Dairy Design for a Semi-Arid Climate

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Introduction

A semi-arid climate has certain definite advantages for dairy husbandry. In the southwestern United States the climate is very favorable for about eight months of the year. Temperature for portions of the remaining four months are above the thermal comfort zone for high-producing dairy animals. However, with good management practices, production can be kept at acceptable levels. Indeed, production records indicate that this region is consistently among the leading areas in the United States for production per cow per year.

Except in the mountain areas, the annual temperatures range from 20° to 115°F. The rainfall varies from 3–14 inches per year, enough to support various forms of rangeland vegetation adequate to keep soil in place and to cause severe mud problems if site drainage design is neglected.

Good design takes time and skill, and must follow an orderly development process. A professional designer works in concert with the owner and the builder throughout the planning and construction of a complete facility. A typical sequence is as follows:

1. **Preliminary Design Services**
   a. Development of a prospectus
   b. Consultation with various dairy design experts
   c. Site analysis
   d. Preliminary layout drawings
   e. Preliminary cost estimates
   f. Checking on code and regulatory agency require ments
2. **Working Drawings and Specifications**
   a. Detailed drawings of all building and subsystems, including typical sections, earth work, structural, plumbing, heating, electrical and mechanical systems
   b. Conferences with equipment manufacturer and supplier
   c. Semi-detailed cost estimates
3. **Construction Document Phase**
   a. Preparation of forms of proposal and contract documents
   b. Securing the bids and analysis of proposals
4. **Construction Phase**
   a. Periodic checking on construction progress
   b. Surveying and establishing critical construction control points
   c. Checking test samples and shop drawings and submitting alterations
   d. Issuing change orders
   e. Checking contractors' request for payment

Developing the Prospectus

The prospectus is a clear, concise statement of the management constraints or intentions of the owner and the long-range goals for the enterprise. It is prepared by the dairy management and/or consultant to help communicate project needs to consultants, advisers and financing agencies. It is designed to keep everyone on track during the complicated planning and building process. Depending upon the circumstances, it may be as brief as a simple, concise one-sentence statement, or a long complex document. It should set forth all conditions of the project that are important in management contacts with consultants, advisors, builders, suppliers and regulatory and financial agencies.

Site Analysis

1. **Water Supply.** An adequate quantity of quality water and a backup water source must be available. Supplies less than 130 gallons per cow per day and greater than 1500 ppm total salts are considered unacceptable.

2. **Climatic Data.** Normally a designer needs to know wind loads, rainfall, temperature and humidity conditions. However, there are semi-arid regions in the world where standard data are misleading. Prevailing wind direction is not always the direction of maximum wind flow, and 8 a.m. humidity averages are often worthless. The best index for evaluating high temperature stress is design dry bulb-wet bulb values such as are published by ASHRAE.[7] Lacking these data, temperature humidity traces taken directly from hygrothermograph recordings are helpful.

3. **Land Area.** Ten acres overall are required for each 100 lactating cows; 5 acres for dairy facilities and the

remainder as crop land for waste water disposal, preferably through an irrigation system. To prevent groundwater contamination, the following land area in acres per 100 milking cows for different waste disposal systems of semi-arid dairy farms have been recommended.

1. Desert dry waste – 6 acres/100 cows
2. Flush feedline – 32 acres/100 cows
3. Total flush-free stall – 50 acres/100 cows

4. **Topographic Survey.** A 100-foot grid topographic survey is to be made for the entire dairy site. Survey should include a reference benchmark, top and bottom elevation of any irrigation ditches and corners of permanent structures. The topographic map is analyzed for natural slope drainage. Aerial photos and topographic studies are also helpful in overall planning and are particularly desirable where major surface features need improvement.

5. **Soil Survey.** Identify the pertinent engineering characteristics of the underlying soil conditions. The presence of a high water table, poor soil structure, rock and/or caliche requires careful design consideration.

6. **Off-site Considerations.** The site must be within the acceptable travel pattern of the milk processing plant and other dairy services. All-weather roads, utility services, access to feed resources and marketing services, rural housing developments and urban subdivisions, flood zoning, water management district, air and water pollution districts, zoning and building code and right-of-way restrictions must be evaluated. Legal restraints may close the project and prevent investment recovery, so suitability of site and plans must be checked with appropriate authorities.

Developing Preliminary Plans

A preliminary dairy layout involves space requirements, functional flow, and orientation of all facilities and activities on the site. The major components of a dairy system are housing, milking, feeding, cow treatment and waste handling facilities. See Figure 1 for typical dairy layout.

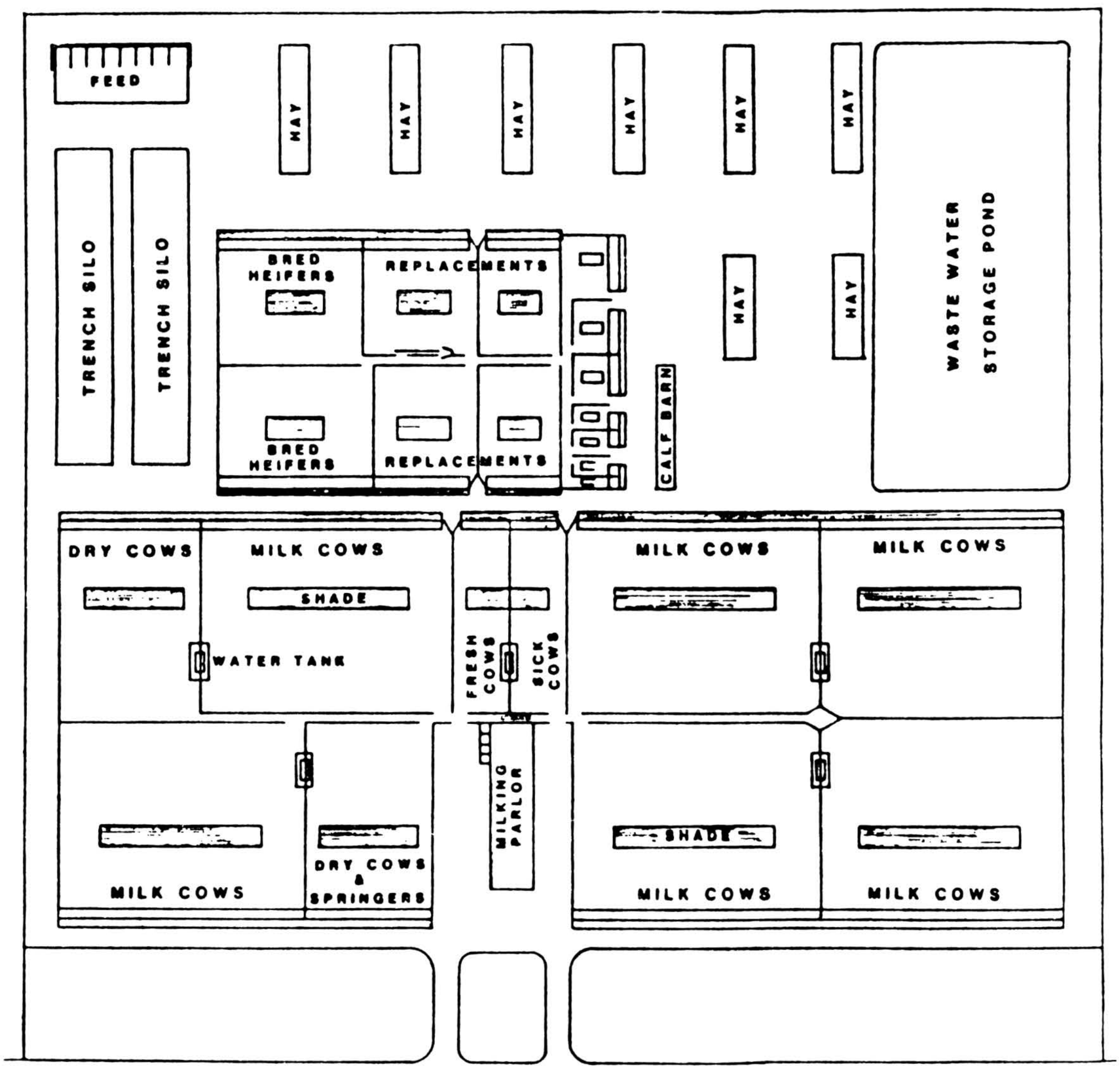

FIGURE 1. Typical layout for large herd dairy.

1. The prospectus sets livestock number and space requirements to meet long-range goals. It is important to design for the ultimate goal, not for the first building phase.

Corral space requirements have evolved from dairy practice as the best compromise for manure management, sanitation and heat stress relief. Table 1 represents a range of space recommendations for most semi-arid conditions, but improved drainage slopes and surface conditions may dramatically change these space requirements.

2. The milking parlor should have capacity to milk the entire herd once in eight hours or less including setup, cleanup and corral changes. See Tables 2, 3 and 4 and section on "Selecting the Milking Parlor."

TABLE 1. Dairy corral space estimates for semi-arid conditions.

Herd Function	Lactating Cows	Space Holes/ 10ft	Shade Ft^2/ Head	Corral Ft^2/ Head
Lactating Cows	100	4	40	500±100
Dry Cows	15	4	40	500±100
Bred Heifers (17 to 26 mo)	33	5	30	400±100
Growing Heifers (6 to 16 mo)	37	6	30	300±100
Heifer Calves (1.5 to 5 mo)	13	7	20	200±100
Calves (birth to 1.5 mo)	6 (Provide 9 individual calf pens/100 cows)			
Fresh Cow Pen	1	4	40	500±100
Sick Cow Pen	1	4	40	500±100
Total Herd Number	Lactating No. x 2.0			
Mature Cow Equivalents	Lactating No. x 1.5			

*Based on continuous A.I. breeding system, year-round 390 day average calving interval, 5% death loss, and excluding male calves.

3. Dry cows are usually separated into two corrals. Fresh cows and sick cows should be located in two small pens near the parlor area unless a separate milking facility is used.

4. Facilities for calves and replacement heifers are normally located in an area separate from the milk cow herd.

5. Feed storage space requirements for roughage are extensive and important to consider in the initial layout design. Feed constitutes about 50% of the cost of milk production. Practices involving the management of feed are varied and subject to change from year to year. Hence, it is important to consider potential variations in both short- and long-term requirements. Many dairies in the southwest purchase nearly all roughage feed at harvest

TABLE 2. Throughputs for herringbone parlors with no mechanization or partial mechanization under good management. Mechanization includes power-operated entrance and exit gates and detachers.

Parlor Type	Mechanization	Number of Operators	Slow Operator	Efficient Operator
Double 4	None	1	29	42
	Partial	1	39	52
Double 6	None	2	50	66
	Partial	1	54	70
Double 8	None	2	64	80
	Partial	1	70	88
Double 10	None	2	80	92
	Partial	1	76	95
Double 12	None	2	88	120
	Partial	2	88	120
Double 16	None	2	96	150
	Partial	2	96	150
Double 20	None	3	130	180
	Partial	2	130	180

TABLE 3. Cow throughput in cows per hour for side-opening parlors under good management. Mechanization (power-operated entrance and exit gates and detachers).

	Mechanization	Number of Operators	Slow Operator	Efficient Operator
D-2	None	1	25	35
D-2	Partial	1	40	50
D-3	None	2	50	63
D-3	Partial	2	50	63
D-4	None	2	56	70
D-4	Partial	2	65	76
D-5	None	2	62	76
D-5	Partial	2	71	82

TABLE 4. Cow throughput in cows per hour[a] for polygon parlors with no or partial[b] mechanization under good management.

Number of Stalls	Mechanization	Number of Operators	Slow Operator	Efficient Operator
16	None	2	71	93
	bPG, CG & D	1	73	95
20	None	2	78	103
	PG, CG & D	1	80	109
24	None	2	102	126
	PG, CG & D	2	114	138
32	None	3	130	165
	PG, CG & D	2	138	173
40	PG, CG & D	3	145[c]	186[c]

[a]Steady state throughputs. Parlor setup and cleanup and changing groups not included.
[b]Power gates, crowd gates and detachers.
[c]Calculated from work routine time.

time, so peak roughage storage will approach 65–75% of the annual dairy requirement. The fire insurance carrier usually dictates the maximum hay stack size and the distance between stacks. A common stack specification is a 250-ton maximum with 100 feet minimum pacing between stacks. Hay stacks should not be located within 50 feet of the north, east or west corral fenceline because the solar heat reflected from the stacks will discourage cattle from feeding during the summer.

6. When trench silos are used, it is desirable to locate them near the feed mixing center. Two silos or more are preferred to eliminate conflict between filling and feeding functions. Spoilage can be minimized by limiting the silo vertical cross-section so that two feet or more of length can be fed out per day.

Dust from silo filling or feed processing frequently is the cause of pneumonia in baby calves, so the silo and feed processing center should be kept as far away from the calf facilities as practical.

7. A truck scale and office may be part of the feed service center, but both are usually located near the main entrance to improve security and control.

8. Under semi-arid conditions, non-roughage inventory feed supplies are stored in open front bins set on a concrete slab, referred to as a "feed commodity barn."

Water System Design

Peak water use estimates per lactating cow per day on *twice a day milking* schedule are as follows:

1. Drinking – 65 gallons (this includes 25 gallons per lactating cow for the replacement herd).
2. Parlor and milk room – 20 gallons.
3. Holding area jet cow wash – 25 to 60 gallons.
4. Evaporative cooled shades – 35 gallons.

Well water pump capacity is selected to deliver peak daily requirements in 12 hours.

Since a backup water supply is imperative, an intermediate storage tank supply equal to one day's needs should be installed above ground so that water can flow throughout the system by gravity if necessary. Locating this tank near the holding pen provides an immediate reservoir of water for the high volume water flow required of the holding area udder wash system.

The water system should be designed by a competent engineer. To facilitate the engineer's calculations, a detailed schematic of the entire water distribution network drawn to scale and estimates of water flow in gpm at every point of use is necessary. Friction losses between the tank and any fixture should be limited to 10 psi and the water velocity in the pipes limited to six feet per second.

When well water is used to precool milk and/or the vacuum pump, substantial water savings can be achieved by installing a salvage water tank. Salvage water can be used for barn washing and the jet wash system.

Waste Water and Sewage Disposal

In a semi-arid climate, waste management is relatively simple because of the high evaporation rate and absence of prolonged freezing. The feedline cow platform and area under shade are scraped every few days as needed, and wet manure is dragged to dry areas of the corral. The entire corral area is drag harrowed lightly to keep manure spread and uniformly exposed to sun and air. This also serves to maintain a uniform surface for good draining of storm runoff. Corrals are cleaned completely once or twice yearly and the manure stockpiled locally or spread directly onto farmland.

Waste water and storm runoff should be returned to the land as quickly and directly as practical. Gravity drainage should be used whenever possible. However, in most cases, waste water from the milk barn and holding area are drained to a sump pit from which it is pumped to a waste holding pond. When topography permits, corral runoff water is also drained into the pond. Water levels in the pond are controlled by frequent pumping of the liquid fraction into a nearby irrigation system. The pond also must have sufficient reserve holding capacity to accommodate the dairy corral runoff from an EPA "design storm" (25 year, 24-hour storm event).

Required pond storage capacity depends on the number of animals served, wash-down waste (hose wash-down or parlor flush), the design storm runoff reserve volume, the non-biodegradable solids accumulation, the evaporation rate and the irrigation interval. Of these, the greatest variable is the wash-down waste. Only 8–10% of the total cow manure is deposited in the milk barn and conveyed in the wash water. However, a few dairies have reused their barn water to flush the feedline platform in the corrals. This flush concept involves 50 to 60% of total manure produced. Since sludge build-up is proportional to the manure fraction, pond storage must be enlarged proportionally, or the frequency of sludge removal increased.

Corral Design

In warm semi-arid regions, housing is simply a fenced pen or a "corral" with protection from the sun provided by an overhead shade. A feeding slab (manger) is located on one fenceline and a tank for drinking water is located at an easily accessible site within the corral.

Under hot semi-arid conditions, total confinement of dairy cattle within an enclosed building is not recommended. This concept makes a heat trap of the building for 12 months of the year to solve a four-month problem. Refrigerated barns are impractical for commercial dairy production.

Shades and Cooling

Shades should be at least 12 feet high and provide a solid shade pattern. For shade area per animal, see Table 1. Shade orientation is a compromise. East-west reduces ground temperature while a north-south orientation promotes feces drying and reduces the "dirty" cow problem. Shades located near the feeding area can create poor corral space utilization and serious manure management problems. In hot climates, cattle are fed very early in the morning and late afternoon to encourage eating during the cooler hours. Placing shades over a feed area will increase feed consumption during the hot summer months and increase milk production. However, a manger shade should be used in addition to, not instead of, a shade in the central area of the corral. Additional protection from the heat during the hot summer months can be accomplished by evaporative cooling. These are particularly effective in areas where low humidity conditions prevail. These are described in the companion paper "Cooling Dairy Cattle in a Hot Climate."

Cow Lane

Since cows must be moved to the barn at least twice daily for milking, the lane and gates should be carefully located and all associated equipment should be reliable and efficient. Concrete surfaced lanes 12–16 feet wide are used for cow traffic lanes. The larger the corral group the wider the lane should be for easy cow movement. The lane also serves as a collection drain for rainfall runoff. The concrete assures a solid base, even in wet weather, but a small layer of manure left to accumulate on the lane surface enhances comfort for the animals while walking.

Water Tanks

A float-controlled water tank must be available to provide drinking water at all times. A minimum of one linear foot of tank space should be provided for each five cows. If the water tanks are located adjacent to the cow lane fence, overflow and cleanout drainage from the tank is no problem because it will drain to the surface of the concrete cow lane. This location minimizes accumulation of water in the area around the tank. Concrete tanks with a roof inhibits heat intake in hot weather and are preferred over steel or fiberglass tanks.

Fenceline Feeding

A flat feed apron is favored in the southwest because it lends itself to tractor sweep maintenance. The concrete feed apron and road are sloped about 1/8 inch per foot to drain away from the feedline. In areas where high winds are frequent the traditional feed bunk may be more satisfactory.

The cow stand also is sloped to drain away. Lock stanchions are provided along the feed line for all lactating cows and heifers of breeding age. Cattle can be locked in at feeding time and held briefly for breeding, pregnancy diagnosis or minor treatment.

Calf Housing Alternatives

Calves can be housed in shaded individual pens with buckets for milk, water and dry feed. Portable outdoor calf pens require only a small investment, although labor requirements are high. Sanitary practice includes careful cleaning and relocation to an alternate site after each occupancy.

Respiratory problems which are principal concerns with calves can be reduced by locating calf housing in a dust-free area. Areas where heavy vehicle traffic is likely should be avoided. Because of the higher labor requirements of the portable calf pen, some producers favor a more permanent calf barn. The most successful model has two rows of individual pens separated by a convenient work alley all under shade. The pens are made of steel fenceline material set on the concrete floor so that the barn is essentially open on four sides. Canvas and/or other windbreak systems provide winter protection for the calves. Under semi-arid conditions, attempts at completely closed environmentally controlled structures generally have been unsuccessful.

Replacement Animal Corrals

Replacement animals are grouped according to feeding and management programs. Refer to Table 1 for basic space requirements.

Heifers six weeks to six months of age are grouped in lots up to 25 with no more than two months age or 50 lb. body weight difference.

Heifers 5–15 months are grouped in lots of 40–100.

Breeding age heifers, 14–18 months, are grouped in lots of 40–100. Lock-stanchions are convenient facilities for artificial insemination and pregnancy diagnosis.

Bred heifers, 17–28 months, are grouped in lots of 40–100. They can be confined with dry cows and moved to the springer pen about one month before calving.

Dry cows are generally divided into two corrals. Cows recently "dried up" are located in the most remote pen in the dairy layout. Cows and heifers about to freshen are moved into the springer pen for precalving observation. The springer pen should conveniently access the maternity pen and treatment facilities.

Treatment Facilities

Treatment facilities are needed for breeding, pregnancy checking, maternity, calf care, vaccination, dehorning, foot care, mastitis treatment, milk fever and culling. Most routine functions such as breeding, pregnancy checking and post-calving examinations can be done in lock stanchions at the feedline.

Cows requiring more vigorous examination and/or treatment by a veterinarian are moved to a special treatment area. A diversion gate at the milking parlor exit lane into a treatment lane is used to separate cows needing treatment. A reduced dimension version of this treatment system is also needed in the replacement heifer growing area. The head gate and chute system should provide easy access to the cow's mouth, neck, horn area, udder, tail end, side body cavity and rear muscle area. Side gates may swing in either direction and provision should be made so that the head gate can be removed and replaced with a hoof-trimming chute. The treatment lane should have access to an isolated sand floor pen equipped with belt lift, floor rings, overhead supports and with access for front-end loader for downed animal handling. A concrete floor, drain, hose bibb, refrigerator, hot plate and electric outlets are also desirable. Several small hospital pens and a permanent loading chute should also be available to the main treatment lane.

The hospital treatment facilities should be located as far from the equipment noise as practical.

The Milk Barn

The holding area, milking parlor and milk room are the main elements of the milk barn. The holding pen and parlor design can seriously affect the time and fatigue factors involved in milking, set-up, clean-up and corral changing. The holding pen, milking parlor, milker pit, cow stall entrances and return lanes must be designed for safe and efficient milker and cow movement. Anything that tends to impede cow or milker movement through the holding pen should be avoided. Eleven-inch clear man-escapes should be installed throughout to allow the milker free movement from one area to another without opening a gate or door.

Selecting the Milking Parlor

The milking parlor is the center of a dairy operation. It should be designed to milk as efficiently, safely and economically as practical. Milking involves 50% of all labor costs and is the most demanding and difficult to supervise operation in the entire dairy.

Milking parlor capacity usually is the limiting factor in determining the ultimate size of a herd. Cow throughput is influenced by operator routine and level of milk production[2]. Table 2 presents total milking time for herringbone-type parlors for 2X and 3X milking for selected herd sizes. Additional data and criteria on a variety of parlor systems are available in references 3, 4, 5, 6 and 8.

The milker's workday has a great influence on the milking capacity for a given parlor type and degree of mechanization. Milking requires both physical and mental work. The average milker frequently approaches his normal work limit in an eight-hour shift. More importantly, after eight hours the milker tends to lose concentration and herd health suffers. While some workers are capable of extra performance, especially for short periods of time, it is not sound design practice to base operator output on these exceptions. Time and motion studies[4,5,6] conducted on various parlor systems have established uninterrupted throughput capacities that are representative for the average worker on a full eight-hour shift. These capacities do not include set-up, clean-up or corral changing time, so it is necessary to discount the milker's design shift time by realistic estimate for these operations. Hence, the design herd capacity of most parlors should be limited to six hours of actual milking time.

Holding Area Design

1. The capacity of the milking parlor should be large enough to milk one corral of cows in an hour or less. The holding area is designed to accommodate corral changes. This permits continuous milking of a corral of cows while a second corral is moved into the holding area behind the crowd gate or training divider.

2. Holding area space requirements are 16–18 square feet per cow for large breeds and 14 square feet for small breeds.

3. The holding area floor and return lane are one continuous concrete slab sloping to 3 to 5% from the parlor to the corral lane.

Return lanes are usually located inside the holding area wall to facilitate the post-milking clean-up. The floor should be of high quality concrete with a broom roughened or equivalent finish. One pound of sidewalk-grain aluminum or ferric oxide antislip aggregates per square foot worked into the surface of 4000 pounds per square inch (psi) concrete is a good antislip specification. Surface retreatment with an epoxy resin and antislip aggregate is usually applied after 3 to 5 years of use.

4. A milker access ramp is extended from the parlor floor back into the holding pen area a minimum of 10 feet to assist with cow movement into the parlor.

5. A crowd gate is used to encourage cow flow. Alternatively, a training gate system can be located at a point in the holding area one-third the distance from the milking parlor entrance. A vertical lift gate system and either slide or hinged gates are used to separate the wash and drip areas.

6. The half of the holding area nearest the corral lane is usually equipped with a spray wash system and the half next to the parlor operates as a drip area. Holding area udder wash pump capacity depends upon sprinkler head selection, system pressure and wash pen size. Full circle 3/32 by 3/32-inch double-nozzle irrigation impact sprinkler heads are installed on the holding pen floor to form a grid about 6 feet by 5 feet on center. Nozzle angles are varied by alternating 5 and 15-degree double heads with 10 and 20-degree double heads in the grid system. Impact sprinklers can also be mixed with stationary head sprinklers for a combination of flow patterns. Since each sprinkler head delivers about 5 to 7 gpm at 55 psi, it is important that pump capacity and line size be calculated carefully to meet this high flow rate demand. At 16 square feet of flow area per cow, the jet wash pump capacity should be 4 to 5 gpm per cow depending on grid size and type of heads used.

The jet wash system is turned on for 2 or 3 brief intervals per corral. If the water supply is in an above ground storage tank, a slow-closing electric valve (usually in the six-second range) and a vertical U-trap must be installed between the pump and jet wash distribution system to prevent flow from gravity pressure when the pump is off. All systems connected to a potable water source must be equipped with a vacuum breaker to prevent back siphoning of water. A splash panel mounted between the two lower rails of the return lane fenceline prevents the jet spray from washing teat dip off the cows as they exit.

7. An eight-foot long foot bath may be installed in the return lane. The foot bath is equipped with a rubber ball plug and a two-inch drain pipe that empties on the holding pen floor surface.

8. The holding area walls are about six feet high and the rear wall is on the opposite side of the cow lane. A shade extends over the entire holding area and the vertical area between the wall and eave is left open for ventilation. Continuous slot ridge ventilation, power exhausts or evaporative cooling are also desirable.

9. A treatment lane separates the return lane from the holding pen. A pneumatic cutting gate is controlled from the access ramp to single out cows from the return lane. Provision should also be made so animals in the treatment lane can be directed back into the holding area to fill the last gang of stalls in an uneven string.

10. Holding pen entrance gates swing into the corral lane to control entry in either direction. A one-way or leaf gate at the return lane prevents cows from re-entering the exit lane.

11. A sand trap is located at the end of the holding area.

Milking Parlor Design

1. **Milker Pit.** Parlors for milking in six-to-eight hour shifts should be designed to prevent back and leg muscle fatigue. The milker pit floor should be 38 ± 2 inches below the cow platform. This distance minimizes stooping and knee bending, but it also positions the milker's elbows lower than the hands when working on the udder. This distance is generally reduced 4–6 inches in colder climates. The center of the pit floor should be crowned to drain toward the cow stand. Excessive slopes on the pit floor must be avoided and drains should be located outside of the milker's normal traffic pattern.

2. **Cow Platform.** The cow platform is usually sloped to match the milk-line slope and away from the pit. A 1½% slope in both directions is appropriate except when hydraulic flushing is desired. Then the cow platform slope is opposed to milkline slope and the platform is level from pit curb to the return lane wall. When platform slope is counter to milkline slope it is more difficult to locate the milk receiver and pump favorably. To accommodate animal wastes, a grave over a concrete gutter and a stainless steel curb are located on the platform adjacent to the milker pit.

3. **Lane Dimensions.** Exit lane widths are 34 ± 2 inches clear in straight runs and 54 ± 4 inches clear in the turning areas. Double exit lanes in larger parlors will speed up cow movement.

4. **Barn Floors.** Antislip concrete floors of the same characteristics outlined in Item 3 under holding area design should also be specified for cow platform and return lanes.

5. **Clean-up Facilities.** Wash-down hose reels should be located for easy access to all parts of the parlor and holding area. Water connections should be located to limit hose length to 65 feet.

6. **Gates.** Power gates are operated by air cylinders with a locking latch on the exit gate. The location of control switches for each gate is critical for proper operation. Entrance and exit gate switches are to be located at each end of a gang of stalls.

7. **Drain Lines.** Gravity drain lines are sloped a mini-

mum of 1½% and provide cleanout access every 150 feet and at major turning points.

Standby Generator

Standby electric power is essential for continuation of critical operations during power failures. The type of generator needed depends upon the size of the critical loads and the choice of full-load or part-load design. Tractor-driven generators require careful motor-starting procedures and generating capacities are frequently marginal. Engine-driven generators require protection against environmental extremes and adequate room ventilation. Vibration isolation is also necessary. Standby generators require frequent testing under load conditions and regular maintenance to insure performance when needed.

The National Electric Code requires that a standby generator be connected so as to prevent the interconnections of two power sources. Check the requirements of the local power supplier and engage a qualified electrical engineer for system design.

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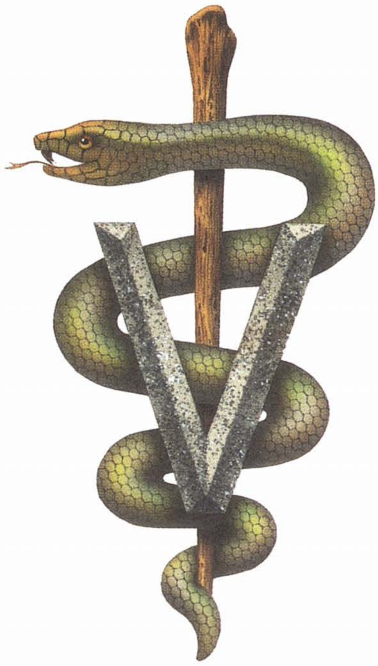

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