Water Conservation for Next Gen Dairies

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Introduction

Water availability is an issue in many dairy regions in the US and internationally. Conserving water for the next generation of dairies in important to meet the global nutritional needs projected for 2050. There are many factors which determine water usage of a dairy such as heat abatement practices, milk parlor protocols and milk production (drinking water). Priority by the management and helping employees understand the long term importance of water to the future of the dairy industry is necessary to transition dairies to the next generation. This paper reviews current studies related to dairy water usage and outlines 10 potential conservation practices as starting point for water conservation.

Overall Water Usage on Dairies

Bjorneberg and King (2014) studied ground water withdraws on six Idaho dairies ranging in size from 660 to 6,400 milk cows. They based their water usage on "equivalent cow" to account for relative differences due to dry cows, heifers, milk cows and calves on each dairy. Average water withdrawals ranged from 29.1 to 66.1 gallons per day (gpd) per equivalent cow with an overall average of 50.2 gpd/ equivalent cow. Waste water that was available for irrigating crops was measured on three dairies and ranged from 5.5 to 39.6 gpd/equivalent cow. In this study, none of the dairies used sprinklers or misters to cool cows but summer water withdraw rates increased 26.4 gpd/ equivalent cow. Daily milk production averaged 70.4 pounds per milk cow. The average water to milk ratio was 6.8 +/- 1.8.

Robinson et al. (2016) monitored water usage on 17 Ontario dairy farms over a 20 month period using continuous flow water meters. Meters were installed to measure cow consumption and milk-house and parlor usage. They found water usage was on dairies equaled 35.0 +/- 13.0, 37.0 +/- 13.4, 37.8 +/- 8.7 and 26.8 +/- 0.2 gpd/cow for dairies with parallel, robotic, rotary and tie stall types of milking systems, respectively. These averages and ranges were based on sample sizes of 2 to 4 dairies per type of milking system. Overall, the water to milk ratio averaged 5.3 +/- 1.3 lbs water/lb of milk. This study found water usage per cow per day similar to those reported by Brugger and Dorsey (2008). The dairies in Robinson et al. (2016) study averaged 122 total cows with 13.5 % dry cows in the herds. Average water usage was reported as 35.6, 44.6, 26.8 gpd/milk cow for parlor, robot and tie stall type of dairies, respectively. For milk house parlor, water usage was 5.4 gpd/lactating cow. Overall the water usage was 20 to 25 % higher in summer months versus winter months.

Bray et al. (2014) published water budgets for Florida dairy farms. The average water consumptions was 25 gpd/cow with variation depending on "milk yield, dry matter intake, temperature and other environmental conditions." They showed predicted water intakes ranged from 22.2 to 31.9 gpd/cow depending on temperature, dry matter intake and milk production using Murphy et al. (1983) model.

Potts (2012) evaluated meter well water records for twenty-four dairy farms consisting of 10 dry lot dairies, 12 freestall dairies, and 2 dairies using both freestalls and drylots were obtained from 2000 to 2009. The dry lot dairies average size was 4,387 cows and freestall dairies averaged 3,632 cows. The combined average water usage was 57 gpd pumped/cow. The dry lot dairies averaged 52.6 gpd/cow and freestall dairies average 61.4 gpd/cow.

Zuagg (1989) summarized the daily water usage on five dairies in Arizona (Table 1). Early lactating cows drank between 29 and 35 gpd/cow while late lactating cows drank 25 to 28 gpd/cow. Water consumption was less than 20 gpd/cow during the dry cow period on all of the farms. Water usage on a dairy varied from 72 to 186 gallons per lactating cow per day and averaged 127 gpd/cow. In reviewing the data in Table 1, wash pens accounted for 37.5% of the total water usage per cow on average. Comparing water usage on Dairies B, C, and D, where some form of heat abatement was implemented and heifers beyond 6 months were not raised on the dairies, the average water usage was 89.3 gpd/cow when considering the water used in wash pen and 58.6 gpd/cow when the water used in the wash pen was omitted. For the 5 dairies, the wash pen water usage ranged from 19 to 93 gpd/cow and averaged 50 gpd/cow. However, on dairies B, C, and D, the water usage in the wash pen averaged 30.6 gpd/cow. Water usage in the milking center excluding the wash pen ranged from 2.3 to 18.3 gpd/cow and averaged 11.2 gpd/cow.

Table 1. Summary of daily water usage on five dairies (adapted from Zaugg, 1989).

	Dairy Identification and Milking Frequency				
	A(3X)	B(3X)	C(2X)	D(2X)	E(3X)
Calf include from 0 to 6 month	No	Yes	Yes	Yes	Yes
Heifers include from 6 to 22 months	No	No	No	No	Yes
Dry & Close-ups cow (D–dry * C- close ups)	D	D & C	No	No	D & C
Cooling (M – Milk Center & P – Pen)	M only	M & P	M & P	M & P	M & P
Total Water Usage per Lactating Cow (gpd)	186	101	95	72	182
Wash Pen Usage per Lactating Cow (gpd)	93	49	19	24	65
Drinking Water per Lactating Cow (gpd)*	71.2	32.2	59.3	40.1	81.1
Milk Center Usage per Lactating Cow (gpd)**	18.3	2.3	7.7	3.3	14.5

* Includes water for dry cows, close-ups, calves and heifers

** Includes water reported usage for vacuum pump

Water Usage at the Milk Center

The most comprehensive study involving water usage in the milking center was conducted in Victoria, Australia, where water usage on 780 dairies was analyzed (Williams, 2009). Water usage varied among herds of similar size which is similar to previous studies. The 75th percentile water usage was defined by the industry as the "upper limit of what is 'reasonable' dairy water use for Victorian dairy farmers". Herringbone parlors water usage per cow tends to increase with herd size and water usage in rotary parlors tended to level out after 500 cows at 16 gpd/cow. This extensive data set suggests an upper limit of 'reasonable' dairy water use equals 16 gpd/cow in the milking center.

Meyer et al. (2006) evaluated parlor water use on 16 dairies to calculate the amount of water flowing into dairy lagoons and holding ponds from August 1998-August 1999. They found parlor and udder hygiene water comprised an average of 56% of the total water entering the farms' lagoons. The range was 45 to 194 gpd/cow with an average of 78.5 gpd/cow. Like the other studies, they reported that parlor water use was consistent throughout the year on each farm (Meyer et al., 2006). A second study in California (Castillo and Burrow, 2008) installed 64 water meters on 3 dairies in Merced County. Average water usage was 44, 51, and 49 gpd/cow.

House et al. (2014) monitored water usage in milking center from 29 different types of dairies in the Ontario Providence of Canada during the summers of 2011, 2012 and 2013. There was variability amongst the dairies but the milk center water usage averaged 5.97 gpd/cow (11 dairies), 8.95 gpd/cow (6 dairies), 3.67 gpd/cow (only 1 dairy) and 5.10 gpd/cow (4 dairies) for parlor, robotic, rotary and tie stall milking centers, respectively.

Water Conservation

Potable water usage on a dairy occurs primarily at the parlor facility (milking center) or the housing area. Water usage in the milk center includes sanitation, cow area including milking deck and holding pen, and plate cooler. The primary use of potable water in the housing area is either for drinking or heat abatement. The authors are not aware of any studies specifically designed with an objective to determine the overall water savings potential on a dairy. The milking center and housing area provide opportunities to begin to develop water conservation strategies.

Conservation Practice 1: Repair Water Trough Leaks and Adjust Floats Valves

Water leaks are common on most dairies in the parlors and housing areas. Leakage may occur due to inadequate pipe and joint connections, improperly adjusted floats on water troughs or toilets, and damage to main pipe lines. An observation of an improperly adjusted water float on a single water trough (Brouk 2013) estimated water losses of nearly 1.5 million gallons of water per year. The overflow pipe was discharging 2.81 gpm of water into the cow alley. In another pen the float was allowing 1.31 gpm to discharge into the alley resulting in annual water losses of 690,000 gallons assuming no adjustments. In other barns on the same dairy, water leaks from water troughs resulted in more than 1,000,000 gallons of water lost annually. It was calculated that daily at least 3 gpd per cow were lost due improperly adjusted floats on water troughs and leaks. Similar water losses were observed on a 2nd dairy.

Brouk et al. (2001b) studied water consumption on three dairies during the summer months. Water consumption averaged 40 gpd/cow in the north barn and 64 gpd/cow in the south barn (Figure 1). Figure 1 shows the water consumption for individual water troughs in the north and south barns. The far water trough in the south barn indicated water consumption of nearly 31 gpd/cow. This water consumption was found to be significance due to monitoring in each water trough but was due to what was considered "a minor leak". While a minor leak, the cost were significant since the purchased water resulted in about $0.25 extra production cost per cow housed in the south barn per day.

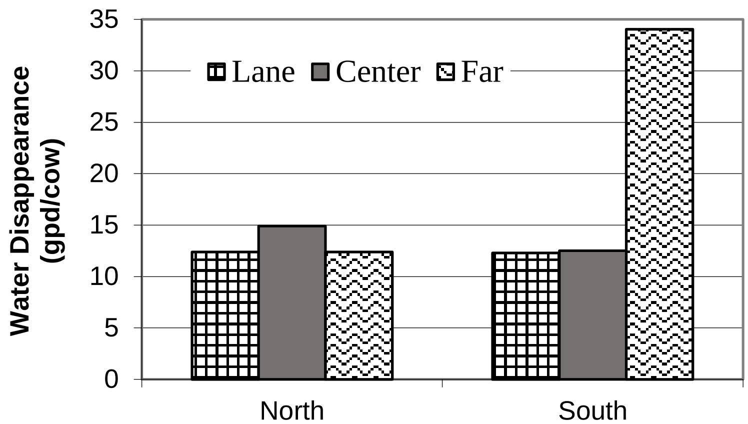

Figure 1. Water disappearance of individual water troughs in freestall barns on a northeast Kansas dairy (Brouk et al., 2001b).

Improperly adjusted toilets can result in water losses of 0.5 to 2 gpm. A 1 gpm overflow in a single toilet we result in extra 0.5 gpd/cow being required. EPA (2016) estimates the average household leaks are equivalent to 270 loads of laundry. Similar leaks in a milk center would equate to 0.5 to 1 load per day for washing towels.

Conservation Practice 2: Recycle Plate Cooler Water for Potable Uses

Most recycle the plate cooler water for other usages on the dairy. The warm water is most often used to supplement drinking water requirements or parlor deck flushing in parallel or herringbone parlor. To reduce water consumption on a dairy, the plate cooler water should be recycled for activities requiring potable water, such as drinking and parlor deck flushing, rather than using as an additional water source. Many state milk sanitation codes allow for non-potable water to be used for flushing the holding pen and some allow non-potable water to be used for flushing the parlor deck. Using potable water for flushing the holding pen should be minimized unless required by milk codes. Since the water exiting the plate cooler is clean even though warmer than ground water, usage for filling water troughs or washing the cow deck are better options. Generally the plate cooler water usage is 2 to 4 lbs of water per lb of milk. Assuming 80 lbs of milk and a ratio of 3 to 1, 28.8 gpd/cow of water should be available for refilling water troughs. During the winter months when water consumption is lower (Bray et al., 2014), the balance of the plate cooler water could be used for washing the cow deck.

Brugger and Dorsey (2008) monitored water usage on a 1,000 cow dairy in Ohio via installing 13 water meter at various water use locations. Monitoring water use enabled the dairy to implement water conservation strategies including adjusting the water flow rate through the plate cooler. The flow rate initially was 42 gpm through the plate cooler and this was reduced to 21 gpm without compromising the milk quality of plate cooler performance. Brugger and Dorsey (2008) reported this reduction saved 24 gpd/cow of water savings with lower the water flow rate through the plate cooler. The herd was reported to have an 80 lb milk herd average so the milk to water ratio was reduced from approximately 5.2 to 2.6 assuming the parlor was used 20 hours per day (not reported in the paper).

The water requirements of plate coolers is 1 to 2 lbs of water per lb of milk (Reinemann and Springman, 1992; Spencer 1992). Water usage may be more than 2:1 if no attempts are made to control water and irrigation water is diverted through the plate cooler prior to cropland application. At ratios of 4 to 1 or 6 to 1 the plate cooler water should be able to meet most of the other water demands on a dairy depending on time of year and current consumptive uses.

Conservation Practice 3: Adjust Feed Line Soakers and Holding Pen Sprinkler Nozzles

Feed line soaker systems for heat abatement may account for 10 to 30 % of the annual water consumption depending on the duration of hot weather. Water usage for heat abatement ranges from 17 to 100 gpd/cow. Brugger and Dorecy (2008) reported only 1 gpd/cow was used for cooling so there was minimum heat abatement on the NW Ohio dairy. One of the early recommendations was 2.6 lbs of water every 15 minutes. Armstrong et al. (2004) studied the impact of feedline soaker systems in a tunnel ventilated building in Thailand. The study compared evaporative cooling of the air vs strategies using evaporative cooling of the air and feed line soaking cows with 2.2 lbs or 4.4 lbs of water every 5 or 10 minutes. They reported body surface temperatures and respiration rates were lower for all treatments compared to the control. Treatment respiration rates ranged from 40 to 55 while control respiration rates were above 75. Lowest respiration rates were obtained using the 5 minute soaking cycle.

Means et al. (1992) studied consumptive water use for cooling dairy cows using nozzles with flow rates of 1.4, 1.9 and 3.1 gpm and 1.5 minutes and off 13.5 minutes. The sprinkler nozzles were turned on any time dry bulb temperatures exceed 78 °F. There was no difference in milk production, corrected milk yield, dry matter intake or milk protein between three trails using of 57, 84.4 and 120.4 gpd/cow for cooling cows. Means et al. (1992) recommended changing the nozzle size to reduce the water usage.

Strickland et al. (1989) studied the impact of cooling on cow performance. Milk production increased from 39.8 lbs. to 44.4 lbs. or 11.5 %. Cooled cows had an increase in both feed consumption and milk protein. In this study, cows were cooled in the holding pen with a sprinkler on cycle of 30 seconds every 5 minutes when temperatures exceeded 78 °F. They compared 3 treatments: sprinklers that delivered 0.34 or 13 gpm (both 3 min on and 9 min off, 24 h/d) and an unsprayed control.

Chen et al. (2016) found cows spent 5.8 ± 0.9 h/24 h (mean ± SD) at the feed bunk overall regardless of sprinkler delivery rate using a soaking strategy of 3 minute on and 9 minute off cycle. The cows soaked at the feed line stayed at the feed bunk on average 23 to 27% longer and made 13 to 16% less frequent trips compared non soaked cows. They found cows which were soaked at the feed line, had on average body temperatures increase 01.1 to 1.26 °F per 18 °F temperature rise in the hot dry climates in California. Non-soaked cow's body temperature increased 2.88 °F per 18 °F ambient temperature rise. They found no difference in milk production between soaking cows with application rates of 0.34 gpm versus 1.30 gpm but a water savings of 73 %.

Water conservation with feed line soakers is possible since research does not indicate an advantage to using more water assuming the same on cycle time. The original recommendation of 0.05 inches (Florida) appears to be still valid. Assuming the cows back is equivalent to 10 sq ft, this presents an application amount of 2.6 lbs. or 0.31 gallons per soaking cycling. The current recommendation of 1 gpm nozzles spaced 8 ft on center and on for 1 minute results in 0.25 gallons or 2.1 lbs. per application cycle. Water conservation requires individual dairies to adjust the nozzle "on" cycle to limit water application rates to 0.25-0.35 gallons per cycle per cow. Some suggest turning off soaker nozzles when water is observed reach the widest (belly region) of a cows body using visual inspection.

Harner et al. (2015) estimated annual water requirements per dairy cow for heat stress abatement for different locations in the US (Figure 2). Annual water requirements were between 1,500 and 2,000 gallons per cow. However, in the extremely hot regions and areas where dry lot dairies are located the water utilized for cooling cows exceeds 4,000 gallons per year. Current heat stress abatement is based on air temperature control strategies; however, as shown in Figure 3 an estimated 30 to 50 % water savings could occur if technology was available to operate the controllers on THI rather than air temperature.

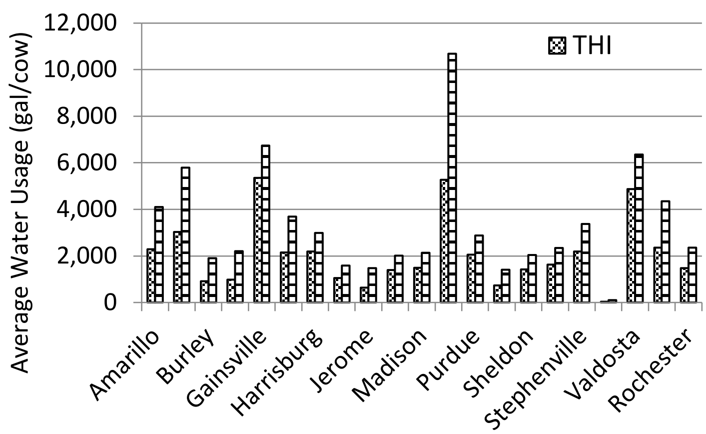

Figure 2. Estimate of the annual water requirements per cow for cooling using a feedline soaker system with 1 gallon per minute nozzle and spaced 8 feet on-center.

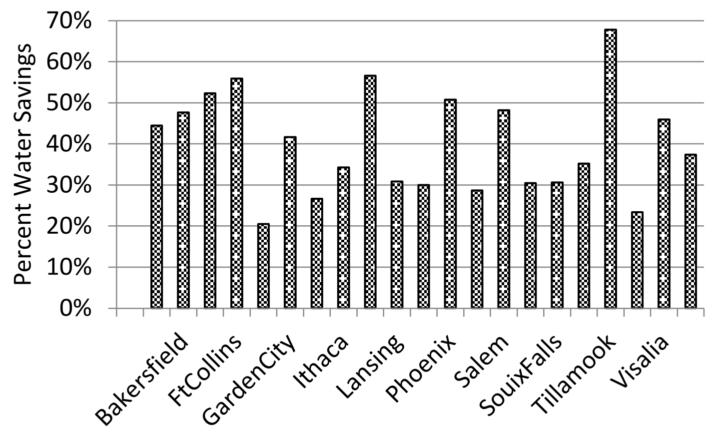

Figure 3. Estimated annual water savings if feedline soaker system was controlled based on THI rather than temperature

Conservation Practice 4: Adjusting Milking Center Floor Flush System and Use of Cow Deck Washers

Meyer et al. (2006) reported that dairies with wash pens averaged 78.5 gpd/cow while dairies without wash pens averaged 53.4 gpd/cow. This data is similar to the findings of Zaugg (1989). Sweeten and Wolfe (1993) found on Texas dairies milk centers with flush systems used 47 gpd/cow and scrape systems using 20 gpd/cow. The average water usage was 39.6 +/- 20.3 gpd/cow. Zuagg (1989) summarized the daily water usage on five dairies in Arizona (Table 1). The wash pens accounted for 37.5% of the total water usage per cow on average. For the five dairies, the wash pen water usage ranged from 19 to 93 gpd/cow and averaged 50 gpd/cow. However, on dairies B, C, and D, the water usage in the wash pen averaged 30.6 gpd/cow (Table 1). The range of water usage in the wash pens varies greatly based on available research reports. A reasonable goal for dairies would be to have the average water consumption in the wash pen of less than 40 gpd/cow.

Fresh, potable water is required by most milk codes when flushing the parlor deck of parallel or herringbone parlors. Water can be recycled from the plate cooler to perform this task. Weeks (1992) reported that 7.5 gpd/cow was required for flushing the milk parlor and holding pen. However, the milk parlor was only used several hours per day. Some data suggest an adequate flush can be obtained using 1.3 gallons per sq. foot per flush (Moore, 1989).

The parlor decks area is approximately 4,000 sq. ft. in a D50 parlor (3,000 cow dairy) or 40 sq ft per milk unit. Daily water usage is 12 gpd/cow if the deck flushing routine uses 1 gal of potable water per sq ft for flushing 3 times per 8 hour milk shift. Some dairies are using Programmable Logic Controller (PLC) controllers to limit the valve open cycle and frequency of flushing the parlor deck to reduce potable water usage. If a dairy is trying match plate cooler water to parlor deck flushing, then only 19 gpd/cow of water should be used or a total of 14 flushes per day. Using the 1.3 gal/sq ft (Moore, 1989) then with the above example the deck floor could be flushed 11 times per day to balance the flush water required with plate cooler water utilized.

A target based on a plate cooler ratio of 2 to 1 should be to use less than 2/3 of plate cooler water for flushing the deck and the remaining 1/3 for available for filling water troughs. If a dairy flushes between every group of cows, then potable water usage is 32 gpd/cow and additional water will be necessary. Dairies using more than 1 to 1.5 gal per sq ft for deck flushing should evaluate their protocols and determine if water usage can be reduced. In rotary parlors, the plate cooler water should be utilized to fill water troughs since potable water is not necessary for washing a parlor deck. Some dairies flush the parlor deck more frequently than necessary to eliminate water tank overflows due to excessive plate cooler water. Water conservation strategies should incorporate protocols to reduce flush frequency and transfer water to other applications.

Conservation Practice 5: Evaluate Water Trough Protocols

Brouk et al. (2001b) monitored summer water disappearance in the housing area on three dairies. Combined water trough disappearance on one dairy averaged 35 gpd/cow. Based on Murphy et al. (1983) drinking water equation and Bray et al. (2014) water recommendations, water consumption was higher than anticipated. This dairy had a protocol to tip and clean all water tanks once a day. Based on the tank volume, it was estimated that refilling required 4.7 gpd/cow or was equal to approximately 14 % of the anticipated water consumption of 30 to 32 gpd/cow. Modern tanks which are shallower and have less water capacity use about 1 gallon per cow to refill a drained tank. Adjusting the frequency of cleaning water troughs to every 2 or 3 days may be a way to reduce water consumption without reducing herd health impacts. The other option is for the cow pusher to use a skimmer to remove the "crud" from the tanks rather than tipping or pulling a drain plug to clean the tanks.

Many dairies are located in colder regions where ice in water trough is a problem. One common solution is to adjust the floats to allow for a continuous flow of water. This management strategy results in approximately 1 gph/cow of extra water used with the continuous overflow management strategy. If water is being purchased, frost free or insulated water troughs may be economical.

Conservation Practice 6: Use and Control of Water Hoses in the Parlor

The authors are not aware of any studies looking at the water use by hoses located throughout the milk center. The general consensus of the milk center data collected is water used probably ranges from 6 to 12 gpd/cow. Strategically located hoses are critical in the milk center to maintain necessary sanitation to meet milk quality standards. Assuming a least one hose of the many hoses in a milk center is on 25 % of the time, then estimated water usage is 1 to 2.5 gpd/cow. Monitoring hose usage and total time per day to wash down individual claws may reveal an opportunity to conserve water in the milk center. Installing and maintaining easy to hose nozzles so no water flow is occurring when hoses are not in use will help conserve water.

Conservation Practice 7: Look for Abnormalities in the Cow Wash Cycles

Brugger and Dorsey (2008) relatively early in the Ohio pilot project discovered metering to be an effective management tool for water conservation. He noted:

> "*Observation of parlor water data revealed a 6-gallon per minute spike over "normal" usage. This 6-gpm flow remained even during down time of parlor water usage. Investigation eventually led to a faulty valve in the high pressure parlor wash down line. This*

> *"leak" was responsible for 8,640 gallons of waste water in a single day. Undiscovered, it could have resulted in much greater loss."*

Monitoring parlor water usage also led to observations of shorter and longer wash down cycles. This led management to conduct corrective employee training. After the training, the parlor wash water use was very consistent and at a reasonable level." Metering of the water usage during cleaning of the bulk tank metering discovered the recommended wash down cycles was shorter than desired. The drivers were not turning the activation knob to the full 60-minute position.

The Dairy Practice Council (DPC) (Weeks et al. 2004) recommends water requirement for bulk tanks with an automatic washing, cleaning in place (CIP), of 5 gallons of water per 100 gallon. So for a 5,000 gallon tank, the CIP water required would be 250 gallons. The DPC guide suggests 1, 4 and 3 gpd/cow for udder washing (towels), stall preparation and back flush milker units, respectively. The DPC "Guidelines for milkrooms and bulk tank installation" provide additional water usage recommendations for cleaning pipe line systems on pipe diameter and length.

Conservation Practice 8: Consider Eliminating Extra Yard Work (infrastructure leaks)

Most dairies have a small "wet spot" creating extra yard work due the green grass or weeds growing. These "wet spots" are due to infrastructure losses such as an above ground pipe joint that has a small "drip" leak or an underground leaking pipe. No one knows the volume of water lost on dairies due infrastructure leaks. A 2011 report by the California Public Utilities Commission estimated 10 % of all urban water deliveries are lost due to leaks and antiquated infrastructure. Review of web news articles of municipal public water supplies shows estimated infrastructure water losses from 3 to 20 percent. Martin (2016) noted California water losses could equal 840,000 acre-feet of water. This is approximately 75 gpd per US dairy cow.

Conservation Practice 9: Take Advantage of Free Water

Dairy cow's water intake is a combination of ration water and free water. Brugger and Dorsey (2008) estimated in the Ohio study cows obtained 6 gpd/cow of water from the fed ration. A 5 % decline in harvested silage moisture (from 60 % to 55 %) results in a loss of 67 gallons of water per ton of silage available as part of the ration water. This equates on a 3,000 cow dairy feeding 50 lbs of silage to 1.7 gpd/cow of free water that is lost by harvesting dry silage. Potts (2012) showed the free water to equal about 2.82 lbs of water per pound of milk based on his meta- analysis of research studies measuring water consumption of dairy cows.

Conservation Practice 10: Plug the Evaporative Cooling System Leaks

Harner et al. (2007) looked at water consumption of evaporative cooling pads on five different dairies. The average water usage was 0.33 gallons per hour (gph)/sq ft of evaporative pad and ranged from 0.1 to 0.75 gph/sq ft depending on temperature and relative humidity. Evaporative pad system leakage has been observed on US as well as international dairies. On each dairy, the distribution pipe and the return pipe were observed to have significant water leaks. It is recognized most leaks are due to inadequate implementation of the manufacture's recommended installation procedures of the evaporative cooling system. Proper installation to avoid leaks requires time during installation to seal all the joints and seams. While it is difficult to quantify the losses, to a casual guest on a dairy the water wastage is observable. A best guess is probably 3 to 5 % of the designed water consumption recommendation for an evaporative pad systems is lost from pad leaks occurring outside and inside the pad system.

Summary

There are many factors which determine water usage of a dairy, such as heat abatement practices, milk parlor protocols and milk production (drinking water). Many conservation practices may be implemented based on changes in management strategies such as on time of soaker systems, fixing leaks or cleaning of water troughs. Other conservation strategies will required installation of water meters to monitor actual usage in certain areas and then developing a plan to reduce water consumption. Priority by the management and helping employees understand the long term importance of water to the future of the dairy industry is necessary to transition dairies to the next gen.

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