Sows gestating in a conventional barn were assigned to groups of four per pen (6 x 14 ft) on partially slatted concrete floors and drop-fed twice per day on the floor. There was no difference between housing methods on number of pigs born alive per litter, birth weight, or average number of pigs weaned per litter (*Table 14*). The weaning-to-estrus interval was not different for sows housed in a hoop structure (HS) or conventional barn (CB) at parity 1 (HS, 9.0; CB, 8.5), parity 2 (HS, 6.4; CB, 5.8), or parity 3 (HS, 5.0; CB, 5.5).

Lammers et al. (2007) evaluated the effect of breeding season and gestation housing system on litter size (*Figure 22*). The gestation housing systems were group pens with individual feeding stalls in deep bedded hoop barns and individual gestation stalls in a confinement building. During the fall-winter breeding period (October to March), sows gestating in hoop barns farrowed a significantly larger number of live piglets per litter compared with sows gestating in stalls. During the spring-summer breeding period (April to September), there was no difference in the number of piglets born alive per litter between sows gestating in hoop barns and sows gestating in individual stalls. Farrowing rate was not reported by Lammers et al. (2007).

Table 14. Effect of gestation housing type on average number of pigs born alive per litter, average birth weight, or average number of pigs weaned per litter. [Connor et al., 1997; Conner 1998].

Housing method	Parity	Number of litters	Number born alive per litter	Birth weight, lb	Number pigs weaned per litter
Hoop	1	87	9.9	3.02	8.8
Barn	1	73	9.3	3.24	8.6
Hoop	2	64	11.1	3.40	9.6
Barn	2	59	11.2	3.33	9.5
Hoop	3	46	11.9	3.42	9.8
Barn	3	58	12.1	3.33	10.1
Hoop	4	29	12.3	3.28	9.5
Barn	4	27	11.6	3.06	9.0
Hoop	5	7	10.8	3.08	8.2
Barn	5	10	11.0	3.26	8.2
Combined data					
Hoop		233	11.0	3.24	9.3
Barn		227	10.7	3.26	9.2

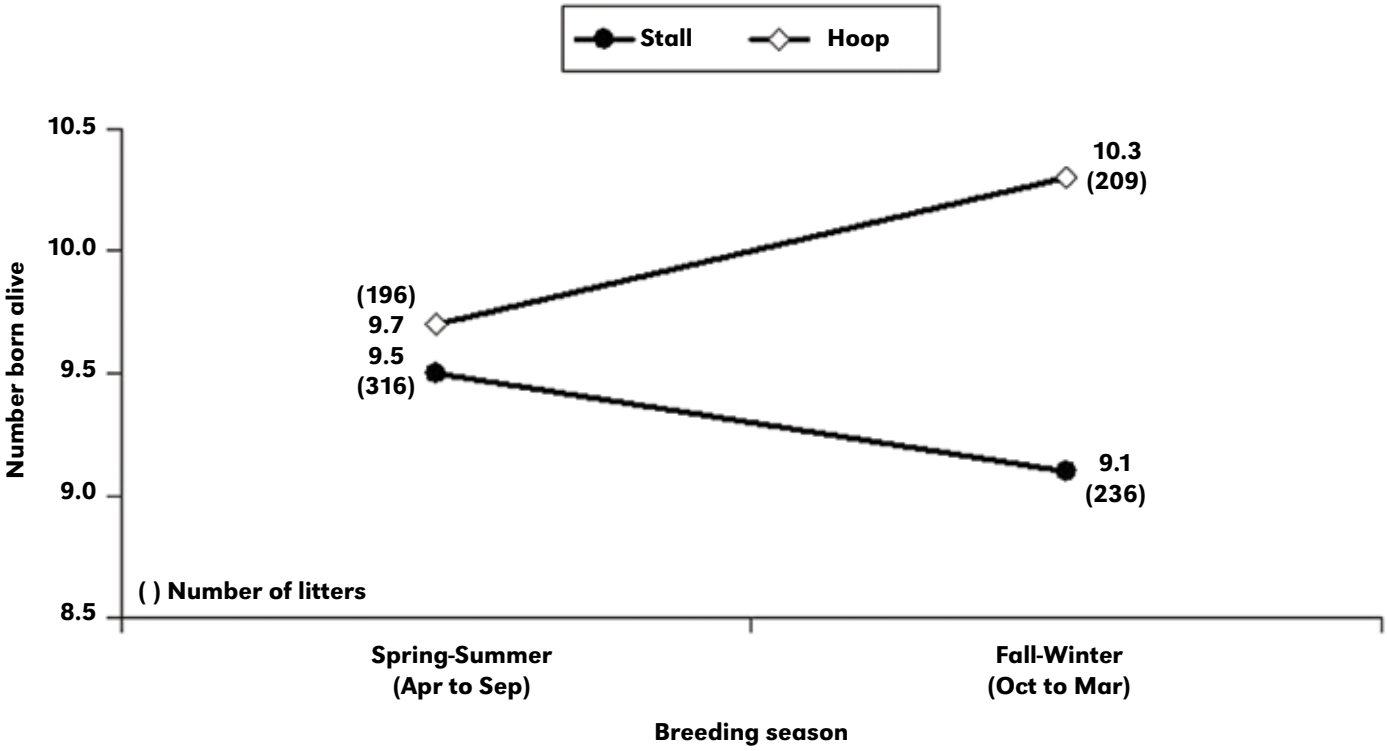

Figure 22. Effect of breeding season and gestation housing on litter size (Lammers et al., 2007).

Karlen et al. (2007) compared reproductive performance of gestating sows when housed in individual stalls with that of gestating sows housed in large groups (85 sows per pen; 24.3 square feet per sow) on deep litter (*Table 15*). The group-housed sows were individually fed daily by moving them 44 to 66 yards to a central feeding area. Sows housed in hoop had a 10.9 percentage point decrease in farrowing rate. The number of piglets born alive was not different between gestation systems. Although the number of piglets weaned was greater for sows housed in hoops, the fecundity index was 44 weaned pigs per 100 sows greater for sows housed in stalls. Culling rate due to lameness was greater for sows housed in stalls compared to sows housed in hoops.

Health and Welfare. Holmgren and Nilsson (2000) found that the use of straw bedding increased the risk of

Table 15. Effect of gestation housing system on reproductive performance (Karlen et al., 2007).

Item	Individual Stall	Hoops (groups)	P value
Farrowing rate, %	76.9	66.0	<0.001
Return to estrus, %	7.35	13.2	<0.05
Reproductive failure, %	14.5	27.3	<0.06
Number of piglets per litter			
Total born	11.2	11.1	Nonsignificant
Born alive	10.1	10.2	Nonsignificant
Stillborn	0.7	0.6	Nonsignificant
Mummified	0.3	0.3	Nonsignificant
Weaned	8.3	9.0	<0.05
Culling rate due to lameness, %	4.1	0.7	<0.01
Fecundity index [a]	638	594	

[a]Fecundity index = (Farrowing rate x number of piglets weaned per litter) x 100

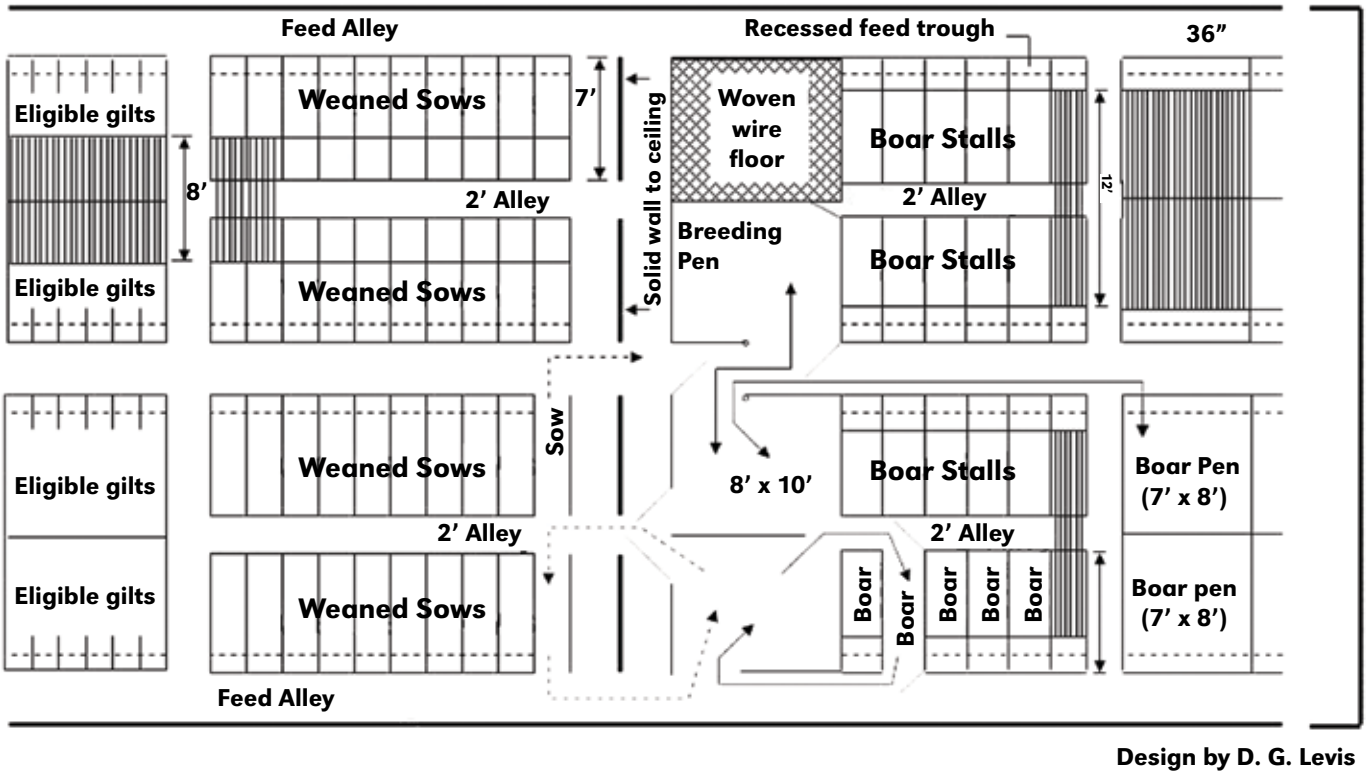

Figure 23. Levis Hand-Mating System: Boars and sows are separated before mating.

sows becoming infected with internal parasites, e.g., *Oesophagostomum* spp. (strongyloid nematodes). Publications comparing health and welfare aspects between various types of hoop structure systems and management procedures were not located.

5.2. Indoor breeding and gestation. Because of societal views, several states have banned the use of sow gestation stalls. However, many scientific evaluations have concluded that: (1) the well-being of the pregnant sow is equivalent whether sows are kept in individual gestation stalls or in group pens, and (2) reproductive performance of dry sows kept in individual gestation stalls is at least as good as, and in some instances exceeds, that of sows kept in groups (Curtis et al., 2009; McGlone et al., 2004). Pork producers need to seriously consider whether individual stalls should be

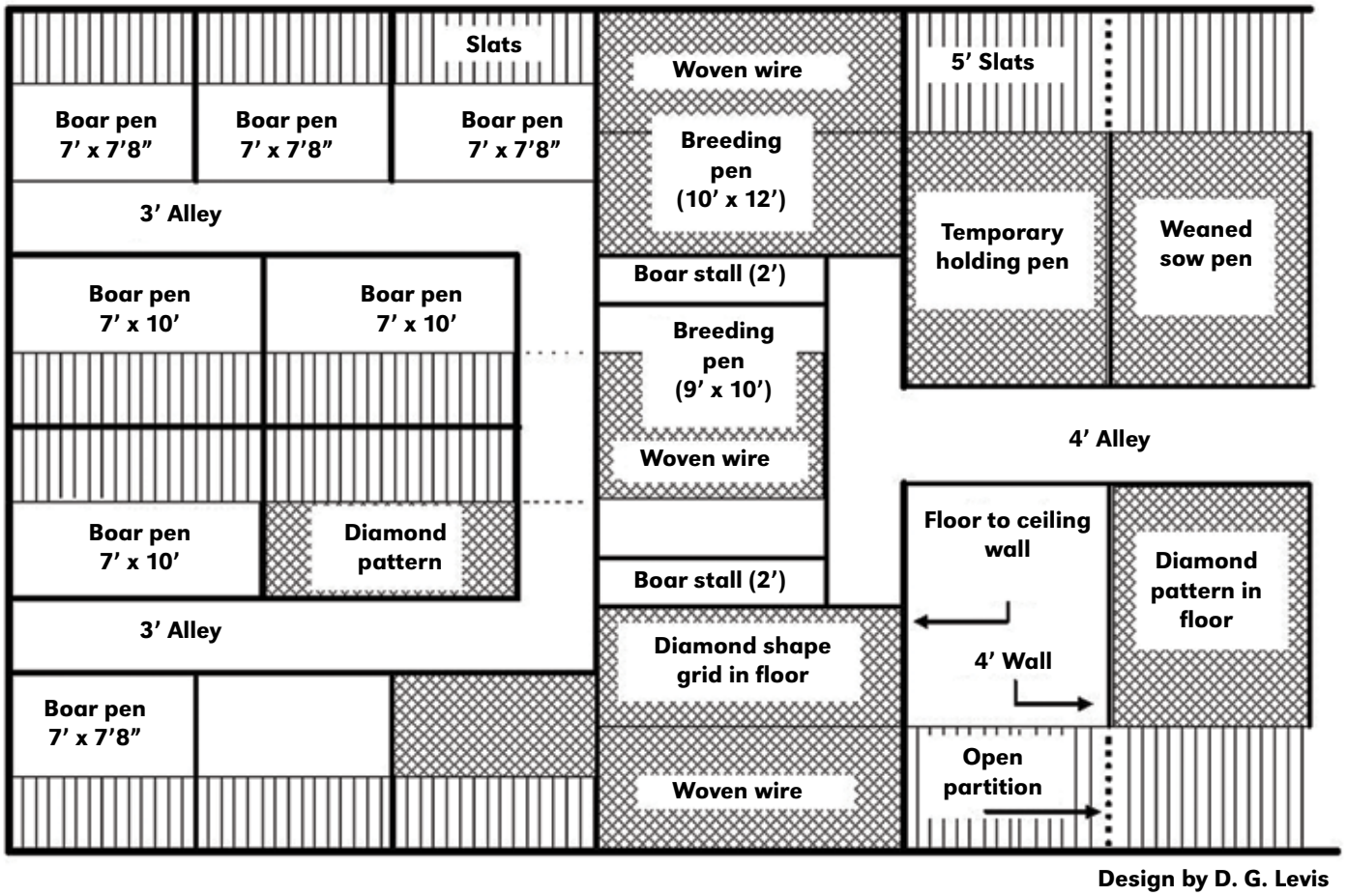

Figure 24. Modified Levis Hand-Mating System with boars in small pens and sows in group pens.

used when designing, constructing, and managing an indoor swine breeding and gestation facility. If pork producers plan to market their pigs to a particular meat processing plant (i.e., a niche market), they need to consider the animal housing and welfare requirements established by the company.

When housing boars and sows indoors, there is no single right system for every operation. Choices need to be made on the type of construction (walls, ceiling, floor, roof, etc.), ventilation system (mechanical or nonmechanical), floor layout (placement of boars, recently weaned sows, replacement gilts, late cycling females, cull females, gestation females, and "hospital" pens), penning style for sows (stalls, group housing, or a combination of stalls and group housing), penning style for boars (individual stalls, small pens, or a combination of stalls and small pens), feeding system (manual or mechanical), watering system (nipples or trough), type of mating (hand-mating or pen-mating), and type of service (natural, artificial, or a combination of natural and artificial). An excellent reference to help answer questions about the design, construction and management of a hand-mating system is the MWPS-43 *Swine Breeding and Gestation Facilities Handbook*. Levis (1988a; 2001) has presented various types of floor plan designs for breeding sows indoors.

Examples of the Levis hand-mating system are shown in *Figures 23* and *24. Figure 23* shows that: (1) boars can be individually housed in either stalls or small pens; (2) the boars and breeding pens are separated from the sows by a solid wall to the ceiling; (3) at the time of weaning the sows are temporarily housed in stalls; (4) after mating the bred sows can be moved to either a gestation stall or group-housing system; (5) replacement gilts are housed in groups; and (6) movement of sows and boars is easy. *Figure 24* shows that: (1) boars are individually housed in small pens; (2) boars and breeding pens are separated from the sows by a solid wall to the ceiling; (3) at the time of weaning the sows are group-housed in pens; (4) bred sows are group-housed during gestation; (5) a diamond pattern is imprinted in the floor to prevent sows and boars from slipping when moving around in the pen; and (6) animal movement and control is easy.

Figure 25. Injuries due to fighting after mixing (Johnson, 2006).

6. Minimizing stress during and after breeding

Generally, all systems that house sows in groups will require regrouping. Regardless of whether sows are housed indoors or outdoors, some degree of aggression is inevitable when unfamiliar sows are mixed. Aggression among sows at the time of grouping is considered a negative aspect of group housing. Because of fighting after mixing, injuries are quite common (*Figure 25*).

It takes two to seven days to reach a relative stability of social hierarchy in a group of newly mixed sows. The presence of a boar at the time of mixing sows has been suggested as a management tool to reduce aggression among sows. However, the results from different scientific studies are contradictory. A study in England found that boar presence led to a reduced frequency of aggressive interactions, flight distance, duration of aggressive incidents, and skin lesions of sows during the first 28 hours after mixing newly weaned sows (*Table 16*).

A study in Germany found that having a mature boar (about 2 years of age) in a mixing pen (17 feet x 17 feet) with eight sows did not affect the total number of attacks, duration of attacks, aggressive interactions, or skin lesion score per sow during the first 48 hours after the mixing of newly weaned sows (*Table 17*). However, boar presence significantly decreased the number of fights per sow and the duration of fights between sows. The higher ranking sow was the aggressor in 90.3 percent of all agonistic interactions and started 94.8 percent of the attacks. The boar was involved only in 2 percent of all agonistic interactions.

A Canadian study found that having a mature boar (about 2 years of age) in the pen during either the feeding (49.6 minutes) or nonfeeding (21 hours) periods did not reduce aggression between females during the first 48 hours after mixing (*Table 18*). The sows were mixed at 2 to 28 days after mating.

The welfare and productivity of sows improves when sows are exposed to less physical and environmental stress. Extreme levels of stress may be caused by high stocking density, new social grouping, poor environments, thermal extremes, and human-animal interactions which cause physical and psychological trauma to animals. All types of physical and environmental stress should be minimized for 28 days after mating. Some of the reasons to reduce stress include:

- After mating, the fertilized eggs are retained within the oviduct for about two days before they are released into the uterus. If stress causes the eggs to be released into

Table 16. Mean observations per hour for sows mixed in pens in the presence or absence of a boar (Docking et al., 2001).

	Mature boar		Square feet per animal	
Item	Present	Absent	37 square feet	43 square feet
Number of incidents	2.54	4.49**	3.39	3.65
Flight distance, feet	5.8	9.1*	7.0	7.9
Chase distance, feet	3.0	5.0	3.6	4.5
Duration of incidents, seconds	3.5	9.0*	6.6	5.9
Skin damage score, Day 1	23.5	34.1*	Not reported	Not reported
Skin damage score, Day 2	47.4	63.8*	Not reported	Not reported

*Significantly different from presence of boar ($P < 0.001$)
**Significantly different from presence of boar ($P < 0.05$)

Table 17. Effect of boar presence on attacks, fights, agonistic interactions, and skin lesion score during first 48 hours after mixing (Borberg and Hoy, 2009).

Item	Boar present	Boar not present	P value
Total number of attacks[a]	1,019	1,086	ns
Duration of attacks, seconds	2.8	3.1	ns
Number of fights per sow[b]	3.6	6.4	<0.01
Duration of sow fights, seconds	14.9	39.6	<0.01
Number of agonistic interactions between sows[c]	47.7	52.3	ns
Skin lesion score[d]	8.1	8.4	ns

[a]The attacked sow does not bite back.
[b]The attacked sow bites back with duration greater than three seconds.
[c]Biting the head, neck, or body of another sow, causing the recipient sow to immediately retreat or flee.
[d]Skin lesions were assessed separately for each left and right body region (ear, head, shoulder, back, udder, neck, flank) and vulva. The sum of 17 scores per sow was calculated ranging from 0 to 51.

Table 18. Effect of boar presence on the frequency and duration of intersow agonistic behavior during feeding and nonfeeding periods (Seguin et al., 2006).

	Aggressive contact[a]	Threats[b]	Fights	Total duration of fights/group (Seconds)	Avg fighting bout duration (Seconds)
Item	--- Number per group per hour ---				
Feeding period[d]					
0 to 24 hours after mixing					
No boar present	29.3	42.4	2.4	64.7	14.1
Boar present	47.0	47.8	6.0	227.1	30.0
25 to 48 hours after mixing					
No boar present	36.7	41.6	1.4	66.1	31.7
Boar present	59.5	57.9	0.3	28.6	21.0
Nonfeeding period					
0 to 24 hours after mixing					
No boar present	3.2	3.6	1.2	72.1	61.7
Boar present	4.2	4.7	1.3	51.8	38.1
25 to 48 hours after mixing					
No boar present	2.0	2.0	0.4	24.7	58.3
Boar present	4.0	2.8	0.4	18.1	47.8

[a]Frequencies of bites, head knocks, and body knocks were summed to obtain the frequency of independent aggressive contact.
[b]Sudden head movement or movement toward another sow without physical contact, subsequently causing the recipient sow to retreat
[c]The reciprocal occurrence of head-to-head, head-to-body knocks, parallel or inverse parallel pressing, and biting for greater than 5 seconds.
[d]Feeding periods (49.6 minutes) were defined as beginning when the feed was dropped on the floor by the feeders and ending when greater than 50 percent of the sows were no longer engaged in oral and/or nasal activity directed toward the floor.

the uterus too early, they will die because the uterus is a hostile environment prior to the normal time the eggs enter.

- About 10 to 12 days after mating, the blastocysts start to develop into a 39-inch long, extensively folded structure that signals the female to maintain pregnancy. Thus, the level of stress should be minimal when the sow receives the pregnancy signal.
- Attachment of the blastocyst to the uterine wall starts around 12 to 14 days after mating and continues until about 28 days after mating. Research studies have found that sows regrouped every two or three weeks during pregnancy tend to have lower farrowing rates compared to sows not regrouped.

Most likely, sows that are group-housed indoors will encounter more stress because they have less space to escape when fighting compared to sows housed outdoors. The distance required for a subordinate sow to escape from an aggressive sow is very important. One study using a dynamic grouping system found the distance over which a subordinate sow is pursued following aggressive interactions can vary from 0 to 66 feet, with 75 percent of the encounters resulting in chase distances of less than 8 feet.

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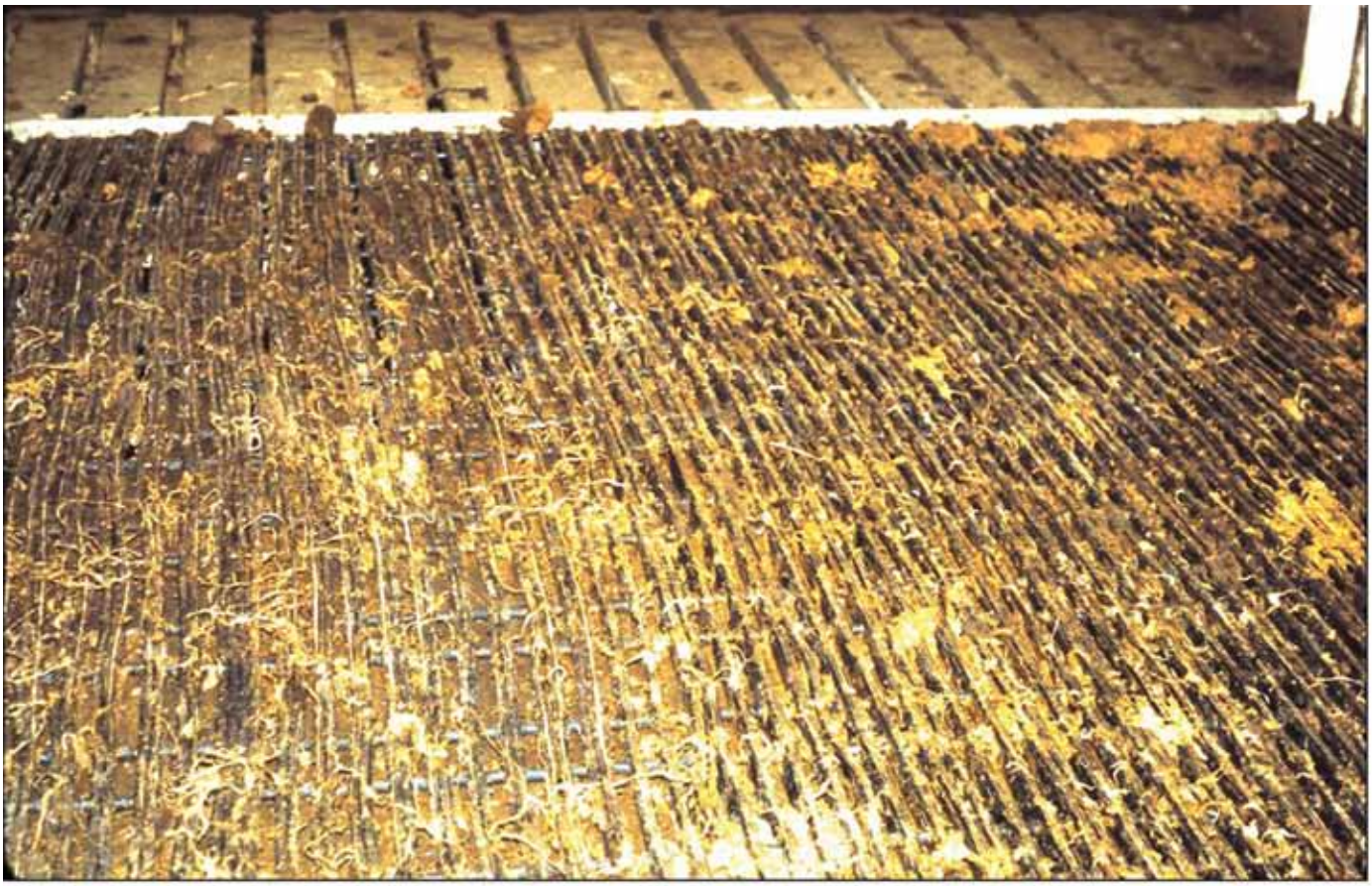
Appendix A
Floor Mats for Swine Hand-breeding Pens

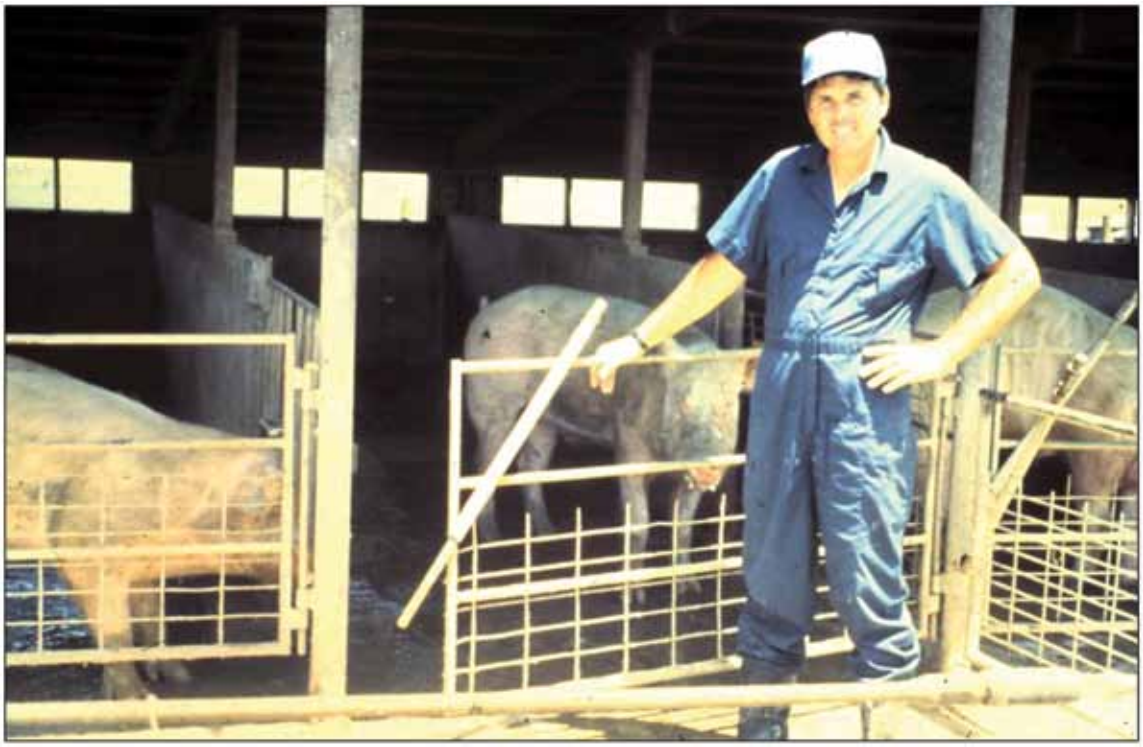


Picture 1. A breeding pen floor mat made from used truck tires.

Picture 2. An example of a rubber mat that can be used on the floor of an indoor breeding pen.

Appendix B
Gate Latch Designs

Picture 1. An angle gate latch fastened to gate (outdoor breeding facility).



Picture 2. An angle rod slides into a hole in the steel post that supports the roof of the building.

Picture 3. A gate latch attached to a swing gate (closed position).

Picture 4. A gate latch attached to a swing gate (open position).

Picture 5. A horseshoe shaped gate latch with a locking mechanism.

One-Handed Gate Latch

Mike & Troy Cammack
DeWitt, NE

We modified a commercial gate latch by designing a handle that lets us open and close breeding pen gates with one hand. The handle acts as a striker to open the gate.

Most latches are attached to the post and the pin they lock onto is welded to the gate. We mounted the latch on the gate instead, then welded the striker/handle to the top of the gate. The pin is welded to the post. To open the gate, we simply pull or push the handle in the direction we want it to open. The gate latches again when it's swung shut.

Materials list and cost:

1	Commercial gate latch	$18.00
24 in.	3/4-in. hot-rolled rod	0.70
7 in.	7/8-in. (ID) pipe	0.40
1 in.	1/4x2-in. flat steel	0.15
1 in.	1/2-in. hot-rolled rod	0.10
Total		$19.35

To build gate latch handles like these, you'll need an arc welder, a cutoff saw, a hand grinder and a level. It takes 30-60 minutes to install each handle.

National Hog Farmer August 15, 1993 29

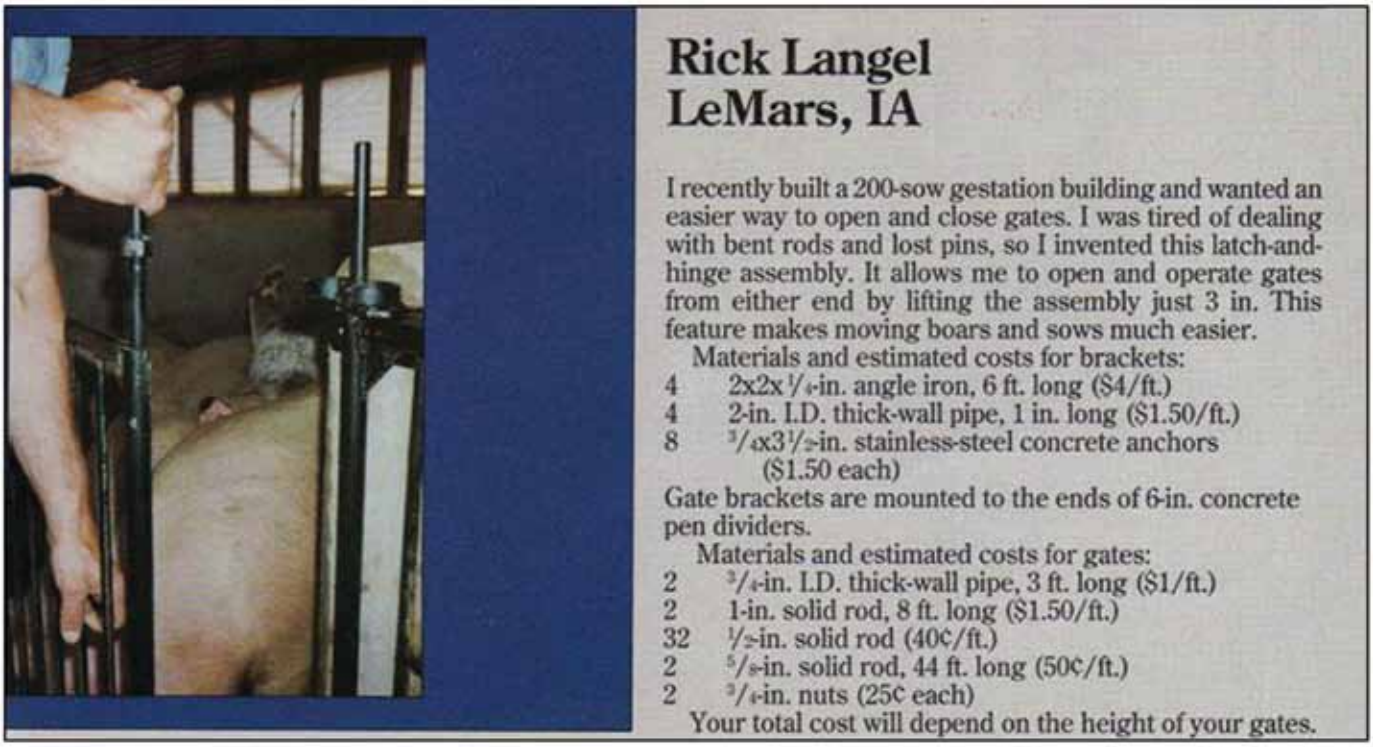
Picture 6. A gate latch mounted on top of gate (National Hog Farmer, 1993).

Picture 7. A spring-loaded gate latch fastened to gate (locked position). (Levis et al., 1996).

Picture 8. A spring-loaded gate latch fastened to gate (unlocked position).

Picture 9. An overhead structure to prevent gate latch corner post from moving.

Picture 10. An overhead braces to enhance the functionality of the gate latches.



Rick Langel
LeMars, IA

I recently built a 200-sow gestation building and wanted an easier way to open and close gates. I was tired of dealing with bent rods and lost pins, so I invented this latch-and-hinge assembly. It allows me to open and operate gates from either end by lifting the assembly just 3 in. This feature makes moving boars and sows much easier.

Materials and estimated costs for brackets:

4	2x2x1/4-in. angle iron, 6 ft. long ($4/ft.)
4	2-in. I.D. thick-wall pipe, 1 in. long ($1.50/ft.)
8	3/4x3 1/2-in. stainless-steel concrete anchors ($1.50 each)

Gate brackets are mounted to the ends of 6-in. concrete pen dividers.

Materials and estimated costs for gates:

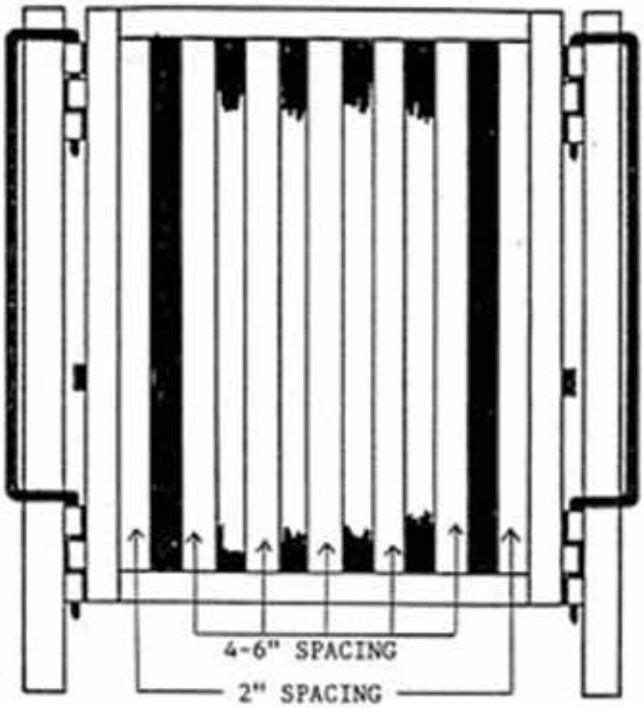
2	3/4-in. I.D. thick-wall pipe, 3 ft. long ($1/ft.)
2	1-in. solid rod, 8 ft. long ($1.50/ft.)
32	1/2-in. solid rod (40¢/ft.)
2	5/8-in. solid rod, 44 ft. long (50¢/ft.)
2	3/4-in. nuts (25¢ each)

Your total cost will depend on the height of your gates.

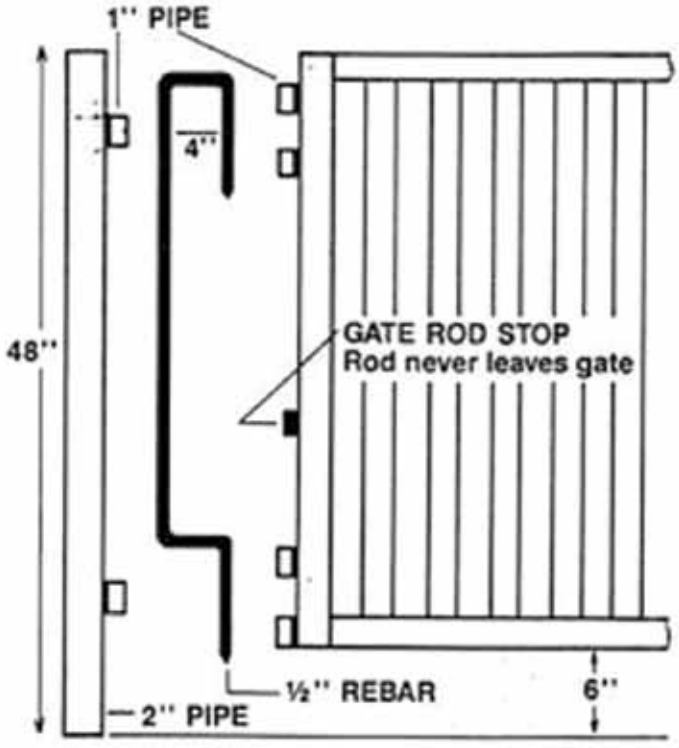
This picture shows the latch closed on the gate on the right side, and the gate on the left side is open. The latch is opened by pulling up on the handle of the rod and the 1" solid gate rod slides through a slot in the circular latch. When the latch is closed, the ¾" nut welded to the 1" rod will not slide through the slot in the circular latch.

Picture 11. Langel latch (National Hog Farmer, 1992)

The gate's latch-hinge solves boar movement problems



No more searching for the latch pin and trying to thread it through a series of latch holes. No more being left in a boar's path after opening the gate to its pen. Levis' gate latch-hinge solves these problems. The latch stop in the center of the gate keeps the latch pin attached to the open gate. The pointed ends of the shaped-rebar pin make it easy to guide through the bottom two of the three latch holes in each set. With the latch-hinges on both sides, the gate can be opened from either side, always putting the gate between the producer and the exiting boar.



Levis' latch-hinge is easy to build and basically has three components. The six pieces of 1-inch pipe should form two sets of three latch holes. The two center hole pieces are welded to a corner pipe or a side panel's end pipe, and the remaining pieces are welded to the gate's end pipe. A piece of rebar should be shaped as shown to form the latch pin. The latch stop—another piece of 1-inch pipe—should be welded to the gate's end pipe where it will allow the latch pin to be pulled up out of the two lower latch holes of each set (permitting the gate to open), but will prevent the pin from slipping out of each set's top latch hole.

Source: D.G. Levis, University of Nebraska

Drawing is courtesy of Pork '88.

Picture 12. Design specifications for a Levis Gate Latch-Hinge

Appendix C
Boar Usage Chart[a]

	WEEK OF: ______ TO: ______														WEEK OF: ______ TO: ______													
Boar No.	MON		TUE		WED		THU		FRI		SAT		SUN		MON		TUE		WED		THU		FRI		SAT		SUN	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM

[a]Use this template to construct a 2' × 3' wall board with erasable surface to record daily boar usage.

Picture 1. Laminated boar usage chart.