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DAIRY FACILITY DESIGN

J. P. Murphy¹

Introduction

When planning new construction or major modification of a dairy system, consider:

- calf, heifer, dry cow, and milking cow housing;
- feed types, handling equipment, and storage;
- manure handling method;
- milking system and equipment;
- labor requirements;
- building environment;
- sanitary and pollution control regulations;
- future expansion.

Many dairy farmers produce their own feeds and raise their own herd replacements. The needs of each groups require different housing, feeding, storage, and handling systems.

Herd Makeup

Herd size can mean either the number of cows actually milking or the number of both dry and milking cows. In this paper, herd size is the total of dry and milking cows. Add calves and heifers to the herd makeup, if you raise replacements. Table 1 gives typical herd makeups, assuming uniform calving year-round.

Feeds and Cropland

Determine the best ration for each group of animals based on available feeds, feed quality, animal size, and milk production levels. Estimate cropland and storage needs based on your ration and total number of animals. Without a specific ration, use Table 2 to determine approximate storage needs.

Cropland needed is affected by milk production, ration, forage choice, crop yields, etc. See Table 3 for estimated cropland needs. If all feeds except supplements are raised on the farm, a good estimate is 3 to 4 acres per cow and replacement.

¹Department of Agriculture Engineering (Extension).

Table 1. Typical Herd Makeup

Item	Number				Avg. weight, lb
Cows milking	33	62	83	208	1,400
Dry cows	7	13	17	42	1,550
Herd size = total mature cows	40	75	100	250	1,450
Heifers					
16-24 mo	15	28	38	95	1,050
13-15 mo	5	9	12	30	800
9-12 mo	7	13	17	43	600
5-8 mo	7	13	17	42	400
3-4 mo	3	6	8	20	250
Calves 0-2 mo	3	6	8	20	150
Total replacements	40	75	100	250	

^aReplacement numbers assume uniform calving year-round, 12-month calving interval, no death loss or culling, 50% male and 50% female calves, and all males sold at birth.

Housing

Provide housing for different animal groups based on Table 1. More than one group can be housed in the same building, but allow for managing each group separately. Also allow for different requirements for sanitation, environment, etc. In larger dairies, separate facilities may be provided for each group.

Farmstead Planning

Many factors determine the best plan, and although some are common sense, overlooking one can cause a poorly planned farmstead. Collect ideas from publications, farm visits, county agents, experienced producers, scientists, and engineers. Plan on paper, where mistakes can be easily corrected. It is less costly to correct a mistake during the planning stage than after construction begins. Stake out the best arrangements on the site to see how they fit.

Table 2. Annual Feed Requirements^a

Level of silage	% Dry matter	Lb milk/cow-year			
		12,000	14,000	16,000	18,000
----- quantities/cow and replacement -----					
<u>Medium</u>					
Hay silage, T	40-50	11.0	11.6	12.3	12.9
or hay, T	80-85	4.3	4.5	4.7	4.9
Corn silage, T	30-35	12.0	12.0	12.0	12.0
Shelled corn, bu	84.5	52	64	86	106
<u>High</u>					
Hay silage, T	40-50	6.7	6.9	7.1	7.5
or hay, T	80-85	2.6	2.7	2.8	2.9
Corn silage, T	30-35	16.5	16.5	16.5	16.5
Shelled corn, bu	84.5	52	64	86	106

^aTable values are for each cow and replacement. Determine total needs based on herd size. If using high moisture grain, multiply shelled corn figures by 1.267 to get bushels based on 30% moisture grain and a density of 60 lb/bu (1.25 ft³/bu).

Source: *Chore Reduction for Free Stall Dairy Systems, Hoard's Dairyman*, Fort Atkinson, WI.

Table 3. Estimated Cropland^a

Level of silage	% Dry matter	Lb milk/cow-year			
		12,000	14,000	16,000	18,000
----- acres/cow and replacement -----					
<u>Medium</u>					
Hay silage, 6 T/A	40-50	1.8	1.9	2.1	2.2
or hay, 3 T/A	80-85	1.4	1.5	1.6	1.6
Corn silage, 15 T/A	30-35	.8	.8	.8	.8
Shelled corn, 80 bu/A	84.5	0.9	1.1	1.3	1.5
<u>High</u>					
Hay silage	40-50	1.1	1.2	1.2	1.3
or hay	80-85	.9	.9	.9	1.0
Corn silage	30-35	1.1	1.1	1.1	1.1
Shelled corn	84.5	.7	.8	1.1	1.3

^aAcreage to produce annual feed required per cow and replacement. If using high moisture grain, adjust shelled corn figures. Values based on Table 2 and yields shown.

Consider the entire farmstead when planning a new or modified housing system. Solving one problem may create another. With proper planning and attention to details, a well organized, functional farmstead can result.

Site Selection

Many factors determine the best site for dairy facilities. Provide for these items during construction.

Space for buildings, clearance between buildings (at least 35 ft for most buildings and 50 ft for naturally ventilated buildings), lots, and expansion. Assume the operation will double in size, and plan accordingly. Provide lanes for vehicle access and room for parking. Allow for a feed center and adequate separation from family housing. A typical 100-cow dairy farmstead requires 2 to 6 acres for barns, lots, home, machinery, and feed storage.

Drainage away from barns and lots. Ditch and fill low areas. Divert runoff away from buildings and traffic areas. Provide a 2% to 5% slope on outside lots. Use mounds to provide dry resting areas. Earth moving is inexpensive compared to facility costs.

Wind and snow control. Windbreaks help deflect winter winds and control snow. Take advantage of trees, buildings, hills, and haystacks for winter wind protection. Allow for summer air movement and drainage when locating windbreaks. Consider prevailing wind directions for reducing odors, snow drifting, insects, and noise.

Water. A year-round supply of potable water is essential for watering animals and sanitation. Water also is needed for fire protection and waste dilution.

Milking cows need 35 to 40 gal/head-day ($4\frac{1}{2}$ to 5 lb water/lb milk produced). Peak water consumption is shortly after feeding. Provide a system that meets peak and total daily requirements. Where ground water supplies are not adequate, use surface sources such as farm ponds or community water systems. Approval of your water system may be required. For more information, see MWPS-14, *Private Water Systems Handbook*.

Access. Provide all-weather roads for milk trucks, repair persons, technicians, veterinarians, feed handling equipment, etc. Provide adequate parking for visitors. Minimum road width is 12 ft. Minimum turning radius for large milk trucks is about 55 ft. A hay wagon can turn 180^0 in about 50 ft.

Manure storage, handling, and disposal. Select a site with sufficient land for spreading manure. Minimum acreage required by many state pollution agencies is based on satisfying the nitrogen requirement of the growing crop.

Avoid steep slopes where manure runoff can cause water pollution, and avoid land adjacent to neighboring residences.

Feed storage and handling is a consideration, but not an overriding concern, in choosing a site. Transport wagons can link a grain-feed center to dairy facilities.

Electric power is needed for heating, lighting, pumps, and motors. A 200 amp, 220 volt barn entrance is common. Thorough grounding reduces stray current problems. Provide standby emergency power in the event of a power outage. Some producers install three phase power; consult your power supplier.

Security. Consider theft, vandalism, and fire safety. Limit farm visitor access to control disease and to reduce interference with farm work. If 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. Provide only one access road—unauthorized persons are less apt to visit if there is no escape route should the manager return. If possible, make access roads at remote sites visible from a public road or neighboring residence.

Remodeling

When planning to expand, you may have to decide whether to remodel or abandon an existing building. Carefully consider future as well as present needs. Evaluate these general factors:

- compatibility with final setup;
- structural integrity;
- location of existing building;
- cost of remodeling vs new building.

Remodeling is not always the cheaper route, especially when future needs are considered. If remodeling cost is more than 1/2 to 2/3 new building cost, a new building is usually best. Sometimes, it is possible to use some materials from an existing building in a new one.

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.

The following tables (Data Summary; Tables 4 to 16) give basic planning information for designing dairy facilities.

Data Summary

Table 4. Cow Stall Platform Sizes^a

Cow weight	Stanchion stalls		Tie stalls	
	Width	Length	Width	Length
Under 1,200 lb	4'0"	5'6"	4'0"	5'9"
1,200-1,600 lb	4'6"	5'9"	4'6"	6'0"
Over 1,600 lb	Not recommended		5'0"	6'6"

^aUse electric cow trainers. Dimensions from edge of curb to edge of gutter.

Table 5. Recommended Stall Barn Dimensions

<u>Alley width</u>	
Flat manger-feed alley	5'8"-6'6"
Step manger-feed alley	6'0"-6'6"
Step manger	24"
Feed alley	4'0"-4'6"
Service alley with barn cleaner	6'0"
Cross alley ^a	4'6"
<u>Manger width</u>	
Cows under 1,200 lb	20"
Cows 1,200 lb or more	24"-27"
<u>Gutters</u>	
Width ^b	16" or 18"
Depth, stall side	11"-16"
Depth, alley side	11"-14"

^aTaper the end stalls inward 6" at the front for added turning room for a feed cart.

^bOr as required for barn cleaner.

Table 6. Free Stall Dimensions^a

Age	Width	Length
<u>Heifers</u>		
5-8 mo	2'6"	5'0"
9-12 mo	3'0"	5'6"
13-15 mo	3'6"	6'6"
16-24 mo	3'6"	7'0"
<u>Cows (average herd weight)</u>		
1,000 lb	3'6"	6'10"
1,200 lb	3'9"	7'0"
1,400 lb	4'0"	7'0"
1,600 lb	4'0"	7'6"

^aStall width measured center-to-center of 2" pipe dividers. For wider divider dimensions, increase stall width accordingly. Stall lengths are measured from front of stall to alley side of curb.

Table 7. Typical Free Stall Alley Widths

Feeding and stall access alley	10'-12'
Access alley between 2 stall rows	
Solid floor	8'-10'
Slotted floor	6'-9'
Feeding alley	9'-10'

Table 8a. Replacement Animal Space Requirements: Calf Housing

Housing type	Pen size
<u>0-2 mo (individual pens)</u>	
Calf hutch (plus 4'x6' outdoor run)	4'x8'
Bedded pen	4'x7'
Tie stall	2'x4'
<u>3-5 mo (groups up to 6 head)</u>	
Super calf hutch	25-30 ft ² /hd
Bedded pen	25-30 ft ² /hd

Table 8b. Heifer Housing

Housing type	Age, months			
	5-8	9-12	13-15	16-24
	----- ft ² /animal -----			
Resting area and paved outside lot	25	28	32	40
	35	40	45	50
<u>Total confinement</u>				
Bedded resting area ^a	25	28	32	40
Slotted floor	12	13	17	25

^aAssume access to 10' wide scraped feed alley.

Table 9. Feeding Space Requirements

	Age, months					Mature Cow
	3-4	5-8	9-12	13-15	16-24	
	----- in/animal -----					
Self feeder						
Hay or silage	4	4	5	6	6	6
Mixed ration or grain	12	12	15	18	18	18
Once-a-day feeding						
Hay, silage, or ration	12	18	22	26	26	26-30

Table 10. Floor and Lot Slopes

Handling facilities	1/4"-1/2"/ft
<u>Lots</u>	
Paved	1/8"/ft minimum
Earth	1/2"-3/4"/ft
Mound sideslope	1/5'
Bunk apron	3/4"-1"/ft nearly self-cleaning
	1/2"/ft minimum

Table 11. Water Requirements

	Gal/hd/day
Calves (1-1.5 gal/100 lb)	6-10
Heifers	10-15
Dry cows	20-30
Milking cows	35-45

Table 12. Dairy Manure Production^a

Animal size, lb	Total manure production			Nutrient content		
	lb/day	ft ³ /day	gal/day	N	P	K
				lb/day		
150	12	.19	1.5	.06	.010	.04
250	20	.33	2.4	.10	.020	.07
500	41	.66	5.0	.20	.036	.14
1,000	82	1.32	9.9	.41	.073	.27
1,400	115	1.85	13.9	.57	.102	.38

^aProvide 2.5 ft³/d of storage per 1,000 lb live weight for solid manure with bedding. Table values based on manure at 87.3% water and 62 lb/ft³.

Table 13. Bunk Design

Throat height (max.)	
Calves	18"
Heifers	20"
Mature cows	24"
Bunk width (max. 60")	
Both sides feeding	
Calves	36"
Heifers	48"-60"
Mature cows	48"-60"
One side feeding	18" bottom width
Mechanical feeder	Add 6"-12" up to max width
Step along bunk	
Height	4"-6"
Width	12"-16"
Bunk apron	
Slope	3/4"-1"/ft
Width	10'-12'
Neck rails	
3/8" cable, 2" pipe, 2×6 plank	16"-24" opening

Table 14. Dairy Barn Ventilating Rates^a

	Ventilating rates		
	Cold weather ^b	Mild weather	Hot weather
	----- cfm/animal -----		
Calves 0-2 mo	15	+35=50	+50=100
Heifers			
2-12 mo	20	+40=60	+70=130
12-24 mo	30	+50=80	+100=180
Cow, 1,400 lb	50	+120=170	+300=470
Milkroom			600 cfm
Milking parlor		100 cfm/stall	400 cfm/stall

^aSize the system based on total building capacity. Table values are additive—e.g., for calves, mild weather requires 15 + 35 = 50 cfm/calf.

^bAn alternative cold weather rate is 1/15 the room or building volume; ft³/15. An alternative hot weather rate is the building volume divided by 1.5.

Table 15. Conversions^a

Unit	Times	Equals
Acres	43,560	ft ²
	4,840	yd ²
	160	square rods
Acre-ft	1/640	square mile
	325,851	gallons
	43,560	ft ³
Acre-in	3,630	ft ³
Acre-in/hr	453	gpm
Bushels	1	cfs (approximate)
	1.25	ft ³
	2.5	ft ³ ear corn
ft ³	7.48	gallons
	1728	in ³
	62.4	lb water
cfs	.4	bu ear corn
	.8	bu grain
	448.8	gpm
Cubic yard	646,317	gal/day
	27	ft ³
	81	ft ² of 4" floor
Gallons	54	ft ² of 6" floor
	231	in ³
	.134	ft ³
Miles	8.35	lb water
	5,280	ft
	1,760	yd
Pressure, psi	320	rods
	2.31	ft of water head
	16.5	ft
Rods	5.5	yd

^aMultiply to the right: acres × 43,560 = ft².

Divide to the left: ft² ÷ 43,560 = acres.