Dairy Freestall
Housing and Equipment

MWPS-7 Seventh Edition, 2000

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Dairy Freestall
Housing and Equipment

MWPS-7 **Seventh Edition, 2000**

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MWPS
MidWest Plan Service
A Foundation of Knowledge

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Chapter 1

Data Summary

This chapter contains many of the design tables upon which the recommendations of this book are based. The tables refer to the chapters that discuss the use of the data. The tables include information about the following topics:

- Freestall dimensions.
- Freestall alley widths.
- Calf and transition heifer housing.
- Heifer and dry cow resting areas.
- Feeding fences.
- Feed space requirements.
- Floor and lot slopes.
- Water requirements.
- Ventilation rates.
- Manure production.
- Management categories.

Table 1-1. Freestall dimensions.
Freestall width measured center-to-center of 2" pipe dividers. For wider dividers, increase width accordingly. Freestall length, and neck-rail and brisket-board distances measured from alley side of curb to front of stall.

Animal weight (lb)	Freestall width (in)	Freestall length		Neck rail height[b]	Curb to neck rail and brisket board (in)
		Side lunge	Forward lunge[a] (in)		
800-1,200	42 to 44	6'-6"	7'-6" to 8'-0"	41 to 43	62
1,200-1,500	45 to 48	7'-0"	8'-0" to 8'-6"	44 to 46	66
over 1,500	48 to 52	7'-6"	8'-6" to 9'-0"	46 to 48	71

[a] An additional 12" to 18" in stall length (compared to side lunge stalls) is required to allow the cow to thrust her head forward during the lunge process.

[b] Above top of curb or top of mattress (Ref. point A in Figure 4-3 and 4-4), in.

Table 1-2. Typical freestall alley widths.
See Figure 4-9.

Type	Width
Feeding and stall access alley	12' to 14'
Feeding alley	10' to 12'
Access alley between 2 stall rows	
Solid floor	8' to 10'
Slotted floor	8' to 10'
Cross Alley	8' to 10' Clear of waterer

Table 1-3. Bedded-pen space needs for calves and transition heifers.
See Chapter 3, **Replacement Housing,** for more information on calf and transition housing.

Housing type	Pen size
0-2 months (individual pens)	
Calf hutch (plus 4'x6' outdoor run)	4'x8'
Bedded pen	4'x7'
Tie stall (warm housing only)	2'x4'
3-5 months (groups up to 6 head)	25 to 30 ft^2/hd
Super calf hutch or bedded pen	minimum

Table 1-4. Replacement heifer resting area space requirements per animal.

See Chapter 3, **Replacement Housing,** for more information on space requirements.

Age, mos	Weight, lb/hd	Self-cleaning resting area[a], ft^2/hd	Bedded resting area[b], ft^2/hd	Slotted floor, ft^2/hd	Paved outside[e] lot, ft^2/hd
0-2[c]	100 to 190	Do not use	32 (4'x8' hutch) 28 (4'x7' pen)	Do not use	Do not use
3-5	190 to 350	Do not use	28	Do not use	Do not use
6-8	350 to 500	10	25	12	35
9-12	500 to 650	12	28	13	40
13-15	650 to 800	15	32	17	45
16-24	800 to 1,200	18[d]	40	25	50
Dry cow, far-off	> 1,300	20[d]	50	35	55
Dry cow, close-up	> 1,300	—	10	—	—

[a] 8% slope (1"/ft).
[b] Assumes access to 10' wide scraped feed alley or paved outside lot.
[c] Use hutch or individual pens. House separately from older animals.
[d] Heifers and dry cows in late pregnancy may have difficulty breathing if they lie facing downhill on self-cleaning floors. Incidence of mastitis may be a problem for this group also.
[e] Provide proper treatment for concentrated runoff.

Table 1-5. Suggested dimensions for post and rail feeding fences.

Refer to Chapter 3, **Replacement Housing,** for more information on post and rail feeding fences.

Age, mos	Weight, lb/hd	Throat Height, in	Neck rail height, in
6-8[a]	350-500	14	28
9-12	500-650	16	30
13-15	650-800	17	34
16-24	800-1,200	19	41
Cows	1,200-1,500	21	48

[a] A diagonal bar feeding fence is recommended for this group to prevent calves from escaping. Manufacturers can provide information about available panels.

Table 1-6. Minimum feed-space requirements.

See Chapter 3, **Replacement Housing,** and Chapter 4, **Milking Herd Facilities,** for more information on feed space requirements. Feed always available.

	Age, months					Mature
Type	3-4	5-8	9-12	13-15	16-24	cow
	- - - - - - - - - inches per animal - - - - - - - - -					
Feed always available						
Hay or silage	4	4	5	6	6	6
Mixed ration or grain only	12	12	15	18	18	18
All animals eat at once						
Once a day feeding	12	18	22	26	26	26-30

Table 1-7. Floor and lot slopes.

Type	Slope
Handling facilities	2% to 4% (1/4" to 1/2"/ft)
Lots	
Paved	1% (1/8"/ft) minimum
Earth[a]	4% to 6% (1/2"-3/4"/ft)
Mound sideslope	20% (1'/5')
Bunk apron	6% to 8% (3/4" to 1"/ft) nearly self-cleaning 4% (1/2"/ft) minimum

[a] Earth lots used as managed dry lots for heat detection should have a minimum of 150 ft^2 per animal.

Table 1-8. Drinking water requirements.

See Chapter 4, **Milking Herd Facilities,** and Chapter 10, **Utilities,** for more information on water requirements for dairy animals and operations.

Animal	gal/hd/day
Calves (1.0-1.5 gal/100 lb)	6-10
Heifers	10-15
Dry cows	20-30
Milking cows	35-50[a]

[a] Design water supply to deliver 6-7 gpm per cow drinking simultaneously.

Table 1-9. Cumulative ventilating rates for warm dairy barns.

Size the system based on total building capacity. See Chapter 3, **Replacement Housing,** for more information on ventilating rates for dairy animals.

Animal	Cold weather[a]	Mild weather	Hot weather[b]
	- - - - - - - - - -	cfm/animal	- - - - - - - - - -
Calves 0-2 months	15	50	100
Heifers			
2-12 months	20	60	130
12-24 months	30	80	180
Cow 1,400 lb	50	170	470

[a] An alternative cold-weather rate can be calculated by dividing the room or building volume in ft^3 by 15.

[b] Maximum ventilation for hot-weather should provide for at least one air change per minute. The alternative hot weather ventilating rate can be calculated by dividing the volume by 1.5.

Table 1-11. Typical management categories of a herd.

This table is only a management guideline. See Chapter 2, **Total Dairy Facilities,** for additional information on management categories. If using this table as a planning guideline, then 15 to 25% more space may be required. These are categories and **not** group size. Refer to Chapter 3, **Replacement Housing,** and Chapter 4, **Milking Herd Facilities,** for proper group sizes.

Herd size = total cows[a]	100	250	400	800
Female calves	**100**	**250**	**400**	**800**
0-2 months	8	20	32	64
3-5 months	12	30	48	96
Heifers				
6-8 months	12	30	48	96
9-12 months	18	45	72	144
13-15 months	12	30	48	96
16-24 months	38	95	152	304
Dry cows (total)	17	43	68	136
Transition (first 4-14 days)	1-5	4-9	5-16	9-32
Next 40 days (divide in 2 groups)	11-12	28-30	45-48	90-96
Close-up (2-3 weeks prepartum)	4-6	8-14	16-24	32-42
Maternity				
(no. of individual pens, average stay = 2 days max.)	4-6	10-15	16-24	32-48
Fresh cows (1-7 days postpartum)	1-4	2-5	4-12	8-20
Two-year-olds	26-30	65-75	104-120	208-240
Three years and older	58	145	232	464
High producers (120 days or less)	20-24	50-60	80-96	160-192
Medium producers	15-18	40-45	60-72	120-144
Low producers	15-18	40-50	60-72	120-144
Sick cows	0-5	0-12	0-20	0-40

[a] Numbers assume uniform calving year-around, 12-month calving interval, first calving at 24 months of age, all males sold at birth, a 30% culling rate, 0% mortality, 305-day lactation and a stable herd size.

Table 1-10. Daily fresh manure production of dairy cattle.

Values are approximate. The actual characteristics of a manure can easily have values 30% or more above or below the table values. The volumes of manure that a manure handling system has to handle can be much larger than the table values due to the addition of water, bedding, etc. Refer to Chapter 8, **Manure and Effluent Management,** for more information on manure production.

Stage of Production	Size (lb)	Daily Raw Excreted (lbs)	(cu ft)	(gal)	Water	Density (lb/cu ft)	TS (lb)	VS (lbs)	BOD_5 (lbs)	Nutrient content N	P_2O_5	K_2O
Heifer	150	13	0.20	1.5	88%	65	1.4	1.2	0.20	0.05	0.01	0.04
	250	21	0.32	2.4	88%	65	2.3	1.9	0.33	0.08	0.02	0.07
	750	65	1.00	7.5	88%	65	6.8	5.8	1.00	0.23	0.07	0.22
Lactating	1,000	106	1.70	12.8	88%	62	10.0	8.5	1.60	0.58	0.30	0.31
	1,400	148	2.40	17.9	88%	62	14.0	11.9	2.24	0.82	0.42	0.48
Dry	1,000	82	1.30	9.7	88%	62	9.5	8.1	1.20	0.36	0.11	0.28
	1,400	115	1.83	13.7	88%	62	13.3	11.3	1.70	0.50	0.20	0.40

TS = total solids; VS = volatile solids; N = total nitrogen

BOD_5 = the oxygen used in the biochemical oxidation of organic matter in 5 days at 68 F. A standard test to assess wastewater strength.

Elemental P (Phosphorus) = 0.44 x P_2O_5; Elemental K (potassium) = 0.83 x K_2O

Table 1-12. Recommended floor thickness.

Edge thickness is twice the thickness of slab by 2 feet wide.

Application	Thickness (inches)
Feeding aprons, with minimum vehicle traffic	4
Paved feedlots, building driveways	5
Heavy traffic drives (grain truck, wagons, manure spreaders)	6

Table 1-13. Concrete strengths.

Durability (weather and chemical resistance) and strength depend primarily on water-cement ratio. Adding extra water rapidly lowers durability and strength. Only 1/2 gal/bag (about 3 gal/yd) separates the groups in the table. Follow plans or specifications when available. Materials in this handbook are based on the following recommendations. One bag cement = 94 lb; 1 gal water = 8.34 lb.

Application	Maximum approximate strength (psi)	Minimum Water-cement ratio (Gallons water per bag cement)	Minimum Water-cement ratio (lb water per lb cement)
Mangers	4,500	5.0	0.44
Feedlots, floors, drives	3,500	6.0	0.53
Footings	3,000	6.5	0.62

Table 1-14. Conversions.

Multiply to the right: acres x 43,560 = ft^2.
Divide to the left: ft^2 / 43,560 = acres.

Unit	Times	Equals
Acres	43,560 4,840 160 1/640	ft^2 yd^2 square rods square mile
Acre-ft	325,851 43,560	gallons ft^3
Acre-in	3,630	ft^3
Acre-in/hr	453 1	gpm cfs (approximate)
Bushels	1.25 2.5	ft^3 ft^3 ear corn
ft^3	7.48 1,728 62.4 0.4 0.8	gallons in^3 lb water bu ear corn bu grain
cfs	448.8 646,317	gpm gal/day
Cubic yard	27	ft^3
Concrete	81	ft^2 of 4" floor
Concrete	54	ft^2 of 6" floor
Gallons	231 0.134 8.35	in^3 ft^3 lb water
Miles	5,280 1,760 320	ft yd rods
Pressure, psi	2.31 27.72	ft of water head in. of water head
Rods	16.5 5.5	ft yd

Table 1-15. Metric Conversions.

Multiply to the right: acres x 0.4047 = hectares.
Divide to the left: hectares / 0.4047 = acres.

Unit	Times	Equals
Acres	0.4047	hectares
Bushels	35.24	liters
cubic feet	28.32	liters
cubic feet per minute	0.472	liters per second
cubic yards	0.7646	cubic meter
gallons	3.785	liter
miles	1.609	km
pounds per square inch	6895	Pa
Rods	5.029	meters

Chapter 2

Total Dairy Facilities

William G. Bickert, Extension Ag Engineer, Michigan State University

A sound management plan is the basis for planning new construction or remodeling of dairy facilities. The plan sets forth all factors related to nutrition, health, and growth, as well as all other activities of the dairy operation. Among the goals of the management program are these:

- Increase milk production per cow.
- Increase milk quality (i.e. reduced somatic cell count, reduced plate count, increased protein, etc.).
- Lower calf mortality.
- Improve the genetic quality of the animals.
- Provide quality water and feeds.
- Raise healthy replacement animals.
- Improve overall herd health.
- Increase labor efficiency.
- Maximize operator safety.
- Improve environmental protection.
- Increase profitability.
- Improve animal welfare.
- Provide plenty of fresh air.
- Maintain good neighbor relations.

Buildings and equipment on a dairy farm facilitate the job of caring for the animals. They are tools that allow essential tasks prescribed by the management plan to be implemented on a regular basis. Labor requirements, flow of animals and materials, pollution control, future expansion, management requirements, and animal environment are important design considerations.

Creating an environment that meets the needs of the animals is essential. Calves, heifers, and cows require an environment that permits them to grow, mature, reproduce, and maintain health. If the basic needs of the animals are not met, no amount of management can guarantee success.

The ability to group animals and select facility components that relate to the animals' environment are important aspects of facility design. However, more important is understanding the concepts of managing groups and the environmental needs of the animal.

Management Groups

Provide facilities for different animal groups for management purposes. When formulating the management plan, define needs of each group according to nutritional requirements, medical treatments and other procedures, and breeding. More than one group can be housed in the same facility—but each group is considered separate for management purposes. Allow for different requirements for sanitation and environment. In large dairies, separate facilities may be provided for each group. Consider parlor size for the maximum number of cows per group. Limit cows to 2 hours per day total in the holding pen.

Table 2-1 gives typical management categories for dairy herds of various sizes. Use this table to help determine housing needs for the different groups in a management plan. The numbers in the table are intended as guides and may need adjustment to fit a particular management plan. The numbers in Table 2-1 assume uniform calving year-round, 12-month calving interval, first calving at 24 months of age, all males sold at birth, a 30% culling rate, 0% mortality, 305-day lactation, and a stable herd size. See Chapter 3, **Replacement Animal Housing**, and Chapter 4, **Milking Herd Facilities**, for further explanation of Table 2-1.

Table 2-1. Typical management categories of a herd.[a] If using this table as a planning guideline, then 15 to 25% more space may be required. These are categories and **not** group size. Refer to Chapter 3, **Replacement Housing,** and Chapter 4, **Milking Herd Facilities,** for proper group sizes.

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Manure Management

The manure management system not only influences barn design, but also affects the total farming operation including fertilizer use, feeds grown, and the rest of the cropping program. Manure management is more than scraping manure out of the barn and getting rid of it—manure management is an integral component of the production system.

The incentives for improving manure facilities and practices include:

- Convenience, as when reducing the need for daily hauling and easier manure management .
- Increased manure nutrient use in the cropping program.
- Reduced potential for water and air pollution.
- Improved cow cleanliness and health.
- Labor efficiency.
- Nutrient recycling.
- Better use of storage.
- Treatment for various reasons.

A wide range of manure management facilities and practices are acceptable, depending upon individual circumstances. Even daily hauling can be a responsible method of managing manure. But, as environmental and societal pressures increase, manure management systems based on long-term storage may become more desirable.

Site Selection

Many factors affect site selection. Before construction, consider the space required for buildings, feed centers, manure storage, and clearance between buildings. Provide at least 40 feet between most buildings, 50 feet for snow control, and 75 feet for fire safety considerations. Four-row and six-row barns typically need a minimum spacing of 75 feet between buildings for adequate ventilation. See Chapter 7, **Building Environment,** for additional information on spacing buildings for ventilation. Provide space for lots and expansion. Assume the operation will at least double in size and plan accordingly. Consider local zoning, highway set backs, well protection rules and other regulations. Provide lanes for vehicle access and room for parking. Allow for a feed center and adequate separation from family housing. Think about overall farmstead layout, and consider using some of the concepts illustrated in Figure 2-1.

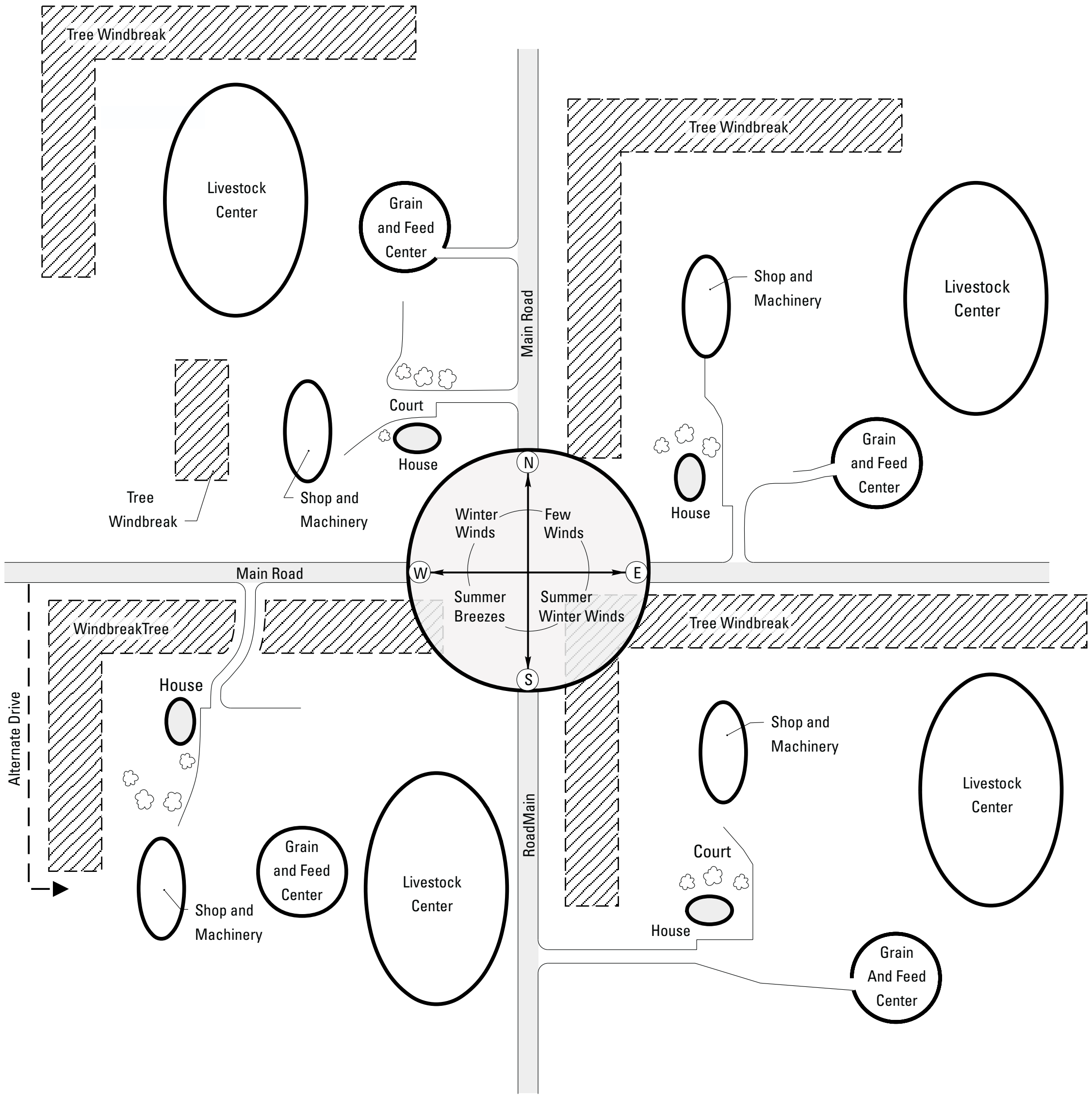
Drainage. Select an elevated building site. Divert runoff away from buildings, livestock yards, and traffic areas. Provide a 2 to 5% (1/4 to 5/8 inch per foot) slope on outside animals lots. Mounds may be used to provide dry resting areas. Earth moving is inexpensive compared to facility costs. Plan to capture and field apply or otherwise treat contaminated runoff.

Wind and snow control. Windbreaks help deflect winter winds and control snow. Take advantage of trees, buildings, and hills for winter wind protection, but do not overlook their impact on summertime ventilation. Allow for summer air movement and drainage when locating windbreaks. Consider prevailing wind directions for reducing odor complaints and for controlling snow drifting, insects, noise, and dust.

Water. A year-round supply of potable water is essential for watering animals and sanitation. Water is also needed for fire protection, manure dilution, and cooling of cows and milk.

a. Farmstead west of the road.
Some winter winds come from the northwest. Locate the house as far west and the livestock area as far north as practical. South windbreak may interfere with summer ventilation.

b. Farmstead north of the road.
A good relationship between house, windbreak, livestock center, and main road is easy with this layout.



c. Farmstead south of the road.
A curved drive avoids a straight cut through the windbreaks. Moving the house farther south and the livestock area northeast is desirable. If the house and machine center can be reversed, use the alternate drive.

d. Farmstead east of the road.
As in Figure 2-1b, a good layout is easy, assuming drainage and other factors permit this arrangement.

Figure 2-1. Farmstead and main road relationship for common wind conditions.
The direction of the farmstead from the main road affects farmstead layout. Layouts assume prevailing winter winds are from the north and west, and prevailing summer winds are from the southwest, south, or east.

Lactating cows need 35 to 50 gallons per head per day of drinking water depending on milk production. Peak water consumption usually occurs shortly after milking. Each cow drinks at a rate of 6 to 7 gpm. Provide a system that can supply peak and total daily requirements. Where groundwater supplies are not adequate, use surface sources such as farm ponds or community water systems. Approval of the water system may be required by a local milk inspector.

Access. Provide all-weather roads for milk trucks, repair persons, technicians, veterinarians, feed delivery, and manure handling equipment. Provide adequate parking for employees, service people, and visitors. Minimum road width is 12 feet. Minimum turning radius for large milk or feed trucks is at least 55 feet. A hay wagon can turn 180 degrees in about 50 feet. Consider a separate access for sick/dead animal removal trucks.

Manure storage, handling, and utilization. Select a site with sufficient land for applying manure. Minimum acreage required by many state pollution agencies is based on satisfying the nitrogen and phosphorus requirement of a growing crop. Typically, 1 to 2 acres of land are required per cow if manure is applied to meet nitrogen needs, and 3 to 4 acres of land are required per cow if manure is applied to meet phosphorus needs. Avoid steep slopes where manure runoff can cause water pollution, and avoid land adjacent to neighboring residences or public facilities. Incorporate manure to reduce odors, runoff, and nutrient losses. Check state and local environmental regulations.

Feed storage and handling. Feeds can have an offensive odor and can be unsightly. Typically storage and handling of feed is not an overriding concern, but larger operators should consider their implications when selecting a site. The location of the feed center to the dairy facilities is another important consideration when selecting a site.

Electric power. Electricity is needed for heating, lighting, pumps, and motors. A 200-amp, 230-volt entrance is minimum. Thorough grounding reduces stray current problems. Provide standby emergency power in the event of a power outage. Some producers install three-phase power for larger motors; consult the local power supplier.

Security. Consider theft, vandalism, and fire safety. Limit farm visitor access to control disease and to reduce interference with farm work. When dairy facilities are located on the same farmstead as the manager's residence, run the access lane near the home. If a second access is used for feed, manure, and animal transport vehicles, provide an alarm system to guard against unauthorized traffic. Facilities remote from the manager's residence pose the most problems. Install gates at remote accesses with signs warning about unauthorized entry. When possible, make access roads at remote sites visible from a public road or neighboring residence.

Safety. Locating the residence away from the dairy facilities can reduce the risk of exposure of children to injury or death from equipment and animals.

Remodeling

When planning to expand, decide whether to remodel or abandon an existing building or farmstead. Carefully consider present and future needs. Evaluate these general factors:

- Functional final setup.
- Structural integrity.
- Location of existing building.
- Labor efficiency.
- Cost of remodeling vs. cost of new building.

Remodeling is not always the cheaper route, especially when considering future needs. When the estimated remodeling cost is one-half to two-thirds the cost of a new building, a new building is usually best. Sometimes, using materials from an existing building in a new one is possible.

Plans, Specifications, and Contracts

Detailed documents help provide needed communication and understanding between owner and builder. **Plans** show all necessary dimensions and details for construction. **Specifications** support the plans; they describe the materials to be used, including size and quality, and often outline procedures for construction and quality of workmanship. The **contract** is an agreement between the builder and the owner; it includes price of construction, schedule of payments, guarantees, responsibilities, and starting and completion dates.

Several options are available for preparing this material:

Be your own contractor. Draw a final plan, making sure dimensions are correct and construction details and materials are determined. Have the appropriate regulatory agencies check the plans when required. Determine total costs before beginning construction.

Hire a consulting engineer. Check the engineer's qualifications and previous work in dairy construction.

Use a design and construction firm. Some firms make working drawings and specifications and have standard contract forms.

Consulting Engineers

Consulting engineers can provide the following services:

- Direct personal service (technical advice, etc.).
- Preliminary investigations, feasibility studies, and economic comparison of alternatives.
- Complete state permits.
- Assist in public hearings related to zoning and environment.
- Planning studies.
- Design and plans.
- Cost estimates.
- Engineering appraisals.
- Bid letting.
- Construction monitoring and inspection.

Consulting engineers usually do a project in three phases: preliminary planning, engineering design, and construction monitoring. They may be retained to help with one or more of these phases.

When looking for a consulting engineer, consider the engineer's qualifications and experience. Check the engineer's educational background and ask for a list of previous clients and projects. Determine the availability of the engineer. Engineers with many on-going projects may have difficulty in meeting deadlines and may have trouble completing projects on time.

Long-range Planning

Decisions regarding facilities are difficult. Buildings and equipment are expensive. The consequences of major investments must be lived with for a long time. Construction disrupts farm and management activities. Among other consequences, expanding facilities often will produce these results:

- Purchasing additional animals.
- Hiring and training new labor.
- Changing management practices.

Before new construction, develop a long-range plan for the operation. Include the following in the plan:

- Production goals for the next 5 to 10 years.
- Management goals.
- Environmental needs of the animals.
- Future alternatives for the operation.
- A drawing of the future farmstead.

Chapter 3

Replacement Housing

Brian Holmes, Extension Ag Engineer, University of Wisconsin

As replacement heifers grow, their needs change, including the physical environment. When a heifer is young, she is physically separated from other animals to minimize the risk of disease. As she grows, she is grouped with other animals to improve labor and facility efficiency and to prepare the animal for the breeding herd. Eventually the animal enters the breeding herd and finally the milking herd. This chapter describes recommendations and options for housing replacement heifers.

Each stage of production requires housing to meet the animal's physical needs. While using or constructing facilities for replacement animals on the farm might seem like the natural way to go, consider custom calf- and heifer-raising options before making major investments in facilities. Facility and labor costs can be weighed against custom charges, biosecurity concerns, etc.

Management Factors Affecting Design

House replacement animals in separate facilities away from the milking herd to foster a healthy environment for each group. Well designed and properly managed replacement animal housing provides the ability to adopt the best management practices currently recommended. Plan space, equipment, environment, rations, and care to meet the needs of each group. Manage replacements in groups according to their specific requirements. Facility design should allow for easy implementation of the management plan for each group. When planning replacement animal housing, provide:

- Adequate resting and exercise space.
- Covered, dry resting areas.
- Absence of excessive drafts.
- Good quality fresh air.
- Adequate space to access feed and water.
- Space to group animals by size or age.
- Clean lots to maintain sanitary conditions.
- An isolation area for sick animals.
- An area from which to observe the animals.
- Treatment breeding facilities.
- Space for handling and restraining animals.

Poorly planned or improperly managed animal housing increases the risk of disease or injury. High humidity levels and large daily temperature changes are especially detrimental to animal health. Calves and heifers raised in a poor environment may never reach their full genetic potential for milk production. Pneumonia, scours, and other diseases can permanently damage vital body organs and reduce a cow's milk producing potential.

Facility Management

For healthy, high producing replacement animals, provide high quality housing and a management plan that addresses the animals' needs. Good management, understanding what to do and then doing it on schedule, is important to the success of any housing system. Sanitation, stall maintenance, bedding, ventilation control, feeding, treatment, and close observation are all important management practices. Young animals may need training and/or time to get accustomed to using freestalls. Daily or routine chores such as feeding, stall maintenance, or manure removal should be made as convenient as possible to ensure they are accomplished in a timely manner.

Herd Size and Makeup

Herd size can mean either the number of cows actually milking or mature cows, both dry and milking. In this publication, herd size refers to the number of mature cows, both dry and milking.

Table 2-1 shows typical herd makeup, assuming uniform calving year-round. The numbers in the table reflect no culling of heifers or calves. Use this table to determine housing needed for each management group.

- Calf housing (0-2 months).
- Transition heifer housing (3-5 months).
- Heifer housing
  - 6-8 months.
  - 9-12 months.
  - 13-15 months (breeding age).
  - 16-24 months.

The number of replacement animals to be housed depends on the number of mature cows and bred heifers, and can be larger at times than the average values in Table 2-1. As herd size increases, so does the number of replacements. Increasing herd size without expanding facilities for replacements results in crowding, which can increase injury and disease transmission and can lower growth rates.

Management Groups

Separating replacement animals into groups according to age, size, or special management needs allows each group to be treated according to its needs. Plan building space and layout for these groups of animals using Tables 3-1 and 3-2. More than one group can be housed in the same building, but allow for managing each group separately. In larger herds, separate facilities may be provided for each group. Some of the benefits of managing animals in groups are:

- Healthier animals by minimizing the risk of transmitting disease to younger animals.
- Good feed efficiency by reducing competition for feed.
- Calving at proper weight and size at 24 months.
- Feed handling ease and proper diets according to age.
- Manure handling ease.
- Animal observation and handling ease for breeding, treatment, and grouping.
- Proper ventilation and environment.
- Proper resting space or freestall size.

Space requirements for a particular operation depend on the housing system chosen and how replacements move from the resting area to feed and to water and back again. Herd size and makeup are guides to estimating the space needed for resting, but alley size, water space, and bunk space also must be included to accommodate the animals and provide an animal-friendly environment.

Provide separate areas for resting and feeding. Feeding in resting areas increases manure accumulation, and more bedding is required to keep animals clean and dry.

Table 3-1. Bedded-pen space needs for calves and transition heifers.

Housing type	Pen size
0-2 months (individual pens)	
Calf hutch (plus 4'x6' outdoor run)	4'x8'
Bedded pen	4'x7'
Tie stall (warm housing only)	2'x4'
3-5 months (groups up to 6 head)	25-30 ft^2/hd
Super calf hutch or bedded pen	minimum

Table 3-2. Replacement heifer resting area space requirements per animal.

Age, mos	Weight, lb/hd	Self-cleaning resting area[a], ft^2/hd	Bedded resting area[b], ft^2/hd	Slotted floor, ft^2/hd	Paved outside[e] lot, ft^2/hd
0-2[c]	100-190	Do not use	32 (4'x8' hutch) 28 (4'x7' pen)	Do not use	Do not use
3-5	190-350	Do not use	28	Do not use	Do not use
6-8	350-500	10	25	12	35
9-12	500-650	12	28	13	40
13-15	650-800	15	32	17	45
16-24	800-1,200	18[d]	40	25	50
Dry cow, far-off	> 1,300	20[d]	50	35	55
Dry cow, close-up	> 1,300	—	10	—	—

[a] 8% slope (1"/ft).
[b] Assumes access to 10' wide scraped feed alley or paved outside lot.
[c] Use hutch or individual pens. House separately from older animals.
[d] Heifers and dry cows in late pregnancy may have difficulty breathing if they lie facing downhill on self-cleaning floors. Incidence of mastitis may be a problem for this group also.
[e] Provide proper treatment for concentrated runoff.

Table 3-3. Heifer freestall dimensions.
Stall width measured o.c. of 2" pipe stall dividers. Stall length measured from alley side of curb to front of stall.

		Freestall size		Neck rail	
Age, months	Weight, lb/hd	Width, in	Length^a, in	Height above curb, in	Distance from back curb, in
6-8	350-500	30	60	31	46
9-12	500-650	33	64	33	49
13-15	650-800	37	72	37	57
16-24	800-1,200	42	78	40	62

[a] Length for side lunge stalls. Add 12-18 inches for front lunge stalls.

Resting Space

Adequate resting space for management groups is a key factor in efficient growth. Tables 3-2 and 3-3 show the space required for different housing alternatives, including bedded resting areas, self-cleaning resting areas (solid, sloped floors), and freestalls.

Feeding and Watering Space

Provide adequate feeding space, so young stock do not have to compete for feed. Optimum feeding space varies with type of feed, feeding schedule, and animal size, Figure 3-1 and Tables 3-4 and 3-5.

Water is essential at all times. **Provide at least one waterer per 20 animals.** Dairy heifers need 1 to 1.5 gallons of water daily per 100 pounds of body weight. Select waterers that are easy to clean; protect them from freezing and equipment. Locate waterers on elevated curbs and in a location that allows easy manure removal around them. Adjust waterer height to allow small animals access. Provide for easy draining and clean-out. Avoid electrically heated waterers because of the potential of stray voltage.

Handling and Treatment Facilities

Animal treatment areas are a necessary part of the replacement housing system. Vaccinations, artificial insemination, checking for pregnancy, deworming, dehorning, and examinations are done easily and safely for animals and workers when animals can be separated and restrained easily. A list of some equipment that eases labor and saves time in handling animals follows:

- Scales.
- Self-locking feed stanchions.
- Gating/fencing.
- Squeeze chute/breeding chute.
- Treatment/palpation rail.
- Hoof trimming table.

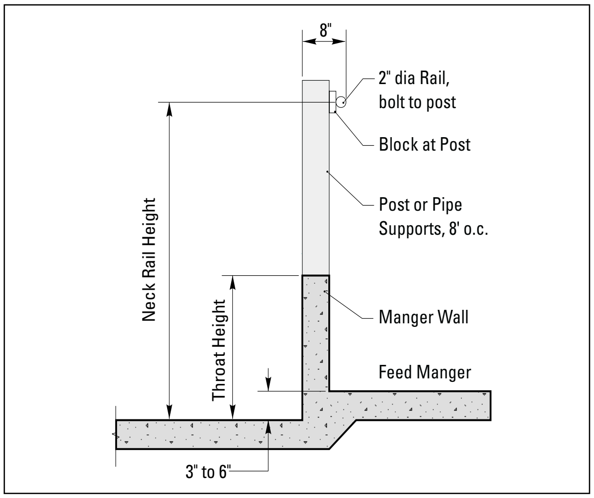


Figure 3-1. Post and rail feeding fence.
Refer to Table 3-4 for neck rail and throat heights.
Note: Each rise in bunk elevation from 3'' to 6'' decreases feed volume and may encourage feed wastage.

Table 3-4. Suggested dimensions for post and rail feeding fences.

Age, months	Weight, lb/hd	Throat height, in	Neck rail height, in
6-8^a	350-500	14	28
9-12	500-650	16	30
13-15	650-800	17	34
16-24	800-1,200	19	41
Cows	1,200-1,500	21	48

[a] A diagonal bar feeding fence is recommended for this group to prevent calves from escaping. Manufacturers can provide information about available panels.

Table 3-5. Minimum feed-space requirements.

	Age, months					Mature cow
Type	3-4	5-8	9-12	13-15	16-24	
	- - - - - - inches per animal - - - - - -					
Feed always available						
Hay or silage	4	4	5	6	6	6
Mixed ration or grain	12	12	15	18	18	18
All animals eat at once						
Hay, silage, or ration	12	18	22	26	26	26-30

Prep Room

Locate a work room near calf housing for feed storage, a refrigerator/freezer, water heater, cleaning sink, health records, and supplies. This area can be used to prepare milk replacer and to clean feeding equipment.

Feed and Bedding Storage

Reduce daily hauling and feeding time by storing a one- to two-week supply of bedding and feed in or near the building. Storage space depends on number of animals, animal density, feeding frequency, bedding density, and frequency of restocking.

Cold Housing

Cold housing is the recommended system for raising replacement animals. Cold-housing systems provide a dry environment free of excessive drafts in winter, and wind ventilation and shade in summer. The building is usually uninsulated and has natural ventilation designed as an integral part of the building. Indoor temperature follows outside temperature very closely.

Advantages of cold housing over warm housing are:

- Less expensive to build.
- Less expensive to ventilate.
- Better disease control.

During cold weather, disadvantages of cold housing are:

- Freezing can make manure handling difficult.
- Waterers must be protected from freezing.
- Frostbite of calves' ears may be a problem.
- Increased feed is required to maintain body heat.

Warm Housing

A warm housing system is less desirable for raising replacements. Environmentally controlled systems are often improperly managed, resulting in health and growth problems. The building must be insulated heavily and supplementally heated, and a controlled mechanical ventilation system delivers fresh outside air. Properly designed inlets allow fresh outside air to be evenly distributed throughout the entire structure.

Design mechanical ventilation systems in calf barns to provide minimum continuous exchange of air, Table 3-6. Do not cut back on the minimum ventilating rate. Small animals do not generate sufficient heat to warm the ventilation air enough to keep the room warm; therefore, supplemental heat must be used.

Table 3-6. Dairy cumulative ventilating rates for warm barns.
Size the system based on total building capacity.

Animal	Cold weather[a]	Mild weather	Hot weather[b]
	- - - - - - -	cfm/animal	- - - - - - -
Calves 0-2 months	15	50	100
Heifers			
2-12 months	20	60	130
12-24 months	30	80	180
Cow 1,400 lb	50	170	470

[a] An alternative cold-weather rate can be calculated by dividing the room or building volume in ft^3 by 15.

[b] Maximum ventilation for hot-weather should provide for at least one air change per minute. The alternative hot weather ventilating rate can be calculated by dividing the volume by 1.5.

Animal health is generally better with larger rates of cold-weather ventilation. Since the number of calves and young heifers in a facility varies, design mechanical ventilation systems for a range of stocking rates.

Calf Housing (birth to weaning)

Calves and young heifers are very susceptible to respiratory illness and other diseases. Keep calves less than two months old in clean, dry, draft-free facilities with adequate space, bedding, and fresh air. Separate calves to reduce disease transfer from nose-to-nose contact. Separate calf groups from older animals to minimize exposure to disease organisms. Keep calves in individual pens in an enclosed building or outside in individual hutches until weaning. After weaning they can be moved to small group pens.

Hutches in Cold Housing

Calf hutches have proved to be an excellent way to house calves. Only one calf occupies each hutch. Typical hutches are 4 x 8 x 4 feet, Figure 3-2. Leave one end of the hutch open, and provide a wire fence enclosure so the calf can move outside. Optional tethers are used where predators are not a problem. Seal tightly all sections of the hutch, except for the front and bottom, to reduce the wind blowing through the hutch in winter. During summer, the rear of the hutch can be blocked open (up to 6 inches) to allow for cross ventilation. An alternative is to design an opening in the rear of the hutch with a tightly fitting door.

Many types of prefabricated plastic/fiberglass hutches are available. Hutches made of a translucent material **require shade in summer**. Summer shade

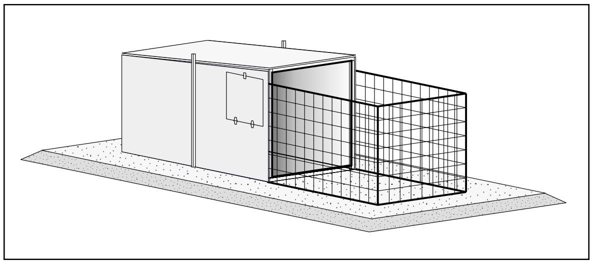


Figure 3-2. Calf hutch.

reduces heat stress on all types of hutches. Provide enough space to allow hutches to be moved.

Face hutch fronts south or east to provide draft protection during winter and sun exposure during the day. Provide enough hutches to allow a minimum two-week idle period between calves to reduce disease transmission. Locate hutches on a well drained area. Crushed rock or sand provides a solid base for bedding and lessens the possibility the hutch will freeze to the ground in winter. After removing the calf, wash and disinfect the hutch and move it to a clean site to break disease cycles. Use enough bedding to keep calves clean and dry and to insulate calves from the ground. A properly designed, well managed calf hutch provides the perfect environment for the calf. In harsh environments, operators may be uncomfortable managing calves in outside hutches. Locating calves inside a structure improves operator comfort but compromises the design features of an outside hutch. As design and management features of a calf housing unit stray from those of a properly designed and managed hutch, the risk to calf health and well-being increases.

To provide operator comfort, hutches may be placed inside a well-ventilated shed or structure, Figure 3-3. Putting hutches in sheds provides a cold housing environment in winter and shade in the summer.

Individual Pens in Cold Housing

Individual calf pens, Figure 3-4, can be used inside cold housing, Figure 3-5. Pens are typically 4 x 7 feet and removable. Solid partitions between pens and beyond the front of the pen prevent nose-to-nose contact and draft control. They provide isolation for each calf. A hover or cover on the back half of the pen

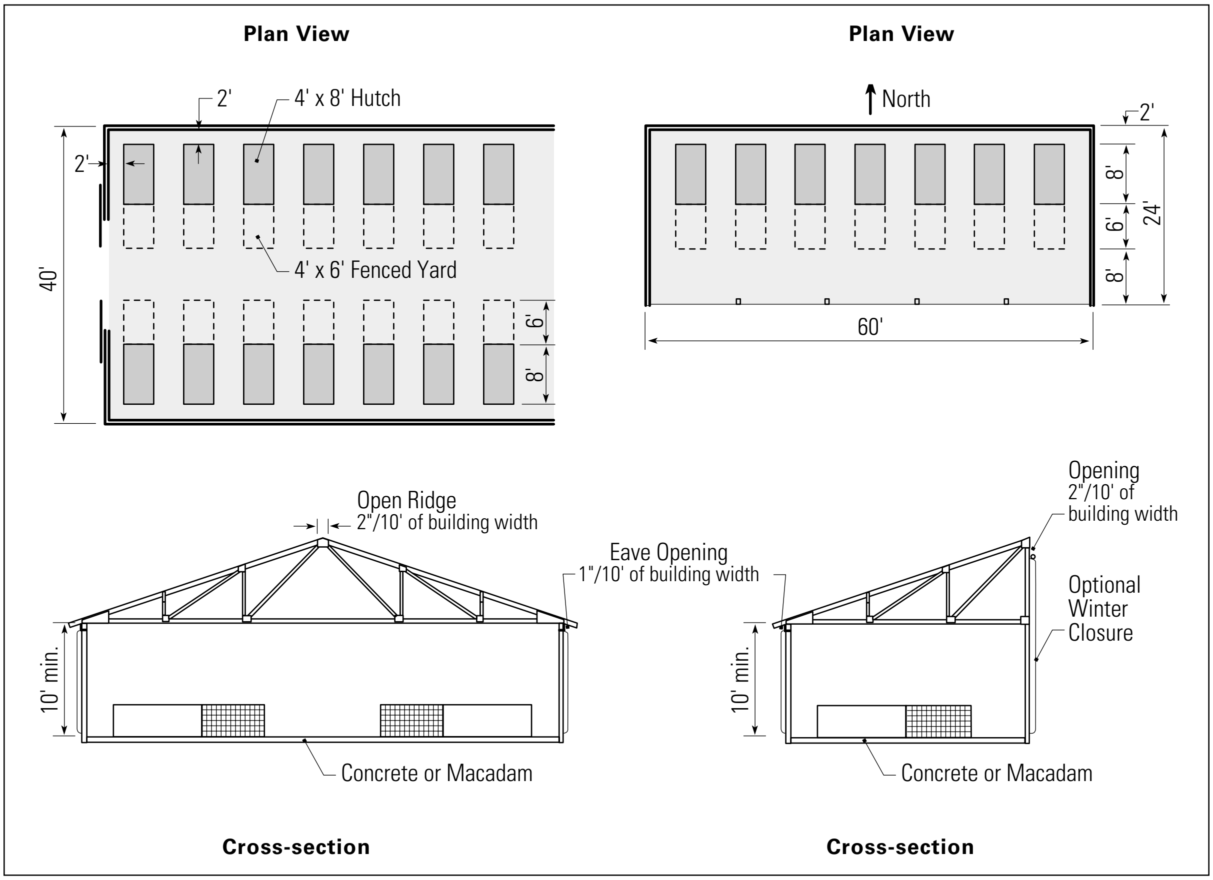


Figure 3-3. Protecting calf hutches.

gives the calf additional protection, especially in cold drafty locations. Pens use building space more efficiently than do calf hutches, although increasing animal density increases ventilation requirements. Place pens on crushed rock or concrete to provide a base for bedding. **Individual pens require the same type of management as calf hutches**. Leave enough space within the building to allow a rest period between calf occupancy. Usually increasing the building size by 50% will provide enough area to allow a rest period between calf occupancy. Clean pens promptly and allow the surface to dry to help control flies and kill pathogens.

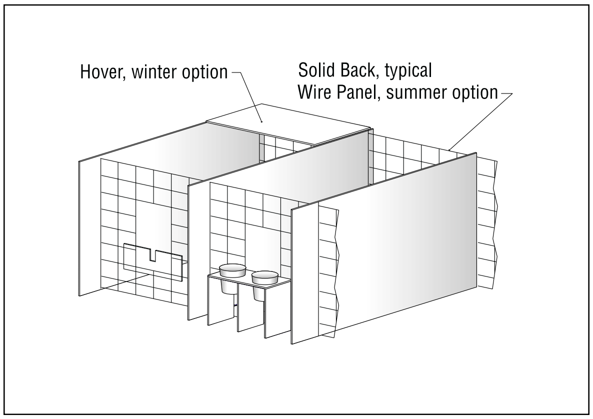


Figure 3-4. Individual calf pen.

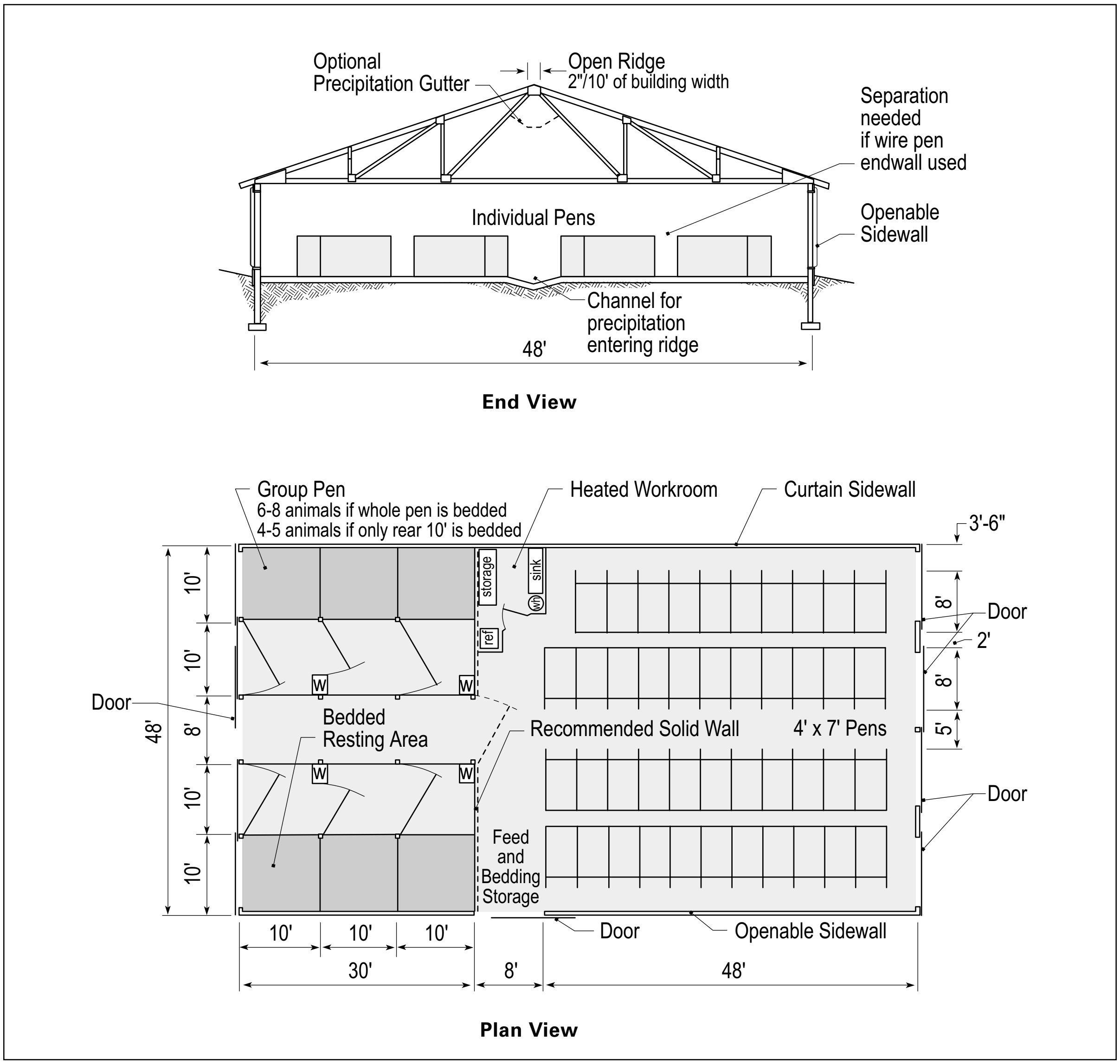


Figure 3-5. Calf barn.
Locate older calves downwind.

Individual Stalls in Warm Housing

Use individual 2 x 4 foot stalls only in warm housing. This system requires the least space per calf, but must be used in insulated, environmentally controlled buildings with mechanical ventilation and **supplemental heat**. Air distribution systems which produce good air mixing can cause drafts on calves. Solid pen dividers and floors help to reduce drafts. Avoid unbedded wire-mesh floors that allow air movement through the pen and are uncomfortable where calves contact the mesh. Urine and/or floor washdown water contribute significant quantities of moisture to the room air. Urine and manure stored within the building or in a pit below the building can contribute noxious gases to the room air inhaled by calves.

Drafts, which occur in elevated stalls with open floors for drainage, are detrimental to calf health. The incidence of calf disorders increases in warm housing facilities after several years, due in part to warm temperatures. Warm temperatures increase the viability of disease organisms and allow ventilation rates for moisture control to be reduced. The combination of desirable growing conditions for pathogens and low air-exchange rates presents a serious health risk for calves. The facility must be adequately ventilated and sanitized routinely. To reduce disease, good ventilation, proper sanitation, and careful observation of calves are especially essential in warm housing systems. Periodic depopulation and building washdown/disinfection of these buildings may be needed to break disease cycles. Consider the all-in, all-out technique for managing disease cycles.

Calf Group Housing for Calves

Some producers raise unweaned calves in groups in bedded pens where calves are given access to a common feeder. This system is fraught with potential risks which can have devastating results on animal health and survivability. A common unsanitized feeding system can cause rapid spread of disease within the group. Sucking behavior within a group can spread disease from face-to-face and face-to-navel contact. Draft control within a group pen must be accomplished with draft barriers, not by reducing the ventilation rate. Reduced ventilation rates contribute to spreading disease by allowing accumulation of moisture, noxious gases, pathogens, dust, and other respiratory system irritants.

Transition Heifer Housing (3-5 months)

Moving a newly weaned calf from an individual pen to a small group environment is an abrupt change or transition. The combination of stresses due to new social interactions with other calves, competition for feed and water, and a new housing system can seriously affect calf growth and performance.

Giving special consideration to the calf's environment can make this transition less stressful as the calf adjusts to group living and learns to compete. Monitor calves for adequate feed and water intake, and make sure calves are disease free before moving them into a group pen.

Provide transition housing for calves from weaning until 5 months old. For smaller herds maintain 4 or 5 calves per group with a small range in size or age (1 month maximum). Provide well-bedded pens that allow 25 to 30 square feet of resting space per calf. Have fresh water available at all times. Transition housing should provide an environment similar to that which calf hutches provide, only in a group setting. To maintain the ability to observe an individual calf for larger herds, limit group size to 20 calves.

Calf Shelter or Super Hutch

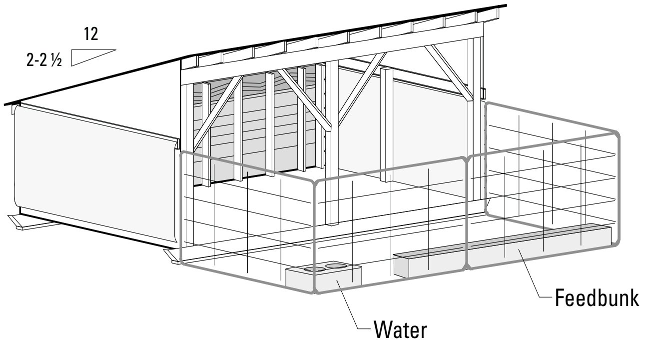
Portable shelters or super hutches provide cold transition housing for calves. A calf shelter is designed for up to six calves, Figure 3-6. An optional paved lot and addition of a fenced area can be used with the shelter, Figure 3-7. Keep the shelter well bedded, and alternate the shelter site between groups of calves. In a pasture system, the calf shelter can be rotated on the pasture, Figure 3-8. Waterers can be located centrally or moved with the shelter site.

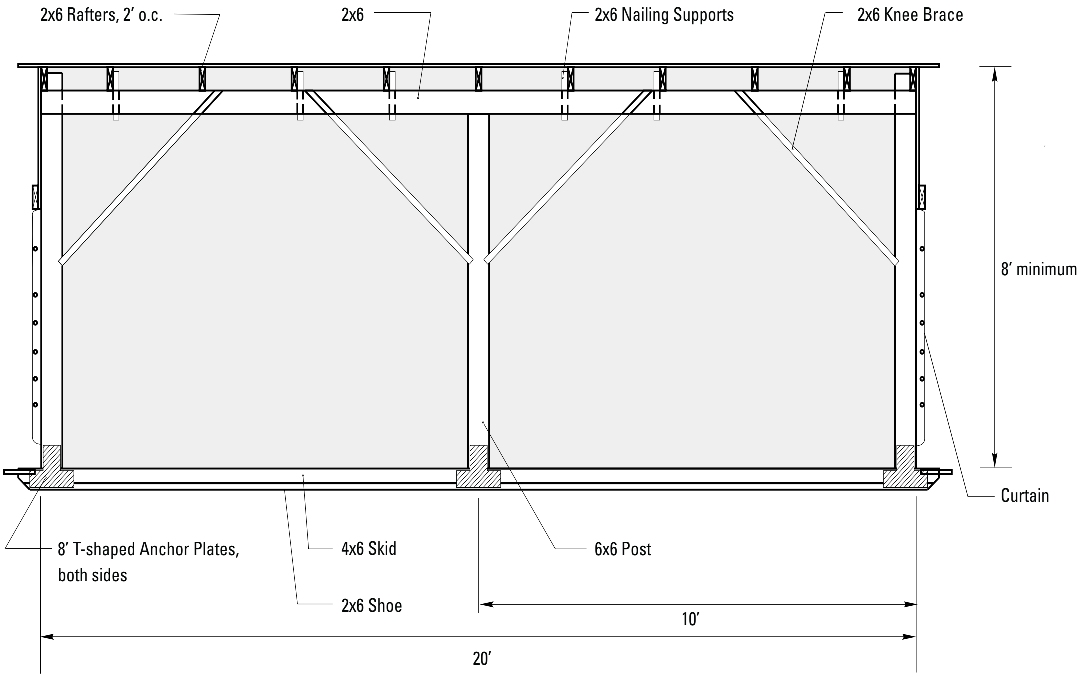
Transition Heifer Barn

For herds greater than 100 milking cows, a series of 10 x 24 foot pens can be used in a transition heifer barn for calves up to 6 months old, Figure 3-9. Capacity for each pen in this arrangement is 6 animals if the feed alley is scraped and 8 animals if the entire pen is bedded.

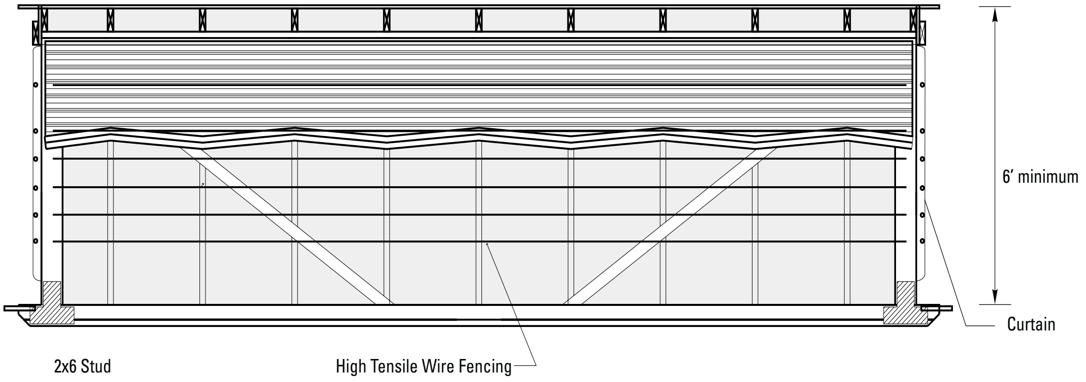
Transition barns commonly have a 3:12 single slope roof with no insulation. The barns should open to the south or east to take advantage of the sunlight and provide protection from winter winds. The eave in the back wall is open to aid in moisture control in winter. During summer, remove fabric or other coverings on the back and endwalls for natural ventilation. Locate waterers in the feed manger line to minimize splashed water in the bedded area. Protect the manger from splashed water by use of a plastic or sheet metal shield.

To minimize excessive drafts in long barns, attach plywood to gates, and hang fabric from the underside of the roof down to the gate between alternate pens. During cold weather, place straw bales along the





Front View



Rear View

Figure 3-6. Super calf hutch, typical 12' x 24'.

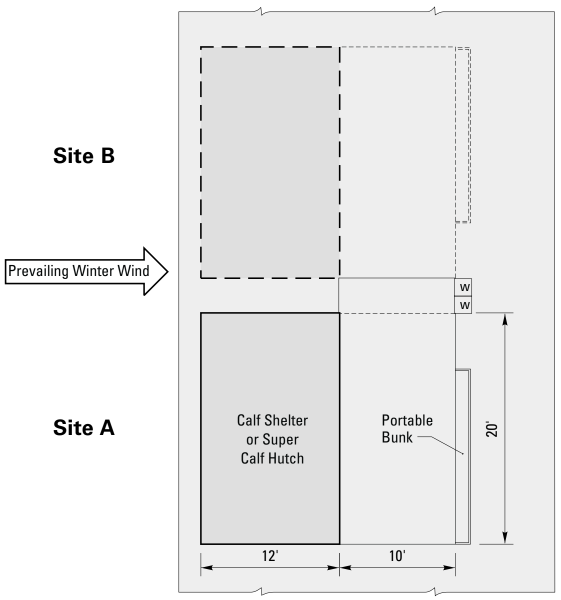


Figure 3-7. Super calf hutch with paved outside lots. Alternate lots between groups of calves. Capacity for up to six calves, six months old.

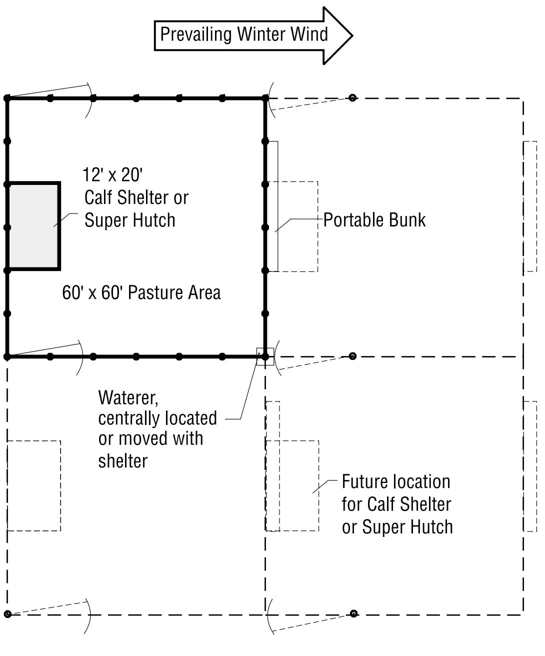
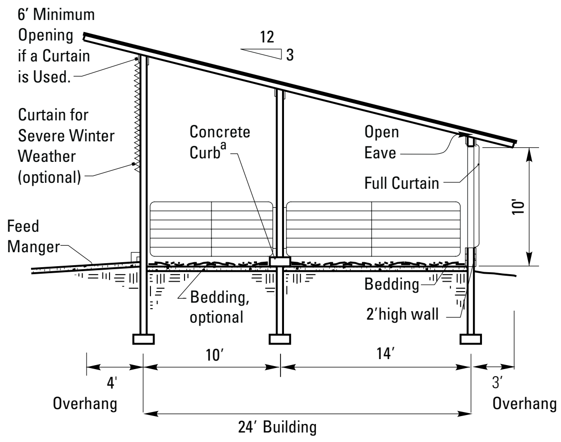


Figure 3-8. Super calf hutches with a fenced dirt lot area.
Rotate lot and move super calf hutch as required. Locate on well-drained sites to maintain sod cover. Capacity for up to 6 heifers, 6 months old.



[a]Curb is 12" to 15" wide, 5" high. Capacity for 6 to 8 calves, up to 5 months old.
3:12 minimum roof slope.

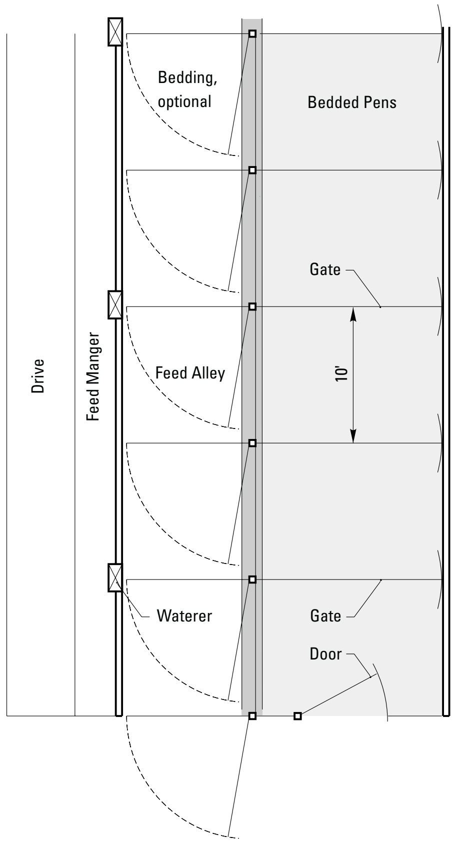


Figure 3-9. A transition barn.

bottom edge of the gates to stop drafts. Remove bales and draft barriers during warm weather.

Calf and Transition Heifer Barn

Calf barns combine individual pens, Figure 3-4, and transition heifer group pens in one building design, Figure 3-5. A full-open sidewall with curtain provides cross ventilation in summer and draft protection in winter. The upper half of the building wall can be a pivot door or curtain for draft protection in winter. The lower part of the wall can have removable panels for better summer ventilation. Air movement through the building should be sufficient to maintain inside temperature only slightly above outside temperature in winter and slightly below outside temperature in summer.

Heifer Housing (6-24 months)

Several options are available for housing heifers after transition housing. Regardless of housing type, group animals according to a management plan, considering the nutritional, health, and reproductive needs of each group. At a minimum, a logical break in grouping is a breeding-age group and a bred-heifer group.

Heifer housing has these primary management functions:

- Allows convenient animal handling for treatment.
- Allows for animal breeding.
- Allows for animal observation.
- Allows convenient feeding, bedding, and manure handling.

Even though heifers can tolerate more stress as they grow older, they still must be protected from wet conditions, drafts, and poor environment. In open-front housing, provide group pens of sufficient depth to protect heifers from winter winds. Solid pen partitions help reduce drafts.

Freestall Housing

Young heifers are grouped in freestall housing with stalls sized according to the age or size of the heifer, Table 3-3. Freestall housing requires a stable herd size to match the number of freestalls in a pen with the number of animals in a group. There is little flexibility in the system. Freestall housing requires considerably less bedding than bedded-pack housing. Frequent manure removal is required (once or twice a week) unless floors are slotted. Frozen manure can be a problem in cold barns, but it is manageable by cleaning more frequently.

Several different layouts are used in freestall housing. Each alternative is suited to particular feeding and manure handling situations. Each alternative has adequate feedbunk space, Table 3-5. Freestalls can be inside with outside lots for exercise and feeding. The trend is towards freestalls and feeding included under the building roof or confined area. Outside exercise lots still may be provided for use during periods of good weather. Lot runoff must be handled properly to prevent pollution.

Two-row Freestall Barn

Two-row freestall barns as illustrated in Figure 3-10 are used for up to 100 heifers. Freestall length for each group in Table 3-3 is sized to provide maximum comfort for the size of the animals in the group. Heifers are grouped in pens around the perimeter of the building.

Manure is scraped automatically; the alley is

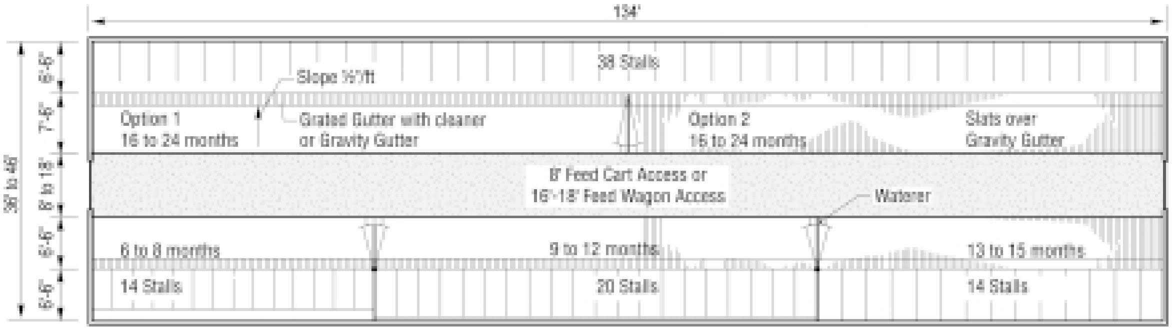


Figure 3-10. Two-row freestall barn (center feed), 36' to 44' by 134'.
Note: Dimensions are for building interior and do not include wall thicknesses.

flushed or the floor is slotted because it is not possible to move animals during tractor scraping. When animals have access to outside runs, tractor scraping can be accomplished. Build an 8-foot alley when a feed cart is used. For drive-through feeding, a 16- to 18-foot alley is required.

Two-row Graduated Freestall Barn

A two-row graduated freestall barn changes the length of the freestall in the pen by placing the curb at an angle to the side of the building. Stalls at one end of the building are shorter than stalls at the other end. The alley floor is sloped toward the freestalls, where a grated gutter is used to remove manure. The floor slope provides a self-cleaning floor. Stalls are bedded with chopped bedding to allow movement of the manure and bedding through the grate. A gravity gutter, flush gutter, or barn cleaner can be used to remove manure. Building temperatures must remain above freezing most of the time to prevent frozen manure in the gutters. This type of building requires insulation and a controlled natural ventilation system.

Two-row Gated Freestall

A two-row gated freestall barn can provide good housing, Figures 3-11 and 3-12. Having two rows of freestalls along one side of a single bunk, all under roof, provides flexibility in feeding system design. Depending on the layout, feeding may be accomplished with a feed cart, mechanical bunk, or mobile scale mixer. In three-row barns, there is limited bunk space. When feed is always available, competition for feed can be managed.

An alternative layout for a two-row gated freestall barn is shown in Figure 3-12. Manure in the gated freestall system is easily removed by a tractor-mounted scraper. Animals are fenced in one alley while the other alley is cleaned. When the feed bunk is located on the south or east side in a cold barn, the bunk side of the building may be left open.

Four-row Gated Freestall

Two-row gated freestall barns can be expanded for larger herds by using a common center feed alley. Stall rows are located on both sides of the feed alley. Feeding can be accomplished with drive-through feeding alleys sized for a feed wagon or feed cart.

Bedded Pack

Bedded-pack housing, Figure 3-13 and 3-14, is commonly used in conjunction with an outside feeding area. However, roofing the entire area including the scrape and feeding alley has advantages. Providing a roof over the bedded area keeps precipitation off animals while animals rest and keeps bedding dry. A roof also eliminates contaminated runoff from the alley. Provide enough space, for each group of animals in the bedded resting area Table 3-2. The bedded area is roofed and provides a warm, draft-free resting surface. Additional heat develops from the decomposing manure in the bedded pack. Bedded-pack barns are often sized to allow installation of a scrape alley and freestalls at a later date. Use a shed (single slope) roof if an expansion will occur on the other side of the drive-by feed alley. A macadam or crushed rock surface can be used under the resting area pack. Macadam is a built-up rock base (see *Using All-Weather Geotextile Lanes and Pads,* AED-45) which distributes concentrated surface loads over the original soil. Macadam also provides a slip-resistant surface and is porous enough to allow good drainage. Take measures to avoid groundwater contamination. If concrete is used rather than macadam, slope the floor to the scraped manure alley. Add bedding to the upper end of the pack as needed. Remove manure and bedding as a solid two to four times a year. A substantial amount of bedding is required to keep animals clean and dry.

Paved feeding alleys are typically scraped two or three times a week. Extending the roof over this area reduces runoff. To provide for a system with an outside lot, the feeding alley is extended away from the building and generally is not roofed. Runoff must be controlled to prevent surface water and groundwater contamination.

Counter-sloped Barn

The counter-sloped barn, a relatively low-cost facility, is based on a sloped resting and feeding floor separated by a tractor-scraped alley, Figure 3-15. The resting floor and feeding floor are sloped 8% (1 in/ft) toward the center scrape alley and are self-cleaning. Size the resting area of the pens to allow for a self-cleaning resting area, Table 3-2. Runoff from uncovered alleys must be controlled to prevent stream and groundwater pollution. The building also can be designed to be completely under roof to control water entry. This system is not recommended for heifers younger than six months or bred heifers during the last three months of pregnancy because of lack of cleanliness.

Optional Outside Lots

Optional outside lots sometimes can be incorporated into building design when desired. Outside lots help reduce manure accumulation in the building but must be cleaned and managed properly. Outside lots

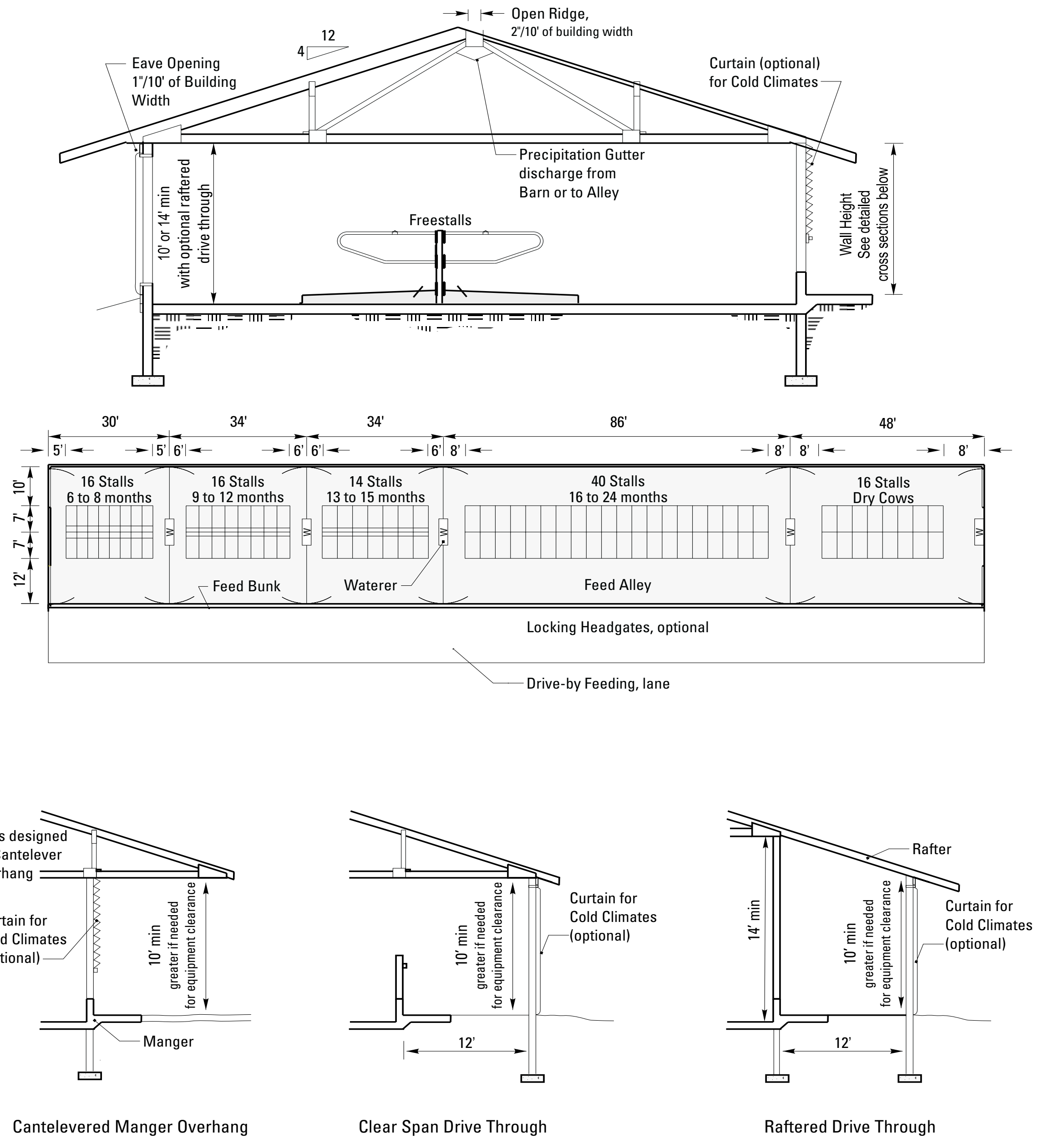


Figure 3-11. Two-row gated, head-to-head freestall barn, 38' by 232'.
A freestall barn for four groups of heifers and a group of dry cows.
Note: Dimensions are for building interior and do not include wall thicknesses.

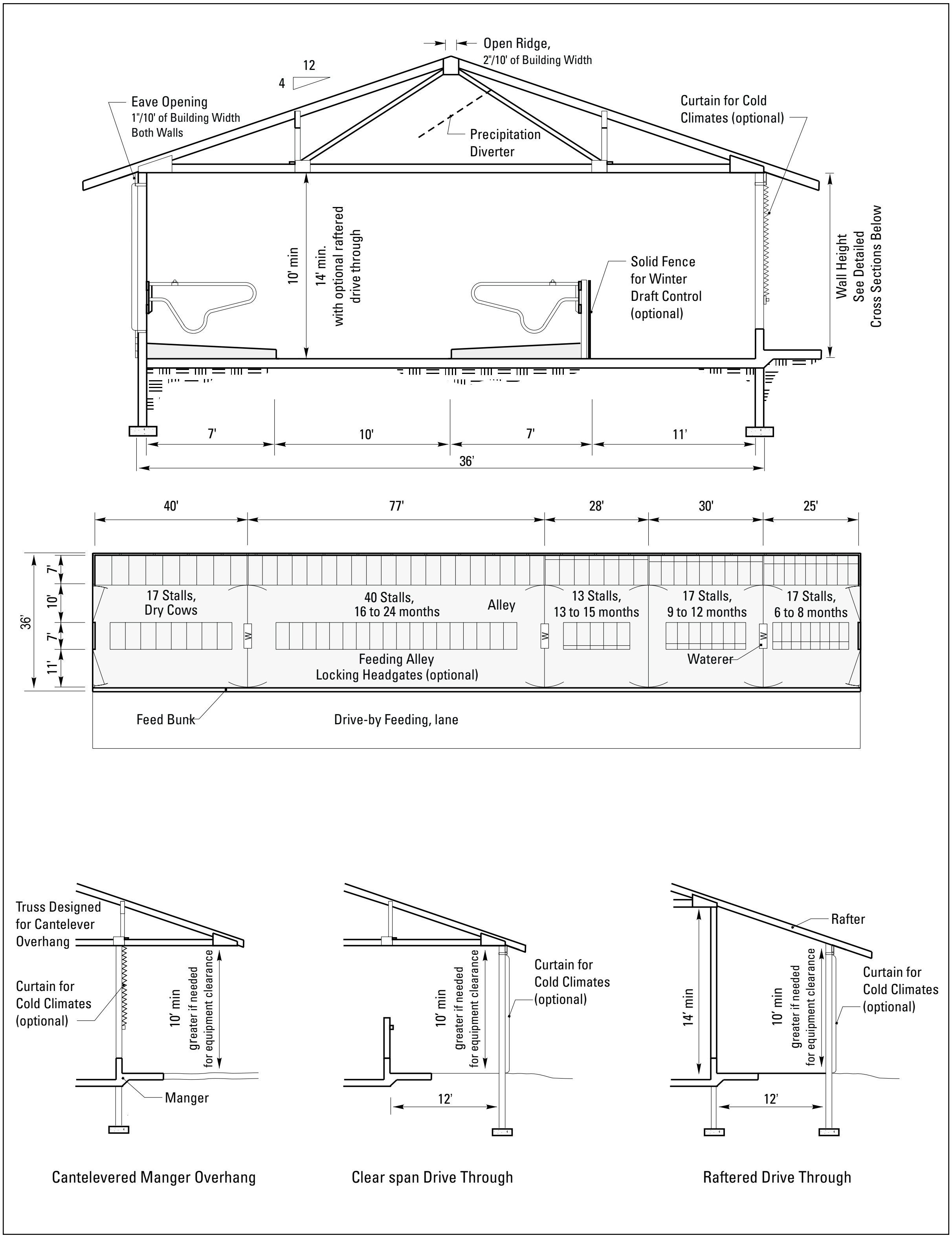


Figure 3-12. Two-row gated, tail-to-tail freestall barn, 36' by 200'.
A freestall barn for four groups of heifers and a group of dry cows.
Note: Dimensions are for building interior and do not include wall thicknesses.

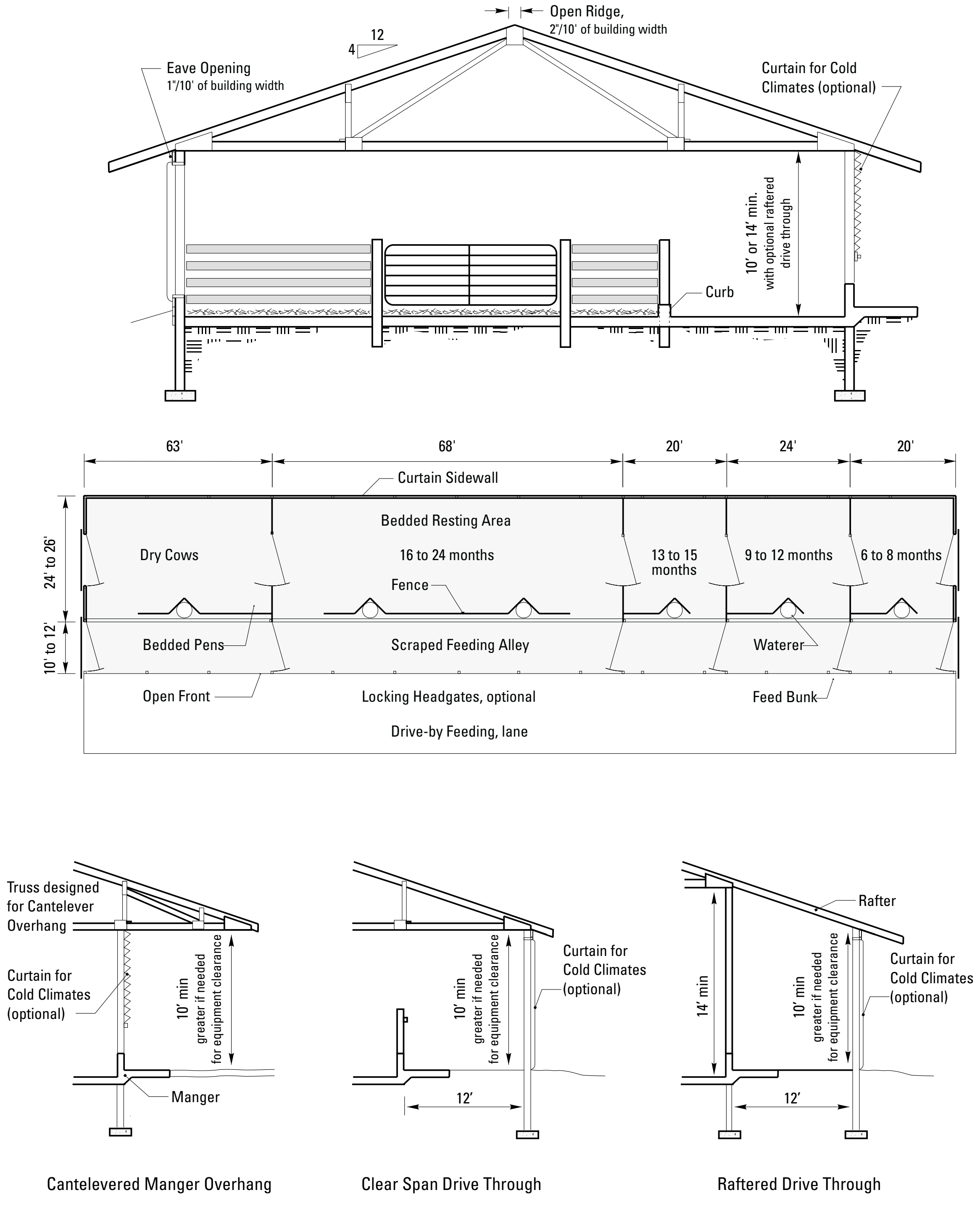
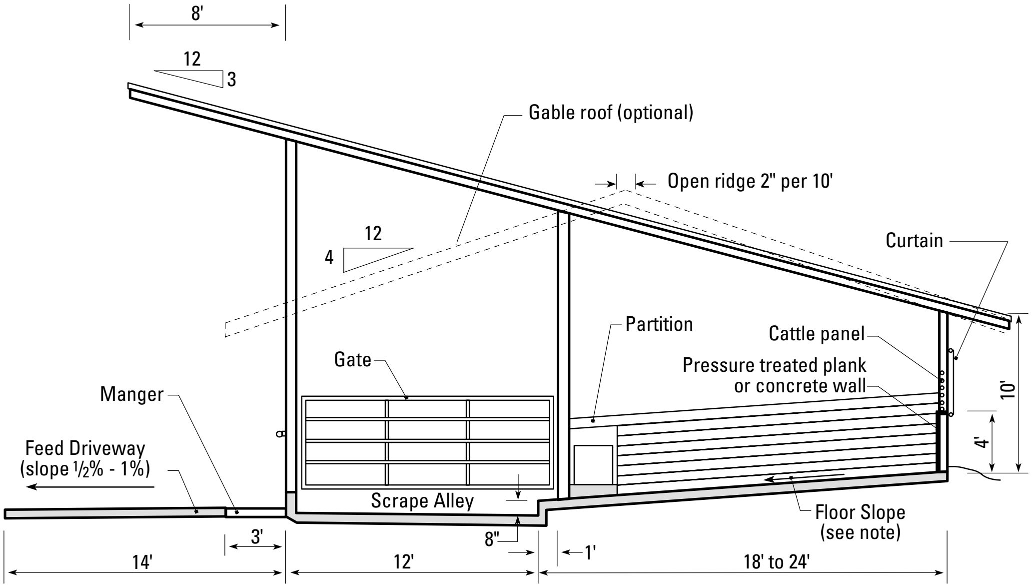
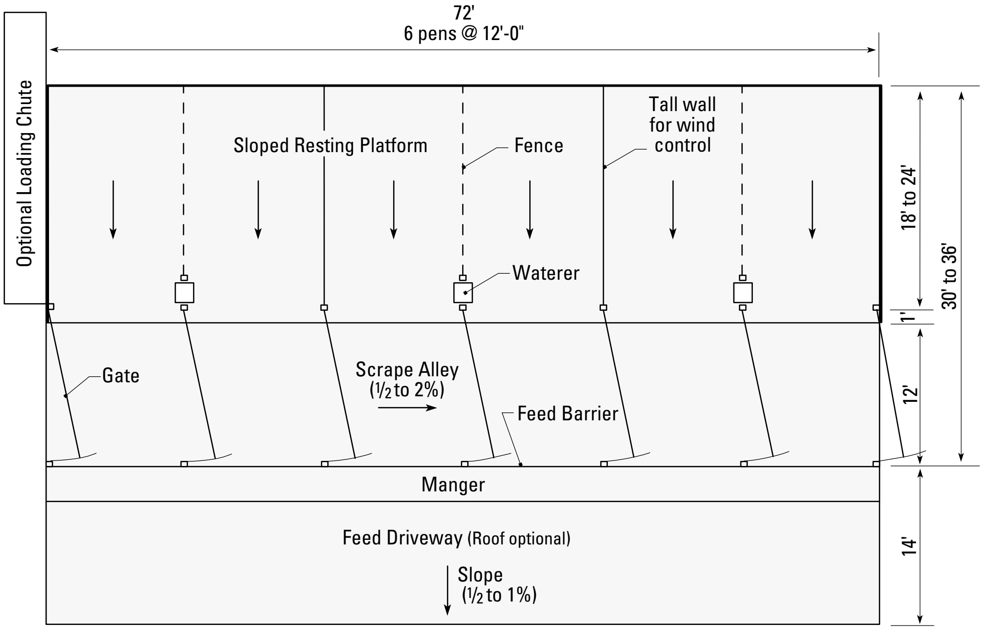


Figure 3-13. Bedded pack heifer and dry cow barn.
Bedded pack barn for four groups of heifers and a group of dry cows. Gates across the feeding alley are used to hold animals in bedded pens during alley scraping.



a. Building cross-section.
Note: For bedded pack rest area, use a 2% slope. For a self-cleaning floor rest area, use a 8% slope. Solid partition for self-cleaning sloped floors or 4' tubular steel gate for bedded pack with adjustable height hinges or attach 4' x 8' plywood to gates. Extend every other partition to ceiling to reduce wind swirl. Face open front away from prevailing winter winds. Open front facing SE will provide afternoon shading in hot weather.



b. Building plan view.
Notes: Maximum number of animals per pen:
5 per pen when 12 to 24 months
7 per pen when 6 to 12 months

Figure 3-14. Heifer housing for heifers older than 6 months.

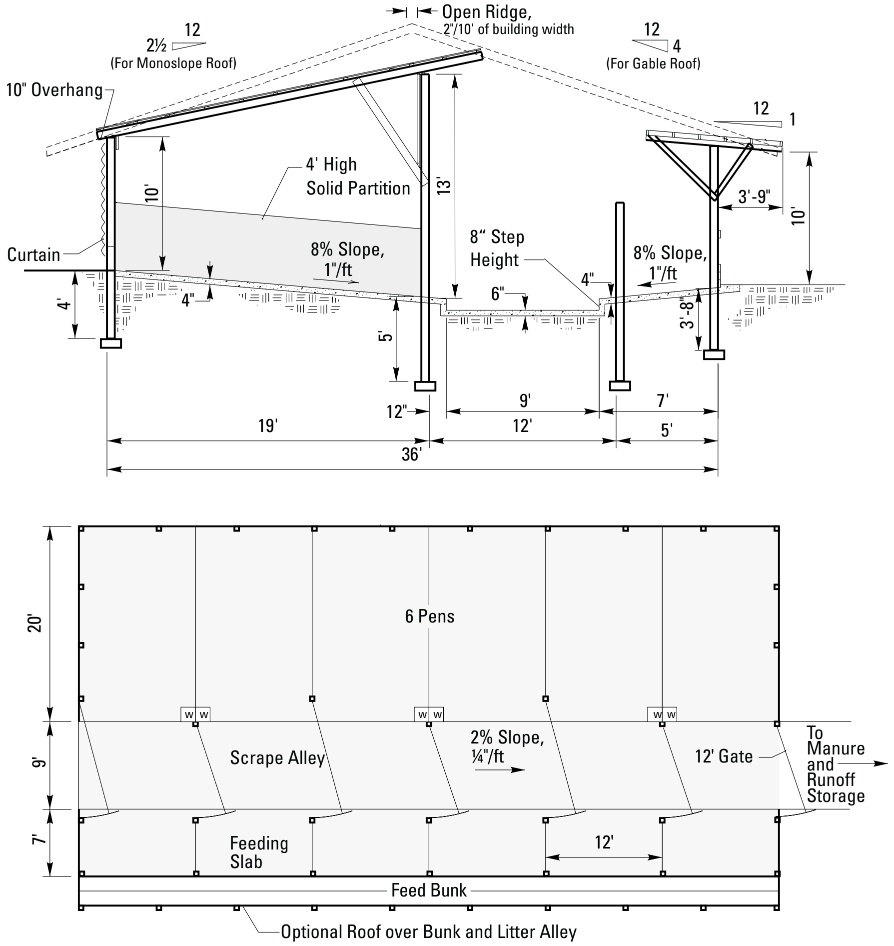


Figure 3-15. Counter-slope youngstock barn.
Sample barn layout for 72 to 90 animals with outdoor feeding and scraped manure alley.

may be of some benefit in reducing foot and leg problems in dry cows.

Pasture sometimes is used as part of the feed ration. When this is the case, animal density must be kept low to allow the pasture to recover after grazing. Pasture can be rotated to provide rest and recovery of vegetation. Pasture that is too heavily grazed becomes a dirt lot over time and can cause problems when not managed properly.

Dirt exercise lots tend to have a high animal density and typically have little or no vegetative cover. They become muddy in wet weather and can cause environmental mastitis in heifers before they enter the milking herd. Use dirt lots only when weather permits. Cattle mounds can improve drainage of a dirt lot to help keep the surface dryer.

Concrete paved exercise lots can be incorporated into building designs either as exercise areas or as integral parts of the building design. Runoff from lots must be controlled and handled as part of the manure handling and storage system. Additional labor is required to scrape lots and field apply manure. Consider the cost of a runoff control system in the total system cost. Also consider water quality issues in the overall design of the housing option.

Chapter 4

Milking Herd Facilities

William G. Bickert, Extension Ag Engineer, Michigan State University

The most common housing type being built in the Midwest is a freestall barn. Freestall barns allow cows to be housed and managed as groups. There are various barn layouts and stall designs. Before deciding on a barn layout or selecting a stall design, weight the advantages and disadvantages of each alternative. When making this decision, consider labor, cow comfort, and personal preference.

Freestalls

The freestall is a vital element of the cow's environment, affecting cow comfort, cleanliness, and health. There is more to freestall comfort than to properly size the stall and to properly locate the freestall equipment. How cows use freestalls is also important. Cows should want to use the stalls. If cows are standing in the alleys more often than lying in the freestalls, then there may be a problem with the design of the freestall. **Take time to observe how cows are using freestalls.**

Freestalls must provide a clean, comfortable resting space for cows. In addition, cows should be able to enter and leave stalls easily, and lie down and rise without interference. Additional considerations are freedom from injury, stall cleanliness, bedding requirements, labor, durability, and ease of removing downed cows.

Proper stall conditions must be maintained if cows are to use stalls and potential benefits are to be realized. Improperly designed or maintained stalls may lead to cows lying in alleys or elsewhere. Wet, contaminated stall beds increase the incidence of environmental mastitis. While attention to design and maintenance of the stall is indeed important in each of these situations, the willingness of cows to use stalls and the dryness of stall beds are directly linked to other elements such as poor ventilation and lack of shade.

Freestall Design

A freestall is an individual resting place that provides the cow a reasonably clean, dry, resilient bed. The cow is free to enter and leave at will. The stall must be wide enough for the cow to lie comfortably, but narrow enough to keep the cow from turning around. The stall must be long enough to allow the cow to rest comfortably on the platform without injury, yet short enough so manure and urine fall into the alley. The stall bed must have a surface that is resilient and that remains relatively dry.

In addition, the stall should accommodate the natural reclining and rising behavior of the cow. The cow should not touch the stall partition in a manner that can injure her. In particular, the body of the cow must not strike any portion of the partition while she is in the act of lying down, the last portion of this movement being uncontrolled.

As a cow rises from a lying position in the pasture, she lunges forward, transferring her weight forward to help raise her hindquarters, much like a springboard action. To achieve this natural movement, a cow thrusts her head forward as she lunges. When she cannot lunge forward, she has difficulty rising on her hind legs. When restricted too much, she rises front legs first, like a horse, which is an unnatural behavior for a cow.

The cow's lying and rising space needs consist of three elements:

- **Body space** — the space from the rear of a cow to the front of her knees.
- **Head space** — the space ahead of a cow's body occupied by her head.
- **Lunge space** — the additional space necessary for the thrust of a cow's head as she lunges forward during rising.

In an ideal freestall, the partitions:

- Define the cow's lying position.
- Have minimum contact with her body.
- Accommodate the cow's natural lying and rising behavior.

Limited length can reduce defecation in the rear of the stall, important to good udder health. But if limited length restricts the forward thrust of the head then rising will be more difficult for the cow.

Freestall Types

There are two types of freestalls identified by where the cow places her head during rising:

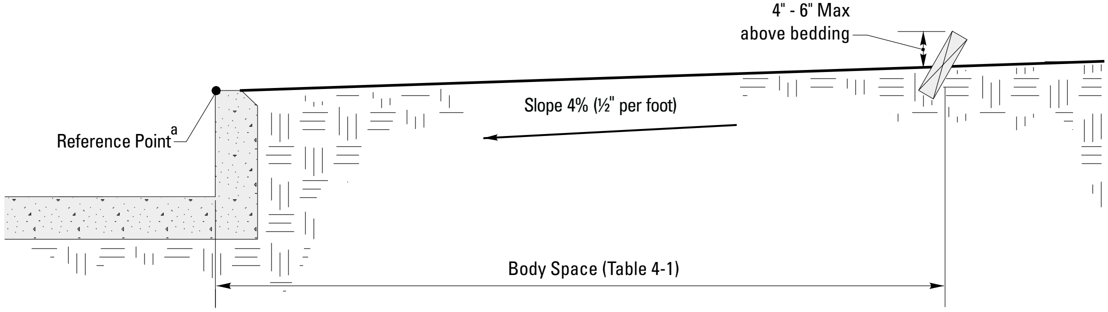
- Forward-lunge.
- Side-lunge.

The two freestalls differ in partition and stall base design to account for the cow's lunge during rising. To reduce injury, both types of freestalls should provide space beneath the lower rail at the rear to minimize contact with the cow's hip and pelvic area.

In a forward-lunge freestall, additional stall length is needed to allow the cow to lunge forward. A brisket board, Figure 4-1, is required to position the cow in the freestall. See Figure 4-3a. In head-to-head freestall arrangements, the cow is able to lunge into the opposite freestall. See Figure 4-3b. In a head-to-head freestall arrangement provide as much open lunge space as possible with a minimum of 24 inches of open vertical space. This arrangement also requires a brisket board, Figure 4-1.

In a side-lunge freestall, the cow thrusts her head into an adjacent stall space as she rises. The lower rail of the partition is either high enough in the front to allow the cow to thrust her head under the lower rail, or low enough to allow the cow to thrust her head over the lower rail without interference. If the cow thrusts her head under the partition rail, the bottom partition rail should be a minimum of 32 inches above the back curb, Figure 4-4a. If the cow thrusts her head above the bottom rail, the bottom partition rail should be a maximum of 11 inches above the back curb, Figure 4-4b. Side lunge stall dividers are a

a. Location in stall.



b. Construction.

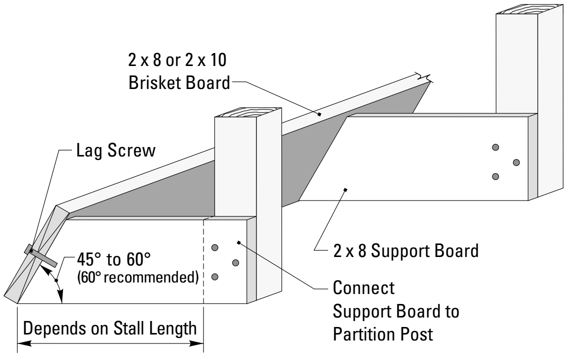


Figure 4-1. Freestall dimensions.

[a] Location of reference point may vary. See Figure 4-2 for more details.

good choice for replacement dividers on shorter stall platforms.

Freestall Dimensions

Dimensions chosen for freestalls represent a compromise between cow comfort and cow cleanliness. Stalls must enable cows to lie down and get up naturally and comfortably. Stalls should be wide enough that cows normally do not contact stall partitions in any way that could cause injury or that could damage the partitions. But, stalls that are too wide may allow cows to turn around in them or lie diagonally. Stalls that are too long or have the brisket boards improperly placed allow cows to lie too far forward. All of these conditions increase the possibility of manure being deposited on the stall bed.

The lower values of the ranges in Table 4-1 represent a livable compromise between comfort (high rate of stall usage) and cleanliness. The upper values, which provide for wider and longer stalls, favor cow comfort over cleanliness and result in more stall maintenance. When animals in a group are different size, design stalls based on the average size animal in the largest 25% of the herd.

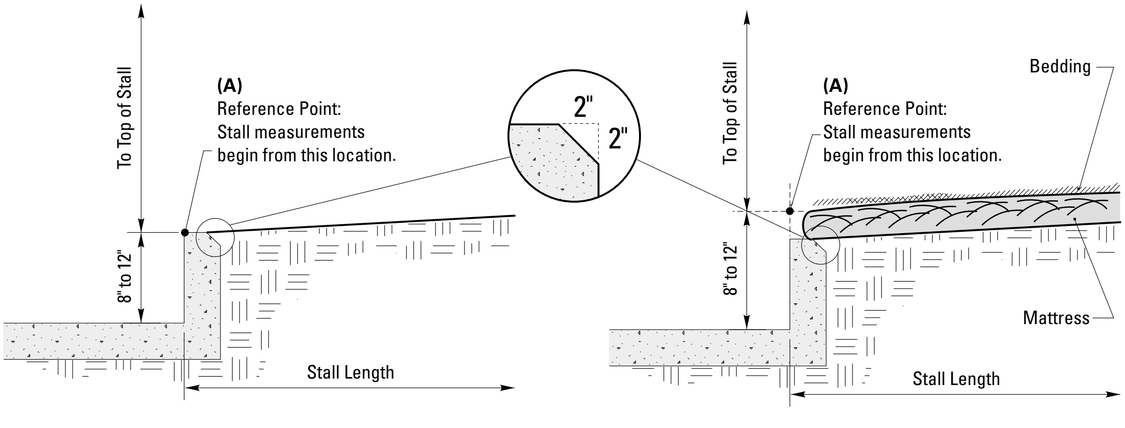
It is important that stall measurements be taken from the same reference location as shown in Figure 4-2. Some producers and designers incorrectly mix and match the information in Figures 4-3 and 4-4 with information in Table 4-1 and are disappointed in the results. The reference location is taken according to Figure 4-2. This is the reference location for most stalls bedded with sand. When the freestall has an elevated bed, such as when bedding mattresses are used, then the reference location is taken at a point directly above the corner of the curb. The distance above the curb is equal to the mattress thickness or additional bed depth.

Table 4-1. Freestall dimensions.
Freestall width measured center-to-center of 2" pipe dividers. For wider dividers, increase width accordingly. Freestall length, and neck-rail and brisket-board distances measured from alley side of curb to front of stall.

Animal weight (lb)	Freestall width (in)	Freestall length Side lunge	 Forward lunge[a]	Neck rail height[b]	Curb to neck rail and brisket board (in)
800-1,200	42 to 44	6'-6"	7'-6" to 8'-0"	41 to 43	62
1,200-1,500	45 to 48	7'-0"	8'-0" to 8'-6"	44 to 46	66
over 1,500	48 to 52	7'-6"	8'-6" to 9'-0"	46 to 48	71

[a] An additional 12" to 18" in stall length (compared to side lunge stalls) is required to allow the cow to thrust her head forward during the lunge process.

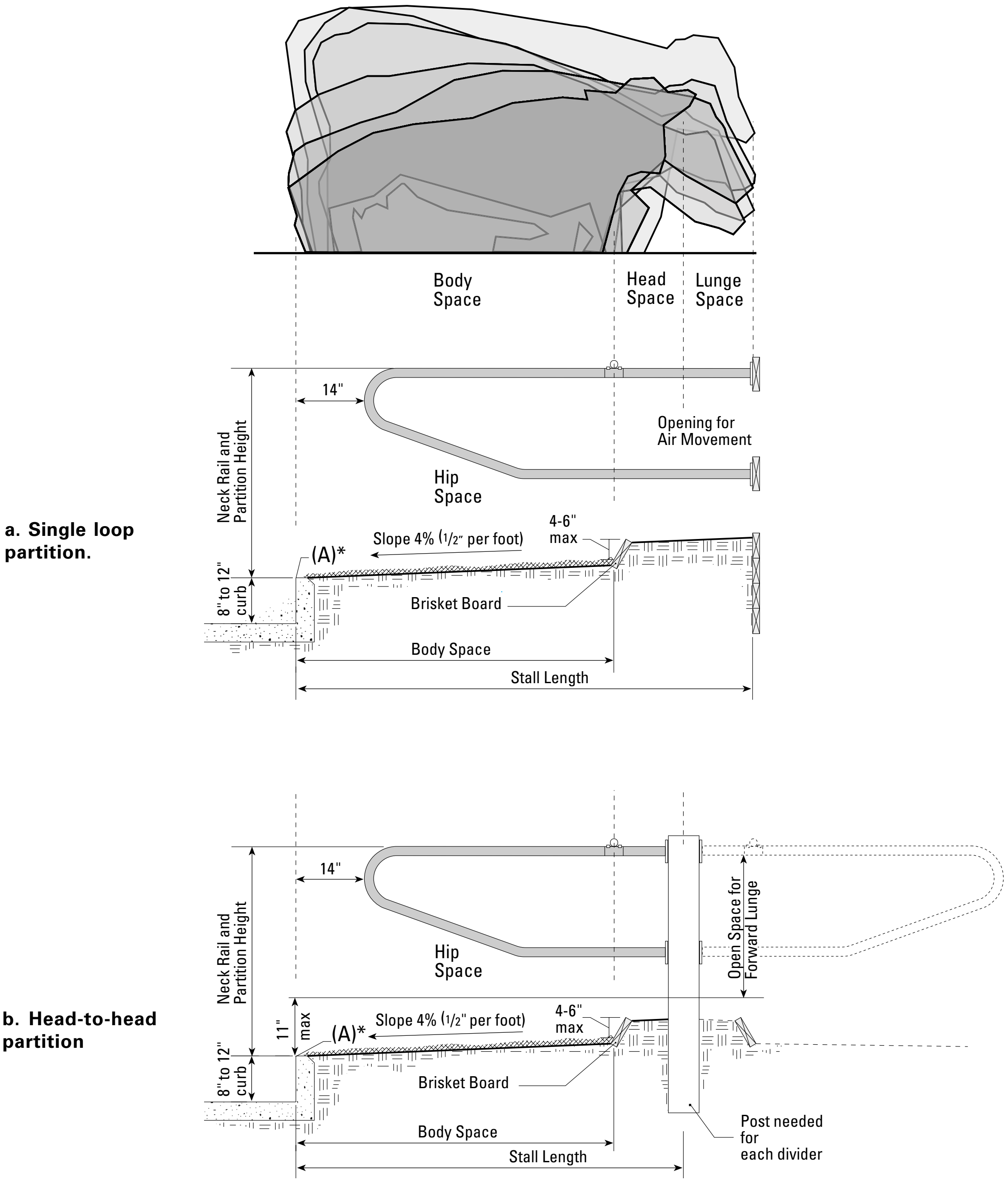
[b] Above top of curb or top of mattress (Ref. point A in Figure 4-3 and 4-4), in.



a. Measurement when stall bed is level with curb.

b. Measurement when bedding extends above stall base.

Figure 4-2. Location from which to start measurements for sizing freestall cubicles.

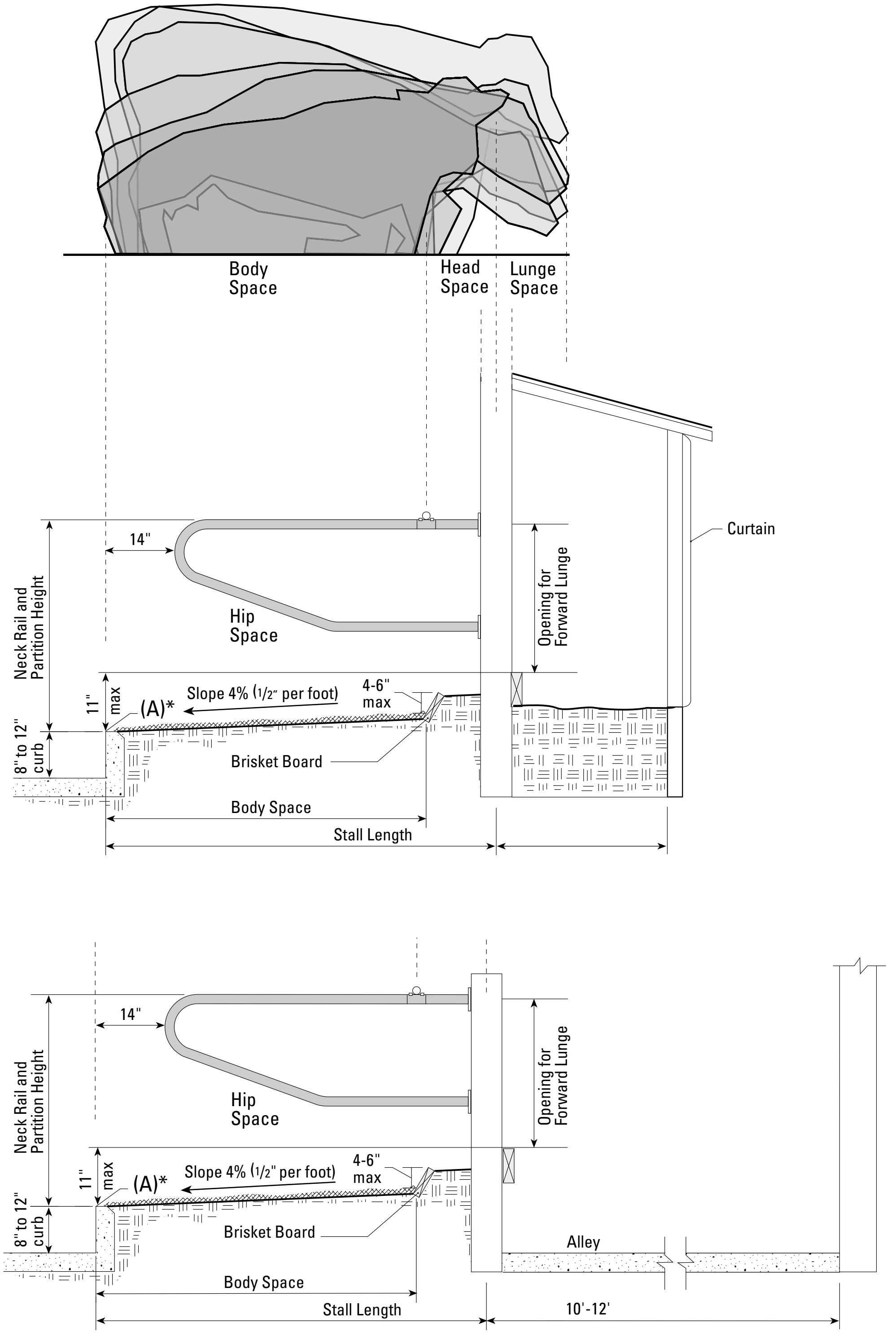


a. Single loop partition.

b. Head-to-head partition

Figure 4-3. Forward-lunge freestalls.

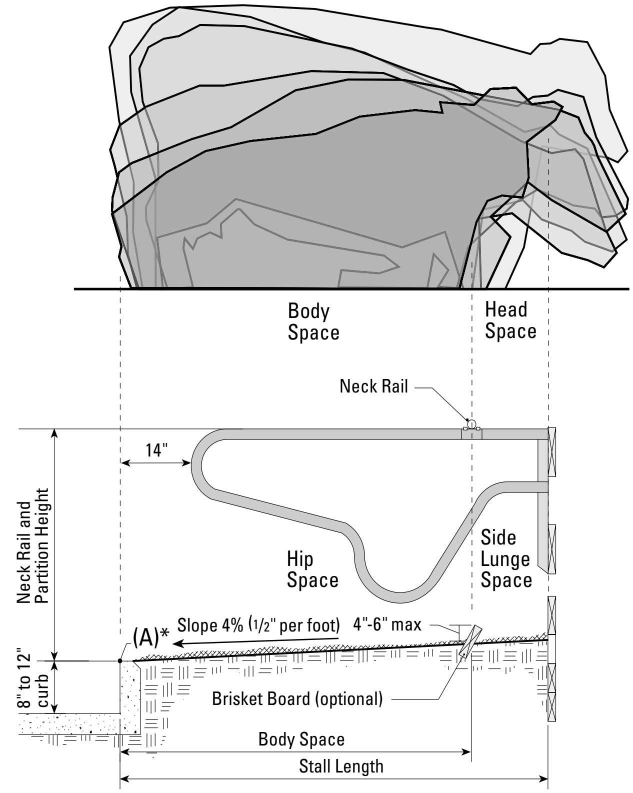
* **Note:** Top of curb on the alley side is used as the primary reference point for measurements except when the stall bed is elevated. When the stall bed is elevated, the apparent top of the stall bed at the curb is the reference point (See Figure 4-2). Dimensions are for a 1,400 lb cow. **Refer to Table 4-1 for proper freestall size.**



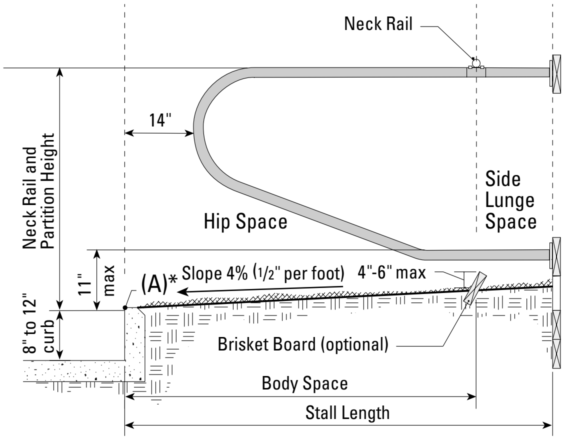
c. Lunge into "doghouse".

d. Lunge into alley.

Figure 4-3. (Continued)



a. Side lunge partition



b. Wide loop partition

Figure 4-4. Side-lunge freestalls.

* **Note:** Top of curb on the alley side is used as the primary reference point for measurements except when the stall bed is elevated. When the stall bed is elevated, the apparent top of the stall bed at the curb is the reference point (See Figure 4-2). Dimensions are for a 1,400 lb cow. **Refer to Table 4-1 for proper freestall size.**

Partition

Extend the stall partition horizontally toward the rear of the stall to within 14 inches or less of the alley to prevent cows from walking from stall to stall. For most mature cows, install the top rail of partitions 44 to 48 inches above the reference point to discourage turning around. The bottom rail should be high enough at the rear to avoid injury to hips and ribs, yet low enough at the shoulder to prevent cows from lying under the partition. See Figures 4-3 and 4-4.

Neck Rail

Place a neck rail across the top rail of the stall partition to prevent cows from defecating in the stall. Without being a nuisance to them, a neck rail stops cows from moving too far forward when standing and encourages cows to back up when rising. A neck rail that is too low may hinder the lying and rising movement. Rigid neck rails may be an integral support component for partitions with no rear posts. Unshielded cable used as a neck rail can cause severe injury to a cow’s neck and vertebrae. Cover cable with 2 inch or larger PVC pipe or similar shield.

Position the neck rail approximately 66 inches ahead of the alley side of the curb and 44 to 48 inches above the top edge of the curb for a 1,400-pound cow. Neck rail placement may cause cows that are new to freestalls to use the stalls improperly. If this is a problem, move the neck rail forward temporarily. When the cow becomes accustomed to using the stalls, move the neck rail back to improve cow positioning.

Stall Base and Bedding

The stall base and bedding should provide a resilient bed for cow comfort and provide a clean, dry surface to reduce the incidence of mastitis.

Use an 8- to 12-inch high curb to elevate the stall base above the alley. Height and construction should help keep manure and scraping equipment or flush water in the cow alley and out of the stall. An elevated curb discourages a cow from lying part way out of the stall, but a curb that is too high may discourage use and cause udder injury when a cow enters and leaves the stall. Long alleys may require a higher curb to keep manure from overflowing into the stalls during cleaning.

For sand-based stalls, bevel the cow-side of the curb. See Figure 4-2a. Otherwise, the top of the curb should be flat and at a right angle to the alley-side of the curb.

Slope the stall base downward 2 to 4% (1/2 inch per foot) from front to rear. Commonly used materials for the base include concrete, clay, sand, and stone dust. Hardwood planks tend to rot. Rubber tires, if not firmly embedded, tend to come loose.

Bedding material added on top of the base:

- Absorbs moisture and collects manure tracked into the stall.
- Adds resilience.
- Makes the stall more comfortable.
- Reduces the potential for injuries.
- Provides traction.

Possible bedding materials include straw, sawdust, wood chips, sand, ground limestone, separated manure solids, shredded newspaper, corn stalks, bark, peanut hulls, sunflower hulls, and rice hulls. Choice of bedding material influences selection of a manure handling and storage system. Excessive use of straw or other organic material builds up a substantial crust in a storage, creating problems with agitation at time of emptying. But a crust can help reduce odors from the manure storage. The use of short, fine bedding material reduces the amount of bedding material dragged into the manure alley.

Resilient mattresses over hard stall bases such as concrete or well-compacted earth can provide a satisfactory cushion. See Figure 4-5. A mattress consists of loose filler material sandwiched in a fabric—heavyweight polypropylene or other material. Shredded rubber is frequently used as mattress filler. Use small amounts of bedding (chopped straw) on top of the mattress to keep the surface dry and the cows clean. To prevent leg injuries, 3 to 4 inches of bedding is recommended.

Rubber mats, plastic mats, carpeting materials and other compressed products are less satisfactory cushioning materials.

Relying upon an earthen base with only bedding for the cushion requires substantial amounts of bedding. In addition, pockets develop in the earthen base as cows struggle while standing and lying. Without periodic maintenance, these pockets deepen. Deep pockets at the front of the stall bed make it very difficult for cows to rise. Pockets near the rear trap moisture and manure, contributing to udder health problems.

A sand bed (6-inch minimum depth maintained in the stall area) can act as both freestall base and bedding. See Figure 4-6. Sand contributes to cow comfort, good udder health, and clean cows. In addition, sand kicked into the alleys improves cow footing. Every one to two weeks, add sand to the front of the stall bed; the cows work it toward the rear of the stall. Replenish sand before the front of the stall bed becomes lower than the rear, a condition

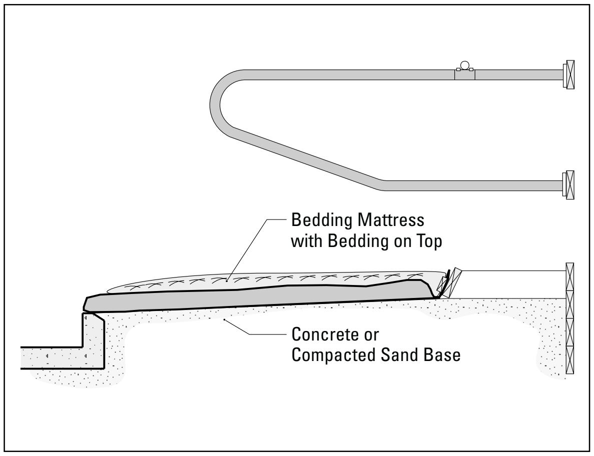


Figure 4-5. Stall using a mattress.

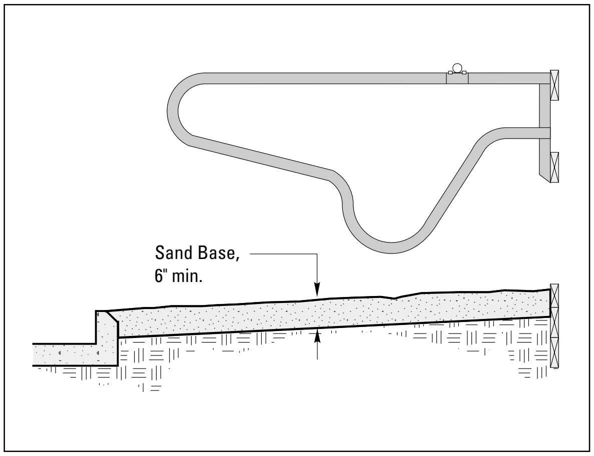


Figure 4-6. Stall using a sand-based bed.

that makes it difficult for cows to rise and causes them to lie diagonally. Cows lying diagonally are more likely to defecate in the stall, leading to dirtier cows. If the sand level is not maintained, the inside of the rear curb determines body length available. Moving the brisket board ahead about 6 inches or the thickness of the curb can help.

Sand accumulation in the manure can be as high as 75 pounds per stall per day. Sand-laden manure is heavier than manure without any bedding (75 to 80 lbs /cu ft vs. 62 lbs /cu ft). Besides being abrasive to equipment, the sand in the manure inevitably settles out during an extended storage period, making pumping difficult. Alternatives for handling sand-laden manure differ primarily in length of storage, level of dilution, and requirements for labor and equipment.

Freestall Management

Proper stall management includes a minimum twice-daily inspection and removal of wet bedding and manure, as well as additions of dry bedding once or twice a week. At least twice-a-day removal of manure from alleys is essential as well. If stalls are neglected and contain excessive moisture or manure, bacterial populations may exceed critical values, markedly increasing the rate of udder infections.

With stall bases of less permanent materials such as clay, holes created by the action of the hooves must be filled periodically. Maintaining the stall bed higher in front discourages cows from lying diagonally in the stall. A relatively flat surface sloping up towards the front allows the cow to lie down and rise more easily and to lie more comfortably. Keep stall partitions and other hardware in good repair.

Ventilation of livestock facilities is essential to maintaining a proper environment for the animals being housed. Desirable conditions in stalls depend on proper ventilation as well. With adequate air exchange, the moisture produced by the animals is removed, and the inside air retains its potential to take on additional moisture. The greater evaporation rate associated with drier air results in drier alley surfaces and drier bedding.

In hot weather, cows show a preference for stalls with good air movement. Thus, barns should be well-ventilated in summer, and stall fronts and partitions should be open to allow ventilating air to move through the stall space.

Hot weather combined with inadequate air movement through stalls may cause cows to lie elsewhere. Most often they seek a wet alley surface or other highly contaminated area in an effort to increase the rate of heat dissipation from their bodies. Again, attention to summer ventilation is essential.

Floors

Concrete floors (3,500 psi) must have adequate texture for good footing. Secure footing reduces injuries from slipping and falling, enhances cow movement to feed, water, and stalls, and improves heat detection.

In livestock housing, wood-float and broom-finished surfaces become smooth in time due to tractor scraping and constant animal traffic. Select the degree of floor roughness based on the intended use and animal type.

New floors can be scored or grooved with a homemade tool as they are placed, Figure 4-7. Make grooves up to 3/8 inch deep, up to 1/2 inch to 1 inch wide, spaced up to 4 to 5 inches on center with parallel grooves in a single direction, up to 6 inches

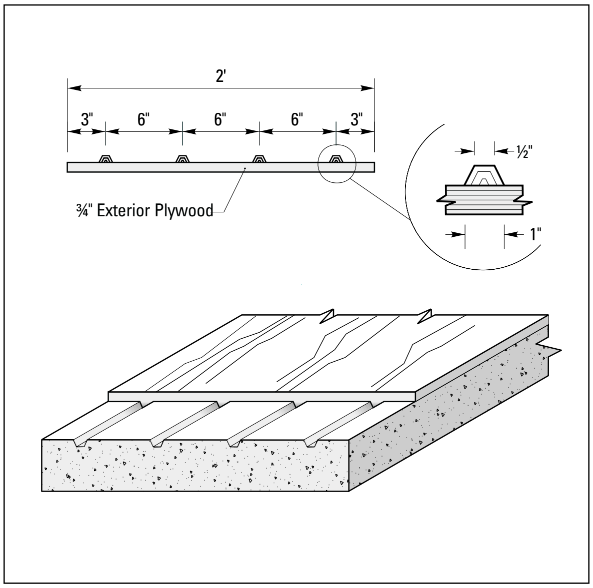


Figure 4-7. Homemade beveled groover.

on center in a diamond pattern. Make grooves parallel to alley length when flush or alley scrape manure removal is used. Grooves are typically in a diamond pattern. Grooving should be done shortly after concrete is placed and before it sets up too much. The finished grooving should leave the area between the grooves flat, and the edge of the groove should not have a ridge. Wide grooves make cleaning and disinfecting more difficult and can cause foot and leg problems in smaller animals.

With new floors, where disinfection is required and grooves present a problem, aluminum oxide can be added to the surface when the floor is poured. Apply aluminum oxide grit (as in sandpaper) at 1/4 to 1/2 pounds per square foot before the concrete sets. Coarse grit (four to six meshes per inch) is recommended.

Existing slick floors can be grooved with a mechanical saw (similar to ones used for sawing concrete) or painted with chlorinated rubber paint or exterior latex. For additional traction, sprinkle with sawdust or coarse ground cornmeal while paint is wet. Repaint annually.

Badly worn but sound floors can be resurfaced with a concrete overlay. Bonding a thick overlay to an existing floor requires special cleaning and concrete mixes.

Several tasks should be completed prior to using the new flooring for livestock. First, any *stalagmite type* roughness or sharp, very rough surfaces should be removed from the surface of the concrete. These *stalagmites* can be removed by scraping the new concrete with a steel blade before the concrete fully cures. Dragging a concrete slab or block over the concrete surface several times can also be used to smooth down the rough surface. Second, the entire floor should be cleaned with a power broom to remove all loose concrete and any gravel. Loose concrete or gravel can cause injury to feet and must be removed before use. Finally, the concrete should have cured for at least 7 days to minimize adverse reaction of livestock to the new concrete.

A machine called a *scabbler* pounds the concrete surface with a series of hammers, providing an alternative roughening treatment.

Alley Slope

The design slope of alleys in freestall barns may vary from 0 to 4%, depending upon circumstances. Usually, some slope is desirable to control drainage in the event of an unexpected leak from a waterer. This helps to ensure the leaking water flows to a certain location where it can be managed (perhaps to the manure storage). A small elevation difference between the two ends of an alley (6 inches or so) accomplishes this goal.

To drain concrete floor surfaces and avoid puddling of water, a minimum slope of 1.5 to 2% is recommended. This amount of slope is generally required in order to overcome the birdbaths left in concrete floor surfaces as a result of the inability to finish the surface as a perfect plane. Therefore, a slope of at least 1.5% drains the majority of liquids (urine, for example) from a freestall alley, resulting in drier alley surfaces.

For manure flushing systems, slope may vary from 1 to 4% depending upon the method of releasing water onto alleys and related barn construction features. A sloped alley also places freestalls on a slight slope across the stall width. This encourages cows to lie with their legs in a down-slope direction, which may reduce the likelihood of stepped-on teats.

If the waterers in the barn are gravity fed, all waterers on a particular line must be at the same level. Thus, there can be no elevation difference between sections of the barn where these waterers are located.

Feeding Fences, Bunks, Mangers, and Waterers

A post-and-rail feeding fence is usually used for fence-line feeding, as in a drive-through freestall barn. The animal reaches over a short concrete wall for feed. Elevate the feed surface 3 to 6 inches above the cow alley. The rail, which defines the upper limit

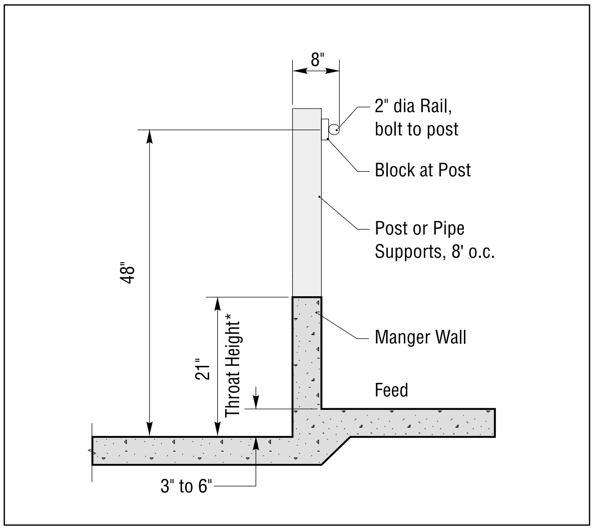


Figure 4-8. Post-and-rail feeding fence for cows.
*Reduce throat height for heifers and if using headlocks.

of this space, is made of pipe, plank or cable and is positioned as shown in Figure 4-8.

Design feeding spaces using Table 3-5. These space requirements can be met in open dry-lot systems and are still recommended for situations where mature cows are all expected to eat at once. However, freestall barns in colder climates typically allow less feeding space per cow. While 18 to 24 inches feed space per cow appear adequate when a TMR is available most of the day, these space recommendations must be continually reevaluated as barns are designed for the higher producing cows of the future, or as over stocking in a group occurs.

Provide sufficient volume to hold the amount of feed delivered at a feeding, especially when feeding only once per day.

Self-locking gang stanchions, a variation on the divided feeding fence, can restrain animals and permit selective feeding. A lever mechanism opens or closes all stanchions simultaneously. Desirable features are individual or group cow release, self-locking stanchion as a cow lowers her head after entering, and a quick release for downed cows. Feed space for self-locking stanchions is either 24 or 30 inches per opening.

Additional planning is needed if designing a post-and-rail feeding fence with the possibility of converting to self-locking gang stanchions in the future. The manger wall in a post and rail feeding fence manger is higher than the manger wall used for self-locking gang stanchions. The key to the design of the manger wall is to provide for the proper throat height. Because designs of self-locking stanchions vary, request accurate dimensions from the manufacturer of the type of self-locking stanchions being considered.

Manger Surfaces

Concrete used in dairy facilities must be resistant to manure, freezing and thawing, expansion and contraction, feed acids, and abrasion from animals and equipment. To be strong and resistant, concrete must be properly mixed, handled and cured. Concrete must withstand forces from livestock, vehicles, soil, and manure, Table 4-2.

In concrete, cement and water form a paste that hardens and glues the aggregates together. Concrete quality depends on the binding qualities of this cement paste. The strength and durability of concrete depend primarily on the water-cement paste. The strength and durability of concrete depend primarily on the water-cement ratio. Enough water is needed for full curing, but excess water leaves voids when it evaporates, which weakens the concrete. Strength will likely be adequate when durability is adequate.

When a mix is too stiff to handle well, use a super plasticizer or add both cement and water to the mixer, then reduce the amount of aggregates in subsequent batches. Do not just add water, which weakens concrete, Table 4-3. Adding one gallon of water to a cubic yard of concrete can:

- Decrease strength by 200 to 300 psi.
- Increase shrinkage potential by approximately 10%.
- Waste as much as a bag of concrete.

Eating surfaces must be smooth, clean, and free from leftover feed and other debris to encourage feed intake and help control disease. In new construction, use high-strength concrete (4,500 psi) to prolong the useful life of the manger surface used for feeding silage and other feeds that tend to etch the concrete, Table 4-3. Or, line the manger with a resistant material such as ceramic tile. Inspect manger surfaces for etched conditions, exposed aggregate, or worn, splintered wood; repair as needed.

Table 4-2. Recommended floor thickness.
Edge thickness is twice the thickness of slab for 2 foot width.

Application	Thickness (inches)
Feeding aprons, with minimum vehicle traffic	4
Paved feedlots, building driveways	5
Heavy traffic drives (grain trucks, wagons, manure spreaders)	6

Table 4-3. Concrete strengths.

Durability (weather and chemical resistance) and strength depend primarily on water-cement ratio. Adding extra water rapidly lowers durability and strength. Only 1/2 gal/bag (about 3 gal/yd) separates the groups in the table. Follow plans or specifications when available. Materials in this handbook are based on the following recommendations. One bag cement = 94 lb; 1 gal water = 8.34 lb.

Application	Maximum approximate strength (psi)	Minimum Water-Cement ratio (Gallons water per bag cement)	Minimum Water-Cement ratio (lb water per lb cement)
Mangers	4,500	5.0	0.44
Feedlots, floors, drives	3,500	6.0	0.53
Footings	3,000	6.5	0.62

Table 4-4. Drinking water requirements.

Animal	gal/hd/day
Calves (1-1.5 gal/100 lb)	6-10
Heifers	10-15
Dry cows	20-30
Milking cows	35-50[a]

[a] Design water supply to deliver 6 to 7 gpm per cow with cows drinking simultaneously.

Waterers

Provide at least one watering space or 2 feet of tank perimeter for every 15 to 20 cows, Table 4-4. At least two waterer locations are needed for each group of cows. Provide more space and more locations when two-year-olds are housed with older cows. Limit water depth to 6 to 8 inches for fresher water and less debris accumulation. Provide drains in tanks or use tip troughs for ease of cleaning.

Access to adequate fresh water becomes more important in summer as consumption per cow increases. Provide space for extra water tanks in the barn for use during hot weather. (See **Cross Alleys**, page 40). Heaters will not be required as these tanks are removed for cold weather.

Barn Layout

Barn layout evolves from a management plan that views the animals not as a herd but as a logical assembly of management groups. Actually, a barn is a management tool used to implement the management plan, rather than as a place intended strictly to house animals. Barn layout design evolves as:

- Management groups are defined.
- Needs of animals are established.
- Essential tasks prescribed by the management plan are outlined.
- Future expansion is considered.

Freestall barn layout depends on the relationship between the feed and stall alleys, Figure 4-9. With the trend toward feeding complete mixed rations and the use of scale mixers for assembling these rations, feeding systems can be classified as stationary, Figure 9-8, or as mobile, Figure 9-9, according to use of the scale mixer. See Chapter 9, **Feeding Facilities**, for additional information on mixers.

In a mobile feeding system, the scale-mixer is mounted either on a tractor-drawn trailer or a truck. Horizontal silos for corn silage and possibly grass silage and bulk storage for dry grains and supplement are compatible with this system. A tractor with a front-end loader loads feed components into the mobile scale-mixer. The scale-mixer itself is used to deliver the mixed ration to the bunk.

Mobile mixers are more flexible than stationary ones; feed storage location is less critical and animals can be fed at remote sites. Mobile feeding systems are time and cost efficient for herds of 100 cows or more.

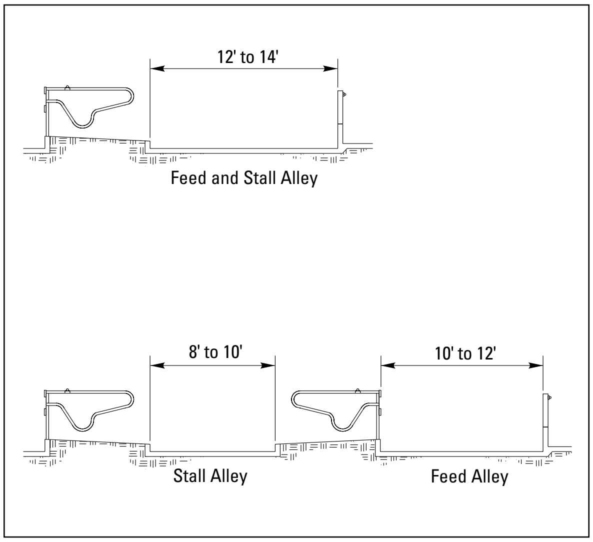


Figure 4-9. Alley types.

Barn Layouts for Mobile Feeding

Several different freestall barn layouts, based on mobile feeding systems, are shown for illustration purposes. These layouts are not presented as ultimate plans. Rather, each barn layout applies to a particular set of requirements associated with a management plan developed for a particular situation. But, collectively, these layouts illustrate concepts related to barn management groups, flexibility, future expansion, and ventilation as related to barn layout.

Figure 4-10 shows a four-row, drive-through freestall barn with approximately 200 freestalls and a milking center. There are four cow groups, but the barn can be built to accommodate groups of different sizes. For example, all stalls might be occupied by milking cows—67 in a high production group, 33 in a medium production group, 33 in a low production group, and 67 in their first lactation. Or, there might be three groups of milking cows (67 high, 33 low, and 67 first lactation) along with a group of 33 dry cows. Other combinations are possible as well. Future expansion occurs as additions are made to each end of the barn. For example, based on a double-8 milking parlor the future expansion would be limited to 400 to 500 stalls. See Chapter 9, **Feeding Facilities**, for more information on feeding systems.

A variation on the freestall arrangement in a four-row drive-through freestall barn is shown in Figure 4-11. Freestall rows are placed head-to-head to better utilize wind forces for ventilation in barns where walls are removed in summertime. The amount of open wall area is increased because no stalls are mounted on the

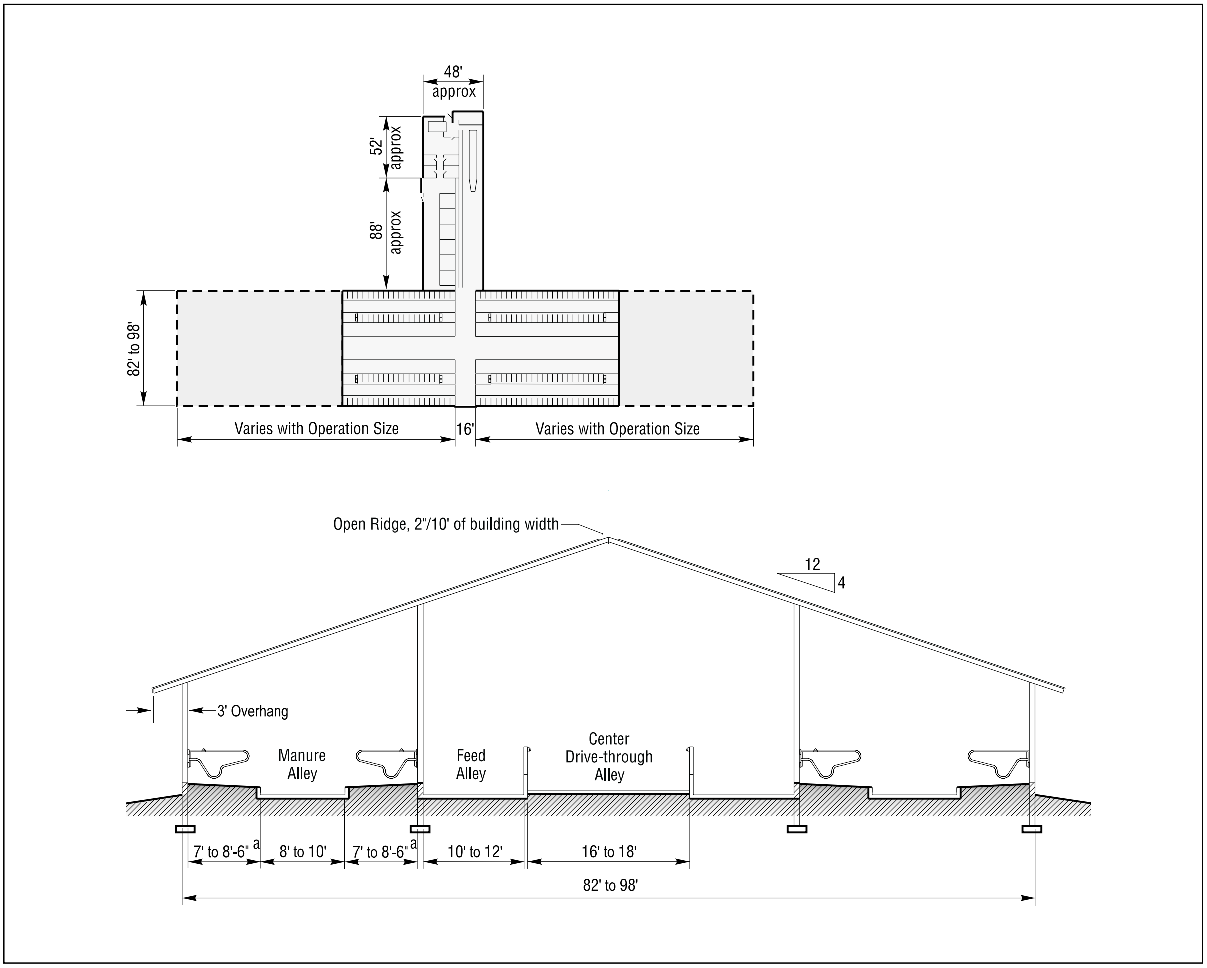


Figure 4-10. A four-row tail-to-tail freestall barn with drive-through feeding and stalls along the outside walls. Based on double-8 milking parlor. Dotted extensions indicate opportunities for expansion from 200 to approximately 400 stalls. If this option is planned then size holding area to accommodate about 100 cows. [a]Stall length depends on type of partition used.

outside wall. High-tensile-wire, corral-type fence can be used in the walls. Further, moving the freestalls away from outside walls reduces problems with incoming rain and sun in barns with full-wall ventilation for summer. A disadvantage is that cows may not be locked away from all freestalls as is the case when all cows are confined to the feeding alley, Figure 4-10.

The barn in Figure 4-11 has additional cross alleys in two of the quadrants, which enhances the ability to manage animals in groups. When desired, each of these quadrants may be subdivided for two groups by placing temporary gates across the alleys. For example, a larger group of milking cows may be further subdivided for feeding purposes. The group farthest from the milking center will travel through the larger group's area to get to the milking center. A section of freestalls may be devoted to close-up dry cows where they may be fed a special ration and will likely be observed more often; or to a group of cows newly-freshened. When subdividing groups, the resultant dead-end alleys are acceptable only for very small groups.

The barn layout in Figure 4-12 is suitable for 60- to 300-cow dairies with wings extended in both directions. For larger herds, similar barns may be constructed parallel with the first. Separation distances of at least 75 feet are recommended (more if summertime prevailing winds are marginal or restricted).

Figure 4-13 shows layout options for sites with multiple buildings.

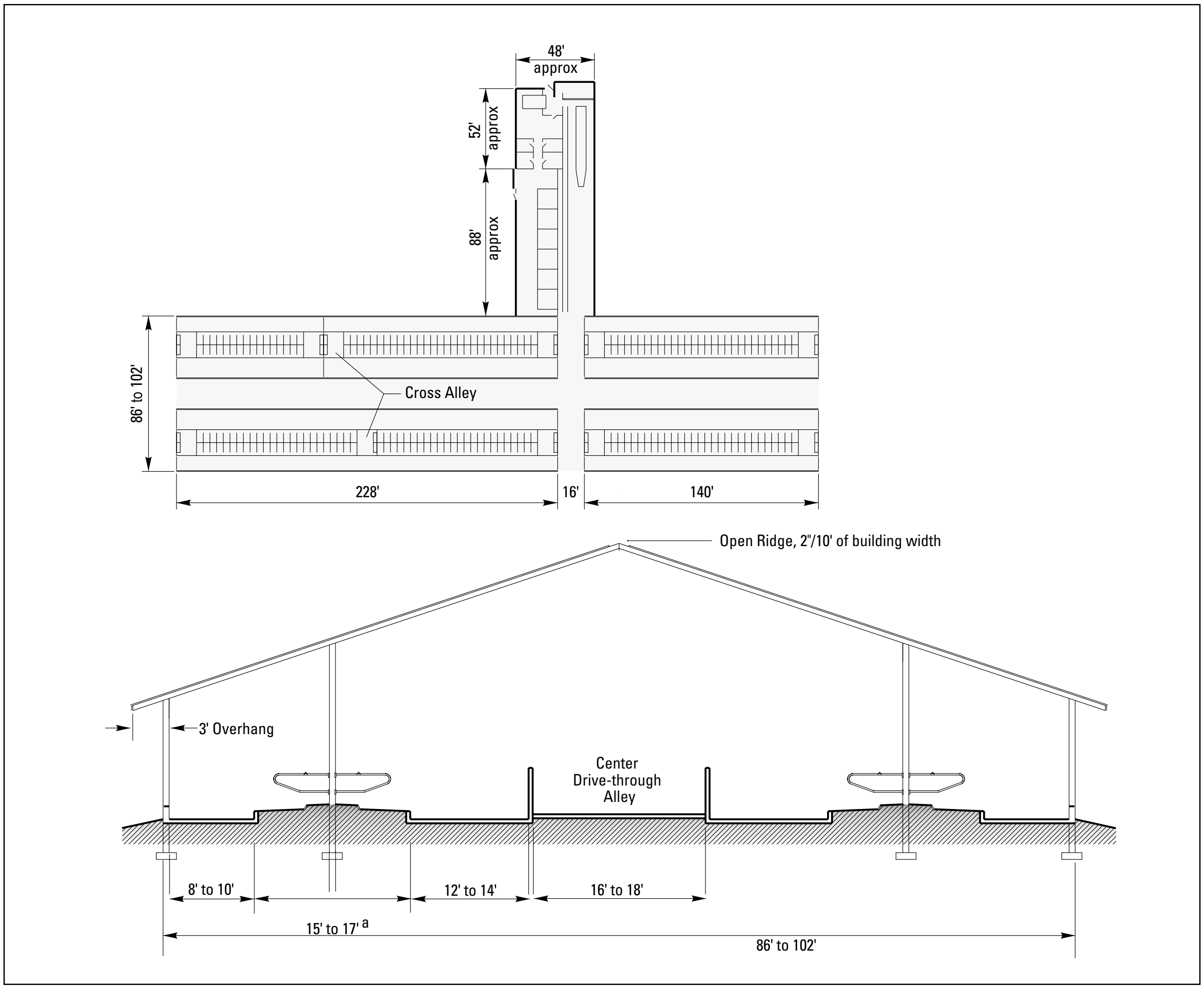
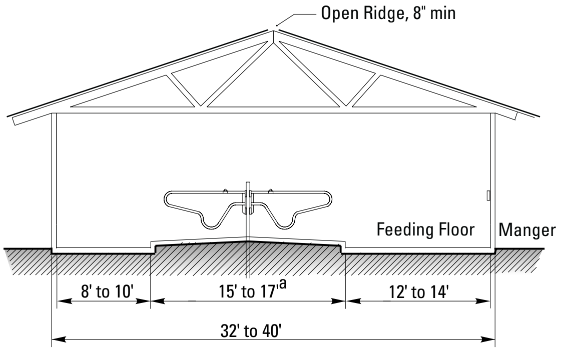
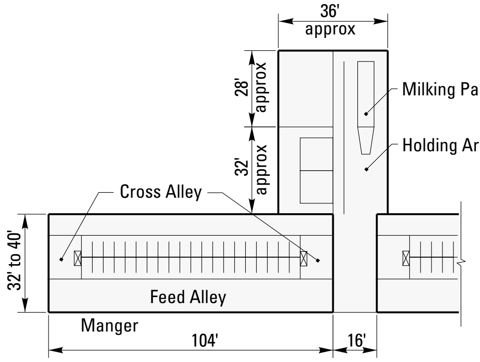


Figure 4-11. A four-row face-to-face freestall barn with drive-through feeding and alleys along outside walls. Additional crossover areas allow for subdividing groups.
[a] Stall length depends on type of partition used.



a. Two-row barn cross-section.
[a] Stall length depends on type of partition used.



b. Two-row barn layout.

Figure 4-12. Two-row barn with drive-by feeding. Alleys along outside walls.

Layouts with Reduced Bunk Space Per Cow

A six-row drive-through freestall barn has a center drive alley for feeding with a mobile scale-mixer, but with three rows of freestalls on either side, Figure 4-14. This barn is typically 104 to 116 feet wide. A variation on this arrangement is a three-row freestall barn with fenceline feeding, Figure 4-15. A three-row barn is typically 44 to 48 feet wide.

The six-row arrangement results in lower building cost, about 20% less per stall than a four-row barn. However, costs for freestalls, waterers, and doors remain essentially the same. Also, in a six-row barn, building length (same as alley length) for a given number of cows is less. Shorter alley length may be of advantage if mechanical alley scrapers are installed. Because manure accumulation per unit length of alley will be greater because of the higher animal density scraping frequency may need to be increased. The same applies to a three-row barn.

Feed bunk space in six-row and three-row barns is about 1-1/2 foot per cow. Research has shown reduced bunk space to be of no problem if a total mixed ration is fed. However, the most recent research on reduced bunk space (1 foot vs. 2 feet) was done with cows averaging about 82 pounds of milk per day. The effect on groups of cows averaging 100 pounds of milk or more has not been studied. High stocking density (more than one cow per stall) reduces bunk space per animal even further.

When headlock stanchions are installed along the feed manger line in a six-row barn, the resulting number of stanchions is less than the number of stalls. This reduces the effectiveness of the stanchions when restraining cows for treatment purposes.

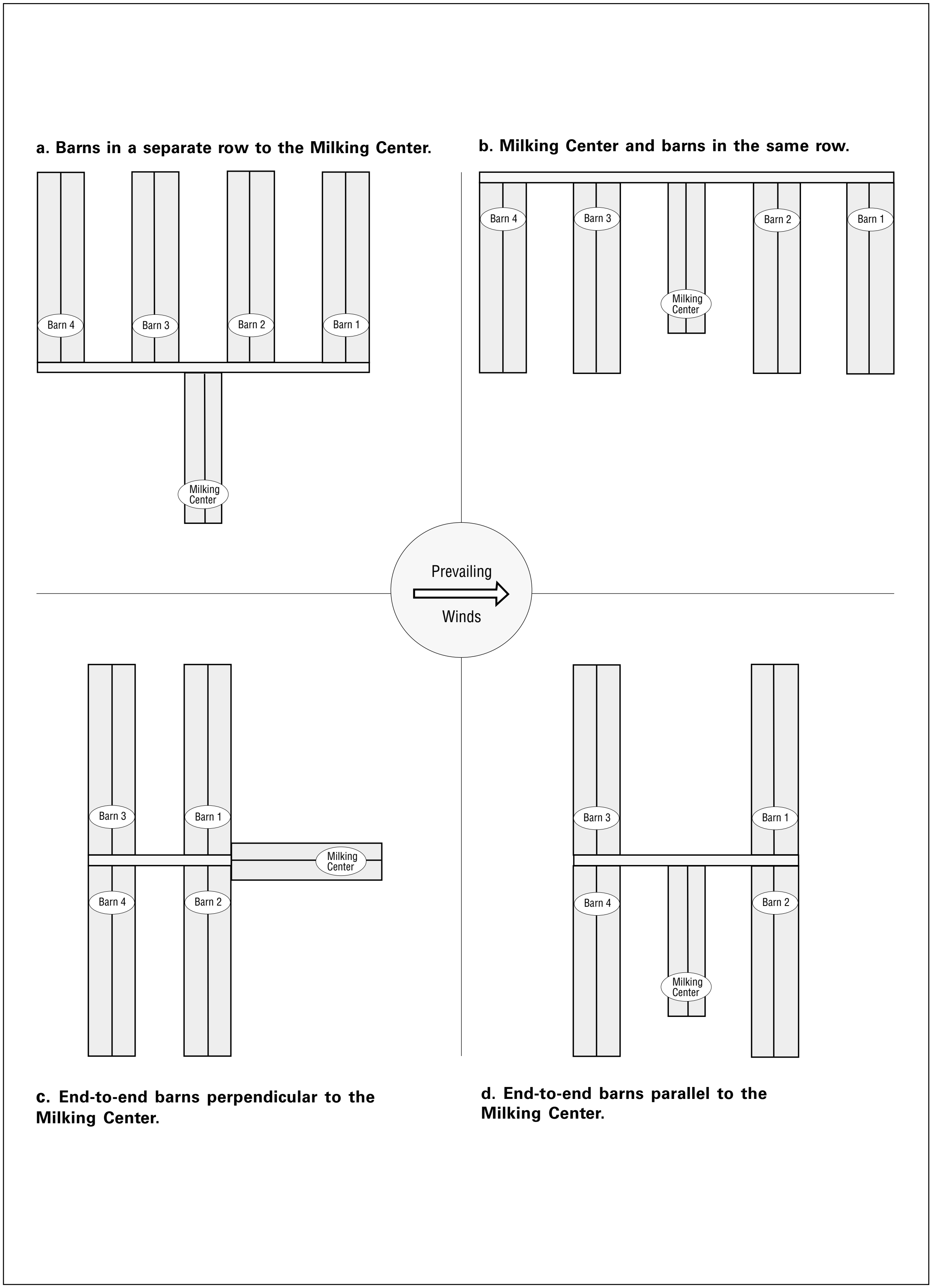
Ventilation is another concern with a six-row arrangement. With a given sidewall height and wind speed in the summer, 50% more cows share the total ventilation rate in the six-row barn compared to a four-row barn. The resulting higher temperatures and relative humidities that result may cause additional animal stress, particularly with high-yielding cows.

Examine carefully the added costs of changes recommended for a six-row barn intended to correct deficiencies compared to a four-row. The added costs of features such as additional sidewall height, more frequent crossover alleys and wider freestall spacing may exceed the initial cost savings of the six-row barn.

Cross Alleys

A cross alley at each end of an interior freestall row increases accessibility to feed, water and freestalls and allows escape from aggressive cows. See Figure 4-12. Also, a cross alley is a convenient location for a waterer. Provide additional cross alleys for groups larger than 60 to 80 cows or to allow subdividing a group, Figure 4-10. Cows should not walk more than 15 to 20 stall widths to a cross alley. Therefore, locate cross alleys every 30 to 40 stalls.

If a waterer is located in crossover, the minimum clear width should be 12 feet with 15 feet preferred. Elevate cross alleys above the cow alleys to reduce manure flowing into the cross alley during scraping. Crown the cross alley to promote self-cleaning by animal hoof action. In most arrangements, a properly elevated and crowned cross alley eliminates the need to navigate the area with equipment.



a. Barns in a separate row to the Milking Center.

b. Milking Center and barns in the same row.

c. End-to-end barns perpendicular to the Milking Center.

d. End-to-end barns parallel to the Milking Center.

Figure 4-13. Farmstead layouts for multiple freestall barns on single site.
Ventilation and the movement of animals, feed, and manure are important considerations.

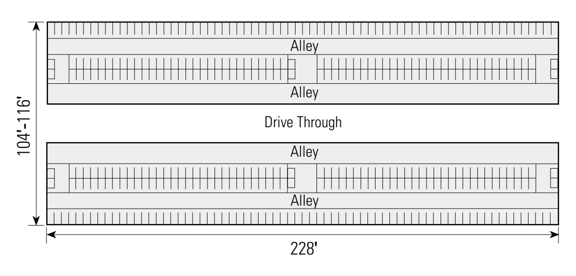


Figure 4-14. Six-row barn with drive-through feeding.

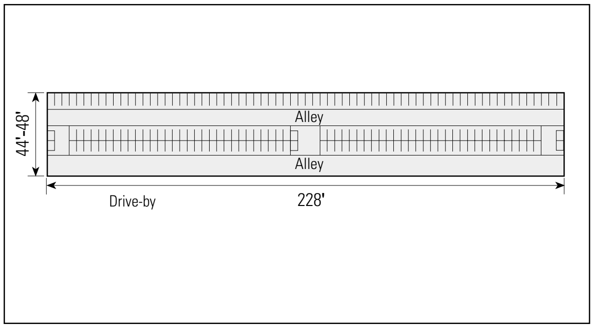


Figure 4-15. Three-row barn with drive-by feeding.

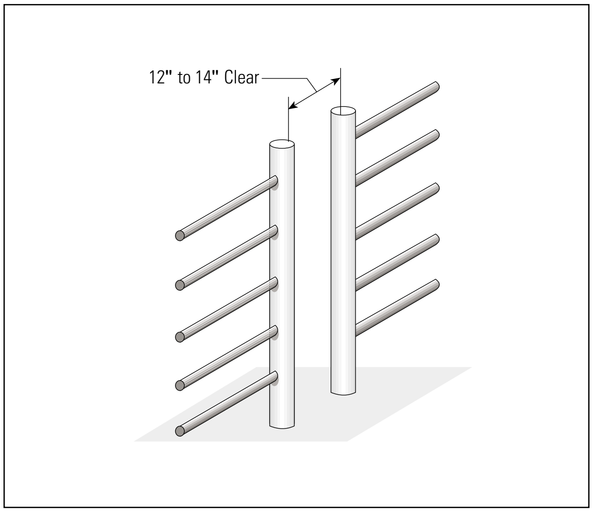


Figure 4-16. Personnel or safety pass.

Personnel Passes

Personnel passes are narrow vertical openings in gates or fences that allow a person to pass through. Personnel passes are typically 12 to 14 inches wide, Figure 4-16. Locate personnel passes wherever it is anticipated that workers would otherwise need to climb over a fence or open a gate on a regular basis.

Housing for Dry Cows

Housing needs for dry cows change as the cows get closer to calving.

Early Dry

The early-dry-cow category begins with a successful transition from a lactating state to a non-lactating (dry) state. Early dry cows are housed as one group for approximately 40 days. Early dry cows may be housed on pasture, on a bedded pack, in freestalls, or in comfort stalls.

Transition

Approximately two to three weeks prior to expected calving date, move dry cows and heifers to the pre-calving group. The pre-calving management program calls for more careful attention to nutrition and sanitation since cows and heifers near, during, and after giving birth to offspring are at greater risk for infectious diseases and non-infectious disorders. Housing for pre-calving cows and heifers should allow for frequent observation and be convenient to the maternity area. Freestall housing is recommended to reduce exposure of the udder to mastitis-causing organisms. Restricting access to outside dirt lots reduces risk of mastitis.

Calving

Immediately prior to calving time, move cows and heifers to individual pens that are separate from other animals, especially younger calves. The location of this area and assignment of responsibilities to personnel should encourage frequent observation. Then, the animal that has just calved should be observed frequently for problems before moving her to the milking herd. The newborn calf, having received about 2 to 4 quarts of high-quality colostrum, a dry haircoat, a disinfected naval, and other medical treatments, should be moved to a calf hutch or individual pen until weaning.

Design Considerations

Freestalls must provide a clean, comfortable lying space for cows and heifers. Also, animals should be able to enter and leave stalls easily and to lie down and rise without interference. Stall components should avoid contact with the animal's body, thereby lessening the potential for injury. Stall partitions for dry cows should be 48 inches on center, which is slightly more than the space allotted for lactating cows.

Bedded-pack resting areas for groups of pre-calving cows and heifers should allow at least 100 square feet per animal, assuming that animals have access to a scraped feed alley or outside lot. Early dry cows should be provided at least 50 square feet per cow.

Individual pens for calving should be 12 x 12 feet, or 10 x 14 feet. A 4-inch layer of sand on concrete provides good footing for cows. Cover the sand with a deep layer of long straw. Dirt floors covered with straw bedding also will provide improved footing. Provide access to pens for removing animals unable to walk or stand.

Other facility design considerations are these:

- Easily cleaned feeding space.
- Convenient feeding access.
- Quality water in easy-to-clean waterers.
- Stanchions or headgates for restraining animals to enhance safety.
- Provisions for lifting cows unable to stand.
- Good lighting and convenient electrical outlets.
- Observation aids such as video cameras and noise monitors.
- Access for veterinary treatment.
- Access for removing dead animals.
- Access for cleaning pens.

Example Barn Layouts

The freestall barn plan illustrated in Figure 4-17 shows housing for dry cows, bred heifers, and heifers of breeding age. A particular group may be subdivided using temporary gates across the alleys, allowing greater flexibility in using the barn to accommodate a variety of management strategies. For example, the dry cows may be divided into two groups—one group for the early dry cows, the other for the pre-calving cows. Various group sizes may be created merely by shifting the temporary gates. Cows would calve elsewhere.

Advantages of this layout include:

- Heifers housed in freestalls will more likely use freestalls after calving.
- Well-designed and managed freestalls result in cleaner udders and less exposure to mastitis-causing organisms.
- Less bedding is necessary.

Disadvantages include:

- Freestall barns cost more initially than barns with bedded manure packs.
- A specific number of freestalls of each size reduces flexibility in later adjustments to management or grouping strategy.

A barn with multiple pens as shown in Figure 4-18 may be used for cows needing special attention. Combine two or more pens for groups of pre-calving cows and cows that have just recently calved; use individual pens for cows at time of calving. Or, place cows in individual pens from two to three weeks prepartum through calving.

Each pen has a waterer and a stanchion. Cow traffic is along the outside walls; the center aisle is reserved for personnel. Gates serve as pen dividers, allowing two or more pens, each intended for one cow, to be combined into a larger pen for a small group. A small storage room for supplies and portable milking equipment as well as an area in which to sanitize equipment and utensils could be added.

Advantages of this layout include:

- The barn provides individual pens for calving.
- Pre-calving cows and cows that have just calved may be housed as a small group by shifting gates to form a larger pen.
- As an alternative, a pre-calving cow could be moved to an individual pen in this barn two to three weeks ahead of her expected calving date,

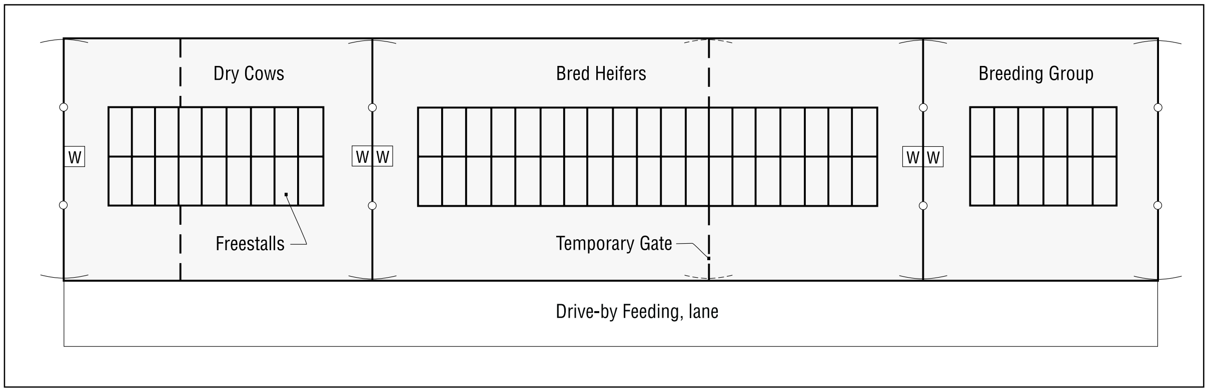


Figure 4-17. Freestall barn for dry cows, bred heifers, and heifers of breeding age.

allowing her to adjust to new surroundings and isolation.

Disadvantages include:

- Housing cows in individual pens or small group pens requires more labor than in freestalls or other group arrangements, especially if a cow is moved to this barn two to three weeks ahead of expected calving.
- Because calving dates cannot be predicted with sufficient accuracy, moving cows to this barn just three to four days ahead of calving is impractical. So, moving cows to the barn when calving is imminent seems to be the best strategy, and the barn should be located near housing for pre-calving cows.
- Frequent observation of pre-calving cows must not be left to chance but be an assigned responsibility to assure that cows will, in fact, be in the calving barn at calving time.

Group pens for pre-calving cows and individual pens for cows at time of calving are shown in Figure 4-19. Pre-calving cows and heifers can be moved to this barn into a group setting 2 to 3 weeks ahead of calving. Then they are near the maternity area, which allows an animal to be easily moved to an individual pen just ahead of calving.

Advantages of this layout include:

- Housing for pre-calving cows and heifers is close to the maternity area.
- With frequent observation, animals will spend a minimum amount of time in the individual pens, reducing labor.

Disadvantages include:

- Moving pre-calving cows and heifers to individual pens only a few hours before calving requires frequent observation; this observation task must be an assigned responsibility.
- The bedded pack in the group pens may increase exposure of udders to mastitis-causing organisms. To minimize this risk, frequent removal of manure and soiled bedding followed by additions of clean bedding is essential.

The layouts in Figure 4-20 and Figure 4-21 provide freestalls for a group of pre-calving cows and heifers, and individual pens are provided for calving. The layout of Figure 4-20 is more readily expandable; additional freestalls and pens could be added to either end. The layout of Figure 4-21 allows dividing the freestalls into two groups; e.g., early dry and pre-calving, using temporary adjustable gates across the two alleys.

Advantages of these layouts include:

- All important design criteria are met.
- An animal can be readily moved from the freestall area to an individual pen when calving is imminent, lessening labor for caring for animals in the individual pens.

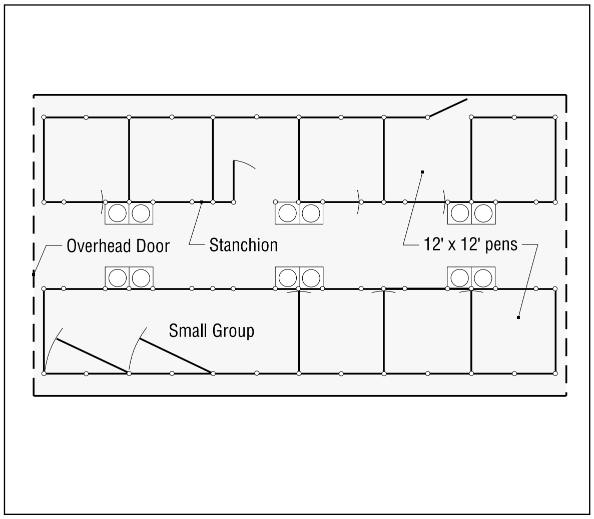


Figure 4-18. Separate handling/treatment barn. Cows requiring additional observation, treatment, or having other special needs can be separated from the milking herd and housed in a separate barn. Include a small storage room for supplies and portable milking equipment.

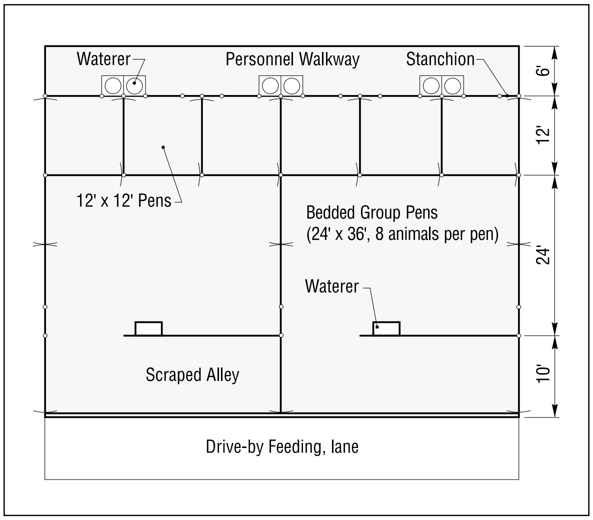


Figure 4-19. Barn with bedded group and individual pens. Group pens used for pre-calving cows and individual pens used for individual cows at calving time. This layout is easily expanded by adding on to either end.

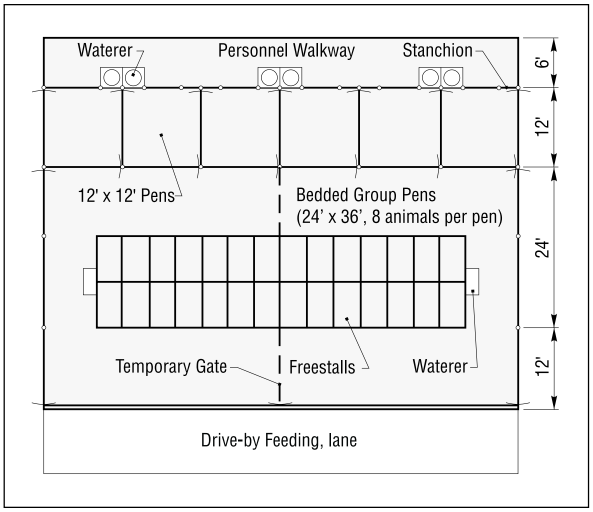


Figure 4-20. Barn with head-to-head freestalls and individual pens.
Freestalls used by pre-calving cows, pens used by individual cows at the time of calving. This layout is easily expanded by adding on to either end.

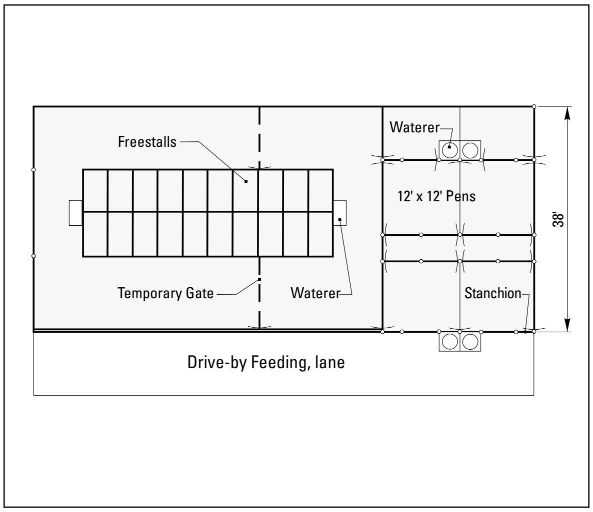


Figure 4-21. Barn with head-to-head freestalls and individual pens at the end of the building.
Freestalls used by pre-calving cows, pens used by individual cows at the time of calving. Given sufficient stalls, the freestall area could be divided into one group for early dry cows, and the other for pre-calving.

Disadvantages include:

- Moving pre-calving cows and heifers to individual pens just a few hours prior to calving, a labor-saving management strategy, requires that animals be observed frequently. As with previous layouts, the responsibility of detecting when animals are about to give birth and then moving them to individual pens must be assigned. These activities should not be left to chance.

Pasture

Pasture is another acceptable alternative for pre-calving cows and heifers and maternity animals, particularly when rotational grazing is practiced. Exposure of the udder to manure is less apt to occur as animals are moved frequently to clean, grassy areas. Avoid areas without grass.

Chapter 5

Milking Center

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The milking center is more than a place to milk cows, especially on farms where milking occupies less than a majority of the day. A milking center for freestall housing can include a milking parlor, holding area, utility room, milk room, lounge area, office, and treatment area. Consider providing for the capability of sorting cows as they leave the parlor, and install handling and treatment facilities in the area alongside or opposite the holding area. On smaller dairies, the time remaining after milking allows for using the holding area and cow lanes in the milking center for other purposes

On larger dairies, milking may occupy most hours of the day. Handling and treatment (and even sorting) operations are usually apart from the milking center opposite the holding area.

Milking center dimensions depend on milking parlor type, cow size, milk tank size, type, equipment location, and type of washing and milk handling equipment. Coordinate construction with the building contractor and equipment supplier

The U.S. Public Health Grade A Pasteurized Milk Ordinance requires approval of a milking facility prior to operation. Obtain approval of a plan for each farm before construction or remodeling begins. Contact the milk buyer about approval procedures before building. Approval agencies usually require an overall plan drawn to scale and dimensions, showing electrical lighting, ventilation, insulation, waste disposal, and water supply

Milking Parlors

Milking parlor type is the first consideration in designing milking centers. Parlor type and size influence:

- Milking center size, layout, and location.
- Cow traffic patterns.
- Milking routine.
- Amount of mechanization.
- Profitability.

Parlor size depends on:

- Group size.
- Initial mechanization.
- Plans for future improvements.
- Number of cows milked.
- Available labor and capital.
- Milking time available.
- Milk production level.

Parlor selection depends on:

- Herd expansion.
- Initial investment.
- Annual costs.
- Personal preference.

Selection

Consider total chore time, including the following tasks, when selecting a milking parlor:

- Parlor setup.
- Actual milking.
- Changing cow groups.
- Cleanup.

Note the only segment of chore time the parlor itself affects directly is the time spent actually milking. Keep this in mind when comparing how fast parlors milk. Milking performance figures for milking parlors, expressed in cows per hour on a steady-state basis, are useful for comparing and estimating milking time. But the total labor required to accomplish milking is a more important figure to have in mind when selecting a milking parlor.

To estimate total chore time and overall labor efficiency, sum up the times estimated to be spent on each aspect of the milking operation. For estimating purposes, assume 20 minutes for parlor setup, 30 to 45 minutes for parlor cleanup, and 15 minutes per 100 cows for changing groups (although numerous factors affect actual time spent on each task). To estimate actual milking time for herringbone and parallel, assume 4 to 5 cows per hour per milking stall. Estimate the time required for milking in an assumed milking parlor of a given size and with a given degree of mechanization by dividing the total number of cows to be milked by the quoted throughput in cows per hour. But be aware that a quoted throughput can be considered only an approximation. Numerous factors affect parlor performance, effective utilization of labor, and quality of the milking operation.

On small dairies, actual milking time is a smaller part of the total chore time than on larger dairies. So investing in larger parlors and in more mechanization to achieve higher throughput affects a smaller percentage of the total time required for milking. In other words, smaller dairies benefit less from added investments in larger parlors and mechanization than do those with more cows. Also, the annual costs of buildings and equipment have to be borne by fewer cows.

Parlor Types

When choosing a parlor type, evaluate the investments in a milking parlor in terms of benefits and cost per cow. While initial investment and annual cost are important to parlor selection, the least-cost parlor system may not always be the best alternative when available labor, milking time, and expansion potential are considered.

Flat-barn

Flat-barn parlors with 6 to 16 stalls have been used as an alternative to more expensive elevated parlors, Figure 5-1. A flat-barn parlor can serve well until an elevated parlor can be afforded.

When making the transition from a tie stall to a freestall system, consider converting a section of the stanchion or tie stall facility to a flat-barn parlor for milking only. Install lever-lock stanchions or walk-through stanchions and a proper pipeline milking system. Automatic take-off units improve throughput labor efficiency and reduce work effort. Adapt a portion of the barn for a holding area, and use the flat-barn arrangement much like an elevated parlor. Moving cows through the flatbarn as a stall becomes available gives higher throughput than moving cows in groups.

Do not invest a lot of money in developing this system. Flat barn parlors are low cost and are intended to be used until cash flow supports the construction of a more efficient parlor design.

Side-opening

Side-opening parlor layouts are usually double-2 to double-5, Figure 5-2. The advantage of side-opening parlors is more individual cow attention, but there is a greater distance between udders compared with the herringbone. This distance becomes important when the parlor is mechanized and more cows are needed in the parlor to keep the milker and the equipment busy. Pit length increases by 8 to 10 feet for each pair of milking stalls.

Herringbone

Herringbones are the most common elevated parlor. They often range from double-4 to double-24, Figure 5-3, although some dairies use larger herringbones.

Herringbone stalls are adaptable to mechanization. The walking distance between udders varies from 36 to 45 inches depending on the manufacturer.

Cow movement improves when cows are handled in groups compared with being handled individually in side-opening and rotary parlors. A slow-milking cow, holding up an entire group, can seriously affect cow throughput in larger herringbones. Slow-milking cows may be culled or may be segregated in a group by themselves.

Parallel

Parallel parlors, Figure 5-4, range in size from double-6 to double-50. Cows stand parallel at a 90 degree angle to the operator's pit, requiring the operator to attach teat cups from the rear by reaching between the hind legs. Some designs have cows physically separated from each other by dividers activated as individual cows enter. Walking distance between cows is 27 to 30 inches.

Swing Parlor

Swing parlor designs are an attempt to minimize the investment in a parlor. Purchased herringbone or parallel stalls or home built stalls are used for the cow platform. A high line milking system is installed over the operator area. One milking unit is used on two stalls and is swung from one side of the parlor to the other side.

Rotary Parlor

Rotary parlors—tandem, herringbone, turnstile—have received some attention. Rotary parlors have up

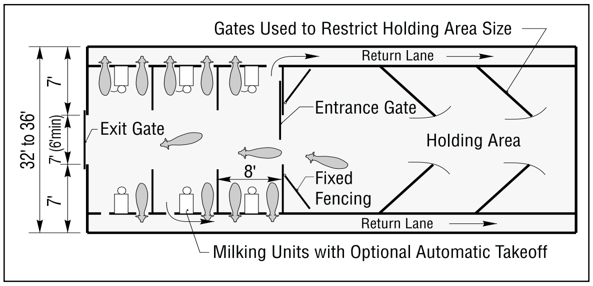


Figure 5-1. Flat-barn parlor.
Cows move to the milking unit rather than the milking unit moving to the cow.

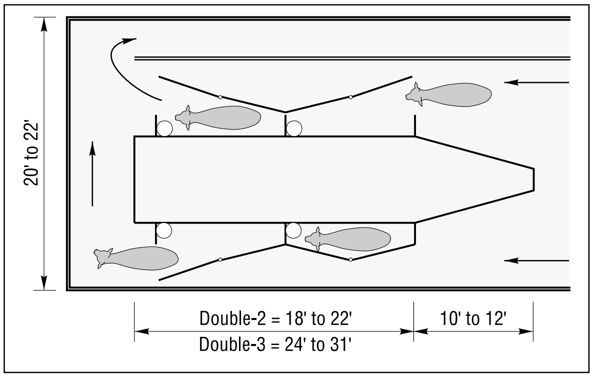


Figure 5-2. Double-2 side-opening parlor.

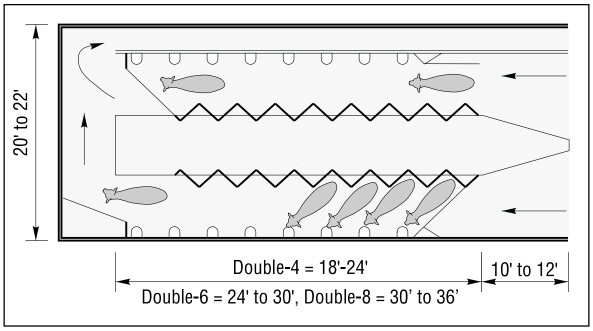


Figure 5-3. Double-8 herringbone parlor.

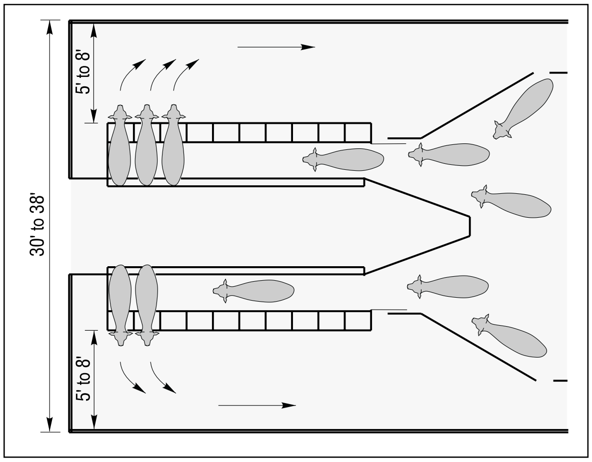


Figure 5-4. A parallel parlor.

to 80 stalls on a rotating platform. The large number of stalls is necessary to achieve reasonable throughput rates with high-yielding cows. Cows usually stand radially facing the center. Rotary parlors promote a regimented, assembly-line-like work routine. But this may result in less desirable working conditions. Operators of a rotary must meet frequent deadlines in order to maintain the pace set by the rotating platform. If the pace is too fast and the operator falls behind, elements of the work routine must be skipped or platform rotation must be interrupted. Also, a full pre-milking udder preparation routine will suffer in a rotary parlor because of the natural tendency of the operator to attach the milking machine to the cow soon after she enters. In fact, since current rates of rotation are often less than 15 seconds per stall, a single operator cannot both prepare the udder and attach the milking machine. More than one person is required to prep and install units. Extra people will be required. Platform rotation is often interrupted because of balking cows at the entrance, milking not being completed as cows arrive at the exit, operators falling behind in their work routine due to machines dropping off or other malfunctions, and other delays. Actual throughput in rotary parlors is about 80% of the calculated theoretical throughput.

Other Parlor Types

There are a variety of hybrid and specialized parlor designs available in the market place. In parabone parlors, the angle at which cows stand is between herringbone and parallel parlors. Sometimes cows are milked from the side, sometimes from the rear. Polygon parlors increase the number of sides to four to minimize the effect of a slow milking cow on parlor throughput. Robotic milking systems are just recently being introduced into the U.S. market. Housing layout is quite affected by this alternative. A robotic milking system can handle 50 to 70 cows. Automated cow ID and sorting gates are used in the system to move cows through the milking robot as they go to feed and return to the resting area.

Parlor Layout

A straight entrance from the holding pen into the milking parlor and a straight exit from the parlor are preferred for good cow flow. Turns at the entrance can slow cow movement, interrupting the operator. When cows must be turned, make the turn at the exit rather than at the entrance. Avoid steps or ramps at the parlor entrance.

Provide return lanes from the parlor to the housing unit. A single return lane is common—one group of cows crosses over the front of the parlor to exit. Return lanes outside the building should be wide enough to scrape with a tractor. Make clear openings of the inside lanes 33 to 36 inches wide to prevent exiting cows from turning around. Lanes can be hosed or hand scraped. Design return lanes so a down cow can be easily removed. Allow for sorting and catching cows for treatment from the return lane. Figures 5-5 and 5-6 show some examples of milking center layouts.

Rapid-exit Stalls

Rapid-exit stalls allow all cows in a group to move directly out of the milking stalls through individual gates or a raised barrier in front of the cows. The resulting benefit of decreasing overall exit time can be justified for larger parlors (e.g. double-10 herringbones and larger).

With a rapid-exit herringbone or parallel parlor, cow exits usually lead to return lanes along both sides of the holding area (Figure 5-6). Thus, any provisions for sorting cows must be duplicated on both sides.

Because of the two return lanes, rapid exit is not desirable where sorting, handling, and treatment are incorporated into the milking center. A single return lane from the herringbone parlor permits sorting cows into a catch lane with a sorting gate controlled from the pit and allows the cow to be held or moved into a pen having self-locking stanchions. With gates to block the parlor entrance, animals can be moved through the holding area into the treatment area for sorting, examination, or treatment. See Chapter 6, **Special Handling and Treatment Facilities**, for additional information.

Parlor Mechanization

Milking parlor mechanization depends on parlor size, available labor, initial investment, and personal preference. Increase parlor size as mechanization is added to better use labor and equipment. Automatic detachers are usually standard equipment in large parlors. Other mechanization to consider includes crowd gates, cow I.D., sorting gates, and power-operated entrance and exit gates, and indexing (adjusting front rail—a feature that shortens milking stalls).

Holding Area

The holding area confines cows prior to their entering the milking parlor. Usually this area is enclosed and is a part of the milking center, which in turn, may be connected to the barn or located in the immediate vicinity of the cow housing. To reduce

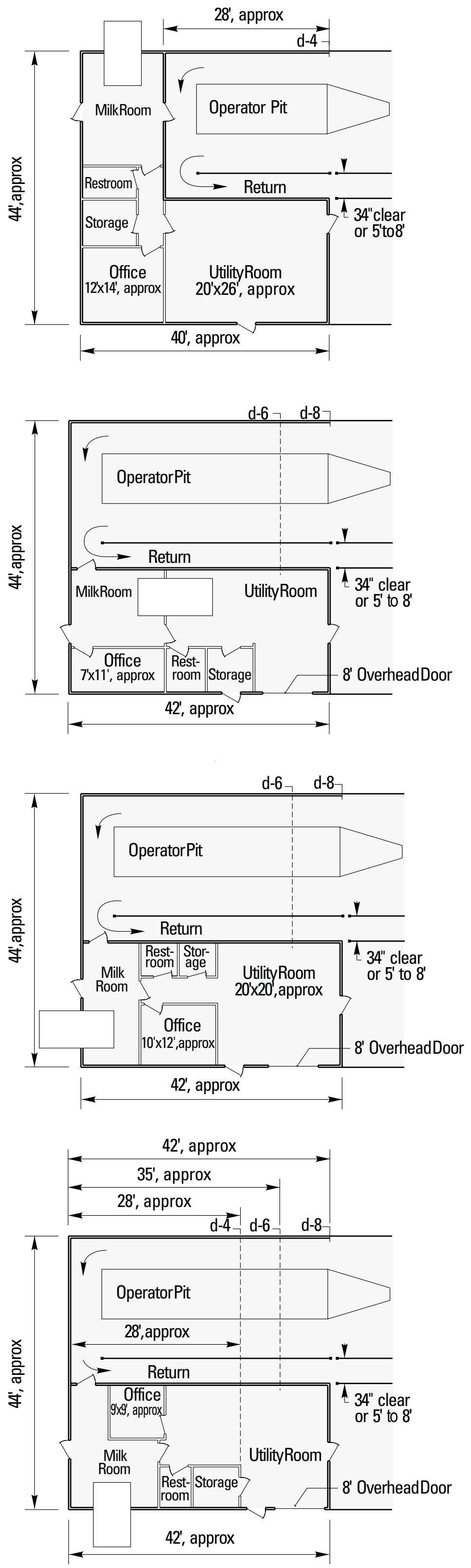


Figure 5-5. Examples of milking center layouts.

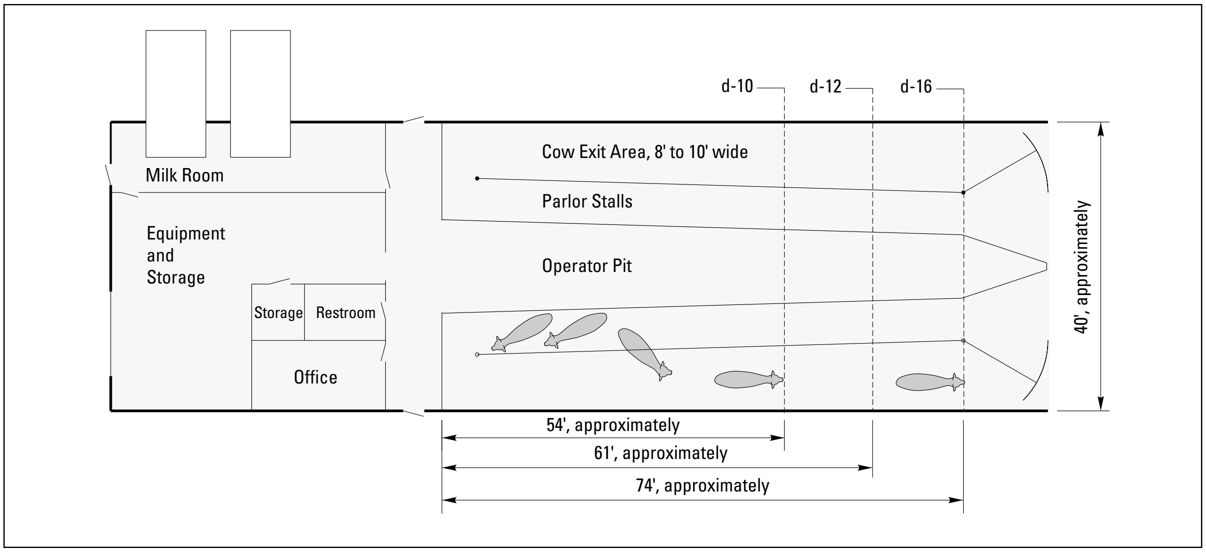


Figure 5-6. Rapid-exit parlor.
Extra parlor width to accommodate return on both sides and rapid exit.

pollution potential from runoff, provide a roof over all animal traffic areas to and from the milking center.

Provide 15 square feet per cow in the holding area. Slope the floor down 2 to 4% away from the parlor. Consider parlor capacity when planning the holding area. Hold cows no more than one hour at each milking. Normally, group sizes can not exceed 4 to 5 times the number of milking stalls to meet this criteria, e.g., a double-4 parlor, should have group sizes of 32 to 40 cows (e.g. 2 sides x 4 stalls per side x 4 times the number of milking stalls = 32). For parlors that continue milking while changing groups, increase the holding area 25% to allow for overlap.

Crowd gates are used to limit the size of the holding area, encouraging cows to the parlor. Crowd gates should not be used to pressure the cows to move. Electrified crowd gates should not be used.

With an enclosed holding area, replace the wall between the holding area structure and milking parlor with an overhead door. Movement into the parlor is improved when cows can see parlor activity while waiting in the holding area. During cold weather, an assembly of overlapping plastic strips hung vertically between the holding area and parlor allows leaving the overhead door open. Also, this facilitates the use of a ramp for operator movement from pit to holding pen, Figures 5-7, 5-8, and 5-9. Cows require minimal training to enter the milking parlor through the hanging plastic strips.

Except in severe climates, the holding area does not need to be insulated. Cows, brought in for milking, warm the holding area. The overhead door

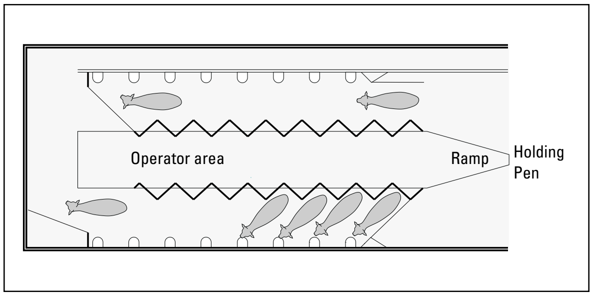


Figure 5-7. Parlor with ramp.
A ramp makes it easier to get behind balky cows without chasing them away from the entrance.

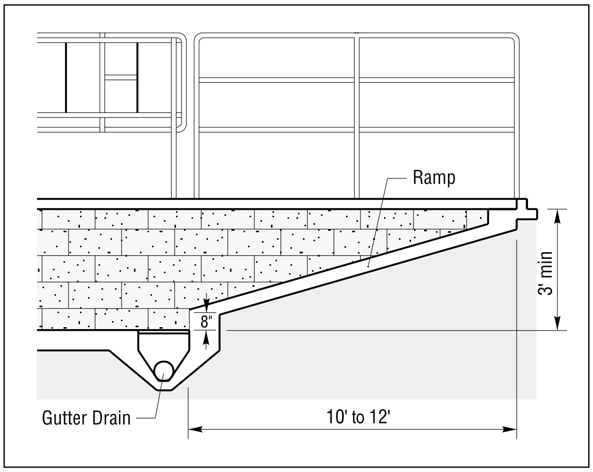


Figure 5-8. Interior side view of ramp and pit.
The ramp slopes up from a step at the back of the pit through a distance of 10'-12' to a step into the holding pen. A gutter with a grate drains the pit and ramp. Provide good footing for the operator.

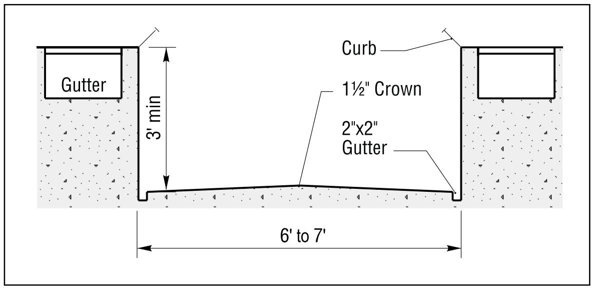


Figure 5-9. Pit cross-section.
A 1-1/2" crown reduces strain on the operator's legs and directs water to pit walls. A 2"x2" gutter along each pit wall carries water to the gutter at the end of the pit. Slope the pit floor and gutters toward the end of the pit. Use a rough broom finish on the pit floor for operator safety. Rubber mats on the pit floor improve operator comfort.

Table 5-1. Floor area required for equipment in the utility room.

Item	Area, ft^2
Milk Vacuum Pump	6 to 9
Compressor	8 to 10
Chiller	31 to 48
Water Heater	4 to 6
Furnace	3 to 5
Storage	3 to 5
Work Alleys	20 to 30
Refrigerator	6 to 9
Desk	4 to 12

to the parlor does not need to be lowered except during very cold weather and equipment washing.

Natural ventilation of the holding area is preferred for the necessary removal of animal moisture and heat. Provide an open ridge and open eaves for moisture removal during cold weather. Open sidewalls fully in summer; cover with sidewall curtains or fabric in winter. Provide supplemental cooling with fans and sprinklers.

Avoid using part of a feeding or resting alley in the barn as the holding area. Initial money is saved in construction cost, but this practice limits the use of a crowd gate, interferes with future expansion, and increases the difficulty of dividing the herd into production groups. Feeding and alley scraping also can be difficult. In the long run, this alternative is more expensive.

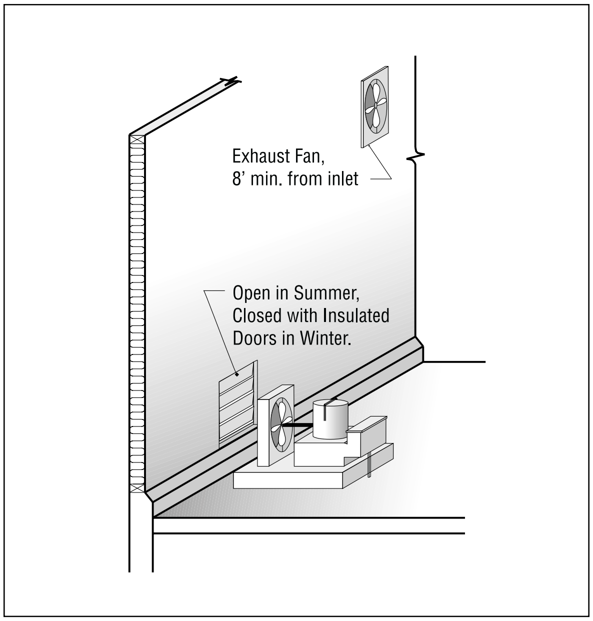


Figure 5-10. Compressor ventilation.
Also see Figure 5-11.

Utility Room

Provide a location for milking and support equipment. Use the information in Table 5-1 to estimate space needs. Allow equipment access by means of an overhead door. Most utility rooms are built too small. Be sure to leave enough room to work around equipment. Provide space for additional equipment.

Install good lighting, a floor drain, and good ventilation. Ventilation is essential to cool vacuum pumps and compressors, Figure 5-10. Design a ventilating system to use heat from the compressor to warm the rest of the milking center in the winter. See Chapter 7, **Building Environment**, for environmental recommendations.

Electrical service is required for vacuum pumps, milk cooling equipment, water heaters, ventilating fans, furnace, grain meters, and electric fence controllers. Locate the electrical service entrance panel on an interior wall of the utility room to reduce condensation and corrosion of electrical contacts. For safety and to meet National Electrical Code requirements, do not locate equipment within 42 inches in front of, above, or below the panel. Do not locate other utility lines, such as water lines, within 42 inches of the entrance panel.

The utility room must not freeze during the winter. Usually, the equipment produces enough heat to prevent freezing. Provide adequate ventilation for efficient equipment operation. Extra heat in the winter can be used to partially heat the milkroom or parlor.

Storage Room

Provide a separate room for storing cleaning compounds, medical supplies, bulk materials, replacement milking system rubber components, and similar products. Separate and insulate the storage room from the utility room to reduce deterioration of rubber products.

Design the room to minimize high temperatures, and ozone associated with motor operation. An interior, windowless space with ventilation to control temperature rises is recommended. Provide this area with good lighting, a floor drain, and a refrigerator for medical products. Federal regulations require separate, clearly labeled storage areas for medications for lactating and non-lactating cows. A third storage area or refrigerator for calf and heifer medications is recommended.

Maintain storage room temperatures between 40 and 80 F. Low temperatures can damage medical supplies while high temperatures can accelerate rubber component deterioration. Maintain safe storage temperatures with a supplemental heater or duct from a central heating system. Do not use air from the utility room, milk room, or parlor.

If an interior space is used and all surrounding walls are insulated, an additional heat source may not be needed. Heat from refrigerators used to store rubber products and pharmaceuticals will keep the space warm. Provide a source of fresh air and a thermostatically controlled exhaust fan to control temperature. Do not bring air from dusty driveways, the parlor, or animal housing into the storage room.

Milk Room

The milk room often contains the milk bulk tank, a milk receiver group, a filtration device, in-line cooling equipment, and a place to wash and store milking equipment. Milk room size depends on the size of the bulk tank and whether it is bulkheaded. Plan for a larger tank or a second tank and possible expansion.

Minimum recommended separation distances are 24 inches from the rear-end of the tank and 36 inches from the outlet valve and working ends. Gravity-type milk filtration systems and large bulk tanks may require ceiling heights of 10 feet or more. Check local milk codes for required separation distances between the bulk tank and other equipment, ceiling, or walls. Also consider any other special requirements.

Many larger bulk tanks are designed so a major portion of the tank extends through one wall (bulkheaded) to the outside or to an adjacent utility room. This reduces milk room size and the cost of building materials. Special wall construction techniques are required around bulkheaded tanks. Design the footing to hold the tank and to prevent frost heaving.

A properly maintained environment includes removing excess moisture, reducing heat buildup, and preventing freezing of equipment. Because this is the room where milk is stored and equipment is cleaned, take care to minimize odors and dust.

A pressurized ventilating system with filters on the inlet to the fan is preferred. Locate the fan away from sources of excess dust, odors, and moisture. The pressurization minimizes the opportunity for odor to enter from the parlor. Provide 600 to 800 cfm. A larger fan is needed when compressors are located in the milk room. Additional fan capacity is needed to provide one air exchange per minute when compressors are located in the milk room. Provide a louvered outlet for air to exhaust to the outside. Provide heat in the milk room with a unit heater or central heating system to prevent freezing.

Office

A milking center office is needed for keeping herd health and production records. It may also be the main farm office. Protect computer-based feeding and record systems from dirt and moisture.

Use the central-heating system or a space heater to heat the office and restroom. Heater size depends on building insulation levels and winter design temperatures. Install a small exhaust fan in the restroom. Consider installing additional summer ventilation or air conditioning in the office.

Employee Areas

The employee areas might include showers, lockers, break room, and conference room. These areas provide comfortable rest areas for the workers when they are off their shift or taking a break from their duties. These areas can also be used for communication with employees and management.

Toilet

An enclosed restroom can be located in a section of an employee lunch/break room or can be built into the utility space of the milking center. Provide a room with at least a toilet and sink in the milking center. Consider a shower, lockers, and a resting area for workers. Separate facilities for men and women may be required by local regulations. For sanitary reasons, do not open the restroom door into the milk room. A septic system is required to handle waste material from this area.

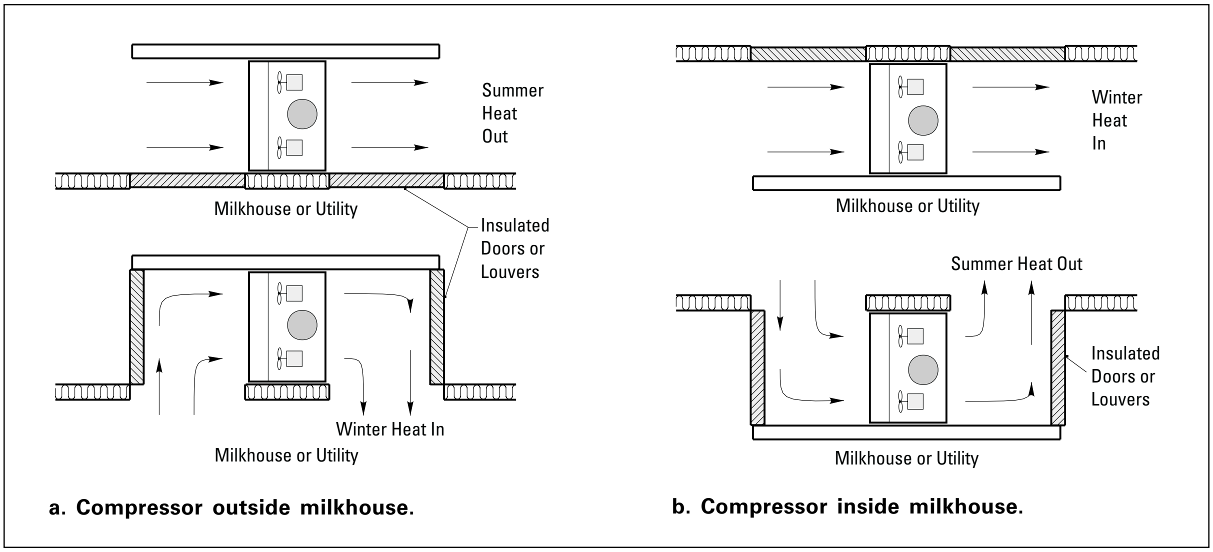
Milking Center Environment

Each room in the milking center has its own environmental requirements. Consider heating, ventilating, and cooling principles when designing an environmental control system. Bring fresh air from outside or from the utility room.

Heat Rejected from Compressor

Consider directing heat generated from air-cooled compressors to other rooms with a fan and duct or with a compressor shed, Figure 5-11. Use an induced draft or powered vent furnace to force exhaust gases out through powered dampers, Figure 5-12. Select a furnace with easily changeable filters.

A central hot water system can heat each room with exchangers, Figure 5-13. The heated water from the milk cooling unit can be used as a hot water source. Allow for individual temperature control in



a. Compressor outside milkhouse. **b. Compressor inside milkhouse.**

Figure 5-11. Compressor sheds.
The doors retain compressor heat in cold weather and open to remove it in warm weather. Make the cross-sectional area of all air passages 1-1/2 times the size of the condenser area.

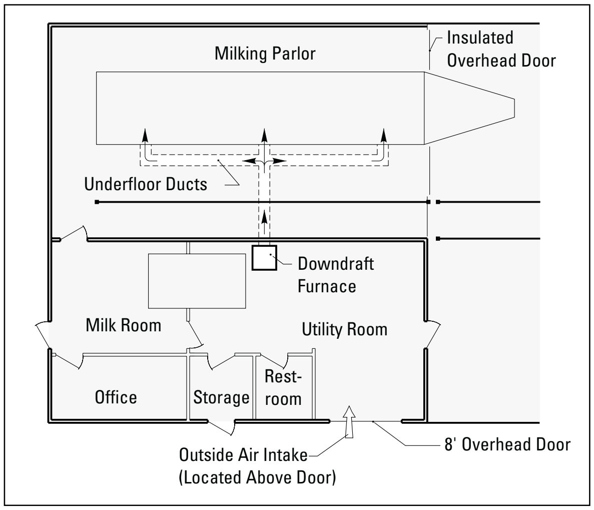


Figure 5-12. Parlor forced-air central-heating system.
Heat also directed to office, storage, and restroom.

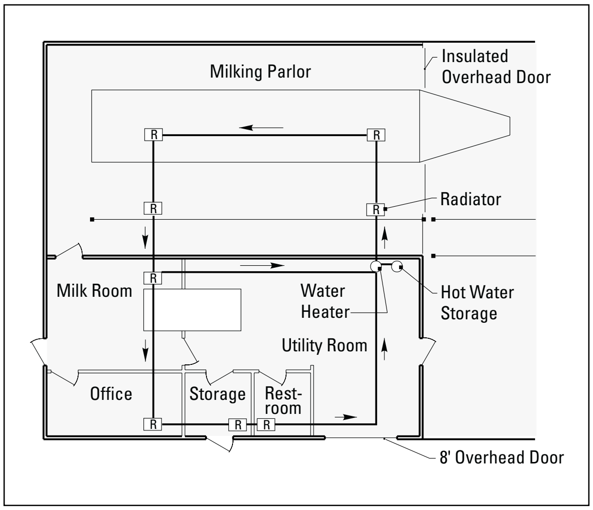


Figure 5-13. Hot water central-heating system.

each room. Use a water heater or a boiler for supplemental heat when needed. Local regulations may not allow this system if the same heat exchanger is used in preheating the washwater.

Regardless of the methods of using the waste heat in winter, provide a thermostatically controlled exhaust fan that turns on at a preselected temperature. Select a fan to provide one air exchange per minute from the utility room. Provide 1 square foot of air inlet area for each 600 cfm of fan capacity. Cover the air inlets with gravity or motorized louvers that open when the fan turns on. Locate the inlet so the air from the inlet is not drawn out of the room immediately by the exhaust fan (a conditon known as shortcircuiting).

Holding Area Environment

The ventilating system for the holding area must remove animal moisture and heat. With natural ventilation, provide an open ridge and open eaves for winter moisture removal. Open sidewalls fully in summer; cover with sidewall curtains or fabric in winter. With a mechanical ventilating system, base fan capacity on the animal holding capacity and recommended ventilating rates. See Chapter 7, **Building Environment**, for information on ventilation system design. Install proper air inlets and controls. Consider positive pressure where mechanical ventilation is used. This avoids drawing contaminated air from the barn when holding areas are attached to the barn. Also, avoid moving air from the holding area into the milking parlor area. Pay particular attention to the air conditions during hot humid weather. Extra fans and/or sprinklers may be required to keep high producing cows from overheating.

Treatment Area Environment

When the treatment area is adjacent to the holding area, use the holding area's ventilating system. When the treatment area is a separate room, provide a separate mechanical or natural ventilating system. Design the system to accommodate varying animal densities.

Consider supplemental heat (individual space heater or central heating system) when water freezing or worker comfort are concerns.

Milking Parlor Environment

Because the milking parlor and seasonal conditions vary, the milking parlor requires a very versatile ventilation system. Consider using fans with an interval timer and manual switch in parallel for greater flexibility. During summer, use the manual switch for continuous operation during milking and cleanup. During winter, use a timer to provide ventilation after milking and wash down to dry out the parlor. A timer should operate until the floor is dry before shutting off the fan.

Summer Ventilation and Cooling

The preferred option for summer ventilation is a positive pressure system. Provide 1,000 cfm per cow occupying the space at 1/8-inch static pressure for minimum summer ventilation. An alternative design is to provide 6 to 9 room air changes per minute. A fan and duct system is an option that has been used successfully in milking parlors, Figure 5-14. Locate the fan in the gable end, and duct the air to the parlor. Provide 1 square foot of cross-sectional area of duct for each 1,000-cfm fan capacity. Use two or more openings to the parlor. Provide a total net discharge area that is 30% less than the duct cross-sectional area.

Increasing air movement in the pit area provides additional summer operator comfort. Ceiling fans mounted to move air down across the operator or fans to blow air through the pit area are an alternative.

Winter Ventilation and Heating

Ventilate the parlor for operator comfort and moisture removal. Winter ventilation can be designed as a negative pressure system if doors remain closed most of the time. Use exhaust fans to remove heat and moisture given off by cows, and use circulating fans for air movement in the operator pit and heaters. Provide an exhaust fan capacity of 100 cfm per cow occupying the space at 1/8 inch static pressure for minimum winter ventilation. An alternative design is to provide 0.1 to 0.15 room air changes per minute. Locate the exhaust fans on the leeward side of the parlor, and exhaust directly outdoors, away from any milk room, holding area, or office air intakes. Provide 1/2- or 3/4-inch mesh screened air inlets with a total net area of 1 square foot for each 400-cfm of fan capacity. Locate the air intakes to ensure air movement through the entire parlor area. Use heaters to maintain room temperature.

Supplemental heating is affected by building location, insulation and operator preference. In most cases in a well insulated parlor, cows will produce enough heat during the milking period to maintain desired inside temperature above freezing. Use supplemental heat during milking on the coldest days. When not milking, proper insulation is important for efficient use of supplemental heat. Use radiant, floor, unit space, or central heat to heat the parlor. Use radiant heaters for warming the operator without heating the air. Hang heaters from the ceiling and direct them toward the cow's udder and the milker's hands. Additional heaters can be installed over other work areas.

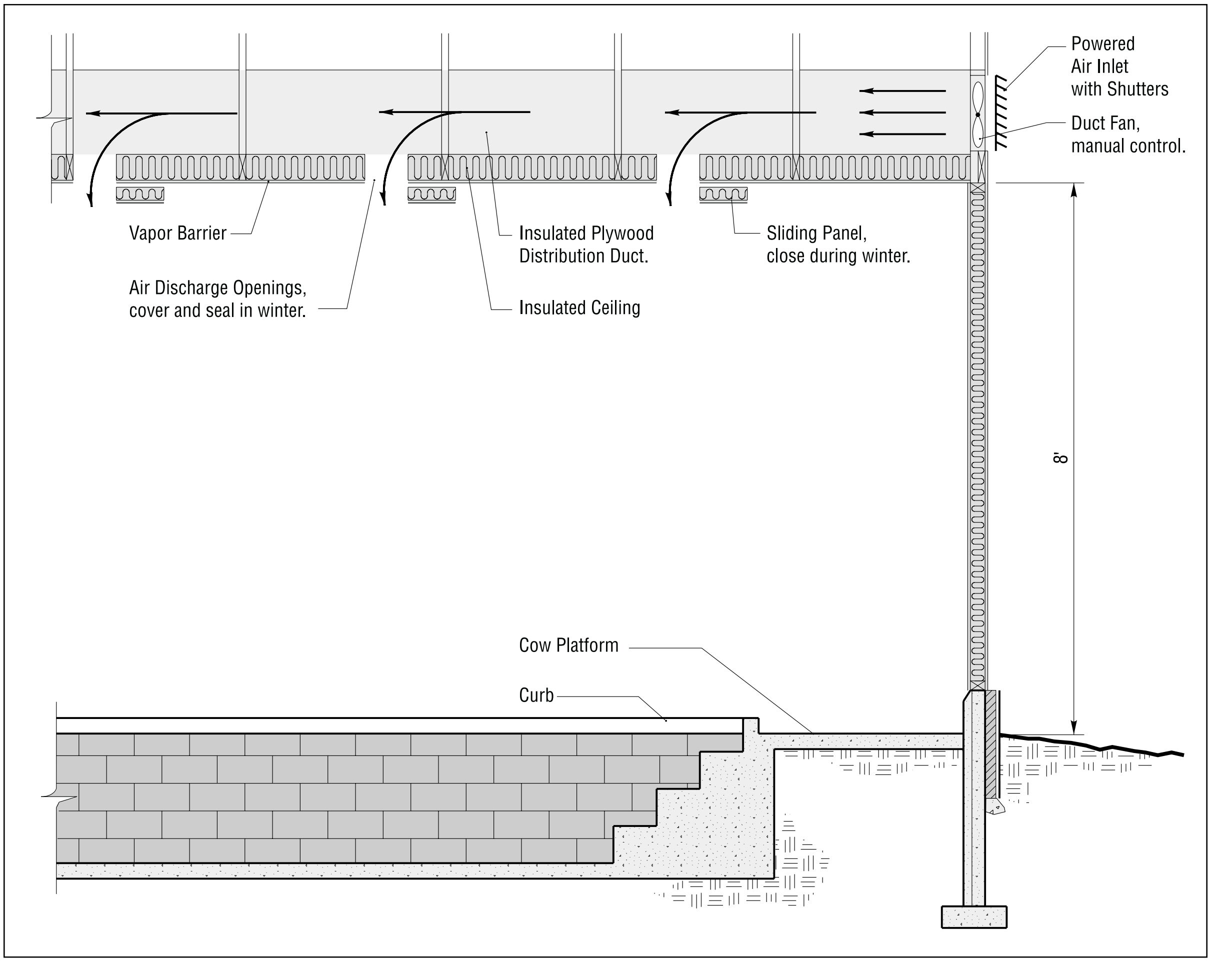


Figure 5-14. Summer air duct.
Provide at least two air discharge openings to the milking parlor.

When possible, use heat removed from the milk to heat the milking center. A central forced air or hot water heating system can allow for this option. Install underfloor ducts to the milker's pit at 8 inches above the pit floor with the hot air directed toward the floor. Use insulated plastic or clay bell tile 8 to 12 inches in diameter for the ducts. Locate cold air returns high on the wall to provide an airflow path back to the furnace. Size the cold air return area larger than the warm air discharge area. Do not use the air from this system to heat the milkroom, office, or lounge area.

Milking Equipment

A milking system includes all equipment to collect, cool, and store milk. Milk quality cannot be improved, but can be maintained with properly functioning milking equipment. Malfunctioning equipment can reduce milk harvest, cause mastitis, and diminish milk quality.

The most common milking system is the pipeline system. With a pipeline system, milk flows through a milker claw into a stainless steel pipeline and travels by gravity through the pipeline to the milk receiver from which it is pumped into the bulk tank.

The location of milk and vacuum lines can be either high or low. A high line is usually more than 4 feet above the cow platform, and a low line is below or at the cow platform. Low milk lines are preferred so milk flows down to the pipeline requiring a lower vacuum level (11 to 13 inches Hg). With a high line, the milk must be lifted to the milk line requiring a high vacuum level (13 to 15 inches Hg). Low lines reduce vacuum fluctuations that can cause damage to the teats and udders.

Install milk lines in a complete loop with a double inlet at the receiver to reduce vacuum fluctuations. Install vacuum and pulsation lines in a complete loop with both ends attached to the distribution tank. Slope milk lines according to Table 5-2. Milk line slopes of less than 0.8% (1 inch per 10 feet) increase the risk of milk line flooding and vacuum fluctuations. Check with the milk inspector before installing any milking equipment.

Consult milking equipment dealers or manufacturers, state extension engineers, veterinarians, or consulting engineers for more details on selecting, installing, and operating the milking system equipment. See **Milking Machine Installations–Construction and Performance, ASAE S518.2 JUL 96**, for minimum system design requirements.

Vacuum Pump Sizing

Size vacuum pumps to have adequate capacity to meet the operating requirements for milking and cleaning, including all ancillary equipment operating during milking. In addition, there must be enough vacuum pump capacity to provide sufficient effective reserve capacity so that the vacuum drop in or near the receiver does not exceed 0.6 inches Hg during the course of normal milking. In most conventional milking systems this will be achieved with a vacuum pump capacity of 35 cfm plus 3 cfm per milking unit. Some systems may be fitted with components such as air lubricated regulators, and air sweeps on some backflush systems, that require greater pump capacity.

If more than one vacuum pump is installed, the system must be able to isolate the pumps not in use.

Milkline Sizing

Milklines should be designed so the milk flows in the lower part of the milkline and air flows in a clear continuous path above the milk under normal milking conditions. A vacuum drop of more than 0.6 inches Hg from the receiver to any point in the milkline is an indication of slugging in the milkline. Slugging is caused by sudden air admission to the milkline during unit attachment or detachment, or by unit falloffs. Using the design guidelines in Tables 5-2 and 5-3 should achieve this requirement in most conventional milking systems.

Milk Cooling

To maintain milk quality, cool milk from the first milking to 40 F or less within 30 minutes. Keep the blend temperature on subsequent milkings below 50 F. The maximum blend temperature permitted by Federal and State agencies is 50 F. Store milk at 36 to 38 F. Regularly verify the bulk tank thermometer is registering the correct temperature. Storage temperatures less than 35 F will lower fat tests and cause rancid flavor due to freezing of a thin layer of milk on the cooling plate.

Table 5-2. Maximum number of units per slope for milklines with LIMITED AIR admission.

Looped milklines. Guidelines based on a mean milking rate of 12 lbs per minute per cow. Steady air admission of 0.35 to 0.70 cfm per unit through claw air vents and air leaks. Transient air admission of 3.5 cfm per milkline slope. Pipe fittings do not substantially reduce the cross-sectional area of the milkline. Designs assume that units are attached simultaneously by an **operator using CAREFUL attachment procedures.** Based on ASAE S518.2 JUL96.

Milk diameter	Milkline Slope				
(inches)	0.8%	1.0%	1.2%	1.5%	2.0%
2.0	2	3	3	4	5
2.5	6	6	7	9	10
3.0	11	13	14	16	19
4.0	27	30	34	38	45

Table 5-3. Maximum number of units per slope for parlor milklines admitting EXCESSIVE AIR.

Looped milklines. Guidelines based on a mean milking rate of 12 lbs per minute per cow. Steady air admission of 0.35 to 0.70 cfm per unit through claw air vents and air leaks. Transient air admission of 7 cfm per milkline slope. Pipe fittings do not substantially reduce the cross-sectional area of the milkline. Designs assume that units are attached simultaneously by an **operator using TYPICAL attachment procedures.** Based on ASAE S518.2 JUL96.

Milk diameter	Milkline Slope				
(inches)	0.8%	1.0%	1.2%	1.5%	2.0%
2.0	1	1	2	2	3
2.5	4	4	5	6	8
3.0	9	10	12	13	16
4.0	24	27	31	36	41

Some milk cooling devices are the following:

- Conventional *compressor/condenser* bulk tank cooler. Size compressors according to the milk flow per hour entering the tank.
- Combination of heat exchanger and bulk tank cooler. Plate coolers and tube coolers are between the receiver jar and the bulk tank. Well water runs countercurrent to milk flow through the heat exchanger. Milk temperature decrease depends on heat exchanger surface area, water temperature, and water and milk flowrates. A bulk tank cooler completes the cooling process.
- Heat exchanger plus ice bank. Well water circulates through one heat exchanger, and ice water is circulated through another heat exchanger to finish the cooling process. Milk is stored in an unrefrigerated tank truck, or milk enters the bulk tank at about 36 F. The bulk tank maintains milk temperature and does not cool the milk.

Plate and tube precoolers usually are installed between the milk pump and refrigeration system.

Milk and water pass through the precooler simultaneously, with heat being transferred to the cooler water from the warmer milk. Because milk is cooler upon entering the bulk tank, milk cooling costs may be reduced by 20 to 60%. To maximize the benefit of a precooler for energy savings, utilize the warmed water to the fullest extent (e.g. to partially supply the cow waterer system). Consult the precooler manufacturer's literature for optimum water-to-milk flow ratio, and design the system to reuse this water accordingly.

Milk Heat Recovery

Heat recovery equipment is practical for almost all dairies. Potential cost savings derive from two sources:

1. Using heat recovered from milk to offset energy costs for heating water.
2. Reducing energy for operating mechanical refrigeration systems that cool milk.

To maximize the benefits of heat recovery equipment, do the following:

- Determine the hot water and space heating needs of a particular milking center.
- Select appropriate equipment to maximize energy savings.
- Design a system for greatest cost benefit.

A desuperheater heat exchanger removes heat from the refrigerant gas after it leaves the compressor. Concentric tubes carry water and refrigerant gas in a countercurrent pattern. Depending on compressor horsepower and operating time, water can be heated to 180 F. Tempered water may be used either directly or to supply a water heater.

Water-cooled condensers can heat water. Because water is the condensing medium, the condensing temperature typically limits the heated water temperature to 110 F, but in some units, temperatures can reach 180 F.

Heat produced from an air-cooled condensing unit can be used to heat the milking center. If a down-draft furnace is used in the utility room, the furnace fan can be used to pull air from the air-cooled condensing unit and distribute the heat to the milking parlor through under-floor ducts. The furnace serves as a backup heat source during colder weather.

Water Supply

Use 115 F water in the milking parlor to wash and sanitize udders. For clean-in-place milking equipment, water temperature requirements are 95 F to 110 F for sanitize, pre-rinse, and acid rinse cycles, and 120 F to 160 F for the detergent wash cycle. Two separate water heaters are recommended. Water heaters should provide water at temperatures 10 F to 20 F warmer than is required by each cycle. Insulate all hot water pipes with preformed insulation.

Pipe hot and cold water to all wash and rinse vats and sinks in the milk room. Provide a mixing faucet with a hose and nozzle for cleaning the bulk tank, floor, and walls. Dispense acidified water and/or sanitizer through this hose and nozzle to improve sanitation and milk quality.

For some installations, an insulated and covered wash vat is required to help maintain water temperature, especially during cold weather.

Check local regulations when designing the water supply system. A tendency is to size too small. Carefully evaluate hot water requirements. The water heater needs to be sized to wash equipment, pipelines, and any other equipment requiring hot water. Use a water softener to protect the water heater and to reduce cleaning chemical cost where minerals cause hardness. See Chapter 10, **Utilities**, for additional information on water requirements.

Milking Center Construction

Material and construction requirements vary with milking center operating conditions. Consider operator use, animal contact, sanitation, fire risk, temperature, and moisture levels. Proper construction and materials can reduce maintenance and improve operation. Also, base selection on initial cost and compatibility with existing structures.

Wall Construction

Most milking center walls are stud or post-frame construction. Use fiberglass batt insulation in the wall cavity with a vapor retarder and protective interior liner. When an insulated wall is not needed, masonry block walls are durable and economical. Non-bearing walls can be 4 inches thick or just enough to endure animal abuse. Waterproof epoxy paint or tile-faced block on the inside resists moisture penetration and is easily cleaned. Stud-frame, post-frame, or masonry construction can be used separately or in combination.

Inside Lining Material

Milk room and milking parlor activities require wall linings with the following characteristics:

- Easily cleaned.
- Resistant to cleaning detergents, acids and water.

- Impervious to water.
- Light-colored.
- Durable.

Fire-rated, fiberglass-reinforced plastic supported by plywood is one of the best lining materials. High initial cost is offset by cleanability, durability, and low maintenance. Masonry walls sealed and painted with a good epoxy paint are another alternative when insulation is not needed. Other materials are exterior plywood, glazed tile, and glazed block. Carefully finish and seal joints. Aluminum and painted steel sheets are suitable for ceilings.

In other milking center rooms, plywood, chipboard, or similar materials can be used. Seal all materials to keep moisture out and improve cleanability. Tightly seal all joints to protect building materials.

In animal traffic areas, a rub rail 36 inches above the floor protects wall surfaces. A rub rail can be a 2-inch pipe spaced about 2 inches from the wall for a total of 4 inches. Maintain 34 inches clearance in lane.

Insulation

Insulate rooms, including the utility room, that will be kept warm. Provide the same insulation levels that are recommended for warm barns. Use 4- to 6- mil polyethylene vapor retarder to protect insulation. Be sure the vapor retarder has no breaks or holes. See Chapter 7, **Building Environment**, for additional information on insulation.

Floors

Concrete floors are durable, cleanable, waterproof, and safe. A compressive strength of at least 4,000 psi is necessary for the milking center floor. High quality concrete is more resistant to deterioration from milk and cleaning compounds. When placing concrete, do not overwork the surface. Embedding a piece of slate or tile under milking equipment and bulk tank drains can reduce chemical damage. (**Plastic pipes or stainless drains can solve this problem)** Embed a black tile in the floor of each milking parlor stall to check foremilk for clinical mastitis.

Where a non-skid surface is needed for cow and human traffic, trowel carborundum or aluminum oxide chips (1 pound per 4 square feet) into the surface. A stiff broom finish is a common alternative. Groove the concrete in the holding areas and return lanes.

Install curbs at doorways to prevent water from flowing between rooms. Use preformed stainless or galvanized steel curbing on the cow platform to reduce splashing.

If frozen manure is a concern in the holding area or return lanes, consider installing hot water floor heat. For more discussion about floors, see **Equipotential plane and voltage ramp**.

Drains

Use deep-water-seal trap drains, Figure 5-15. These drains have high flowrates and provide continuous trapping, preventing gas backflow. Install sewers, drains, fittings, and fixtures according to the state plumbing code. Use materials approved in the code. Cast iron sewer piping with approved seals is recommended. Use at least 4-inch drain lines.

Large floors in milk rooms and milking parlors may require more than one drain. Locate drains in gutters or room corners to improve drainage. Recess drains 1/2 inch below the floor or gutter surface. Collection gutters along walls are usually 2 to 6 inches wide, and center floor gutters are 8 to 12 inches wide. Limit floors to one or two sloping surfaces to ease installation and reduce ponding, Figure 5-16.

Milk room drains must handle milking equipment and bulk tank washwater. For easy access and good sanitation, do not locate floor drains under the bulk tank or its outlet valve. Size drains and pipelines to handle the water from cleaning and sanitizing operations. Usually, 4-inch diameter pipelines can be used for branch lines, and 6-inch diameter pipelines for main lines.

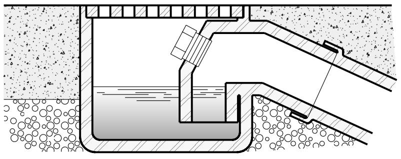
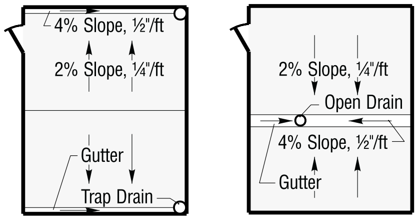


Figure 5-15. Deep-water-seal trap drain.



a. Two-slope floor to wall gutter.

b. Two-slope floor to center gutter.

Figure 5-16. Milk room floor slopes.
Slope floors a minimum of 2% (1/4"/ft).

The amount of solids the waste disposal system can handle affects the design of the cow platform drainage system. A flat floor without gutters is easier to clean and reduces the amount of solids washed into the system. However, there is more splashing of manure and urine with a solid floor than with a grated gutter. For easier cleaning and washdown, slope the floor along the length of the parlor toward the entrance to a cross gutter, Figure 5-17a. When gutters are used along the length of the parlor, slope the floor toward the entrance with a cross slope from the pit to the gutter, Figure 5-17b. Slope the gutter bottom to drain toward one end.

Plan ahead to minimize the number of deep-water-seal trap drains needed. Install one drain in the milk room and another in the gutter at the end of the operator pit. The parlor, cow platform, and milk room drains can discharge through the pit wall about 6 inches above the pit gutter. Bringing these drains through the pit wall allows for observing the drains for problems, Figure 5-18.

Lighting

Milking center lighting requirements vary depending on the task carried out. Recommended illumination levels, in Table 10-4, range from 50 footcandles (fc) in the operator pit of the milking parlor and in office areas to 10 fc in storage rooms. See Chapter 10, **Utilities** and *Farm Building Wiring*, MWPS-28, for more information on lighting.

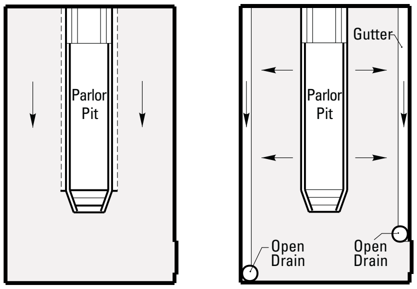
Stray Voltage

Stray voltage is a voltage difference between two cow-contact points. A common example is a small voltage difference between the water cup and the floor of a dairy barn, Figure 5-19. When the animal touches both surfaces, completing the electrical circuit, a small current flows through her body. Cow contact voltages should be kept below 1 volt, a level which has been shown to cause no harm to dairy cows. When stray voltage problems occur, a thorough investigation using proper equipment will locate the sources and allow the problem to be corrected. If a stray voltage problem is suspected, contact the local power supplier and a licensed electrician who is familiar with wiring for livestock facilities.

Symptoms of Stray Voltages

Small shocks or tingles associated with detectable high cow-contact voltages can result in animals altering their behavior. These voltages are generally not large enough to directly harm the animal. Some of the changes in animal behavior are:

- Nervousness during milking.



a. Platform sloped toward entrance. **b. Platform with cross slope.**

Figure 5-17. Milking platform drain system.

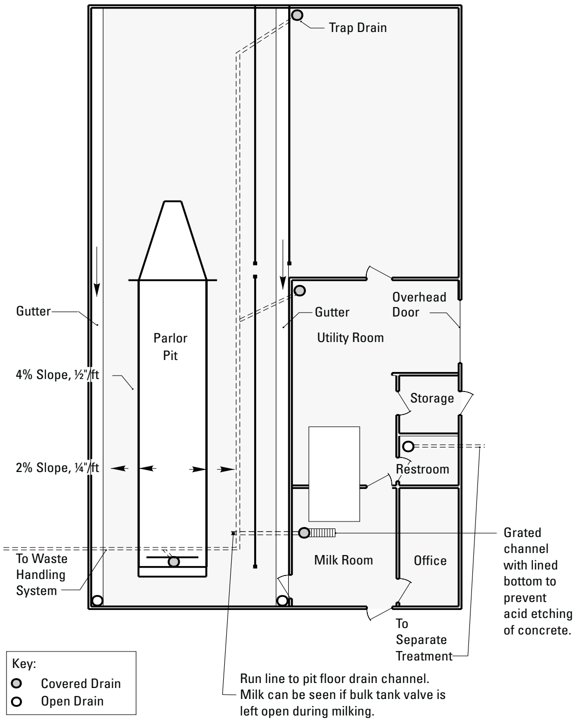


Figure 5-18. Milking center drainage system.

- Reluctance to enter the parlor.
- Reluctance to use waterers.
- Reluctance to consume feed.
- Poor milk letdown.

These changes in animal behavior also can occur due to problems with milking equipment, changes in milking routine, spoilage of feed, or pollution of drinking water. Therefore, investigate all potential

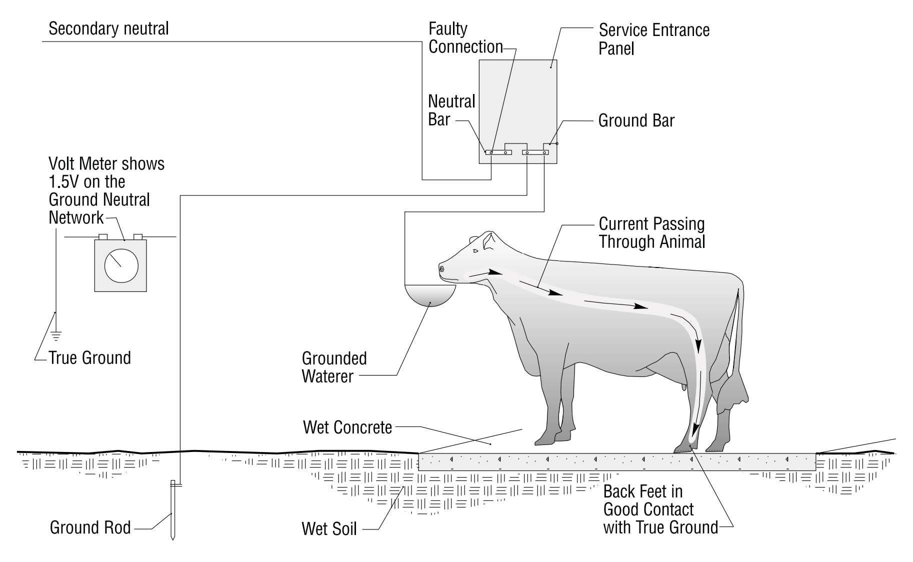


Figure 5-19. Example of stray voltage.
In this case, the grounded neutral network is 1.5 V relative to true ground. This 1.5 V may be created by one or more sources such as the faulty connection shown here. Part of the 1.5 V is accessible to the cow through the waterer, because it is a part of the grounded neutral network. When the cow touches the water and the wet concrete, she provides a path for current flow.

sources of behavioral changes. If dangerous levels of voltage are present, then a safety problem exists; contact a licensed electrician to correct the problem immediately.

Causes of Stray Voltage

Stray voltage may occur from on-farm and off-farm sources. Off-farm stray voltage sources can be dealt with by the electric utility. Off-farm sources of stray voltage can be created by these conditions:

- Voltage on the primary neutral.
- A ground-fault at a neighbor's electrical system.
- Problems with the off-farm electrical distribution system.

Common on-farm sources of stray voltage on dairy farms include the following:

- Ground-faults.
- Equipment ground used as a circuit neutral or a circuit neutral used as an equipment ground.
- Large voltage drop on the secondary neutral.
- Electric fencer or cow trainer wires short-circuiting to or inducing a voltage in pipes and equipment.

All of these sources of stray voltage can be corrected. Finding and correcting sources of stray voltage requires complete investigation by qualified professionals using proper equipment.

Equipotential Plane and Voltage Ramp

In new milking parlors and/or holding areas, install an equipotential plane and voltage ramp, Figure 5-20. A properly installed equipotential plane maintains all floor surfaces and parlor equipment at the same voltage. As a result, no voltage difference can occur across cow-contact points. A properly installed equipotential plane provides the greatest insurance against future stray voltage problems in new milking centers. An equipotential plane and voltage ramp can be installed in an existing milking center, but at great expense. Equipotential planes are not needed in freestall barns because freestall barns are not wired to the extent of milking parlors. Check with an extension engineer to determine the local requirements for installing equipotential planes.

Use the following procedure to construct an equipotential plane in the parlor and/or holding area.

- Use 6x6, 10-ga welded-wire mesh, or weld together #3 reinforcing steel bars in a grid pattern, 15 inches on center. Where fibre mesh concrete is used, lay #4 copper wire spaced 18 inches on-center on the compacted base before placing the concrete. Bond all metal structures together and to this copper wire. Connect this system to the electrical grounding system for the building.
- Weld all parlor equipment supports to the reinforcing steel before concrete placement.

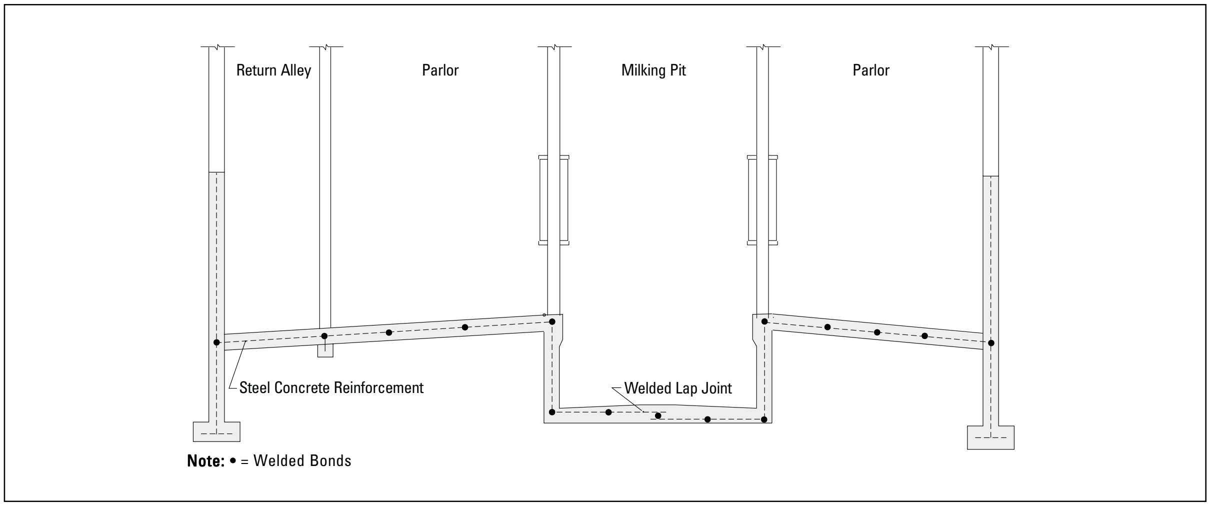


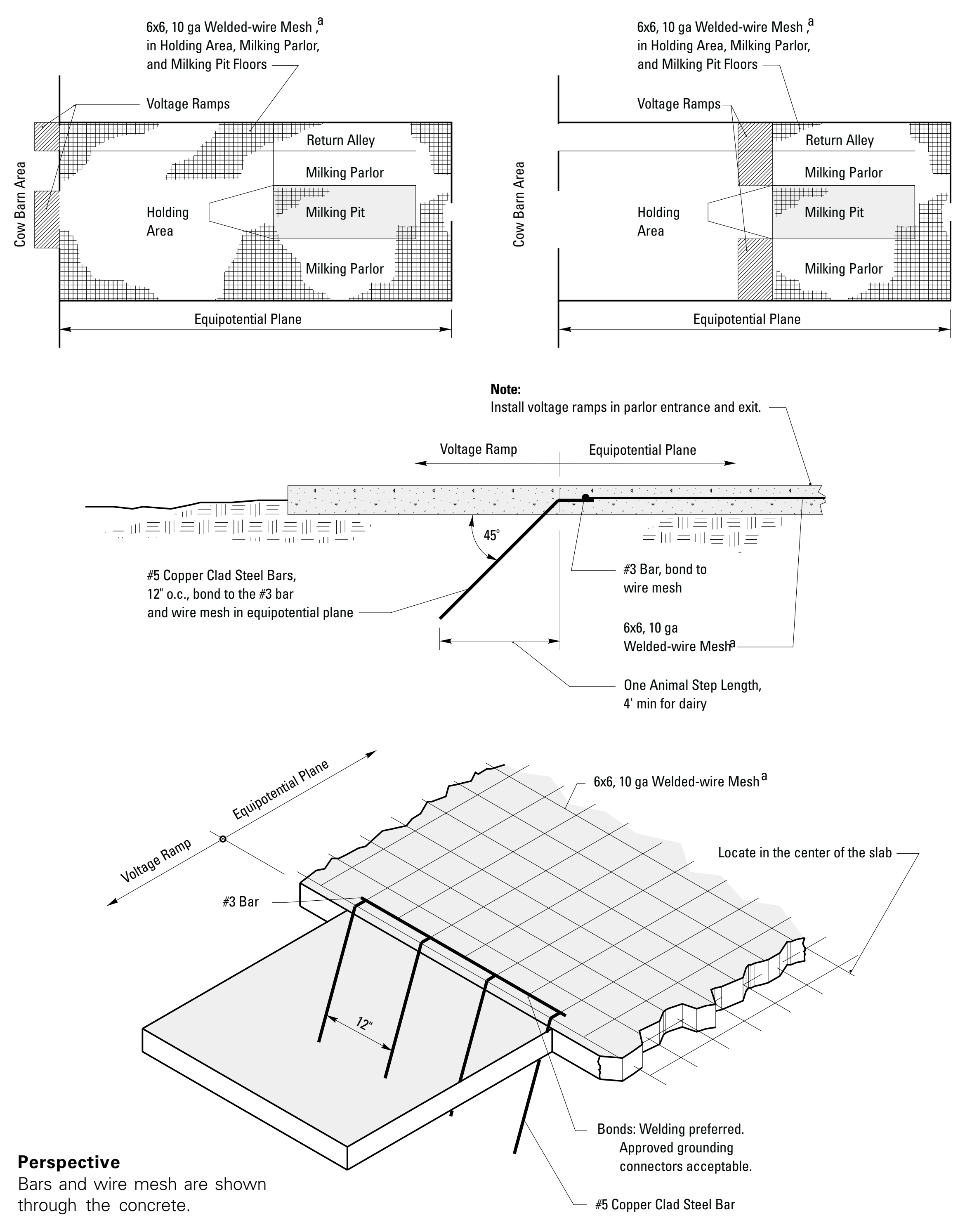
Figure 5-20. Construction of an equipotential plane in a milking parlor.

- Ground the metal system to the service entrance panel.

Welded-wire mesh can be difficult to weld to, but placing reinforcing bars in a grid pattern requires more welding. Bolted, wired, or clamped connections are not satisfactory for connections between reinforcing steel and parlor equipment. Use an approved clamp-type connector and AWG 6-CU wire to ground the floor and parlor steel at the service entrance panel. Install a voltage ramp at every location where an animal steps onto or off of the equipotential plane, Figure 5-21. If the voltage on the equipotential plane is higher than the rest of the farmstead, a voltage ramp provides a gradual increase in voltage as the cow walks onto the plane. If a voltage ramp is not used, a cow may receive a small shock that creates parlor entry problems. Therefore, voltage ramps are always needed with an equipotential plane.

Improper Grounding

Improper grounding is a safety problem, not a stray voltage problem (even though it can cause stray voltage). Correct the problem immediately because it is a serious hazard. Proper use of grounding wires on electrical equipment is required in all buildings. However, proper grounding is a common oversight on many farms. As long as all of the electrical equipment is in good condition, an improperly grounded system will work. However, if a motor or heating element fails, a person or an animal could receive a fatal shock due to improper grounding of the system. Have a licensed electrician find and correct any grounding problems. If a producer routinely feels shocks while operating electrical equipment or when touching metal in any type of livestock building, a grounding problem may exist.



Perspective
Bars and wire mesh are shown through the concrete.

Figure 5-21. Voltage ramp to an equipotential plane.

[a] #3 reinforcing steel bar, 15" o.c. can be substituted for 6x6, 10 ga welded wire-mesh. Where fibre mesh concrete is used, lay #4 copper wire spaced 18 inches on-center on the compacted base before placing the concrete. Bond all metal structures together and to this copper wire. Connect this system to the electrical grounding system for the building. Locate voltage ramps at all animal entrances to and exits from the equipotential plane. See the *National Electric Code (NEC) and the Farm Building Wiring Handbook*, MWPS-28, for additional information on proper wiring practices and stray voltage.

Chapter 6

Special Handling and Treatment Facilities

William G. Bickert, Extension Ag Engineer, Michigan State University

Buildings and equipment serve as tools for carrying out essential management tasks. Well-planned facilities with proper handling, restraint, and treatment facilities make it possible to implement a management program. Regardless of herd size or housing type, properly designed facilities promote calf, heifer, and cow care.

A complete handling, restraint, and treatment management plan includes areas for the following:

- Observation.
- Separation.
- Treatment.
- Maternity.
- Loading/receiving.

Herd size, expected treatment types, and handling frequency determine needed facilities. Provide handling and treatment facilities for each group of animals. When planning new facilities or evaluating existing ones, plan for and consider the following features.

- The ability for one person to easily observe and move a single cow or group of cows.
- Animal handling lanes that promote smooth cow traffic flow with maximum safety for handlers and cattle.
- Restraint facilities for medical examinations, treatment, artificial insemination, calving, and routine hoof trimming.
- Access to water, medical supplies, and records.
- Areas that are easy to clean and maintain.
- Suitable heat and ventilation.
- Good lighting.
- The ability to separate or discard non-salable milk.
- Parking space for a veterinarian's truck, possibly inside.
- Convenient feeding and bedding.
- Access to assist down cows when necessary.

When selecting or designing a handling and treatment facility recognize that no one system best meets the needs of all dairy operators. Personal management style, conditions, and traditions determine the selection of the best workable system.

Handling and Observation Groups

Develop a management plan based on separate handling and observation areas. Management groups are typically based on the opportunity to house and view animals as a group because of similar characteristics and needs. These cows are usually housed, fed, and handled as a group. Only when an animal becomes an exception due to illness, injury, or calving cycle is the animal separated and handled differently. Cows that may require separate management groups can include:

- Close-up cows (2-3 weeks prepartum).
- Maternity (calving).
- Freshened cows (0-7 days postpartum).
- Cows recently dried off.
- Ill or injured cows.

Close-up cows require a clean, dry environment. Feeding facilities should allow for preparing cows for the high energy ration they will receive upon entering the milking herd. Freestall housing close to the maternity area allows frequent observation.

Locate maternity pens away from other animals, especially young calves, and sick cows to minimize the spread of disease. Use individual maternity pens for calving to provide individual attention to and observation of cows during calving. Keep pens clean, dry, and well-bedded. Feed and water may be needed in maternity pens.

Freshened cows need frequent observation before being moved into the milking herd. Freestalls or a large well-bedded pen can be provided for this group. For a large herd, a separate hospital/maternity barn, possibly equipped with a pipeline or portable milker, could be provided, Chapter 4. Monitor individual feed intake and milk production to determine whether or not each cow is progressing normally.

Cows recently dried off also require special attention. Separate these cows from the milking herd for feeding. Provide a freestall area or bedded-pack group pen to observe regularly, conduct necessary medical treatments, and monitor progress. Provide a separate area for animals with long-term illnesses or injuries.

Observation

In any housing system, the operator should be able to observe all animals easily. Dairy cattle that are observed easily receive better and more immediate care. Common observation points include the milking center, feeding fences, exercise lots, resting areas, and calving areas. House animals needing more regular observation in areas where they can be checked conveniently. A drive-through freestall barn with a center alley allows more regular observation than a converted, loose-housing dry lot system.

Separation

Plan handling facilities to provide for separation of an entire group or an individual animal. Animals housed in dry lots, freestalls, corrals, or pastures can present a difficult separation challenge. The milking center provides a convenient place to separate animals housed in loose or freestall housing. An area alongside the holding area can provide a convenient place to sort and separate animals for medical examination and treatment. Allow easy access for feeding and manure removal.

Separation also can be achieved along feeding areas. Using a feeding alley with gates allows cows to be driven along familiar resting or feeding alleys that open into sorting or treatment pens. Proper gate location can block a cross alley and direct cows into treatment pens. Position gates to gradually funnel cows toward the opening. Attempting to direct a cow through an open gate along a sidewall or feeding fence can be difficult.

Fenceline (headlock) stanchions, Figure 6-6, can be used for separating individual animals or groups of animals from the larger group. The necessary provision is that the array of stanchions be furnished with individual cow release mechanisms.

Provide separate pens for maternity and treatment to reduce disease transmission. Recommended maternity and treatment pen size is at least 12 x 12 feet. Large pens provide more room to assist calving and are easier to keep clean and dry. Depending on the farm and management situation, provide up to five calving pens for every 100 cows. On farms where the management plan calls for a cow to be moved to the calving pen when calving is imminent, only two pens per 100 cows may be necessary.

Provide one or more stanchions in pen sides to restrain cows for examination or treatment. Diagonal lockup stanchions can limit access to the head and neck. Stanchion pens used for calving must allow for adequate space behind the cow. Consider providing at least one lifting ring centered over the pen capable of supporting a cow. A dirt floor in the pen may enable cows to move easier.

Gates can be used within pens to form a funnel to direct a reluctant cow into a stanchion or other type of lockup, Figure 6-1. Gates also can become part of a pen area for breeding or rectal examination. Use sturdy, well constructed gates. Gates that are too weak or improperly sized can break and cause injury to animals and operators. Use gates that have no more than 10 inches between rails and that are at least 66 inches high to discourage jumping. Hang them 16 to 18 inches from the ground so animals will not crawl under them.

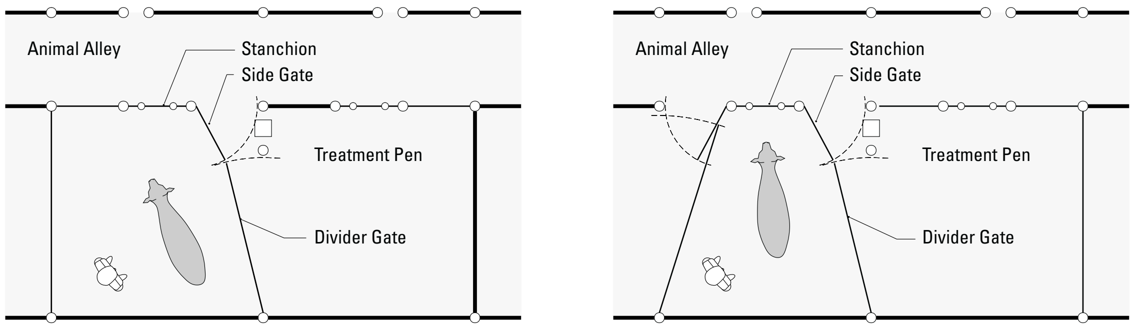
Treatment Areas

Provide a treatment area for confining cows for artificial insemination, postpartum examination, pregnancy diagnosis, sick cow examination, and surgery. Sorting, handling, restraint, and treatment can be incorporated into an existing or remodeled barn without difficulty, Figure 6-2. Use a crowding pen to direct cows toward a headgate. Provide a blocking gate in the animal handling lane to keep other animals away from the operator working behind a restrained animal. Provide a storage cabinet and table for veterinary supplies.

Treatment Stall

A single stall can be used for treatment, Figure 6-3. Locate the stall so there is access to both sides of the cow during examination. An existing stall barn can be converted to a treatment area during the transition to freestall or loose housing. A separate handling facility for easier restraint, examination, treatment, and surgery can be added later.

Restrain the cow's head with a swing stanchion that can lock into position with a removable bar. Position the bar above the cow's head to reduce the risk of choking if the cow goes down. Use a sturdy ring in the wall in front of the stall for further restraint. Provide three rings in the ceiling over the centerline of the stall for lifting points. Locate one lifting point above the cow's shoulders, another above the tailhead, and a third 4 to 6 feet behind the cow. The lift rings and the ceiling must be strong enough to support the cow's weight. In barns with gutters, place a removable, 6-foot long cover over the gutter behind the stall. Partitions help prevent the cow from moving sideways.



a. Single side gate.
Swing side gate and divider gate to direct cow toward stanchion.

b. Both side gates and stanchion.
Swing both side gates and divider gates to funnel cow into stanchion.

Figure 6-1. Treatment pen stanchion and gates.

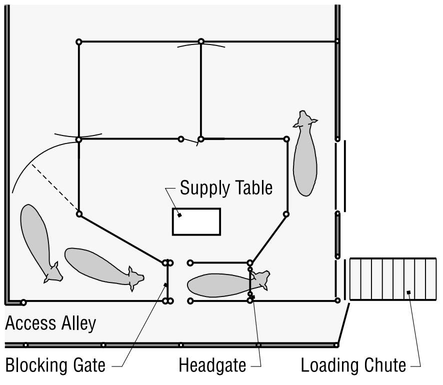


Figure 6-2. Handling and treatment area in a barn corner.
Crowd pen, headgate, treatment pens and supply storage located in the corner of existing or remodeled barn.

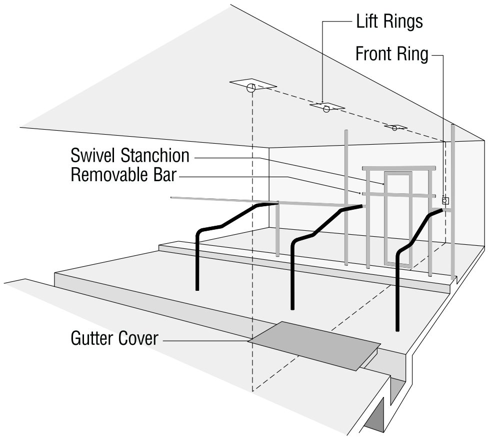
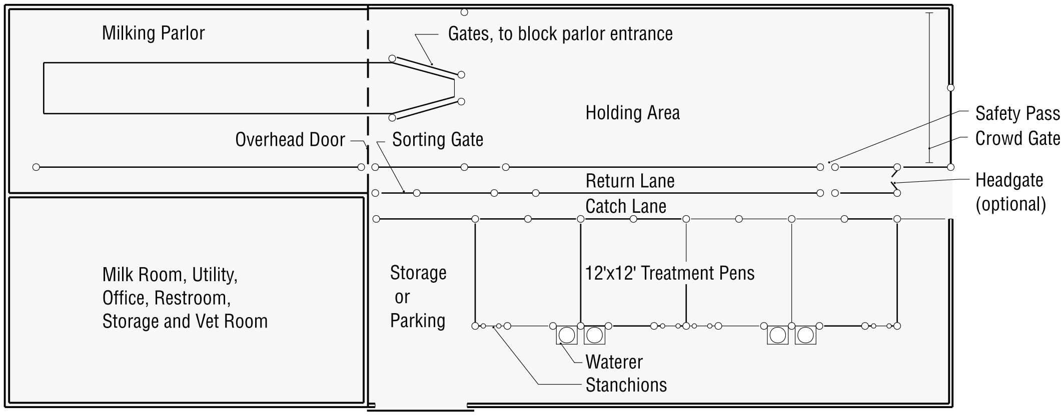
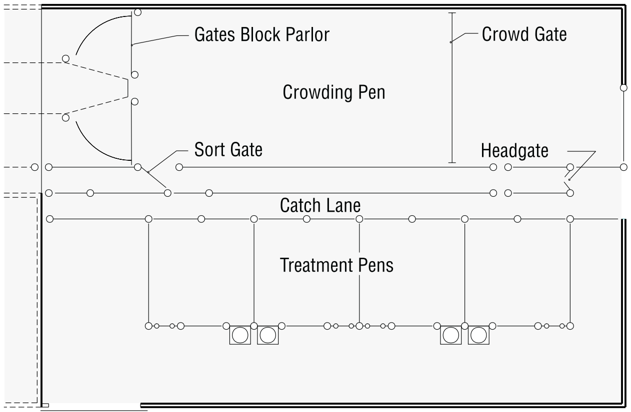


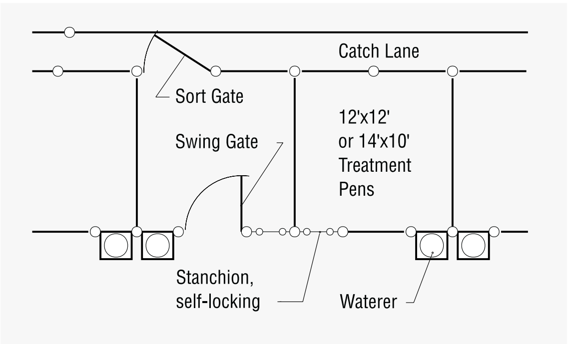
Figure 6-3. Treatment stall.



a. Holding area, handling alleys and treatment pens.
Holding area, animal movement alleys, and treatment pens located in the milking center.



b. Gates block parlor entrance.
Use gates to block parlor entrance. Holding area acts as a crowding pen to direct cows into the handling lane. A headgate can be used to restrain cows, or they can be directed into a separate pen.



c. Treatment pen.
Equip with self-locking stanchion and gates to restrain cow.

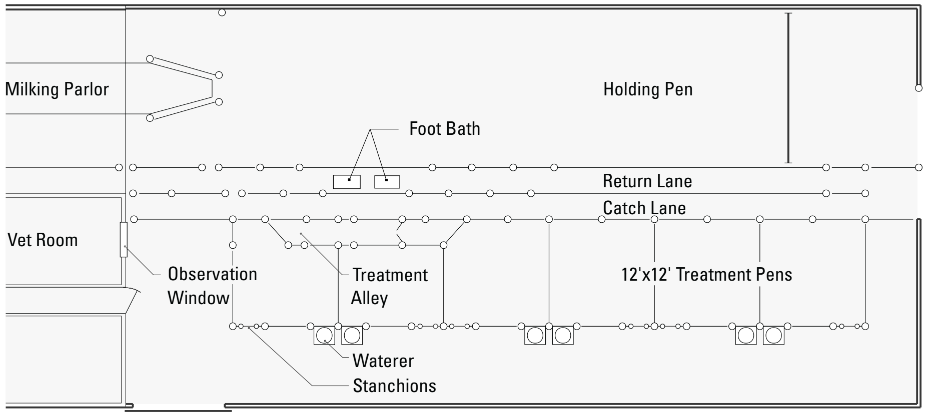
Figure 6-4. Milking center treatment area.

Milking Center Treatment Area

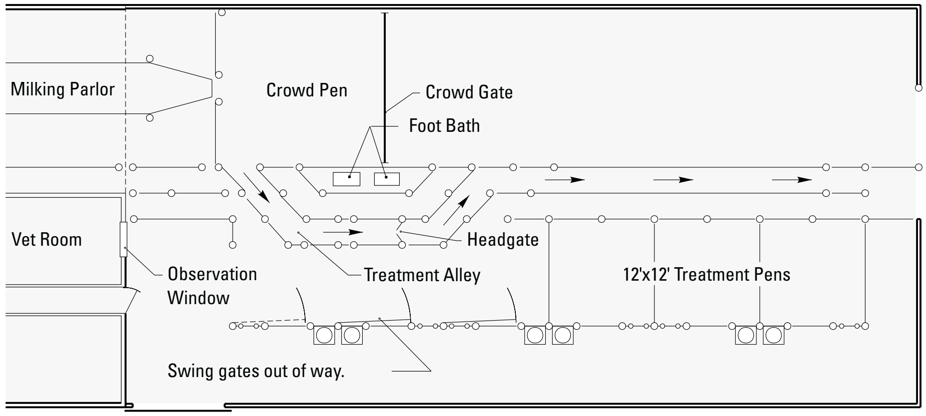
On farms where the milking parlor is used only part of the day, the milking center can double as a treatment area. Use the holding area and cow lanes in the milking center for sorting, handling, restraint, and treatment. An area alongside the holding area provides a convenient place to sort animals and to perform medical examinations and treatments, Figure 6-4. However, do not examine or treat animals in the milking parlor. It is not designed for, or intended to be used for, these purposes.

Sort cows exiting the parlor into a catch lane with a sorting gate controlled from the operator's pit. As cows travel single file from the parlor, individual animals easily can be diverted. Two parallel lanes—one for returning cows to the housing area, the other for catching cows—can be used for sorting cows as they exit the parlor, Figures 6-4 and 6-5. Cows can be held in a catch lane or can be moved into one of the pens equipped with self-locking stanchions.

With gates to block the parlor entrance, a group of cows can be moved through the holding area into the treatment area. Use a headgate positioned in one of the animal lanes for restraint, Figure 6-5. Animals also can be diverted to treatment pens equipped with self-locking stanchions. Although the milking center



a. Holding area, catch lane, headgate and treatment alley.
Two parallel lanes are used as a return lane and a catch lane for cows exiting the parlor. A third, short lane is located along the treatment pens as a headgate and treatment stall area.



b. Gates block parlor entrance to treatment stall.
Use gates to block parlor entrance and direct cows from holding area (crowding pen) to treatment stall and headgate, catch alley, or treatment pen. Adjust gates in selected treatment pens to allow access to treatment stall.

Figure 6-5. Milking center treatment area with treatment stall and headgate.

is used primarily for the lactating herd or cows exiting the milking parlor, this area can be used for replacement animals and dry cows.

Milking parlor type affects decisions when planning and incorporating sorting, handling, and treatment into the milking center. A single return lane from the milking parlor permits sorting cows into a catch lane using a sorting gate controlled from the pit. Cows to be treated are moved into a treatment pen with self-locking stanchions.

Automatic sorting gates used in combination with a cow identification system can be used to separate cows. Careful planning will help ensure ample pens and other facilities for handling and treating sorted groups of cows.

With a rapid-exit parlor, cow exits lead to return lanes along both sides of the holding area. Provisions for sorting cows must be duplicated on both sides of the holding area. Some rapid exit parlors are constructed with single return lanes for more convenient sorting. Handling and treatment areas are needed on each side of the holding area and may not be feasible or practical. Sorting and handling after the animals reconverge at the rear of the holding area is an option. A separate handling facility may be more effective for meeting cattle sorting, restraint, and treatment requirements.

Footbaths

Many dairy producers use footbaths to help maintain healthy feet and to treat problems such as foot rot and hairy or strawberry warts. The most appropriate treatment product will depend on the problems in the herd. Producers need to check with their veterinarians for the preferred product and mixing instructions.

To be effective, the treatment solution must be kept clean. One way to help ensure cleanliness is to have two footbaths in a series. The first contains only water to clean the cows' feet; the water in this bath needs to be changed frequently. The second footbath contains the treatment solution.

Portable and permanent footbaths have been used successfully. Typically footbaths are 6 to 8 feet long and 6 to 8 inches deep. Usually they are the same width as the alley in which they are installed.

Following are other suggestions for footbath use:

- Locate them where all cows must walk through them, for example, in a return/exit lane from the milking parlor.
- Construct them of durable materials such as concrete, plastic, fiberglass, or treated wood.
- Make them so they are easily cleanable. For example, install a 2-inch drain in the corner of permanently installed units.
- Place a hydrant and adequate storage for ingredients nearby.
- Make provisions to contain the material emptied from a footbath. A good plan is to discharge to the manure storage facility.

Fenceline (Headlock) Stanchions

Headlock stanchions provide another option for handling and treatment. Headlock stanchions can be used along a feed manger to restrain animals for examination or treatment. Headlock stanchions also provide a convenient method for restraining and examining cows in dry lots or pastures.

In group housing, fenceline stanchions along a feed manger can restrain animals for heat detection, breeding, and pregnancy-checking. Fenceline stanchions near pastures and other feeding areas provide convenient access to animals. A lever mechanism opens or closes all stanchions simultaneously.

Desirable features of fenceline stanchions include:

- Individual or group cow release.
- Self-locking mechanism as a cow lowers her head after entering.
- A quick release for downed cows.
- A method to lock animals away from feed.
- A method to lock out animals when not in use.

For mature cows, place stanchions at least 2 feet on center. Provide at least the same number of stanchions as cows in the group.

Separate Handling Facility

On dairies where milking occupies most working hours, a separate veterinary facility may be desirable, Figure 6-7. A separate facility allows greater efficiency.

Figure 6-6. Fenceline stanchion.

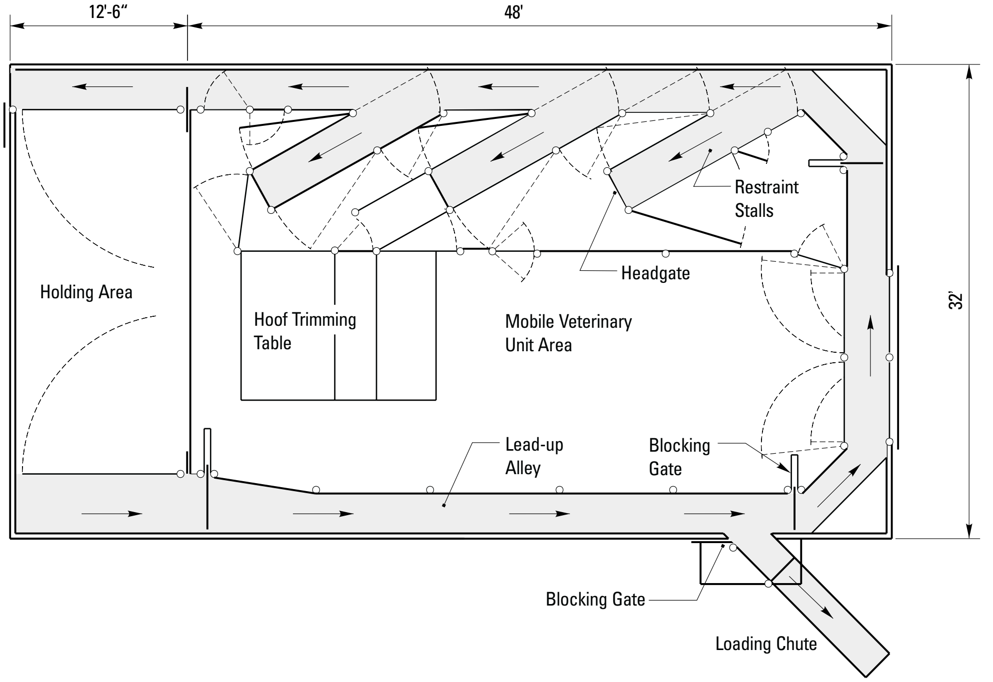


Figure 6-7. Handling and treatment building.
A variation of this building concept or layout can be incorporated into an existing stall barn or other existing barn.

A holding area provides space for working cows into the facility. The lead-up alley restrains a group of cows single file for routine vaccinations or for loading animals out. Blocking gates positioned along the lead-up alley prevent cows from backing up. Angled restraining stalls permit the veterinarian unrestricted access to the rear and sides of a cow. Hinged sides allow for unrestricted access, and walk-through headgates provide for smoother cow movement. After cows are released, they can be returned to the barn or diverted to a hoof trimming table.

A variety of group and individual pens meet the needs of different cow groups. With loose housing systems, it is not as convenient to handle cows individually or in small groups. A separate handling/treatment barn or area may be needed for specific management groups in freestall or loose housing systems, Figure 6-8. Provide enough pen space to meet the needs of the different management groups. Consider space for animals that need additional attention (e.g. close-up cows, cows after freshening, maternity, and treatment). Provide this space in a separate barn or an area incorporated into a freestall barn, existing loose housing barn, or stall barn.

Maternity Area

See the section **Housing for Dry Cows** on page 42 in Chapter 4 for information on maternity areas as well as housing for pre-calving and newly freshened cows.

Headgates and Chutes

Headgates can provide many features not found in a fixed stanchion or pen wall. Either homemade or purchased commercially, they can be placed in alleys and other areas to provide a convenient treatment system, Figure 6-9. The self-locking headgate can be adjusted for animal size. Headgates used for dairy cows must provide a complete opening from top to bottom to allow front exit. This type of headgate allows easy removal of downed cows and heifers. Some commercially available headgates hinge at the bottom and open in a fan-like fashion, obstructing the cow's exit and increasing the potential for injury to wide hips, low-hanging udders, and rear legs. This style of headgate is not recommended.

Chutes prevent side-to-side cow movement during treatment. Side gates or panels can be opened for complete examination of a cow's udder and body. Tapered sidewall chutes are not suitable for dairy cattle.

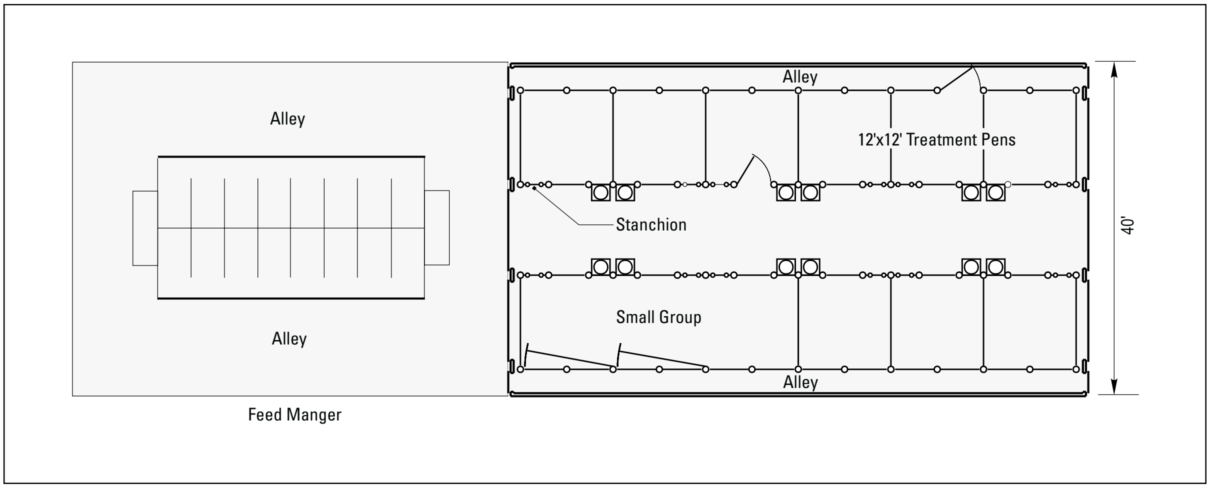


Figure 6-8. Separate handling/treatment barn.
A separate barn can be provided for cows with special needs. Cows requiring additional observation or treatment can be separated from the milking herd and housed in a separate barn. Provide about one individual pen for every 20 cows. Include a small storage room for supplies and portable milking equipment.

Figure 6-9. Commercial headgate.

Loading Chutes

Well-designed animal loading facilities reduce loading time and the likelihood of injury to cattle and operator. Required ramp dimensions are determined by the transport equipment popular in the area. Low-bed trailers, less than 12 inches from the ground, require only a drive-in alley and side gates to funnel the cows.

Provide a chute with solid sides for receiving and shipping cows. Provide a holding pen to hold cows before loading. Provide steps or cleats on the chute floor so the cows do not slip.

Unloading large numbers of animals is easier with wide docks. Some trucks may require wide platforms because of wide, built-in unloading ramps. Include combination swinging and telescoping gates to close off areas between permanent loading dock sides and a truck. Solid sides 5 to 6 feet high prevent distraction of animals.

Provide a catwalk on one side of the ramp for the operator. A catwalk can be a 20-degree incline with grooves or steps 1 foot wide and 3 to 4 inches high to reduce the chance of slipping or falling.

Safety

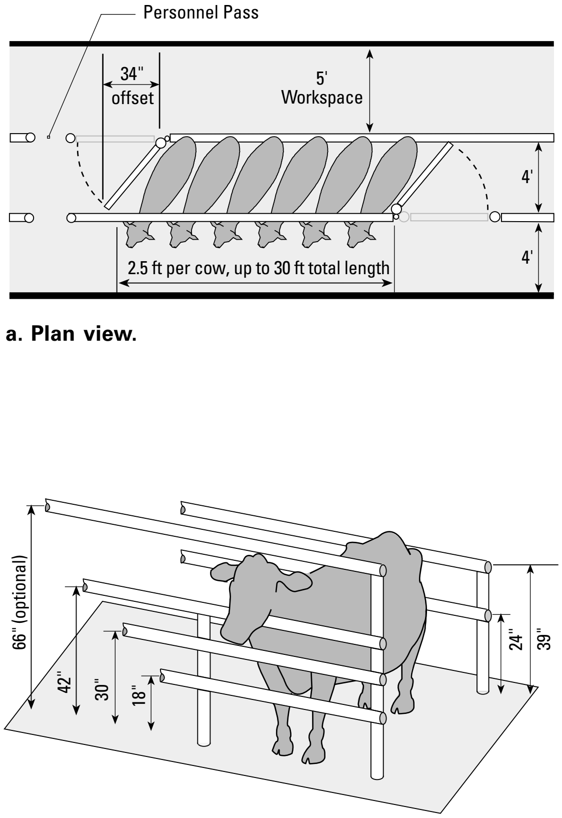
Safety passes are similar to personnel passes, Figure 4-16. Safety passes typically provide 12 to 14 inches of clear space for people to pass through. Provide at least one safety pass in each pen and one every 25 to 30 feet in animal movement and handling alleys to allow an operator to exit quickly. Avoid locating safety passes where animal flow is directly at the pass. Excited animals may try to use the safety pass for an escape route and become trapped. Wider passes are more convenient, but require a self-closing gate or a third *guard post.* A 16- to 18-inch opening between the bottom rail of the fence or gate and the floor will allow a person the opportunity to roll away from an aggressive animal.

A separate alley for people allows movement through facilities without animal contact.

Herringbone Palpation Facility

A herringbone palpation facility is a simple, inexpensive way to handle cows in groups and is easy to construct, Figure 6-10. The palpation facility provides the worker with a comfortable, safe environment, and places the group of cows at ease. The palpation facility should be located adjacent to animal traffic lanes between the milking center and housing facilities. Swing gates in return alleys are the most common method used to create the herringbone palpation facility. The length of the facility determines the size of the group that can be handled. After the separated cows are checked, bred and/or treated, they can be returned to housing facilities.

A herringbone palpation facility can also be used in conjunction with a central workstation for record collection and access. The record system would provide the operator with complete health history quickly when the cows are being examined to help during the examination.



a. Plan view.

b. Isometric view.

Figure 6-10. Herringbone palpation facility.

Chapter 7

Building Environment

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Dairy animals need a clean, dry environment with plenty of fresh air. They perform very well over a range of temperatures. Cool temperatures that are comfortable to dairy cows may not be as comfortable to humans, but it is necessary to put cow comfort first.

A ventilating system must exchange air and maintain an acceptable environment uniformly and economically all year-round. Proper ventilation is key to providing cows with fresh air and maintaining a dry environment.

Ventilating Process

Ventilation is an air exchange process that accomplishes the following:

- Brings fresh air into the building through planned openings.
- Thoroughly mixes incoming and inside air.
- Picks up heat, moisture, and air contaminants.
- Exhausts warm, moist, contaminated air from the building, Figure 7-1.

Failure to provide for any step of this process results in inadequate ventilation, which can create an unhealthy indoor environment.

The purpose of ventilation is to provide a healthy environment for the animals. Ventilating system design and management should be based on animal requirements. When operator comfort is considered and adjustments made to the ventilating system, the resulting environment may not be best for livestock.

Ventilating systems affect:

- Air temperature.
- Moisture level.
- Moisture condensation on surfaces.
- Air temperature uniformity.
- Air speed across animals.
- Odor and gas concentrations.
- Airborne dust and disease organism levels.

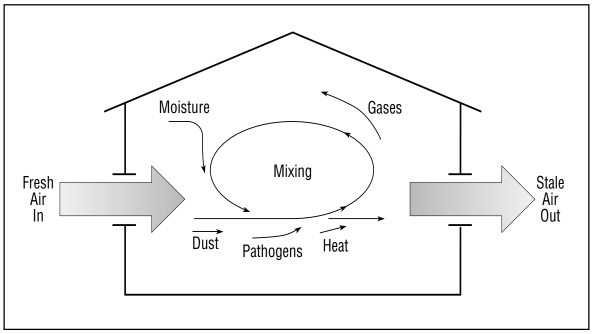


Figure 7-1. A basic ventilating process.

As the ventilating system exchanges air, it brings in oxygen to sustain life. It removes and dilutes harmful dust and gases, undesirable odors, airborne disease organisms, and moisture.

Types of Ventilating Systems

Ventilating systems can be either natural or mechanical. Natural ventilation is commonly used for housing dairy animals in freestall barns and open front buildings. It relies on wind and differences between inside and outside temperature to move air through the building. A mechanical ventilating system uses fans to provide air exchange. Both naturally and mechanically ventilated buildings need properly sized openings for fresh air to enter and exhaust air to exit. Ventilating system control can be accomplished either automatically or manually. Mechanical ventilating systems almost always use thermostatic control while natural ventilating systems are commonly adjusted manually.

Ventilating Dairy Facilities

Dairy animals perform very well over a wide range of air temperatures. In cold weather it is important to provide plenty of fresh air without drafts and avoid high humidities and condensation or frost formation. In hot weather it is important to provide shade and plenty of fresh air, and to avoid excessive temperatures that lead to heat stress. Supplemental cooling can be used to minimize the effects of hot weather.

Dairy animals can be housed in buildings in which there is no temperature regulation. The indoor temperature is about the same as the outside temperature all year. These buildings are usually uninsulated and naturally ventilated with curtain sidewalls. The building protects the animals and their resting area from cold winds, rain, and snow in inclement weather and provides shade in hot sunny weather. When kept dry, adequately ventilated, and properly fed, dairy animals do very well in these barns. Proper equipment selection and management minimize the inconveniences associated with freezing weather. Cooling systems can be included and used during hot weather.

Uninsulated barns will have problems with condensation and frost formation in cold climates where wintertime outdoor temperatures drop below zero for extended periods of time, and managers want to keep indoor temperatures above 10 F to minimize problems with frozen manure. Uninsulated barns in such cold climates cannot provide both adequate air exchange to remove moisture given off by the animals and keep the indoor temperature raised enough to prevent manure from freezing without adding supplemental heat. Installing insulation under the roof or an insulated sloped ceiling with a continuous open ridge can reduce condensation and frost formation. Attic or ceiling insulation does not reduce the need for air exchange. Adequate air exchange is essential even in very cold weather to provide fresh air and to remove airborne contaminants and moisture. The insulation needs to be installed properly and protected from damage by birds for it to be effective. The insulation adds to the initial cost of the building. Roof and ceiling insulation has little effect in hot sunny weather on animal heat stress compared to that available from supplemental evaporative cooling system.

Dairy animals can also be housed in insulated barns designed to be kept at 40 F or above using an automatically controlled ventilating system and supplemental heat. The insulation prevents condensation and reduces building heat loss during cold weather. Insulated barns require a well designed and managed ventilation system that will include inlets, fans and controls. Insulated barns are typically mechanically ventilated year round.

Natural Ventilating Systems

In a natural ventilation system, wind and the difference between inside and outside temperature move air through the building. Naturally ventilated buildings are best ventilated with a continuous ridge opening, large continuous sidewall openings, a smooth roof underside, continuous eave openings, and a roof slope with a pitch of 4/12 to 6/12.

Wind blowing across the open ridge and through sidewall and endwall openings and indoor/outdoor temperature differences move air through the building to provide the air exchange. Fresh air enters through eave or sidewall openings, Figure 7-2. Heat, moisture, and contaminant-laden air exits through the open ridge and down wind sidewall opening. Some ventilation occurs even on calm days because warm, moist air rises, causing a chimney effect. Large, adjustable or full sidewall openings allow increased air movement due to wind in summer. Continuous openings help provide good fresh air distribution.

Location and Siting

Building location is critical for natural ventilation to work well. Locate buildings on high ground, where trees or structures do not disturb airflow around or through the building.

Trees, silos, tall growing crops, and other structures disrupt airflow for a distance of 5 to 10 times their height downwind. Locate naturally ventilated buildings at least 75 feet (in any direction) from such obstructions. See Table 7-1. As a rule, greater

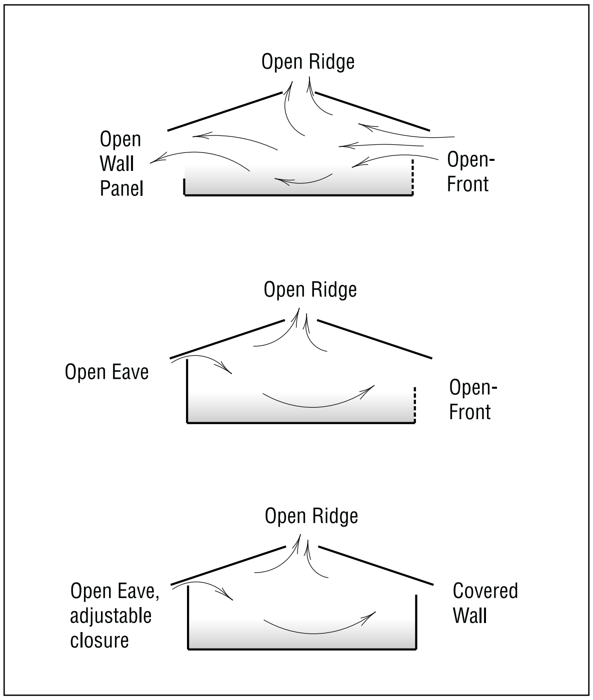


Figure 7-2. Airflow in naturally ventilated buildings. Airflow patterns vary with wind direction and velocity.

Table 7-1. Minimum separation distance between naturally ventilated buildings (feet)[a].
To account for changes in wind direction, determine the minimum separation distance for each building. Use the larger of the two values.

Length of Nearby Building	Height of Nearby Building 20'	25'	30'	35'
100'	75[b]	75[b]	75[b]	75[b]
200'	75[b]	75[b]	80	85
250'	75[b]	80	85	95
400'	90	100	110	120
500'	100	110	125	135
1,000'	140	160	175	190

[a] Buildings with solid sidewalls present greater blockage to airflow and require more separation distance. See *Natural Ventilating Systems for Livestock Housing,* MWPS-33, for more information on separation distances between buildings.
[b] Distance specified is based on other limitations such as fire control and equipment operation.

separation is needed if the upwind structure is more than 80 feet long. Also, a distance of 75 feet between buildings is recommended for fire safety, especially for major buildings or complexes.

Building Orientation

Building orientation affects natural ventilating system performance. Orient naturally ventilated buildings to provide maximum wind exposure, especially for summer winds. Greater and more uniform wind driven air exchange occurs when the wind enters through the continuous sidewall or eave opening rather than through the smaller endwall. Cross ventilation, from side to side, is especially important during warm weather. Orient buildings so prevailing summer winds are perpendicular to the ridge openings.

In the Midwest, buildings with the long axis east-west usually have the best summer cooling, winter sun penetration, and winter wind control. Consider local wind conditions and terrain when orienting naturally ventilated buildings.

Ventilation Openings

Properly sized ridge and eave openings and large adjustable sidewall openings are important parts of a natural ventilating system.

Ridge Openings

Provide a ridge opening of at least 2 inches (measured horizontally) for each 10 feet of building width. For example, a 75-foot wide building would have a 15-inch wide ridge opening. Protect exposed areas of the truss top chord from weathering by covering, painting or sealing the exposed framing. Avoid using kingpost trusses because the center web can wick moisture to the main connection at the lower chord.

With a properly sized ridge opening and proper animal density, precipitation entering the building is not a serious problem. Air exiting through the ridge prevents most rain and snow from entering. Raised ridge caps usually are not recommended because they are expensive and require maintenance. Also, if not properly designed, they can disturb airflow as well as trap snow, Figure 7-3. An upstand may be necessary to prevent snow from blowing into the building. An upstand 1-1/2 to 2 times the ridge opening, Figure 7-4, can be added to help keep out snow and rain at a lower cost than a raised ridge cap. Overshot ridges are also popular and provide protection to the truss ridge

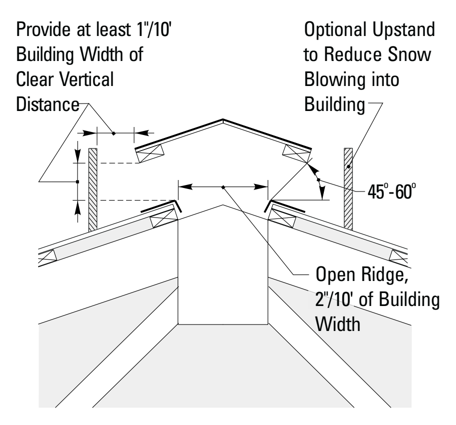


Figure 7-3. Raised ridge cap.

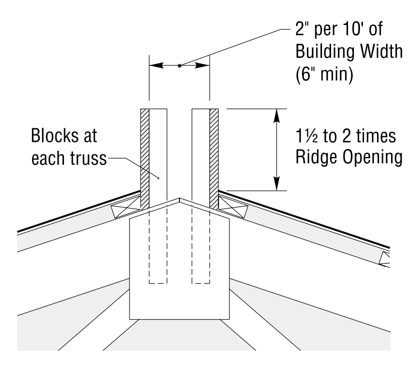


Figure 7-4. Upstand.
Upstand or baffle is 1-1/2 to 2 times ridge width to help keep out wind and snow and increase chimney effect when the wind is blowing perpendicular to the ridge.

connection. Provide 3 inches of opening per 10 feet of building width when designing overshot ridges.

When possible, locate manure alleys or other less critical areas under the ridge. In four- and six-row drive through freestall barns, the driveway is normally under the open ridge. Slope the driveway so that precipitation drains away from the feed manger. When the amount of precipitation coming through the ridge is objectionable, it is better to protect areas below the ridge than to build a cap. Cover critical components, such as a feeder motor or feeder belt, or place an internal gutter 2 to 3 feet below the open ridge to collect rainwater and channel it out of the building, Figure 7-5. Upstands can be used to help guide precipitation to the gutter.

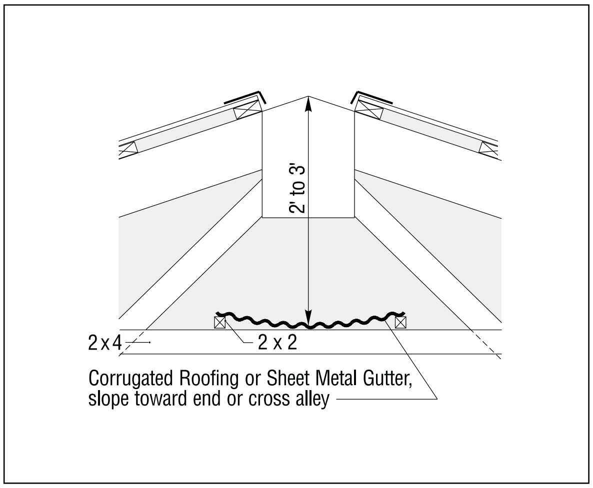


Figure 7-5. Interior trough with an open ridge.

Eave Openings

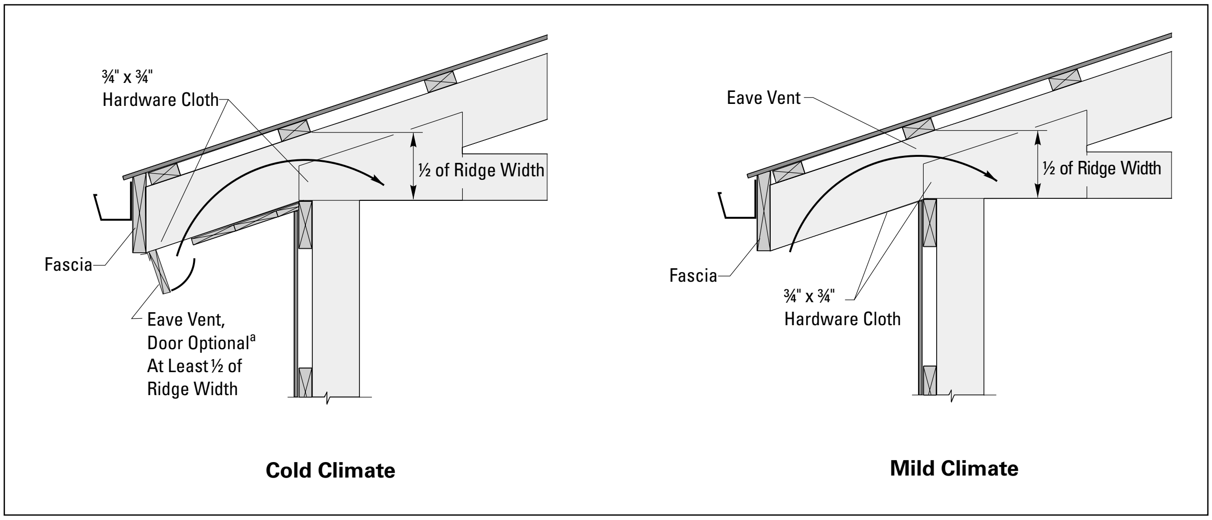
Construct continuous eave openings along both sides of the building. Size each opening to have at least half as much open area as the ridge opening. Eave openings can be provided at the open spaces between trusses or on the underside of the roof overhang, Figure 7-6.

In severe climates, adjustable eave vents reduce airflow and snow blow-in. Close eave vents only part way and then only during severe winter weather (blizzard conditions). Open them immediately after the storm passes. Do not leave the vents closed all winter. A fascia can protect eave openings from direct wind gusts and reduce drafts in rest areas.

Sidewall Height and Openings

Open buildings as fully as possible in the summer so that the building acts as a sunshade during hot weather. Large sidewall openings increase warm weather cross ventilation. Make sidewalls a minimum of 10 feet high. Use 12- to 14-foot sidewalls for drive-through barns, high animal density, or situations where prevailing winds are obstructed. Higher sidewalls are sometimes needed for maneuvering equipment and can partially offset obstructed prevailing winds.

The sidewall opening should be at least 8 feet high, continuous the entire length of the building. Open sidewalls fully to provide maximum summer ventilation. With large sidewall openings, provide a 3- to 4-foot overhang at the eave to shade and partially shield the opening from blowing rain and snow piles and drifts.



Cold Climate

Mild Climate

Figure 7-6. Eave openings.

[a] Make the length of eave vent doors about 75% of the opening length. Extended solid soffit keeps wind from blowing up wall. Use 3/4" x 3/4" hardware cloth to keep birds out.

Ventilation through existing buildings can be improved by increasing the amount of open area, but do not compromise the structural integrity of the building by removing structural members and sheathing. Provide openings in the back of open-front buildings and in both long walls in enclosed buildings. For good airflow at the animal level, put the lower edge of the opening as low as operation will allow. When construction details and animal access allow, lower openings improve airflow through the animal zone in warm weather.

Sidewall openings can be closed or covered using plastic or nylon curtains, pivot doors, top- or bottom-hinged doors, and removable panels, Figure 7-7 and Figure 7-8. Curtains, protected from the animals, are a low cost method for covering large openings during the winter.

In one type of installation, the curtain is rolled up as a rug and tied at every post. To close the sidewall, ties are released, and the hanging curtain is then fastened in place using vertical nailing strips at each post and horizontal nailing strips all along the bottom. A plastic mesh or cord strung over the sidewall opening may be necessary to reduce flapping of curtains in the wind. Various systems are available for adjusting curtain openings, but none offer the advantages of simplicity and low cost this method provides. Use of nailing strips does not provide convenience of sidewall opening management, which may be desired when wide temperature fluctuations occur.

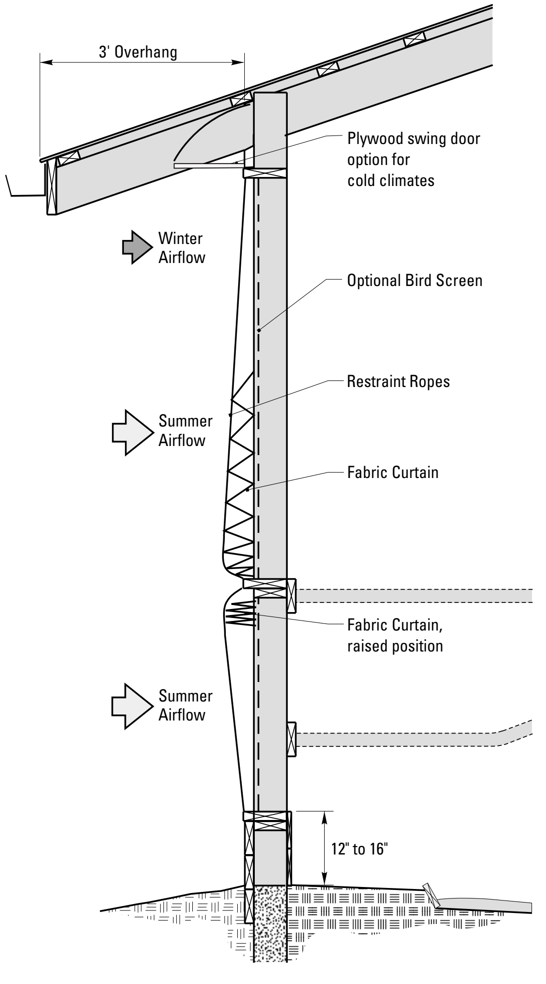


Figure 7-7. Split or two-curtain sidewall opening.

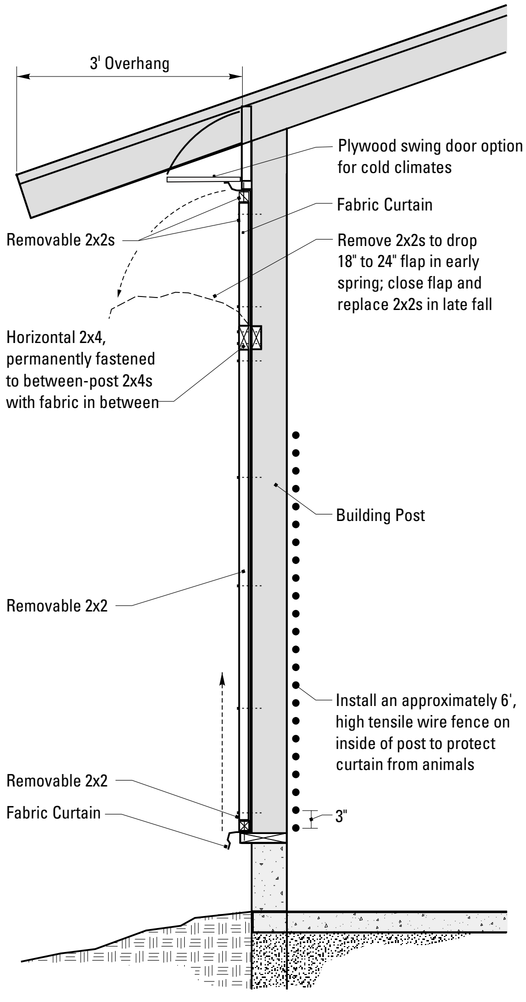


Figure 7-8. Full wall curtain system.
To open sidewall, roll up fabric curtain and tie to permanent horizontal 2x4s.

Endwalls

Endwall openings can provide additional ventilation to supplement sidewall openings in the summer. Additional openings in the gables of endwalls improve summer ventilation, Figure 7-9. Provide removable ventilating panels, wall sections, or curtain endwalls. Alley doors alone do not provide adequate ventilation.

Roof Slope

Roof slope affects wind flow across the open ridge and the chimney effect (warm air rising). Roof slopes of 4/12 to 6/12 work very well in naturally ventilated dairy barns. Condensation and high interior summer temperatures are more likely with roof slopes less than 4/12 because of reduced air movement. Buildings with roof slopes steeper than 6/12 have greater chimney effect but are generally not needed. Slopes of 3/12 are acceptable for open front buildings less than 30 feet wide.

Avoid using exposed purlins that extend more than 4 inches below the roof line. Keep the underside of the roof smoother to enhance airflow.

Facility Management

Management of facilities changes as weather conditions change. Managing the ventilation system is often the key in maintaining an acceptable building environment. Poor building environment can lead to corrosion of metals and deterioration of wood and can decrease cow comfort and health.

Cold Weather Management

Preventing water and manure from freezing and controlling building humidity are the main concerns during extended periods of cold weather. Use waterers and pipes that are heated or protected from freezing. Fresh manure deposited in a cold building adds heat and moisture to the building. To prevent excess moisture from accumulating, remove manure from alleys more often during cold weather using an automatic or rubber tire scraper. Scrape the barn immediately after cows are moved to the holding area, at least twice a day. In extremely cold weather, scrape in the afternoon when conditions are slightly warmer. A heavy tractor scraper or bucket with steel blade and down pressure helps remove frozen manure. Bedded packs do not require extra manure management in cold weather.

Inadequate winter ventilation (air exchange) and high humidity can cause fog, condensation, or frost to form in the building, leading to animal health problems. Eave and ridge openings must be open for air exchange. Attempts to warm the building by closing eave inlets, wall openings, or ridge openings with baffles increase the problem. Do not completely close eave openings; leave them open at least one-half inch per 10 feet of building width. Eave openings could be closed temporarily during severe storms. Attempts to raise building temperature by closing ventilation openings during cold weather often result in a building being left closed through milder temperatures, which can result in poor air quality. During normal winter weather, open sidewalls to provide increased air exchange as average outside temperatures rise.

Hot Weather Management

Hot, muggy summer weather is one of the most critical times for animal health, comfort, and productivity. When winds are calm and there is little air movement, providing adequate air exchange to avoid heat stress is difficult. (See **Supplemental Cooling**).

Continuous large openings are important for good summer ventilation. Sidewall and endwall openings allow for better airflow. Summer sidewall openings

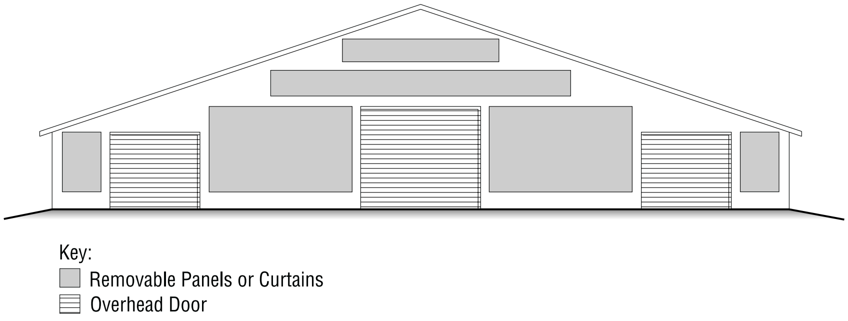


Figure 7-9. Summer openings in endwalls.

must allow wind to blow through the animal zone for heat stress reduction. Open sidewalls and endwalls as much as possible to provide the best summer environment by allowing the building to act as a sunshade. Adequate ridge and eave openings help provide more airflow through the building. Do not remove structural members. If sheathing is removed, consider adding supports to retain structural integrity. Low, wide buildings and buildings with flat ceilings or low-pitched roofs are difficult to ventilate naturally.

Existing single-story buildings can be modified to be naturally ventilated by removing any existing flat ceiling, opening the ridge, and removing the sidewalls, endwalls, *and* gable ends for better natural air movement. Low, wide buildings will still be difficult to ventilate adequately. Remove external obstructions such as tall corn, trees and other vegetation, and interior obstructions such as solid partitions that restrict airflow.

Supplemental Cooling

Consider supplemental cooling to reduce heat stress when shade and maximum natural airflow are insufficient. Dairy cows suffering from heat stress have reduced feed intake and milk production and increased breeding problems. Dairy cows can be stressed when a combination of the following conditions exist:

- High daytime temperatures.
- High nighttime temperatures (less cooling).
- High relative humidity.
- Low wind velocities.

Supplemental cooling can be provided in different ways. One common method is to increase the airflow past the cows using fans. Two other methods rely on evaporative cooling to either cool the air around the cows or wet the cow’s skin and allow body heat to evaporate the water.

Cooling Fans

Provide cooling fans to increase air movement over the body of the cow. Air should move past cows’ bodies at 200 to 400 ft/min. (2.2 to 4.5 mph). The main criteria for selecting cooling fans are capacity to provide a good air *throw*, fan size, drive type, and purchase and operating costs.

Supplemental cooling fans need to have good throw. Fans with more throw have a higher air velocity at a greater distance away from the fan. Look for fans that expel air in a fairly tight cone. Typical fans throw air a distance equivalent to 10 times the fan diameter. Space 36-inch fans 30 feet apart; 48-inch fans 40 feet apart. Do not sacrifice a sustained air velocity at a greater distance for broader coverage (wider distribution) when selecting cooling fans.

Use propeller or other axial-flow fans. Typically, these fans are 24 to 48 inches in diameter and operate with 1/4- to 1-horsepower motors. They generate high airflow rates when operating at little or no static pressure - roughly 10,000 cfm per 1/2 Hp. Orient fans in the same direction as prevailing summer breezes so that the airflow generated by the fans supports wind driven air exchange rather than fighting it under warm conditions. When these fans are installed in the open air over feed alleys and freestalls, they mix the air but do not draw fresh air into a barn.

Install supplemental cooling fans wherever cows may be confined for extended periods and over areas where cows tend to voluntarily spend considerable amounts of time. Recommended priority areas for supplemental cooling fans are:

1. In holding pens,
2. In close-up (dry cow) pens,
3. In maternity and sick/treatment pens,
4. Fresh cows,
5. High producers,
6. Low producers.

In the holding area, blow air away from the milking parlor, Figure 7-10. In freestall barns, locate fans over the feeding alley where cows will be standing to eat, and in the resting area, Figure 7-11.

Evaporative Cooling

Evaporative cooling systems for dairy cows usually use either low-pressure sprinklers or high-pressure misters (also called foggers). Both systems are used in conjunction with supplemental cooling fans. Their design, mode of action, and management are different. Improperly designed systems may not provide the cooling effect the cows need during hot weather. They may also create wet conditions that lead to increased mastitis. Adequate ventilation (air exchange) is essential for evaporative cooling to work properly.

Low-pressure Sprinklers

Low-pressure sprinklers can be used in both the holding pen and over feeding alleys to completely soak the cows to the skin. When the skin is wet, sprinkling is stopped to allow the cows’ body heat to evaporate the water. Use a timer to run the sprinklers long enough to soak the cows to the skin, perhaps 1 to 3 minutes on per 15-minute cycle. Cooling fans are required to increase airflow past the cows and increase evaporative cooling. It is critical that the sprinklers be turned off to allow time for evaporation.

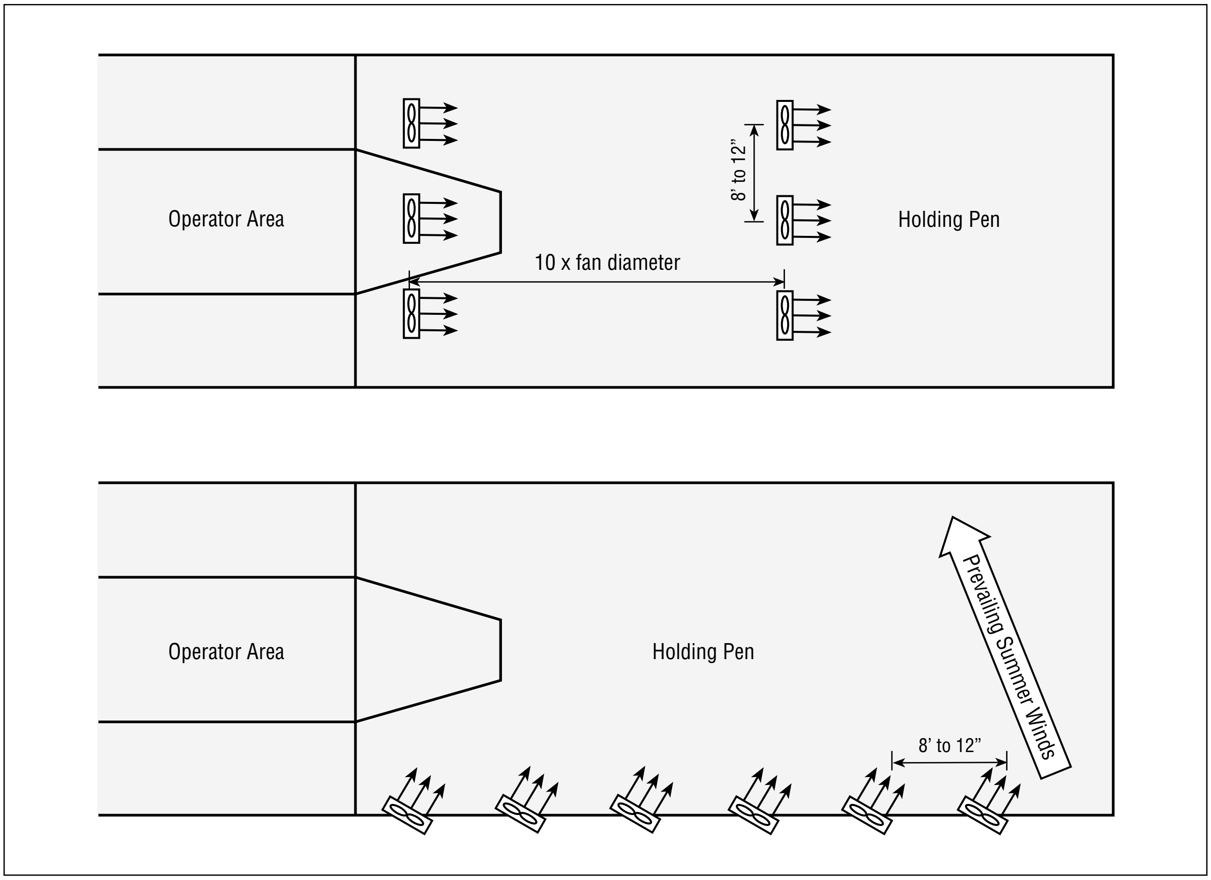


Figure 7-10. Supplemental cooling fan placement in the holding pen.
Place fans in the pen when possible. Bottom figure shows an alternative fan placement.

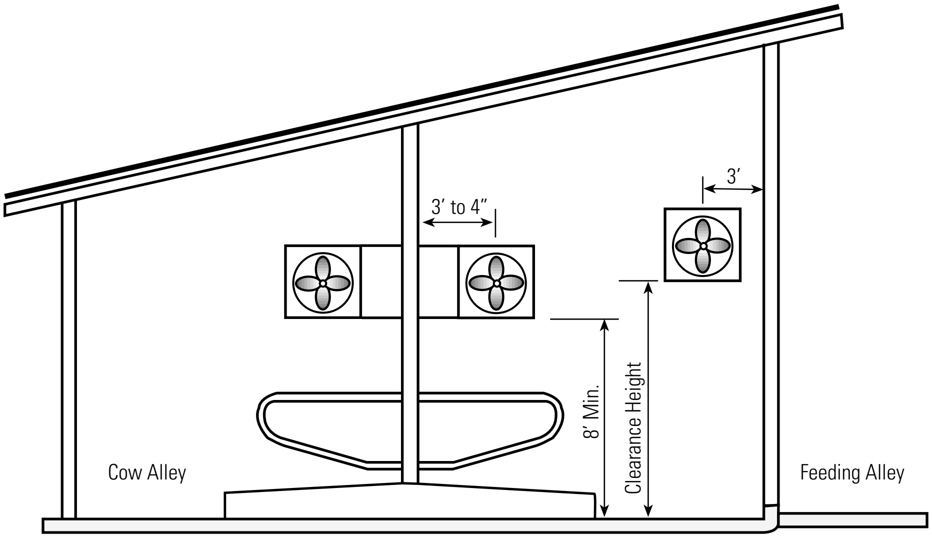
Avoid excessive sprinkling. Excess sprinkling can increase chances of wetting the udder, feed, and bedding and can increase the amount of water that runs off into the manure storage.

Use either 180 degree (half-circle) or 360 degree (full-circle) low pressure (20 to 40 psi) sprinkler nozzles that produce large droplets, which readily wet the cow's skin. A fine mist should not be used. Irrigation nozzles and solid-cone coarse droplet spray nozzles with flow rates between 0.2 and 0.5 gallons per minute work very well. Along a feed manger, the 180-degree nozzles mounted next to the bunk to spray away from the feed bunk minimize wetting of the feed. The 360-degree nozzles work well in holding areas.

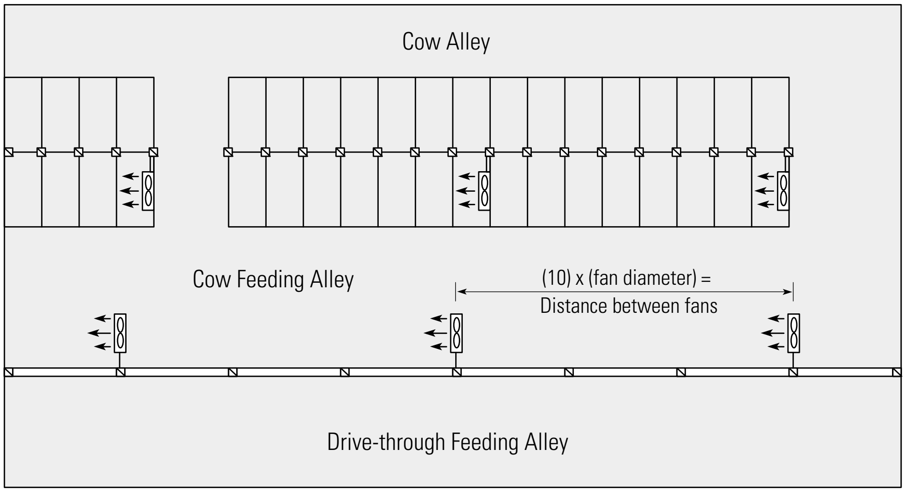
Use information from a sprinkler supplier to determine nozzle spacing based on water pressure. Space nozzles so that the system provides a uniform distribution. Size water lines adequately to provide sufficient water flow and minimal pressure drop to produce a more uniform spray, especially along long feed bunks. Consider installing a pressure regulator to keep the water pressure within operating limits. Excessive pressure may produce a mist or smaller droplets that do not wet the cow's skin but cling to the outer regions of the haircoat effectively insulating the cow. Sprinkler systems can be automatically controlled using a thermostat and 30-minute cycle timer in series. Sprinkler systems are usually set to turn on when air temperatures exceed 78 to 80 F. If water is being blown onto feed then either droplet size is too small or fans need to be repositioned.

High-pressure Misters

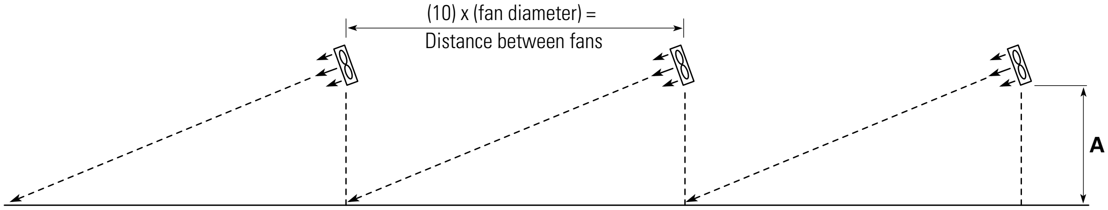
High-pressure misters (sometimes called foggers) operate at pressures around 200 psi and are designed to create very fine droplets that evaporate in the air. As the droplets evaporate the air temperature is reduced a few degrees. The cooler air is blown past the cows. The amount of cooling achieved depends on the air temperature and relative humidity and the amount of evaporated water. Misting systems work



a. Front view



b. Plan view



c. Side view
A= Height above floor to avoid contact by animals and equipment (see Figure 7-11a)

Figure 7-11. Supplemental cooling fans in the cow alley and freestall areas.

best in dry climates. Adequate ventilation (air exchange) is required to remove the humidified and heated air.

High-pressure misting systems run continuously when cooling is needed. Equipment suppliers have misting systems that can be mounted directly on cooling fans. Booster pumps are required to provide the water pressure needed to create the fine droplets. When designed, installed, and maintained properly, a high-pressure misting system can cool air around cows without wetting the cows or their surroundings. This means that misting systems can be used in areas where sprinklers cannot be used. However, improperly operating units can quickly wet a considerable area. Incomplete evaporation of the droplets results in wet stalls, inefficient water use, and ineffective cooling. Again, small water droplets cling to the cow's haircoat, creating an insulating layer. Misting systems suffer from nozzle plugging. Water filters reduce plugging but add to the maintenance required. Use piping and connectors that can handle the water pressure required by the nozzles. Size pipes to provide adequate water flow and minimal pressure drop. Misting systems can be automatically controlled using a thermostat. Misters are usually set to turn on when air temperatures exceed 78 to 80 F.

Bird Control

Excessive numbers of birds can be a nuisance in naturally ventilated barns. Screening the ventilation openings can often reduce bird numbers. Cover the openings with 3/4-inch hardware cloth or plastic netting and increase the opening size proportionally to account for the blockage by the screen. Screened ridge openings may freeze shut in cold weather and disrupt the natural ventilation. Remove ice when it accumulates on the screen. Consider blocking nesting areas on truss chords and framing, or put plastic netting under trusses.

For eave inlets, horizontal screening under the eaves keeps birds from roosting or nesting in the eave area. Vertical screening above the siding may be less susceptible to plugging. Choose the screen location by ease of installation and maintenance or by cost of installation. The framing system dictates these choices.

Selecting structural designs that provide fewer nesting and resting locations can reduce bird numbers, nesting, and the mess from droppings. Wild bird hunting and poisoning is regulated. Federal statutes protect all wild birds, except sparrows, starlings, and pigeons. Permits are required to hunt or poison grackles and black birds. Attracting natural predators like owls and American Kestrels can reduce bird numbers.

Troubleshooting Natural Ventilation

Proper siting, design, construction and management will prevent most problems with natural ventilating systems. Check the following items when planning a naturally ventilated building.

- Locate building with clear access to wind.
- Design and size inlets and outlet openings for adequate air exchange.
- Avoid a site with high silos, trees, or other buildings close by that limit airflow to the building.
- Manage inlets and outlets properly. Do not close openings to increase inside temperatures. The result is usually severe moisture buildup, condensation on the roof and walls, high levels of ammonia odor, animal respiratory illness, and a temperature rise. Do not totally close ventilation openings.
- Do not block inlets or outlets by attaching sheds or roof extensions.
- Provide proper sanitation and housekeeping. Remove wet bedding and manure regularly. Control extra moisture sources (manure, wet bedding, leaky waterers).
- Select equipment and systems (i.e., waterers) that function in cold weather.
- Maintain curtains and doors to minimize drafts.
- Check for blocked ventilation openings. Remove dirt and debris. Raise or remove a ridge cap that restricts the ridge opening.
- Check recommended animal stocking density. Overcrowding can cause problems.
- Keep insulation protected and in good repair.
- When summer ventilation openings cannot be added or obstructions cannot be removed, consider adding supplemental cooling.
- Provide fascia boards to reduce direct wind gusts.
- Provide a horizontal baffle below the eave inlet. See Figure 7-6.

More detailed trouble shooting recommendations for naturally ventilated buildings are available in *Natural Ventilating Systems for Livestock Housing,* MWPS-33.

Mechanical Ventilating Systems

Mechanical ventilating systems have fans, controls, and either air inlets or outlets. A well-designed system provides greater control over room temperature and air movement than natural ventilation. Mechanical ventilation works well to ventilate the milking parlor, milk room, utility/mechanical room, office, conference room, break room, and restrooms in the milking center. See Chapter 5, **Milking Center**, for ventilation recommendations.

Mechanical ventilation is used to ventilate barns or rooms with flat ceilings and buildings that are blocked from good natural ventilation by existing buildings and obstructions. See *Mechanical Ventilating Systems for Livestock Housing*, MWPS-32, for more complete design information.

Types of Mechanical Ventilating Systems

Mechanical ventilating systems types can be broken into three general categories, negative pressure (exhaust), positive pressure, and neutral pressure. In negative pressure systems, the exhaust fans blow air out of the building and create a negative pressure inside the building. In positive pressure systems, the fans blow air into the building and create a positive pressure inside the building. Neutral pressure systems have fans that blow air both into and out of the building and maintain a neutral pressure inside the building.

Negative pressure systems are commonly used for animal facilities because they avoid problems with moisture being blown into the wall and ceiling insulation through small cracks. Positive and neutral systems can be used to correct ventilation problems in existing buildings. See *Mechanical Ventilating Systems for Livestock Housing*, MWPS-32, for design information on other types of ventilating systems.

Mechanical Ventilating System Elements

Mechanical ventilating systems use fans, inlets or outlets, and controls to distribute and mix fresh outside air uniformly in the ventilated room or building. The fans, usually mounted in a wall, ceiling, or duct connected to the outside, force air to flow and create a static pressure difference between inside and outside of the building or room. Mixing fans hung inside a room increase air circulation, but they do not cause the air exchange required by a ventilating system. Inlets provide a place for fresh air to enter and are key to fresh air distribution and mixing in a negative pressure ventilating system. Controls can provide automatic adjustment to the ventilating rate by turning fans on and off or changing fan speeds. Controls can also be used to adjust inlet opening size to improve air distribution and mixing. Together the fans, inlets or outlets, and controls make up the ventilating system for a building or room.

Ventilating Rates

Ventilating rates for good environmental control depend on many factors. Simple tables are commonly used to account for number of animals, animal size and age, and weather (i.e., cold, mild, or hot). For warm barns, base ventilating rates on Table 1-9 and the expected animal occupancy for the room or building. Ventilating rates for different weather are used for selecting fans and sizing and adjusting inlets. For cold barns, air exchange requirements range from no less than 0.17 air changes per minute in winter to at least 1 air exchange per minute in summer.

Negative Pressure (Exhaust) Ventilating Systems

In negative pressure ventilating systems, fans exhaust air from a building, creating a vacuum or negative pressure inside the building. The slight vacuum pressure difference between inside and outside the building causes airflow through designed inlets and other openings. Inlets need to be sized properly, well distributed, and adjusted as the ventilating rate changes to get uniform fresh air distribution and mixing. It is critical that a clear path exist for ventilating air to follow between the outside and the inlet for a mechanical ventilating system to work properly. If winter ventilation air is taken from the attic, adequate openings from the outside into the attic are necessary. Use 3/4-inch screen on attic or eave openings to exclude birds and minimize screen plugging, which will reduce opening area and airflow.

Size long narrow slot inlets based on 1 square foot (144 sq in) of inlet area for each 540 to 750 cfm of fan capacity. Continuous slot air inlets in both sidewalls work well for buildings up to 38 feet wide. The inlets should be continuous along the length of the building, except over individual fans or fan banks and 8 feet on either side of the fans. Group fans in one bank for barns up to 150 feet long. Use two or more fan banks for longer barns. See *Mechanical Ventilating Systems for Livestock Housing*, MWPS-32, for more complete design information.

For inlets to perform properly, seal doors, windows, and unplanned openings so fans develop the desired negative pressure. Fresh air infiltrating through unwanted openings reduces the amount of air entering through planned inlets and disrupts air distribution. Unwanted openings include:

- Open doors, windows, manure system discharges, feed conveyors, and hay chutes. Ridge and eave openings for naturally ventilated buildings are unwanted openings for mechanical ventilation. Too much air entering one area can leave other areas stagnant.

- Cracks in walls, ceilings, and around doors and windows. Even small openings can interfere with good air distribution, especially at low winter ventilating rates.
- Flush or scraper openings, or manure pits/channels to the outside or between rooms. Close these large openings with removable doors or weighted curtains.

Positive Pressure Ventilating Systems

In positive pressure ventilating systems, fans blow air into a building creating a positive pressure inside the building. The positive pressure difference between inside and outside the building causes air to exit the building through designed outlets and other openings. Fresh air is usually distributed through designed area inlets or ducts. Positive pressure ventilating systems generally provide good air distribution and mixing, but can force moist air into walls and attic spaces. This is a critical problem in climates where the moisture can condense or freeze on insulation in the walls or attic. A properly installed and well-protected vapor retarder will minimize moisture problems but not eliminate them. Frost may freeze doors and windows shut. Fans mounted in the endwall of a parlor blowing in during summer with air leaving through the holding area is a good application of a positive pressure system. See *Mechanical Ventilating Systems for Livestock Housing*, MWPS-32, for more complete design information.

Neutral Pressure Ventilating Systems

In neutral pressure ventilating systems, similarly sized fans blow air into and exhaust air from the building at the same time. The two or more push-pull fans create a near neutral pressure inside the building. Exhaust fans are usually sized slightly larger to create a slight negative pressure. Like positive pressure systems, fresh air is distributed through designed area inlets or ducts to provide good air distribution and mixing. Neutral pressure systems are more expensive to build and operate because they have twice the number of fans. See *Mechanical Ventilating Systems for Livestock Housing*, MWPS-32, for more complete design information.

Fan Selection Guidelines

Select fans to move the required air flow against at least 1/8 inch (0.125 inch) static pressure. Consider the reduction in fan capacity due to screens, shutters, and hoods when selecting fans. Provide the cold weather ventilation capacity with single-speed or two-speed fans. Provide additional capacity with single-speed, multiple-speed, and/or variable-speed fans to provide mild and hot weather ventilating rates. Purchase fans that have an Air Movement and Control Association (AMCA) certified rating seal or equivalent testing and rating.

Use fans designed specifically for animal housing. Buy totally enclosed, split phase or capacitor-type farm-duty fan motors. Wire each fan to a separate circuit to avoid shutdown of the entire ventilating system when one motor blows a fuse. Protect each fan with a time-delay-fused switch at the fan. Size time-delay fuses at 25% over fan amperage.

Select fan motors with thermal overload protection with manual reset switches. Manual reset switches reduce the safety hazard of a fan starting while being checked and reduce on-off cycling that can damage the motor.

Proper maintenance is important for good ventilation. Keep fans, shutters, and other equipment clean and properly lubricated. Adjust and replace belts as required. Use belt tighteners on fans to reduce maintenance time.

Ventilating System Controls

Various controllers are available to automatically adjust fans, heaters, inlets, sidewall openings, and sprinklers. The controllers can turn devices on and off or make incremental changes (i.e., change variable speed fans or adjust inlet opening) depending on the device being controlled. Check controller settings and performance every six months. Replace damaged or corroded units.

Thermostatic control is the most common type of control used. Temperature control is done using single or two stage thermostats or solid state controllers and computer systems. Thermostatic controllers can be used to control heaters, cooling system sprinklers and mixing fans, ventilating fans in mechanically ventilated systems, and sidewall opening size in naturally ventilated buildings. Sensor location is important for obtaining a representative temperature. Avoid placing thermostatic sensors in inlet or heater air streams, sunlit areas, on exterior walls, and where animals can damage them. See *Mechanical Ventilating Systems for Livestock Housing*, MWPS-32, for information on fan and heater staging to avoid wasting supplemental heat.

Timers turn devices on and off based on time. Interval or cycle timers are the most common. Common periods are 5, 10, 30 minutes, and 1, 2, 4 and 24 hours. During an interval, the timer can turn a device on and off for one or more periods of time. Interval timers can be used to control lights, sprinklers in a supplemental cooling system (i.e., on 3 out of 15 minutes), and exhaust fans in milking parlors for moisture control after cleanup. Timers are not recommended for providing the minimum ventilating rate in mechanically ventilated barns.

Static pressure sensor/controllers are available for automatically adjusting inlets for mechanically ventilated buildings and rooms. Locate the pressure sensors to minimize wind effects and protect the outside sensor. Set the sensor to maintain a static pressure difference of between 0.04 and 0.08 inches of water.

Manure Pit Ventilation

Well-designed pit ventilation reduces manure gas and odor in the animal area, improves air distribution, and helps warm and dry floors. All mechanically ventilated, slotted floor buildings can benefit from pit ventilation. **Pit ventilation does not mean the pit is free of harmful gases.** Entry into manure pits requires proper safety precautions or the person entering the pit could be overcome by harmful gases and die.

Allow at least 12 inches of clearance between the bottom of slat support beams and the manure surface for pit ventilation airflow. Variable-speed fans are not recommended. Fans made with corrosion resistant materials or finishes are required. See *Mechanical Ventilating Systems for Livestock Housing*, MWPS-32, for design information.

Attic Ventilation

Provide continuous ventilation of attic spaces to minimize moisture buildup caused by weather changes and stable moisture. Use gable louvers and ridge and soffit vents. Provide 1 square inch of net opening area for each square foot of ceiling area. Divide the open area between eaves and ridge and/or gable areas. Be sure that attic ventilation openings do not trap large amounts of warm, moist air exhausted from an animal space. Use 3/4-inch by 3/4-inch hardware cloth to screen openings to keep birds out. Check screens annually and clean as needed to maintain adequate opening area.

Supplemental Heaters

Supplemental heat may be required to maintain the desired temperature and improve thermal comfort. Radiant, space, and make-up heaters are available. Radiant heaters warm surfaces and can provide warmth without heating the air. Unit heaters heat room air directly. Make-up air heaters heat incoming ventilation air. Regular and proper maintenance is required to maintain efficient and safe operation. See *Heating, Cooling and Tempering Air for Livestock Housing*, MWPS-34, for design information for sizing supplemental heating systems.

Unvented heaters add both heat and products of combustion into the building. The products of combustion include gases that can create health and safety problems within the building if concentrations accumulate. For this reason unvented heaters are not recommended.

Insulation

Insulation is any material that reduces heat transfer from one area to another. Although all building materials have some insulating value, the term *insulation* usually refers to materials with a relatively high resistance to heat flow. A material's R-value indicates its resistance to heat flow. Good insulators have high R-values. See *Mechanical Ventilating Systems for Livestock Housing*, MWPS-32, for more discussion on insulation and insulation values.

Insulation Levels

Insulation levels for milking centers are based on wintertime building heat loss and the potential for moisture to condense on ceilings and exterior walls. Provide a minimum insulation level of R=11 in the walls and R=19 in the ceiling. Additional insulation is desirable if it can be installed easily and economically.

Insulation is not needed in dairy barns kept within a few degrees of the ambient temperature all year. Roof insulation is needed when interior temperatures are to be kept above 10 F while outdoor temperatures are below 0 F. When using roof insulation provide an R-value greater than or equal to five. Do not use roof insulation to hide condensation problems caused by inadequate ventilation.

Installing Insulation

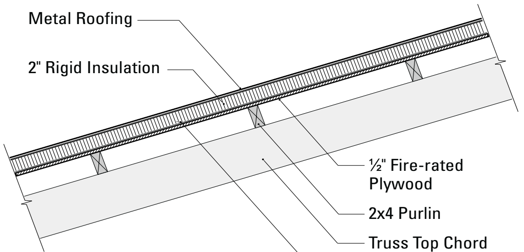
Figures 7-12 through 7-15 show common construction methods for insulated roofs, ceilings, walls, and foundations. Do not compress or pack batt, blanket, or loose fill-type insulating products.

Perimeter insulation reduces heat loss through the foundation and eliminates cold, wet floors in heated buildings. Insulate the entire concrete exterior to a minimum of 24 inches below the ground line. Rodents can burrow as much as 36 inches below grade, damaging insulation and foundations. Use 2-inch rigid, closed-pore insulation, and protect it with high-density fiberglass reinforced plastic or foundation grade plywood above and below ground. See Figure 7-15.

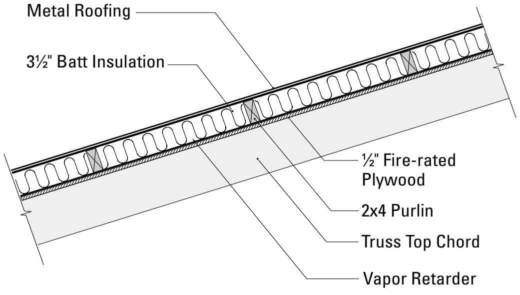
Vapor Retarders

Wet insulation loses its insulating effectiveness, which increases heat loss and building deterioration. Vapor retarders protect insulation effectiveness by restricting moisture migration through walls, ceilings, and roofs. Vapor retarders are classified by their permeability rating measured in perms.

Install 4- to 6-mil polyethylene (plastic) vapor retarders on the warm side of all insulated walls, ceilings, and roofs. Use polyethylene vapor retarders underneath concrete floors and foundations to control soil moisture penetration. Use waterproof rigid insulation if in contact with soil. See Figures 7-12 through 7-15 for proper vapor barrier locations. Avoid puncturing or cutting holes into vapor retarders to minimize moisture migration through the holes. **Provide ventilation in enclosed areas (see Attic Ventilation) on the cold side of insulated surfaces.**



a. Rigid foam over purlins.



b. Insulated roof panels over trusses. Fabricate on the ground and lift into place—then apply roofing.

Figure 7-13. Insulating roofs.

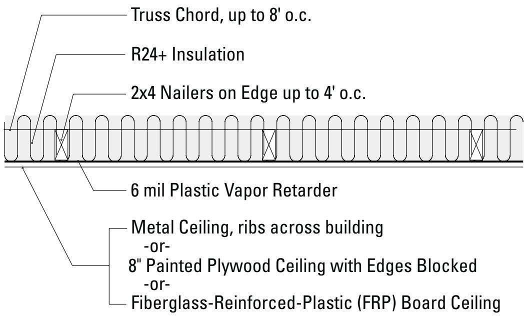


Figure 7-12. Insulating ceilings.
Loose-fill, batt, or blanket insulation recommended for insulating ceilings in environmentally controlled buildings. Insulation must cover the truss bottom chord.

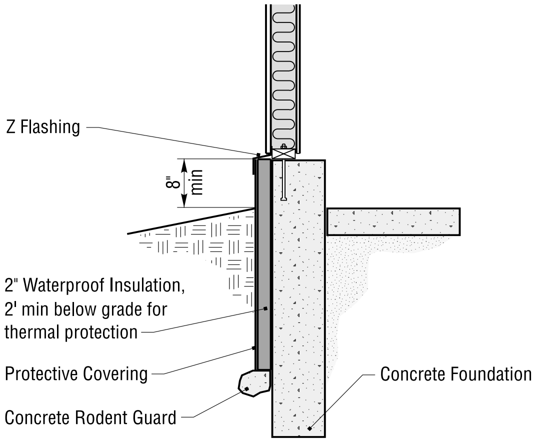
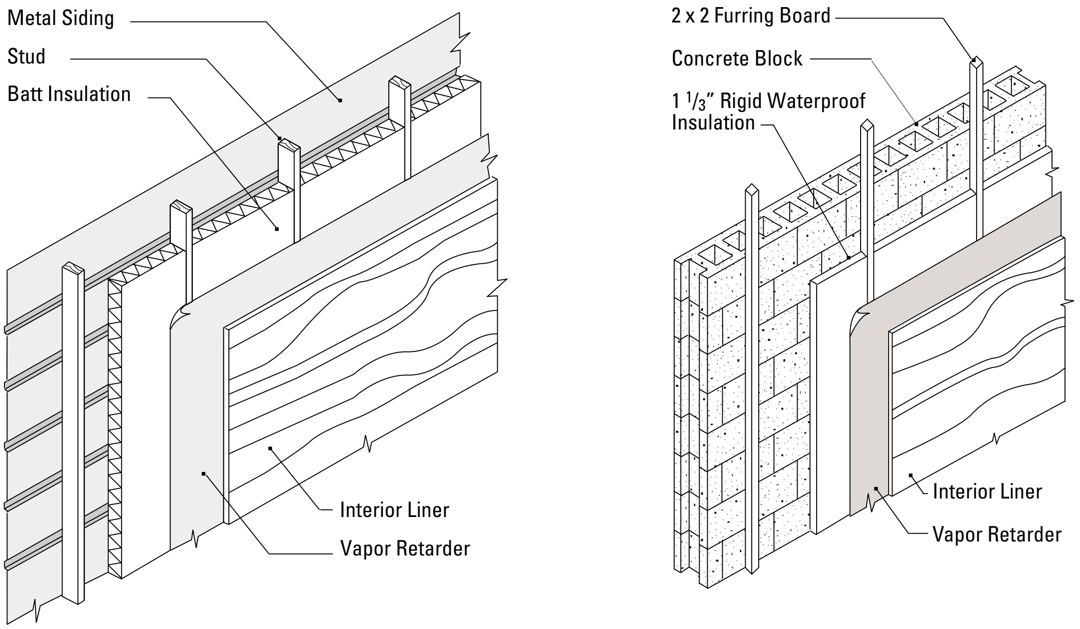
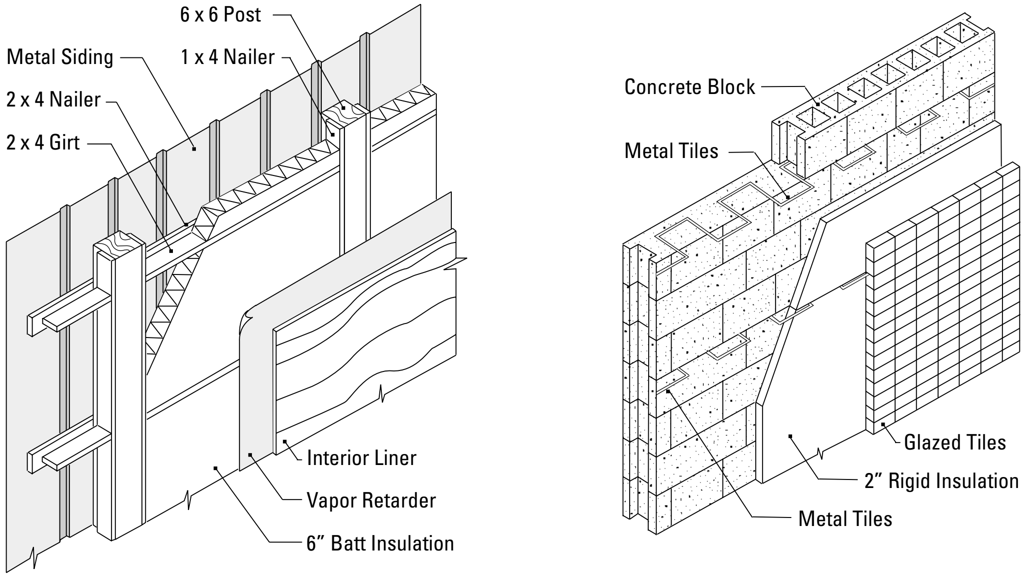


Figure 7-14. Insulating foundations.
Foundation perimeter insulation on outside (R=2.2 per foot). Use waterproof insulation and protect from damage with a rigid, waterproof covering. Tempered 1/4" hardboard and 3/8" foundation grade plywood resist physical and moisture damage but are not rodent proof. Backfill with soil to within 6" to 8" of insulation top.



a. Stud wall insulation.
Approximate R=12 if 2x4 studs, 20 if 2x6 studs. Common in warm buildings.

c. Concrete block wall insulation.
Approximate R=10 if standard blocks, R=14 if lightweight blocks with cores filled. Can be used for remodeling.



b. Post frame building wall with 6" batt insulation.
Approximate R=21.

d. Glazed tile and block wall insulation.
Approximate R=10 if standard blocks, R=14 if lightweight blocks with cores filled.

Figure 7-15. Insulating walls.

Fire Resistance

Many types of plastic foam insulation commonly used in farm buildings have extremely high flame spread rates and need to be covered with a fire-resistant material. When plastic foam insulation is not covered, insurance may be refused for the structure.

To reduce risk, protect foam insulation with fire-resistant coatings. Do not use fire rated gypsum board (sheet rock) in high moisture environments such as animal housing. Materials that provide satisfactory protection include

- 1/2-inch thick cement plaster.
- 1/4-inch thick, sprayed-on magnesium oxychloride (60 pounds per cubic foot) or 1/2-inch of the lighter, foam material.
- Fire rated 1/2-inch thick exterior plywood.

If using fiberglass reinforced plastic coverings, choose fire rated products.

Birds and Rodents

Protect insulation from bird and rodent damage with interior liners and exterior siding or roofing. Be sure to protect the ends of the insulation. An aluminum foil covering is not sufficient protection.

Cover exposed perimeter insulation with a protective liner. High density, fiberglass reinforced plastic is preferred. Foundation grade plywood 3/8-inch thick resists physical and moisture damage but is not rodent proof. Seal holes and cracks in walls and ceilings to limit rodent access. Maintain a rodent bait program.

Screen eave and gable openings with 3/4-inch by 3/4-inch hardware cloth to exclude birds. Remove any ice that accumulates on the screen during prolonged cold periods.

Doors and Windows

Loose fitting doors and windows and cracks around window and doorframes, pipes, and wires can create cold spots, drafty areas, or condensation problems in mechanically ventilated buildings. Cracks and leaks also reduce the effectiveness of the ventilating system inlets. Use insulated and weather stripped entry doors to minimize leaks and heat loss. Locate doors on the downwind side to minimize drafts during entry. For upwind entries, a vestibule or hallway between outer and inner doors prevents cold wind from blowing directly into the building. To conserve floor area, consider making the vestibule entrance part of a hallway, storage area, wash room, or office.

Minimize windows and skylights in animal housing. In warm buildings, windows and skylights increase winter heat loss. The insulation value of single and double glazed windows (R=1 to 2.5) is well below the R-value of an insulated wall (R=13 to 15). In cold barns, skylights can cause roof water leaks and increase the summer heat load.

When remodeling a building, consider replacing all windows with insulated inlets or permanent wall sections. Insulated through-the-wall inlets can be used for summer ventilation. Caulk cracks and joints on outside surfaces.

Chapter 8

Manure and Effluent Management

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and Joe Zulovich, Extension Ag Engineer, University of Missouri

Management of animal manure and effluent is an integral part of a total farm management plan. Changes in agricultural production have led to fewer producers, larger average herd sizes, purchase of feed from distant areas, and a much higher concentration of animals and production facilities on less land. In some areas livestock operations have become concentrated, and non-farm residents have located amongst the farms. These features increase the challenge for implementing good manure management plans.

This chapter identifies the sources of manure and effluent and provides an overview of selected handling and storage systems. See the *Manure Management* publications from MWPS, for detailed system design. Contact a registered professional engineer or the local Natural Resources Conservation Service (NRCS) office for specialized design assistance.

A manure management system includes these components:

- Collection.
- Transfer.
- Storage.
- Possible treatment.
- Land application.
- Nutrient utilization and sampling.

Intensive, more specialized, concentrated animal production systems have altered the nutrient cycle and balance between crop production and animal production. Independent of operation size, a proper manure management system and plan are essential. A complete manure management system has the following goals:

- Maintain good animal health and milk quality by providing sanitary facilities.
- Avoid pollution of soil, groundwater or surface water.
- Reduce odors and dust.
- Control insect and rodent (other pest) reproduction.
- Balance capital investment, cash-flow requirements, labor, and nutrient use.
- Comply with appropriate state and local regulations pertaining to manure and effluent handling.

Failure to provide adequate manure collection, handling, and storage facilities in conjunction with adequate land area for proper application and utilization of manure nutrients could adversely affect air, water, and land resources.

Degraded stream water quality and fish kills can result from manure and feed waste entering from surface runoff. Improperly designed or constructed waste storage facilities, or over-application of nitrogen or phosphorus can lead to groundwater pollution. Many livestock owners and operators are conscious of manure's pollution potential and have taken steps to control it.

Proper design and management are essential to pollution control when operating animal facilities. Choose a manure handling system that most nearly matches a producer's resources, including abilities and desire to operate the system.

Beyond the concern for pollution control and compliance with local, state, and federal standards, livestock producers benefit from the manure's fertilizer value. Using manure nutrients in crop production wisely is a practical method of controlling pollution. The value of manure as a source of plant nutrients needs to be given strong consideration in a manure management system.

A complete manure management plan includes:

- Estimate of annual manure production.
- Estimate of annual nutrient production.
- Estimate of annual crop nutrient utilization potential.
- Cropping rotation.
- Land available for application during the year.
- Adequate collection, handling, and storage facilities.

- Analysis of animals' rations to avoid overfeeding nutrients.
- An emergency action plan to quickly deal with accidental manure spills or other environmental emergencies.

No single manure management system is best for all operations. Each system has advantages and disadvantages. Proper implementation and management are the keys to a successfully operated manure management system. When selecting a manure management system for a specific operation, consider these factors:

- Animal, age and size.
- Feed.
- Housing.
- Bedding.
- Cropping practices.
- Topography of farmstead.
- Proximity to waterways and neighbors.
- Labor and equipment.
- Personal preference.
- Future expansion.

Manure and Effluent Volumes

Estimating the amount of manure and effluent that must be collected and stored is an important step in a management plan. To calculate manure and effluent volumes on a dairy, consider the following:

- Manure from livestock.
- Bedding.
- Milking center effluent and recycling wash water.
- Precipitation on open storage area.
- Evaporation from open storage area.
- Flushing water from the freestall barn, parlor, or holding area.
- Runoff from roofs and outside lots.
- Seepage from stored silage.

Use Equation 8-1 to determine the size of manure and effluent storage for the desired storage period. See *Manure Management* publications from MWPS for more on sizing storages.

Dairy cattle produce 1.2 to 1.6 cubic feet (69 to 103 pounds) of manure per day per 1,000 pounds of body weight. Fresh manure, a mixture of urine and feces, is 12 to 14% solids (86 to 88% moisture content, wet basis). Actual manure volume and solids content of fresh manure vary depending on the ration fed, animal age, and level of milk production. Table 8-1 gives approximate daily manure production values for dairy cattle of various weights. If possible, use site specific data in designing a storage unit instead of the values shown.

Bedding

The type and amount of organic bedding used depends on housing type, Table 8-2. Manure from loose housing or bedded pens is typically handled and stored as a solid. Manure from freestall barns is handled as a semi-solid or slurry. Adding organic bedding, such as straw, to manure increases the solids content.

Equation 8-1. Manure storage volume.

$$\begin{matrix}\text{Storage}\\ \text{Volume}\end{matrix} = (\text{Manure}) + (\text{Bedding}) + \begin{pmatrix}\text{Milking Center}\\ \text{Effluent}\end{pmatrix} + \begin{pmatrix}\text{Flush}\\ \text{Water}\end{pmatrix} + \begin{pmatrix}\text{Open Storage}\\ \text{Precipitation}\end{pmatrix} - (\text{Evaporation})$$

Table 8-1. Daily fresh manure production of dairy cattle.

Values are approximate. The actual characteristics of a manure can easily have values 30% or more above or below the table values. The volumes of manure that a manure handling system has to handle can be much larger than the table values due to the addition of water, bedding, etc.

Stage of Production	Size (lb)	Daily Raw Excreted (lbs)	(cu ft)	(gal)	Water	Density (lb/cu ft)	TS (lb)	VS (lbs)	BOD_5 (lbs)	Nutrient content (lbs) N	P_2O_5	K_2O
Heifer	150	13	0.20	1.5	88%	65	1.4	1.2	0.20	0.05	0.01	0.04
	250	21	0.32	2.4	88%	65	2.3	1.9	0.33	0.08	0.02	0.07
	750	65	1.00	7.5	88%	65	6.8	5.8	1.00	0.23	0.07	0.22
Lactating	1,000	106	1.70	12.8	88%	62	10.0	8.5	1.60	0.58	0.30	0.31
	1,400	148	2.40	17.9	88%	62	14.0	11.9	2.24	0.82	0.42	0.48
Dry	1,000	82	1.30	9.7	88%	62	9.5	8.1	1.20	0.36	0.11	0.28
	1,400	115	1.83	13.7	88%	62	13.3	11.3	1.70	0.50	0.20	0.40

TS = total solids; VS = volatile solids; N = total nitrogen

BOD_5 = the oxygen used in the biochemical oxidation of organic matter in 5 days at 68 F. A standard test to assess effluent strength.

Elemental P (Phosphorus) = 0.44 x P_2O_5; Elemental K (potassium) = 0.83 x K_2O

Bedding used in freestalls also adds to the manure storage volume needed. For sand bedding, add the full volume of bedding to the total storage needs. For organic materials, allow additional storage volume for one half of the total bedding volume because organic bedding materials absorb moisture from the manure. Estimate the total bedding volume by dividing the weight of bedding used by the bulk density, Table 8-3.

Handled properly, almost any type of absorbent, soft material can be effective bedding. However, some types of manure handling equipment and storages limit the use of certain bedding materials. Long or chopped straw, sawdust, sand, shredded newsprint, composted manure solids, or rice hulls can be used to bed freestalls. Use finely chopped bedding materials with hollow-piston pumps, gravity flow pipes, flush systems, or slotted-floor barns. Long straw and other coarse bedding materials can be handled with tractor scraping and solid-piston pumps and chopper pumps.

Sawdust from kiln-dried lumber can be used on stall mattresses and clay bases. Very fine lime (powder) works when dusted daily on mattresses. However, as deep bedding on dirt surfaces it may encourage coliform mastitis. Do not use woodchips when other choices are available. Green sawdust can harbor organisms that cause Klebsiela mastitis, so age green sawdust before using it as bedding.

Sand provides a very comfortable freestall surface for dairy cows. Sand drains well and, unlike organic bedding materials, does not provide a good growing environment for mastitis-causing microorganisms. Sand that is worked out of the freestalls into the alley also helps to prevent cows from slipping. However, manure mixed with sand is abrasive and causes manure pumping and scraping equipment to wear out quickly. If allowed by state regulations daily spreading of manure is common on farms that use sand bedded freestalls.

Sand is incompatible with most gravity flow and slotted floor systems because it tends to settle out in storages and clog pipes. The same is true for crushed limestone, paper mill sludge, clay, and other materials that are more dense than water. Sand does not absorb moisture from the manure. An absorbent material may be needed to remove manure from a semi-solid storage with a loader during warm weather.

Producers who plan to hire a contractor to empty a storage unit and spread manure and effluent on cropland should contact the contractor to see if they will handle sand-laden manure. Well-managed stall mattresses, Figure 4-5, can provide the cow with the comfort and cleanliness benefits without the manure and effluent handling complications.

Estimating Manure and Bedding Volumes for Storage

The volume of manure produced by cows varies greatly depending on the level of milk production and rations fed. The amount and type of bedding used also varies greatly. Therefore, use higher estimates of the storage volumes for manure and bedding is warranted. (Equation 8-2 and Table 8-4).

In Example 8-1, freestall housing requires 20,440 cubic feet less storage than loose housing. However,

Table 8-2. Bedding requirements for dairy cattle.

Bedding material	Freestall	Bedded pack
	- - - lb/day per 1,000 lb of animal weight - - -	
Chopped straw	2.7	11.0
Long straw	NR	9.3
Shavings	3.1	NR
Sand	20-40	NR

NR = not recommended

Table 8-3. Bulk densities of common bedding materials.

Material	Bulk density, lb/ft^3
Shavings	9
Sawdust	12
Baled straw	4-5
Chopped straw	6-8
Loose straw	2-3
Sand	100-120

Example 8-1. Determining the annual storage volume for manure and bedding.
Determine the annual storage volume required for manure and bedding for 100 cows. Compare freestall versus loose housing needs using chopped straw.

Solution:
Assume all cows weigh 1,400 pounds. The required storage volumes are:

Freestalls:
(100 cows) x (1,400 lb/cow) x (1.7 ft^3/day/1,000 lb cow) x 365 days = 86,870 cu ft

Loose housing (where all manure and bedding stored):
(100 cows) x (1,400 lb/cow) x (2.1 ft^3/day/1,000 lb cow) x 365 days = 107,310 cu ft

Equation 8-2. Storage volume for manure and bedding.

$$\begin{matrix}\text{Manure \& Bedding}\\ \text{Storage Volume}\end{matrix} = (\text{Number of Cows}) \times \left(\begin{matrix}\text{Avg. Cow}\\ \text{Weight}\end{matrix}\right) \times \left(\begin{matrix}\text{Total Manure Volume}\\ \text{per 1,000 lb cow - day}\end{matrix}\right) \times \left(\begin{matrix}\text{Length of}\\ \text{Storage}\end{matrix}\right)$$

much, if not all, loose housing storage is in the bedded pack and not in an outside storage. The storage capacity for manure scraped from alleys in a bedded pack barn where the pack is spread directly may need to be 53,655 cu ft (107,310 cu ft x (1 - 0.50)). Also, bedded pack manure can be stacked, while freestall manure must be contained.

Milking Center Effluent Volumes

The amount of milking center effluent generated varies greatly depending on the type of cleaning methods for floors and udders, and the type of milking system, Table 8-5. For example, a parlor floor that is cleaned with a hose may require only 80 gallons of water per day, but a flush system can require as much as 4,000 gallons of water per day. Effluent generated from a 100-cow operation with automatic milking system washing equipment and a hose for cleaning the parlor floor, can vary from 450 to 850 gallons per day. Small operations tend to use less water for cleaning floors and equipment, but more water per cow. Water conservation measures, such as using effluent water from a pre-cooler to clean floors or water livestock, can greatly reduce the amount of effluent created in the milking center. Effluent generation rate is related more to system design and management than the number of cows milked.

Precipitation and Evaporation

Precipitation that falls on uncovered manure storage must be included in storage volume calculations. Figure 8-1 shows a normal annual precipitation for the United States. The amount of precipitation that needs to be included depends on:

- Desired storage period.
- Average amount of precipitation during the storage period.
- The amount of evaporation that is likely to occur from the storage surface.
- Top area of storage.

Table 8-4. Volumes of manure and bedding used in sizing storages.
Based on live animal weight.

Housing type	Manure volume	Bedding volume	Total volume
	- - - - ft³/day per 1,000 lb - - - -		
Freestall			
Sand bedding	1.7	0.3	2.0
Organic bedding	1.7	0.2	1.8[a]
Loose Housing[b]			
Chopped bedding	1.7	0.8	2.1[a]
Long straw	1.7	1.9	2.7[a]

[a] Assumes that bedding absorbs water up to 50% of bedding volume.

[b] Assumes all manure and bedding is delivered to storage where bedding pack is hauled directly to the field, reduce total volume to storage by 50%.

Table 8-5. Approximate milking center effluent and flush volumes.

Washing operation	Water volume
Bulk tank	
Automatic	50-60 gal/wash
Manual	30-40 gal/wash
Pipeline in parlor (Volume increases for long pipelines in stanchion barns)	75-125 gal/wash
Pail milker	
Miscellaneous equipment	30 gal/day
Cow preparation	
Automatic	1.0-4.5 gal/washed cow
Estimated average	2 gal/washed cow
Manual	0.25-0.5 gal/washed cow
Parlor floor	
Cleaned with a hose	20-40 gal/milking
Flush[a]	800-2,100 gal/milking
Well water pre-cooler	2 gal/gal of milk cooled
Milkhouse floor	10-20 gal/day
Toilet	5 gal/flush

[a] Amount of water needed depends on width of flush alley. See Table 8-7 for more information about flush parameters. To convert to cubic feet, divide gallons by 7.5.

Most dairy manure storages that use an organic bedding form a crust due to the high fiber content of the manure. If a large amount of dilution water is added to the storage unit, then a crust does not form. Examples of manure storage units that do not form a crust are storage units used with flush systems and anaerobic lagoons. The rate of evaporation from an encrusted surface is small; do not include evaporation in sizing calculations.

Runoff

Polluted runoff from outside lots must be collected and disposed of in an environmentally safe manner. Polluted runoff comes from several sources:

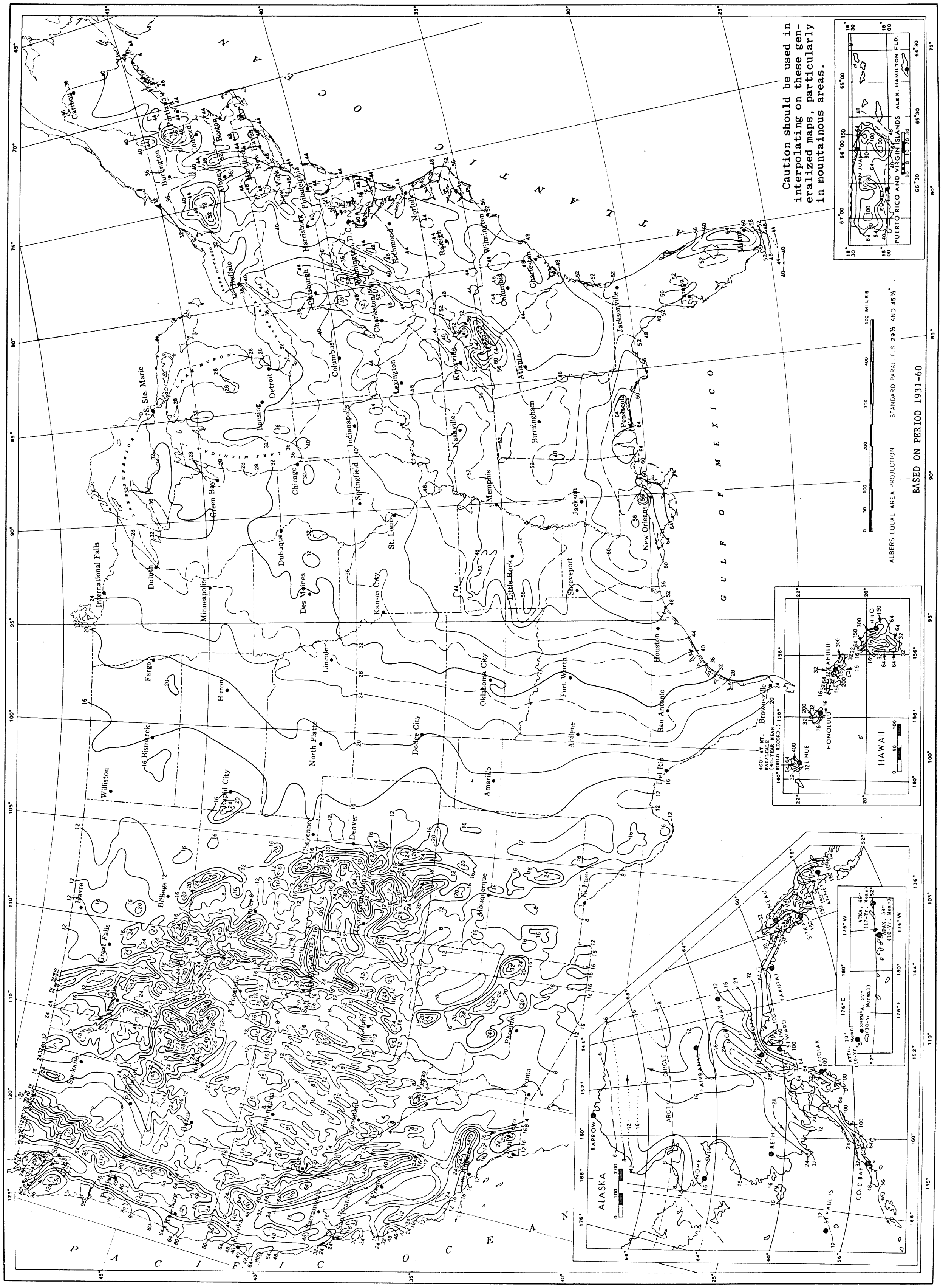


Figure 8-1. Normal annual precipitation, inches.

- Precipitation that falls directly on a lot.
- Precipitation that flows off a roof into a lot.
- Runoff water from surrounding areas that flows through an open lot.

Reduce runoff collection and storage requirements by not allowing clean upslope runoff to flow into a feedlot. Divert clean runoff around an outside lot with earthen or concrete channels. Use gutters, downspouts, and/or concrete channels to divert roof runoff away from outside lots and to reduce collection requirements.

If runoff water is added to the same storage unit as the manure and milking center effluent, then the design storage period will be reduced greatly during periods of heavy rainfall. For lot runoff, a separate collection and storage unit that removes solids is recommended. Such a system allows liquids to be irrigated onto cropland between heavy rainfall events. (See **Managing Lot Runoff,** page 112).

On many farmsteads it is less expensive to prevent the creation of polluted runoff by roofing the feeding and resting areas for heifers and dry cows than to store the runoff. Manure must be cleaned from the feedlot by periodic scraping, but a collection system for runoff is not required. Covered feeding areas are recommended for farmsteads located in areas of Karst geology or sandy/gravelly soils, or near lakes, rivers, or wetlands.

Manure Consistency and Handling Characteristics

Manure consistency is the primary factor that determines the methods used to collect, transfer, and store manure. Manure consistency is typically stated in terms of the solids content on a wet basis. Manure handling and storage methods are classified according to four consistencies:

- Solid.
- Semi-solid.
- Slurry.
- Liquid.

Additionally, sand-laden manure has special handling needs.

Solid

Solid manure can be stacked easily and is obtained when the manure is dried sufficiently or bedding is added to increase the solids content to 18% or more. About 12 pounds of bedding needs to be added per 100 pounds (1.67 ft^3) of fresh manure to handle dairy manure as a solid. (This is roughly the amount of manure produced per day from a 1,400 lb cow.) Solid manure can be handled using front-end loaders, tractor-mounted blades, or mechanical scrapers. A conventional box-type spreader is used for application. Possible spreading mechanisms include paddles or augers. Sand laden manure will not stack even if the moisture content is below 80% unless it is contained.

Semi-solid

Semi-solid manure has a solids content ranging from 10 to 16%. The solids content of fresh dairy manure is 12%, and it may be handled as a semi-solid if precipitation or milking center effluent is not added. Semi-solid manure may be pumped with a piston pump, unloaded from storage using an auger, or handled with the same type of equipment as is solid manure. Box spreaders with tight end-gates can be used with semi-solid manure. However flail-type or V-bottom spreaders generally allow for more uniform application of semi-solid manure. Flail-type spreaders usually have a shaft mounted parallel to the main axis of the tank. Chain flails mounted to the shaft discharge the manure out the side. V-bottom spreaders convey manure by means of an auger to an impeller located at the side or rear of the spreader.

Slurry

Slurry manure contains 4 to 10% solids. Adding 30 gallons of dilution water from precipitation, runoff, or milking center effluent per 100 gallons (13.4 ft^3) of fresh manure (about 10 cows) reduces the solids content to less than 10%. A slurry can be handled with submerged centrifugal, piston, helical rotor, and positive-displacement gear-type manure pumps. To pump heavy slurries against low pressures, use submerged centrifugal, piston, auger, or diaphragm pumps. Slurry manure is most often applied to cropland using direct injection, or tanks mounted on wagons or trucks. Special irrigation equipment can be used if the solids content is less than 6% solids.

Liquid

Liquid manure has a solids content of less than 4%. Liquid manure is typically the effluent from liquid-solid separation equipment, milking centers, or lagoons. Without solid separation, about 250 gallons of dilution water must be added per 100 gallons of fresh manure to reduce the solids content to less than 4%. With proper management and screening, liquid manure can be handled with liquid pumps. However, a slurry or trash pump is more trouble-free. Liquid manure can be spread using direct injection, tank wagons, or irrigation equipment.

Sand-laden Manure

Sand bedding improves herd health and milk quality by reducing mastitis and somatic cell counts. However, moisture from the manure is not retained or absorbed in the sand when compared to *organic* types of freestall bedding. The consistency of sand-laden manure is similar to a slurry when wet and can not be stacked on concrete areas like manure containing straw, paper or wood shavings. While sand's abrasiveness decreases the life of equipment during handling, many producers feel that improvements in herd health offset this disadvantage.

Collection and Transfer

Several collection and transfer methods are possible. Selection considerations include:

- Facility type.
- Labor requirements.
- Investment.
- Manure management system.

Collection Methods

Freestall housing, loose housing, and open-lot systems have different requirements and options for collection systems.

Before removal, freestall manure is usually a semi-solid and can be stored in an outdoor storage. With outdoor storages, remove manure from the building with a mechanical or tractor scraper, front-end loader, flushing gutter, or gravity-flow gutters or channels.

Clean freestall alleys each time the cows are moved to the parlor. Frequent removal of manure from the barn keeps cows clean resulting in a probable decrease in somatic cell count due to environmental mastitis. Clean cows also increase the throughput rate of the parlor because less time is required to clean udders before milking.

An open-lot system requires two manure-handling systems. Lot scrapings and sheltered-bedded packs are semi-solid or solid. Lot runoff is liquid. Solid or semi-solid manure from shelters or lots can be moved to storage with a tractor scraper or front-end loader.

Lot runoff contains manure, soil, chemicals, and debris and must be handled in the manure management system. Runoff from roofs, drives (not animal alleys), and grassed or cropped areas without animal traffic are relatively clean; divert clean runoff from the manure handling system.

Tractor Scrape

One of the most common methods of manure collection from freestall alleys, outside lots, and loose housing is scraping with a tractor-mounted blade or bucket, or a skid loader. To reduce polishing of the concrete floor, many producers use a rubber scraper fabricated from half of a large tire. The tire is bolted to a metal frame that can be mounted to the front of a tractor or a skid loader. The curved shape of the tire also results in less manure flowing out along the edges. During sub-zero weather, remove frozen manure with a hydraulically operated metal-edged bucket or blade.

Large, tractor-mounted loaders are suitable for removing manure from outside lots and scrape alleys with straight runs and few turns. Wide front wheel spacing is desirable for stability. A loaded bucket reduces rear wheel traction, so limit use to relatively flat areas. Avoid using tractor-mounted loaders in buildings that require backing down long alleys or that have restricted turning areas.

Skid loaders can be used to clean manure from cramped areas, such as resting areas in bedded-pack heifer barns. Most loaders have a low height and a turning radius of their own length, so they can be used in tight quarters. One disadvantage is that some have a relatively low lifting capacity. Another disadvantage is the damage caused by maneuvering into the structure and equipment.

Mechanical Alley Scrapers

A typical alley scraper has one or more blades, a cable or chain drive to pull the blades, a 0.5- to 1-horsepower electric motor and controls. The cable or chain is typically recessed into a groove in the center of the alley. The blade is wide enough to scrape the entire alley in one pass. A time clock can be used to operate an alley scraper several times per day. Continuous operation is needed in cold weather to prevent the blade from freezing to the floor and to keep frozen manure from building too deep. Alley scrapers are not effective at removing frozen manure. Therefore, they do not perform well in cold barns when the outside temperature falls below 0 F. Tractor scraping must be used as the backup manure collection system during extreme winter weather.

Mechanical scrapers can reduce daily labor requirements. However, maintenance requirements can be high because of corrosion and deterioration due to the environment.

Slotted Floor

Concrete slotted floors provide a means by which manure is quickly removed from the animal environment with minimal labor cost. Manure either falls through the slotted floor or is worked through the floor by animal traffic. Manure is stored in a pit beneath the floor or removed with gravity-flow channels, flushing systems, or mechanical scrapers. Mechanical alley scrapers are not recommended for use beneath slotted floors because equipment repair or replacement is difficult. Operations using deep pit storage and gravity flow channels should avoid using sand in the freestalls. Sand that accumulates in the pit tends to settle to the bottom of the pit and is difficult to remove. The result is a decrease in storage capacity.

Storage of manure and milking center effluent in a pit beneath a slotted floor combines manure collection, transfer, and storage. However, manure pits can lead to a buildup of manure gases and moisture in the animal environment. The increased concentrations of corrosive gases and moisture can lead to premature deterioration of metal gusset plates on trusses. Manure gas concentrations can become dangerously high inside buildings during agitation and pumping. Therefore, evacuate all people and livestock from the building, and maximize the ventilation rate while emptying the pit. Proper management of the ventilation system (natural or mechanical) is critical to the safe operation of a slotted floor over a manure pit. Pits large enough to accommodate eight months or more of storage can be difficult to agitate to ensure adequate solids removal and are expensive to construct.

Manure collected beneath a slotted floor also can be removed by flushing. The channel beneath the slotted floor should have straight sides, and the flush parameters are similar to those given in Table 8-6. Flushing beneath slotted floors has these primary advantages:

- Animals are separated from the flush water resulting in dryer hooves.
- Freezing of flush water below the slots creates less slipping problems for cows.

However, using slats with a flush system significantly increases the capital investment.

Gravity-flow Channels

Gravity-flow channels beneath a slotted floor or a grate can be used to collect manure and milking center effluent. Manure continuously flows slowly to a reception pit, cross channel, or discharge pipe so minimal labor is required to collect or transfer manure to storage. Biological activity helps liquify manure and maintain flow.

The basic elements of a gravity-flow channel, shown in Figure 8-2, include a flat, level bottom; a 6-inch high dam at the discharge end; and a designed depth and length. The 6-inch dam is required to hold back a lubricating liquid layer. The manure assumes a slope ranging from 1.5% to 3%, depending on the moisture content of the manure. A slope of 3% is typically used for design. The level floor and the dam conserve liquid in the system to facilitate flow. If no dam is present, liquids will tend to flow out of the system leaving a build up of solids, and flow will stop.

This system usually does not work well for dry cows and heifers because of the thick consistency of their manure. The required depth of the channel depends on the length of the channel, the slat thickness, and the required freeboard. See Equations 8-3 to 8-6 to calculate channel depth.

Equation 8-3 shows the initial channel depth needed for a length of 80 feet is 3.9 feet or 47 inches. The maximum practical channel length recommended between steps is 80 feet; however, lengths up to 132 feet have been used. Table 8-6 summarizes some common gravity-flow designs.

The overflow dam can be concrete blocks, poured-in-place concrete, a steel plate, or pressure-treated wood. A removable dam and an access port allow for total clean out if desired.

Before putting cows in the building, fill the channel with 6 inches of water to form a lubricating layer. Limit the use of finely chopped bedding to 1 pound per cow per day. Do not use long straw. Do not use sand. Avoid adding milking center effluent containing disinfectants to channels in the freestall area because it may kill desired biological organisms.

Three conditions typically slow or stop the flow of manure in gravity-flow channels:

- Drying of the manure surface during the summer.
- Freezing of manure in winter.
- Manure sticking to sidewalls.

Provide a convenient way to add water to all channels at the end opposite the dam to restart the flow of manure. During sub-zero weather, the channel serves as temporary storage for two to three weeks. Restart the flow of manure when the weather moderates.

Table 8-6. Gravity-flow step height.
Based on level channel bottom and 3% manure slope. Reception pit depth should be 2 ft minimum, Figure 8-2.

Channel length, ft	Initial channel depth[a], in	Step height[b], in
40	32	20
50	36	24
60	40	28
70	43	31
80	47	34

[a] Includes 6" freeboard, 6" dam and 6" slat thickness
[b] Includes 6" dam.

Equation 8-3. Initial gravity flow channel depth.

$$\text{Initial Channel Depth (feet)} = \left(\text{Length, feet}\right) \times \left(0.03\ \text{ft / ft}\right) + \left(1.5\ \text{feet}\right)^{*}$$

*Includes 6" freeboard, 6" step dam, and 6" slat thickness for a total of 18" or 1.5'.

Equation 8-4. Total gravity flow channel depth.

$$\text{Total Channel Depth (feet)} = \left(\text{Initial Channel Depth (feet)}\right) + \left[\left(\text{Number of Steps}\right) \times \left(\text{Step Height (feet)}\right)\right]$$

Equation 8-5. Cross channel depth.

$$\text{Cross Channel Depth (feet)} = \left(1\ \text{foot}\right) + \left[\left(\text{Number of Steps}\right) \times \left(\text{Step Height (feet)}\right)\right] \geq 2\ \text{feet}$$

Equation 8-6. Total depth.

$$\text{Total Depth (feet)} = \left(\text{Total Channel Depth (feet)}\right) + \left(\text{Cross Channel Depth (feet)}\right)$$

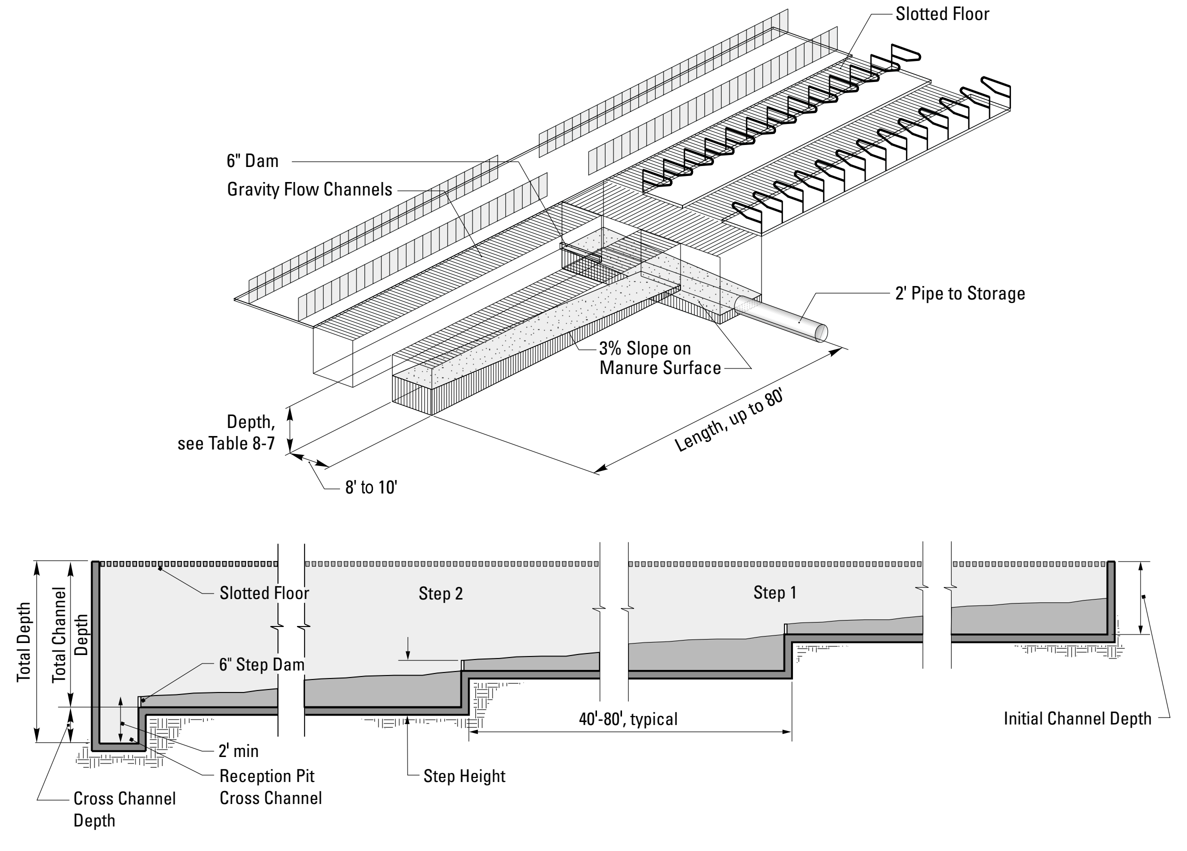


Figure 8-2. Stepped gravity-flow channel.
See Table 8-6 to determine channel depth. Channel bottom has 0% slope.

Alley Flush

Flush systems can be used to clean freestall alleys, parlor floors, and holding areas when temperatures are above 25 F. Flushing may be possible all winter in mild climates.

The volume of flush water required depends on the alley width and slope, Table 8-7. The parameters in Table 8-6 were developed to provide an initial flow depth of 3 inches, a velocity of 5 feet per second, and a 10-second flow duration for alley lengths up to 150 feet. Care must be taken to match the correct alley slope with the proper flush volume and flow rate to ensure good solids removal.

A large amount of water is required for flushing freestall alleys. A two-row freestall barn with alley widths of 10 feet and 12 feet requires about 2,750 gallons per flush with a floor slope of 2%, Table 8-7. Flushing the alleys two or three times per day requires 5,500 to 8,250 gallons per day. The amount of fresh water required per day for alley flushing can be greatly reduced by recycling the water used for flushing. Water can be reused for flushing freestall alleys when cows are not in the barn. With recycled water, salt and mineral concentrations increase and can cause pumps and distribution pipes to plug.

Recycling flush water requires a solids separation system. Flushed manure is typically stored in an earthen storage basin and periodically pumped for irrigation. Often, solids settle out and are difficult to agitate and suspend. Consider using a liquid-solid separator before flushed manure enters the storage. The use of two earthen storage basins connected in series is another common liquid-solid separation technique. The use of recycled flush water leads to increased concentrations of corrosive gases and moisture and premature deterioration of metal gusset plates on trusses. Even with recycled flush water, some fresh make-up water is needed to enhance dilution of solids.

Recycled effluent cannot be used to flush parlors. Therefore, if a flush system is used only for cleaning the parlor and holding area, then the daily flush volume must be clean water. The storage requirements for parlor flush systems can double the volume of a manure storage. Use a 2% slope in the parlor instead of a 1% slope to reduce the amount of flush water required by 40 to 50%.

Table 8-7. Flush parameters.
Assumes 5 fps water velocity for 10 sec.
Alley lengths up to 150 feet

Alley slope, %	Flow depth, inches	Flow rate, gpm/ft	Flush volume, gal/ft[a]
1.0	7.0	1,306	220
1.5	5.0	933	156
2.0	4.0	747	125
2.5	3.4	635	106
3.0	3.0	560	94

[a] Per foot of alley width.

Transfer

Transfer manure to storage by tractor scrape, gravity flow, or pumping. Move milking center effluent to storage by gravity flow or pumping. System selection depends on manure characteristics, bedding practices, available labor, elevation of barn above the storage and storage system. Add milking center effluent where sand will settle out of sand-laden manure (usually in the storage.)

Floor Heating Systems

A floor heating system can be used to assist manure removals in a dairy freestall barn. This system is not intended to heat the entire area or completely melt ice, but is intended to allow thawing to the point that manure and ice detach from the floor surface. Floor heating systems are typically placed in animal drive and walk alleys, and holding areas.

Use a 3/4-inch thermoplastic pipe (such as polybutylene piping or comparable) placed at either 12 or 18 inches on center in the concrete of alley floors. One complete floor heating system circuit is a single continuous length of 3/4-inch pipe placed within the alley floor. The pipe orientation of a circuit can be either a serpentine pattern or a single straight pipe. If a serpentine pattern is used, the effective length of the circuit will increase due to the elbows in the system. Several circuits will be required to effectively heat a complete alley floor. The circuits for an alley floor can be connected to a common manifold piping system. This manifold system connects to the required water pumping and water heating system.

The design of a floor heating system incorporates the following design assumptions:

1. A 10 F temperature difference is allowed between the beginning and end of a piping circuit. This design assumption dictates that a piping circuit requires a 1-gpm water flow rate for each 5,000 BTU/hr circuit heat output.
2. The 3/4-inch pipe size minimizes the impact of other alley floor design considerations including minimum steel reinforcing requirements and equipotential plane requirements.
3. An operating temperature of 45 F is assumed for the inlet temperature into a piping circuit.

Table 8-8. Flowrate for floor heating system for pipes 18" o.c. (gpm).
Numbers right of the dark line have a head loss greater than 40'. Numbers in shaded area have a head loss greater than 80'. Avoid designs in the shaded area.

Temperature Difference F	Estimated Heat Loss BTU/hr-ft^2	Required Output BTU/hr-ft	Total effective length of one circuit (feet)									
			100	200	300	400	500	600	700	800	900	1000
5	1.9	2.8	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.6
10	4.7	7.1	0.1	0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.3	1.4
15	8.1	12.1	0.2	0.5	0.7	1.0	1.2	1.5	1.7	1.9	2.2	2.4
20	11.8	17.7	0.4	0.7	1.1	1.4	1.8	2.1	2.5	2.8	3.2	3.5
25	15.9	23.9	0.5	1.0	1.4	1.9	2.4	2.9	3.3	3.8	4.3	4.8
30	20.3	30.4	0.6	1.2	1.8	2.4	3.0	3.6	4.3	4.9	5.5	6.1
35	24.9	37.3	0.7	1.5	2.2	3.0	3.7	4.5	5.2	6.0	6.7	7.5
40	29.7	44.6	0.9	1.8	2.7	3.6	4.5	5.4	6.2	7.1	8.0	8.9
45	34.8	52.2	1.0	2.1	3.1	4.2	5.2	6.3	7.3	8.3	9.4	10.4
50	40.0	60.0	1.2	2.4	3.6	4.8	6.0	7.2	8.4	9.6	10.8	12.0
55	45.4	68.1	1.4	2.7	4.1	5.4	6.8	8.2	9.5	10.9	12.3	13.6
60	51.0	76.5	1.5	3.1	4.6	6.1	7.6	9.2	10.7	12.2	13.8	15.3
65	56.7	85.1	1.7	3.4	5.1	6.8	8.5	10.2	11.9	13.6	15.3	17.0
70	62.6	93.9	1.9	3.8	5.6	7.5	9.4	11.3	13.1	15.0	16.9	18.8
75	68.6	102.9	2.1	4.1	6.2	8.2	10.3	12.3	14.4	16.5	18.5	20.6
80	74.7	112.1	2.2	4.5	6.7	9.0	11.2	13.5	15.7	17.9	20.2	22.4
85	81.0	121.5	2.4	4.9	7.3	9.7	12.2	14.6	17.0	19.4	21.9	24.3

Table 8-9. Flowrate for floor heating system for pipes 12" o.c. (gpm).
Numbers right of the dark line have a head loss greater than 40'. Numbers in shaded area have a head loss greater than 80'. Avoid designs in the shaded area.

Temperature Difference F	Estimated Heat Loss BTU/hr-ft^2	Required Output BTU/hr-ft	Total effective length of one circuit (feet)									
			100	200	300	400	500	600	700	800	900	1000
5	1.9	1.9	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4
10	4.7	4.7	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.8	0.9
15	8.1	8.1	0.2	0.3	0.5	0.6	0.8	1.0	1.1	1.3	1.5	1.6
20	11.8	11.8	0.2	0.5	0.7	0.9	1.2	1.4	1.7	1.9	2.1	2.4
25	15.9	15.9	0.3	0.6	1.0	1.3	1.6	1.9	2.2	2.5	2.9	3.2
30	20.3	20.3	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.1
35	24.9	24.9	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
40	29.7	29.7	0.6	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	5.9
45	34.8	34.8	0.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7.0
50	40.0	40.0	0.8	1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.2	8.0
55	45.4	45.4	0.9	1.8	2.7	3.6	4.5	5.4	6.4	7.3	8.2	9.1
60	51.0	51.0	1.0	2.0	3.1	4.1	5.1	6.1	7.1	8.2	9.2	10.2
65	56.7	56.7	1.1	2.3	3.4	4.5	5.7	6.8	7.9	9.1	10.2	11.3
70	62.6	62.6	1.3	2.5	3.8	5.0	6.3	7.5	8.8	10.0	11.3	12.5
75	68.6	68.6	1.4	2.7	4.1	5.5	6.9	8.2	9.6	11.0	12.3	13.7
80	74.7	74.7	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5	14.9
85	81.0	81.0	1.6	3.2	4.9	6.5	8.1	9.7	11.3	13.0	14.6	16.2

This will minimize the design temperature difference for a circuit. Also, insulation will not be required under the heated alley floors and around most piping. Minimizing the operating temperature of the system tends to minimize the total size of the boiler system required.

4. The heating system assumes heat loss from the top of the floor surface only. As long as the operating temperature of the system is kept low, heat loss into the soil will be negligible since deep soil temperatures are typically 55 to 60 F.
5. The flow rates required for a given piping circuit are in Tables 8-8 and 8-9. The length of a circuit depends upon piping layout. The design temperature difference depends upon location and is the difference between the estimated

inside barn air temperature and an average floor temperature of 40 F. Flow rates causing 80 feet of circuit head loss are generally not acceptable.

6. The layout of circuit piping depends upon barn layout, manifold piping design, other site considerations, and location of boiler for heating.
7. Total boiler size is estimated as the sum of 50 BTU/hr per foot of total manifold piping, plus the larger value of either 50 BTU/hr-foot of total circuit piping or the required BTU/hr output of circuit pipe, Table 8-8 or Table 8-9.
8. Pumping requirements and manifold piping are designed on a case-by-case basis.

Tractor Scrape

Scraping animal manure from freestall alleys directly into a below ground storage structure is an effective transfer method. Push-off ramps are common for herds of 200 cows or fewer; these ramps provide inexpensive manure transfer for sites that do not accommodate gravity flow. Use pipe fencing on all sides of the push-off ramp for the safety of the tractor operator and for security purposes, Figure 8-3.

The greatest problems with push-off ramps occur in winter. Frozen manure can accumulate and block the push area. One way to eliminate this problem is to provide a very wide push-off ramp (20 to 100 feet) so manure can be pushed into the storage at multiple locations. A concrete stacking slab along the edge of the push-off ramp also may be used during periods of freezing weather. In the spring, the thawed manure is pushed or flows into the storage.

Gravity-flow Pipes

Gravity-flow transfer pipes use the hydraulic head exerted by liquid manure to force it to flow. The required transfer-pipe size depends on the manure characteristics. Liquid manures, such as milking center effluent, flow well through small-diameter (6- to 8-inch) pipes. Larger (24- to 36-inch diameter) pipes with smooth interiors work well with dairy manure with well-mixed bedding and solids content of up to 12%. The required pipe diameter depends on the total flow rate and the solids content. Gravity-flow pipe systems are compatible with:

- Tractor scraper.
- Mechanical alley scraper.
- Gravity-flow channels.
- Flush systems.

To assure adequate hydraulic head for manure flow, the minimum elevation difference between the

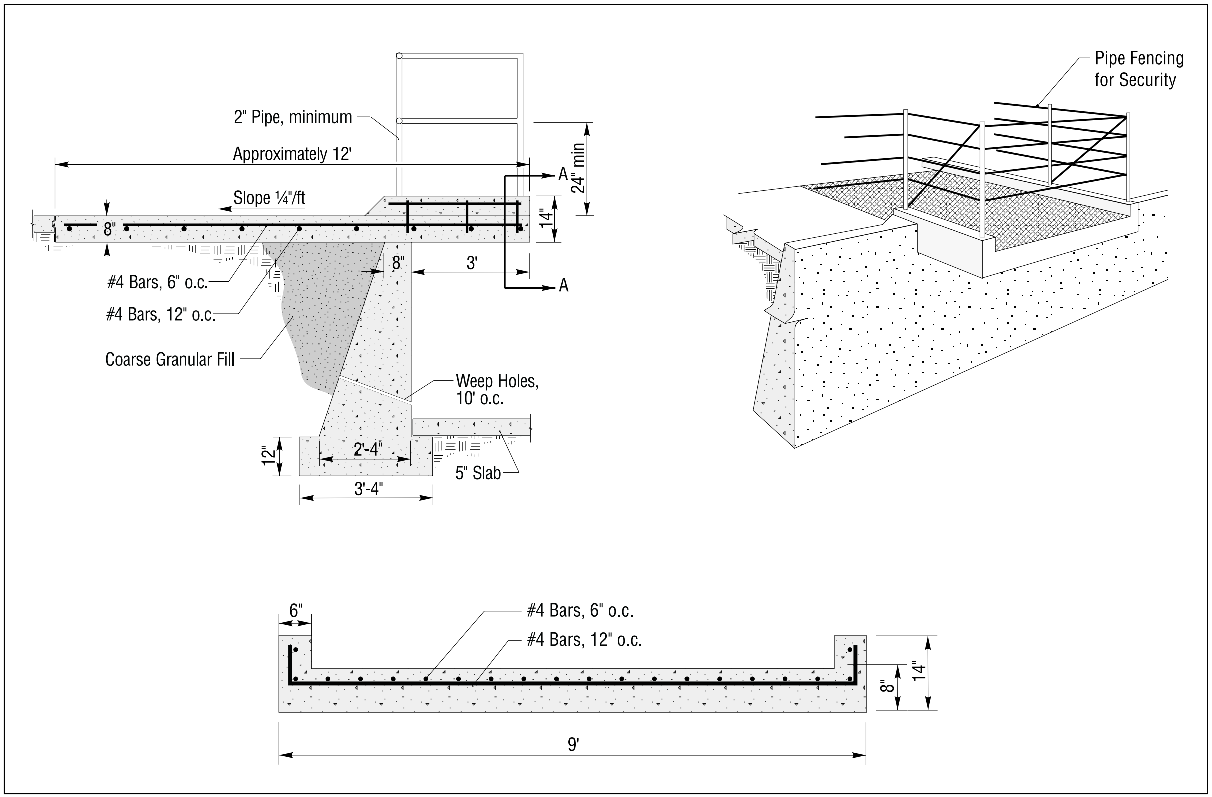


Figure 8-3. Push-off ramp.

scraped alley or collection pit and the top of the maximum depth of the stored material should be 4 to 6 feet for transfer distances up to 300 feet, Figure 8-4.

Gravity-flow manure systems are very dependent on material consistency. Separation of material is more likely to occur in long pipe runs or the reception pits if solids are not mixed uniformly with the liquids or if the solids content is very low. Plugging can result with an accumulation of solids. Provide clean-out ports every 100 feet and at all bends. Solid material mixed uniformly in liquids will flow better from gravity-flow channels. The system works best when less than 3 pounds of organic bedding per cow per day are used. Also, slugs of material dropping suddenly in a vertical section of pipe can entrap air, causing air locks.

Use air vents to help prevent air locking. Typical locations for air vents include:

- A few feet downstream from the reception pit.
- At or near changes in vertical direction.

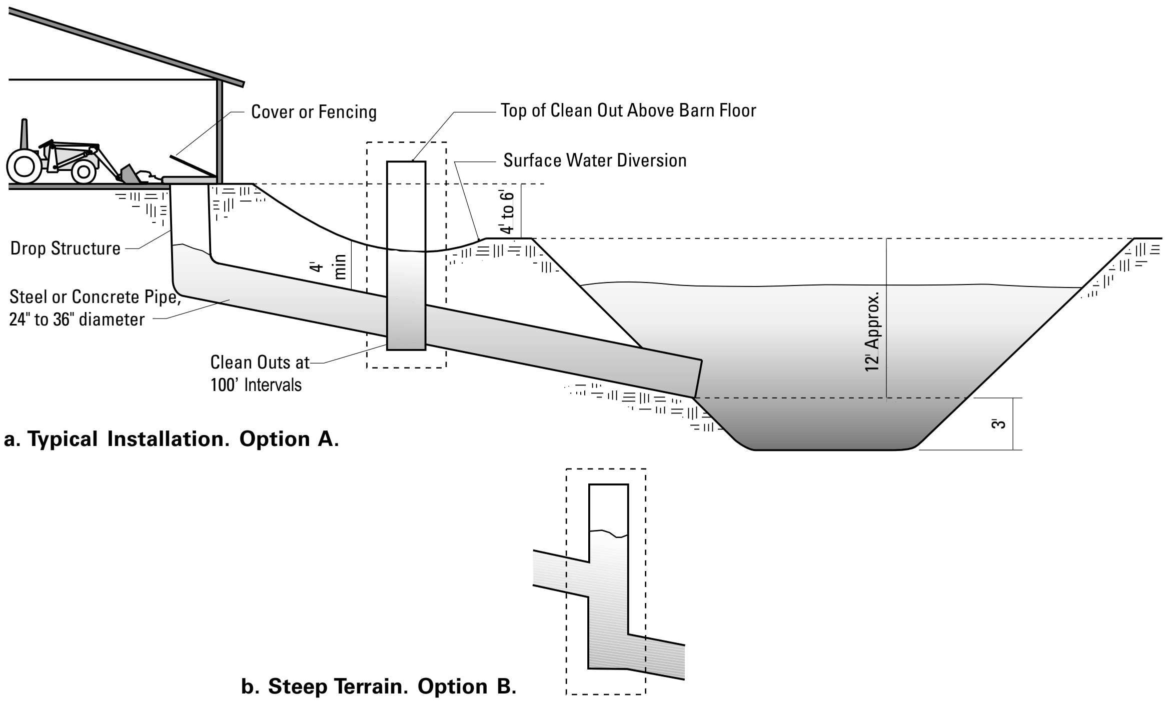
Consult the manufacturer's recommendations for installation of air vents. Avoid bends in the transfer pipe if possible. If a change in direction is needed, use long sweeping bends. Limit horizontal elbows to two, 22.5-degree bends, and separate them with a 10-foot section of pipe.

Air locking may be a problem with steep changes in direction. Also, liquid portions may travel faster along steeper slopes than solids, resulting in plugging. Vertical change in direction can be accomplished with two, 45-degree bends or by using a clean out. See Figure 8-4.

Design the reception pit or hopper that feeds the manure pipe to hold the entire manure volume for at least one day. Many reception pits hold three to seven day's manure volume.

Milking center waste is typically less than 6% solids. Therefore, it can be transferred to the manure reception pit in the freestall barn or the manure storage through 6- to 8- inch pipes. Provide a continuous 1% (1/8 inch per foot) slope for 6-inch pipes and a 0.5% (1/16 inch per foot) slope for 8-inch pipes. Greater pipe slopes cause solids to settle out and could cause clogging. The maximum bend in the pipe should be no more than 45 degrees. Do not add milking center effluent to sand-laden manure until the area of the manure handling system where sand settling occurs.

Install gravity-flow pipes below the frost line, and load the storage structure from the bottom to prevent freezing. Before winter freeze occurs, make sure the end of a pipe is covered with 2 feet of manure where it enters the storage.



a. Typical Installation. Option A.

b. Steep Terrain. Option B.

Figure 8-4. Manure transfer to storage.
Assumes storage is within 300 feet of drop structure.

During extreme winter weather, the manure in most cold freestall barns is partially or completely frozen. Do not push manure that is partially frozen down gravity flow pipes. Stack frozen manure on a concrete slab near the building; use a push-off ramp, or haul to the field.

Pipe Selection

Early systems often used concrete culverts. Problems with these systems have included absorption of liquid by extremely dry concrete and loss of liquid through leaking or misaligned joints.

Pipe used for gravity flow systems should meet the following criteria:

- Have a smooth interior.
- Be non-absorbent.
- Have watertight joints.

Smooth walled sewer pipe with joints capable of withstanding 40-psi internal pressure is recommended. Satisfactory pipes include PVC, high-density polyethylene sewer pipes, and smooth wall steel pipes with welded joints. Storm drain culvert can be used if coupled properly to keep sections aligned to prevent leakage. Leakage through the joints can contaminate groundwater and decrease moisture content, thus preventing proper material flow. Have a reliable contractor properly prepare the trench to provide vertical and lateral support for the pipe.

Reception Pit and Pumping

Pumping is compatible with any type of manure collection method. Manure and milking center effluent are collected in a reception pit located in the center or on the end of a freestall barn, Figure 8-5. The size of the reception pit depends on what role it plays in the overall manure management plan. Reception pits may contain hazardous gases. Pits also are potential drowning sites. See **Safety** page 107.

Some farms design reception pits to storage manure for 7 days before pumping to a larger storage. This helps eliminate daily pumping. A reception pit also can be designed to provide 7 to 30 days of storage. Periodically agitate and pump the manure to a long-term storage unit.

In cold climates, sizing the reception pit to provide three to four months of storage eliminates the need for pumping manure to a long-term storage during sub-zero weather.

The type of pump required depends on the solids content of the manure. Select a pump that can handle manure with bedding and is capable of developing enough pressure to lift manure from the bottom of the pit to the highest point in the long term storage unit or the spreading equipment. A backflow valve may be needed when pumping manure uphill.

A centrifugal chopper pump is commonly used with reception pits in freestall barns. Centrifugal pumps are not positive-displacement pumps because the impeller can slip in the liquid. Centrifugal pumps typically cannot handle large solids. Pump performance depends on impeller design. Closed impellers are more efficient with water and very liquid manure, but cannot handle large solids. Semi-open impeller pumps can handle liquids with larger solids content. **Select pumps that are removable to allow for service and repair outside of the pit**.

Positive-displacement pumps include screw pumps and piston pumps. Screw pumps handle manure with high solids content, but it must be free from hard or abrasive solids. Do not operate screw pumps dry; always add a small stream of water directly into the pump casing during operation. Piston pumps are used to move high-solids content manure to storage. They are commonly used to transfer lot-scraping or tie-stall and freestall barn manure to storage. Plugging the discharge pipe can cause very high pressures, which can lead to pipe damage. Large diameter (10- to 15-inch) pipes are typical and seldom plug. Therefore, release valves are seldom used for manure transfer. Additional information on pump characteristics is given in the *Manure Management* publications from MWPS.

Manure Storage

Consider all farmstead operations, building locations, and prevailing summer winds when planning storages. Allow at least 100 feet between a water supply and the location of any part of a storage.

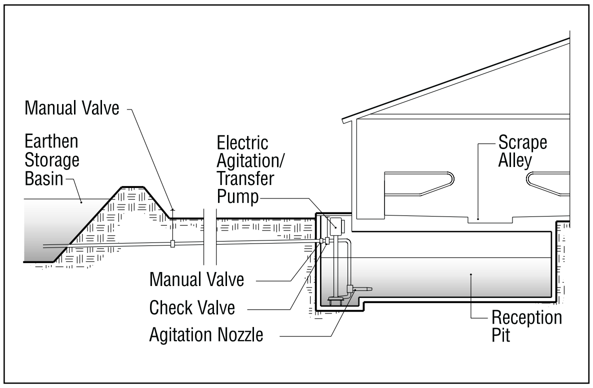


Figure 8-5. Reception pit and pump.

Locate manure storages at least 50 feet from the milking center. Check with milk inspectors, health authorities and water quality regulations for additional separation requirements.

Evaluate site and soil conditions carefully to avoid contaminating groundwater and surface water. Avoid locating storages over shallow, creviced bedrock, below the water table, in gravel beds, or in other areas where serious leakage can cause groundwater pollution. Depending on local pollution control regulations, keep the bottom of the storage at least 3 feet above bedrock and at least 2 feet above the water table. Contact local regulatory agencies for additional site requirements.

Locate, size, and construct storages for convenient filling and emptying and to keep out surface runoff. Provide all-weather access and a firm base for the tanker loading area. Design roadways for drive-through loading to avoid backing or maneuvering the tank wagon.

Slurry and Liquid Storages

Similar to other storages, the required storage capacity for slurry and liquid storages depends on regulations, number and size of animals, quantity of milking center effluent, amount of stored runoff and precipitation, and desired storage time. Provide enough storage to spread manure when field, weather, and local regulations permit. In most climates, 10–12 month storage capacity for all sources of manure is recommended. If the storage receives only animal manure, increase the storage volume to allow for waterer wastage, ballast water, rain, and snow. Provide at least 1 foot of freeboard.

Below-ground Storage Tanks

Liquid manure can be stored in below ground concrete tanks. Storage depth may be limited by soil mantle depth over bedrock, water table elevation, and effective lift of a pump. Tanks must be designed to withstand all anticipated earth hydrostatic and live loads, plus uplift, if a high water table exists. To make agitating manure easier, some producers install partition walls in the pits to separate the manure into smaller volumes. Because there is a smaller volume of manure to agitate in individual compartments, producers can have a more uniform effluent being removed from the pit and applied to the land application area. Partition walls need to be designed to withstand different pressures that can result from one compartment being emptied and the adjoining compartment being full of manure. See *Concrete Manure Storages Handbook*, MWPS-36, for design details for below ground storage tanks. NRCS offices also can provide concrete tank designs.

When construction is completed, clean out foreign material that could damage pumps. Before filling with manure, add 6 to 12 inches of ballast water to keep manure solids submerged and to counteract the uplifting forces caused by external pressures. Keeping manure solids submerged can help reduce odors. The additional water needs to be considered when calculating storage volume.

Earthen Storage Basins

Earthen basins are earth-walled structures at or below grade that may be lined, Figure 8-6. They can provide long-term storage at low to moderate investment. Depending on location and unloading methods, a clay, synthetic, or concrete liner may be required. Earthen storages are designed and constructed to prevent groundwater and surface water contamination. Check with the NRCS office, or hire a qualified professional engineer to help evaluate site suitability, dike construction, bottom sealing, and basin wall side slopes.

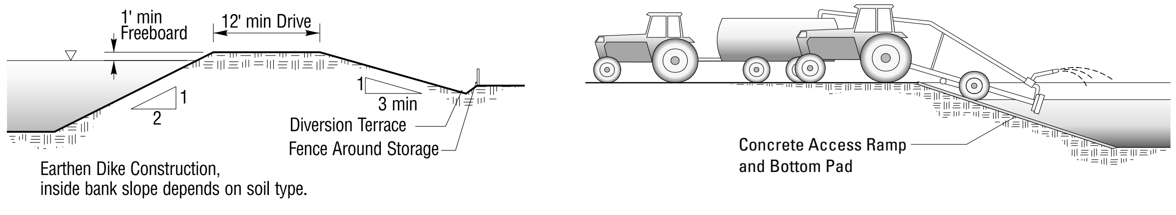


Figure 8-6. Earthen storage basins.

Be sure to obtain approval from the appropriate agencies before construction begins. Special permits are required in many states. Some jurisdictions do not allow earthen storage.

In general, steeper banks conserve space (see Figure 8-6), reduce the amount of rainfall entering the storage, and leave less manure on the banks when emptied. Inside bank slopes of 2:1 to 3:1 (run:rise) are common for most soils. Make the external side slopes no steeper than 3:1 for easier and safer maintenance. Make the embankment wide enough (at least 12 feet) for access by mowers and agitation equipment. Provide a concrete ramp and bottom pad at each agitation and pumping location to protect the basin liner during unloading.

Above-ground Storage Tanks

Above ground circular manure tanks are usually short, large-diameter tanks resembling silos. They are expensive compared to earthen basins and usually are not used to store runoff or dilute manure. However, they are a good alternative where basins are limited by space; high groundwater; shallow, creviced bedrock; or where earthen basins are not acceptable.

Above ground liquid storages are 10 to 30 feet high and 30 to 120 feet in diameter. They are made of concrete staves, reinforced concrete, preformed concrete panels, and steel. Leaks from joints, seams, or bolt holes can be unsightly, but most small leaks quickly seal with manure. The joint between the foundation and the sidewall can be a problem with improper construction. The reliability of the dealer and construction crew are as important as the tank material in ensuring satisfaction. See *Concrete Manure Storages*, MWPS-36, for details about designing concrete manure storages.

Filling

Manure can be transferred to below ground tanks or earthen basins by pump, gravity, or tractor scrape. Above ground tanks are generally filled using pumps. With outside storages, locate collection pits and sumps where manure can be conveniently scraped in. Water, from parlor waste, may need to be added for easier transfer.

Load storages from the bottom if possible. A crust will form and help reduce fly and odor problems if excess dilution water is not added by flushing the parlor. Keep the inlet pipe about one foot above the bottom to prevent blockage and freezing and to keep gases from leaking back into the barn. Bottom loading pushes solids away from the inlet and distributes them more evenly. Top loading a structure works, but solids pile up around the loading point in cold weather. Also, odor is more of a problem because a crust does not form. Flies are often a problem with top loading storages.

Agitation and Unloading

Agitate slurry and liquid manure storages by diverting part or all of the pumped liquid through an agitator nozzle. Propellers are also used. The liquid stream breaks up surface crust, stirs settled solids, and makes a more uniform mixture. Agitate and pump as much manure as possible, then agitate the remaining solids and dilute if necessary. Diluting manure to 90% water (or 10% solids) may be necessary.

Agitation pumps include open- and semi-open impeller, centrifugal chopper agitator pumps, and helical screw pumps. Earthen basins usually are agitated with a three-point hitch or trailer-mounted high capacity manure pump mounted at the end of a long boom. The pump is lowered down the ramp, placing the pump inlet under the manure surface. These pumps have a chopper and/or rotating auger section at the inlet to break the crust and draw solids into the pump for thorough agitation.

Above- and below ground storage and manure tanks usually are agitated with a submerged centrifugal pump. With silo storages, pumps can be mounted on the storage foundation. Large diameter tanks may have a center agitation nozzle. Locate agitation sites no more than 40 feet apart in tanks without partitions (20 feet on center for vacuum pumps). With below-building storage, a 5-foot long by 6-foot wide annex can be used. Locate support columns so they do not interfere with agitation.

Long propeller agitators on trailers also are used to agitate earthen basin storages from various locations. This system requires large amounts of horsepower, but may be more maneuverable than large pumps on banks.

Irrigation

Irrigation provides a convenient method to unload liquid manure. Most irrigation systems can handle liquid manure with up to 4% solids, which is typical of effluent from liquid-solid separators, effluent from a lagoon, or milking center effluent. Surface irrigation and big guns can handle liquids with higher solids content.

Surface irrigation is an effective method of manure application. It has low cost, low power requirements and few mechanical parts. Do not use surface irrigation on land with more than 2% slope. Design and manage the system to prevent runoff and erosion.

Sprinkler irrigation of manure must be managed carefully. The applied manure does not readily infiltrate. Also, manure solids tend to clog soil pores. Surface runoff may be a problem, especially with excessive application rates. Before irrigating, loosen the soil surface with a disk, chisel plow, or aeration tool to improve infiltration. Plan to till the surface to incorporate manure. This helps reduce runoff, odors, and nitrogen loss due to volatilization. See *Sprinkler Irrigation Systems*, MWPS-30, for more details on sprinkler irrigation.

Safety

Liquid manure handling systems can reduce labor requirements in handling manure but can introduce potential hazards due to the toxic effects of manure gases. Outdoor and open-top manure storages also can be potential drowning sites. Fatalities have occurred due to manure handling accidents. Designers, sales personnel, and installers share in the responsibility to educate the end-users of the dangers of manure pits. Provide warning signs and fences.

Toxic gases released during the agitation of liquid manure are deadly. Dangerous concentrations of hydrogen sulfide, the most toxic gas from liquid manure storages, can be released due to agitation or can accumulate in confined spaces. Ammonia, carbon dioxide, and methane are other gases that can create hazardous conditions when handling or storing manure. Consider the following safety points when working with liquid manure storages and handling equipment:

- Do not enter a manure pit without wearing a self-contained breathing apparatus or a mask with supplied air and a safety harness with at least two people standing by to assist in an emergency.
- Use pumpout and agitation pumps and equipment that can be serviced outside a reception or pump pit. Do not enter a reception pit to repair or adjust equipment.
- Remove people during agitation; provide maximum ventilation in the building.
- If possible, move animals from the building before agitating manure. Reports of animal deaths during agitation are common.
- Protect tank openings and agitation ports with grills and/or covers or fences.
- Install railings around all pump docks and access points for protection during agitation and clean out.
- Post signs near manure storages and agitation sites to warn of potential dangers. Possible warning statements for signs are **Danger-Manure Storage, Danger-Toxic Gases,** and/or **Keep Out**, Figure 8-7.
- Keep all guards and safety shields in place on pumps, around pump hoppers and on manure spreaders, tank wagons, power units, etc.
- Use fences to exclude animals and people, including small children who may crawl under or through fencing and gates.

Manure storage pits, storage tanks, and earthen basins are potential drowning sites, especially for children and animals. Failure of slats or covers on pits can result in livestock drowning. Lack of protective barriers or railings around pit openings can lead to accidents. A push-off platform or ramp can be a site for the tractor scraper and driver to tumble into an open storage structure. All push-off platforms need a barrier strong enough to stop a slow-moving tractor. Crusts on earthen storage basins can be misleading. The crust may appear capable of supporting one's weight. It is usually thick at the edges and thin in the middle.

Prevent accidental entry by people, livestock, and equipment into earthen storages and open top tanks with a fence at least 5 feet high. Erect signs to identify the potential dangers, Figure 8-7. Provide at

Attention to safety details could save a life . . . it might be yours.

Figure 8-7. Danger sign to be posted around manure storages.

least one lifesaving station that is equipped with a reaching pole and a ring buoy on a line near each liquid storage basin or open-top tank. Review the total manure management system from a safety viewpoint during the design process. Also, make an annual safety inspection after construction. Think through each step of the collection system, storage or treatment units, and the land application. Correct any unsafe conditions immediately.

Semi-Solid Manure Storages

Dairy manure can be stored and hauled as solid or semi-solid if ample bedding is used and additional water excluded. Calf pens, maternity pens, and young stock housing are heavily bedded, and manure is often handled as a solid. However, combining heavily bedded manure with sufficient quantities of manure scraped from freestall or feeding alleys and precipitation results in a semi-solid mixture.

A picket dam may be used to allow rain water and melted snow to flow away from a semi-solid storage, Figure 8-8.

Roofed storages were developed for dairy stall barns where significant amounts of bedding are mixed with manure. Roofing provides an aesthetically pleasing structure that appears to be another building on the farmstead.

Above ground roofed storages have a concrete floor as much as 3 feet below the existing grade, Figure 8-9. The roof protects collected manure from rainwater and keeps the manure as dry as possible. Manure in storage encrusts, reducing odor and fly breeding problems. Scraping dry-yard manure to a roofed storage can help prevent leaching of nutrients. Provide a ventilating space between the top of the walls and the trussed roof.

These storages are typically bottom-loaded with a large diameter piston pump. Unload by lifting horizontal planks out from a door in one end of the storage. Manure then flows over the wall onto a concrete slab outside the storage where a front-end loader fills a conventional spreader. Remove the planks with a hoist supported from a beam above the doorway.

Solid Manure Storage

Solid manure storage can be used with loose housing for heifers and dry cows. Provide for convenient filling with a tractor-mounted loader or scraper, elevator stacker, or piston pumping system. Unload with a tractor-mounted bucket. Locate storage for year-round access so manure can be spread when field, weather, and regulations permit. Prevent surface runoff water from entering the storage.

Adequate storage capacity is needed for convenience, maintaining maximum fertility, and preventing water pollution. Storage capacity depends on number and size of animals, type and amount of bedding, and desired storage period. In cold climates, provide 180 days of storage; less storage capacity is needed in warmer climates.

Provide convenient access for unloading and hauling equipment. Slope entrance ramps upward to keep out rain and surface water. Provide a load-out ramp at least 40 feet wide with a 10:1 slope (20:1 preferred). A roughened ramp improves traction. Angle grooves across the ramp to drain rainwater. Concrete floors and ramps 5 inches thick are recommended. Slope the floor 2% (1/4 inch per foot).

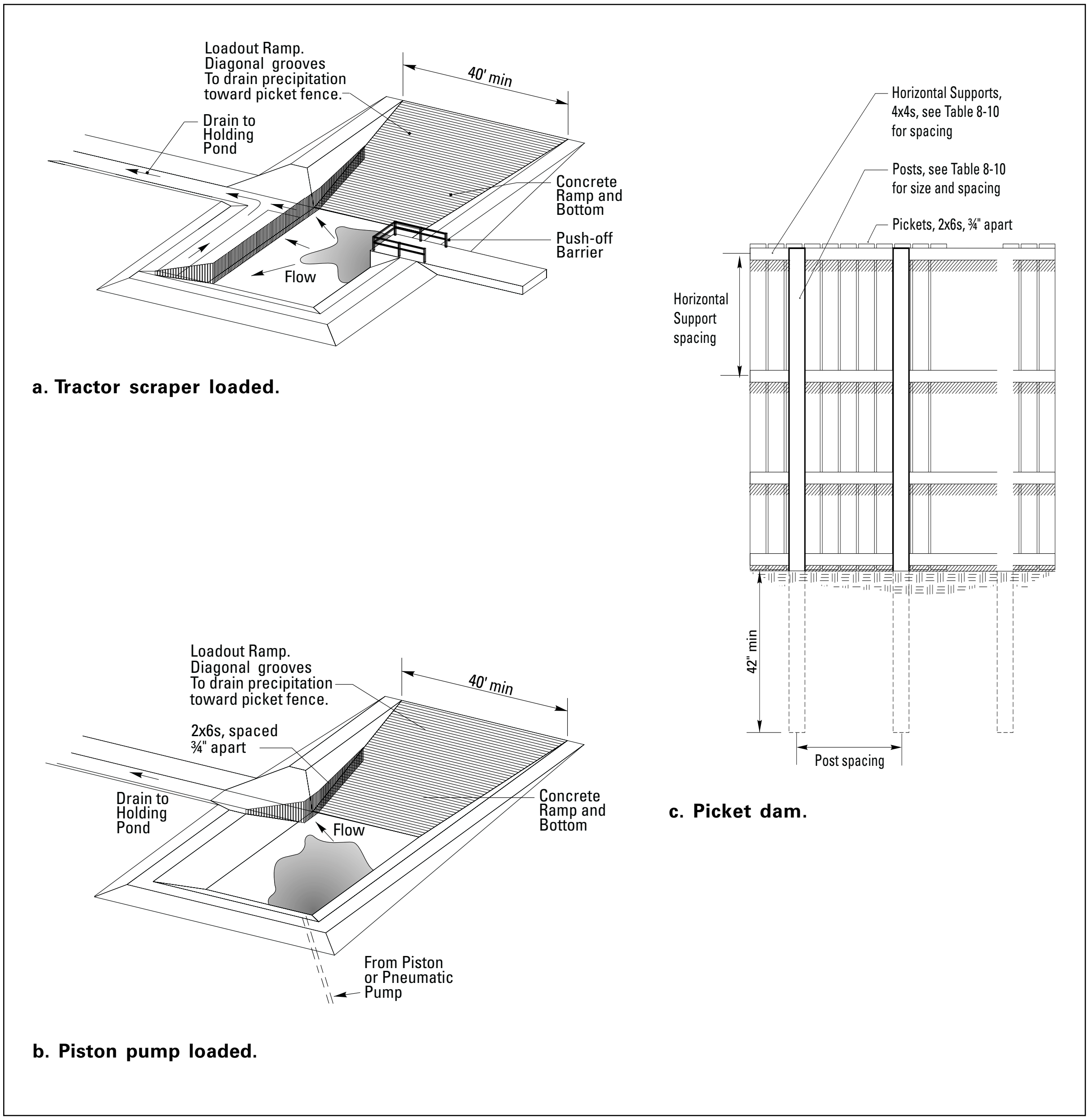
Usually walls are concrete or post-and-plank. Provide one or two sturdy walls to buck against for unloading.

Odor Control

Manure odors from dairy facilities originate from three primary sources: the animal housing, manure treatment and storage units, and land application. Odor control can be achieved by reducing odorous gas generation and emissions or by increasing dispersion to dilute the odors below the detection threshold. Odors and their control is a rapidly changing topic.

Emissions from manure storage units can be reduced with covers. There are numerous materials that can be used for a cover. Permeable covers float on the manure surface creating a barrier between the manure surface and the air, which reduces emissions. Manure that includes organic bedding (i.e., straw, sunflower hulls and wood shavings) will generally form a natural crust that can serve as a cover for the storage unit. Manure that does not include long fiber bedding (i.e., sand or paper) generally will not form a natural crust. Floating crusts can be added to manure storages by blowing chopped straw onto the stored manure. Wheat and barley are the most common straws used. Field experience suggests straw covers should be 8 to 12 inches thick. They will last 2 to 6 months, but occasionally sections will last for more than a year on second stage lagoons that are not agitated or pumped. Other permeable materials, such as geotextiles, that float can also be used as a cover. These inorganic and longer lasting materials may be suitable on units that are not annually agitated or pumped.

Impermeable covers simply capture the emissions, which need to be treated or burned. They can either float on the manure surface or be inflated. When used on storage units that are annually agitated and



a. Tractor scraper loaded.

b. Piston pump loaded.

c. Picket dam.

Figure 8-8. Storage using a picket dam.

Table 8-10. Storage using a picket dam.
Post and horizontal supports are rough sawn pressure-treated timbers. Pickets are pressure preservative treated 2 x 6; rough sawn or surfaced. See Figure 8-8 for the design layout.

	Post		Horizontal supports		
Picket height, ft	Size, in x in	Spacing, feet	Distance from top of pickets, feet	Size, inches	Spacing, inches
1-4	4x6	5	0-4	4x4	36
5	6x6	4	4-6	4x4	30
6	6x8	4	6-8	4x4	24

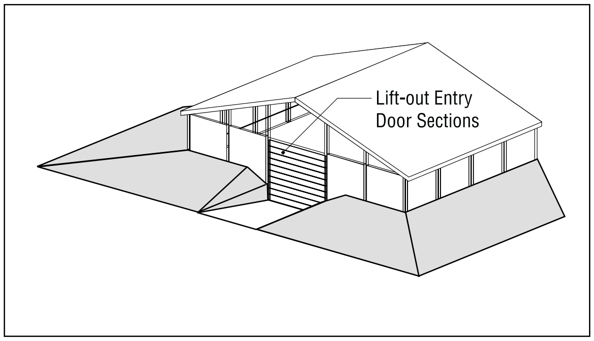


Figure 8-9. Roofed above-ground storage.

pumped, the covers pose problems with temporary removal and reinstallation.

Odor and gas emissions during manure storage agitation and pumping can be significant. There are no widely accepted practices for reducing emissions during this period.

Odor and gas emissions during land applications can be reduced by direct injection of the manure into the soil. Emissions from surface applied manure can be reduced by incorporation within a couple of hours after application.

Collection and Storage of Milking Center Effluent

Milking center effluent (or effluent) is dilute and contains milk solids, manure, grit, detergents, disinfectants, and sometimes feed. When dairy barn manure is stored and handled as a slurry or liquid, milking center effluent can be included with the animal manure. In such systems, milking center effluent serves as dilution water to improve pumpability. Add milking center effluent at the manure collection point in the barn when gravity is used to transfer manure to storage. When sand bedding is used, add milking center effluent where the sand is expected to settle from the manure.

Consider a separate storage unit for milking center effluent if manure is hauled daily or a semi-solid storage unit is used. Toilet waste must be handled and treated according to state or local requirements for human waste disposal.

Effluent handling, storage and/or treatment systems can be reduced in size and cost if source control practices are initiated within the milking center. Reduce volume with these strategies:

- Use well water precooler discharge for watering animals, or wall and floor clean-up.
- Use pipeline cleaning and sanitizing cycles (not rinse cycle) for wall and floor clean-up.
- Use air injector wash manifold and wash sink level management to limit wash cycle volume.
- Use water softener discharge for wall and floor clean-up.

Reducing the pollutant load in effluent is useful if the milking center effluent is to be applied intensively to a given disposal site or transported to application areas far away. Effluent pollutant strength can be reduced by the following practices:

- Capturing drained pipeline milk and using it to feed animals, or disposing with manure.
- Using prerinse (3 to 5 gallons of water) to remove milk from the pipeline and using that milky water to feed animals, or disposing of manure.
- Using or improving cleaning water treatment and then reducing detergent concentration.
- Manually scraping parlor and holding area manure to manure handling before washing.
- Feeding colostrum, mastitic, or antibiotic milk to animals, or disposing of with manure.

Manure and milking center effluent storage units must be located at least 50 feet away from the milking center. Before constructing any effluent storage unit, consult local inspectors and other regulatory authorities to determine the required separation distances for the location.

Holding Tanks and Ponds

Use below ground storage tanks and earthen holding ponds to provide separate milking center effluent storage. Below ground tanks are generally used for short-term storage until conditions allow spreading on cropland, pastures, or woodlots. Holding ponds often are sized to store milking center waste for 8 to 12 months. Because tanks and ponds are not generally designed for aerobic conditions at the surface, they will be odorous.

Septic Tank With Absorption Field

Do not use a septic tank with absorption field to dispose of milking center effluent. Manure, milk solids, and soaps plug the absorption field. If a septic tank is used for toilet room waste, use a minimum-size septic tank; a 500- to 700-gallon tank likely will be the smallest size available. Use absorption fields only in well drained soils. Consult the appropriate regulatory agency for additional septic system requirements for disposal of toilet room waste.

Settling Tank With Surface Disposal

Grass filter strips can be used for surface disposal of milking center effluent if solids are removed. Adequately sized settling tanks can effectively remove solids that float or settle. Provide a tank capacity of at least 40 gallons per cow, but not less than 2,000 gallons. Make the tank twice as long as it is wide. The outlet baffle must be at least 5 feet away from the inlet baffle; locate the inlet pipe 3 inches above the liquid surface in the tank. The tank either can be compartmented, or there must be 2 or 3 tanks in a series. Pump the tank when it is no more than half full of solids.

Intensive application of pretreated milking center effluent to sloping grass filter strips can be an effective means of effluent treatment for small to medium size pipeline milking systems and small parlors (effluent generation less than 500 gallons per day). As effluent flows down a filter strip, it evaporates or seeps into the soil. Fine solids and bacteria are filtered out. Organic compounds are degraded aerobically (creating little odor), and phosphorus and nitrogen are consumed by plants or tied up in the soil. Fine-textured soils of moderate permeability, sandy loam to clay loam, are recommended. Tall fescue and reed canary grass are good cover crops because they are moisture tolerant and develop thick ground cover, preventing erosion. Divert effluent flow until vegetation is fully established. Vegetation must be harvested periodically to remove trapped nitrogen and phosphorus.

Slope filter strips 2 to 6% to allow slow movement of effluent. Strips should be flat across their width to prevent channeling, Figures 8-10 and 8-11. Use strips that are approximately 12 feet wide to provide greater hydraulic loading capacity and less stress on the vegetation. Long, narrow strips may be used in areas with steeper slopes or greater topographical relief. Serpentine or switchback strips provide a greater length of flow. Effluent also can be dispersed across wide filter strips by delivering it to the top of the strip through a concrete or gravel spreader, Figure 8-10. Effluent can also be pumped out through an ejector with a movable discharge nozzle that is rotated a quarter turn every 3 or 4 days.

The ability of soils to filter effluent is affected by hydraulic loading rate, effluent characteristics, soil permeability, and soil management. Hydraulic loading must be managed to maintain soil aeration. Rest filter strips at least two days per week by constructing two filter strips and using them alternately, Figure 8-11, or by dosing a single strip periodically with pretreated effluent from a pump chamber or siphon tank. Point source control practices and devices that reduce effluent volume and limit milk and solids content are recommended to extend filter strip life and achieve adequate treatment.

Filter strips require surface water diversion to prevent flooding and run-off during wet weather or spring thaw. Fencing is necessary to exclude livestock; minimize equipment traffic on ridges and berms. Thick vegetation mats near effluent discharge points help insulate soils during winter and maintain infiltration capacity.

To prevent the discharge pipe from freezing when liquid is pumped to the treatment area, install the discharge piping on a uniform slope back to the pump. No check valve is used; liquid in the pipe

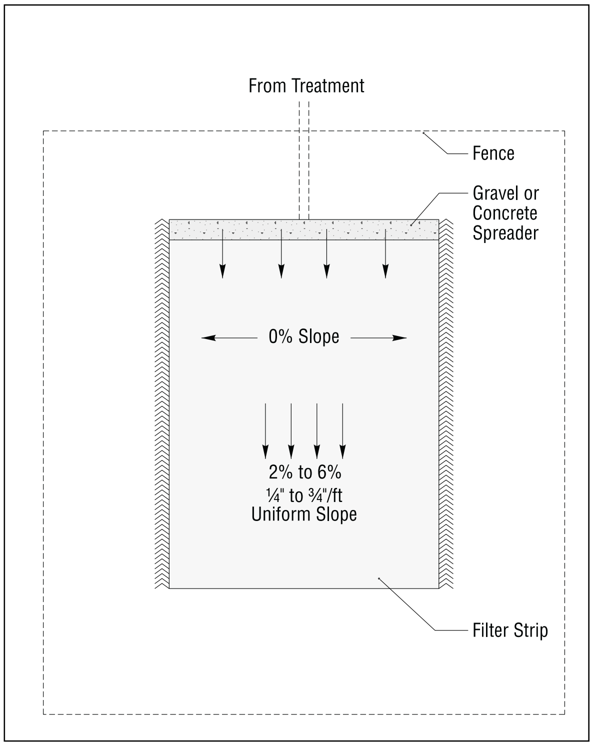


Figure 8-10. Grass filter strip.

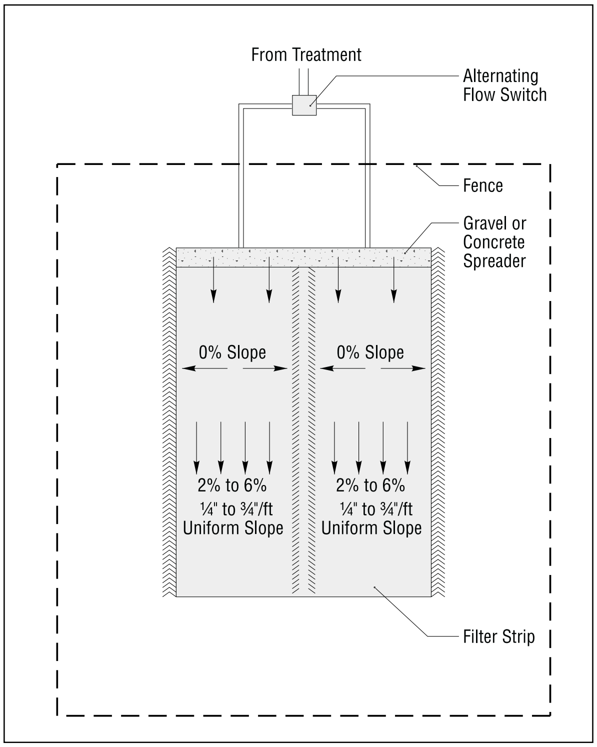


Figure 8-11. Two grass filter strips with alternate dosing.

drains back when the pump stops. In cold climates, elevate the discharge end of the pipe at least one foot above the gravel or concrete spreader to prevent ice from blocking the end of the pipe.

Grass filter strips may not be allowed in some areas. Contact the NRCS about regulations and/or for assistance in designing grass filter strips.

Aerobic Lagoons for Milking Center Effluent

Aerobic lagoon treatment systems provide an alternative for milking center effluent treatment and storage on farms that use a daily haul or semi-solid storage for animal manure. A lagoon used in these situations needs to be pumped out regularly.

Construct the lagoon 3 to 5 feet deep with 10 square feet of surface area for each gallon of parlor waste per day. For example, a facility that discharges 2,000 gallons of effluent per day would need 20,000 square feet of surface area for adequate aerobic treatment. Do not pump the aerobic lagoon empty. Leave 2 feet of liquid in the storage after pumpdown. Discharge liquid into the lagoon through a 4- to 6-inch diameter pipe at about a 1% slope. Do not install the inlet pipe below the water line because the pipe may freeze shut. Install the inlet point at least 20 feet from the edge to avoid lagoon bank erosion. If the inlet pipe cannot be extended this far, install large rock rip rap (2 inches or larger) on the bank to avoid erosion.

Managing Lot Runoff

Lot runoff, whether from rainfall or snowmelt, contains manure, soil, chemicals, and debris. Handle it as part of the manure management system, Figure 8-12.

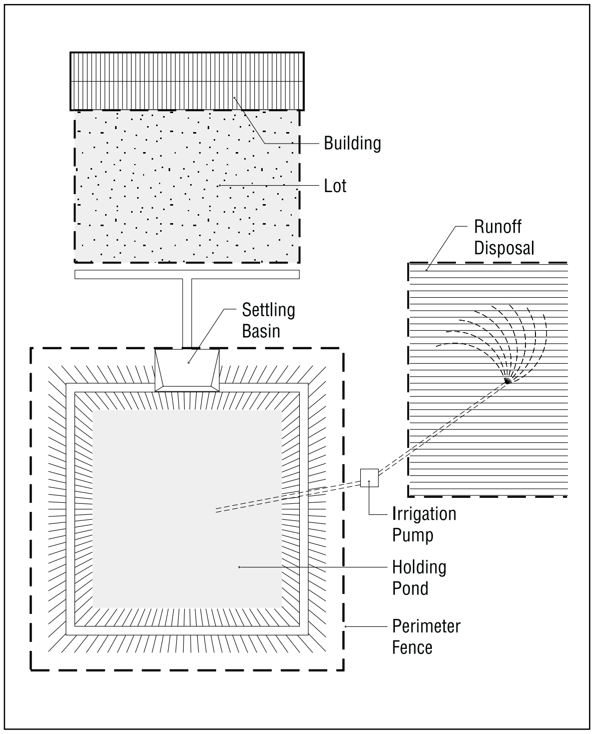


Figure 8-12. Lot runoff handling system.

Collecting Clean Runoff

Runoff from roofs, drives (excluding animal alleys), and grassed or cropped areas without livestock manure is relatively clean and need not be handled in the manure management system. Divert clean runoff either away from the system to reduce the total volume or into the system for dilution. Use curbs, dikes, culvert pipes, and terraces to divert clean water away from a manure area. For help with runoff control, consult the local NRCS office.

Liquid-Solid Separation

A well-designed runoff collection system includes three elements:

- Structures to collect effluent.
- A liquid-solid separation stage.
- A holding pond for the effluent from the separator.

Liquid-solid separation is accomplished by gravity or mechanically. For dilute runoff material, a simple settling basin and screens are sufficient. After solids are removed, spread as a fertilizer and soil conditioner. Composted manure solids have been used for freestall bedding but udder health can be a concern. Store liquid wastes from the separator in a separate holding pond or in the main manure storage. If a separate holding pond is used, the effluent can be irrigated onto cropland or used to recharge a manure pit that is mostly empty.

Settling basins are effective gravity liquid-solid separators and are used widely in runoff collection systems, Figure 8-13. Settling basins remove 50 to 85% of the solids from lot runoff. Baffles and porous dams slow the flow enough so that settling occurs. Make the settling basin floor concrete to improve solids removal following settling. Remove solids as needed between runoff events. The settling basin may be incorporated into the lower portion of the lot. Settling basins should be sized to contain 0.0017 cubic feet of manure per pound of animal live weight per day. A 10 to 21 day retention time is recommended to settle solids. See the *Manure Management* publications from MWPS for more design information on liquid-solid separation.

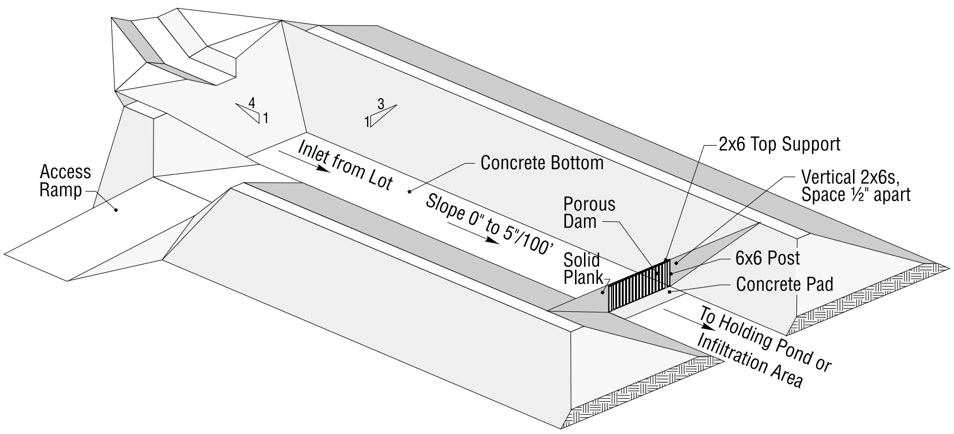
Mechanical separators require a pump to deliver the slurry or liquid manure to the separator and are more expensive than settling basins. Several types of mechanisms are used to separate solids from liquids, including roller press, piston, screw press, stationary screen, and cyclones. The power requirements of a separator can be as large as 25 horsepower depending on separator type.

Holding Pond

A holding pond temporarily stores runoff water from a settling basin, Figure 8-14, or the effluent from a mechanical separator. A holding pond does not receive roof water, cropland drainage, or clean water from other sources. Use state requirements to determine minimum storage time (usually 180 days). Base capacity on inches of rainfall on a drained area, such as a 25-year, 24-hour rainfall event. With additional capacity, emptying the pond can be timed to fit labor and cropping schedules without fear that another runoff event will cause overflow. Pump before the storage is full and when liquids will infiltrate into the soil. Avoid spreading on frozen or wet ground.

A holding pond includes these important features:

- A design to allow it to receive runoff from a lot, usually after the runoff has been through a settling unit, or from lagoon overflow.
- Interior banks of earthen dams that usually are no steeper than 2.5:1 (run:rise), depending on soil type. To maintain sod and mow weeds, limit exterior slopes to no steeper than 3:1.
- The ability to empty the pond by pumping, usually through irrigation equipment.



a. Earthen sidewall settling basin.

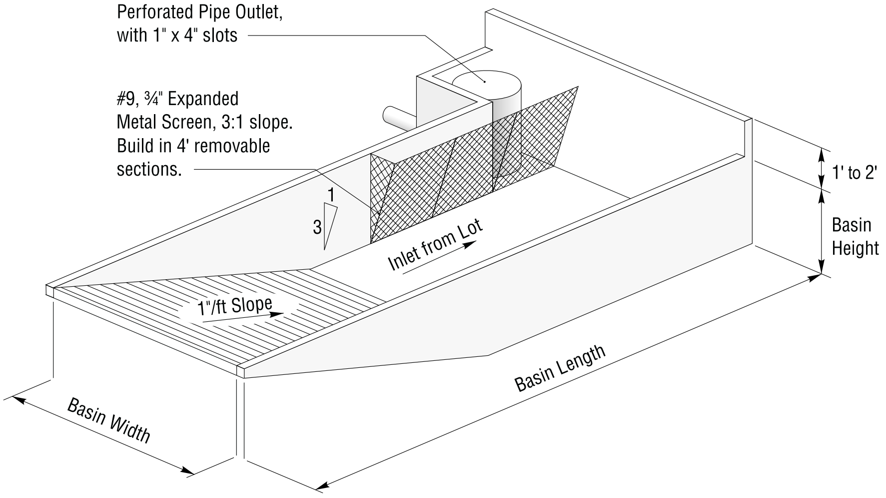


Figure 8-13b. Concrete settling basin.

Figure 8-13. Settling basins.

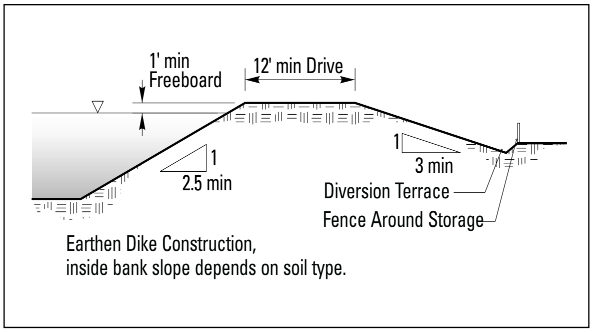


Figure 8-14. Holding pond.
Vertical dimensions in the figure are exaggerated to emphasize slopes. The steepest exterior side slope is 3:1 (run:rise) 4:1 if it is going to be mowed. Interior side slope varies from 1:1 to 4:1 depending on the soil construction characteristics. Make the berm at least 12' wide if agitation equipment will travel on top. Provide an emergency spillway in undisturbed earth near the holding pond dam. Make it 1' to 2' below the top of the dam. Overflow from liquid storages is a potential pollutant; therefore, it must be controlled. Run the spillway overflow to secondary treatment or to a grassed disposal field.

Vegetative Infiltration Area

Lot runoff treatment by vegetative infiltration is practical and economical when land is available. A settling basin to remove solids is essential. The infiltration area is a long, 10- to 20-foot wide channel or a broad, flat area. For uniform distribution, slope the first 50 feet 1% to move the runoff rapidly away from the lot and settling unit before further settling occurs. The rest of the area should be nearly flat (less than 0.25%) with just enough drainage to prevent water from standing. The runoff must travel through the vegetative area at least 300 feet before entering a stream or ditch. Vegetative infiltration areas may not be allowed in some areas. Inquire of the proper regulatory agencies before installing one. See the *Manure Management* publications from MWPS, or contact the local NRCS office for more detailed information on vegetative infiltration areas.

Land Application and Utilization

Land application of dairy manure and effluent helps build and maintain soil fertility, improve soil tilth, increase water-holding capacity, and reduce erosion effects. Runoff or dilute manure provides water as well as nutrients for crop production. See the *Manure Management* publications from MWPS for more information on manure land application and utilization.

Preparing for Environmental Emergencies

Disaster can strike even the best-managed farm. Advance planning and training is essential to minimize manure-handling emergencies, such as a discharge or spill. This process will also help to prepare for other emergencies such as fire, medical, or weather. Two phases of the planning and training process should include preventing and reacting to a manure spill.

Preventing Manure Spills

Whenever manure is stored, transported, or applied to land there is a potential for an accidental manure spill. Manage and design manure-handling systems to minimize the chances of a spill and to *fail safely* if a failure occurs within the system. Proper management and system design will help lessen the odds of an environmental emergency.

For all operations manure handling systems:

- Identify key areas and components of the system.
- Develop a checklist and inspect the system on a monthly basis.
- Correct or repair necessary components of the system.
- Keep a copy of each month's inspection report in an organized area such as a filing cabinet or book binder.

For all outdoor storages:

- Inspect gravity and recycle lines for signs of dead vegetation that may indicate a discharge.
- Prevent any excess surface runoff water from entering the storage.
- Maintain the appearance area around the storage.
- Identify environmentally sensitive areas (such as surface waterways or tile inlets) on or near the operation.
- Study the drainage patterns on and near the operation.
- Determine the point at which the discharge might enter surface waterways or tile inlets on and near the operation. For some operations, manure may travel long distances before entering a ditch or stream. In other cases, the stream may be nearby, demanding a much faster response.

For earthen storages such as lagoons:

- Inspect the area around an earthen storage and note any evidence of wet spots that may indicate leakage.

- Maintain adequate vegetation on the berm to prevent erosion.
- Check for berm damage from burrowing animals.
- For lagoons, install pumpdown stakes that clearly indicate pump start and pump stop levels.

For manure application:

- Verify adequate land area is available for manure application each year.
- Test nutrients in manure every 2 to 3 years and soils receiving manure every 3 to 5 years, then calculate application rates based on soil and manure tests, and crop utilization.
- Inject to reduce odor, decrease the chance for runoff and help conserve nutrients. If surface applying then till manure into the soil within 24 hours.
- Identify and provide protection for environmentally sensitive areas, such as streams, and tile inlets.
- Monitor application closely and stop application before runoff occurs.
- Do not apply manure before, during, or immediately after a rainfall event.
- Equip pumps handling manure with an automatic shutdown if pressure drops in the piping system.
- Never leave a pump unattended, especially when irrigating effluent.
- Document application area and rates.
- Document crop yields.

Developing a Written Emergency Action Plan

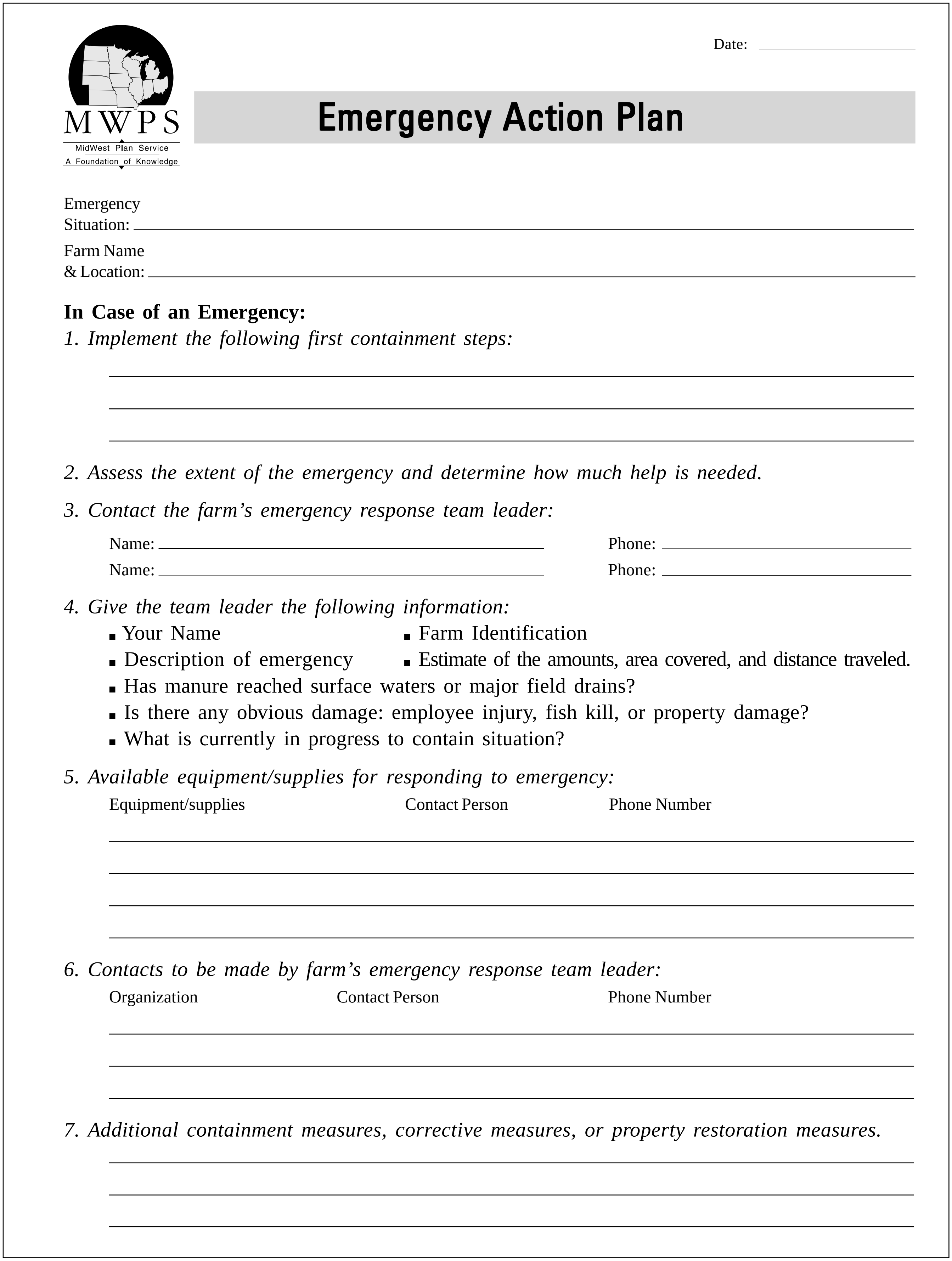
Liquid manure or effluent has the highest potential to negatively affect surface or ground water during the time of a spill because of the difficulty in containment. An Emergency Action Plan is a common sense plan that will help personnel make the right decision during an emergency. Having a **written** Emergency Action Plan is important because a written plan**:**

- Communicates clearly to family and/or employees specific actions to be taken in case of an emergency.
- Shows responsible preparation.
- Protects the producer and others against environmental damage.
- May be required by the state.

The written Emergency Action Plan should be posted prominently in each building, in the employee area, and next to all phones. Train and periodically review the procedures listed in the plan with all personnel working with the operation. The plan should be reviewed and undated annually to reflect any changes in the operation. The written format of the Emergency Action Plan should describe procedures and/or methods to do the following:

1. **Eliminate the source of the spill.** For example, if a lagoon overflows due to a heavy rainfall event then action needs to be taken to stop any discharge. One possible action would be to increase the elevation of the top of the berm.
2. **Contain the spill, if possible, and minimize manure movement off the farm or downstream.** If manure has leaked from a lagoon then a berm may have to be constructed to prevent manure from flowing to areas that could affect ground or surface water.
3. **Provide contact information for key individuals who can assist in implementing the emergency action plan.** These individuals can assist personnel unfamiliar with the plan or personnel needing assistance to implement the plan. In addition to implementing the Emergency Action Plan, these individuals can help determine the amount of personnel and equipment necessary to correct the problem.
4. **Assess the extent of the spill.** Note any obvious damages.
5. **Contact appropriate agencies as soon as possible.** In many states the Department of Natural Resources is the contact agency. The state may require individuals to report any spills that could affect ground or surface water. If a spill that affects ground or surface water is not reported promptly, regulatory fines are usually higher.
6. **Clean up the spill and make repairs.** Keep written records on the method of clean up and the type of repairs performed to prevent future spills. The contact agency may offer suggestions on clean up procedures and repair methods.

Figure 8-15 shows an example of an Emergency Action Plan. Contact an extension engineer or a consulting engineer for more information on developing Emergency Action Plans and emergency action strategies.



Date: ____________________

MWPS
MidWest Plan Service
A Foundation of Knowledge

Emergency Action Plan

Emergency Situation: ____________________

Farm Name & Location: ____________________

In Case of an Emergency:

1. Implement the following first containment steps:

____

____

____

2. Assess the extent of the emergency and determine how much help is needed.

3. Contact the farm's emergency response team leader:

Name: ____________________ Phone: ____________________

Name: ____________________ Phone: ____________________

4. Give the team leader the following information:

- Your Name
- Farm Identification
- Description of emergency
- Estimate of the amounts, area covered, and distance traveled.
- Has manure reached surface waters or major field drains?
- Is there any obvious damage: employee injury, fish kill, or property damage?
- What is currently in progress to contain situation?

5. Available equipment/supplies for responding to emergency:

Equipment/supplies	Contact Person	Phone Number

6. Contacts to be made by farm's emergency response team leader:

Organization	Contact Person	Phone Number

7. Additional containment measures, corrective measures, or property restoration measures.

____

____

____

Figure 8-15. Example Emergency Action Plan.

Chapter 9

Feeding Facilities

David Kammel, Extension Ag Engineer, University of Wisconsin

The choice of feeding system depends on the goals of the feeding program and the capabilities of the systems under consideration. Common goals include:

- Reducing labor.
- Reducing feeding time.
- Increasing feeding flexibility.
- Improving animal nutrition.
- Reducing feed loss.

Design requirements for a feeding system are determined by:

- Group size.
- Ration(s) fed.
- Type of handling and mixing equipment.
- Design, location, and size of the feed storage structures.

Feed ingredients change with time; provide some flexibility in storage and handling facilities to accommodate changes in rations and future expansion.

Generally, the greater the degree of mechanization, the larger the initial cost and operating costs for repairs and energy. However, mechanization helps improve the diet delivered and reduces physical labor.

Knowledge of dry matter intake is essential to provide a nutritionally balanced ration. If feed is not weighed as it is delivered, only an estimate of dry matter intake can be made. If only grain is weighed, forage intake must be estimated. But, if forage and grain are weighed, the dry matter intake is known if all of the feed is consumed and moisture content is known.

Cows have individual preferences for different feedstuffs, and given the opportunity, cows will consume feedstuffs based on those preferences. Thus, individual cows may or may not consume a balanced ration if left to their own preferences. The highest assurance cows will consume a balanced ration comes when feedstuffs are delivered as a total mixed ration (TMR). The lowest assurance that cows will consume a balanced ration occurs when feedstuffs are fed separately

Cows on pasture selectively graze an uncontrolled pasture. The quantity or quality of forage consumed is unknown, making it difficult to balance the grain ration. However, rotational grazing of pastures improves the knowledge of forage quality consumed, and estimates of DM intake can be made. Challenges still exist for balancing the ration.

Planning the Feeding System

When planning a feeding system, prepare a scale drawing of the farmstead showing existing buildings, utilities, and characteristics such as the following:

- Feedlots.
- Silos.
- Feed storage.
- Fences.
- Power lines.
- Water supply.

- Drainage patterns.
- Structures.
- Roads/drives.

Determine the fate of existing buildings (use as is, remodel, tear down, replace) and equipment (use as is, modify, upgrade, replace in the future).

Allow room for future expansion; a system based only on present needs is difficult and expensive to expand. A rule-of-thumb for planning is to project needs five years into the future and then double.

Forage Storage

Forages are the largest volume feed ingredient. The trend is to increase the use of ensiled forages due to convenience, ease of mechanization, reduced labor, and improved quality. At least two silage storages must be available to allow flexibility in controlling forage use in the feeding system.

Silo design and management affect the quality of ensiled forage. Measuring storage losses is difficult; values shown in Table 9-1 are estimates. In some cases, little dry matter loss occurs, but substantial feeding quality loss can occur.

Size the silage storage unit to ensure adequate face removal can be achieved. Silo bags, tower silos and silage piles are appropriate for small to intermediate size dairies. Consider bunker silos, and larger piles for intermediate to larger dairies. Operator preference, ration, annual costs, and feeding circumstances affect storage selection.

Horizontal Silos

Horizontal silos cost less per stored ton than upright silos but can have higher storage losses. Wind, rain, snow, birds, and rodents are problems. For large herds, horizontal silos provide a more economical storage than upright silos and usually can be filled and unloaded more quickly. Use bunkers and

Table 9-1. Estimate of silage harvesting and storage losses.
Based on Forages: The Science of Grassland Agriculture, 4th edition.

Silo type	Moisture[a]	Field	Filling	Seepage	Gaseous	Top	Feed Out[b]	Total
		- - - - - - - - - - - - -	- - - - - - - - - - - - -	- - - - - - - - - - - - -	Dry matter, %	- - - - - - - - - - - - -	- - - - - - - - - - - - -	
Conventional tower	80	2	1-2	7	9	3	1-5	23-28
	70	2	1-2	1	8	4	1-5	17-22
	65	4	1-3	0	8	3	1-5	17-23
	60	6	1-3	0	6	3	1-5	17-23
	50	8	2-4	0	5	3	1-5	19-25
Gas-tight tower	70	2	0-1	1	7	0	0-3	10-14
	60	6	1-2	0	5	0	0-3	12-16
	50	8	2-3	0	4	0	0-3	14-18
	40	11	2-4	0	4	0	0-3	17-22
Silage Bags[c]	80	2	1-2	2	6	2	1-5	14-19
	70	2	1-2	0	5	2	1-5	11-16
	60	6	1-2	0	5	2	1-5	15-20
Trench or bunker (no cover)	80	2	2-5	4	9	2	3-10	22-32
	70	2	2-5	1	9	9	3-10	26-36
	60	6	3-6	0	10	12	5-15	32-49
Trench or bunker (covered)	80	2	2-5	4	9	2	3-10	22-32
	70	2	2-5	1	7	3	3-10	18-28
	60	6	3-6	0	6	4	5-15	24-37
Stack (no cover)	80	2	3-6	7	10	11	3-10	36-46
	70	2	3-6	1	11	19	3-10	39-49
	60	6	4-7	0	6	6	5-15	51-64
Stack (covered)	80	2	3-6	5	8	2	3-10	23-33
	70	2	3-6	0	7	4	3-10	19-29
	60	6	4-7	0	6	6	5-15	27-40
Wrapped Silage Bales	70	2	1	0	8	5	1-5	17-21
	60	6	2	0	7	5	1-5	21-25
	50	8	3	0	6	6	1-5	24-28

[a] Avoid ensiling hay crop above 70% moisture and above 60% moisture in wrapped bales to prevent clostridial fermentation.

[b] For trench or bunker silos and silage stacks, feed out losses are 3 to 5% with good management on concrete floors. Use 4 to 6% for asphalt, 6 to 8% for macadam, and 8 to 20% with earth floor assuming good face management. With less than good management, add up to 7% additional loss.

[c] University of Wisconsin estimates.

stacks on level sites and trenches on sloping sites. Sidewall heights usually are 8 to 14 feet, and widths are 20 to 60 feet.

Chop corn and hay at 3/8-inch theoretical cut with 65 to 70% moisture content (wet basis), for corn silage and 60 to 65% moisture for hay silage. Horizontal silos adapt readily to feed wagon distribution and to high speed unloading with tractor loaders. Maintain a hard surface floor in the silo and at the approaches to allow easy access by tractor and loader. Slope the floor for drainage out of the silo.

Minimize surface exposure during filling; fill one end full as quickly as possible, Figure 9-1. Pack 6-inch thick layers of silage in horizontal silos continuously with a tractor while filling. Use a weighted-wheel tractor with lugged tires, rollover protection, and seat belts. Use extreme care when packing silage in a horizontal silo. Consult an Extension Safety Specialist for information on packing techniques and recommendations.

Shape the silage surface to shed water. Cover with 6-mil plastic and weight down with tires laid side by side, limestone, bags of sand, or other material to keep the plastic from billowing and pumping air into the silo, Figure 9-2. If using tires, one option is to slice the tires in half. This reduces the number of tires and minimizes the amount of water trapped in the tire. It may be necessary to tie the tires together to prevent the tires from sliding down steep slopes.

When feeding off the face, remove only what is to be fed that day. Disturb as little of the remaining face as possible to minimize exposure to oxygen, which increases spoilage, Figure 9-2. When removing silage, break off silage with a downward movement of the bucket.

Silage Bags

Horizontal plastic silage bags can be used for long-term storage or for emergency storage, Figure 9-3. Bags vary in length from 100 to 300 feet depending on diameter and the manufacturer. Bags can be partially filled, closed, and later completely filled. Portable bagging machines fill 8-, 9-, 10- and 12-foot diameter bags. Keep bags tightly closed because billowing plastic pumps air over the silage, increasing losses. Moisture content of silage ranges from 50 to 70%. Higher moisture content can cause freezing problems.

Bags are not reusable and must be protected from punctures. Common causes of spoilage are tears or holes made by rodents or animals or impact by equipment, splits at the seam, punctures from objects on the ground, and weather damage. Use tape supplied by the bag manufacturer to seal any

Table 9-2. Minimum feed rate for forage.

	Feed rate, in/day	
Silo type	Hot weather	Cold weather
Conventional stave/poured (top unloading)	4	2
Oxygen limiting (bottom unloading)	2	2
Silage bag	6	4
Silage stack	6	4
Horizontal silo	6	4

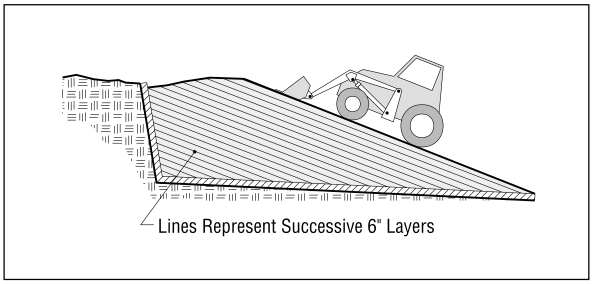


Figure 9-1. Filling horizontal silos.
Caution: Tractor may roll over during packing if done incorrectly, causing injury, and possibly death. Use extreme care when packing. Consult an Extension Safety Specialist for information on packing techniques and recommendations.

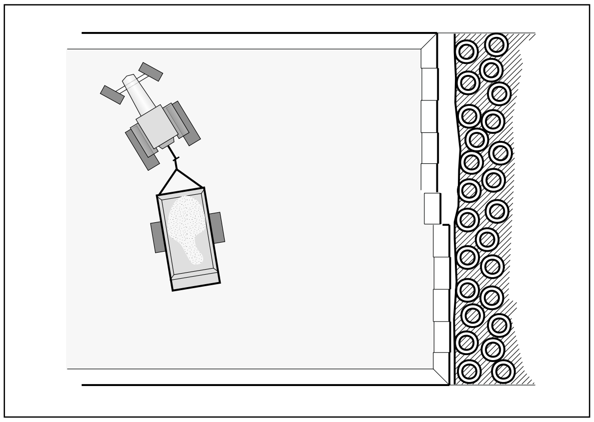


Figure 9-2. Unloading horizontal silos.
Unload bunker silos for minimal spoilage losses. Keep face vertical.

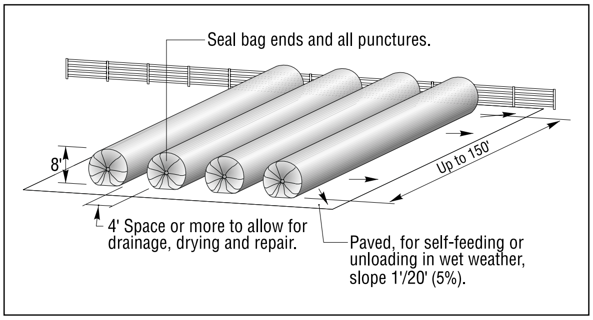


Figure 9-3. Horizontal plastic bags.

punctures to reduce spoilage. Plastic may be recyclable.

A firm, well-drained site is essential for year-round access. Orient bags north-south to promote melting of snow and drying on sides. Provide a 5% slope away from the bags for good drainage. A fenced and paved storage area is recommended for self-feeding, loading, and unloading in poor weather. A specially designed feeding fence can be used to self-feed bags. A prepared and paved site may be used for bags and later converted to bunker storage by adding walls.

Upright Silos

Upright silo types include poured concrete and concrete stave silos with top unloaders or air limiting silos with bottom unloaders. They are commonly used to store forage and grains. Upright silos with unloaders offer protection from the weather and possible complete mechanization of silage handling. Upright silos require tight walls and sealed doors. A roof and plastic seal over the silage reduces storage losses.

Upright silos with top unloaders cause feeding to be interrupted during filling so the unloader can be raised.

Air limiting silos offer more flexibility because refilling does not interfere with the unloader or feeding. Air limiting silos usually have lower storage losses but higher field losses because of low harvesting moisture content. Close the unloading hatch between unloadings to prevent air entry and silage spoilage. Top spoilage that occurs between filling will be hidden as the sludge mixes together with silage during unloading. This loss may be difficult to detect. Many air limiting silos are being converted to top unloading silos or are being abandoned due in part to the high maintenance cost and replacement of the unloaders.

Silage Piles

Silage piles, Figure 9-4, work well for emergency, temporary, or long-term storage. For silage piles with no walls, keep the slopes on the sides shallow enough to drive and pack in both directions. Poorly packed sides result in large spoilage losses when packing is only done in one direction. They can be used as a short-term solution prior to building permanent horizontal structures. Corn silage piles are fairly successful with material at 70% moisture. With silage piles, use the management practices recommended for horizontal silos. Provide a firm base and access to the pile to provide year-round access to the feed when used for long-term storage.

Several other methods for retaining silage pile sides include using silage bags, round bales, and adjacent horizontal silo walls. When using silage bag walls, remove silage from the pile and from the adjacent bags uniformly. The silage between the bags should be the same material as that in the bags. It is difficult to remove the silage between the bags without damaging the bags and causing the silage in the bags to spoil prematurely. Using an adjacent horizontal silo wall for one wall of a pile improves the ability to pack the pile. The slope of the silage pile wall should allow packing in both directions parallel and perpendicular to the horizontal silo wall. Round bale walls should be avoided. They can shift, possibly causing a tractor rollover.

Dry Hay Storage

Indoor hay storage preserves quality and reduces dry matter losses compared to outside storage, Figure 9-5. Provide indoor storage in areas with more than 20 inches of annual rainfall.

For outdoor storage, provide a gentle slope and at least a 1-foot space between stacks or bales to promote drainage and air movement. Divert surface runoff away from storage areas. Locate haystacks near feeding areas. The amount of spoilage (as much as 50%) depends on the stack or bale quality, storage method, and local rainfall. Elevate bales off the ground to prevent *wicking* of moisture into the bale.

Grain and Concentrate Storage

Grain is the second largest proportion of feed in the ration. Store dry grains in bins. Use upright silos to store high moisture grains such as shelled corn or ground ear corn. Use roller mills to roll shelled corn or cob corn. Silo bags also can be used to store high moisture grains. Horizontal silos can be used for large volumes of high moisture grain. Dry feeds such as commodity feeds are stored in commodity barns.

Bins

Grain can be stored at harvest or bought when needed. To allow storing different grains, using fresher grain, and having more flexibility, the biggest bin should not exceed half of the total volume of the annual grain requirements of the operation. For freshly harvested grain, equip storage bins with aeration to cool grain. Smaller bins are needed if grain and other feed ingredients are purchased as needed. Feed stored in commodity bins experiences less shrink (loss) than feed stored in sheds. See *Grain Drying, Handling and Storage Handbook*, MWPS-13, and *Managing Dry Grain in Storage*, AED-20, for more information on bins and grain handling.

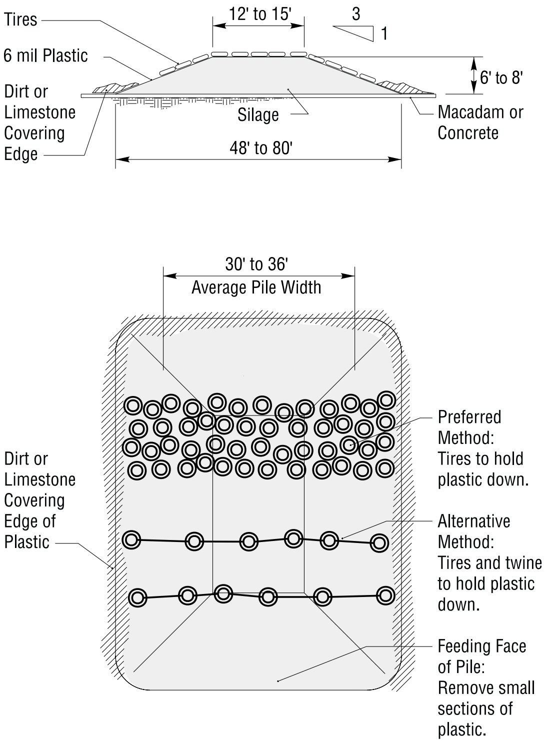


Figure 9-4. Silage pile.
Drive-over silage pile for temporary storage. Provide a firm base and access.

Hopper bottom bins permit gravity unloading of stored materials before and after processing, Figure 9-6. Side draw hoppers are for materials that tend to bridge, such as concentrates and ground feeds. Steep side slopes allow these materials to flow more freely. Center draw unloading can cause a dent to form in the sidewall because of uneven distribution of material. Limit bulk feed tank capacity for off-center unloading bins to 20 ton.

Commodity Storage

Many commodity feed ingredients flow to some degree and can be handled with conventional conveyors and hopper bottom bulk storage bins. Pelleted feeds have improved handling characteristics.

Whole cottonseed, in particular, does not flow and cannot be moved with augers or stored in conventional bins where gravity flow is required. Cottonseed can be transported with belt or pneumatic (vacuum) conveyors, but these are relatively expensive and not practical for most farms.

The characteristics of commodity feeds vary from time to time depending on moisture content, type of processing at the originating plant, and length and type of storage. Due to the inconsistency and unpredictability in handling characteristics of by-product ingredients, flat storage is often the best choice.

Feed costs can be reduced by purchasing commodities and by-product feeds. Many of these feeds can be purchased in 10- to 20-ton loads at a substantial savings on cost and trucking. Losses from commodity sheds have been higher than losses from bins.

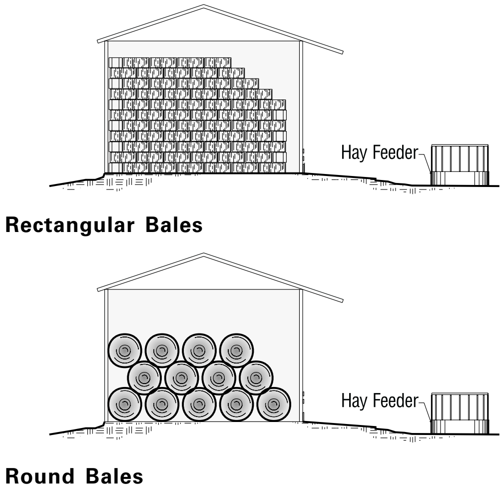


Figure 9-5. Dry hay storage.
Do not stack bales against sidewalls unless building is designed for the loads imposed. Indoor hay storage helps preserve quality and reduce dry matter losses.

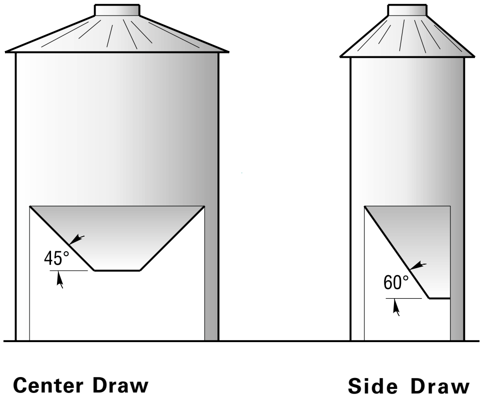


Figure 9-6. Hopper bottom bins.
Center draw-off bins work best for whole grain and free flowing materials. The steeper sloped side draw-off bins are for ground feed.

Commodity storage sheds, such as the one shown in Figure 9-7, are a popular method of storing feed ingredients in bulk. Commodity storage sheds are divided into storage *bays*. Each bay will typically hold 1 to 2 trailer loads of ingredients. For example, the storage shed shown in Figure 9-7 can hold approximately 1 1/2 trailer loads of cottonseed and most other loose by-products, and 2 trailer loads of pelleted ingredients. Plan for enough space to receive a load of feed ingredients before the bays are completely empty. The number of bays required will depend on the quantity of feed that is purchased on a regular basis.

To properly design the commodity shed, check with the hauler on the type of trucks or semi-trailer being used to deliver feed materials and the method of unloading the feed from the vehicle. There are four main methods of unloading from a truck or semi-trailer:

- **Dumps.** The front end of the box raises out the back allowing the feed material to slide into the bay or onto the pad in front of the commodity shed where the feed material is pushed into the bay. If the vehicle is backed into the shed, then enough space must be provided to allow the front end of the box to tip up. This may require an eave height of 20-feet or more.
- **Walking bottoms**. The vehicle is backed into the shed. A conveyor on the trough floor moves the feed material into the bay.
- **Hopper bottoms**. The feed material is dumped from underneath the trailer onto the concrete pad in front of the shed. The feed material is then pushed into the bay. Feed also can be dumped directly into a portable conveyor that transfers the feed into the commodity shed.
- **Unloading ramp.** A fixed unloading ramp is used to allow a front end loader to drive into a van box.

Designs similar to Figure 9-7 have been used successfully by many producers. These designs use a monoslope building with an open front. Buildings are typically 30 to 36 feet wide, but buildings should be no less than 24 feet wide. Bays are typically 16 feet wide, but should be no less than 12 feet wide. The eave height should be 12 to 20 feet depending on equipment and loader reach height. The concrete floor slopes 2% toward the building front. An overhang of 4 to 6 feet can be used to protect feed from rain and snowfall and offers some additional protection from wind blown snow and rain.

Provide a 20 to 24 foot wide concrete slab the length of the building in front of the building for traffic. The size of the concrete slab should be large enough to unload a semi-trailer load of feed and have room to push the feed into one of the bays with a tractor or skidsteer loader.

Design these buildings to withstand the loads of the product and the loads caused by loader tractors pushing into walls. Wall construction consists of a 4- to 8-foot high poured concrete retaining walls with an additional 4 to 6 feet of stud or post frame wall clad with plywood or tongue and groove plank on top of the concrete stub wall. Other wall construction options include poured concrete walls or concrete precast movable wall panels of any desired height. The wall can be constructed with post frame or stud wall clad with tongue and groove planking or plywood but is subject to damage by the loading operation.

Another popular option for walls is the use of heavy precast concrete blocks. Local concrete suppliers may have available 2- by 2- by 4-foot precast blocks that weigh approximately 1 ton each. These blocks are formed to allow some interlocking between blocks and are stacked up to 3 or 4 high to form walls 6 to 8 feet high. Caution must be taken not to stack the blocks too high since the blocks may not provide enough horizontal loading support for walls over 8 feet high and could tip over. Low-cost bin walls can also be made from precast highway dividers.

Feeding Total Mixed Rations

The continuing trend has been toward feeding Total Mixed Rations (TMR) to individual groups of animals. All forages, grain, and supplements are mixed into a homogeneous mixture prior to feeding. When feeding TMR, provide for feeding separate groups according to their nutritional requirements. For example, a milking herd can be separated into production level groups with each group receiving a different ration.

High initial capital investment and problems with animal grouping may preclude retrofitting an existing facility unless major remodeling/expansion is planned. For extensive remodeling and new facilities, TMR can:

- Maintain the ratio of feed components and nutrients.
- Reduce digestive upsets.
- Improve palatability of low quality roughages and by-products.
- Include hay if it is ground.
- Allow mechanized feeding.

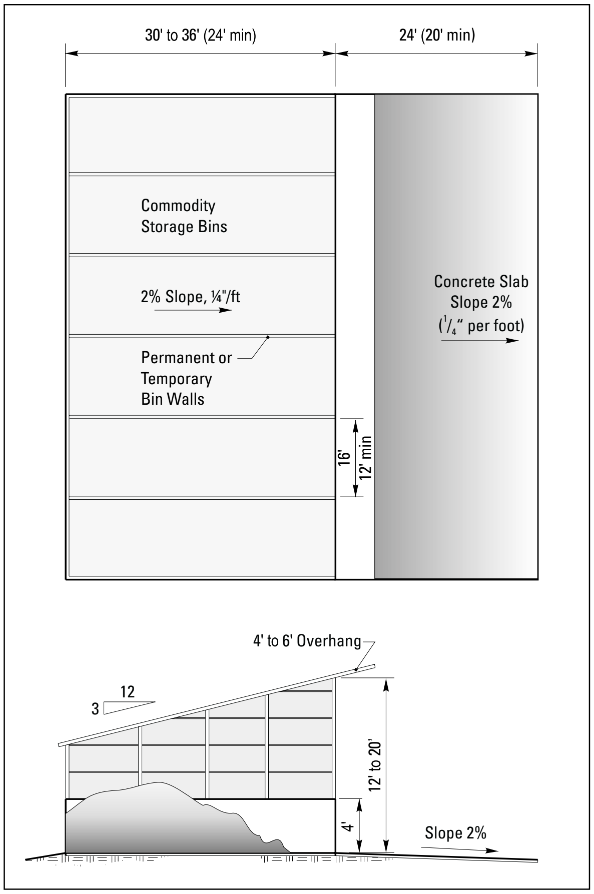


Figure 9-7. Commodity storage sheds.
The size of each bay depends on the quantity of feed stored. Front opening height is dependent on loader reach height.

Prepare the TMR with a stationary or mobile weigh/mixer as part of the total feeding system. Weighing allows for accurate selection of the right amount of each feed ingredient and for maintaining a feed inventory.

Mobile Systems

The mobile TMR system uses a trailer- or truck-mounted weigh/mixer for assembling, weighing, and mixing the feed ingredients and delivering the TMR to the feed bunk or other feed delivery equipment, Figure 9-8. The unit moves between the different feed storage areas and the different animal feeding areas.

Mobile mixers are more flexible than stationary ones; feed storage location is less critical, and cows can be fed at remote sites. Mobile feeding systems are time and cost efficient for herds of 100 cows or more.

Stationary Systems

Figure 9-9 shows a stationary mixer for TMR feeding where the mixing or blending equipment is at a specific site. All feed ingredients must be conveyed to the stationary mixer. After mixing, the ration is delivered to the animals by conveyors or feed carts. The stationary system is common for small herds (less than 90 cows) that depend on upright silos and mechanical conveyors for moving feed, Figure 9-13.

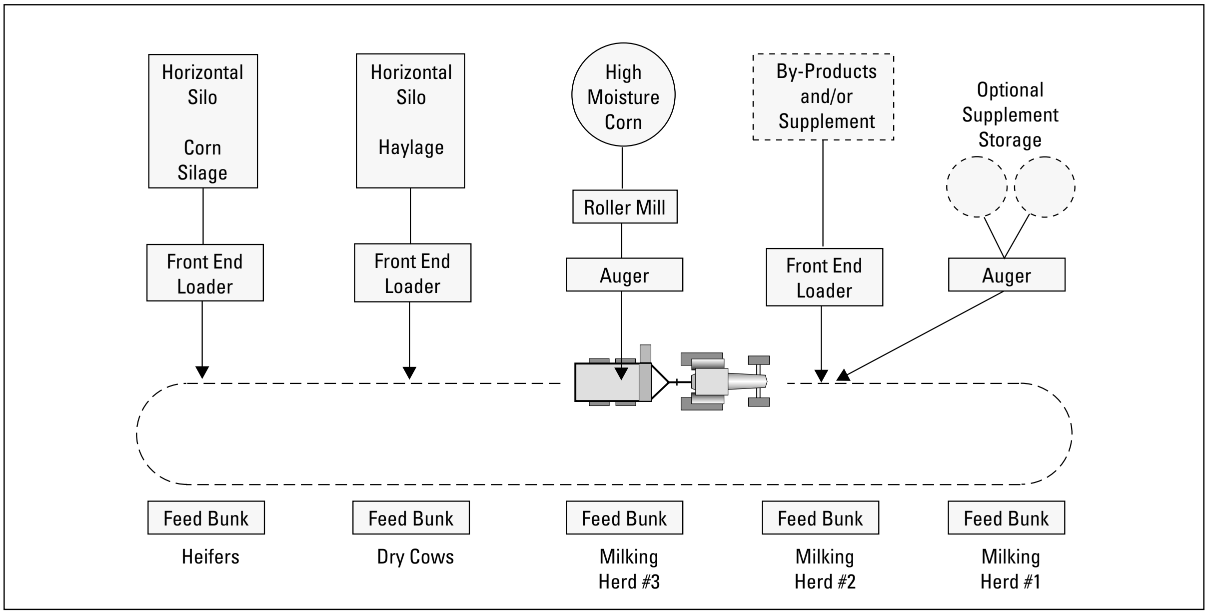


Figure 9-8. Mobile TMR flow chart with scattered feed storages and animal feeding areas.

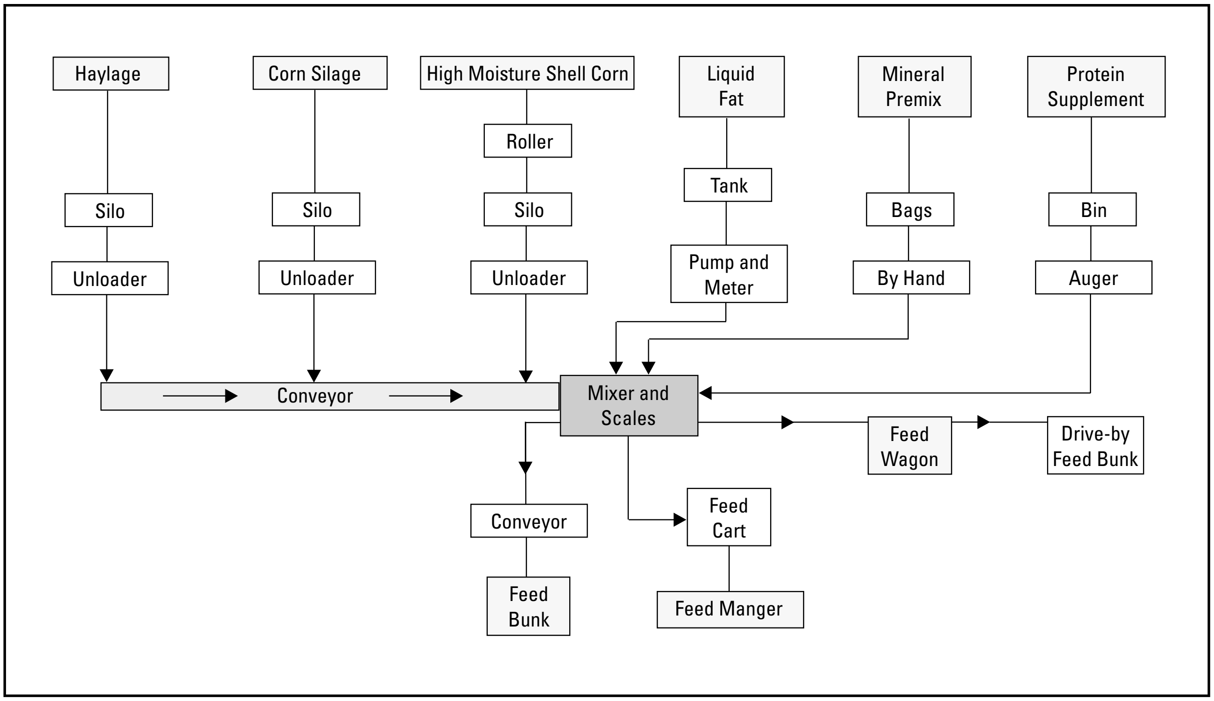


Figure 9-9. Stationary feeding system.

Batch Mixing

Adequately mix forages and concentrates before putting them in the bunk. Top-dressing is not recommended because animals will sort out feeds they do not like.

In batch mixing, a recipe is followed, and feed ingredients are added one at a time until the required weight of each specific ingredient is reached and the batch is complete. The mixer size depends on the group size and the number of times each group is fed, Table 9-3.

The struck or level capacity of a mixer is the total volume of the mixing compartment. Mixers are rated from 60 to 90% of the struck level capacity of the mixer depending on the manufacturer. A good estimate of a mixer required in an operation would be to buy a mixer based on 60 to 70% of the struck level capacity of the mixer.

Overloading mixers beyond their rated capacity increases the mixing time required to provide a uniform mix. In tumble mixers, free space is needed to allow ingredients to tumble. Overloading an auger mixer causes some feed to be thrown out of the mixer.

The time required to fill and unload the mixer depends on the conveying equipment used to deliver feed to and from the mixer. The order of addition of ingredients varies depending on the type of mixer. Consult the manufacturer's recommendations for the mixer. A separate accumulator box overhead to preweigh bulky materials for the next batch speeds up feeding from upright silos. If there is room, silage can be allowed to accumulate at the base of the chute. The chute should be able to be raised to allow silage to be scraped out with a loader.

Premix small quantities of ingredients to eliminate addition of small single quantities of feed. Completely mix the ration before delivering it to the animals. Typical mixing time ranges from 3 to 6 minutes. Consult the mixer manufacturer to determine the minimum mixing time.

Table 9-3. Mixer sizing[a].

	Group Size				
Feedings/day	**10**	**20**	**50**	**75**	**100**
	- - - - Mixer Working Capacity, ft^3 [b] - - - -				
1	60	120	300	450	600
2	30	60	150	225	300
3	20	40	100	150	200

[a] Assumes 50 pounds dry matter (DM) feed ration intake per cow per day with a 50% moisture content (MC), i.e. wet bulk density of feed ration is 17 lb/ft^3. 100 pounds wet feed per cow per day divided by 17 lb/ft^3 bulk density equals 6 ft^3 of feed ration per cow per day.

[b] Check with manufacturer to determine working capacity of the mixer.

Including long dry hay in a TMR is difficult. The amount of long hay that can be used in a ration is limited by the ability of the mixer to blend the dry hay into the ration, and is usually small. The maximum amount of long dry hay that can be incorporated into a mixer is approximately 10% of the weight capacity of the mixer. Chop hay before delivering to mixer if more dry hay is needed.

TMR Mixers

Several designs of mixers are available. Auger, reel, tumble, and ribbon mixers are the most popular designs, Figure 9-10. All do a satisfactory job if not overfilled and if the recommended mixing time is followed. Follow manufacturer's recommendations for loading.

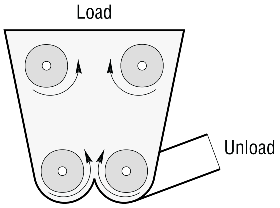
Scales

Scales are required on a mixer to weigh the ration. Electronic digital readout scales use load cells to weigh ingredients in the mixer and are accurate to 0.25% when properly calibrated. Dust and moisture can cause malfunctions if the unit is not sealed properly. Beam scales, a mechanical means of weighing, are accurate to 1% and can withstand the building environment. Fluid scales are simple, but not as accurate, and can be used to read at remote locations from the mixing site as can electronic scales. Elevate the mixer 6 to 12 inches off the floor to prevent dirt and feed buildup from causing inaccurate scale readings. Spring scales for small amounts of ingredients such as salt, vitamins, and additives can be used to weigh these materials before adding them to the batch.

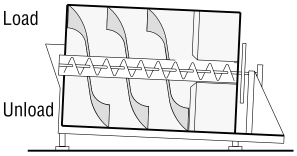
Platform scales should also be considered on large farms. They are used to maintain data on feed inventories. Trucks and wagons are run over the scale to record all feeds entering and leaving the farm. Reconciling feed inventory becomes very important as farms increase in size and purchase more feeds or sell back total mixed rations to other farms in the area.

Continuous Mixing

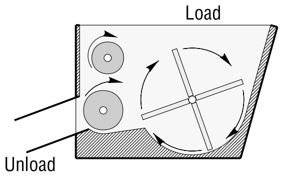
With a continuous mixer, ration components are metered onto a feed conveyor to yield the desired ration. Silage is usually monitored with an in-line weighing device. Adjust concentrate and supplement rates to the silage flow rate. If silage is metered by volume, check the flow rate often—bulky, high moisture material does not flow uniformly. Check the flow rate of any metering system at least once a day. Accumulator boxes are used to meter a volume of forage or grain. They can greatly increase the speed of the batch mixing process.



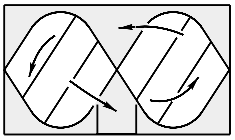
a. Auger.



b. Tumble.



c. Reel.



d. Ribbon.

Figure 9-10. TMR mixers.

Feed Center Design

The feed center encompasses all the conveyors, mixing equipment, and feed storage. Design the feed center for efficient silage handling into the mixer. Locate the bulk and supplement storage for easy access by the delivery truck and easy addition to the complete ration. Minerals, salt, and other small quantities of bagged or bulk ingredients also require space in the feed room. A 10- to 12-foot eave height on the feed room allows room for overhead conveyors and inclined conveyors to elevate feed into the mixer. A 12- to 14-foot eave height is required for mobile mixers. Allow approximately 3 feet of space around a stationary mixer. This allows the mixer to be accessed by a set of stairs or ladder for filling the mixer or for conveyors. Provide an appropriate rail for the stairs/ladder accessing the feed mixer and provide a bar screen over the area where materials enter the mixer.

Mobile Feed Center

A mobile scale-mixer is often used in combination with horizontal silos and a commodity barn. Also, with a mobile feed center, forages and high moisture grains can be stored in upright or horizontal silos, Figure 9-11. Store dry grains and concentrates in flat bulk storages or hopper bottom bins. Use the same equipment to unload horizontal silos and flat storage bays into the mixer. Plan for future herd expansion. Provide space for additional storage and expansion of the feed center building. Provide an adequate roadway for mobile equipment, Figure 9-12.

Stationary Feed Center

Locate conveying and processing equipment and the stationary scale mixer in a separate feed center building, Figure 9-13. Separate the feed center building and feed storages from the barn by at least 50 feet to reduce interference with natural ventilation. The feed center should be placed on the leeward side of a naturally ventilated building.

This separate feed center allows loading a mixed batch into a feed wagon for delivery to animals at other locations. Store forages and high moisture grains in upright silos and dry grains and concentrates in bins with unloading devices. Ration components added in small amounts (minerals and vitamin pre-mixes) can be stored in sacks and weighed on a separate scale before being added to the scale mixer for blending. A conveyor delivers the mixed batch to a mechanical bunk feeder in the barn, lot, or feed wagon.

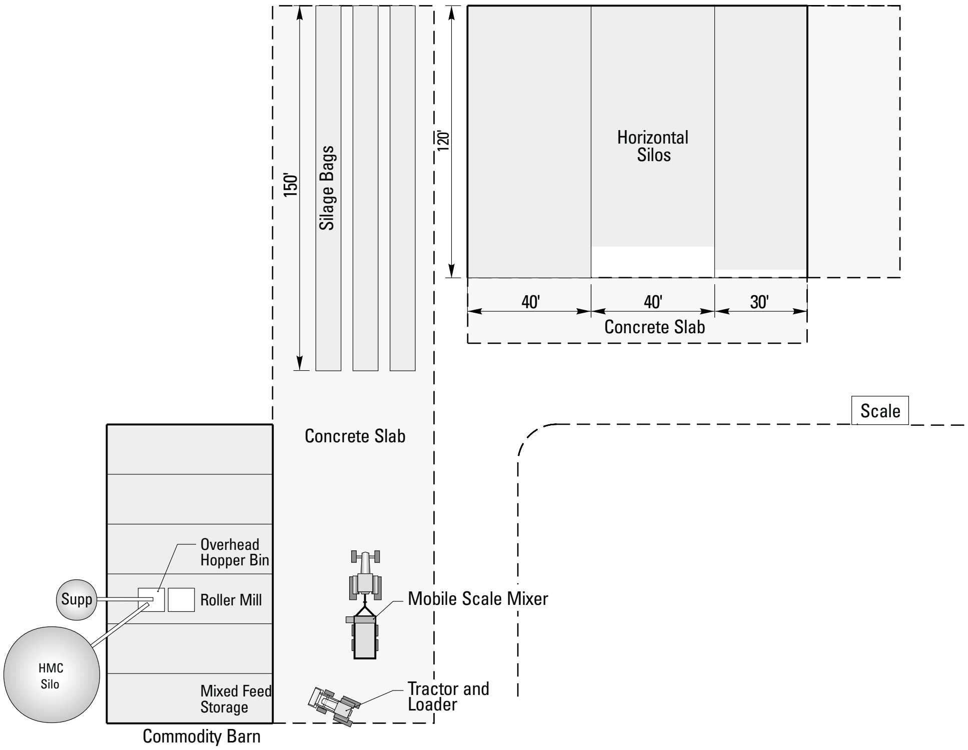


Figure 9-11. Feed handling center with mobile mixer.
Provide a building over the processing area to protect equipment. The building can also be used for feeder wagon storage.

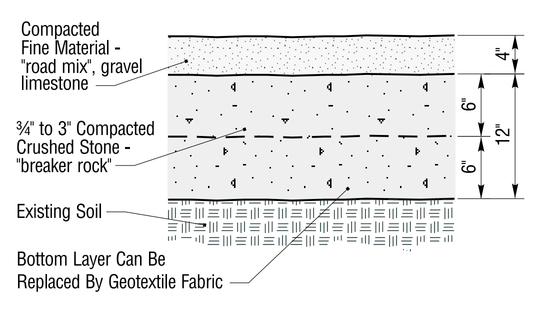


Figure 9-12. Cross-section of an adequate roadway. **Note:** Layers placed individually then compacted.

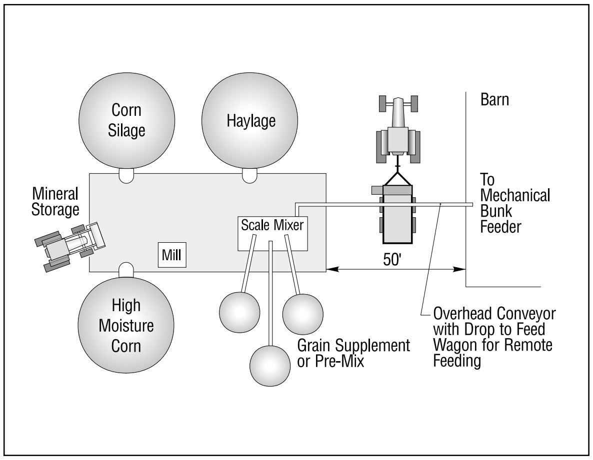


Figure 9-13. Feed center for stationary mixer system.

Conveying Forage

Forage is the largest proportion of the ration. The volume of forage fed must be considered in the system design. Handling forages, including dry hay or silage, requires large quantities of material to be moved in a short amount of time. A variety of conveyors and bunk feeders are on the market, each with its own characteristics.

Belt Conveyors

Belt conveyors handle forage gently, but are expensive and generally unsuitable for steep inclines. Textured belts allow conveyors to be inclined up to 40 degrees. Belt conveyors have higher capacity per horsepower than augers. Belt speed can be as high as 300 fpm moving large volumes of feed quickly.

Belt feeders are filled from the end, and a plow attachment pushes feed off the continuously running belt into the bunk or manger. There are several styles of plows including a floating plastic blade and a rotating brush. Plows can be set to push feed off one or both sides of the feeder. The belt feeder can be mounted close to the ceiling for in-barn feeding. Automatic controls can move the plow to feed up to 12 lots. Distribution is uniform along the bunk length with little separation of the feed.

Chain and Flight Conveyors/Feeders

Double chain flight conveyors, like those for ear corn or baled hay, are low cost. Capacity decreases as flight depth or speed decreases and as flight spacing or conveyor incline increases. Chain and flight conveyors have speeds of 150 to 200 fpm. The conveyors are typically 25 to 60 feet long. Single chain and flight conveyors are low cost and often used to convey forage from a silo unloader or elevate feed over a short distance. A reversing motor on the conveyor offers the ability to move feed in opposite directions.

A bunk feeder or mechanical cart/wagon delivers forage to the cows. A scale under the belt conveyor weighs forage and/or grain prior to delivery. Grain also can be metered through a calibrated tipping bucket or auger. The ration is blended, but there is little control of the proportions. Little to no physical labor is required.

A chain and paddle similar to a gutter cleaner moves forage around the bunk. Feed can be delivered to any point on the feeder. The amount of feed delivered is controlled by allowing the chain to make several trips around the bunk or manger. For cows with neck chains, there is a hazard of chains becoming entangled in the chain or paddle if the system is operated while the cows are eating.

Shuttle Feeder

Several types of shuttle feeders using belts, chains, or a moving trough are available. The shuttle feeder uses a reversing motor and conveyor to move feed back and forth from a central fill point. Distribution is uniform over the length of the bunk, and there is little separation of fine and coarse material. The unit can be used in either an outside feed bunk or suspended from the ceiling for in-barn feeding. This type of feeder would be best used in barns where cows face in and have a common feed alley because only one feeder would be needed. In outside feed bunks, the conveyor can be designed to feed several lots of cattle by splitting the bunk.

Auger Conveyor and Feeder

U-trough augers are used for horizontal conveying of large volumes. Consider them for hard-to-maintain locations, such as overhead augers. They operate at slower speeds, which increase auger life. U-trough augers do not work well at inclines over 15 degrees because the enclosure does not hold feed in the flights. Open auger feeders distribute feed unevenly along the bunk length. Enclosed augers distribute feed more uniformly and provide a mixing action as the material moves through the tube.

Auger Conveyors for Grain

Augers convey grain at any angle from horizontal to vertical and can be stationary or portable. They are relatively low cost and come in many diameters and capacities. Compared with other conveyors, augers generally have low capacity per horsepower, especially for wet grains. For example, compared with dry shelled corn, high moisture shelled corn requires nearly twice the horsepower for half the capacity. Augers are commonly used to remove high moisture grain from a silo.

The flex auger or coreless auger is a high tensile spring auger that rotates in an enclosed PVC tube. It is used to move high and low moisture grains and concentrates. A variation of the flex auger is a device in which the auger is pushed along the tube length by a gear drive meshing into the flights.

Feed Carts for Grain

Powered carts are popular alternatives to conveyors. Carts can be used to deliver forage or concentrate. The self-propelled carts dispense feed using augers or chain aprons. Unloading can occur at the bottom or top of the cart depending on the bunk or manger construction.

A computer-controlled grain cart can meter grain by using proximity sensors to control feed delivery rate accurately to one-tenth of a pound. Also available is a computerized dual feed cart that can meter feed accurately to one-tenth of a pound and can be programmed for a capacity of 400 cows. Feed carts with a capacity of 30 bushels that weigh and mix a TMR also are available.

Electronic Feeders

Supplemental concentrate feeding is needed for operations where dividing cows into feeding groups is not possible. A computer-controlled concentrate feeder feeds cows on a selective basis. Computer-controlled feeders can be used to feed all or part of the required concentrate.

Selective feeding systems have individual feeding stalls. Each cow wears a device that identifies her to a computer as she approaches the feed dispenser. A computer, programmed to the portions of the cow's daily concentrate, apportions the cow's daily concentrate allotment. When the cow leaves the stall or eats the allotment, the feeder stops. The dispensing rate is slow enough to allow the cow to eat all the feed that is delivered. The computer records any unused allotment which is made available the next time that cow enters the feeding stall. Some feeders divide the daily allotment among four or more periods to ensure multiple feedings. Daily feed consumption data can be printed out for each cow, assisting the producer with record keeping.

Advances in electronic technology in the past 10 years have provided the opportunity to control and monitor the concentrate intake of individual cows housed and fed in groups in freestall barns. A number of available systems can allocate up to three concentrate sources or ingredients to each cow. An electronic feeder:

- Permits control and allocation of concentrate to each individual cow based on her requirements.
- Provides a system of monitoring the actual concentrate intake of a cow.
- Allows a cow to consume her concentrate allocation in a number of small meals per day.
- Offers the potential to feed special supplements and varied proportions of three concentrates to individual cows in the herd.
- Can be used to gradually increase or decrease the concentrate allocation for individual cows.
- Requires frequent electronic feeder calibration to monitor and adjust concentrate delivery rates for individual cows based on milk production, body condition and age.
- Bases concentrate feeding schedules on assumed forage intake, which may, in fact, be less than desired.
- Requires time and labor to formulate individual rations for each cow.
- Cannot determine total dry matter intake.
- Allows individual cows to select the ratio of forage to grain consumed.
- Cannot force a cow to eat her daily allotment of grain.

Feeding Dry Hay

Dry hay must be chopped or ground to be incorporated into a TMR. Otherwise, if dry hay is to be fed, make separate provisions. Various types of hay feeders are available for outside lots. Feeding panels or fences reduce the amount of hay animals pull into the animal area and waste.

In a freestall barn, space for a hay feeder can be created by omitting a few freestalls. Allow for 6 inches of feeding space per cow when feeding limited quantities of hay in a self-feeder. In freestall barns with drive-through or fenceline feeding, distribute hay along the manger daily.

Feed Processing

Shrink is a term used to describe feed losses. For harvested feeds like forages these losses include field and storage losses that are normal in the harvest and storage of forages. But they may also include real losses in quality due to wind, rain, tracking and varmint damage.

For purchased feeds, shrink usually describes losses based on the difference of the quantity purchased to the amount actually fed. Some of these losses may be real losses due to wind, rain, tracking, birds, and varmints. Another apparent loss can be the result of worker indiscretion. The worker may approach the mixer with only slightly more material in the bucket of the loader than called for by the ration. Rather than returning the remainder to the storage, the worker may dump it into the mixer, in addition to the prescribed amount. Others may be perceived losses because weigh back of rations doesn't account for animal intakes. In fact it is difficult to determine the true amount of shrinkage on the farm unless all quantities of feeds are reconciled. Records of the quantity of feed entering the farm and the quantity of feed used in the rations must be reconciled to determine the true shrink.

Most farms have some type of feed processing equipment as part of the feeding system. As farms increase in size and feedstuffs change, demand for on-farm processing may increase.

Roller mills are usually used in conjunction with high moisture shelled corn or high moisture cob corn from upright silos. Soybeans and barley also are run through a roller mill to crack the seed.

Hay mills shred and screen solid bales of hay or straw. They are expensive, have a capacity of 6 to 20 ton per hour through a 1-inch screen, and require 25 to 150 horsepower. Bedding choppers for small square bales can be used to grind small quantities of hay for mixing in a batch mixer.

Tub grinders usually are PTO-powered with a 75- to 100-horsepower tractor. A large tub rotates slowly and feeds a constant supply of roughage to a hammermill in the floor of the grinder. After the roughage is screened, it can be piled on the ground or loaded in a wagon for distribution. A tub grinder is usually fed with a front loader and handles 10 to 12 ton per hour. Processing rate depends on roughage moisture content, screen size, and power available.

Safety

Consider safety in the design of the feeding system. A control center for motor switches allows easy access and monitoring of equipment. Provide head space below conveyors to reduce head injury. Keep shields in place to prevent accidental injury. Use skid resistant steps with handrails or a ladder to fill the mixer. Provide an appropriate rail for the stairs/ladder accessing the feed mixer and provide a bar screen over the area where materials enter the mixer.

Locate emergency shutoffs on conveying and mixing equipment. Install properly sized electric wiring and motors; ground equipment as required. Dust and moisture can cause corrosion of equipment and potential shock hazard. Wiring should follow the local code for high moisture environments. Keep the feed room and mixing area clean of trash and debris. Provide ventilation to reduce moisture, dust, and gases.

Silo gas or the absence of oxygen are very real hazards in any type of upright silo. Never enter upright silos alone; always use proper breathing equipment. When using breathing equipment check with the manufacturer or sales company for instructions on where and how to use the equipment.

Augers are a major farm hazard. Manufacturers put safety shields on exposed auger drive assemblies and grates over auger intakes to keep hands, feet, and clothing from contacting the auger flighting or being caught between the flighting and housing. Do not remove safety shields.

Anyone in a grain bin, when the unloading auger is running, risks being pulled down through the grain and suffocating. **A knotted safety rope hanging near the center of the bin is not adequate protection against the tremendous pull of unloading grain**. Never start machinery before locating children and co-workers.

Disconnect power to the unloading auger before entering a bin. Place lockouts on switches that control auger or unloader motors before entering the storages. Spoiled or wet grain sometimes bridges over the auger and inhibits unloading. Never walk on the bridge because it may collapse. Break up the bridge with a long pole from the outside. Wear an effective dust mask when exposed to grain dust. In particular, avoid breathing mold dust from spoiled grain.

Sizing Silos

Crop moisture is an important consideration in determining silage needs and acreage requirements. But silos should be sized based on a dry matter, DM, basis for each type of forage desired. Silage is usually between 50 to 70% moisture content. Having two or more silos in a feeding system increases handling and management flexibility.

The dry matter factor, DMF, converts moist silage to dry matter content. Estimate the percent *as-harvested* moisture, and select the DMF from Table 9-4. Corn silage is usually stored at about 65% and haylage at about 50% in upright silos. In horizontal silos, corn silage is stored at about 70% and haylage at about 65% moisture content.

Annual silage needs, length of silage storage time, feed type, and inventory dictate the number of silos an operation needs. Annual silage needs should be based on DM intake. When calculating the number of acres needed for a particular forage crop, assume 15% dry matter handling loss from harvest to storage and an additional 10% dry matter handling loss from storage to feed delivery. See Table 9-1 for storage loss estimates. Dry matter loss will increase if proper storage and handling methods are not employed.

Upright Silos

Upright silo capacity depends on height and diameter. Select the maximum diameter for upright silos from Table 9-5 using the minimum height and ton of DM. Silos with greater height and smaller diameter that meet the needed storage can also be used. If silage is stored at 65% moisture, determine silo size from Table 9-6 without converting to ton of DM. In addition to being able to store the quantity of

Table 9-4. Dry matter factor, DMF.

To convert from wet ton to ton of dry matter, divide by the DMF. To convert from ton of dry matter to wet ton, multiply by the DMF. DMF = 100 / (100 - % moisture).

Moisture, %	DMF
30	1.43
40	1.67
50	2.00
55	2.22
60	2.50
65	2.86
70	3.33
75	4.00
80	5.00

Table 9-5. Upright silo capacity, ton DM.

Capacities allow 1' of unused depth for settling in silos up to 30' high and 1' more for each 10' beyond 30' height. To determine silo capacity in "wet ton", multiply silo capacity value, dry matter, by the DMF value from Table 9-4. Capacities rounded to nearest 5 ton. Adapted from *1994 ASAE D252.1 DEC93.*

Silo height, ft	Silo diameter, ft									
	12	14	16	18	20	22	24	26	28	30
	- - - - - - - - - - - - - - - - Ton - - - - - - - - - - - - - - - -									
20	10	15	20	25	35	40	45	55	65	75
24	15	20	25	35	45	50	60	70	85	95
28	20	25	35	45	55	65	75	90	105	120
32	25	30	40	50	65	80	95	110	125	145
36	30	35	50	60	75	90	110	130	150	170
40	30	45	55	70	90	105	125	150	175	200
44	35	50	65	80	100	125	145	170	200	230
48	40	55	75	95	115	140	165	195	225	260
52		65	85	105	130	155	185	220	255	290
56		70	95	115	145	175	205	245	280	325
60		80	100	130	160	190	230	275	310	355
64				140	175	210	250	300	340	390
68				155	190	230	270	325	370	425
72							295	350	400	460
76							315	375	425	490
80							335	390	455	520

forage needed, make sure daily removals satisfy the feed off rate of Table 9-2.

Horizontal Silos

Horizontal silo capacity depends on width, height, length, and packing density. Provide enough width to accommodate equipment during packing and removing silage, but minimize the width to reduce spoilage on the face and top. Packed silage will usually have a density between 30 to 50 pounds as fed per cubic foot.

The following factors can affect dry matter loss in a horizontal silo:

- Moisture content (too wet or too dry).
- Length of cut.
- Length of time required to fill silo, that is, how long the surface is exposed to air and rain.
- Packing method and thoroughness of packing.
- Condition of silo walls and floor.
- Effectiveness of cover in excluding oxygen, precipitation, and avoiding air spaces between cover and silage surface.
- Method used to remove silage (improperly used front-end loaders increase rate of DM decomposition).

To determine silage needs and to calculate horizontal silo size, base calculations on the following criteria:

Daily Silage Needs: Consult a dairy nutritionist or feed specialist to help calculate average daily DM needs for each forage crop to used. Add another 10% to the calculations to compensate for handling loss from storage to feed consumption.

Face Removal Rate: For design purposes, use a face removal rate of at least 12 inches per day. This will provide some leeway if feeding needs change over the year due to a change in the number of animals fed, feed quality, or ration fed. Face removal rates should never go below 6 inches per day during the summer and 4 inches per day during the winter, Table 9-2. Minimum removal rates are most critical with hay crop silages and become more important as moisture content and density decrease.

Silo Sidewall Depth: Sidewall depths of 8 to 14 feet are considered most practical. These depths match sizes of commonly available precast panels. Typically, sidewalls have an 8:1 slope, and the silage is packed with a rounded top. Because of variations in packing, horizontal silos are usually designed by assuming vertical sides and a flat top. Do not stack silage taller than the unloading equipment can reach. When common silo walls are used, surface runoff from the plastic covers should be diverted so as to keep water from entering the silage at the walls.

Silo Width: A width of at least 16 feet is needed to facilitate packing. To increase labor efficiency,

Table 9-6. Upright silo capacity, wet ton.

Silage at 65% moisture, wet basis. Capacities allow 1' of unused depth for settling in silos up to 30' high and 1' more for each 10' beyond 30' height. Capacities rounded to nearest 5 ton. Adapted from *1994 ASAE D252.1 DEC93*.

Silo height, ft	Silo diameter, ft									
	12	14	16	18	20	22	24	26	28	30
	Ton									
20	35	45	60	75	95	115	135	160	185	210
24	45	60	75	95	125	150	175	205	235	275
28	55	75	100	125	150	185	215	255	295	340
32	65	90	115	150	185	225	265	310	365	415
36	80	105	135	175	215	265	310	370	430	490
40	90	125	165	205	255	305	365	430	495	570
44	105	145	185	235	290	350	420	490	570	655
48	120	160	210	265	330	400	475	555	645	745
52		185	235	300	370	450	530	625	725	830
56		205	265	335	410	495	590	695	805	925
60		225	290	370	455	550	650	780	885	1,020
64				405	495	600	715	850	970	1,115
68				445	545	650	775	925	1,055	1,215
72							835	1,000	1,145	1,310
76							895	1,075	1,220	1,395
80							955	1,120	1,300	1,485

design for a bottom width of 30 feet, provided a 6-inch removal rate can be maintained. This will help in positioning the transport vehicle near the silage and minimize loader travel time. This is especially important when the silo length exceeds 75 feet. To maintain labor efficiency in smaller operations, it may be important to reduce the sidewall depth or reduce the feeding rate to keep the silo width at least 16 feet. When making the decision about silo width, remember that feed quality is more important than labor efficiency. Keep the design face removal rate above 6 inches per day when adjusting for width.

Storage Period: Providing quality feed at all times should be a high priority in all operations. Consider using a separate bunker that is shallower and narrower for warm weather.

Silo Length: The silo length is determined by multiplying the face removal rate by the storage period. If calculated lengths are much over 150 feet, then using multiple horizontal silos should be a consideration because of labor efficiency. Another reason to use multiple horizontal silos may be the construction limitations of the site where the silos are located. Multiple horizontal silos provide more flexibility of materials stored and faster filling. Designing horizontal silos that share a common wall may cost less than one long silo.

The size of horizontal silos, including silage bags and silage piles, can be estimated using Tables 9-7 through 9-11. For design and management guidelines, refer to *Managing and Designing Horizontal Silos*, AED-43.

Table 9-7. Horizontal silo capacity, ton DM.
Silo assumed level full 14 lbs DM/ft^3 density. Capacities rounded to nearest 5 ton.

	Silo floor width, ft								
Depth, ft	20	30	40	50	60	70	80	90	100
	- - - Ton dry matter/10' length - - -								
8	10	15	20	30	35	40	45	50	55
10	15	20	30	35	40	50	55	65	70
12	15	25	35	40	50	60	65	75	85
14	20	30	40	50	60	70	80	90	100
16	20	35	45	55	65	80	90	100	110
18	25	40	50	65	75	90	100	115	125
20	30	40	55	70	85	100	110	125	140

Table 9-8. Horizontal silo capacity, wet ton.
65% moisture; 40 lb/ft^3 or 50 ft^3 = 1 ton; Silo assumed level full. Capacities rounded to nearest 5 ton. To calculate capacity of other silo sizes, multiply silage depth, ft, by silo width, ft, by silo length, ft, and divide by 50 cu ft/ton.

	Silo floor width, ft								
Depth, ft	20	30	40	50	60	70	80	90	100
	- - - Ton dry matter/10' length - - -								
8	30	50	65	80	95	110	130	145	160
10	40	60	80	100	120	140	160	180	200
12	50	70	95	120	145	170	190	215	240
14	55	85	110	140	170	195	225	250	280
16	65	95	130	160	190	225	255	290	320
18	70	110	145	180	215	250	290	325	360
20	80	120	160	200	240	280	320	360	400

Table 9-9. Horizontal silo capacity.
Assumes 65% moisture, 40 lb/ft^3 density (14 lb DM/ft^3). Capacities rounded to nearest 5 tons.

	Silo floor width, ft									
Depth, ft	16	20	30	40	50	60	70	80	90	100
	- - - Ton - - -									
8	150	185	280	375	465	560	655	745	840	935
10	185	235	350	465	585	700	815	935	1,050	1,165
12	225	280	420	560	700	840	980	1,120	1,260	1,400

Table 9-10. Silage bag capacities.[a]

Bag Diameter (feet)	Bag Length (feet)	Hay Silage (Tons)	Corn Silage (Tons)	Ground Ear Corn (Bushels)	Ground Shelled Corn (Bushels)	Shelled Corn (Bushels)
8	100	80-90	90-100	2,000	3,100	2,600
	150	120-140	140-150	3,200	5,000	4,100
	200	170-180	190-200	4,300	6,800	5,735
9	135	120-140	130-160	3,500	5,500	4,300
	150	150-170	160-190	3,900	6,100	4,800
	200	190-210	220-240	5,300	8,400	6,600
10	150	240-260	260-280	6,000	9,400	7,400
	200	300-320	345-365	8,200	13,000	10,000
	250	375-395	430-455	10,250	16,250	12,500
12	200	360	410			
	250	440	520			
	300	530	620			

[a] These quantities are only approximations. Actual quantities will vary with moisture content and length of cut.

Table 9-11. Silage piles.
Assumes 70% moisture content, 40 lb/ft^3 silage density (12 lb DM/ft^3). See Figure 9-4 for pile details.

	Average pile width, ft					
Depth, ft	24	28	32	36	38	42
	- - - - Ton dry matter/10' length - - - -					
4	6	7	8	9	9	10
5	7	8	10	11	11	13
6	9	10	12	13	14	15
7	10	12	13	15	16	18

Sizing Dry Hay and Straw Storages

Indoor hay and straw storage helps preserve quality and reduce dry matter losses. Store hay and straw near loading or feeding areas. Hay and straw storage sheds can be sized using Tables 9-12 and 9-13.

Table 9-12. Hay and straw densities.

Material	ft^3/ton	lb/ft^3
Loose		
Alfalfa	450-500	4-4.4
Non-legume	450-600	3.3-4.4
Straw	670-1,000	2-3
Baled		
Alfalfa	200-330	6-10
Non-legume	250-330	6-8
Straw	400-500	4-5
Chopped		
Alfalfa, 1-1/2" cut	285-360	5.5-7
Non-legume, 3" cut	300-400	5-6.7
Straw	250-350	5.7-8

Table 9-13. Hay shed capacities.
Shed has 20' high sidewalls.

Shed width, ft	Small Square, Bale	Chopped
	- - - - - - - Ton/ft of length - - - - - - -	
24	2.0	1.9
30	2.6	2.3
36	3.1	2.8
40	3.4	3.1
48	4.0	3.7

Sizing Commodity Storages

In most cases the amount of storage needed for a particular ingredient will be a multiple of the unit truck capacity plus a cushion of 25 to 50% depending on purchasing and transportation arrangements. A semi-trailer truck's capacity is about 24 ton. For dense products such as grain, cottonseed, soybean meal, and pelleted ingredients, one truck load will nearly equal the semi's weight capacity. For less dense products, like brewers and distillers grain, experience shows that truck volume is the limiting factor; the load will contain 20 to 22 tons of material.

Table 9-14. Commodity storage densities and storage requirements.
Based on *Proceedings: Alternative Feeds for Dairy and Beef Cattle*, and American Feed Industry Association publications.

Description	Density, lb/ft^3	Storage Vol., ft^3/ton
Alfalfa meal, dehydrated, 13%	16-18	111-125
Alfalfa meal, dehydrated, 17%	18-22	91-111
Barley, ground	24-26	77-83
Barley, malt	30-31	65-67
Blood meal	39	52
Bone meal	50-60	33-40
Brewers dried grain	14-15	133-143
Brewers grain, spent, dry	25-30	67-80
Brewers grain, wet	55-60	33-36
Calcium carbonate	75	27
Corn distillers dried grains	18	111
Corn distillers dried soluble	25-26	77-80
Corn, whole shelled	45	44
Cottonseed hulls	12	167
Cottonseed oil meal	37-40	50-54
Cottonseed with lint	18-25	80-111
Cottonseed, delinted	25-35	57-80
Dairy, concentrates	43	47
Dried beet pulp	11-16	125-182
Dried citrus pulp	21	98
Hay, loose	5	400
Hay, pressed	8	250
Limestone	68	29
Malt sprouts	13-16	125-154
Milo, ground	32-36	56-63
Oats, rolled	19-24	83-105
Oats, whole	25-35	57-80
Phosphate, tricalcium	21	95
Rice, hulls	20-21	95-100
Sorghum, grain	32-35	57-63
Soybean hulls, ground	20	100
Soybean hulls, unground	6-7	286-333
Soybean meal (solvent)	42	48
Soybean oil meal (Expeller)	36-40	50-56
Soybeans, grain	46-48	42-43
Wheat middlings (std)	18-25	80-111
Wheat, ground	38-39	51-53

Example 9-1. Sizing commodity storage.
Determine the commodity storage required for a semi load of soybean meal.

Solution:
Assuming the semi capacity is 24 ton, storage need per ton of soybean meal is 48 ft^3/ton, Table 9-14. Allowing 25% extra storage, the storage required for soybean meal is:

24 ton x 48 ft^3/ton x 1.25 = 1,440 ft^3

A 16-foot wide by 30-foot long bay will be filled about 3 feet deep (1,440 cu ft/(30 ft x 16 ft)).

Sizing Grain Storages

Grain can be stored at harvest or delivered when needed. The biggest bin is not always the least costly per bushel of storage. Bins should not exceed half of the total volume of the operation. Size the bin using Table 9-14. See *Grain Drying, Handling and Storage Handbook*, MWPS-13, and *Managing Dry Grain in Storage*, AED-20, for more information on drying, storing and aerating grain. Ground shelled corn, ground ear corn and whole-shelled corn can also be stored in upright silos. Select silo size from Tables 9-16 and 9-17.

Table 9-15. Storage capacity for round grain bins.
Capacity does not include space above eave line. Based on 1.25 cu ft per bushel.

	Depth of grain, ft				
Diameter, ft	1	11	13	16	19
	- - - - - - - - - - - - Bushel - - - - - - - - - - -				
14	125	1,375	1,625	2,000	2,375
18	203	2,200	2,635	3,250	3,850
21	277	3,050	3,600	4,400	5,300
24	362	4,000	4,700	5,800	6,900
27	458	5,050	5,950	7,300	8,700
30	565	6,215	7,345	9,040	10,735
36	814	8,950	10,600	13,000	15,450
40	1,005	11,050	13,050	16,100	19,100

Table 9-16. Upright silo capacity for ground shelled corn.

For 30% moisture grain and 68 lb/bu (1.25 ft^3/bu) density. Capacities allow for 1' of unused depth and are rounded to the nearest 5 ton and 10 bu. Capacity increases 5% with moisture contents between 25%-35%. Capacity also varies with fineness of grind and filling procedures. Values based on no settling or compaction of material. Because some settling and compaction will occur, these values should be considered minimums. DM = dry matter.

Silo height, ft	Unit of measure	Silo diameter, ft						
		10	12	14	16	17	18	20
20	Wet ton	40	60	80	105	—	—	—
	Ton DM	30	40	55	75	—	—	—
	Bushel	1,200	1,730	2,370	3,100	—	—	—
28	Wet ton	60	85	115	150	170	190	230
	Ton DM	40	60	80	105	120	135	160
	Bushel	1,700	2,470	3,330	4,370	4,930	5,530	6,830
36	Wet ton	—	110	145	190	215	245	300
	Ton DM	—	75	100	135	150	170	210
	Bushel	—	3,170	4,330	5,630	6,370	7,130	8,800
44	Wet ton	—	—	180	235	265	300	365
	Ton DM	—	—	125	165	185	210	255
	Bushel	—	—	5,300	6,900	7,800	8,770	10,800
52	Wet ton	—	—	—	280	315	355	435
	Ton DM	—	—	—	195	220	250	305
	Bushel	—	—	—	8,200	9,270	10,400	12,830
60	Wet ton	—	—	—	325	365	410	510
	Ton DM	—	—	—	230	255	285	355
	Bushel	—	—	—	9,570	10,800	12,100	14,930

Table 9-17. Upright silo capacity for ground ear and whole shelled corn.

For 30% moisture shelled corn and 27% kernel moisture (32% blend moisture) ear corn and 60 lb/bu (1.25 ft^3/bu) density. Capacities allow for 1' of unused depth and are rounded to the nearest 5 ton and 10 bu. Capacities increase approximately 5% with moisture contents between 25%-35%. Capacities also vary with fineness of grind and filling procedure. Values based on no settling or compaction of material. Because some settling and compaction will occur, these values should be considered minimums. DM = dry matter.

Silo height, ft	Unit of measure	Silo diameter, ft						
		10	12	14	16	17	18	20
20	Wet ton	35	50	70	95	—	—	—
	Ton DM	25	35	50	65	—	—	—
	Bushel	1,200	1,730	2,370	3,100	—	—	—
28	Wet ton	50	75	100	130	150	165	205
	Ton DM	35	55	70	90	105	115	145
	Bushel	1,700	2,470	3,330	4,370	4,930	5,530	6,830
36	Wet ton	—	95	130	170	190	215	265
	Ton DM	—	65	90	120	135	150	185
	Bushel	—	3,170	4,330	5,630	6,370	7,130	8,800
44	Wet ton	—	—	160	205	235	265	325
	Ton DM	—	—	110	145	165	185	230
	Bushel	—	—	5,300	6,900	7,800	8,770	10,800
52	Wet ton	—	—	—	245	280	310	385
	Ton DM	—	—	—	170	195	215	270
	Bushel	—	—	—	8,200	9,270	10,400	12,830
60	Wet ton	—	—	—	285	325	365	450
	Ton DM	—	—	—	200	230	255	315
	Bushel	—	—	—	9,570	10,800	12,100	14,930

Chapter 10

Utilities

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All the planning and designing that goes into a dairy facility can be wasted if the utilities are not properly designed to meet the needs. Utilities for dairy facilities include:

- Water for sanitation, cow cooling, and drinking.
- Electricity for milking and milk cooling, water pumping and heating, feed handling, lighting, heating, and ventilating.
- Gas for heating and water heating.

Provisions must be made for times of drought, high water usage, and power outages. Always check with the insurer, milk inspector, power supplier, local building official, and electric power supplier, where applicable, for information on approved construction practices before making major changes or installing new utilities.

Water

Total water requirements include water for consumption and spillage, sanitation, parlor and milking system cleaning, cooling sprays, milk cooling, and fire protection. Water consumption depends on animal size, activity, diet, lactation, production, and season of the year. Estimate normal animal drinking water needs from Table 10-1. Animals experiencing heat stress conditions often consume twice their normal drinking water requirements. See Table 8-5 to estimate milking center water usage. Size the water supply system to meet maximum instantaneous and daily needs.

Table 10-1. Water requirements.

Usage	gal/hd-day
Animals[a]	
Calves (1 to 1.5 gal per 100 lb)	6-10
Heifers	10-15
Dry cows[b]	20-30
Milking cows[b]	35-50
Sprinkler System	10-20

[a] During periods of heat stress (hot weather) drinking water intake can easily reach twice the highest amount in each size category. (From Chapter 28, Large Dairy Herd Management, 1992).

[b] Cows drinking from a water trough may consume at the rate of 6-7 gpm.

Grade A milk rules require water supply wells to be cased and properly sealed to reduce the risk of contaminants entering the water supply. In most instances, the well casing must extend 18 inches or more above ground level.

Depending upon location, a surface water supply (e.g. spring) may be approved for use in a dairy operation. The spring must be enclosed to reduce entry of dirt and prevent direct access by animals.

Check with the local health department, milk inspector, or milk market field specialist for local requirements. Some states require at least an annual analysis to verify water quality. A contaminated water supply causes elevated bacteria counts in milk and may pose health problems for both people and animals. Safety characteristics of water sources are listed in Table 10-2. Refer to *Private Water Systems Handbook*, MWPS-14, for additional information on water sources.

Storage

A water system's pressure tank provides a small amount of storage. The storage volume is usually 10 to 30% of the tank size, which provides small amounts of water without starting the pump. The storage also helps satisfy water demand during short, peak use periods.

Table 10-2. Safety characteristics of water sources.
Water treatment may be needed to remove undesirable minerals.

Source	Primary uses	Safety	Treatment usually recommended to be safe for DOMESTIC use
Drilled well (properly located)	Domestic and livestock	Usually best of all sources	None, unless subject to contamination
Dug, jetted, driven, or bored well	Domestic and livestock	Subject to contamination	Automatic chlorination
Spring	Domestic and livestock	Subject to contamination	Automatic chlorination
Cistern (untreated water)	Domestic, livestock, and fire protection	Subject to contamination	Automatic chlorination and filtration
Farm pond	Livestock and fire protection	Subject to contamination	Automatic chlorination and filtration
Stream or lake	Livestock and fire protection	Subject to contamination	Stream not recommended for domestic use without extensive treatment
Controlled catchment	Domestic and livestock	Subject to contamination	Automatic chlorination and filtration
Hauled water	Domestic	Good if hauled from safe source in safe containers	None if safely stored, but chlorination is desirable
Community water system	Domestic, livestock, and fire protection	Good if properly maintained	None by user, but if stored underground, chlorinate

Consider intermediate water storage under these conditions:

- Water source and pressure tank cannot deliver the required peak flow rate.
- Water sources do not sufficiently meet peak two-hour capacity (the largest volume of water needed in any two hours).
- Standby power is not available. In this instance, elevate the water storage tank for gravity feed to waterers.

Intermediate water storages are usually concrete, fiberglass, plastic, or steel tanks. Protect the storage from contamination. When the water source can deliver the required flow rate the majority of the time, size the intermediate water storage for two hours of peak flow. Dairies using rural water systems should have a minimum of 4 to 6 hours of peak flow storage.

A two-pump system commonly is used for intermediate water storage when the water source and pressure tank cannot deliver the required peak flow rate. The first pump (usually the well pump) has a low level cut-off and a capacity slightly less than the water source's production level to prevent pumping the source dry. This pump fills an intermediate water storage with water for peak use periods. A second pump draws the water from the intermediate water storage and forces it into a pressure tank. Size the second pump to provide the peak use flow rate. If the water source tends to decrease or dry up for short periods, size the storage to meet the operation's minimum requirement for one day's total water usage.

Fire protection requires large quantities of water to be available on short notice. For fire protection, provide 1,200 to 6,000 gallons of intermediate water storage to maintain 10 to 50 gpm of water flow for two hours.

Distribution

Provide a minimum of one watering space (1 cup or 2 feet of tank perimeter) for every 15 to 20 cows. Provide a minimum of two waterer locations per group of cows. (See Chapter 4, section on **Cross Alleys,** page 40, for more information on locating waterers.) During hot weather, 15 to 25% of a group should have access to drinking water to compensate for heat stress. Additional waterers can be located along the outside of outside cow alleys in a freestall barn to provide this additional water access in hot weather. Finally, locating a watering tank near the exit of the parlor is beneficial because cows tend to prefer to drink a significant amount of water immediately after milking. Size waterers so water does not stand for more than a few hours at a time. Consider float-operated waterers for a fresh supply of water and continuous overflow waterers for pasture locations. Water quality must be good. Potable water is best. Clean waterers regularly.

Plumbing in livestock facilities encounters special corrosion and freezing problems. Use PVC, CPVC, or polyethylene pipe with nylon fittings and stainless steel fasteners whenever possible to improve corrosion resistance. Check with the manufacturer for the proper temperature and pressure rating of each type of pipe before installing.

Overhead pipes in naturally ventilated buildings are generally not recommended and will require extra measures to prevent freezing. Insulation of pipes alone usually will not prevent freezing in naturally ventilated buildings. Both heat tape and insulation are required to prevent freezing. If heat tape is not used, the piping system delivering water to waterers will require a loop configuration to allow water to continuously circulate in the delivery system. Drain water systems in unused buildings. Use antifreeze to protect traps that cannot be drained.

Buried lines solve most freezing problems but are difficult to repair. Frost penetration varies from 3 to 6 feet in the Midwest. The frost depth can increase by 2 feet in locations with compact soil, such as under driveways and animal traffic areas, and in areas where snow cover is blown away or removed. Where underground pipes are brought to the surface, run them through a larger diameter, rigid plastic pipe to protect them from abuse and to provide a warmed air film around the waterline. See Figure 10-1. Heavily insulated, nonheated frost-free waterers are commercially available with large diameter pipes to prevent freezing. They generally remain ice-free if water entering them is above 40 F and at least one tank full of water is consumed every four to six hours. Their success depends on the design, weather conditions, and number and size of animals drinking.

All waterers must have a way to prevent water from back siphoning. Use either an anti-back siphoning device in the water line or an air gap between the water inlet and the maximum water level. Include anti-back siphoning devices on all hose bibs. See *Private Water Systems Handbook*, MWPS-14, for information on design of pipes, pumps, and water supplies.

Install all waterers on concrete slabs to reduce mud. Extend the slab away from the waterer at least 10 feet in each direction. Slope concrete 1/4 inch to 1/2 inch per foot away from the waterer for good drainage. Waterer installation details and guidelines are shown in Figure 10-1. Equip all waterers with a drain to facilitate regular cleaning. Select waterers designed to allow easy cleaning.

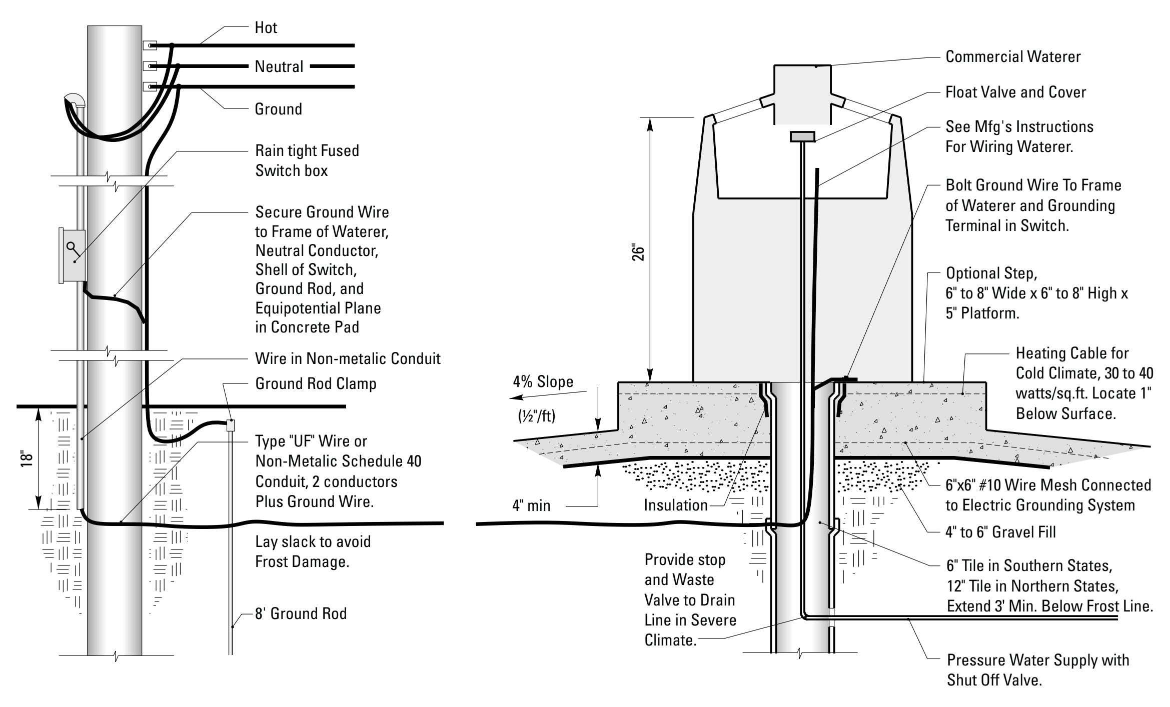

Figure 10-1. Unit waterer.

Install a fused disconnect switch for each waterer. Use a waterproof switch and a corrosion resistant box with appropriate fittings. Fuse only the hot wire with a fuse 25% larger than the total amperage rating of the waterer. Locate the switch on a pole or other suitable surface within sight of and within 50 feet of the waterer.

Enclose all wires mounted on a service pole in non-metallic conduit. Seal the top of the conduit, or extend it into a weatherhead to keep water out. Extend the conduit at least 24 inches into the ground. Install all switches and other electrical equipment where they cannot be damaged. Careful sizing of wiring for waterers is important for reliable and safe operations. All electrically heated waterers must have a grounding conductor as part of the electrical cable. A ground rod alone does not provide adequate protection. Install and connect equipment to an equipotential plane if possible. See the *Farm Buildings Wiring Handbook*, MWPS-28, for more information on equipotential planes.

Pipe and Pump Sizing

Size pipes and pumps to provide water required during the peak three-hour period. Estimate total water requirements from Tables 8-5 and 10-1. When estimating water volumes for the peak three-hour period, include water:

- Consumed after feeding.
- Used for milk cooling.
- Consumed during and after milking.
- Used for washing the milking system (e.g. pipes, weigh jars, bulk tank).
- Used for washing the parlor and holding area.
- Used for flushing gutters.
- Used to sprinkle cows during holding, after milking, and in the freestall barn. Use a feed line sprinkler system.

Table 10-3. Pressure loss in pipes due to friction. Table includes pressure losses in pipes less than or equal to 1.0 psi/ 100' due to friction. See *Private Water Systems Handbook*, MWPS-14, for pressure losses in pipes greater than 1.0 psi/100' due to friction. Losses are for straight lengths. Losses do not include bends or transition sections. PVC = Polyvinyl chloride material

Flow rate (gpm)	Nominal diameter (inches)	Steel (Schedule 40)	Copper (Type L)	PVC (Schedule 40)
		- - - - - - - - - Pressure loss psi/100'	- - - - - - - - -	
1	½	0.9	—	0.5
	¾	0.2	0.2	0.1
2	¾	0.8	0.7	0.4
	1	0.3	0.2	0.1
5	1	—	1.0	0.8
	1-¼	0.4	0.3	0.2
	1-½	—	0.2	0.1
10	1-¼	—	—	0.7
	1-½	0.6	0.5	0.3
	2	0.2	0.1	0.1
15	1-½	—	—	0.7
	2	0.4	0.3	0.2
20	2	0.7	0.5	0.4
	2-½	0.3	—	0.2
30	2-½	0.6	—	0.3
40	2-½	1.0	—	0.5
	3	0.4	—	0.2
	4	0.2	—	0.0
50	2-½	—	—	0.8
	3	0.5	—	0.2
	4	0.2	—	0.1
60	3	0.7	—	0.3
	4	0.2	—	0.2
70	3	1.0	—	0.4
	4	0.3	—	0.2
80	3	—	—	0.5
	4	0.3	—	0.2
90	3	—	—	0.7
	4	0.4	—	0.2
100	3	—	—	0.8
	4	0.5	—	0.2

Select pipes from Table 10-3 based on the following guidelines:

- Maximum pressure loss from pressure tank to building: 5 psi.
- Maximum pressure loss from pressure tank to any isolated fixture: 10 psi.
- Maximum pressure loss per 100 feet of main supply line: 1 psi.
- Maximum water velocity: 4 feet per second (fps) to prevent water hammer.

Design pumps to provide the flow required to overcome the total system head during the peak, three-hour period. Total head includes:

- Pressure loss due to friction.
- Pressure losses through elbows, T's, Y's, and transitions.
- Elevation differences between pump source and point of use.
- System operating pressure.

System operating pressures of 45 to 50 psi are common for farm water systems. If a single pump is to be used to supply the total farmstead, other on-farm water needs (e.g. house, other livestock buildings), must be included in determining pipe size and pump capacity.

Refer to *Private Water Systems Handbook*, MWPS-14, for more detail on sizing water pipes and pumps.

Electrical

This section outlines general materials and methods for electrical equipment and wiring in dairy facilities. It does not cover wiring from the power supplier to the buildings or sizing of building distribution panels. Electrical power requirements vary greatly depending on the size of the herd and electrical equipment used, such as silo unloaders and feed mixing/milling equipment. Refer to the *Farm Buildings Wiring Handbook*, MWPS-28, for additional wiring requirements.

To ensure proper wiring, consult the following sources:

- The local power supplier to help plan and install the distribution system.
- A licensed electrician, who has previously worked with dairy equipment and supplies, to help plan and install distribution panels and motor circuits, select conductors and fixtures, and verify compliance with state and local codes.
- Electrical equipment suppliers for dust- and moisture-tight fixtures and wiring required for damp and wet buildings. Plan ahead because some of this equipment may have to be ordered from electrical wholesale supply stores. Suppliers can list voltage and current needs of equipment.
- Insurance companies to determine coverage requirements.
- Local building officials where applicable.

Wherever possible, provide service through a single service entrance panel with enough circuit breakers to meet present needs and some future expansion. If multiple service entrance/distribution panels are required to meet the needs of the installation, install a separate main disconnecting switch ahead of the multiple panels. Each distribution panel is then wired as a subpanel from the main disconnects.

Article 547 of the *National Electrical Code* requires all electrical equipment used in livestock facilities to be corrosion resistant, waterproof, and dustproof. Light fixtures must be watertight. Use only Type UF cable or appropriate conductors in nonmetallic conduit. Surface mounting (i.e., not recessed into or concealed in walls or ceiling) of all electrical equipment is recommended and is required by some insurance companies.

Lighting

Proper lighting can improve cow performance and management and provide a safer and more pleasant work environment. Lighting-system performance characteristics include light intensity or illumination level, photoperiod or duration, color characteristics, and uniformity.

Illumination Levels

Illumination levels are measured using a light meter. Light intensity is expressed in footcandles (fc), which has units of lumens per square foot. Lumens are the amount of light put out by a light source. In the metric system illumination level is expressed in terms of lux, where 1 fc equals 10.76 lux. The relation between lumen output from a single light or bank of lights and the illumination level below depends on many factors, but distance between the light and the illuminated area is one of the most important.

Table 10-4 lists recommended illumination levels for different areas in a dairy facility. Excessive lighting is uneconomical and wastes energy.

Photoperiod

Cows respond to the day length or total hours of light called the photoperiod. The use of artificial light sources in combination with natural daylight to extend the lighted period is known as photoperiod control. Research has determined that providing dairy cows with a continuous 16-hour lighting period

Table 10-4. Recommended illumination levels (ASAE, 1997)

Work Area or Task	Illumination level (fc)
Freestall feeding area	20
Housing & resting area	10
Holding area	10
Treatment and maternity areas	
General lighting	20
Surgery	100
Milking parlor	
General lighting	20
Operator pit	50
Milk room	
General lighting	20
Washing area	100
Bulk tank interior	100
Loading platform	20
Utility or equipment room	20
Storage room	10
Office	50

followed by 8 hours of darkness results in:

- A 5 to 16% increase in milk production.
- An increase in feed intake of about 6%.
- No negative reproductive performance of cows.
- A possible enhancement in the reproductive development of heifers.

Proper lighting improves cow movement, observation, and care. Cows move more easily through uniformly lit entrances and exits. Cows can be more easily observed and cared for in properly lit areas. Sick cows can be spotted more easily with adequate lighting.

Research indicates that providing more than 16 hours of light per day does not stimulate additional milk production.

Color Characteristics

Sunlight is made up of light at different wavelengths that produce different colors (e.g., rainbows). The color characteristic temperature (CCT) and color rendition index (CRI) are used to describe color characteristics of artificial lights. The CCT describes the color of the light using a Kelvin temperature scale that ranges from 1,500 to 6,500 K. Lights with CCT values closer to 6,500 K produce a whiter light that more closely approximates sunshine.

The CRI indicates a light's ability to render the true color of an object. CRI values range from 0 to 100. Lights with higher CRI values produce light that renders a truer color. Lights with lower CRI values produce some color distortion. Table 10-5 lists CCT and CRI values for common light sources.

Uniformity

Light level uniformity is important for visually difficult tasks. Non-uniform illumination produces bright and dark spots including shadows. Uniformity requirements are not established for dairy facilities. Uniformity generally increases by installing more lamps and decreasing the distance between lamps. Some non-uniformity is acceptable because installation of an excessive number of lamps is too expensive. Tables 10-5 to 10-7 are based on economical lamp distribution and sizing.

Lamps

Three types of lamps are common:

- Incandescent (standard and tungsten-halogen).
- Fluorescent.
- High intensity discharge (high pressure sodium, metal halide, and mercury vapor).

Table 10-5. Color characteristic temperature and color rendition index values for common lights.

Lamp Type	Color Characteristic Temperature (K)	Color Rendition Index
Incandescent	2,500 to 3,000	100
Halogen	3,000 to 3,500	100
Fluorescent	3,500 to 5,000	70 to 95
High Intensity Discharge		
Mercury Vapor		20 to 60
Metal Halide	3,700 to 5,000	60 to 80
High Pressure Sodium	2,000 to 2,700	40 to 60

Select lamps based on light output, initial and operating costs, energy efficiency, maintenance. All lighting fixtures must be watertight.

Incandescent Lamps

Standard incandescent lamps come in a wide range of sizes and have a relatively low initial cost. Consider them when light is needed for short periods and when they are turned on and off frequently. Standard incandescent lamps have outputs ranging from 6 to 24 lumens per watt, making them the least energy-efficient electric light source. They also have a relatively short life (750 to 2,500 hours). Dust- and water- tight fixtures with a heat resistant globe to cover the bulb are required.

Tungsten-halogen lamps generally produce a whiter light than standard incandescent lamps, are more efficient, last longer, and have less lamp lumen depreciation over time. Because the filament is relatively small, tungsten-halogen lamps often are used where a highly focused beam is desired.

Fluorescent Lamps

Fluorescent lamps are widely used because they produce three to four times more light per watt than standard incandescent lamps and a longer operating life. Fluorescent lamps come in different forms, standard, high-light-output, and compact. Use watertight fixtures.

Standard 32-watt T-8 fluorescent lights are usually used when they can be placed 7 to 8 feet above the lighted area. High-light-output (HLO) 32-watt T-8 fluorescent lights are used if the lights must be placed higher, up to 12 feet above the lighted area. Compact fluorescent lights can be used to replace incandescent lights when the existing fixture meets the National Electric Code safety requirements for livestock buildings, but tube fluorescent lights provide the best life cycle cost option for new construction.

Fluorescent bulbs come in different diameters. T-8 bulbs are 1 inch in diameter while T-12 bulbs are 1.5 inches in diameter. T-8 lamps are recommended over the older T-12 lamps because T-8 lamps are more energy efficient.

The color characteristic temperature of fluorescent lights depends on the bulb installed in the light. The last two digits in the bulb number indicate the CCT of a fluorescent bulb. For example, a fluorescent bulb with the number F32 T8 SP41 means that it is a 32-watt fluorescent T-8 (1-inch diameter) bulb with a CCT of 4,100 K.

Fluorescent lights have ballasts that start and keep the bulbs lit. Electronic ballasts are recommended because they are more energy efficient, generate less heat, have a longer life expectancy, and operate and start at colder temperatures (0 F) than other ballasts. Fluorescent bulbs also last longer when electronic ballasts are used. Magnetic and electromagnetic ballasts are not recommended. They generate more waste heat, can hum or click, and cause light flickering at cold temperatures. Magnetic ballasts have operating and starting problems at temperatures of 50 F and below. They can also produce harmonic distortions, which can affect electronic equipment (i.e., computers). Electromagnetic ballasts have operating and starting problems at temperatures of 40 F and below.

High light output (HLO) fluorescent fixtures are available with electronic ballasts. HLO lights generally put out 33% more light with only an 8% increase in energy usage. They are more expensive, approximately 20%, and are generally used only when either extra lumens are needed or the fluorescent lamps need to be mounted between 9 and 12 ft above the lighted area.

High Intensity Discharge (HID) Lights

Metal halide, high pressure sodium, and mercury vapor lights are part of a group of long lasting high intensity discharge lights. They are used to light large areas for extended periods of time.

HID lamps require time to start and warm up before becoming fully lit. Start time varies from lamp to lamp, but the average warm-up time is 2 to 6 minutes. HID lamps also have a “restrike” time, which means the lamp cannot restart for several minutes (5 to 15 minutes) after a momentary power interruption that extinguishes the lamp. HID lamps are used where lamps are left on for extended periods of time (not switched on and off intermittently).

Metal halide lights put out a fairly white light with a CCT value up to 5,000 K and CRI values up to 80%. Their use in dairy facilities is growing.

High-pressure sodium lights put out a gold or yellowish light with a CCT value up 2,700 K and CRI values up to 60%. The lower CCT and CRI values can lead to some color distortion. High-pressure sodium lights are widely used in dairy facilities.

Mercury vapor lights give off a bluish light and have been used commonly as yard lights. They are not recommended for use in dairy facilities because the mercury in burned-out lights is an environmental hazard, they are less energy efficient, their output decreases with time, and their CRI values are lower than other options.

Mounting Height and Separation Distances

Mounting height and the separation distance between evenly distributed lamps lighting a large area impact average illumination levels and uniformity. Illumination levels decrease rapidly with increasing distance from the light source. Excessively high mounting heights waste light by dispersing it over too large an area. Excessive separation distances decrease illumination uniformity. Table 10-6 lists some typical mounting heights for select lights that produce an average illumination level of 20 fc. A rule-of-thumb is to have separation distances between 1.2 and 1.7 times the mounting height.

Locate and mount lights to minimize shadows. In freestall barns with trusses, mount lights at or below the bottom chord so that the truss members do not block the light from reaching the feed bunk and freestall areas. In milking parlors and stall barns,

Table 10-6. Typical mounting heights and horizontal separation distances for select lights to produce an illumination level of 20 fc.

Lamp Type	Mounting heights (ft)	Separation distance (ft)
Standard fluorescent (32 W, T-8)	7 to 8	10 to 16
HLO fluorescent (32 W, T-8)	9 to 12	12 to 20
Metal halide and High pressure sodium		
175 W	11 to 14	24 to 28
250 W[a]	14 to 24	24 to 30
400 W[a]	20 to 35	25 to 40

[a] Typical for 96- to 112-foot wide freestall barns with 12 foot sidewalls and a 4:12 roof slope.

mount fluorescent lights below structural members and other equipment to minimize shadows.

Metal halide and high-pressure sodium lamps can be either mounted directly (i.e., hard-wired) to a structural member or suspended on a sturdy chain using a hook, cord, and plug (HCP). HCP mounting is customary in freestall barns and allows height adjustment to improve light distribution and uniformity. An eyebolt is preferable to a simple hook when attaching the chain to the building to prevent the chain from unhooking and the lamp falling. A safety clip on the lamp is also recommended.

Consider installing extra light fixtures, such as protected compact fluorescent lights, at waterers and leaving these lights on 24 hours per day to encourage drinking during both light and dark periods. Also consider installing a standby lamp with battery backup in freestall barns to provide emergency light for employees during a power failure.

Other factors generally not considered in lighting system design include building surface reflectivity, light loss through open sidewalls (nighttime), light loss due to dust and dirt accumulation, and decreased light output with increasing lamp age. Prompt light replacement and periodic cleaning will minimize light loss over time.

Lighting Controls

Lights in naturally ventilated freestall barns can be controlled automatically with a timer and a photocell in series or a timer alone to provide the 16 hours of continuous light recommended for the milking herd. The timer and photocell in series is the most energy efficient. The timer turns the lights on and off at set times, while the photocell overrides the timer (turns the lights off) when there is sufficient natural sunlight.

Naturally ventilated freestall barns often have ample natural light during midday. Light levels during early morning and evening hours will typically fall below the 10 footcandle minimum. Set the timer so that the lamps come on during early morning, late evening, and nighttime hours. The photocell needs to be shielded from both interior and exterior lighting to work properly. Position the photocell so that sunlight does not strike it directly at daybreak. If the freestall barn is oriented so that the sidewalls run from east to west, then position the photocell below the overhang on the northwest corner. Two-phase timers allow for a manual override. A timer alone can be used to turn the lights on and off to provide 16 hours of light. In this case the lights are on even if there is plenty of sunshine.

Lighting Design

Select lamps that have appropriate mounting heights for the area being lit, Table 10-6. Use Table 10-7 to determine the number of lamps need to light an area needing either 10 to 20 fc (i.e., feeding area, resting area, holding area, equipment room, and storage room). Use uniform separation distances to increase light uniformity. Energy efficient high wattage lights can provide the same average light level with fewer fixtures than lower wattage lights. Frequently this reduces equipment and installation costs, but increases separation distance, which can decrease light uniformity and increase shadowing.

Provide at least two lighting circuits in each building. Install light switches near building and room entrances. Provide at least one light fixture for each maternity or calf pen. Locate switches outside the pen.

In the milking parlor provide 50 fc of light in the operator pit and 20 fc of general lighting in the milking parlor. The operator pit lighting can be provided with a continuous row of fluorescent light (32W - 4 lamps) along the length of the operator pit mounted 8 feet over the pit floor. Select bulbs with a color rendition index of 80 or above. Avoid mounting other equipment below the lights to reduce shadowing and interference with the lighting. The 20 fc of general lighting can be designed using lamp information and data in Table 10-7. Use watertight lights.

In the milk room provide one fluorescent lights (32W -4 lamps) over the outer edge of each wash vat and an additional light (32W - 4 lamps) per 174 square feet of floor area. Install lights near the bulk tank to light the tank interior but away from bulk tank openings to minimize chances of broken glass falling into the tank. All lights must be watertight with gasketed, shatterproof diffusers. Consult a milk inspector for special lighting regulations of bulk tanks.

Safety And Electrical Codes

Lights installed in dairy barns should meet National Electric Code (NEC) requirements (NFPA 70, 1996) for use in agricultural buildings. Be sure to follow all applicable state electrical codes too. Use UL approved fixtures not UL listed fixtures. Dairy barns are damp and dusty so lights installed should be watertight and constructed of corrosion resistant materials (Article 547). Wiring in dairy facilities should also meet NEC requirements for agricultural buildings (Article 547). To minimize the potential for fire and stray voltage, a knowledgeable and qualified electrician should do all wiring.

Table 10-7. Indoor lighting design values.

Lamp Type	Lamp Size	Floor Area (sq ft) per Fixture to provide 10 fc	Floor Area (sq ft) per Fixture to provide 20 fc
Incandescent [a]	100 W	52	26
Fluorescent [a]	32 W – 1 lamp, 4' long	87	44
	32 W – 2 lamps, 4' long	174	87
	32 W – 4 lamps, 8' long	348	174
High Pressure Sodium	150 W [b]	656	328
(Reflector + Refractor)	250 W [b]	1,128	564
	400 W [c]	2,050	1,025
High Pressure Sodium	150 W [b]	512	256
(Refractor only)	250 W [b]	880	440
	400 W [c]	1,600	800
Metal Halide	150 W [b]	250	125
(Reflector + Refractor)	250 W [b]	828	414
	400 W [c]	1,350	675
Metal Halide	150 W [b]	201	101
(Refractor only)	250 W [b]	667	333
	400 W [c]	1,088	544

[a] Mounting height is 8 feet above the feed manger surface.
[b] Use with mounting heights of 10 to 15 feet.
[c] Only use 400 W lamps if mounting height is over 15 feet.

Electric Motors

Use totally enclosed farm duty rated motors in environmentally controlled buildings, in feed processing rooms, and on equipment subject to dust and moisture accumulation. Use totally enclosed, air-over motors for ventilating fans—the air stream cools the motor.

Provide overload protection for motors in addition to the circuit breakers or fuses. Also, install a fused switch with a time delay fuse at each fan sized at 125% of the motor's full load current. Locate the fused switch adjacent to or within 10 feet of the controlled motor or fan. Wire each ventilating fan on a separate circuit; if one circuit fails, fans on another circuit will come on. Have a certified electrician do all wiring. See the *National Electrical Code Handbook* and *Farm Buildings Wiring Handbook*, MWPS-28, for specific wiring requirements.

Standby Power

Standby generators reduce the risk of losses due to power outages. A standby power system requires three elements:

- A transfer switch to isolate the farm system from power lines.
- A generator or alternator to produce alternating current.
- A stationary engine or tractor PTO to run the generator.

Select either a full- or a partial-load system. A full-load system must handle the maximum running load and peak starting load of the farmstead or dairy installation. A partial-load system carries enough load to handle only vital needs and is usually controlled manually. The maximum running load and peak-starting load may include the electrical loads for milking, milk cooling, and mechanical feeding equipment. After milking is complete, these loads are turned off, and other loads are turned on. Select a generator that will have the capacity to operate continuously for an extended period (about one week).

Tractor-driven generators are common and are generally the most economical. During heavy snowfall, getting the tractor to the generator can be a problem. If short duration outages are critical, consider an engine-driven unit with automatic switching. If an engine-driven unit is located inside a building, ensure the space is properly ventilated to remove engine exhaust and excess heat. Consider soundproofing the room containing the engine-driven unit to minimize noise effects on the remainder of the building. Operate engine-driven units at least once a week and tractor-driven units every month to ensure they will function when needed. Frequent running also keeps the battery charged on engine-driven units and ensures starting when needed. During these regular operation cycles, operate the generator or alternator long enough and with sufficient load to cause it to warm to normal operating temperature.

Install a double throw transfer switch at the main service entrance just after the meter so the generator is always isolated from incoming power lines. This switch keeps generated power from feeding back over the supply lines, eliminates generator damage when power is restored, and protects power line repair crews. Contact the power supplier for assistance in sizing and installing a transfer switch.

Sizing a standby power unit is difficult. For a partial-load system, sum the starting wattage of the largest essential motor, running wattage of all other essential motors, name plate wattage of essential equipment, and wattage of essential lights. When sizing standby electric generators, consider the power requirements of future expansion and equipment needs.

For more information about standby generators, contact the local power supplier. Some power suppliers will offer a reduced electric rate if the farmstead can be an interruptible customer. The savings can pay for a larger capacity generator.

Electric Fences

Electric fencing is a low cost and effective way to accomplish the following tasks:

- Managing pasture and rotation grazing.
- Salvaging grain and roughage left in a field.
- Protecting calves and heifers from predators.
- Constructing temporary lanes.
- Extending life of old line fences.
- Protecting hay and silage stacks or other feed supplies.
- Adding safety to bull pen or pasture fences.
- Stopping animals from crowding fences.
- Lowering costs of lot fences.

Solar chargers, batteries, or 115-V electrical service powers fence chargers. Use 115-V chargers if power is available. Combination units also are available but are more expensive. Check with the fence charger manufacturer, and select a unit with output characteristics matched to the length of fence to be energized.

Fence chargers emit current intermittently, not continuously. The on time is 1/10th of a second or less, 45 to 55 times a minute. The shock is sharp, but short and relatively harmless.

Select a charger listed by UL or the U. S. Bureau of Standards. Notice of approval will be printed on the controller near the name plate. Homemade chargers can and often do kill people and animals.

Another type of electric fence charger provides high voltage (1,000 to 2,000 V) and high amperage (30 to 40 A). The line is pulsed 55 times a minute for only about 1/3,000,000 of a second. The units charge many miles of clean, well constructed electric fence.

Lightning Protection

Install lightning arrestors at electrical service entrances to control voltage surges on electrical wiring. Provide a lightning arrestor at each service panel. Always mount arrestors on the outside of panels. Because arrestors can explode and discharge a shower of sparks due to a nearby intense lightning strike, mount lightning arrestors outside if possible. If an arrestor is mounted on an inside panel, keep the surrounding area free of combustible materials to reduce the risk of fire.

In addition to lightning arrestors on service panels, install surge or spike arrestors to provide additional protection for electronic equipment such as milking equipment controls, equipment with microprocessor controls, some feed weighing equipment, computers, and computerized feeders.

Lightning protection for buildings is usually a system of lightning rods with metal conductors attached to several grounds. Install lightning rods 20 feet on center and within 2 feet of the ends of a gable roof. Fasten the metal conductors to the roof and walls at 3- to 4-foot intervals. Drive the ground rod at least 8 feet into earth which remains moist. Use aluminum lightning rod cable on buildings clad with aluminum roofing or siding. Use copper cables within 18 inches of the soil and wherever the cable will be against painted or galvanized steel. Special fittings are available and should be used to interconnect aluminum and copper cables and control corrosion. Locate the ground rod at least 2 feet away from the building. A location at or beyond the eave or drip line is desirable. Install both the ground rod and cable at least 8 inches beneath the soil surface to minimize the risk of damage. Connect lightning rod ground rods to the electrical system ground rods. Always interconnect the two systems.

Metal clad buildings with a continuous connection between roofing and siding can be partially protected by grounding the siding unless there is flammable insulation directly beneath the roofing. However, most insurance companies require lightning rods on metal clad buildings as well. Install at least two grounding cables (on opposite corners) on metal clad buildings up to 250 feet long; add another cable for each additional 100 feet of length or fraction thereof.

Make sure the lightning protection installer has qualified for the Master Label designation from Underwriter's Laboratories. Use only UL listed equipment when installing a lightning protection system.

Heating Devices

The milking parlor is the main area of concern when considering heating. Use radiant, floor, unit space, or a central heating system to heat the parlor. When operating heaters that use a petroleum based product as the fuel to produce heat, the operator needs to have a working knowledge of how the system works in addition to heater venting and safety requirements. The products of combustion must be ventilated to the outside. Where a chimney is not used, increase the ventilation rate. If a chimney is used with a building negative pressure ventilation system, consider a powered chimney fan to prevent combustion gases from being drawn into the building by the exhaust fan.

Heating Source

Propane (LP gas), natural gas, and fuel oil are commonly used to heat buildings and water. Propane is more commonly used in dairy operations because many sites are remote and have no access to natural gas. Careful planning is the key ingredient to designing a propane, natural gas, or fuel oil system that operates efficiently and safely.

Propane

Propane (LP gas) is less expensive than electricity but generally more expensive than natural gas. It has the advantage of being available anywhere a fuel storage tank may be located.

To maintain propane as a liquid, it is stored in special containers designed to withstand high pressure, but most gas appliances require gas delivered at low pressure. A UL listed, first-stage regulator, or pressure reducing valve, located at the supply tank and a second regulator located at the appliance are used to reduce the pressure to a level that accommodates gas appliances. In some instances, a third regulator or pressure reducing valve is installed where the gas line enters a building. To be used safely, regulator vents must be pointed downward or be protected from the elements. They must not be painted or otherwise blocked.

Because propane is heavier than air, leaking propane can settle in low areas of buildings and can pose a risk of explosion and fire. To reduce the risk of propane seeping into a building and the risk of a deadly explosion in the event of a fire, propane tanks must be properly located. Table 10-8 shows spacing requirements for propane tanks. The pressure relief valve discharge must be at least 10 feet from any potential source of ignition, e.g., bulk tank compressors, and any ventilation air inlet.

Tanks should be positioned parallel to buildings since tank ends detach during an explosion. Use proper materials when installing propane systems. Use piping of wrought iron or steel (black or galvanized), brass, or copper. Seamless copper, brass, or steel tubing can be used. Make sure all piping or tubing complies with NFPA 58, *Storage and Handling Liquefied Petroleum Gases* and NFPA 54, *The National Fuel Gas Code*. All piping must be suitable for a working pressure of 125 psi. Flexible hose may be used on the low pressure side of the second regulator. This is common practice where heaters are hanging from the ceiling and may have a tendency to swing when bumped. This hose must be AGA (American Gas Association) approved and should be preceded by a shut-off valve. Only appropriately trained persons are allowed to install and service propane systems and associated equipment.

Natural Gas

Natural gas is an economical fuel in those areas where it is available. Gas is delivered to the point of

Table 10-8. Spacing requirements for propane tanks.
National Fire Protection Association (NFPA) minimum spacing requirements.
Separation distances listed also apply to tanks and large pieces of equipment using propane.

Rated Tank Capacity, gallons	Minimum distance between tank and building (ft) Above Ground	Underground	Separation distance between Tanks (ft) Above Ground
Less than 125 gal	0	10	0
126-250	10	10	0
251-500	10	10	3
501-2,000	25	10	3
Over 2,000 gal	50	50	5

use via a pressurized pipeline system. Installing a pressure reducing valve or regulator near the gas meter reduces pressure.

Natural gas is lighter than air and is odorless, however, a fragrance is added to the gas to aid in leak detection. Care is necessary to protect a natural gas system to minimize the risk of damage to gas lines due to vehicle traffic or the digging of trenches or holes. Use proper materials when installing piping and associated equipment. Persons having appropriate training and experience should do installation and service. Systems must comply with the most current edition of NFPA 54, *The National Fuel Gas Code.*

Fuel Oil

Where fuel oil is used as an energy source for heating water or space heating, the ventilation openings requirements are the same as for propane or natural gas fire equipment. All heating devices should be vented to the outside via a chimney or have a vent constructed in accordance with the applicable codes. Pre-fabricated vents should be UL listed for use with the equipment served. Never use any fuel in a heating system other than the one for which the equipment is designed.

Use only approved tanks for storage of fuel oil. If installed indoors, the total tank capacity may not exceed 660 gallons. If two tanks are installed (e.g., two, 275- gallon tanks), they must be interconnected at the outlet and via a 2-inch cross connection cross line above the tanks. The tanks must be at least 5 feet from the flame of any heating device and must be installed so as to not obstruct access to safety or shutoff switches, valves, etc. Install the tank on rigid, non-combustible supports. Slope the tanks towards the outlet end at least 1/4 inch per foot. A shutoff valve is required immediately adjacent to the burner supply pipe connection at the bottom of the tank. A vent with at least a 2-inch diameter must extend from the tank to the outside of the building. The fill pipe must extend to the outside of the building.

Venting Heaters

Installation of an unvented heater must be accompanied by a continual source of combustion air. Unvented heaters include *salamander* kerosene heaters, hanging unit heaters, gas-fired radiant or catalytic heaters, etc.

Minimum requirements are:

- Mechanical ventilation system providing a CONTINUOUS airflow of at least 4 cfm per 1,000 BTU/hr of heater capacity. (**NOTE**: Timer controlled fans do not satisfy this requirement.)
- Two permanent outlets opening directly to the outside. One must be within 12 inches of the ceiling and one must be within 12 inches of the floor. Minimum size for each opening is 1 square inch per 2,000 BTU/hr of heater capacity. The minimum opening size is 3 x 3 inches. (**NOTE**: Periodic opening of parlor entrance/ exit doors does not meet these requirements.)
- Use fan forced chimney venting in rooms using negative pressure ventilation to avoid drawing fumes from the heater or from down the chimney into the room.

Minimum ventilation openings are required to help ensure complete combustion and minimize the risk of carbon monoxide poisoning.

Heater Safety

Gas heaters for either air or water used in dairy facilities give off carbon monoxide fumes during combustion. Gas water heaters should be properly vented. Monitor the effectiveness of venting closely. Use forced venting in space where negative pressure is used for ventilation because the negative pressure of the ventilation system may bring flue gases back into the building.

All heaters should have control devices that stop fuel flow or shut down heater operation if necessary.

- If fuel does not ignite within approximately one minute of electrical ignitor operation, the fuel and fan should shut off.
- If the gas supply is depleted, a manual reset flame sensor should shut down the heater.
- If no air is moving through the unit before ignition, a sensor that detects air movement should deactivate the ignition circuit.
- If airflow through the unit stops during operation, the main fuel valve is closed.
- If the temperature at the air discharge or at the burner becomes too high, the main fuel valve is closed.
- If the blower motor becomes overloaded, electrical overload protection should activate to prevent overheating and motor damage.
- If there is loss of electrical power, there should be a full shut down of the burner.

To ensure continued safe and efficient operation, install items properly and then maintain them well. Use a totally enclosed motor on the heater fan. Place flame arrestors on the gas lines that lead to heating units or generator engines. Mount regulators 18 inches or higher above ground with the vent facing down.

Establish a regular maintenance schedule. Clean the heating elements, fan blades, and output louvers to enhance complete fuel combustion and heating efficiency. Totally disconnect electric power before cleaning, and be sure no moisture remains in the electrical boxes before restoring power. Inspect electrical wiring and fuel line connections annually. Check LP gas regulators, usually mounted on the exterior of buildings. Make sure debris, or snow and ice are not covering the device or plugging the vent opening.

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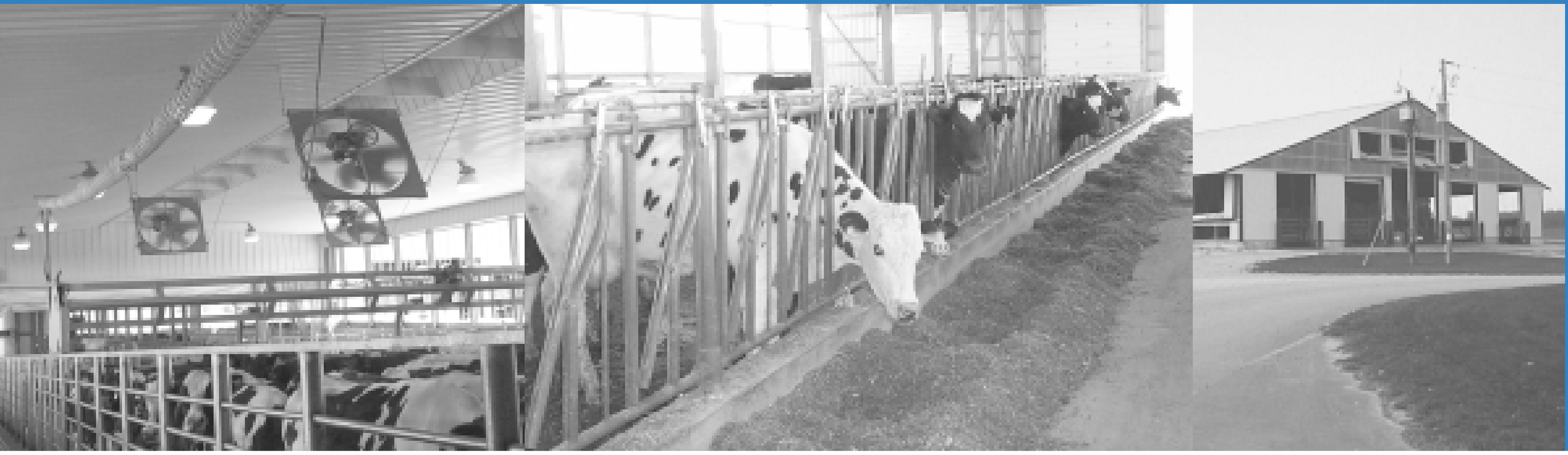

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