The Effects of Implementing Cow Cooling for Oostdam Dairy: Benefits from Milk Production, Feed Intake and Reproduction

A Senior Project

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by

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Abstract

Heat stress has a major effect on management decisions for a dairy operation because of the decrease in the cows productivity. Dairy cattle loose efficiency of economic production due to lower milk yields and decreased pregnancy rates. Milk loss due to heat stressed cows in California averages a loss of 293 kg of milk/cow/year(St.-Pierre et al., 2003), and with milk prices reaching record highs, dairies are losing out on increased revenue opportunity. Increases in reproductive infertility from heat stress also affect revenue for a dairy operation by reducing conception rates (Hansen 1997) and pregnancy rates, which causes the average days open per cow to increase and less milk throughout the cows lactation This special project is guided by research in: the physical and economical effects of heat stress on dairy cattle, and the reduced physical and economical effects of heat stress through heat abatement systems. The goal of this special project is to establish an economically feasible cooling system, that efficiently reduces loss due to heat stress. Establishing cooling systems on the feed lines, and the wash pens on Oostdam Dairy resulted in $10,324.57 of extra income a month from increased milk production and reproductive fertility.

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Introduction

Until recently, dairy farmers have had to endure hard financial times in the dairy industry because of low milk prices and high feed costs. For the past five years, the objective of most dairyman for their dairy was to minimize monthly expenses to pay off some debt, and prevent having to sell their operation. Now that the dairy industry has turned around to having record high milk prices and feed cost slightly dropping, a good step to take is to determine if your cows could be producing more milk. With nationwide milk prices averaging around a record high $23 hundred weight of milk (CWT), dairymen should look to fix any possible causes of milk yield depression, in order to maximize revenue.

One cause that could be affecting the total milk production from dairy cows is if they are under Heat Stress. Heat stress occurs on dairy cows when the temperature of the surrounding environment is elevated above the animals thermoneutral zone, or comfort zone (Buffington et al. 1981). Dairy cows show signs of reduced feed intake, milk production and conception rates while experiencing heat stress, which is due to an increase in rectal temperature and respiration rates (Barth, 1982). Because of the potential for increased revenue, dairymen want to improve their cows production, and should implement tools and practices to maximize it as much as possible. Air, water, shade, and time are the four main elements that cause heat stress, as well as achieve heat abatement for a herd of dairy cows. These elements create unique conditions for dairies that are located in different geographic areas, so establishing a cow cooling system for one dairy might not work for another. This special project was done be reviewing the effects of heat stress and heat abatement tools used in cow cooling systems. By applying costs, this project will establish an economically feasible business plan that incorporates a cow cooling system for the herd of Holstein dairy cows owned by Oostdam Dairy.

Literature Review

Effects of Heat Stress

Avoiding heat stress on a dairy farm has become a key management goal for dairymen, and if it hasn't the dairy operation is probably losing out on economic opportunity. Economic losses for a dairy operation in a year can range up to $383 per cow, but by implementing a heat abatement system, dairymen nationwide could reduce total economic loss by up to $837 million dollars (N. St.-Pierre et al...2003). When a dairy cow experiences environmental conditions that are above its thermocomfort zone (Armstrong 1994), she is going to experience heat stress which causes a loss to the operation that could be avoidable.

Milk production for dairies is the main determinate of revenue for the operation compared to revenue from selling cull cows and day old animals. Total milk production for a dairy is influenced by feed intake, reproduction, culling due to reproduction and death rate. Heat stress affects overall milk production by causing decreases in feed intake and reproduction while increasing reproductive culling and death resulting in a national average loss of $167/cow/year.(St.-Pierre et al. 2003)

Dairy managers want to avoid decreases in dry matter intake because of the affect it has on milk production. This is especially important with current milk prices; it is to the dairyman's best interest to efficiently maximize production. Table 1 indicates that heat stress reduces the average dry matter intake by 145kg. (320 lb.)/year and milk production by 293kg. (646 lb.)/year per cow in California. When a cow decreases her dry matter intake, it has a direct affect with decreased milk yield. A dairy facility with compromised cooling abilities will allow for access heat production and accumulation in dairy cattle which causes an increase in body temperature, reduced dry matter intake, and ultimately reduced milk production (West 2003).

When lactating dairy cattle experience heat stress, they are at risk of a higher rate of infertility which represents an economic loss for the dairy owner. During the summer months, dairy cattle in the U.S. will drop on average 10 - 20% (Figure 1) for conception rates (Hansen, 1997). The increase in reproductive infertility results in less cows getting pregnant, and an increase in average days open with California dairies increasing an average of days open by 12 days(table 1).

Cows that experience heat stress have a correlation between increase in rectal temperature and decline of pregnancy rates. (Ulberg and Burfening 1967) showed that as rectal temperatures increased in dairy cattle, their pregnancy rates decreased along with them (Figure 2). Increased rectal temperatures affects dairy cows reproductive tracks which causes a decrease in reproductive efficiency.

Table 1: Annual production losses and periods of heat stress in California adapted from (St-Pierre et al. 2003)

DMI loss	Milk Loss	Av. increase Days Open	Heat Stress	THI
145 kg/cow per year	293 kg/cow per year	12.1 days	1039 hours/ year	5587 units/ year

Assessing Heat Stress

During the warm summer months, cows become more sensitive to their surrounding environmental conditions, which then affect their ability to perform efficiently. Dairy cattle experience heat stress in multiple areas of an open lot dairy including: the milking parlor/holding pen, and while eating at the feed bunks. The cows are sensitive to a combination of ambient air temperature and relative humidity because of the large production of metabolic heat that come from the cow ruminating and producing high amounts of milk (R. Collier et al...1982). Although this makes holstein dairy cows primary targets for incidences of heat stress, there are tools that management can use to reduce the incidences of heat stress.

Temperature-Humidity Index (THI) is a management tool that is utilized by dairy managers and other dairy specialist to asses a point where dairy cows will start to experience heat stress. The temperature-humidity index is established by finding the sum of dry and wet bulb temperatures in the surrounding environment. Generally, dairy cows will start to experience mild heat stress when the temperature-humidity index rises above their thermal neutral zone which is measured at THI>72, equating to an average of 25°C or 77°F, and 50% humidity (Ravagnolo et al. 2000). THI>72 is considered to be the point where acute enviromental conditions brings stress onto dairy cattle based on decreases in milk production while experiencing conditions greater than 72 (Igono et al.1992). Using THI as an indicator of heat stress is more accurate than ambient air temperature alone because of the measurements between air temperature and relative humidity. The THI can be used to improve management of heat stress more effectivelty by estimating cooling requirments.

An affective tool in reducing heat stress in dairy cattle during periods that THI is greater than 72 is water. Water can be used to cool cows through evaporative cooling. This involves soaking the cows and allowing that water to evaporate off the skin of the cow resulting in reduced heat. (Strickland et al., 1989) showed that the use of evaporative cooling through cooling systems can increase milk production by up to 2.1 kg/day/cow, which was an 11% increase compared to the control group.

Water can be used for heat abatement in the several areas of the dairy one of which is the holding pen in the milk barn. This is an especially critical area for incidences of heat stress because it is crowded and hot from the environment as well as the body heat being produced by the cows. Another area water is useful for heat abatement is over the feed bunks. Presenting a cooling system over the feed bunks promotes more time cows spend at the feed racks. (A. Legrand et al., 2011) showed that with access to water, cows stood underneath it for an average of 3h/24h a day. With increased times at the feed racks, cows should have an increase in dry matter intake.

Another tool for heat abatement is air movement, which can be assesed using fans. Fans help replace warmer air, produced by the dairy cows, with outside air that is cooler than their core body temperature when they are located in the milking parlor and in freestall pens. Because there is a significant ammount of heat produced by the cows and environment that gets trapped in the holding pen, fans are essential for keeping lower ambient air temperatures in the holding pen when the cows are waiting to be milked.

Individually, water is more important then fans for implementing heat abatement on a open lot dairy because of its capabilities of reducing both core body temperature and ambient air rather than just air temperature. Water and air movment together are more affective at heat abatement, especially in the holding pen. A trial in Arizona (Wiersma and Armstrong 1983) implemented a heat abatement system in a holding pen, using a sprinkler system that put out 18L. of water/hour per nozzel, and placed them in front of 48in. fans angled 30 degrees downward to effectively cover the animals. Using a control group that didn't have access to the heat abatement system, the trial found that the cows that did have access averaged 1.7ºC cooler in body temperature and a increase of .79 kg of milk/day during the summer months.

Shade is also an effective tool that helps cows avoid heat stress during the summer months. Shade is also effective for heat abatement because it gives the dairy cows protection from direct sunlight. Shade can be provided to dairy cows using different methods with most popular for open lot dairies being sheet metal structures, and 80% shade cloth structures. The popularity of these shade structures comes from their economic benefit of providing shade to dairy cows for a low price, and low maintenence.

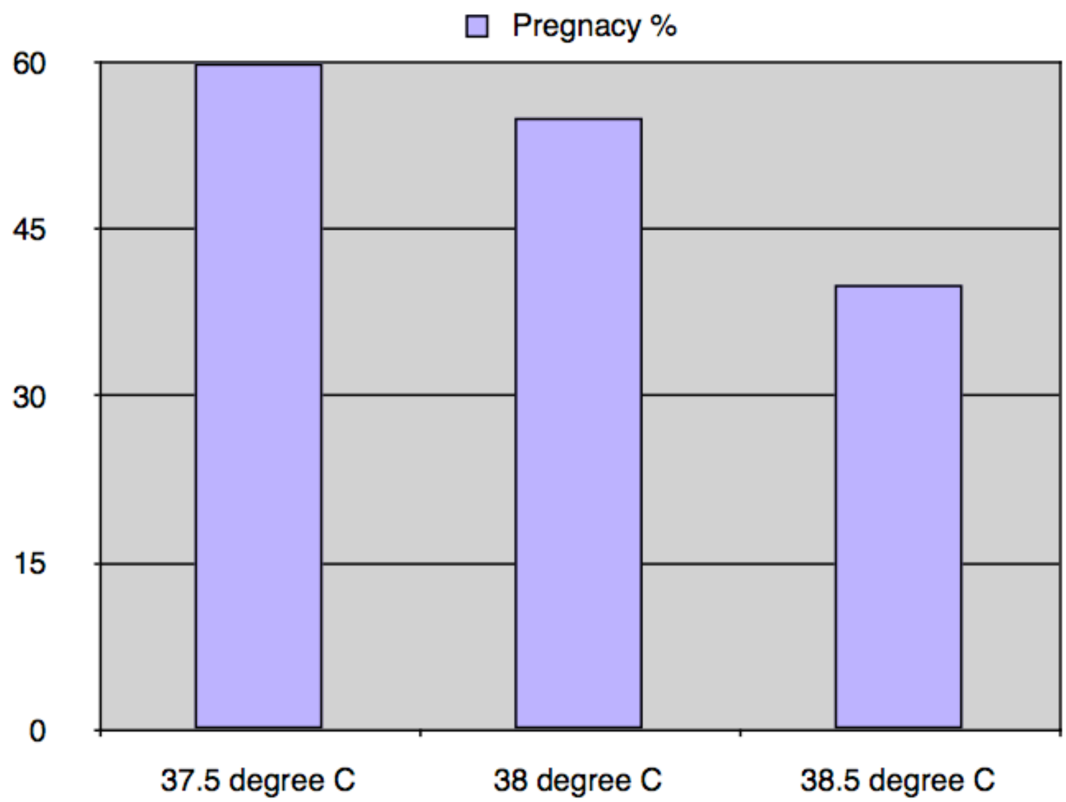

Figure 1: Pregnancy rates for dairy cattle with different rectal temperatures at breeding
Adapted from (Ulberg and Burfening, 1967)

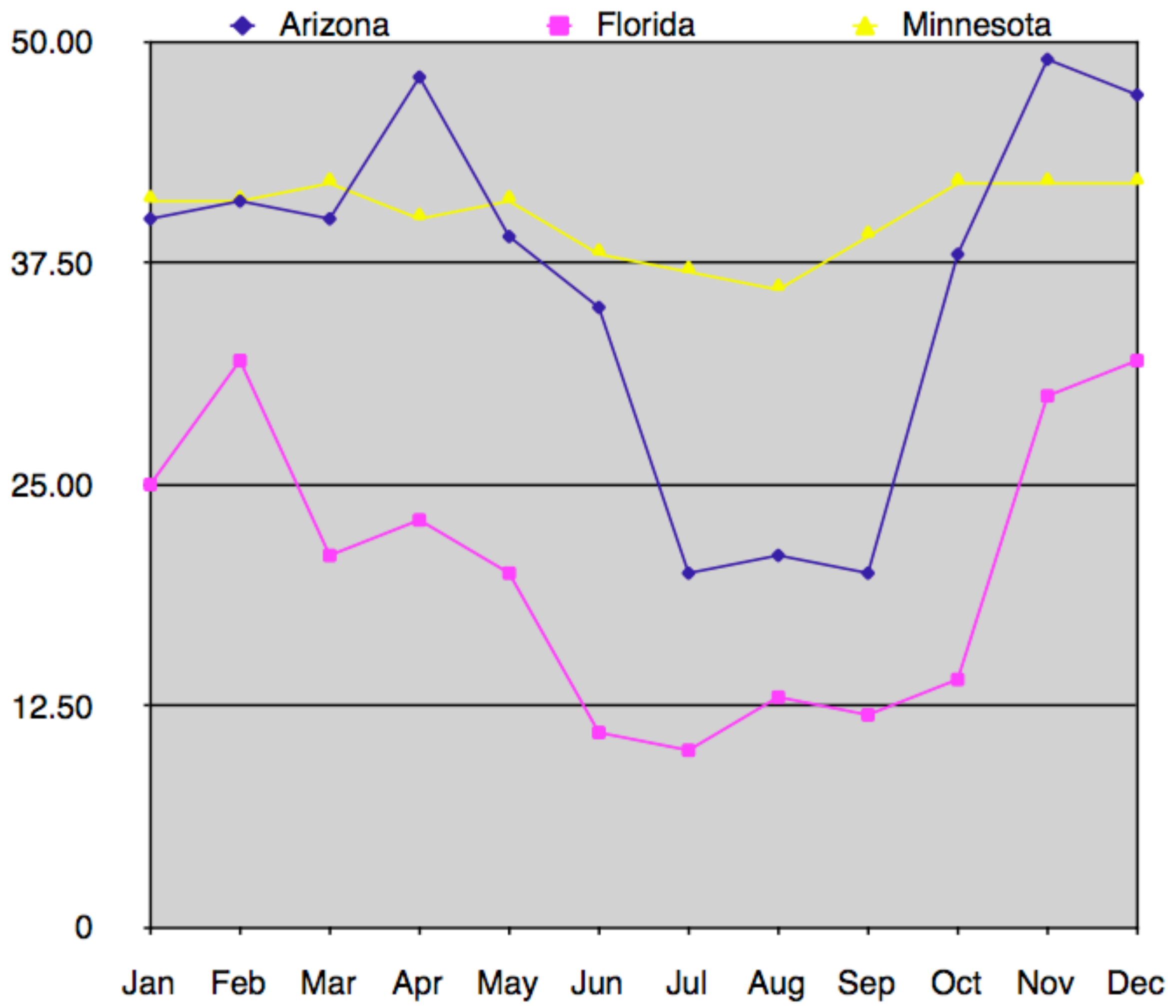

Figure 2: Conception rates for U.S. dairy cows in Arizona, Florida, Minnesota adapted from (Hansen et al., 1997)

Materials and Methods

Milk Parlor Holding Pen

In the holding pen it is recomended by cow comfort proffesionals that each cow receives 1000 cfm of airflow and turned on when the temperature reaches 65°F in order to maximize efficiency of heat abatement. There are two standard sizes of fans used in the dairy industry for heat abatement, one being a 36 in. fan which produce around 11,000 cfm and the other being a 48 in. fan which produces around 20,000 cfm. The fans need to be angled between 15-30° downwards in order to get maximum air flow coverage.

Along with the fans, the holding pen needs adequate water output to soak the cows and cause evaporative cooling. Recomendation for improving water coverage in the holding pen is to use a sprinkler nozzle with the sprinkler system which runs off of 20 psi of pressure and puts out 1.4 gpm of water covering a diameter of up to 20 ft. With the sprinkler nozzles located at least 8 ft above the ground, the sprinklers will be able to cover 150 sq ft, or 10 cows with a gallon of water. In order to maximize evaporative cooling, this system will have a control box that opens the solenoid to the sprinkler system when the teperature reaches 68°F, and pulsates the system to be on for 1 minute and off for 6 minutes.

There are two identical holding pens for Oostdam Dairy which are measured at 20ft. by 80ft., and can hold a just over 200 cows. Each holding pen will have 80 feet of 1.5in. PVC pipe will run down the center of the holding pen supported by cable, and will have ten 1in. droplines every 7ft. from the middle of the supply line. Using I-wob droplines, they will be connected to the water supply with a gooseneck fittings as the check system. Attached to a gooseneck fitting is a 1in. hose that will place the sprinkler 8 to 9ft. above the ground. Connected to the hose is the pressure reducer to achieve 10-15psi and a #6 nozzel that puts out 1.4 gpm of water and have a 20ft diamerter of water coverage. The water supply will be controlled by 1 zone Edstrom controller with thermostat that turns on at 68ºF for 1 minute and is off for 6 minutes. Along with the sprinkler system, fans will be placed near the ceiling at a 15-30º angle towards the ground, and facing towards the entrance of the holding pen so the air flow direction is towards the back. From the front of the parlor, two 48in. 1 hp. Aerotech Apex fans will be mounted on the ceiling 5ft. from the sides and 10ft from each other; there will be two fans mounted every 25ft to have a total of 8 fans mounted on the ceiling of the milk parlor and wash pen. Each fan will provide on average 34,900 cfm of airflow which is about 1,400 cfm per cow through out the parlor and holding pen.

Feed Line Soakers

While at the feed line, proticol for optimum heat abatement for cows is to run the soaker system for 1-2 minutes, with a total cycle time of 15 minutes when the teperature is between 68º and 82ºF. When the temperature rises above 82ºF, it is optimal to to reduce the total cycle time to 7 minutes. Nozzles that put out around .5 gallons/minute are to be spaced every 7.5ft on the feed line soaker to maintain a lower inlet water demand and to get adequate water coverage. Using nozzles with check valves is also a good way of preventing water loss by minimizing dripping and keeping the water lines full instead of having to fill up every time the system turns on.

Feed line soaker systems can be mounted in a high position or a low position which both have strengths and weakenesses. A high mounted soaker system are approximately 6ft. above the cows which prevents from human and animal caused damage, but can allow for water drift due to the wind. A low mounted soaker system has less water drift away from the cows, but it has more potential of being damaged. It is necessarry for both mounting styles that the systems are sturdy and have adequate support to minimize maintenance.

On Oostdam Dairy, roughly 1,400 milking cows are seperated into seven “milk” pens. Pens 1,3, and 7(Group 1) have water supply located on the northern side of the pens and have 520ft. of feed line while pens 2,4,5, and 6 (Group 2) have water supply on the southern side of the pens and have 535ft. of feed line. The soaker system for each pen will be connected to the water line with a water filter with a 50-micron canister, a 2in., 36gpm. solenoid valve that is controlled by a multiple zone control box, and a pressure reducer to achieve 10-15 psi. With each pen being a zone, Group 1 pens will have a

Edstrom C440S multizone control box that regulates three solenoid valves, and Group 2 pens will have a seperate Edstrom C440S control box that regulates four solenoid valves. The control boxes will be programed to cycle every 15 minutes, running each zone for 1.4 minutes when the temperature is above 68ºF in order to manage inlet water demand for the system, and prevent from having an abundance of water in the feed lanes and corrals. The water supply will then be distributed down the feed lines with 2in. schedule 80 PVC pipe running 520ft. for Group 1 pens and 535ft. for Group 2 pens. The PVC pipe will be mounted in low positions approximately 5-6ft above the ground and will be supported by angle iron. TeeJet® brass nozzle body, check valve and cap will be placed every 7.5ft. for each pen and the Turbo Flowjet nozzle TF-VP5 tip will put out .7gal of water/minute at 10-15psi of pressure. With a total of 3,700ft. of feed line distance, there will be about 495 nozzles spaced 7.5ft. apart. Group 1 pens will have approximately 70 nozzles per pen, while Group 2 pens will have about 72 nozzles for each pen.

Results and Discussion

Milk Parlor Holding Pen

The milk barn on Oostdam Dairy is designed with two identical holding pens and parlors that milk aproximately 1,400 cows twice a day. Each holding pen will have the same heat abatement system that has been parted an priced out by Southern California Dairy Equipment(So. Cal. Dairy Equipment) in Chino, Ca. Table 2 presents the parts and the cost for each part used to create the heat abatement systems. The designed system will cost $9,105.50 for each holding pen, giving a total of $18,210 for the parts and equipement for both systems. Additional cost involved with the implementation of heat abatement systems will come from labor/installation cost which is presented on table 4. The estimated costs for installing both sprinkler systems and fans by So. Cal. Dairy Equipment will be approximately $3,000.

Feed Line Soakers

Table 3 presents the parts and cost of each part that will be needed in implementing feed line soakers for the 7 milking pens on Oostdam Dairy. Having a total 3,700 feet in feed line lenth, the feed line soaker system was created by seperating 3 pens into Group 1, and 4 pens into Group 2 with each group being controlled by a Edstrom C440S control box. The designed system with all its parts was priced out by So. Cal. Dairy Equipement and has a cost of $27,771.85. Addition cost will come from labor/installation presented on table 4 and was estimated by So. Cal. Dairy Equipment to cost approximately $2,000.

Milk Production

Table 1 presents the losses in milk production and feed intake due to heat stress experienced by lactaing holstein dairy cows in California. With an esitmated loss of 646lb./milk per cow/year, the dairy operation is loosing roughly $167/cow/year due to heat stress(St. Pierre et al., 2003). By implementing heat abatement systems, the estimated revenue loss can be reduced to about $100/cow/year(St. Pierre et al., 3003). The reduction in revenue loss is the result of productive improvements as shown by (Wiersma and Armstrong 1983), being that cows increase milk production approximately 0.8kg. of milk per day when offered heat abatement.

Reproduction

Dairy cows that experience heat stress in California average an extra 12 days open in their calving interval as shown in table 1. This is caused by increased body temperatures which have a direct effect on reproductive efficiency(Ulberg and Burfening 1967). It is estimated at a dollar value for the dairy owner of $25.00 per cow/day for each percentage change for a dairy's pregnency rate. In figure 1 they show that pregnancy rates drop nearly 20%

when a dairy cows rectal temperature inceases 1°C. By implementing a sufficient cooling system throughout the dairy, the milk cows will have a decrease in rectal temperature on average of 1.7°C(Wiersma and Armstrong 1983).

Table 2: Milk Parlor Holding Pen Cooling System Parts and Costs

WASH PEN/ per Pen		EACH	EXT
80	1.5" PVC PIPE SCHD40	$ 1.00	$ 80.00
10	1.5" PVC TEE SCHD40	$ 2.30	$ 23.00
10	1.5" X 3/4" THRD BUSHING PVC	$ 2.15	$ 21.50
1	1.5" FM THRD ADAPTER PVC	$ 1.10	$ 1.10
1	1.5" PLUG M THRD PVC	$ 1.20	$ 1.20
100	CABLE 1/4" SS	$ 1.80	$ 180.00
4	CABLE CLAMPS 1/4"	$ 0.40	$ 1.60
10	I-WOB SPRINKLER W/ #6 NOZZLE	$ 32.30	$ 323.00
10	GOOSENECK FIT SINGLE 180 NPT	$ 4.95	$ 49.50
10	PRESSURE REDUCER 12PSI	$ 14.70	$ 147.00
10	3/4" FNPT X BARB ADAPTER	$ 1.90	$ 19.00
1	3/4" BLACK HOSE ROLL	$ 118.00	$ 118.00
1	EDSTROM CONTROL C110S	$ 642.00	$ 642.00
1	WATER FILTER 50-MICRON CANISTER	$ 271.00	$ 271.00
1	SOLENOID VALVE 1.5" 15GPM NC 24V	$ 89.00	$ 89.00
1	1.5" BALL VALVE PVC	$ 18.60	$ 18.60
8	Aerotech Apex FAN 48" 3-WING 1HP	$ 840.00	$ 6,720.00
1	MISC MOUNTING HARDWARE	$ 200.00	$ 200.00
1	MISC ELECTRICAL	$ 200.00	$ 200.00
	Total		$ 9,105.50
	Total for 2 Wash Pens		$18,211.00

Table 3: Feedline Soakers Parts and Costs

FEEDLINE SOAKERS			
3700	2" PVC PIPE SCHD80	$ 2.25	$ 8,325.00
7	2" PVC BALL VALVE SCHD80	$ 65.80	$ 460.60
1	MISC PVC FITTINGS - 90s, COUP, ETC	$ 250.00	$ 250.00
3700	ANGLE IRON 2X2	$ 2.05	$ 7,585.00
750	GEAR CLAMP STRAP	$ 1.15	$ 862.50
495	CP1322, TeeJet body DR ¼ npt	$ 2.10	$ 1,039.50
495	CP1325, TeeJet cap, brass	$ 1.30	$ 643.50
495	11750-PP-10, check valve	$ 5.25	$ 2,598.75
495	TURBO FLOWJET NOZZLE TF-VP5	$ 2.80	$ 1,386.00
2	EDSTROM CONTROL C440S	$ 770.00	$ 1,540.00
7	WATER FILTER 50-MICRON CANISTER	$ 271.00	$ 1,897.00
7	SOLENOID VALVE 2" 36GPM 24V	$ 112.00	$ 784.00
7	PRESSURE REDUCER 10-15PSI (included)	$ 0.00	$ 0.00
1	MISC MOUNTING HARDWARE	$ 200.00	$ 200.00
1	MISC ELECTRICAL	$ 100.00	$ 100.00
1	WELDING & CUTTING MATERIALS	$ 100.00	$ 100.00
	Total		$27,771.85

Table 4: Cost of Labor/Installation for Oostdam Dairy Cooling Systems

LABOR	HANG WASH PEN LINE & INSTALL NOZZLES	
	WIRE & PROGRAM CONTROLLERS F/ WASH PEN	
	HANG & WIRE FANS	
	WELD ANGLE IRON F/ FEEDLINES & MOUNT PVC	
	TAP & INSTALL NOZZLES	
	WIRE & PROGRAM CONTROLLERS F/ FEEDLINE	
	Total	$ 5,000.00

Costs of Cooling Systems

The cost of implementing cooling systems for two wash pens and 3,700ft of feed lines for Oostdam Dairy was quoted by Southern California Dairy Equipement to be $50,982.85(tables 2, 3, 4). In order to pay for the cooling systems, a 5 year/$50,000 loan at 6.25% interest will cover the inital cost of the systems and be paid off in only 5 years. The total amount of interest that will be paid on a 5 year/$50,000 loan at 6.5% interest will be $8,347.79.

Along with the intial cost of the system, their will be an increase in energy cost due to adding 16 fans in the wash pens. Each Apex 48in. fan uses about 1.15kWh in order to produce 34,900cfm. The additional 16 fans will increase energy usage in the milk barn by 18.4kWh, with the price being $0.10kWh during the peak-summer months. Running 16 fans from March - September for 18 hours a day results in an additional $6,955.20 a year for the electric bill. Table 5 presents the total cost from the cooling systems, priced out and installed by So. Cal. Dairy Equipment, interest expence from the loan, and the increased electric cost caused by the fans. Results for the costs of implementing this system over 5 years is $94,106.64

Benefits of Cooling Systems

The study done by (Wiersma and Armstrong 1983) showed that dairy cows with access to heat abatement improved milk production by 1.8lb of milk/day/cow. An additional 1.8lb of milk/cow/day applied to Oostdam Dairy's 1,400 milking cows results in an additional 75,600lb. of milk per month. The additional milk multiplied by $23cwt of milk results in $17,388 of increased revenue per month. Utilizing the heat abatement system March - September, 7 months of increased chances of heat stress, Oostdam Dairy has potential revenue of $121,716.00.

(Wiersma and Amstrong 1983) also showed dairy cows with access to heat abatement had an average lower rectal temperature of 1.7ºC. By decreasing the cows body temeperature, there will be an increase in reproductive fertility and pregnancy rates. An industry estimated value of reproduction for a dairy is $25 per cow/ 1% increase in the pregnancy rate. An expected improvment for Oostdam Dairy's pregnancy rate is 3%, from 18% - 21% by maintaing higher rates during the warmer months. A 3% increase in pregnancy rate results in an additional $75/cow per lactation; by multiplying the increased value per cow to Oostdam Dairy's 1,400 cows, the results are an increase in revenue of $105,000. Table 5 presents the profit from increased production of milk from March - September, and the increased profit from increasing the pregnancy rate. Results for the additional revenue from increased milk production and reproduction over the 5 year payoff period is $713,580. By implementing this system, Oostdam Dairy will increase total extra income per month by $10,324.57.

Table 5: Total Cost and Benefit of Cooling System

Cost of Cooling Systems	
So. Cal Dairy Equipment	$50,982.85
6.5% int. on 5yr/$50,000 Loan	$8,347.79
Extra Electricity Usage over 5 years	$34,776
Total 5 Year Cost	$94,106.64
Benefits of Cooling Systems	
Increased Milk Production per Year	$121,716.00
Increased Reproduction/ 3% Preg Rate	$105,000.00
Total 1st Year Revenue	$226,716.00
Total 5 Year Revenue	$713,580.00
Total Extra Income/Month for 5 years	$10,324.57

Conclusion

Dairy cows the experience heat stress lose a lot of production efficiency during their lactation. This to a dairy operation is missed opportunities of potential revenue. Oostdam Dairy having minimal heat abatement, is losing potential revenue due to decreased performance in production and reproduction. By implementing the designed heat abatement systems to the feed bunk lines and the wash pens, Oostdam Dairy could see an increase of $10,324.57 income per month.

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