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6. Water Systems

Section Contents:

Purpose - Water Systems

The availability of an adequate water supply is critical to the operation of any dairy farm. Pumping of water constitutes a major end user of energy on California dairy farms. A milking dairy cow may consume 35 to 50 gallons of water per day. Coupled with all the auxiliary uses, total water consumption can exceed 175 gallons per cow per day.

Overall water consumption is comprised of the following end uses:

- Potable water for direct consumption by dairy animals in all stages of growth and lactation and environmental conditions.
- Cleaning water for CIP washing of parlor and milking system equipment.
- Washdown water for cleaning of milking parlor surfaces and general sanitation.
- Partial cooling (pre-cooling) of milk with well water.
- Water supply to water-cooled refrigeration equipment.
- Water supply to water ring vacuum pumps.
- Wash pen water use to clean cows prior to entering the milking parlor.
- Evaporative cooling sprays [misting] for the dairy cow to reduce heat stress during hot weather and increase cow comfort.
- Flush water for manure removal in confinement areas, holding area and milking parlor.
- Fire protection

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Water Supply

Water sources must provide an adequate supply of potable and palatable water to the dairy farm on a continual uninterrupted basis. The competitive pressures for adequate water supplies from agricultural, residential, municipal and industrial water users that currently exist and are projected to increase in the future must be addressed when planning for dairy water needs.

As herd sizes continue to grow, and other water uses are expanded, the total gallons of water needed to be pumped continues to increase. Adequate planning for the water system on a modern dairy must incorporate added capacity for future growth. This forecast of future use should be partially reflected in present capacity (cushion of 10-30% excess capacity) and a strategy in place to secure additional supply for expansion of the dairy herd.

Water supplies are generally secured from the following sources;

- Individual groundwater wells plus backup wells
- Municipal water supply systems
- Surface water supplies
- Rural water supply districts

An important design consideration is the implementation of on farm “intermediate water storage”. Intermediate water storage extends low volume supplies, provides sufficient water flow during peak water use periods, offers flexibility during instances of water supply restriction or drought and is a source of water for fire protection.

An integral step for determining capacity of intermediate water storage is evaluating the total volume (gallons) of water used in a day and the peak flow rate in gallons per minute (gpm) that will be used in a 1 to 5 minute interval during the day.

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Water Usage

Actual water use can vary significantly from dairy to dairy and reflect seasonal changes to water consumption but reasonable engineering estimates are available to calculate daily water requirements.

Satisfying drinking water requirements for dairy animals in all stages of growth and lactation is the primary component of water supply. Milking cows will consume 4.5 – 5 pounds of water per pound of milk produced. Adequate water supply must be maintained to all lactating animals or production will suffer. A cow producing 100 pounds of milk per day could consume 50 gallons of water depending upon moisture levels in feed consumed. Having water meter to monitor water consumed by the milking herd is a recommended practice. The following table provides information to estimate daily water use for a dairy herd.

Table 6-1, Water Requirements, MWPS-7

Water Consumption	Gal/head -day
Animals	
Calves (1 to 1.5 gal per 100 lb)	6-10
Heifers	10-15
Dry cows	20-30
Milking cows	35-50
Sprinkler systems	10-20

*During periods of heat stress (hot weather) drink water intake can easily reach twice the highest amount in each size category
*Cows drinking from a water trough may consume at the rate of 6 to 7 gpm.
(Source: Private Water Systems Handbook, Midwest Plan Service, Iowa State University)

Wash pens are one of the next larger consumers of water on open-lot dairies. Water use can range from 18-30 gallons per cow per wash. Most wash pens utilize a three-stage cycle to clean cows for milking. First a “soak” cycle of one minute is used to wet the udder and loosen debris from the cow. This is followed by a “stand” time for two minutes to allow material to soften, loosen and drain. The third cycle is a three-minute “wash” stage where water is applied and any remaining matter is rinsed away. All discarded wash pen water is reused as “flush water” for the removal of waste in animal confinement and holding areas.

Figure 6-1. Wash pen on California dairy

The cyclical nature of wash pen usage contributes to the large peak flow requirements imposed on the water supply system. Estimates of usage, peak flow, and booster pump sizing can be made from Table 6-2.

Table 6-2. Estimates of usage, peak flow, and booster pump sizing

Wash pen Capacity	# of Wash heads	GPM Required	Booster Pump Size
50-86 cows	24-40	125-200	7.5 H.P
86-118 cows	40-55	200-275	10 H.P.
118-161 cows	55-75	275-375	15 H.P.
161-214 cows	75-100	375-500	20 H.P

*Based on 30 sq. ft. spacing of wash heads and 14 sq. ft. of wash pen space per cow.

An example of estimating total daily water requirements (gallons) and flow rate (gpm) is provided in Table 6-3 below.

Table 6-3. Estimate of daily water requirements and demand for dairy farm

Number			Average Daily Usage	Total Daily Use	Average Flow rate* GPM
	Drinking Water		(gal / day)	(gallons)	
800	Lactating cows		45	36,000	30
200	Dry Cows		30	6,000	5
500	Calves / Heifers		15	7,500	6
	Milking Parlor				
	Plate Cooler**		1.5 lb. water per lb milk	11,511	10
	Wash Water		5	4,000	3
	Parlor Flush water		7.5	6,000	5
	Cooling sprinkler systems		20	20,000	17
		Total	122.5	91,011	76
			(gal / day)	(gallons)	GPM
	Future Capacity Total		153.1	113,763	95
	* based on 20 hours pumping				
	** based on 80 # milk/cow-day				

Figure 6-2. Parlor flush cleaning

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System Design

Piping System

The water supply distribution system links the water supply source to the water consuming end use. Primary factors affecting design of the water distribution system are based on volume of water required and the peak flow rate that must be delivered thru the system. Other factors that must also be evaluated are frictional losses that occur due to overall pipe length and size, number, type and size of fittings and valves used and head losses due to differences in elevation.

There are three basic components in the water supply distribution system. These include the following:

- **Main line** (or water main) that carries water from the supply source thru any intermediate storage and into the dairy complex. Ample capacity for growth within the dairy complex should be anticipated in sizing the main line.

- **Distribution lines** transfer water from the main line to a specific building (parlor, freestall, wash pen, etc) where the water will be utilized. Distribution lines need to be sized to include capacity for anticipated additions to water use in that building or area. Consideration should also be given to include some capacity for unforeseen future water uses.

- **Branch line** brings water from the distribution line to the final end use (waterers, wash heads, flush tanks, CIP functions, cow cooling sprinkler systems). Branch lines are generally adequately designed because they are sized to handle a defined end use. Problems can occur when a branch line is converted into a distribution line if new end uses are added.

Pressure loss considerations:

- Limit pressure losses in main line to less than 1 psi per 100 feet of pipe.
- Select pipe diameter from Table 6-5 to provide maximum water velocity in main and distribution lines to 4 fps to prevent water hammer.
- Limit pressure losses in branch lines to less than 5 psi
- Limit maximum water velocity in branch lines to 5 fps.

Table 6-4. Frictional losses from pipe fittings and valves

Fitting Type	Pressure loss (psi)	Equivalent pipe length (ft)
90° long sweep elbow	0.05	14
90° standard elbow	0.8	20
45° elbow	0.03	8
Gate valve, wide open	0.02	5
Gate valve, half open	0.41	130
Flow meter	0.14	32

(Source: Martin, J.G., "Water System Design Considerations for Modern Dairies", Western Dairy Management Conference, 2001)

Table 6-5. Recommended maximum flow rate through pipe using different flow velocity. Water hammering may occur at velocities greater than 5 fps [feet per second] and require special fittings

Nominal Pipe Diameter (inches)	Flow through Pipe (gal per min)		
	Flow Velocity		
	4 fps	5 fps	7.5 fps
0.5	2	3	5
0.75	6	7	10
1	10	12	20
1.25	15	20	30
1.5	20	30	40
2	40	50	70
2.5	60	80	120
3	90	110	160
4	160	200	300
6	350	440	660
8	630	780	1,200
10	980	1,200	1,800
12	1,400	1,800	2,600
16	2,500	3,100	4,700
24	5,600	7,000	10,500

(Source: Martin, J.G., "Water System Design Considerations for Modern Dairies", Western Dairy Management Conference, 2001)

Pump Sizing and Selection

Selecting the suitable centrifugal pump can be challenging because of pump performance varies depending on pressure (head). Each pump has it own set of pumping curves and the challenge is to select the pump that will operate efficiently under normal flow rates. The complexity associated with pump selection often results in a pump that is improperly sized for its application. Consequently, using a knowledgeable experienced dealer / installer is essential for selection of an efficient system.

Choosing a pump that is either too large or small will reduce system performance. Too small a pump will not produce adequate flow, so pumps usually end up being oversized. Over sizing however, increase initial costs and higher energy costs because the pump is operating at a lower efficiency. One way to address over sizing pumps to meet future flows is to select a pump that can accommodate larger impellers when system capacity increases.

The two fundamental factors for pump selection are total dynamic head (TDH) and desired flow rate. The capacity or flow rate (gpm) for the pump is developed from the anticipated amount of water used on a daily basis as developed in Table 6-3. Two pump systems are shown in Figures 6-3 and 6-4.

Figure 6-3. Two primary water supply

Figure 6-4. Typical well water supply pump pumps on California dairy

The THD is derived as the sum of the head pressures as follows:

- **Vertical lift / elevation** – The vertical distance (ft) between the pitless adapter and pressure tank
- **Service pressure** – The average pressure maintained in the distribution system to deliver water to the point of use. (E.g. 50 psi would be equal to115.5 ft of head)
- **Pumping level** – The vertical distance in feet from the well seal or pitless adapter to the water draw-down level in the well that yields the flow rate required by the pump.
- **Friction loss** – Loss of head in feet due to resistance to water flow. This is based on the type, length and diameter of pipe use and the number, size and type of fittings.

Once the TDH has been calculated and the water system flow rate is determined from the worksheets above, a pump can be selected. Select an appropriate pump by matching the values obtained for TDH and desired flow rate as a best fit to the pump curves for various pumps. See Figure 6-5.

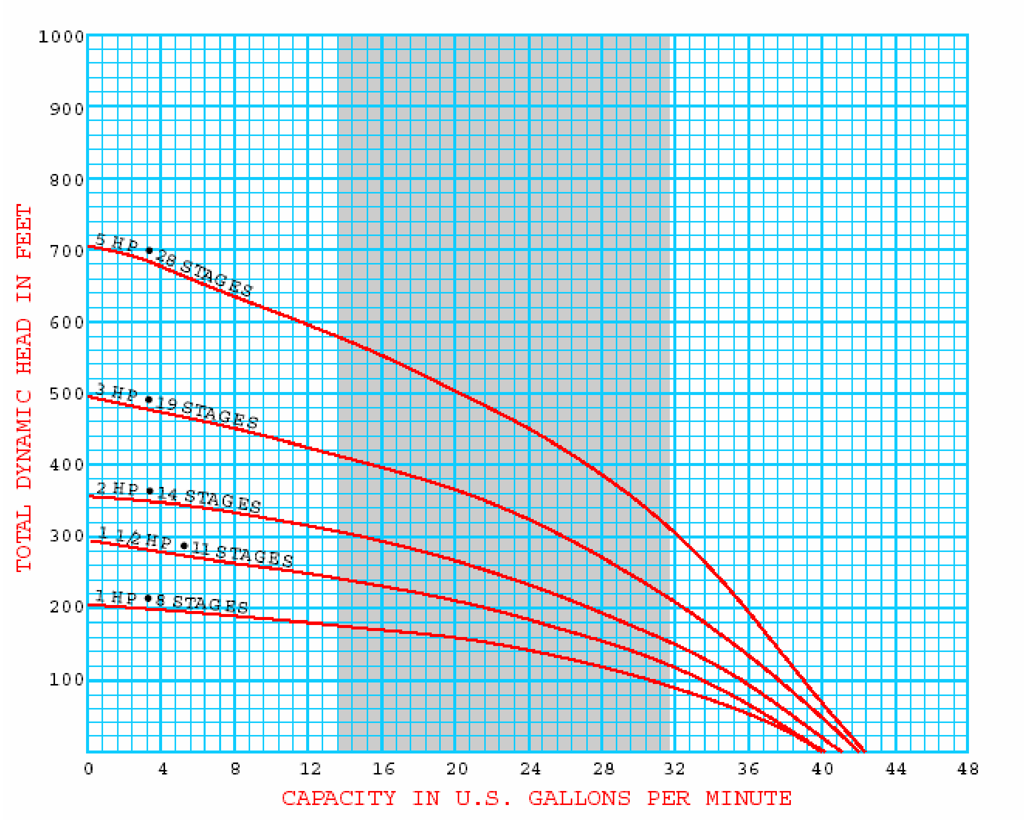

Figure 6-5. Pump curves
(Source: A.Y. McDonald Mfg. Co, Pump Basics, 4/98)

The previous chart shows the pump curves for five different small centrifugal submersible pumps. To illustrate the effect of THD on pump sizing and energy consumption, consider the following example.

- The 1 horsepower pump will deliver a capacity of 20 gpm at a TDH of 160 feet.
- It will require a 5 horsepower pump to deliver the same 20 gpm at a TDH of 500 feet.

Increasing the TDH the pump must work against by slightly over 3 times, the power consumption increases fivefold.

Maximum efficiency of the water pumping system is achieved thru proper selection of all subcomponents and adequate system maintenance. Items to consider for an efficient water delivery system include:

- High efficiency motors.
- Selection of appropriate type and size of pump.
- Adequate storage to satisfy peak water demands.
- Adequate sizing of piping distribution system to reduce pressure losses.
- Timely maintenance to reduce leaks and other losses.

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Intermediate Water Storage

The use of a non-pressurized intermediate water storage reservoir provides many advantages in the dairy water system:

- Supply ample water storage capacity at a low cost to meet daily water volume needs and peak flow rates.
- Allow supply from multiple water sources.
- Can serve as source for pressurized and non-pressurized uses.
- Provide reception point for emergency water supply.
- Water source for fire protection.

Figure 6-6. Intermediate water storage reservoir on California dairy

Figure 6-7. Pressure tank on California dairy

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Equipment - Common Pump Types

Horizontal Centrifugal Pumps

Horizontal centrifugal pumps are frequently used when water supply permits the vacuum at the pump to lift water into the impeller and keep it flowing. Maximum vertical suction lift is limited to 15 feet. Common water sources for horizontal centrifugal pumps are surface supplies such as an irrigation canal or pond, stream, lake, a shallow well or intermediate surface storage.

As the name implies the pump utilizes a rotating impeller within a casing that uses centrifugal force to move water from the center of the impeller and discharge the water into the piping system

Axial Flow Propeller Pumps

Axial flow propeller pumps are designed for pumping at low head and high volume (more than 500 gpm) typical to many irrigation or drainage applications. The pump consists of a revolving propeller contained in a bowl with guide vanes above and below the propeller. Their efficiency is high when pumping against heads of 20 ft. or less. The propeller of an axial flow pump must be completely submerged in water to operate.

Deep Well Vertical Turbine Pumps

Vertical turbine pumps are a form of centrifugal pump installed vertically in a well. They consist of four major components:

- **Bowl assembly** with one or more impellers each contained in their own housing.
- **Column and shaft assembly**, which consists of the pipe to carry water to the surface with the bowl assembly, suspended at the end and a shaft centered inside to power the impellers.
- **Discharge assembly** provides a base for the column, shaft, and bowl assemblies to be suspended from, a connection point to deliver discharge water and a stand to mount the pump driver.
- **The driver** can be either an electric motor or fossil fuel engine that supplies power thru the line shaft to the impeller(s) in the bowl assembly at the bottom of the column.

To supply increased amounts of pumping head several impellers on a common shaft are stacked in series so that the discharge from the first passes to the next impeller. The total head delivered is the sum of head developed by each stage.

Submersible Pumps

The submersible pump consists of a multistage vertical turbine bowl connected directly to the electric drive motor. The complete assembly is suspended below the water line by a pipe that carries water to the surface. Surrounding water cools the pump motor.

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Water Systems Energy Utilization Indices (EUIs)

Delivery of a continuous ample supply of potable water to the dairy is a vital component in the production of milk. Energy used in this function focuses solely on operation of pumping equipment. Careful design, selection and operation of water systems play an important role in determining their overall energy efficiency.

The electrical energy consumed on California dairies to supply water is driven by a number of factors that include:

- Total daily water volumes needed.
- Distribution system pressures required.
- Proper design, sizing & selection of water system components.

The development of a water systems energy utilization index (EUI) provides a benchmark for the efficient delivery of this essential commodity. Typical annual kWh consumption per cow-year on California dairies ranges from 35 to 75 kWh per cow-year.

Water conservation measures are key to managing this energy usage. Conservation, reuse, and sound water management practices reduce total water demands and electrical costs.

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Water Systems Energy Conservation Measures (ECMs)

To help identify potential energy savings in a farmstead water supply system consider the following questions:

- Is the pump or system absolutely necessary or do alternatives exist?
- Is the pump properly sized or has the system been over designed with too much excess capacity for potential future use?
- Was an efficient pump, motor and control system selected?
- Do the head pressures used for design agree with actual pressures utilized?
- Can a variable speed drive (VSD) or improved control package be used to better match actual system requirements

Pump Selection

The process of selecting the appropriate pump for a particular application is crucial in determining the overall efficiency of the water delivery system.
There are a large number of variables that must be addressed when configuring the "best" pumping equipment to meet the dairies need. These variables may include:

- flow rates and pressures
- well depth and vertical lift requirements

- frictional losses
- environmental factors
- operating and duty cycles
- and numerous others

The effectiveness of the final selection process depends on complete communication of all needed parameters between the end user and equipment supplier. Equally important is the careful choice of an experienced, knowledgeable, and reputable pumping equipment supplier who can integrate all design parameters and configure the optimum pumping solution.

Motor Selection

In selecting a pump, there are two components to consider: the pump and the motor. In some applications, the pump and the motor are sold as a package. Often, however, the buyer can select one of several motors to be installed with a pump.

Long-term energy savings can be locked in for the life of the equipment by selecting the most efficient motor available.

Equally important is choosing the correct size of motor. Motors that are not large enough may have to operate above their rated load, forcing them to run at elevated temperatures, which shortens their operating lives. Motors that are much larger than required not only cost more, but also suffer efficiency loss when the operating load falls beneath about one-half of the motor's rated load. For further discussion of electric motors, see Table 8-4, "Energy Efficient Motors", in the General Information Section.

Pump Modification

In-service pumps that are oversized and generating too much pressure may be good candidates for impeller replacement or "trimming". Reducing impeller diameter by machining decreases the speed of the fluid in order to reduce the energy added [pressure] to the system.

Variable Speed Drive Pump Application

Variable speed drive provides one of the best available options to improve pumping efficiency. Variable speed drives can be effective with the following situations:

- To control varying flow conditions. VSD's can provide constant control for pressure, flow or fit to pump curve.
- As a suitable retrofit on oversized pumps to reduce speed and energy use.
- For providing water system pressure from an intermediate water storage.

Although the primary benefit of a VSD is energy reduction they are also able to:

- Reduce need for other pump control equipment.
- Eliminate bypass, throttle, and other types of valves.
- Provide soft start & stop, which allows a reduction in starting loads and stresses to both pump and motor, increasing wear life.
- Reduce incidence of water hammer.

Figure 6-8. Variable Speed Drive Pump (Gould)

Water Conservation Measures

Utilize water-conserving wash heads in wash pens. A new innovative design of wash head can significantly reduce water consumption for cow cleaning compared to conventional dome covered irrigation style sprinkler heads. These water-conserving wash heads offer the following benefits:

- Reduced water consumption of up to 2 gallons per minute.
- Improved nozzle design and rotational spray pattern can reduce cleaning time by 20-50%.
- Gentle fan spray of large droplets less stressful to cows and don't require guards that can cause injuries to cow's legs and udders.

Figure 6-8. Wash head (Cow Washer)

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Operator Level Checks – Water Systems

Water systems serving livestock can be designed to survive the abuse and daily wear animals impose. A few preventative maintenance measures can eliminate many of these situations:

1. Water source maintenance is very important. Public water sources are monitored and provide minimal maintenance if they are available. The dairy's cooperative or milk handler may be able to provide testing and information regarding water quality requirements.

2. Well Inspection - Inspect your wellhead several times a year. Check the condition of the well covering, casing and well cap to make sure all are in good repair, leaving no cracks or other entry points for potential pollutants.

3. An annual bacterial and water chemistry test is recommended to verify water quality. Furthermore, water quality should be checked anytime there is a change in taste, odor or appearance, or if the water supply system or well is serviced.

4. Have the well system, including the pump, storage tank, pipes and valves, and water flow, inspected every 3-5 years by a qualified well driller or pump installer.

5. Inspect valves, controls, fittings, pumps, storage and pressure tanks for leaks or plugging.

6. Re-evaluate total dairy water needs annually. Review existing storage tank and proper sizing of water distribution lines.

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Glossary of Water Systems Terms

Backflow: The flow of water or other liquids, mixtures, or substances into the distribution pipes for a potable water supply from any source other than its intended source.

Cross connection: Any physical connection between a potable water supply and a non-potable supply.

Elevation Head: The elevation head (vertical) is always measured relative to some other elevation, such as sea level. In pumping systems, elevation head generally refers to the difference between the pump elevation and discharge or suction elevation.

Flow Rate: The volumetric flow rate (gallons per minute, GPM) at which a liquid is moved.

Non-Potable Water: Water that is not safe for human consumption, that is of questionable potabilty for farm use. [see potable water below]

Negative Pressure: A vacuum or reduced pressure [in Hg].

Plumbing System: Includes the water supply and distribution pipes, plumbing fixtures, and traps, soil, waste and vent pipes, building drains and sewers.

Potable Water: For a dairy farm water supply to be in compliance with the Food and Drug Administration (FDA), US Public Health Service (USPHS) Grad "A" Pasteurized Milk Ordinance (PMO), the following conditions must be satisfied at point of use:

1. Bacteriologically, it must be safe and practically free of any type of bacterial contamination that may affect milk quality,
2. The chemical and physical quality of the water must be within the limits acceptable to health authorities and regulatory agencies and
3. There should be no impurities present in the water supply that might create problems in cleaning milking center equipment, corrosion in the pipeline, or undesirable milk flavor. [Source:DPC Guideline #30]

Pressure: In this section, pressure refers to gauge pressure, the measure of force per unit of area (pounds per square inch, psi) relative to ambient pressure.

Pumping Efficiency: $\eta = \frac{QH \times 100}{5.31 \times W}$ where η= efficiency (percent), Q = water flow in gal/min, H = total head (ft) and W is input Watts to motor.

Total Dynamic Head: Energy per unit of weight. Hydraulic head is composed of three elements – velocity, pressure, and elevation

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