Dairy and Livestock **RESEARCH REPORT**

California Dairy Energy Project

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Introduction

The California Dairy Energy Project is an on-going team effort by University of California Cooperative Extension farm advisors, the California Energy Commission, Pacific Gas & Electric, Southern California Edison and various dairy industry representatives. It's goal is to improve energy efficiency, promote energy conservation and reduce energy costs on dairy farms.

The project involves intensive field surveys, on-farm demonstrations, monitoring of new technologies for energy conservation and educational activities. Funding for the project is provided by the California Energy Commission, Southern California Edison and Pacific Gas & Electric.

Since the inception of the project, alliances have been forged with other groups who have similar interests such as the Cornell Ag Energy Program in New York and the Wisconsin

Center for Dairy Research in Madison, Wisconsin.

Energy use survey of central California dairy herds.

A survey of 93 dairies in the southern San Joaquin Valley was conducted in 1994-95 to provide baseline information on types and sizes of equipment that contribute to the dairy farm electric load. Data were collected during on farm visits by Extension personnel who interviewed owners and inventoried equipment, lights and ventilation fans in the milking center and corral area. Herd sizes ranged from 95 to 3200 cows and averaged 984 cows/herd.

Ninety percent of the dairies milked twice and 10% milked three times daily. Average daily milk yield for the 93 dairies was 67.5 lbs/cow. Distribution of dairies by milking parlor type was 65% herringbone, 25% flat barn, 5% parallel and 5% side opening.

Types of vacuum pumps represented on the dairies were 95% water ring, 3% lobe blower and 2% turbine. Vacuum pump horsepower (hp) averaged 1.02 ± 0.28 hp/milking unit.

Milk pump hp averaged 0.10 ± 0.04 hp/milking unit. The total connected hp for refrigeration and air compressors, milk and vacuum pumps averaged 67.3 ± 42.0 hp per dairy farm. On a per cow basis, the connected hp per cow averaged 0.08 ± 0.03 hp/cow.

Fifty eight percent of the dairies used heat exchangers (mainly plate type coolers) to precool milk with well water; 36% used heat exchangers with well water and chilled water for instant cooling and 5% of dairies had no precooling. Water heating was fueled by propane on 68% of the dairies; 26% used natural gas, 5% used electricity and one dairy used a vacuum pump heat exchanger.

The survey data are being used to develop energy performance indicators and to help estimate potential energy savings from adopting energy efficient technologies. Similar data for 100 dairies in Southern California is currently being reviewed and summarized. Upon completion, the data set will include a total of nearly 200 dairy farms.

Relationship of herd size to efficiency of electrical energy use

Monthly milk production and electrical energy use data were collected for a 12 month period from 42 of the 93 dairies in the southern San Joaquin Valley. The objectives were to examine connected electrical load patterns and to develop energy performance indicators to help determine energy management opportunities. Energy use data represented electricity used for harvesting, cooling and storing milk, water pumping and heating, ventilation and lighting.

Electrical energy use averaged 1603 kilowatt hours (kWh) per dairy per day or about 42 kWh per cow per month. The average rate for electricity in the San Joaquin Valley is $0.09/kWh, so the 42 kWh/cow/month amounts to $3.78 per cow per month for electrical costs. The performance indicator of milk produced per unit of electricity used averaged 48 lbs milk/kWh, but there was wide variation ranging from 30 to 67 lbs milk/kWh.

Expressed another way, kilowatt hours per hundredweight (cwt) of milk averaged 2.15 kWh/cwt of milk with a range from 1.49 to 3.32 kWh/cwt of milk. If we use a rate of $0.09/kWh, then electricity costs averaged 19.4 cents per hundred pounds of milk. This represents about 1.6% of total milk production costs for the time period.

To examine the relationship of herd size to energy use, statistical tests called regression analyses were performed on the data. These tests show what correlation there is between different parameters of interest.

Regression analyses showed that as herd size increased by 100 cows, there was a significant increase of 4557 kWh per month (r= 0.92, P.01). There was a very weak negative correlation for lbs milk/kWh as herd size increased (r=-0.17, P.29). The regression showed a decrease of 0.2 lbs. of milk/kWh for each 100 cow increase.

There was a wide variation from 1.5 to 3.0 kWh/cwt of milk for dairies of similar size. Not surprisingly, total connected horsepower for refrigeration and air compressors, milk and vacuum pumps increased as herd size increased (r=0.88, P.01). However, total connected hp per cow decreased with herd size increase (r= -0.42, P.01).

Although total connected hp and electrical energy use increased with increasing herd size, efficiency of electrical energy used for milk production (milk/kWh) was unrelated to herd size.

On-farm demonstrations of vacuum controller relocation for improving efficiency of vacuum control and potential energy savings

On-farm demonstrations have been another important part of the CEC Dairy Energy Project. We performed demonstrations on several dairy farms during 1994-95 to show the importance of proper vacuum controller location. Our survey data show that vacuum controllers are improperly located in 70% of dairy barns.

The recommended location in the milking system for direct sensing vacuum controllers like the Sentinel (the controller type used on 90% of California dairies) is as close to the cow as possible. The closest location to the cow on the vacuum supply line side of the milking system is a position near the sanitary trap as shown in Figures 1 and 2.

Over the years, dairies have mounted the controller in a variety of places on the vacuum system, but least often in the recommended position. The usual location is on the balance tank or plumbed from it to the equipment room, a bathroom, an office or a closet. Dairy producers like these installations because noise in the breezeway is reduced and the controller stays cleaner.

For the most part these installations have been successful. However, new instrumentation and methods for measuring the efficiency of vacuum control have been developed during the last few years. The tools are now available to effectively show that the controller operates much more efficiently in the recommended position near the sanitary trap compared to installations at other locations.

Current recommendations of the National Mastitis Council are that efficiency of vacuum control (regulation efficiency) should be 90% or greater. *(1)*

For the demonstration project, we conducted milking system airflow measurements on dairy farms in the San Joaquin Valley and in Chino. Farms were selected based on their willingness to cooperate and their potential for improvement. Effective and manual reserve were measured to determine regulation efficiency. If the efficiency was less than 90%, recommendations for simple design changes involving relocating the vacuum controller were made. Results of efficiency tests are shown in Table 1:

Table 1. Effective and Manual Reserve (CFM) Before System Changes

DAIRY	ER	MR	ER/MR
A	121	126	96%
B	65	328	20%
C	121	203	60%
D	149	314	47%
E	116	216	54%
F	80	180	44%
G	70	140	50%
H	149	250	60%
I	30	204	15%
J	58	194	30%
K	142	198	72%
L	66	176	38%
M	185	278	66%
N	70	176	40%
O	114	236	48%
P	76	128	59%
Q	36	274	13%
R	122	135	90%

S	86	103	84%
Average	98	203	49%

ER = effective reserve; MR = manual reserve; CFM = cubic feet/min
ER expressed as a percentage of MR is the % efficiency, ER/MR
The tests were conducted under modified conditions, i.e. vacuum shut off valves to the claw cluster were closed and pulsators were off. The average efficiency was only 49%. Only two of the dairies tested had efficiencies that were 90% or higher; the others fell below the recommended level of regulation efficiency. All dairies except dairies I and Q had adequate or excessive effective reserve (the air available for milking). The manual reserve (the air potentially available) was much higher than the effective reserve on most of the dairies.

Eight of the dairies that we tested relocated their vacuum controller and improved regulation efficiency as a result. The efficiencies (ER/MR) measured before and after the conversion are shown in Table 2.

Table 2. Regulation Efficiency (ER/MR) Before and After Relocation

Dairy	Before ER/MR	After ER/MR
B	20%	100%
D	47%	98%
I	15%	98%
J	30%	100%
K	72%	92%
L	38%	96%
M	66%	92%
N	40%	100%

Why did the plumbing changes improve regulation efficiency? The system vacuum level varies throughout an installation (it has to in order for air to flow toward the vacuum pump). Pressure differences result from frictional losses in air lines that are related to the length and diameter of the lines, as well as to the velocity of air flowing through them. However, these pressure differences should be kept to a minimum and should not exceed 0.2" Hg in a well designed system.

We measured vacuum levels at the pump, the milk receiver and at the vacuum controller as part of the efficiency test on all the demonstration farms. Large differences in vacuum level were noted on the farms with poor efficiency. For example, vacuum level at the milk receiver on dairy B before the conversion was 12.7" Hg, but was only 10.7" Hg at the vacuum controller. After the conversion the vacuum level was nearly the same at both locations. The ER/MR changed from 65 /328 cfm or 20%; to 328 /328 cfm or 100%.

By moving the vacuum controller closer to the trap and simplifying the plumbing, pressure differences were greatly reduced in the vacuum system. The controller was then able to close and more air became available for milking. After the conversion, excess air was bled off through a filtered valve at the vacuum pump until a decision was made concerning downsizing the vacuum pump. Several dairies have geared down existing motors or installed a smaller vacuum pump and motor. There have been no increased mastitis or cleaning problems on these farms.

In order to estimate electrical energy and cost savings from downsizing vacuum pump motors, the utility companies measured kW demand of vacuum pump motors before and after downsizing. For example, after making the vacuum system changes, dairy B was able to replace a 30 horsepower, Nash 701 vacuum pump with a 20 horsepower, Nash 401. This change has resulted in saving over $6000/year on the utility bill. Since the cost to make the vacuum system changes was only $2400, the investment paid off in less than a year.

Example: Dairy B - Double 24 Herringbone

2200 cows milking 20 hrs/day

	Before	After
Efficiency	20%	100%
Pump	Nash 701	Nash 401
Motor	30 hp	20 hp
kW demand	25.2 kW	15.7 kW

Savings:

25.2 kW - 15.7 kW = 9.5 kW
9.5 kW x 20 hrs/day = 190 kWh/day
190 kWh/day x 365 days/yr = 69,350 kWh/yr
69,350 kWh/yr x 9 cents/kWh = $6,241.50/yr

The potential energy savings on any particular farm will depend on the kW demand before and after changing out (or belting down) a pump and motor, the hours of use and the electrical rate. Our work indicates that each 10 hp in excess of capacity (vacuum pump motor) results in $400 -$600 per month of unnecessary utility costs.

It is difficult to estimate the economic value of other potential benefits from improving regulation efficiency. These benefits might include improved milking performance, milk quality and udder health. In the long run these benefits could far outweigh the energy savings component of the vacuum controller relocation.

One of the dairies (dairy H) was able to improve efficiency of vacuum control without making a plumbing change. Three turbine type vacuum pumps (17 horsepower each) provided the vacuum for this double 25 parallel barn. The initial ER/MR was 149/250 cfm, or 60% as shown in Table 1.

We asked the manager to turn one of the vacuum pumps off and then we repeated the test. The ER/MR with two pumps running was 150/158 cfm or 95%. With less total vacuum pump capacity the same cfm was available for milking as when three pumps were operating! This illustrates the importance of considering airflow in addition to length and diameter of pipelines in vacuum system design.

Our results indicate that many dairies in California create more CFM than can be efficiently used because of poor vacuum controller performance. The poor performance is related to vacuum system design, not to faulty vacuum controllers. There is tremendous potential to improve efficiency and save energy by relocating the vacuum controller on many farms.

New recommendations for lower vacuum pump capacity will soon replace current standards. *(2)* Demonstrations and educational programs for dairy producers and milking equipment technicians will be important activities for encouraging adoption of the new standards.

Monitoring of new technologies

The last task of the CEC project will be to monitor emerging technologies that have potential to conserve energy on dairy farms. Some of these technologies are only new in the sense that they have not had applications on dairies until recently. For example, variable or adjustable speed drives have been around for some time. They are now being used on milk pump motors in dairy barns.

Variable speed drives for milk pumps can even out the flow of milk through a plate cooler to enable more efficient heat exchange. Ag engineers at Cornell University in New York have shown substantial energy savings for milk cooling when comparing variable speed drive milk pumps to conventional milk pumping *(3)*. We will soon be metering energy used by refrigeration compressors on dairies with variable speed drive milk pumps to quantify potential savings under California conditions.

Another application for variable speed drives is on vacuum pump motors. This technology may soon be commercially available. Several demonstration farms with the Cornell Ag Energy Program have installed variable frequency drives with proportional integrated differentiated control on their vacuum pump motors.

Data from these farms have shown that electricity used to run the vacuum pump is about half that of a conventional vacuum system *(4)*. We would like to test this system in California with water ring and blower type vacuum pumps.

Lastly, we want to test the ability of high temperature exhaust from specific vacuum pump types to heat water, and compare the economics of such a system to conventional water heating. These activities will keep us busy during the coming year.

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