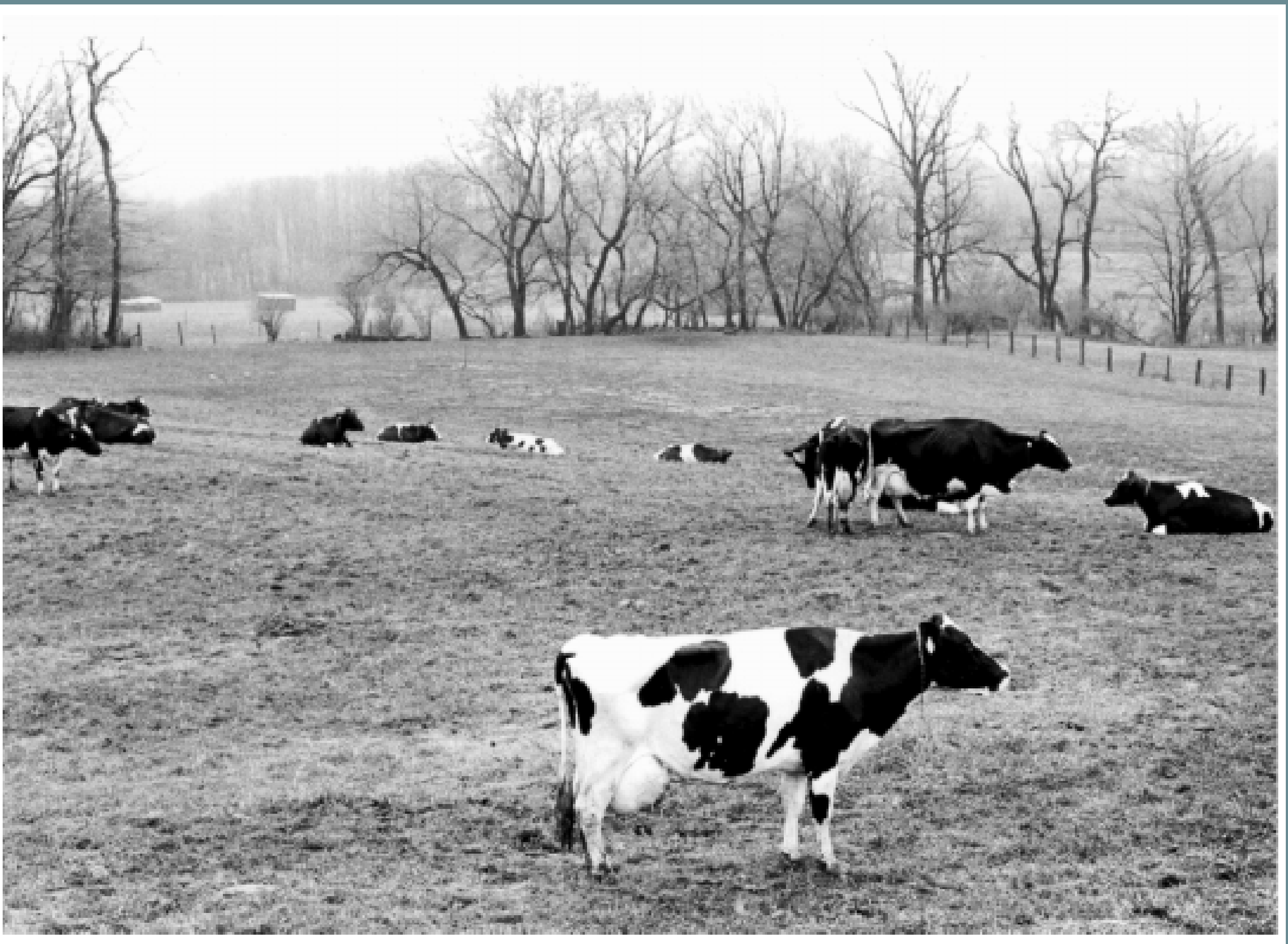
EXTENSION CIRCULAR 402

HEAT DETECTION AND TIMING OF INSEMINATION FOR CATTLE



PENNSTATE

College of Agricultural Sciences
Cooperative Extension

HEAT DETECTION AND TIMING OF INSEMINATION FOR CATTLE

Efficient and profitable reproductive performance of a dairy herd requires routine but conscientious heat detection and proper timing of artificial insemination. Failure to detect estrus (heat) is a major factor contributing to low fertility. Approximately half of the heats are undetected on dairy farms in the United States. In addition, research based on levels of the hormone progesterone in milk shows that up to 15 percent of the cattle presented for insemination are not in heat. Failure to detect cows that are in heat and breeding cows not in heat result in economic loss for the producer because of extended calving intervals and additional semen expense. If a herd producing 16,000 pounds of milk per year and maintaining a 12.5 month calving interval is compared with the same herd maintaining a 13.5 month calving interval, the loss in potential milk alone is between $35 and $45 per cow per year, depending on milk price and feed costs. Therefore, poor heat detection is costly to the producer and should be considered the critical component of reproductive management.

Efficient heat detection and timely insemination also are important to beef producers who use artificial insemination. Failure to detect estrus early in the breeding season or improper timing of insemination due to heat detection errors results in extended calving intervals and additional semen expense.

This publication provides information on characteristics of the estrous cycle, signs of heat and estrous behavior, factors affecting expression of estrus, and management suggestions for improving heat detection. Various ways to monitor the efficiency of heat detection and several heat detection aids also are described.

CHARACTERISTICS OF THE ESTROUS CYCLE

It is important for those who manage cattle to understand the changes in ovarian structures and hormone concentrations during the normal estrous cycle. In general, there are two structures that can be found on the ovary, the corpus luteum and follicles of various sizes. It was thought that several follicles developed large fluid cavities (antrum) toward the end of the cycle or prior to the first postpartum heat but that only one or two follicles were dominant and ovulated, releasing the oocyte (egg) shortly after heat. The other follicles were thought to degenerate and a corpus luteum to develop at the site of ovulation. Recent studies, however, reveal different changes in growth and degeneration of follicles during the cycle.

Using real-time ultrasound technology to monitor ovarian structures on a daily basis, several independent research groups have shown that cows or heifers may have two, three, or four groups of follicles that develop during each estrous cycle. Usually, a single follicle within each group becomes dominant, suppressing the continued growth of the other follicles within that group. Such groups of developing follicles are called "waves" of follicular growth. Thus various populations of small, medium, and large follicles are present on the ovary each day of the cycle.

On about day 18 of a normal 21-day cycle, the corpus luteum (CL) that developed after the previous ovulation begins to regress and progesterone concentrations decline. The dominant follicle of this last wave continues to increase in size and produces the hormone estrogen. Since progesterone concentrations are low, estrogen causes the characteristic signs and behavior associated with estrus. At the beginning of standing heat, estrogen

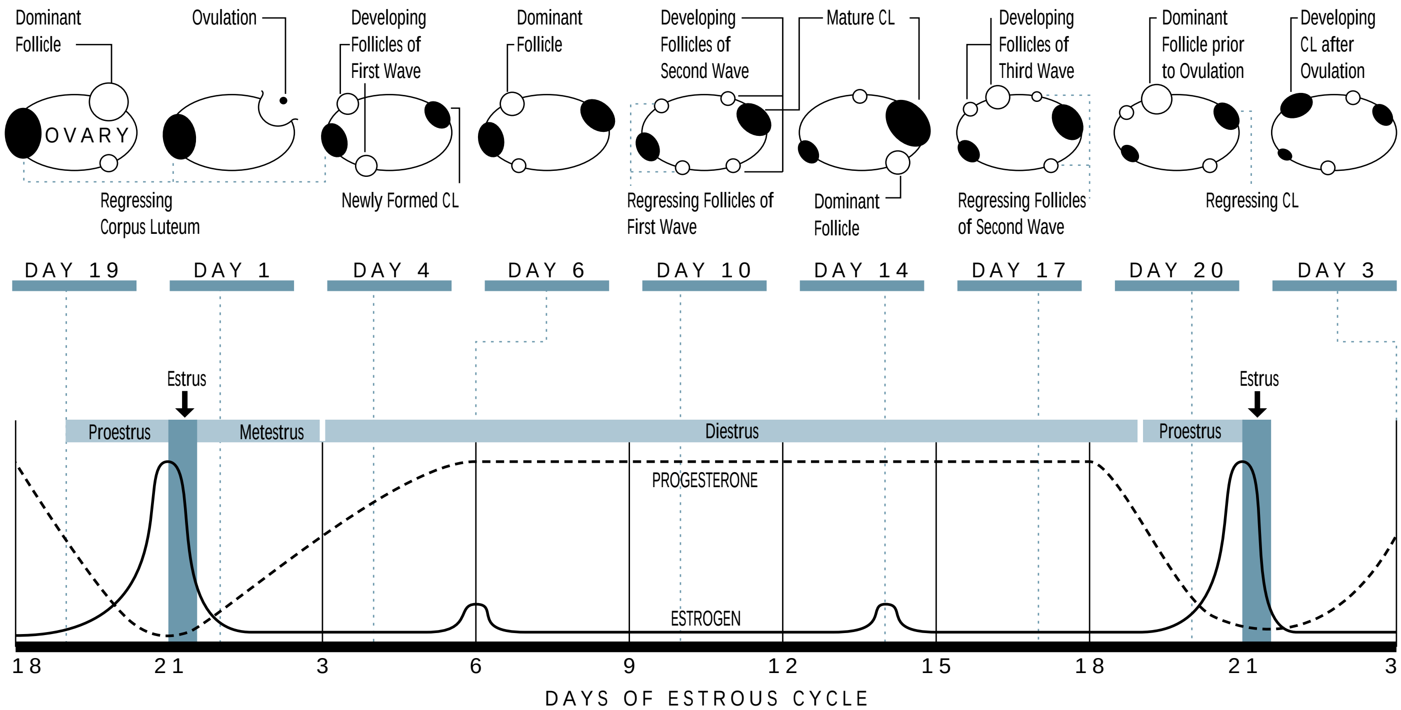


Figure 1. Changes in ovarian structures and hormone concentrations during the estrous cycle. For simplicity, only one ovary is illustrated; however, structural changes are occurring on both ovaries. Specific days of the cycle are listed for illustration only. There is variation among cows.

also initiates the release of a surge of luteinizing hormone (LH) from the anterior pituitary gland in the brain.

Luteinizing hormone begins the process of ovulation, which occurs approximately 25 to 32 hours after the onset of standing heat. At the site of ovulation, the new CL increases in size and gradually produces increasing amounts of progesterone. Concentrations of progesterone in the blood remain high from about day 6 through day 18 of the cycle. Although follicles continue to develop and even produce estrogen (estrogen-active follicles) during midcycle, the high level of progesterone prevents their final maturation and inhibits expression of heat. Eventually these larger follicles degenerate and estrogen production declines.

Progesterone also prepares the uterus for pregnancy, inhibits uterine contractions, and maintains pregnancy. The CL regresses in cows that fail to become pregnant and progesterone levels decline, the dominant follicle completes development, and the cow returns to estrus, initiating a new cycle. If pregnancy occurs, the CL does not regress and progesterone levels remain elevated throughout pregnancy.

Thus the estrous cycle can be divided into four periods: proestrus, estrus, metestrus, and diestrus. Proestrus is the period when progesterone declines with regression of the CL, estrogen increases, and secondary signs of estrus begin to occur. Estrus is characterized by standing behavior (true heat). Metestrus begins immediately after estrus when ovulation and early development of the CL occur, a period that lasts three to five days. Finally, diestrus is the time when the CL is functional, the longest phase of the estrous cycle.

Figure 1 illustrates the structural changes on the ovaries and the hormone concentrations during an estrous cycle with three waves of follicular development. Although specific days of the cycle are indicated on the diagram, this is for illustration purposes only since there is variation among cows.

SIGNS OF HEAT

It is essential to understand the primary and secondary signs of heat in order to achieve accurate and efficient heat detection.

Primary sign

A cow standing to be mounted is the most accurate sign of estrus. *Standing heat* is the most sexually intensive period of the estrous cycle. During this period, cows stand to be mounted by other cows or move forward slightly with the weight of the mounting cow. Cows that move away quickly when a mount is attempted are not in true estrus. In order for standing behavior to be expressed, cattle obviously must be allowed to interact.

The expression of heat is due to the elevated level of estrogen in the blood when progesterone is very low. Occasionally cows in early pregnancy, approaching the end of pregnancy, or with ovarian follicular cysts have similar hormonal relationships and may express signs of heat.

The average duration of standing heat is 15 to 18 hours, but heat duration may vary from 8 to 30 hours among cows. An estrous cow usually stands to be mounted 20 to 55 times during her estrous period. Each mount lasts three to seven seconds. Factors that affect expression of heat are discussed in a later section.

Secondary signs

Secondary signs vary in duration and intensity. These signs may occur before, during, or after standing heat and are not related to time of ovulation. Dairy producers should use these signs as clues or watch the specific cow more closely for standing behavior. To determine whether cows exhibiting secondary signs will stand to be mounted, they may be isolated with a sexually active cow or teaser animal.

MOUNTING OTHER COWS. Cattle that exhibit this behavior may be in heat or approaching heat. Mounting activity is performed much less frequently by cows in midcycle. Although mounting cannot be used as a true primary sign of heat, cows exhibiting such behavior should be watched closely for standing behavior.

MUCUS DISCHARGE. As an indirect result of elevated estrogen levels, mucus is produced in the cervix and accumulates with other fluids in the vagina before, during, and shortly after estrus. Long viscous, clear elastic strands of mucus generally hang from the vulva. Sometimes, however, the mucus does not appear externally until the cow is palpated during insemination and the mucus is expelled. Mucus also may be smeared on the tail, thighs, flanks, or perineal region.

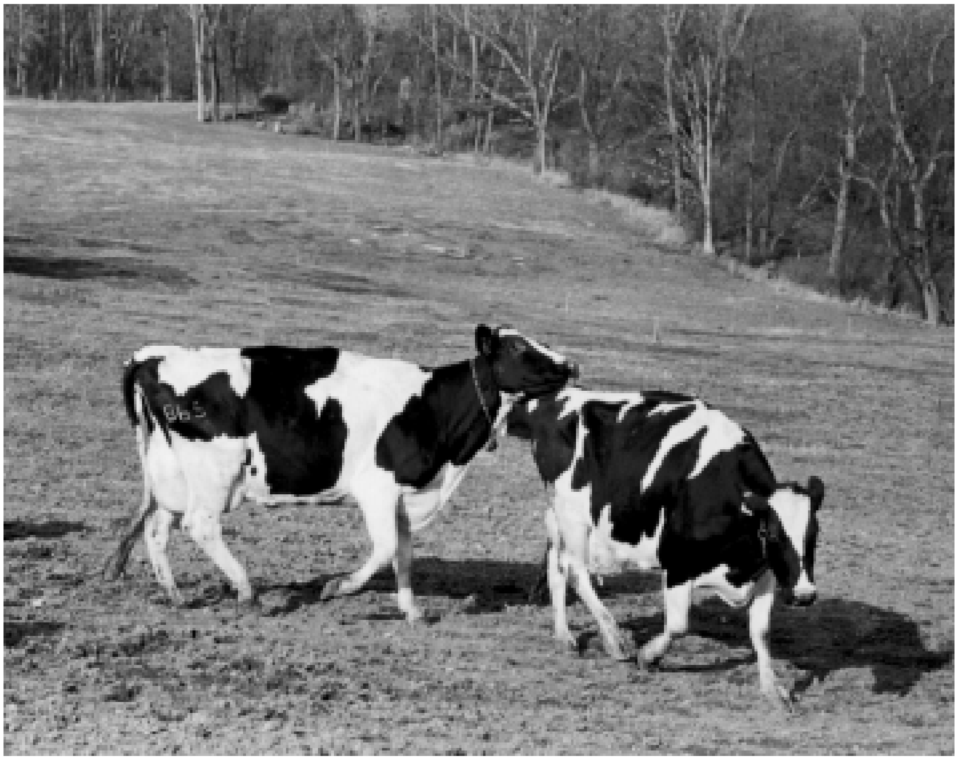
SWELLING AND REDDENING OF THE VULVA. During heat the vulva swells and the interior becomes moist and red. Generally these symptoms appear before heat and remain for a short period after heat. Thus they are not precise indicators of estrus. During midcycle the lips of the vulva are pale and more difficult to separate.

Standing and mounting activity.

BELLOWING, RESTLESSNESS, AND TRAILING. Cows in heat are more restless and alert to their surroundings. When allowed to interact with other cattle, cows coming into heat “proestrus” and cows in heat persistently trail behind to try to mount other cows. Research shows that cows in heat spend less time resting than nonestrous herdmates. Prior to and during heat, they remain standing and alert while their herdmates are lying down and resting. This is more noticeable for stanchioned cows. Cattle may bellow more frequently during estrus. Although these are not definitive signs of heat, cows exhibiting such behavior should be watched closely for standing behavior.

RUBBED TAILHEAD HAIR AND DIRTY FLANKS. As a consequence of being ridden, the hair on the tailhead and rump is fluffed-up, rubbed, or matted, and the skin may be exposed. The legs and flanks may be smeared with mud or manure.

String of clear mucus being discharged.



Chin resting and trailing activity.

CHIN RESTING AND BACK RUBBING. Prior to mounting, cows often rest or rub their chin on the rump or back of the cow to be mounted. This application of pressure may be considered a test for receptivity to being mounted. Both cows should be observed closely for mounting and standing behavior.

SNIFFING GENITALIA. Sniffing the genitalia and licking the vulva of other cows occur much more frequently with cows in proestrus and estrus.

HEAD RAISING AND LIP CURLING. Generally this activity follows sniffing of the genitalia and occurs more frequently if the cow being investigated is in heat and urinates.

DECREASED FEED INTAKE AND MILK YIELD. Estrous cows spend less time feeding. Some studies also have reported decreased milk yield during estrus, and a Canadian study reported a slight increase in milk yield toward the end of heat. But since many factors other than estrus can affect milk yield on a specific day, this is not a reliable indicator of estrus.

METESTROUS BLEEDING. Some cows and most heifers have a bloody mucus discharge one to three days after estrus, but onset of this symptom, called metestrous bleeding, is quite variable. High estrogen levels during estrus cause blood to leak from vessels near the surface of the uterus. This discharge indicates that the cow was in heat and does not mean that she failed to conceive. However, such animals should be watched closely for a return to heat in 18 or 19 days.

FACTORS AFFECTING ESTROUS BEHAVIOR

Various factors related to environment, cow health and nutrition, and herdmates can affect estrous behavior.

TYPE OF HOUSING. Any housing arrangement that allows cattle to interact throughout the day provides more opportunity for mounting and standing behavior to be expressed. Cattle housed in tie-stall or stanchion barns must be turned out in order for this behavior to be expressed. If cattle are not allowed to interact, the herd manager must use less reliable secondary signs to determine which cows are in heat. *Caution:* It would be incorrect to assume that more heats are observed in loose-housing or free-stall barns than in tie-stall or stanchion barns. Although there is a greater opportunity to observe heat when cows interact frequently in free-stall barns, taking time to observe estrous behavior is still necessary.

FOOTING SURFACE. To what extent does a slippery footing surface affect expression of estrus? Research conducted in North Carolina compared estrous activity of high-producing Holstein cows that were watched for heat for one hour every eight hours, 30 minutes on dirt and 30 minutes on grooved concrete. Table 1 shows total mounts and stands during estrus and average number of mounts and stands during a 30-minute heat check period. Duration of heat was longer for cows observed on dirt. Mounting and standing behavior were nearly doubled when cows were checked for heat on dirt as compared to concrete.

A second study also confirmed that mounting activity occurs more frequently when cows are on dirt rather than concrete. When five estrous cows were individually presented with an opportunity to spend time on dirt or on concrete in the presence of a tied cow which was either an estrous cow or a cow not in heat, the test cow spent an average 70 percent of the time on dirt. The test estrous cow mounted more frequently when a tied estrous cow was on dirt rather than on concrete.

Table 1. Mounting and standing activity of thirteen Holstein cows on dirt and concrete.

Activity	Dirt	Concrete
Duration of heat (hours)	13.8	9.4
Total during estrus		
Mounts	7.0	3.2
Stands	6.3	2.9
Average during 30-minute heat check		
Mounts	3.7	2.5
Stands	3.8	2.7

Source: J. Britt et al. (1986), Journal of Dairy Science 69: 2195.

Table 2. Percentage of mounting and standing to be mounted behavior in various locations in a loose-housing arrangement.

Location	Mounts and standing behavior	
	Number	*% of total*
Bedded pack	1098	70
Dry lot	204	13
Feed bunk or manger area	108	7
Free-stall area	94	6
Free-stalls	55	4

Source: J. Pennington et al. (1985), Agri Practice, Vol. 6, No. 9.

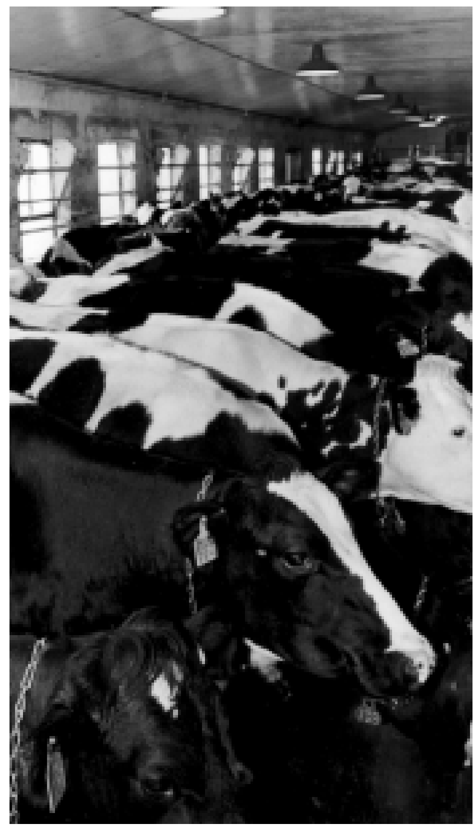
Finally, in a Purdue University study in which heifers were housed in a free-stall barn with access to a bedded pack and observed continuously for estrous behavior over a 96-hour period, 70 percent of the mounting activity occurred in the bedded pack area. Less activity was observed in the dry lot, in the free-stall area, and near the feed bunk (Table 2).

Icy or slick concrete is always a problem for free-stall herds. Concrete should be grooved or scabbled to provide traction. Moving cattle to a dirt lot or from one area to another not only provides a better surface but also provides added stimulation from the movement alone.

FEET AND LEG PROBLEMS. Cows with sore feet or legs or poor structural conformation exhibit less mounting activity, or they stand to be mounted when not in heat because it is too painful to avoid being mounted. One British study involving 770 cows with nearly 1500 lactations showed that lameness caused by specific lesions on the hoof was associated with a 7-day increase in days to first service and 11 more days open compared to herdmates without lameness. These differences were greater for cows with sole lesions that developed between 36 and 70 days postpartum, the time when cows should first be detected in heat. For those cows the interval to first service and days open increased 17 and 30 days, respectively.

COW DENSITY. Data are not available for determining optimal number of open cows per unit area or total number of cows per pen to achieve maximum expression of estrous behavior. However, common sense would suggest that if cattle are forced into a crowded area, such as a holding pen associated with a milking parlor, that mounting activity would be suppressed or cows would be forced to stand to be mounted even when they are not in heat. Too often the only time cows are observed for heat is when they are in holding pens prior to milking. In overcrowded free-stall barns, cows may stand to be mounted in a stall or alley simply because they cannot escape a mounting cow. Crowded conditions also may increase the incidence of false-positive heats determined by rump-mounted heat detection devices or markings.

TEMPERATURE. Research conducted in Virginia showed that as maximum daily temperatures increased to about 75°F, mounting activity also increased. But at temperatures above 85°F, beyond the comfort range for cattle, mounting was less frequent. Research done at Purdue University suggests that cows in cold weather have more mounting activity than cows exposed to hot weather; however, during hot weather estrous cows tend to exhibit more secondary signs, such as rubbing, licking, and chin resting.



Arrangement where cattle are crowded.

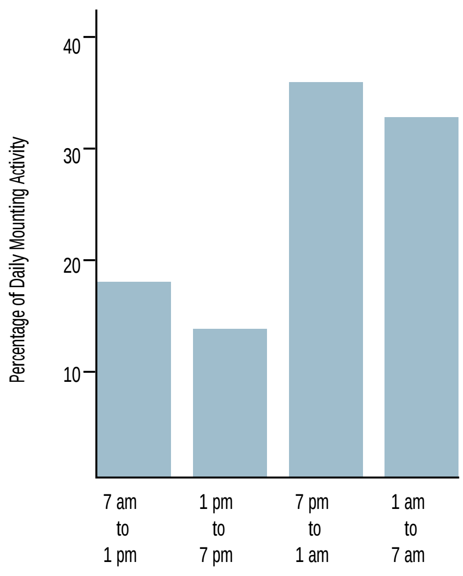


Figure 2. Effect of time of day on mounting activity for estrous cows. Adapted from Hurnik et al. (1975)

VARIATION DURING THE DAY. Do cows prefer to mount other cows at a certain time of day? Herd managers often remark that most mounting occurs in early morning or during the later evening hours. In a study conducted in Canada, video cameras monitored estrous activity in a free-stall area 24 hours a day. This study showed that nearly 70 percent of the mounting occurred between 7 p.m. and 7 a.m. (Figure 2). This observation suggests that cows are most likely to exhibit mounting activity when they are not distracted by farm activities such as feeding, milking, and barn cleaning. The data may further indicate that cattle prefer to mount during the cooler times of day.

HERDMATE STATUS (STAGE OF ESTROUS CYCLE). To determine the cause of silent heats or poor expression of heat, consider the overall reproductive status of the herd and compare the ratio of open to pregnant animals in each group of cows and heifers. Pregnant cows are the least likely group of herdmates to mount a cow in heat. Herd managers must rely on the other open cycling herdmates to detect heat. What about the other nonpregnant herdmates? Do herdmates vary in their ability to detect and mount cows in heat? Does the day of the herdmate's estrous cycle influence her interest in the estrous cow?

When Penn State researchers conducted a very controlled study, estrous cows encountered each of 19 cycling herdmates in an isolated barn one-to-one for 10 minutes. The total number of mounts by each herdmate was determined on day 10, day 15, day of heat, and day 5 of the next cycle. Herdmates varied in mounting activity, as did estrous cows in attracting mounts. More important, for the herdmates as a group, the number of mounts differed substantially with the day of the cycle. Herdmates in midcycle (day 10 and day 15) and on day 5 averaged one mount or less during the 10-minute observation period. Some herdmates did not even mount the estrous cow on those days. However, when the herdmate herself was in estrus, the number of mounts averaged 2.5 during the 10-minute period. Thus, taken as a group, cows are poor heat detectors in the middle of their cycle. Since this represents 50 to 60 percent of the estrous cycle and reduces the number of effective heat-detecting herdmates by a similar percentage, managers must rely on cows in or near heat to detect other estrous cows.

In some herd situations, a few open cycling cows may contribute to the problem of silent or missed heats. In small herds, most of the herd may be pregnant at certain times, and the stage of the cycle of the few nonpregnant cows may be such that they are not effective heat detectors. As more animals become pregnant, the number of potential heat-detecting animals is reduced. The situation is similar for herds that freshen on a seasonal basis. After an intensive breeding period, when a high percentage of the herd is pregnant, it becomes increasingly difficult to identify the few open cycling cows in heat. There simply may not be enough herdmates in the proper stage of the cycle to interact with an estrous cow. A third situation may occur frequently in free-stall herds where cows are grouped according to production. Generally, the lower production group contains pregnant cows, but because of low production, some nonpregnant cycling cows may be included in this group. It becomes very difficult to detect the cows in heat because their herdmates are pregnant.

Table 3. Effect of number of cows in heat on mounting activity.

Number of cows	Average mounts per cow in heat
1	11.2
2	36.6
3	52.6
4 or more	49.8

Source: J. Hurnick et al.(1975), Applied Animal Ethology 2:55.

NUMBER OF HERDMATES IN PROESTRUS OR ESTRUS. Frequency of mounting is considerably higher when more than one cow is in heat or approaching heat (proestrus) at the same time. Canadian scientists found that the number of mounts increased significantly when two or more cows were in heat simultaneously (Table 3).

NUTRITIONAL FACTORS. Mounting activity and other sexual behavior have been shown to decrease in cows that lost more weight since calving than herdmates with minimal weight loss. On the other hand, there are certain cows within the herd or entire herds in which the majority of the cows are truly anestrus (noncycling). Possible causes of anestrus include poor body condition, anemia, uterine infection, cystic ovaries, and parasitism.

LACTATION NUMBER, DAYS POSTPARTUM, AND MILK PRODUCTION. With the possible exception of heifers, lactation number does not seem to affect estrous behavior. Variable results have been obtained from research comparing estrous behavior with level of milk production or number of days postpartum. These factors have much less influence on the expression of estrus than other factors described above.

ESTROUS DETECTION PROGRAM

The following management practices may aid in estrous detection.

- Use your time efficiently, observing for heat when cattle are likely to mount.
- Allow cows to interact, especially during the evening and early morning hours, when most of the mounting activity occurs. Even though loose housing systems provide more time for cow interaction, be sure to observe the cattle frequently. Move pastured cattle to an area where they easily can be observed. In conventional housing systems, turn cows out twice daily for 20 to 30 minutes. Be sure to turn cows out when time can be spent observing them. Avoid scheduling observation periods at feeding time or during the warmest hours in summer.

  An aggressive heat detection program can be effective. A Pennsylvania study involving approximately 200 repeat breeding heifers (three or more services) compared the average and distribution of cycle length based on farm records before the heifers arrived at the research station with these estrous cycle characteristics after arrival. The major difference in management was that the heifers were turned out for heat detection at 8:00 a.m., 4:00 p.m., and midnight. The average duration of cycle length and the frequency of long cycles were reduced. The onset of heat occurred equally for the three heat detection periods. Table 4 shows that the more frequent the observation, the more heats are detected.

Heifers on dirt lot with good footing.

- Slippery and muddy conditions severely inhibit mounting activity. Provide an area with a good footing surface where cattle are free to interact and where few obstacles hinder movement. Moving cattle to a separate area for heat detection may stimulate estrous behavior.
- When cows have sore feet and legs, heat detection is more difficult. Minimize this problem by trimming hoofs periodically, and treat infected feet as soon as a problem is apparent.
- When several people are working with the herd, assign one person to be responsible for heat detection, and allow time for employees to do the job properly. Train employees to recognize signs of heat and promptly report this information to the responsible person. Consider having a financial incentive program to increase heat detection efficiency.

Cows on grooved concrete.

Table 4. Comparison of estrous cycles of repeat breeding heifers before and during an intensive heat detection program.

	Average interval between heats	% short cycles < 17 days	% normal 18-24 days	% long cycles >24 days
Before	48.6	6.3	41.9	51.8
During[1]	20.6	9.9	81.1	9.0

Source: T. Tanabe and J. Almquist (1960), Penn State Research Bulletin 672.

[1] Heifers observed at 8:00 a.m., 4:00 p.m., and midnight.

Cow with large ear tag for easy identification.

- Studies have shown that up to 15 percent of the cattle presented for insemination are really not in heat. Poor cow identification can be one cause of this problem. Legible neck chain numbers, large ear tags, and freeze brands can aid in accurate identification and can reduce mistakes.
- Record all heats, whether the animal is to be inseminated or not. Heat detection will improve if future heats can be anticipated. Use a pocket notebook to record heats and other information. Transfer information to a heat expectancy chart and to the permanent individual cow record. This permits monitoring of abnormally long cycles and long intervals from freshening to first service.
- Consider using heat detection aids to help increase the number of heats detected. Detection devices and detector animals should supplement routine visual observation.
- In larger herds the use of a testosterone-treated heifer will stimulate more mounting and probably will be cost effective.
- Using prostaglandin to induce estrus in one or two cows will increase the overall estrous behavior in the herd.
- Estrous synchronization programs for the lactating herd, or programmed breeding, will synchronize estrus for several days. Also, more heats will be anticipated and thus more heats are likely to be observed.
- Isolate the cow thought to be in heat with a sexually active cow or heat-detector animal. Heat may not be detected in some cows in a large group situation, but when isolated with an active cow or heifer, a cow possibly in heat may exhibit standing behavior.
- Watch for sexually active groups of cattle. Cows in proestrus or estrus tend to congregate and stay together.
- Adjust the feeding program so that cows calve in proper body condition and weight loss is minimized during lactation.

Group of sexually active cows.

TIMING OF INSEMINATION

Since cattle should be inseminated so that viable sperm are at the fertilization site as the unfertilized egg arrives, it is important to estimate the time of ovulation for each cow that is to be inseminated. Ovulation occurs 25 to 32 hours after the onset of standing heat. Standing behavior is the only reliable symptom producers have to determine time of ovulation.

Sperm have to be in the female reproductive tract for approximately six hours before they are capable of fertilizing the egg. This process is termed capacitation. Although live sperm have been found in the female tract up to 48 hours after insemination, sperm viability usually is estimated to be 18 to 24 hours. Improper semen handling or poor insemination technique can dramatically reduce the number of sperm cells available for fertilization and thus can lower the conception rate.

The egg travels very rapidly from the ovulation site to the fertilization site in the oviduct. The fertile life of the egg is shorter than that of the sperm. Ovulated eggs remain fertilizable longer (10–20 hours) than they remain capable of being fertilized and developing into normal embryos (8–10 hours). The likelihood of embryonic death increases as the time beyond this interval increases. Thus viable sperm should be at the site of fertilization awaiting the arrival of the freshly ovulated egg. Breeding either too early or too late allows an aged sperm or an aged egg to interact at the site of fertilization and will result in poor conception. Events and time intervals associated with standing heat and insemination are summarized in Figure 3.

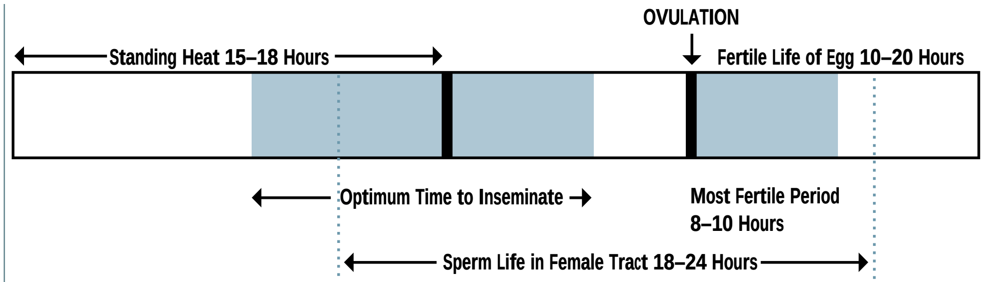


Figure 3. Average time relationships among reproductive events.

Cattle should be inseminated during the last half of standing heat. The a.m.-p.m. rule was developed as a guide. Cows first seen in standing heat in the morning (a.m.) would be inseminated in the afternoon (p.m.) and those observed standing in the evening would be bred the next morning. This system was based on research in which cows were observed frequently (4 to 12 times per day), allowed to interact, and exhibited mounting/standing behavior. Furthermore, insemination was based on standing heat, not secondary signs. Under such conditions, heat detection was very good. But herd managers may not be in a position to accurately predict the latter half of the heat period. Generally it is a challenge just to detect standing behavior. Knowing when to inseminate is another management challenge.

More recent studies conducted by artificial insemination organizations and universities reexamined timing of insemination. In a Virginia study with twice daily heat checks, cows were inseminated either at the end of the heat check period in which they were first observed in heat or at the end of the next heat check period. Using a routine 8:00 a.m. and 8:00 p.m. heat detection system, waiting 12 hours to inseminate resulted in a slight numerical advantage in pregnancy rate over inseminating immediately after heat was first observed (55% *vs.* 51%). However, this was not a significant difference. Thirty percent of the cows stood to be mounted at the 12-hour heat check after they were first observed in standing heat. These cows had higher pregnancy rates than their herdmates, whether they were inseminated immediately after being first observed in heat or 12 hours later.

Results from a field study in New York showed that near optimal fertility was obtained with a single morning insemination of all cows in heat from the previous evening, including those in heat that morning. This result suggests there may be a benefit to earlier breeding under farm conditions.

Applying this information to a herd situation suggests the following guidelines:

- Best fertility is obtained when cattle are inseminated during the last half of standing heat.
- If a management schedule permits routine heat checks and if it can determine when a heat began and thus predict the latter portion of the heat, the a.m.-p.m. system should be used.
- If the conception rate is unsatisfactory or heat detection is not routine, cows should be inseminated soon after they are first detected in standing heat. Waiting 10 or 12 hours probably results in most of the cows being bred too late.
- Remember, factors other than timing of insemination can affect the conception rate.

MILK PROGESTERONE ANALYSIS AS A TOOL FOR HEAT DETECTION

Milk progesterone analysis can be a tool to help herd managers and veterinarians troubleshoot causes of poor reproductive performance, especially problems associated with heat detection. The concentration of progesterone in blood is correlated closely with levels found in milk. The relative relationship between milk and blood concentrations is the same. Progesterone is low during proestrus and during heat. It begins to rise slowly after ovulation as the CL develops.

Verifying suspicious heats

If the herdsperson is suspicious that a cow is in heat, milk progesterone concentration can be used to verify that the cow is in or near heat. Such testing may be useful in the following situations:

- The cow was observed in heat, but was previously diagnosed pregnant.
- Standing heat was observed, but the interestrous interval was abnormally long.
- The cow was detected in heat based solely on secondary signs.

Evaluating heat detection accuracy

Numerous studies using milk progesterone analysis have shown that 5 to 15 percent of cows are inseminated when they are not in or near estrus. Milk progesterone testing can be a reliable method of evaluating the accuracy of heat detection on an individual farm. To make the evaluation worthwhile, 15 to 20 cows should be sampled on the day of insemination. Milk samples should be obtained at the milking immediately after insemination. When compared with a standard progesterone sample, the milk obtained on the day of insemination should have low progesterone.

If more than 5 percent of the samples have high progesterone, the heat detection error rate is too high. A few samples may have intermediate concentrations of progesterone, suggesting that it may be declining, but has not yet reached a minimal level, or that it is rising and low concentrations already have occurred. No definitive interpretation can be made from such results.

Dairy producers and veterinarians must realize that progesterone is low for about six days around the time of estrus. Thus low progesterone indicates the cow is either in or near heat, but progesterone levels cannot be used to precisely time the insemination. Errors in heat detection should be considered the primary cause of low conception in problem herds. Milk progesterone analysis is a tool to help determine whether a heat detection problem exists.

EVALUATION OF HEAT DETECTION EFFICIENCY

It is useful periodically to compare the herd's heat detection efficiency with specific, realistic management goals. Complete and accurate records including all heats, services, and veterinary examination findings are needed to calculate heat detection efficiency. Some DHIA processing centers and herd management computer programs provide a heat detection index.

There is a difference between the accuracy and the efficiency of heat detection. Inaccurate heat detection occurs when cattle are inseminated but are not in true estrus. Inefficient heat detection simply refers to too many unobserved or missed heats. Many reproductive problem herds experience both inaccurate and inefficient heat detection.

Characteristics of herds with heat detection errors

- Estrous intervals between 3 and 17 days exceed 10 percent.
- Estrous intervals between 25 and 35 days exceed 10 to 15 percent.
- Cows inseminated one day and again within three days exceed 5 percent.
- Several cows are checked pregnant to a service earlier than the last one recorded.
- Several cows calve normally three to six weeks before the expected calving date.

Characteristics of herds with missed heats

- Very few heats are observed and recorded before first service.
- Average days to first service exceed 80 days when the voluntary waiting period to first service is 60 days.
- Average interval between breedings exceeds 30 days.
- Estrous intervals between 38 and 45 and 55 and 65 days exceed 15 percent.

Estrous detection goals

- 85 percent of the cattle are detected in estrus by 60 days postpartum.
- Days to first service are 75.
- 60 percent of the estrous intervals are between 18 and 24 days.
- Ratio of the number of 18-24 to 36-48 day estrous intervals exceeds 4:1.
- At least 70 percent of the heats are detected.

Heat detection efficiency equations

Several methods are used to express efficiency of estrous detection. These indexes are used to express the percentage of cows detected in heat relative to number of cows actually in heat. They provide an estimate of the intensity of estrous detection but do not measure accuracy. *The frequency of prostaglandin use to induce estrus and shorten the interestrous interval should be considered when evaluating these indexes.*

PERCENTAGE OF POSSIBLE HEATS DETECTED. The total number of services and reported heats for a group of cows during a specified period of time is divided by the total days in the period divided by 21. This is most useful in a beef cattle breeding program.

$$\%\text{ heats detected} = \frac{\text{heats observed}}{(\text{total cow days in period} \div 21)} \times 100$$

Example: If 20 heats were observed in a group of 40 beef cows over a 24-day period, the estimated percentage of heats detected would be calculated as follows:

$$\frac{20}{(40 \times 24) \div 21} \times 100 = 43.7\%$$

PERCENTAGE OF BREEDABLE HEATS DETECTED. A breedable heat is defined as any heat occurring beyond the voluntary waiting period for a specific herd. The voluntary waiting period (VWP) is the interval of time from calving until the manager is willing to rebreed the cattle. The number of breedable heats can be estimated by this formula:

$$\text{Breedable heats} = \frac{\text{ave. days open} - (\text{VWP}+10)}{21} + 1$$

If the VWP were 50, the first breedable heat beyond 50 days would be detected on the average at day 60 postpartum (10 days is half an estrous cycle). The percentage of breedable heats detected can then be estimated by the formula:

$$\%\text{ of breedable heats detected} = \frac{\text{heats detected/cow}}{\text{breedable heats}} \times 100$$

If this index is to be accurate, all observed heats must be recorded. The percentage of breedable heats detected is not affected by conception rate or the decision to delay breeding.

HEAT DETECTION INDEX (EFFICIENCY). Several formulas have been developed to determine the efficiency of heat detection.

- *Interestrous interval method*: normal cycle length is divided by average interval between consecutive services or heats for all eligible cows.

  $$\frac{\text{21 days (normal cycle)}}{\text{average interestrous interval}} \times 100\%$$

  Example: 21 ÷ 32 x 100% = 65.6%

- *Breeding interval (BI) methods:* These are good indicators of heat detection efficiency after first service. DO refers to days open. (Table 5 shows percentage of heats detected.)

  1. *Pregnant cows*

     a. Breeding interval method using days to first service:

     $$\text{BI} = \frac{\text{average DO for pregnant cows} - \text{days to first service}}{(\text{services per conception} - 1)}$$

     b. Breeding interval method using voluntary waiting period (VWP):

     $$\text{BI} = \frac{\text{average DO for pregnant cows} - (\text{VWP} + 10\text{ days})}{(\text{services per conception} - 1)}$$

  2. *All cows serviced (services per cow)* Services per cow includes average number of services for pregnant cows, cows examined for pregnancy and found open, and cows serviced with at least 45 days elapsed since breeding, but not yet examined for pregnancy.

     a. Breeding interval method using days to first service:

     $$\text{BI} = \frac{\text{average DO for all cows serviced} - \text{days to first service}}{(\text{services per cow} - 1)}$$

     b. Breeding interval method using VWP:

     $$\text{BI} = \frac{\text{average DO for all cows serviced} - (\text{VWP} + 10\text{ days})}{(\text{services per cow} - 1)}$$

     Example: days open = 126, days to first service = 85, and services per cow = 2.0

     $$\text{BI} = \frac{126 - 85}{(2.0 - 1.0)} = 41$$

     % heats detected (Table 5) = 51%

Table 5. Estimation of percentage of heats detected based on breeding interval.

Breeding interval	% heats detected
23	91
26	81
30	70
35	60
41	51
50	42
60	35

D. Grusenmeyer et al. (1983), Western Regional Extension Publication 67.

If complete information including days to first service, days open, and conception rate are available, Table 6 on the next page can be used to estimate heat detection efficiency.

Table 6. Estimation of percentage of heats detected based on average days to first service, conception rate, and days open (use table that best fits average days to first service in herd).

	60 days to first service (average between 50 and 70 days) Conception rate (%)							
Average days open	*35*	*40*	*45*	*50*	*55*	*60*	*65*	*70*
150	33	28						
140	42	37	33	29				
130	52	45	40	34	33	30		
120	63	55	51	45	40	37	35	32
110	77	68	60	54	49	45	42	39
100	93	83	73	66	60	55	51	47
90			90	82	74	68	63	58
80					93	85	80	74
	70 days to first service (average between 60 and 80 days) Conception rate(%)							
Average days open	*35*	*40*	*45*	*50*	*55*	*60*	*65*	*70*
160	29							
150	39	33	30					
140	49	43	38	35	32	28		
130	62	53	48	43	39	34	33	31
120	75	66	58	53	48	44	40	38
110	93	82	73	65	60	55	50	47
100			90	81	73	68	63	58
90					93	86	79	73
	80 days to first service (average between 70 and 90 days) Conception rate(%)							
Average days open	*35*	*40*	*45*	*50*	*55*	*60*	*65*	*70*
160	34	30	27					
150	45	40	35	32	28	26		
140	58	51	45	41	37	34	32	29
130	73	64	57	52	47	43	40	37
120	91	80	72	64	58	54	49	46
110			89	80	73	67	62	58
100					93	85	79	73
	90 days to first service (average between 80 and 100 days) Conception rate(%)							
Average days open	*35*	*40*	*45*	*50*	*55*	*60*	*65*	*70*
170	29							
160	41	36	31	28				
150	54	48	42	38	35	32	29	27
140	70	62	54	49	45	41	38	35
130	89	78	70	63	57	52	48	45
120			88	80	72	66	62	57
110					93	85	78	73

Source: M. McGilliard et al. (1979), Dairy Guideline 54: Evaluating Heat Detection, Virginia Polytechnic Institute and State University.

Note: In developing these tables, all cows were assumed pregnant by 200 days.

ESTROUS DETECTION AIDS

Estrous detection aids include record systems, prostaglandins, mount detection aids, and heat detector animals.

Records

No matter which record system is used, the information should be posted and available to all farm employees. The more people anticipating and watching for the heat, the more likely heat detection efficiency will be maximized. All heats, including those observed in the early postpartum period, must be recorded. Finally, record systems should be used on a daily basis.

HEAT EXPECTANCY CHART. Special calendars are available from artificial insemination organizations. Most charts are organized on a 21-day cycle so that future heats can be anticipated. Some herd managers mark day 19 following insemination so that the expected heat can be anticipated several days in advance.

BREEDING WHEEL OR HERDEX RECORD SYSTEM. These wall-mounted reproductive record systems use color-coded pins or markings to indicate reproductive events for each cow. By either turning a transparent plastic dial or sliding the plastic cover on a daily basis, future heats and reproductive events can be anticipated.

COMPUTER GENERATED ACTION LISTS. Some dairy management computer programs can generate listings of cows that require special attention or action on a specific day. Action lists indicate cows to watch closely for return heats or cows that have not yet been observed in heat.

Prostaglandins

If more than one animal is in proestrus or estrus simultaneously, mounting behavior increases and standing behavior is more likely to be observed. Depending on herd size, it may be worthwhile to inject one or more cows with prostaglandin at various intervals during the week to induce more estrous behavior in the herd.

Mount detection aids

Studies have confirmed that using conventional mount detectors such as Kamar devices and tailhead markings without visual observation for estrous results in lower pregnancy rates. However, normal pregnancy rates and improved heat detection efficiency are obtained when mount detector systems are used to supplement visual observation.

KAMAR PRESSURE-SENSITIVE MOUNT DETECTORS. These devices are glued on the topline of the rump forward toward the hooks according to the size of the cow. Sustained pressure for several seconds by the sternum of the mounting cow will expel red fluid from a small storage chamber into a larger visible plastic chamber. The detectors should be placed further forward on small cows to avoid false activation when large cows attempt to mount them.

The devices can be used for various groups of cattle. To help detect early postpartum heats, they can be applied to cows at 30 days postpartum. Some managers use them to detect heat for cows not observed in heat by the voluntary waiting period (40, 50, or 60 days). Several days after a heat or insemination, the devices are put on cattle in an attempt to detect evidence of mounting activity during the next return heat. They can be helpful in detecting heat after an estrous synchronization program has been established.

Follow these guidelines when using mount detectors:

- Store detectors and adhesive in a cool, dry environment.
- Apply properly according to the size of the animal; don't use an excessive amount of adhesive.
- Write the cow's ID on the detector. If it comes off, the cow can be identified and observed carefully for other signs of heat.
- Do not clip hair or apply the adhesive to wet hair.
- Leave partially activated, or "triggered," detectors on the cows for several additional days. These cows may be in proestrus.
- Remove obstacles such as low branches, cattle back rubbers, and oilers from the pasture, exercise lot, or free-stall barn. Such items can be rubbed and can activate the mount detector. This would result in a false positive.
- Be aware that the orientation of certain partitions and stall dividers can inadvertently activate these devices.

Falsely activated detectors may also be an indication that the devices were applied too far back on small animals. False positives are more frequent when cattle are confined in crowded pens or when cattle infested with external parasites rub or scratch their backs. Partial activation may result when an animal is trapped in a mounting situation but is not in heat. Careful interpretation is essential to efficiently use mount detectors. Table 7 compares the pregnancy rates among groups of beef cattle with fully activated, partially activated, or missing detection devices at the time of appointment insemination 80 hours after prostaglandin injection. Cows missing devices or with fully activated detectors had significantly higher pregnancy rates compared to cows with partially activated detectors.

Table 7. Pregnancy rates following eighty hour appointment insemination after prostaglandin for cattle with fully activated, partially activated, or missing Kamar detectors at time of insemination.

Detector status	% pregnant
Fully activated	67
Partially activated	23
Missing	51

Source: C. Marshall et al. (1978), Proceedings of the Extension-Industry Workshop on Beef Cattle Reproductive Management.

TAILHEAD MARKINGS. Marking the tailhead with chalk, paint, or crayon and observing for evidence of rubbed off or smeared markings is less expensive than Kamar detectors and has gained popularity in larger herds. Markings 10 to 12 inches long and 2 to 3 inches wide are made across the tailhead with a livestock marking crayon or heat detector paint. Tailhead paint is less convenient to use than crayon but lasts longer (up to three weeks). This system works most effectively in loose-housing arrangements where cattle can be restrained in self-locking headgates to be marked or observed for evidence of smeared or rubbed-off markings, which indicate the animal was mounted. Markings can also be touched up at this time.

False positives can occur for reasons similar to those with Kamar detectors. Cattle may need to be remarked every three or four days. One hidden advantage of this system is that when marking or examining the rump region of the cow, the manager may observe mucus discharge, smeared mucus on the tail, swollen and reddened vulva, abnormal vaginal discharge, or metestrous bleeding. In larger herds many of these symptoms go unnoticed. Tailhead marking is inexpensive and large groups of cattle can be marked in a short period of time.

ELECTRONIC MOUNT DETECTORS. Mount detectors are being developed which detect and record legitimate mounts. Each detector is coded with the cow's identification number, and the information is transmitted to a computer to be stored. At regular intervals during the day, the herd manager can access the information to determine which cows were mounted at a particular time. Various prototypes are currently being tested.

VIDEOTAPE. This system has been used extensively in research to continuously monitor estrous behavior. The cattle must be clearly identifiable from a distance and must be allowed to interact in a loose-housing arrangement. The video camera(s) should monitor a large proportion of the housing area. Several cameras may have to be strategically positioned, and the video equipment should be protected from moisture. This system will be effective only if the videotapes are reviewed daily, especially after the herd has been monitored in the evening. The disadvantages are the initial investment for purchase and installation of the equipment and the time required to review the tapes. If used properly, however, videotaping is a very efficient and accurate estrous detection system.

Heat detector animals

Heat detector animals can reduce the days to first service and can improve estrous detection in the herd if they are used properly and supplement visual observation. However, managers must realize that on an individual basis, surgically altered bulls or hormonally treated females vary in their sexual aggressiveness.

In general, such animals have been shown to be effective in detecting heat. The more animals sexually active at one time, the more mounting will occur with each cow in heat. If allowed to interact with the herd throughout the day, detector animals provide a continuous monitoring of estrous behavior. If stanchioned cows are turned out daily for heat detection or cows in loose-housing are checked regularly for estrus but heat detection does not seem to be effective, then use of a heat detector animal should be considered.

MALE EFFECT. Research has shown that in a beef herd the introduction of a bull shortens the interval to first estrus during the early postpartum period. The physiological mechanism for this effect is unknown.

VASECTOMIZED OR SURGICALLY ALTERED BULL. A vasectomized bull or a bull with a surgically altered penis can be an effective heat detector. These animals can be most effective if they are equipped with a chin-ball or ballpoint marker harness which marks the loin and rump of cows that were mounted with a bright-colored marking solution. Surgically altering the penis of a bull to prevent intromission may be more costly than vasectomy, but this method is preferred since vasectomized bulls can copulate with cows and possibly spread disease.

With either method of preparing a bull, the animal will seek out cows in proestrus and estrus and possibly stimulate the overall estrous activity in the herd. These animals can be used with beef cattle to stimulate early estrous activity (male effect) and then be removed from the herd to allow natural service to commence or they can remain with the herd for enhanced heat detection during an artificial insemination program. The major disadvantage is the danger of handling a bull and allowing him to interact with farm employees. There also is the veterinary cost of performing the vasectomy or surgical alteration and general veterinary costs of maintaining the bull.

TESTOSTERONE-TREATED FEMALE. Testosterone, a male hormone, causes increased sexual aggressiveness when injected or implanted into cows or heifers. Potential nonlactating cull cows or heifers, even freemartin heifers, are candidates for masculinization. Most people who have used this system prefer cows that have completed a lactation. However, there are several reports of success with freemartin or virgin heifers. A typical treatment regime consists of administering 200 mg of testosterone propionate intramuscularly every other day for three weeks. Some veterinarians have used larger doses (500 to 600 mg) once weekly or a single injection of two grams of testosterone enanthate in corn oil given in three or four locations. When mounting activity is increased following these initial injections, the cow is given a maintenance injection of about 500 mg testosterone propionate, enanthate, or repository testosterone every 10 to 14 days.

The interval between maintenance (booster) injections should be adjusted on the basis of sexual activity of the detector animal. Some veterinarians prefer to use several Synovex-H implants for a maintenance program. These implants contain testosterone and estradiol.

The results of a trial comparing heat detection methods of routine visual observation by a herdsperson with use of a surgically altered bull or a testosterone-treated cow are presented in Table 8. Although not a significant number, more heats were detected in the group of cattle with the testosterone-treated cow. Conception rates were similar for all groups.

The following should be considered in using testosterone treatment:

- Testosterone treatment is an extra-label use of this hormone. The FDA has not specifically approved using testosterone for this purpose. Guidelines must be followed on the withdrawal period before treated animals can be marketed.
- While a large percentage of the females respond to the testosterone, some do not.
- It may be helpful to remove the estrous cow from the group so that the detector cow can search for other estrous cows.
- Select a healthy cull cow or heifer that has sound feet and legs and is large enough to mount and mark other cows. Heifers must be sexually mature. Do not use a lactating or pregnant animal.
- Treated females can be equipped with a chin-ball marking harness or the herd can be marked with crayon, chalk, or heat detection paint or can be fitted with mount detectors so that mounted cows can be identified.
- This heat detection aid will be effective only when used in conjunction with routine visual heat detection.
- Maintaining a ratio of one treated female to every 30 open cows is necessary to maximize detection efficiency. In large herds, it may be beneficial to have more than one detector animal per herd. Such animals could be rotated on alternate weeks.
- This system can be effective in both loose-housing and stanchion barn housing, provided cows are turned out and allowed to interact.
- Avoid allowing the treated animal to become overconditioned.
- Testosterone-treated females in general are not dangerously aggressive.
- Consult your veterinarian concerning the method of testosterone treatment.

Vaginal electrical resistance

In early research done in Europe, the electrical resistance (ER) of vaginal fluids decreased during proestrus and through the estrous period. Numerous studies have validated this concept. Several probes that measure the ER of vaginal fluids are now commercially available.

Although the concept is physiologically sound, the challenge is to adapt this technology to a management situation. Resistance measurements vary among cows; however, monitoring the relative changes within cows during the estrous cycle can provide the herdsperson with additional information and can serve as a heat detection aid if cattle are probed frequently. Once the ER readings begin to decline, the cow should be probed every 12 hours until the lowest reading is obtained. Theoretically, this reading coincides with the time of standing heat.

This tool is labor intensive since cattle must be probed frequently to detect significant changes in ER. The probe also is expensive. It must be washed in disinfectant, thoroughly rinsed, and dried before it is used in another cow. Without proper sanitation, the device could spread disease among cows.

Miniature electronic devices are being developed which are implanted into the vaginal tissue. They continuously monitor ER and transfer the information to a romote receiver and computer.

Activity monitors

It is well documented that cattle are more active during estrus and thus spend more time walking and standing than resting. Researchers at the USDA facility in Beltsville used pedometers to monitor cow activity between milkings. The study showed that activity increased approximately 400 percent during estrus for cows housed in a free-stall barn, and 275 percent for cows in comfort stalls. During this study, 76 percent of the estrous periods were detected by visual observation and 96 percent were detected by changes in pedometer readings.

Table 8. Percentage of cows detected in heat and first-service conception rate for beef cattle detected in heat by three different methods.

Method	Number	Percentage detected	Conception rate
Herdsperson	31	67	62
Surgically altered bull	30	70	62
Testosterone-treated cow	29	84	67

Source: T. Kiser et al. (1976), Journal of Animal Science 44:1030.

Since those initial studies, various pedometers have been developed and tested. Early prototypes were often inaccurate because of a high rate of false positive signals. Accuracy in identifying true estrous periods has improved in the newer models, which compare activity during a specified interval with activity during the same period on the previous day or the previous three days.

If pedometers are used properly and the equipment remains functional, this method can be effective in identifying some *silent* heat cows which fail to show other obvious signs of estrus. This heat detection aid can be effective if used in a herd environment where the devices are checked twice daily, excessive time is not devoted to cleaning mud and manure from them to observe the readings, and cattle are not agitated or moved excessively. Changes in management activities that prompt excessive cow activity on certain days can cause inaccurate readings.

Estrous detection in the future may involve electronic monitoring of mounting activity, walking, or vaginal electrical resistance integrated into an automated telemetric system. At present visual observation supported by proper use of conventional heat detection aids is the most effective approach to estrous detection.

Vaginal electrical resistance probe.

GLOSSARY OF TERMS

ANESTRUS: absence of estrous cycles.

CORPUS LUTEUM (CL): ovarian structure that develops at the site of ovulation during metestrus and continues to produce progesterone through diestrus and during pregnancy.

DIESTRUS: the period within the estrous cycle when the corpus luteum is functional.

DOMINANT FOLLICLE: generally the largest follicle within a wave of developing follicles which eventually suppresses the continued growth of other follicles. Toward the end of the estrous cycle, the dominant follicle becomes the ovulatory follicle.

ESTROGENS: steroid hormones produced by cells within the follicle. Estrogen induces estrous behavior and muscle contractions with the uterus, oviducts, and cervix. It also is involved in the initiation of luteinizing hormone release.

ESTROUS CYCLE: the interval between two periods of estrus.

ESTRUS (HEAT): period of time when the female is receptive to mounting and will stand to be mounted by another animal (standing heat).

FOLLICLE: the ovarian structure which contains the oocyte (egg). As follicles grow, a fluid cavity (antrum) develops. Cells within the wall of the follicle produce estrogens.

HORMONE: chemical agents secreted by endocrine glands and transported to target tissues, where they induce or regulate a specific physiological activity.

LUTEINIZING HORMONE (LH): one of the protein hormones secreted by the anterior pituitary gland and involved in the process of ovulation, corpus luteum formation, and function.

METESTRUS: phase of the estrous cycle beginning immediately after estrus. Ovulation and early development of the CL occur during this period.

OOCYTE: also termed the egg. Contains the genetic material from the female. It develops within the follicle and is ovulated shortly after estrus.

OVARIES: primary reproductive organs where oocytes (eggs) develop within follicles during the estrous cycle. Estrogens and progesterone are produced by tissues within the ovaries.

OVULATION: process of follicle rupture and release of the egg.

PROESTRUS: phase of the estrous cycle when the CL regresses, progesterone concentrations decline, final maturation of the dominant follicle occurs, and estrogen increases. During this phase, some secondary symptoms of estrus begin to be exhibited.

PROGESTERONE: steroid hormone produced primarily by the CL. Progesterone inhibits final maturation of the dominant follicle and the expression of estrus, prepares the uterus for pregnancy, inhibits uterine contractions, maintains pregnancy, and aids in mammary development.

PROSTAGLANDINS: series of lipid substances which produce hormone-like actions. Unlike most hormones, they are produced by many tissues throughout the body. With regard to reproduction, prostaglandin F_{2a} causes regression of the CL during the later portion of diestrus. Prostaglandin is used for synchronization of estrus.

VOLUNTARY WAITING PERIOD (VWP): the interval from calving until the herd manager is willing to rebreed the cattle.

WAVE OF FOLLICULAR GROWTH: a group of developing follicles. Cattle may have two, three, or four waves of follicles that develop during the estrous cycle.

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