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Relationships Between Teat Shape, Teat Erosion, California Mastitis Test, and Milk Production in a Large Dairy Herd

John Sephen Malan
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RELATIONSHIPS BETWEEN TEAT SHAPE, TEAT EROSION, CALIFORNIA MASTITIS TEST, AND MILK PRODUCTION IN A LARGE DAIRY HERD

by

John Stephen Malan

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE in Dairy Science

Approved:

Major Professor

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UTAH STATE UNIVERSITY
Logan, Utah
1975
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John Stephen Malan
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ABSTRACT

Relationships Between Teat Shape, Teat Erosion, California Mastitis Test, and Milk Production in a Large Dairy Herd

by

John Stephen Malan, Master of Science
Utah State University, 1975

Major Professor: Dr. Robert C. Lamb
Department: Dairy Science

Data were collected from a 1,000 cow commercial dairy unit during three different time periods to determine the interrelationships between teat shape, teat erosion, mastitis (as measured by the California Mastitis Test and somatic cell counts), and milk production.

Results showed no relationship between teat shape or teat end erosion and milk or fat production. The relationship between teat end erosion and mastitis appeared to be masked by the high level of teat erosion. There was an indication that cows with flat and cone shaped teat ends were prone to higher California Mastitis Test scores than cows with pointed, round, or disk shaped teat ends. Pointed teat ends showed the highest amount of erosion and cone and flat teat ends showed the least amount of erosion. There was a high correlation between the California Mastitis Test and somatic cell counts.

Teat end erosion and California Mastitis Test scores decreased and milk production increased when a change in milking equipment and milking technique occurred and teat dipping was instigated.

(67 pages)
INTRODUCTION

The Mastitis Complex

Mastitis is a term derived from the Greek word "mastos" meaning breast and the suffix "itis" meaning inflammation of. The response of the mammary gland to trauma is defined as inflammation or mastitis. The occurrence of inflammation is an attempt to destroy the irritant so that the mammary gland can return to its normal function. Mastitis is very complex, having different causes, different degrees of intensity, and variations in duration and residual effects.

Many definitions have been used to distinguish between different classes of mastitis. Only two terms will be used within this thesis: clinical mastitis and subclinical mastitis. Clinical mastitis refers to the presence of visible signs of abnormal milk such as flakes or clots. The affected quarter may be characterized grossly by swelling, heat, redness, and pain. This form tends to be an individual cow problem and relatively short in duration. Subclinical mastitis refers to the existence of inflammation of the mammary gland, but the absence of visible abnormalities in the milk. The subclinical form is usually detected only by cowside screening tests such as the California Mastitis Test (CMT). Subclinical mastitis is considered a herd problem. Improved management techniques which effectively control subclinical mastitis upgrade the entire herd. Subclinical mastitis usually precedes the clinical form. The subclinical form is of long duration, reduces milk production and adversely affects
the quality of milk. Several authors (Brown et al., 1963; Roberts, 1969; Janzen, 1970) have estimated that annual financial losses due to mastitis in the U. S. range from $225 million to one billion dollars, making it the most costly disease of dairy cows. These losses result from reduced milk secretion, degrading of milk due to poor quality, veterinary fees for care and treatment of mastitic cows, and the cost of replacements for cows culled.

Objectives of Study

It has been suggested that a relationship exists between the shape of the teat and the incidence of mastitis. Erosion of the teat apex may contribute to harboring micro-organisms and may be indicative of milking equipment problems, both of which contribute to mastitis. The relationship between teat shape and teat erosion and their relationship with milk production is unknown.

It is hypothesized that if relationships do exist between teat shape, teat erosion, mastitis, and milk production, management may be able to use teat shape and erosion information as management tools to reduce mastitis and increase production.

The objectives of this study were to determine if correlations exist between teat shape and mastitis and between teat erosion and mastitis and if interrelationships exist between teat shape, teat erosion, mastitis (as measured by the California Mastitis Test and somatic cell counts), and milk production.
Magnitude of the Mastitis Problem

Roberts et al. (1969) estimated the cost per cow per year in the U. S. due to mastitis to be about $70. Five years later, Nicolai et al. (1974) divided the dollar loss due to mastitis: 14% from death and premature culling; 8% from milk discarded at treatment; 8% from drugs and veterinarian expense, and 70% from lost milk production.

Newbould (1968) reported that about 50% of the quarters of cows in a typical dairy herd had subclinical mastitis, yet only 1 to 8% of the quarters were affected with clinical mastitis at any one time. Philpot (1969) surveyed 25 herds and found 62% of the cows were infected in at least one quarter; however, only 9% were infected in all four quarters. The authors of Current Concepts of Bovine Mastitis, Brown et al. (1963), indicate that at least 50% of the cows in the U. S. are infected with pathogenic organisms in an average of two quarters per cow. Nicolai et al. (1974) estimated that where there is no effective mastitis program, approximately 50% of the cows will be infected in an average of two quarters each, and three of every four cows will be infected 75% of their milking life.

In a recent study at Cornell University as reported by Nicolai et al. (1974), milk losses from a single infected quarter averaged 1,700
pounds of milk per year. At $7.50 per cwt. of milk, losses would be $127.50 per cow per year. The same study also showed an increase of 1,051 pounds of milk per cow occurred when an effective mastitis control program was instigated. In another study, economic losses due to mastitis ranged from $23.26 to $154.34 per cow per year before treatment as opposed to $28.09 to $82.00 per cow per year after treatment (Janzen, 1970). Janzen (1970) found that production losses due to mastitis amounted to 5 to 25%. Losses per quarter per day equalled .76 to 5.86 pounds or 9 to 43%. Other losses occurred because of changes in milk composition due to intramammary infection. For example, fat test decreased .10 to .45%; solids-not-fat .10 to .57%; lactose .10 to .77%; and total solids 1.07%.

In a study with 234 cows in six separate herds with an average production of 50 pounds per cow per day, an income of about $2.50 per cow per day was generated. The CMT was used to determine the economic loss from cows having subclinical mastitis. Cows with CMT scores of negative produced 2.2, 11.3, 23.7, and 32.6 cents per cow per day more than cows with CMT scores of trace, 1, 2, and 3, respectively (Appleman, Rowe, and Forker, 1965).

Teat Shape in Relation to Mastitis

Hickman (1964) found that the incidence of mastitis was greater with an increase in the diameter of the bovine teat. He classified teat shape according to cylindrical, funnel, and bottle shapes. There was an indication that cylindrical rear teats were more conducive to mastitis than funnel or bottle shaped rear teats. The
same relationship held true with the front teats, but there was no statistical significance. Cows with short front teats produced significantly more milk than those with long teats. The lowest incidence of mastitis occurred with medium-to-long front teats and short rear teats.

Other authors suggest that the size and shape of the teat, length of the teat canal, and superficial sores on the teats do not appear to be related to the incidence of mastitis (McEwen and Cooper, 1947; Murphy and Stuart, 1955; Stuart and Lancaster, 1949).

Ovesen (1972) classified bovine teats into two categories: bottle-shaped, cylindrical, funnel-shaped, and pear-shaped teats in the first category, and pointed, round, flat, and concave shaped teats in the second category. The average rate of milk flow was significantly higher for teats with flat and concave tips than for cows with pointed and round teat ends. Ovesen (1972) hypothesized that the concave teat end was predisposed to bacterial invasion because of the difficulty in cleaning prior to milking. Milk residue may also accumulate in the concave teat end cavity, contributing to increased bacterial growth and possible entrance into the udder. However, there is no evidence that this is the case.

Radiographic techniques introduced by Appleman (1973) suggest that streak canals with wider diameters milk out faster and are also more susceptible to new intramammary infections. The teat canal with a wide diameter (>1.00 mm) showed more intramammary infection than a narrow teat canal (<0.55 mm). These results concur with those of Dodd and Neave (1951) and Johansson and Rendel (1968).
Appleman (1973) classified teat ends as follows: disk, cone, pointed, round, and flat. The disk and cone teat ends had the widest streak canals; the pointed and round teat ends had the narrowest streak canals; and the flat teat ends had intermediate streak canals.

Johansson and Rendel (1968) found that pointed teats were more predisposed to teat lesions at the teat apex (teat erosion) due to overmilking. Funnel shaped teats were not subject to teat erosion.

Bacterial Invasion of the Bovine Udder

Invasion of the udder by micro-organisms is by way of the orifice and streak canal. The factors affecting the validity of the above hypothesis have been thoroughly reviewed by Newbould (1964).

The method by which bacteria enters the streak canal is not known exactly. Penetration may occur as a single step, in stages, or by continuous growth of the pathogens through the canal (Neave et al., 1969). Two teats of each of 10 young cows that were resistant to Streptococcus agalactiae were subjected to various stresses by Murphy (1959). He removed some of the soft keratin lining with a soft plastic cannulae for three milkings prior to exposing the teats to Streptococcus agalactiae, after which the organisms completely broke the resistance of the glands to infection. The infection was then eliminated by antibiotic treatment. After sufficient time had elapsed for the keratin to be renewed, the streak canals were again resistant to Streptococcus agalactiae.

Adams and Rickard (1963) concluded that small amounts of lipids found in teat canal keratin and fatty acids were responsible
for differences in susceptibility to mastitic organisms. Treece, Morse, and Levy (1966), however, found that lipid groups found in the teat canal keratin had no relationship to mastitis resistance.

The incidence of infection increased when a large number of streptococci and staphylococci were introduced into the streak canal by an inoculated swab (Murphy and Stuart, 1953; Neave and Oliver, 1962; Newbould, 1964).

Hygiene of the teats cannot be overemphasized. According to the National Mastitis Council (under the direction of the writing committee of Philpot et al., 1974):

Because mastitis organisms enter the udder through the teat canal the rate of infection and the occurrence of clinical mastitis are higher when the teat end is abnormal. A high percentage of abnormal teat ends is frequently encountered in mastitis problem herds and may reflect upon the general quality of herd management, milking equipment, performance, milking technique, and indicate whether or not a properly formulated teat dip is being used. Maximum effort should be made to preserve the natural condition of the teat end. (unpaged)

**Teat Lesions in Relation to Mastitis**

The common teat lesions can be broadly classified as erosion of the teat orifice (sometimes called eversion), wounds, infections, and teat chaps. The emphasis of this thesis will be directed toward erosion of the teat orifice.

Udall (1947) coined the term "eversion of the meatus." However, the term did not become popular and the milking machine industry described the condition as "teat erosion," a term used by Espe and Cannon (1942). Teat erosion applies to various epithelial lesions on the distal end of the teat caused by milking machines.
Photographs of normal and abnormal teat ends were shown by Udall (1947). Espe and Cannon (1942) thought that teat erosion was related to mastitis because there was a tendency for the teat sphincter muscle to remain slightly everted and become eroded. When comparing a hand-milked versus a machine-milked herd, erosion was much more prevalent in the machine-milked herd. Their conclusion as to the cause of teat erosion was the constant vacuum on the end of the teat during machine milking. Ferguson (1944) found that after the teat was injured, susceptibility to intramammary infection was greatly increased. Out of 317 injured quarters examined, 283 (89%) were infected. External exposure of the normal teat with bacteria was not sufficient to introduce the organisms into the gland. The closing mechanism of the teat appeared to be the barrier preventing bacteria from entering the udder. Sores involving the teat orifice seemed more susceptible to infection of *Streptococcus agalactiae* than those without, according to Stuart and Lancaster (1949). However, when sores involving the teat orifice were healed, external application of *Streptococcus agalactiae* induced infection of the udder.

Other authors have reported an increased incidence of intramammary infections associated with the presence of teat lesions (Neave et al., 1954; Jackson, 1970). The intact teat canal is generally accepted as a strong barrier against infection (Johnston, 1938; Murphy, 1959; Newbould, 1964; Schalm, Carroll, and Jain, 1971); and injury to the teat canal impairs its function, predisposing the udder to infection (Kennedy, 1943; McDonald, 1974). Authur (1947) showed that a high correlation existed between mastitis and tread
wounds, lacerations, and other inflammatory lesions affecting the teat canal. Neave et al. (1969) found indications that teat blemishes were an important source of streptococci and staphylococci pathogens and that at any one time about 70% of teat blemishes were infected or contaminated with Staphylococcus aureus.

Teat End Erosion and Mastitis

Neave et al. (1954) reported that when the teat end was abnormal there was a significantly higher new infection rate with Streptococcus agalactiae. New infections with this pathogen were found in 8.2% of 219 milk samples from quarters with teats having sores at or adjoining the teat orifice. This compares to 2.7% of 1,656 samples from quarters with teats showing no signs of erosion. These results were in agreement with the findings of Stuart and Lancaster (1949).

According to Newbould (1964), Oliver in his thesis quoted Neave as showing that Staphylococcus aureus frequently colonize severe erosions of the teat orifice, but they seldom invade and cause intramammary infections. Staphylococcus aureus may also be found on clean udders and teats, from which they may colonize the eroded teat duct and persist for several months without necessarily causing an intramammary infection. Why this phenomena exists is not known.

No information as to the relationship between teat erosion and the California Mastitis Test could be found.

Teat Erosion and the Milking Machine

Foley et al. (1972) found there is little conclusive evidence in the literature to indicate that milking with a high vacuum predisposes
a cow to mastitis. However, teat erosion, cyanosis, and edema of the teat ends develop more readily when vacuum levels reach 18 to 20 inches of mercury. Peterson (1964) found that a properly functioning milking machine used incorrectly was capable of severely injuring internal structures of the teat. Overmilking two quarters of each cow and leaving the other two quarters as controls showed hypermia, hemorrhage, and edema of the epithelial membrane lining the teat cistern, along with inflammation in the epithelium and subepithelium of the streak canal. The only external lesions noticed were small erosions surrounding the left rear teat orifices on some of the overmilked cows. No external lesions were evident in the control teats. Overmilking occurred as follows: 20 minutes for 4 milkings, 3 minutes for 26 milkings, and 5 minutes for 16 milkings. It was noticed that teats subjected to numerous short periods of overmilking suffered less injury than those subjected to fewer but longer periods.

McDonald (1971) reported that Neave, Oliver, and Dodd suggested overmilking begins when the milk flow rate for the entire udder drops below 0.5 pounds per minute. Overmilking may cause an increase in teat canal eversion and erosion of the epithelium surrounding the teat orifice. New intramammary infections may also increase when the eroded epithelium permits bacterial build up (McDonald, 1971, 1974). Static vacuum at the teat apex should be between 254 and 330 mm of mercury (McDonald, 1971). Vacuum fluctuations higher than 76 mm of mercury cause irritation to teat ends since the fluctuation is always greatest at the teat end (McDonald, 1971). Pulsation ratios
that are above 2:1 when coupled with vacuum levels above 330.2 mm mercury at the teat end may increase teat canal erosion and eversion, teat end congestion and injury, and mechanical irritation (McDonald, 1971; Smith and Petersen, 1946). Schmidt and Van Vleck (1974) in their new text, *Principles of Dairy Science*, conclude:

Cows milked with machines that have inadequate vacuum reserve, which results in large vacuum fluctuations on the teat end, have a higher new infection rate than cows milked with a properly functioning milking machine. (p. 143)

When wide pulsation ratios are in operation, closer attention to milking technique is required. Dodd and Neave (1951) found that by increasing the milking rate there was a marked and progressive increase in the amount of mastitis occurring in first lactation heifers.

Jackson (1970) associated lesions at the teat apex with faulty pulsation. He found through experimentation that the main feature of a faulty pulsator was a marked reduction in the duration of the liner collapsing on the teat when compared with a normal pulsator. Through the use of a technique developed by Thiel, Clough, and Akam (1964), photographs were taken of the liner through a transparent shell using a cine camera. They were then able to measure the collapse time of the liner. With the faulty pulsator, the liner collapse time was only about half the collapse time produced by a normal pulsator.

Other findings of Jackson (1970) indicated a tenfold increase in the incidence of mastitis in a particular quarter with teat lesions at the apex. Thirty-six of the 256 quarters examined had teat lesions at the apex. Clinical mastitis was evident in 20 of
the 36 teats with end lesions, or 55.6%. Of the 220 normal teat ends, only 13 developed clinical mastitis, or 5.9%.

According to Jackson (1970), Bratlic studied a milking machine operating at a vacuum of 50 cm mercury in relationship to teat damage. Teats with cyanosis, edema of the apex, and eversion of the streak canal resulted from the higher vacuum. Wilson (1958) reported that an inadequate reserve of vacuum, resulting in wide vacuum fluctuations during milking, was an important predisposing cause of mastitis. Stanley, Kesler, and Bortree (1962) suggest that fluctuating milking vacuum did affect udder health, but their data did not indicate whether the harmful effects of their experimental milking machines were due solely to variable vacuum.

Thiel et al. (1973) showed that irregular vacuum fluctuations in the presence of minimal cyclic vacuum fluctuations had no influence on new infection rates of the udder. They also found no influence on new infection rates of large cyclic vacuum fluctuations in the absence of irregular vacuum fluctuations. However, all combinations of irregular vacuum fluctuations with large cyclic vacuum fluctuations resulted in a large increase in the rate of new infections. Their trials showed approximately 50% of the quarters examined became infected in two weeks.

Teat Dipping

During a 13 month study with two herds averaging 125 cows, Wesen and Schultz (1970) dipped the right side teats in a commercial iodine teat dip preparation (10,000 ppm) immediately after milking. The
teats on the left side of the udder were used as controls. Results indicated 36 new intramammary infections on the dipped teats and 77 new intramammary infections on the undipped teats, giving a 53.2% reduction in udder infection due to teat dipping.

Genetics in Relation to Mastitis

Teat patency, or the rate of milk flow, appears to be a factor in susceptibility to intramammary infection (Espe and Cannon, 1942; Murphy, 1944, 1947; McEwen and Cooper, 1947; Stuart and Lancaster, 1949; Dodd and Neave, 1951; Dodd and Foot, 1953; Hughes, 1954; Johansson and Rendel, 1968).

Dodd and Neave (1951) demonstrated a clear relationship between teat patency and susceptibility to udder infection. In a herd with a low incidence of Streptococcus agalactiae and a high incidence of staphylococci infection, they divided 94 first lactation heifers into five groups on the basis of teat patency. The mean peak milk flow in the five groups was 2.4, 3.6, 4.5, 5.6, and 6.8 pounds per minute. The new infection rate from Streptococcus agalactiae in the five groups was as follows: 0.0, 6.6, 3.8, 25.0, and 30.0% and for hemolytic staphylococci was 5.0, 33.0, 46.0, 63.0, and 76.0%, respectively. These results suggest that bacteria gain entrance into the udder more readily if teats have large or slack teat sphincters.

The percentage of animals yielding gargety milk associated with bacterial infection was 18% for "hard milkers," 15% for "moderate milkers," and 33% for "easy milkers" (McEwen and Cooper, 1947).

Several authors have shown that susceptibility to mastitis is inherited (Lush, 1950; Young, Legates, and Lecce, 1960; O'Bleness,
Van Vleck, and Henderson, 1960; Van Vleck, 1964; Schmidt and Van Vleck, 1965; Wilton et al., 1972). Most of these authors agree that genetic correlations for clinical mastitis and bacterial infection is between .20 and .29.

Since research has shown that teat patency and susceptibility to mastitis are closely related, it is possible that the inheritance of susceptibility to mastitis is a reflection of the inheritance of teat patency. It also appears that teat patency is mainly controlled by the structure of the teat orifice. Dodd and Foot (1953) found significant correlations between the milking rate of dams and daughters and between the rates of sibs:

> From these results, and from the striking demonstration of the effect of the sire on the milking rates of his daughters, it is apparent that milking rate is inherited. (p. 144)

This is an interesting example of the way in which heredity affects the susceptibility to disease since milking rate is an inherited character.

Johansson and Rendel (1968) indicate from the experiments of Politiek and Keestra that the heritability of the trait "rate of milk flow" determined at a single milking under field conditions is as high as 0.50 to 0.60. Venge (1963) found heritabilities for average rate of flow, peak flow, and amount of milk were 0.33, 0.26, and 0.72, respectively.

Estimates of genetic correlation between clinical mastitis and leucocyte scores were found to be .80 to .98 by Young, Legates, and Lecce (1960).
History, Mechanics and Nature of the California Mastitis Test (CMT)

The development of the California Mastitis Test (CMT) was instigated by Schalm and Noorlander (1957). The history and physical aspects (advantages, disadvantages, equipment and material needed, conduct, scoring and interpretation, and precautions) of the CMT are discussed in detail by Jasper (1965) and Schalm, Carroll, and Jain (1971).

It is well known that clinical mastitis affects the composition and yield of milk. In fact, changes in composition of milk are used to test for mastitis. Such is the case with the CMT, which measures the number of leucocytes in milk. The number of leucocytes indicates the level of inflammation of the mammary gland. The more severe the inflammation of the udder, the higher the test reaction or numerical score of the CMT.

Investigations into the cause of positive CMT reactions found that the CMT reagent ruptured the somatic cells and released deoxyribonucleic acid (DNA) from the nuclei (Carroll and Schalm, 1962; Paape, Snyder, and Hafs, 1962). The greater the precipitate or gel formation during the reaction, the higher the cell count in the milk. Therefore, the CMT is a measure of the concentration of entire somatic cells entering the milk.

Bacterial multiplication in milk commonly leads to acid production. Schalm and Noorlander (1957) reported that CMT scores on aged milk with a pH below 6.3 may not be accurate. CMT scores declined by 0.5 over a period between zero and four days of age as reported by Tucker and Paape (1966). Similar results have been confirmed by Frank and
Pounden (1963). Milk samples collected for screening via the CMT should be refrigerated to help prevent bacterial multiplication. The refrigerated samples should be tested within 24 to 48 hours (Jasper, 1965; Schalm, Carroll, and Jain, 1971). Preservatives added to the milk to prevent bacterial growth, such as formalin, mercuric chloride or potassium dichromate, may alter the DNA so that no CMT reaction occurs even in milk samples with high cell counts. Freezing of milk samples should also be avoided (Frank and Pounden, 1963; Schalm, Carroll, and Jain, 1971).

**CMT Reaction and Milk Production**

Damaged milk secreting tissue does not retain normal ability to synthesize major milk components such as casein, lactose, and fat. The damaged tissue allows blood proteins and salts to pass into the milk. Thus, the pH of the milk approaches that of blood; the chloride content increases and certain whey proteins are found in greater amounts.

Luedecke, Forster, and Ashworth (1967) found a correlation between the average leucocyte count per ml. and the CMT. CMT scores of negative, trace, 1, 2, and 3 had the number of leucocytes per ml. as follows: 64,700; 113,300; 394,000, 1,700,000; and 7,000,000, respectively. An abnormal condition within the udder exists when samples of trace through three are exhibited. This is in accord with the findings of Schalm and Noorlander (1957) and Miller and Kearns (1967).

Appleman, Rowe, and Forker (1965) observed that cows with a CMT score of negative produced 0.9, 2.2, 4.8, and 6.8 pounds more milk.
than cows with a CMT score of trace, 1, 2, and 3, respectively. Gray and Schalm (1962) found that the average loss in milk production was 6.0, 10.0, 16.0, and 24.5% with CMT scores of trace, 1, 2, and 3, respectively. CMT scores of 1, 2, and 3 compared to opposite negative quarters showed losses of 0.41, 0.65, and 1.48 pounds per quarter per milking respectively. In a similar comparison, decreases in solids-not-fat (SNF) percentages were 0.10, 0.15, and 0.40 (Natzke et al., 1965). Philpot (1967), in determining the presence and severity of subclinical mastitis, screened 178 Jersey cows using the CMT. Milk from each quarter was weighed and tested for milk fat and SNF. Each of the quarters appeared to be normal to the eye even with the aid of a strip cup. The results were as follows:

<table>
<thead>
<tr>
<th>CMT Score</th>
<th>Trace</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<tbody>
<tr>
<td>% milk reduction</td>
<td>2.8</td>
<td>11.4</td>
<td>25.6</td>
<td>45.5</td>
</tr>
<tr>
<td>% fat reduction</td>
<td>3.4</td>
<td>6.9</td>
<td>10.3</td>
<td>13.7</td>
</tr>
<tr>
<td>% SNF reduction</td>
<td>0.7</td>
<td>2.8</td>
<td>6.4</td>
<td>11.3</td>
</tr>
</tbody>
</table>

Test reactions of trace, 1, 2, and 3 were associated with average decreases in milk production of 9.0, 19.5, 31.8, and 43.7%, respectively from a study by Forster, Ashworth, and Luedecke (1967). In their study 1,258 opposite quarter milkings from 763 cows in 30 dairy herds were taken. In another study (O'Donovan, Dodd, and Neave, 1960) the lactation yields of milk, SNF, and fat of infected cows were depressed by 10.0, 11.0, and 12.0%, respectively, in comparison to noninfected cows. When comparing a negative CMT score and a score of 3, there was a decrease in percent total solids, fat, SNF, and lactose of 1.07,
0.45, 0.47, and 0.77%, respectively (Ashworth, Forster, and Luedecke, 1967). Ashworth, Forster, and Luedecke (1967) reported that when a reduced level in milk production was combined with a decreased fat test, an average loss of 48% in total fat production occurred for opposite quarters showing a CMT score of 3 versus a negative CMT score.

Interpreting the CMT

The CMT is a very sensitive, indirect test of inflammation of the udder. For example, only 7.2% of 2,729 quarters which reacted to the CMT were positive to the strip cup test (Marshall and Edmondson, 1962). In the same study only 160 quarters, or 19.1% of the 836 quarters with a CMT score of 3 showed a positive strip cup reaction.

Considerable care must be used in interpreting the CMT. Stage of lactation and lactation age influence the number of somatic cells in milk. With advancing lactation, the volume of milk decreases and somatic cell numbers become concentrated in small volumes of milk. Uninfected cows a few days before to two weeks after calving usually have a high somatic cell count in their milk. The leucocyte numbers in milk are lowest just prior to milking, rise sharply in the strippings, remain high during the next four hours, and then decrease progressively to a minimum value near the end of the intermilking period (Oliver et al., 1956; Plastridge, 1958; Braund and Schultz, 1963; Schalm, Lasmanis, and Carroll, 1966; Smith and Schultze, 1967).

Braund and Schultz (1963) have shown that parity, stage of lactation, and the dry period are the physiological factors that have the greatest effect on the CMT. During the first month of lactation
the CMT showed a relatively low percent of positive quarters. The number of positive quarters increased in the later stages of lactation. When production was below 20 pounds, 43.1% of the cows indicated positive quarters. First lactation animals showed a lower number of positive quarters than older cows; 70.0% of the positive quarters at the end of lactation returned to negative following a dry period. When bucket samples were used, approximately 43.0% of the individual positive quarters were not detected. This is in accord with the findings of Gray and Schalm (1962). Vacuum fluctuations on the milk line during milking related to an increase in positive scores associated with the CMT.

Schalm and Noorlander (1957) express caution in using the CMT:

The California Mastitis Test is a very sensitive indicator of the presence of inflammation of the udder. It cannot, however, tell the cause of inflammation. Udder irritation due to improper mechanical milking will result in positive reactions, as will also inflammation due to bacterial infection. (p. 204)

Indirect tests such as the CMT used routinely to measure the number of leucocytes in raw milk are useful to determine subclinical mastitis, but otherwise have limited value (Platonow and Kathein, 1970). Philpot (1969) found that 13% of culturally negative quarters produced CMT positive milk. If treatment is administered only on the basis of the CMT scores, many uninfected quarters would be treated unnecessarily.

Blackburn (1966) has also shown that older cows have a higher leucocyte count than younger cows due to the higher incidence of mastitis infection in older cows. The average cell count during the first seven lactations was found to increase progressively from 0.30
to 1.08 million per ml of milk. The increase in the average total cell count with advancing lactation was due to an increase in all cell types.

Electronic Counting of Somatic Cells in Milk

Somatic cell counts or total cell counts in milk are composed of epithelial cells and leucocytes. Polymorphonuclear (PMN) or neutrophils are the major leucocytes in mastitic milk and appear in great numbers. The epithelial cells appear in the milk as a result of injury to mammary tissue and the PMN leucocytes appear in the milk in response to that injury (Schalm and Lasmanis, 1968).

Errors can occur in determining somatic cell counts when the CMT is used. There are other methods of detecting somatic cells in milk that are more accurate. The electronic counter is an example of a more accurate, rapid and less tedious method for counting somatic cells in milk (Cullen, 1967; Phipps and Newbould, 1966; Read et al., 1967, 1968). The electronic particle systems allow one to determine a representative number of particles, according to size, within a few seconds (Coulter, 1956; Mattern, Brackett, and Olson, 1957).

The main problem in electronic counting of somatic cells in milk is that nonsomatic cells may also be counted. Fat globules in milk overlap the size range of cells. Unless the fat globules are removed by centrifugation or by chemical dispersion, erroneous cell counts will occur. Efforts are underway to develop an electronic counting machine that would be suitable for processing milk samples at centralized laboratories since speed is desirable in handling large numbers of samples. The semiautomatic cell counting system is such a machine.
The semiautomatic cell counting system has a continuous flow analysis and operates at a rate of 20 milk samples per hour with the precision of the direct microscopic cell count (DMCC). The system has been commercially developed by Technicon Instruments Corporation of Terrytown, New York. The machine has been designated the Technicon Optical Somatic Cell Counter II (OSCC II).

As somatic cells from a milk sample pass through the machine, the OSCC II measures scattered light that occurs as the particles, according to size, pass through a light beam of the electronic micro-optical system. The light pulses are transformed by a photomultiplier tube into electrical pulses. The number of somatic cells (or particles of that range in size) correspond to the electrical impulses and are recorded on graph paper. Since fat globules in milk range from 1 to 15 microns in diameter and overlap the size range of somatic cells, the fat globules undergo chemical treatment (i.e., dissolved without damaging somatic cells) prior to machine counting analysis. Formaldehyde (Formalin) is also added to "fix" the samples before analysis commences (Wang, 1975).
METHODS AND MATERIALS

Data were collected from the 1,000 cow milking operation at Gunnison Valley Dairy, Gunnison, Utah. Data were collected in three time periods. The first time period was from June to September, 1974. Data included the classification of shape of the teat end of cows in the milking herd; collection and analysis of composite milk samples for CMT; CMT evaluation of individual quarters from each cow with a composite CMT score of trace, 1, 2, or 3; classification of teat end erosion; and collection of daily and lactational milk and fat production of cows in the milking herd.

Due to management decisions, changes in milking equipment and milking procedures were made during December, 1974. Time Period II was in November, 1974, before the new equipment was installed in the milking parlor. Data collection included teat end erosion, CMT, and somatic cell counts from composite milk samples, and daily and lactational milk and fat production records. Time Period III was in February, 1975, and was a follow-up study to Time Period II including collection of the same type of data (teat end erosion, CMT, somatic cell counts, and daily and lactational milk and fat production) to help analyze the value of the revised milking equipment and procedures on udder health.

Data for Time Period I were collected at four different times to minimize labor and inconvenience in the milking parlor. Teat shape classification, composite milk samples, and teat end erosion
were obtained during monthly visits of the DHI Supervisor. Labor saving took place at this time because recording of cow numbers was used for both research data collection and DHI records.

**Time Period I**

Teat shapes from 997 Holstein cows were taken on June 11-12, 1974. One teat from each cow was randomly selected and typed for shape of the teat end according to Appleman's (1973) classification. (See Figure 1.) Pointed, round, flat, disk, and cone shaped teat ends were then numerically scored 1, 2, 3, 4, and 5, respectively, to facilitate computer analysis.

The classification of teat ends was made in the milking parlor after the milking machines were removed.

Samples of mixed milk of the entire udder (bucket milk from the weigh jars) from 1,015 cows were taken August 17-18, 1974. Samples were taken immediately after the DHI Supervisor's bucket milk sample. Sets of 50 samples were cooled in an ice bath as soon as the 50 samples were collected. Cooled samples were then placed under refrigeration. All of the samples were screened within 36 hours using the California Mastitis Test (CMT). The results of the CMT were read as negative, trace, 1, 2, and 3. These were later coded as 1 through 5, respectively, to facilitate computer analysis.

There were 250 cows during the August 17-18 collection with composite milk samples having CMT scores of trace, 1, 2, or 3. Of these 250 cows, only 175 were tested as to individual quarters using the CMT. Two men were needed for the collection of this data, and only one man was available resulting in a net loss of 75 cows not
Figure 1. Diagrammatic representation of the five primary teat end classifications.
tested. Time was a critical factor in the milking parlor. Therefore, cowside CMT analysis of individual quarters was not feasible. A method was devised to save time in the milking parlor as follows:

(1) Individual milk sample vials as used by the DHI Supervisor were premarked as to the four quarters of each cow in question.

(2) The 175 cows were premarked before entering the parlor in order that the animals might be quickly identified.

(3) Each of the 175 cows was prepared for milking in the usual manner. That is, the teats and udder were cleaned with an udder cloth with warm water and then dried off.

(4) Samples were then taken as follows:
   (a) One or two streams of milk were taken manually from a quarter and allowed to fall to the floor.
   (b) Approximately 25 ml of milk were manually extracted from the above quarter and placed in a milk sample vial.
   (c) Procedures (a) and (b) were followed for each of the other three quarters.

(5) The individual milk samples were collected in styrofoam containers of 50 and were immediately cooled in an ice bath and then placed under refrigeration. The samples were analyzed as to CMT scores within 24 hours.

Teat end erosion from 913 Holstein cows was taken on September 9-10, 1974. Teat end erosion was recorded according to
severity on a scale of zero to three, zero indicating no erosion and three indicating severe erosion. Approximately 50% of the cows were examined for teat end erosion before the milking machines were attached, and 50% of the cows were examined for teat end erosion after the milking machines were removed. This facilitated speed in the milking process and valuable milking time was not lost due to data collection.

Production data in Time Period I were taken from DHI individual cow records on a 305 day basis. Information such as daily milk yield, extended 305 day lactation milk and fat yield, month of lactation, and lactation number were recorded.

Time Period II

Teat end erosion from 879 Holstein cows was collected on November 29, 1974. The procedure was identical to that in Time Period I.

Composite milk samples were also collected at this time. The samples were cooled in an ice bath, refrigerated, and then tested within 36 hours using the CMT. The samples were taken to the Central Milk Testing Laboratory at Utah State University in Logan, and somatic cell counts of the composite milk samples were made using the Technicon Optical Somatic Cell Counter II (OSCC II).*

Production data in Time Period II were also taken from DHI individual cow records over a 305 day period. Information such

*Reference to any particular piece of equipment, brand name, or firm does not constitute an endorsement of the author or Utah State University over others of a similar nature.
as daily milk yield, month of lactation, and lactation number were recorded.

**Time Period III**

Teat end erosion and composite milk samples were taken on February 14-15, 1975, from 925 Holstein cows. The procedures were identical to those in Time Periods I and II. Somatic cell counts were also taken from the above composite milk samples using the OSCC II at the Central Milk Testing Laboratory at Utah State University in Logan. Daily milk yield, month of lactation, and lactation number were again taken from DHI individual cow records.

**Changes in Milking Equipment and Procedure**

Changes in milking equipment and procedure occurred on December 27, 1974. Table 1 explains the old versus the new milking equipment.

At the same time the milking equipment was changed, there was a change in manpower in the milking parlor. An additional man was added, making a total of three men instead of only two. Teat dipping was instigated for the first time with a commercial teat dip, Bovadine Sanitizing Teat Dip.

**Data Analysis**

The Burroughs 6700 Computer was used to analyze the data. The data were first analyzed by analysis of variance using the least squares method. Teat end shape was used as treatment in this analysis. Because the data were collected over a period of time
TABLE 1

MILKING EQUIPMENT CHANGES

<table>
<thead>
<tr>
<th>Milking Equipment</th>
<th>Time Periods I &amp; II</th>
<th>Time Period III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflations</td>
<td>Surge, Narrow Bore</td>
<td>I.B.A. (Square)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Long Tube Milk Liners</td>
</tr>
<tr>
<td>Claws</td>
<td>DeLaval (DG)</td>
<td>DeLaval (FLO-Vu)</td>
</tr>
<tr>
<td>General System</td>
<td>DeLaval Model 200</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>Double 10 Herringbone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>with individual weigh jars</td>
<td></td>
</tr>
<tr>
<td>Vacuum</td>
<td>15&quot;</td>
<td>12&quot;</td>
</tr>
<tr>
<td>Pulsation Ratio</td>
<td>70:30</td>
<td>70:30</td>
</tr>
</tbody>
</table>

(June, 1974, to February, 1975), many cows were removed from the milking herd due to culling and the dry period. On the other hand, replacement and fresh cows entered the milking string during this time. Because of these differences in cows, data from each of the time periods were analyzed separately so that the most data could be fully utilized.

In order to facilitate multiple regression analysis with teat end erosion, a new variable of erosion score was created. Instead of using each quarter with a score of 0 to 3, the new variable was a total of the erosion score for all four quarters, resulting in a score of 0 to 12.

*Reference to any particular piece of equipment, brand name, or firm does not constitute an endorsement of the author or Utah State University over others of a similar nature.*
The data were then analyzed with a multiple regression analysis using a stepwise deletion procedure. Six dependent variables were included in the analysis: daily milk yield, clinical mastitis, composite teat erosion score, composite CMT, somatic cell count from the OSCC II and CMT from somatic cell counts. The first two dependent variables were analyzed using the following model:

\[ Y_{jklm} = u + t_j + s_k + m_l + L_m + e_{jklm} \]

where:

- \( Y \) = dependent variable
- \( u \) = population mean
- \( t_j \) = \( j^{th} \) time period
- \( s_k \) = \( k^{th} \) teat end shape
- \( m_l \) = \( l^{th} \) month of lactation
- \( L_m \) = \( m^{th} \) lactation number
- \( e_{jklm} \) = random error term representing unexplained variation between observations of the same cow

Milk production was added to the above prediction model for analyzing the last four dependent variables. The model then became:

\[ Y_{ijklm} = u + P_i + t_j + s_k + m_l + L_m + e_{ijklm} \]

where:

- \( Y \) = dependent variable
- \( u \) = population mean
- \( P_i \) = \( i^{th} \) level of milk production
- \( t_j \) = \( j^{th} \) time period
\[ s_k = k^{th} \text{ teat end shape} \]
\[ m_l = l^{th} \text{ month of lactation} \]
\[ L_m = m^{th} \text{ lactation number} \]
\[ e_{ijklm} = \text{random error term representing unexplained variation between observations of the same cow} \]
RESULTS AND DISCUSSION

Time Period I

Table 2 shows the distribution of teat shape, composite CMT scores, and erosion for Time Period I.

<table>
<thead>
<tr>
<th>Teat Shape</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pointed</td>
<td>128</td>
<td>12.9</td>
</tr>
<tr>
<td>Round</td>
<td>362</td>
<td>36.3</td>
</tr>
<tr>
<td>Flat</td>
<td>63</td>
<td>6.3</td>
</tr>
<tr>
<td>Disk</td>
<td>386</td>
<td>38.7</td>
</tr>
<tr>
<td>Cone</td>
<td>58</td>
<td>5.8</td>
</tr>
<tr>
<td>Total</td>
<td>997 cows</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Composite CMT Score</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>765</td>
<td>75.4</td>
</tr>
<tr>
<td>Trace</td>
<td>146</td>
<td>14.4</td>
</tr>
<tr>
<td>1</td>
<td>64</td>
<td>6.3</td>
</tr>
<tr>
<td>2</td>
<td>37</td>
<td>3.6</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td>Total</td>
<td>1,015 cows</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Teat Erosion</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero</td>
<td>354</td>
<td>9.7</td>
</tr>
<tr>
<td>1</td>
<td>416</td>
<td>11.4</td>
</tr>
<tr>
<td>2</td>
<td>1,371</td>
<td>37.6</td>
</tr>
<tr>
<td>3</td>
<td>1,509</td>
<td>41.3</td>
</tr>
<tr>
<td>Total</td>
<td>3,650 quarters</td>
<td></td>
</tr>
</tbody>
</table>
Approximately 50% of the cows had pointed or round shaped teat ends, and approximately 50% had flat, disk, or cone shaped teat ends. Percentage of teat end shapes for the 997 cows were: disk, 38.7%; round, 36.3%; pointed, 12.9%; flat, 6.3%; and cone, 5.8%.

Analysis of composite milk samples for 1,015 cows indicated CMT scores as follows: negative, 75.4%; trace, 14.4%; one, 6.3%; two, 3.6%; and three, 0.3%.

Teat end erosion for 3,650 quarters showed 9.7% with no erosion, 11.4% with an erosion score of 1, 37.6% with an erosion score of 2, and 41.3% with an erosion score of 3. There was no appreciable difference between the four different quarters in their average teat end erosion score.

The analysis of variance for Time Period I (Table 3) showed that cows with pointed teat ends had a lower daily milk yield and lower total milk and fat yield for the lactation than did cows having round, flat, disk, or cone shaped teat ends. Cows with pointed teat ends may have been younger because they were in a later stage of an earlier lactation than other cows in the milking herd. Cows with round, flat, disk, and cone shaped teat ends were very similar and not significantly different from each other as to daily milk yield, extended lactation, milk and fat yield, lactation number, and stage of lactation. Incidence of clinical mastitis did not differ between teat shapes at this time. However, there were only 18 cases or about 1.4% of the herd with clinical mastitis.

The fact that cows with pointed teat ends had lower daily milk yield and lower milk fat yield for the lactation may not have
TABLE 3
ANALYSIS OF VARIANCE FOR TEAT END SHAPES, TIME PERIOD I

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Milk Yield</td>
<td>Lact. Yld.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F Value</td>
<td>5.76 **</td>
<td>6.78 **</td>
<td>3.70 **</td>
<td>8.34 **</td>
<td>3.60 **</td>
<td>1.18</td>
</tr>
<tr>
<td>Treatment means</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>34.17</td>
<td>11,218</td>
<td>401.60</td>
<td>1.70</td>
<td>6.14</td>
<td>.03</td>
</tr>
<tr>
<td>R</td>
<td>39.79</td>
<td>12,467</td>
<td>437.80</td>
<td>2.10</td>
<td>5.76</td>
<td>.02</td>
</tr>
<tr>
<td>F</td>
<td>40.29</td>
<td>12,353</td>
<td>433.30</td>
<td>2.30</td>
<td>4.95</td>
<td>.00</td>
</tr>
<tr>
<td>D</td>
<td>41.21</td>
<td>12,673</td>
<td>438.60</td>
<td>2.10</td>
<td>5.44</td>
<td>.09</td>
</tr>
<tr>
<td>C</td>
<td>42.49</td>
<td>12,561</td>
<td>440.60</td>
<td>2.20</td>
<td>5.19</td>
<td>.04</td>
</tr>
<tr>
<td>Overall trtmnt means</td>
<td>39.79</td>
<td>12,380</td>
<td>433.23</td>
<td>2.07</td>
<td>5.60</td>
<td>.05</td>
</tr>
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</table>

Paired comparison of individual means

<table>
<thead>
<tr>
<th></th>
<th>PR</th>
<th>PF</th>
<th>PD</th>
<th>PC</th>
<th>RF</th>
<th>RD</th>
<th>RC</th>
<th>FD</th>
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<tbody>
<tr>
<td></td>
<td>** **</td>
<td>** *</td>
<td>** **</td>
<td>** *</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>PR</td>
<td>** **</td>
<td>** *</td>
<td>** **</td>
<td>** *</td>
<td>N.S.</td>
<td>N.S.</td>
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</tr>
<tr>
<td>PF</td>
<td>** **</td>
<td>** *</td>
<td>** **</td>
<td>** *</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>PD</td>
<td>** **</td>
<td>** *</td>
<td>** **</td>
<td>** *</td>
<td>N.S.</td>
<td>N.S.</td>
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<tr>
<td>PC</td>
<td>** **</td>
<td>** *</td>
<td>** **</td>
<td>** *</td>
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<tr>
<td>RF</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>*</td>
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<td>** N.S.</td>
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<td>RD</td>
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<td>RC</td>
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<td>N.S.</td>
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<tr>
<td>FD</td>
<td>N.S.</td>
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<td>N.S.</td>
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<tr>
<td>FC</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
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<td>N.S.</td>
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<td>N.S.</td>
</tr>
<tr>
<td>DC</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

1 Teat shape: P, pointed; R, round; F, flat; D, disk; C, cone
2 Individual quarters: LF, left front; LR, left rear; RF, right front; RR, right rear
* (P < .05)  ** (P < .01)
been because of teat shape but because these cows were in an earlier lactation and also in a later stage of lactation than other cows in the milking herd. There are three possible explanations that may account for cows with pointed teat ends averaging in an earlier lactation. First, if cows with pointed teat ends are actually lower producers, then the older cows with pointed teats were culled more heavily than cows with other teat shapes leaving a disproportionate share of cows with pointed teat ends in younger age groups. Second, this herd was assembled from many different sources and over a period of time. It is possible that there were very few animals with pointed teats among the earliest heifers selected, but a group that was purchased and freshened later may have included a large number of animals with pointed teats. Third, it may be possible that cows with pointed teats were less efficient in reproduction, resulting either in longer lactations or longer dry periods which put them behind other cows in the herd with regard to parity.

CMT scores were significantly higher for cows with flat and cone shaped teat ends than for those with pointed, round, or disk shapes. Teat erosion on all four quarters was not significantly influenced by teat end shape. All teat ends, regardless of shape, were eroded approximately the same with a combined average score of 2.13.

Cows with flat and cone shaped teat ends had higher CMT scores than cows with other teat shapes. A possible explanation may be the
anatomy of the different teat ends. Disk and cone teat ends had
the widest streak canals, pointed and round the narrowest, and flat
teat ends had intermediate streak canals according to Appleman (1973).
The diameter of the streak canal is related to teat patency or
rate of milk flow. Cows with wider streak canals are more susceptible
to intramammary infections (McEwen and Cooper, 1947; Dodd and
Neave, 1951; Appleman, 1973). The suggestion is that bacteria gain
entrance into the udder more readily if teats have wider streak
canals. Wider streak canals may also imply large or slack
sphincter muscles, making bacterial invasion into the udder easier.

All teat ends had a high amount of erosion and no conclusions
can be drawn as to the relationship between erosion and teat shapes
and erosion and CMT scores at this time. It appears that milking
equipment and procedure problems may have been causing a high
incidence of teat end erosion, which in turn masked the true
relationship between shape and erosion of the teat ends and between
erosion and CMT score.

Time Period II

After the initial data were collected from the herd, a
decision was made to change some of the milking equipment and
milking procedures. A second set of data were collected in
November, 1974, prior to these changes. Since teat shape does not
change, this data were not recorded. Table 4 shows the results of
teat erosion and composite CMT scores for Time Period II.

Erosion scores of 0, 1, 2, and 3 had risen to 0.8, 2.1, 22.0,
and 75.1%, respectively. There was no appreciable difference
TABLE 4
TEAT EROSION AND COMPOSITE CMT SCORES FOR TIME PERIOD II

<table>
<thead>
<tr>
<th>Teat Erosion</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero</td>
<td>28</td>
<td>0.8</td>
</tr>
<tr>
<td>1</td>
<td>75</td>
<td>2.1</td>
</tr>
<tr>
<td>2</td>
<td>772</td>
<td>22.0</td>
</tr>
<tr>
<td>3</td>
<td>2,640</td>
<td>75.1</td>
</tr>
<tr>
<td>Total</td>
<td>3,515 quarters</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Composite CMT Score</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>602</td>
<td>71.8</td>
</tr>
<tr>
<td>Trace</td>
<td>95</td>
<td>11.3</td>
</tr>
<tr>
<td>1</td>
<td>74</td>
<td>8.8</td>
</tr>
<tr>
<td>2</td>
<td>54</td>
<td>6.4</td>
</tr>
<tr>
<td>3</td>
<td>14</td>
<td>1.7</td>
</tr>
<tr>
<td>Total</td>
<td>839 cows</td>
<td></td>
</tr>
</tbody>
</table>

between different quarters and any particular teat end erosion score. CMT scores from composite milk samples gave the following scores: negative, 71.8%; trace, 11.3%; one, 8.8%; two, 6.4%; and three, 1.7%.

Teat end erosion was not significantly related to teat end shape (Table 5) probably because all teat ends regardless of shape or quarter were eroded approximately the same with a combined average score of 2.68. This compares to a score of 2.13 in Time Period I. Flat and cone shaped teat ends were again more susceptible to a high composite CMT score as compared to pointed, round, and disk
TABLE 5
ANALYSIS OF VARIANCE FOR TEAT END SHAPES, TIME PERIOD II

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F Value</td>
<td>3.33 **</td>
<td>1.12</td>
<td>1.52</td>
<td>.98</td>
<td>2.31</td>
<td>4.10 **</td>
<td>.45</td>
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<tr>
<td>Treatment means¹</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>1.57</td>
<td>11.20</td>
<td>1.21</td>
<td>28.72</td>
<td>7.17</td>
<td>1.91 .06</td>
<td>2.68 2.72 2.68 2.72</td>
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<tr>
<td>R</td>
<td>1.50</td>
<td>12.92</td>
<td>1.32</td>
<td>26.34</td>
<td>8.14</td>
<td>2.19 .09</td>
<td>2.65 2.73 2.71 2.71</td>
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<tr>
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<td>1.66</td>
<td>27.71</td>
<td>7.62</td>
<td>2.37 .10</td>
<td>2.61 2.72 2.50 2.69</td>
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<tr>
<td>D</td>
<td>1.47</td>
<td>14.72</td>
<td>1.39</td>
<td>27.94</td>
<td>7.71</td>
<td>2.23 .08</td>
<td>2.65 2.68 2.66 2.70</td>
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<tr>
<td>C</td>
<td>1.97</td>
<td>14.14</td>
<td>1.33</td>
<td>29.41</td>
<td>7.39</td>
<td>2.39 .01</td>
<td>2.63 2.66 2.60 2.74</td>
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<tr>
<td>Overall trtmnt means</td>
<td>1.56</td>
<td>13.93</td>
<td>1.40</td>
<td>27.53</td>
<td>7.77</td>
<td>2.19 .08</td>
<td>2.68</td>
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<td>Paired comparison of individual means¹</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S. N.S.</td>
<td>**</td>
<td>N.S. N.S. N.S. N.S. N.S. N.S.</td>
<td></td>
</tr>
<tr>
<td>PF</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S. N.S.</td>
<td>**</td>
<td>N.S. N.S. N.S. N.S. N.S. N.S.</td>
<td></td>
</tr>
<tr>
<td>PD</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S. N.S.</td>
<td>**</td>
<td>N.S. N.S. N.S. N.S. N.S. N.S.</td>
<td></td>
</tr>
<tr>
<td>PC</td>
<td>*</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S. N.S.</td>
<td>**</td>
<td>N.S. N.S. N.S. N.S. N.S. N.S.</td>
<td></td>
</tr>
<tr>
<td>RF</td>
<td>**</td>
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<td>N.S.</td>
<td>N.S. N.S.</td>
<td>N.S.</td>
<td>N.S. N.S. N.S. N.S. N.S. N.S.</td>
<td></td>
</tr>
<tr>
<td>RD</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S. N.S.</td>
<td>**</td>
<td>N.S. N.S. N.S. N.S. N.S. N.S.</td>
<td></td>
</tr>
<tr>
<td>RC</td>
<td>*</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S. N.S.</td>
<td>N.S.</td>
<td>N.S. N.S. N.S. N.S. N.S. N.S.</td>
<td></td>
</tr>
<tr>
<td>FD</td>
<td>*</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S. N.S.</td>
<td>N.S.</td>
<td>N.S. N.S. N.S. N.S. N.S. N.S.</td>
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</tr>
<tr>
<td>FC</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S. N.S.</td>
<td>N.S.</td>
<td>N.S. N.S. N.S. N.S. N.S. N.S.</td>
<td></td>
</tr>
<tr>
<td>DC</td>
<td>**</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S. N.S.</td>
<td>N.S.</td>
<td>N.S. N.S. N.S. N.S. N.S. N.S.</td>
<td></td>
</tr>
</tbody>
</table>

¹Teat shape: P, pointed; R, round; F, flat; D, disk; C, cone
²Individual quarters: LF, left front; LR, left rear; RF, right front; RR, right rear
* (P < .05) ** (P < .01)
shaped teat ends. Teat end erosion scores of 2 or 3 and composite CMT scores of trace, 1, 2, or 3 increased by 16.2 and 3.6%, respectively. Cows with pointed shaped teat ends again averaged lower in lactation number as compared with cows with round, flat, disk, and cone shaped teat ends.

Somatic cell counts determined by the OSCC II, CMT scores from the above somatic cell counts, daily milk yield, month of lactation, and clinical mastitis were not significantly affected by teat end shapes. Composite CMT scores and CMT scores based on somatic cell counts from the OSCC II were comparable (Table 5).

Why there was an increase in teat end erosion and composite CMT scores can only be hypothesized at this time. Clinical mastitis in this period reached 7.0% as compared to 1.4% in Time Period I. The mastitis problem continued to plague the dairy and a decision was reached to alter the existing milking system, to have three men milking in the parlor, and to instigate teat dipping.

Time Period III

Data collection during Time Period III (February, 1975) was approximately two months after the milking equipment had been modified. Table 6 shows the percentages for various levels of teat erosion and CMT scores. Percentages of 4.1, 20.5, 49.2, and 26.2 were found to relate to teat end erosion scores of 0, 1, 2, and 3, respectively. Composite CMT scores of negative, trace, 1, 2, and 3 gave percentages of 91.0, 7.2, 1.5, 0.3, and 0.0%, respectively. As in Time Periods I and II, there was no significant
Table 6 shows the analysis of variance for Time Period III. Teat end erosion was higher in all four quarters for pointed teat ends. This difference was significant for cone and flat shaped teat ends which showed the least amount of erosion, but not significant for disk shaped teat ends which showed an intermediate amount of erosion. Cows with pointed teat ends were still a younger age group.
<table>
<thead>
<tr>
<th>Variables</th>
<th>CMT Based</th>
<th>CMT Cell</th>
<th>Daily</th>
<th>Teat End Erosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>F Value</td>
<td>1.39</td>
<td>.20</td>
<td>.33</td>
<td>1.72</td>
</tr>
<tr>
<td>Treatment means</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>1.16</td>
<td>4.51</td>
<td>1.04</td>
<td>4.78</td>
</tr>
<tr>
<td>R</td>
<td>1.07</td>
<td>4.66</td>
<td>1.08</td>
<td>5.44</td>
</tr>
<tr>
<td>F</td>
<td>1.03</td>
<td>3.45</td>
<td>1.03</td>
<td>6.17</td>
</tr>
<tr>
<td>D</td>
<td>1.15</td>
<td>4.87</td>
<td>1.08</td>
<td>5.69</td>
</tr>
<tr>
<td>C</td>
<td>1.12</td>
<td>4.18</td>
<td>1.06</td>
<td>6.04</td>
</tr>
<tr>
<td>Overall trtmnt means</td>
<td>1.11</td>
<td>4.70</td>
<td>1.07</td>
<td>5.53</td>
</tr>
<tr>
<td>Paired comparison of individual means</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR</td>
<td>N.S. N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>PF</td>
<td>N.S. N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>PD</td>
<td>N.S. N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>PC</td>
<td>N.S. N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>RF</td>
<td>N.S. N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>RD</td>
<td>N.S. N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>RC</td>
<td>N.S. N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>FD</td>
<td>N.S. N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>FC</td>
<td>N.S. N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>DC</td>
<td>N.S. N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

1 Teat shape: P, pointed; R, round; F, flat; D, disk; C, cone
2 Individual quarters: LF, left front; LR, left rear; RF, right front, RR, right rear

* (P<.05)  ** (P<.01)
All other variables studied, including composite CMT score, somatic cell count, CMT based on somatic cell count, month of lactation, clinical mastitis, and daily milk yield showed no significant differences among the five teat end shapes. As in Time Period II, composite CMT scores and CMT scores based on somatic cell counts from the OSCC II were comparable.

Tables 8 and 9 show the percent distribution in each time period according to CMT scores and teat end erosion.

**TABLE 8**

PERCENT DISTRIBUTION OF COMPOSITE CMT SCORES FOR TIME PERIODS I, II, AND III

<table>
<thead>
<tr>
<th>CMT Score</th>
<th>% Neg.</th>
<th>% Trace</th>
<th>% 1</th>
<th>% 2</th>
<th>% 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Period I</td>
<td>75.4</td>
<td>14.4</td>
<td>6.3</td>
<td>3.6</td>
<td>0.3</td>
</tr>
<tr>
<td>Time Period II</td>
<td>71.8</td>
<td>11.3</td>
<td>8.8</td>
<td>6.4</td>
<td>1.7</td>
</tr>
<tr>
<td>Time Period III</td>
<td>91.0</td>
<td>7.2</td>
<td>1.5</td>
<td>0.3</td>
<td>0.0</td>
</tr>
</tbody>
</table>

CMT scores of trace, 1, 2, and 3 were reduced by a factor of 2.5 to 3.0 times in Time Period III as compared to Time Periods I and II. Severe teat end erosion (score of 3) was reduced in Time Period III by percentages of 15.1 and 48.9 as compared to Time Periods I and II, respectively. Changes in the milking parlor are suspected as the reason why teat end erosion and CMT scores were lower in Time Period III. The percentage of clinical mastitis in
TABLE 9
PERCENT DISTRIBUTION OF TEAT END EROSION SCORES
FOR TIME PERIODS I, II, AND III

<table>
<thead>
<tr>
<th>Erosion Score</th>
<th>% Zero</th>
<th>% 1</th>
<th>% 2</th>
<th>% 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Period I</td>
<td>9.7</td>
<td>11.4</td>
<td>37.6</td>
<td>41.3</td>
</tr>
<tr>
<td>Time Period II</td>
<td>0.8</td>
<td>2.1</td>
<td>22.0</td>
<td>75.1</td>
</tr>
<tr>
<td>Time Period III</td>
<td>4.1</td>
<td>20.5</td>
<td>49.2</td>
<td>26.2</td>
</tr>
</tbody>
</table>

the herd also dropped from 7.0% in Time Period II to 1.7% in Time Period III. As has been mentioned, prior to the third data collection period milking equipment was changed, a man was added in the milking parlor, and teat dipping was instigated. Undoubtedly all three of these factors either independently or synergistically influenced the reduction of CMT scores and teat end erosion.

With the reduction of teat end erosion from Time Period II to Time Period III, a relationship between teat shape and teat erosion was exposed. Pointed teat ends showed the greatest amount of erosion, cone and flat ends showed the least amount of erosion, and round and disk ends showed an intermediate amount of erosion. Johansson and Rendel in their book, Genetics and Animal Breeding (1968), suggest that pointed teats were more predisposed to teat erosion than other teat types. They also found that funnel shaped (cone shaped) teats were not subject to teat erosion. This study tends to verify their earlier results.
Combined Analysis for All Three Time Periods

Data from all three time periods were combined in order to increase the sample size for the multiple regression and correlation analyses. Correlations among all of the variables studied are shown in Table 10.

Sample time was significantly correlated negatively with daily milk yield, composite CMT score, and somatic cell counts by .15, .14, and .29, respectively, and positively correlated with lactation number by .10. This is a reflection of the younger age of cows with pointed teats which were arbitrarily assigned a shape score of one. As expected, month of lactation was negatively correlated to lactation number and daily milk yield by .30 and .66, respectively. There was a positive correlation of .09 and .16 between month of lactation and composite CMT score and somatic cell count, respectively. Lactation number had a low but positive correlation with daily milk yield, mastitis score, and composite CMT score. Daily milk yield was negatively correlated with composite CMT score and somatic cell count. CMT score had a high correlation (.58) with the CMT score derived from a somatic cell count. There was also a high correlation (.62) between the CMT score and the somatic cell count as determined by the OSCC II. There was a high (.84 to .89) positive correlation between quarters for teat end erosion. Composite teat erosion score had an even higher positive correlation with individual teat end erosion scores. It is also interesting to note than when erosion of the herd was severe, all quarters were eroded approximately the same. In terms of udder management, abnormal teat ends may be indicative
### TABLE 10
CORRELATIONS AMONG VARIABLES

<table>
<thead>
<tr>
<th></th>
<th>Sample Time</th>
<th>Teat End Shape</th>
<th>No. of Lact.</th>
<th>Lact. No.</th>
<th>Daily Milk Yield</th>
<th>Mastitis Score</th>
<th>Teat End Erosion</th>
<th>Left Rear</th>
<th>Right Front</th>
<th>Right Rear</th>
<th>CMT Score</th>
<th>Somatic Cell Count</th>
<th>CMT from Somatic Cell Count</th>
<th>Comp. Teat End Erosion</th>
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<tbody>
<tr>
<td>Sample Time</td>
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<td>.01</td>
<td>-.01</td>
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<td>-.15</td>
<td>.01</td>
<td>-.05</td>
<td>-.02</td>
<td>-.06</td>
<td>-.14</td>
<td>-.29</td>
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<td>-.05</td>
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<td>-.03</td>
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<td>.05</td>
<td>.05</td>
<td>.03</td>
<td>-.03</td>
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<tr>
<td>Month of Lact.</td>
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<td>-.003</td>
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<td>.09</td>
<td>.16</td>
<td>.13</td>
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<td>.09</td>
<td>.06</td>
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<td>.05</td>
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<td>.08</td>
<td>.02</td>
<td>.02</td>
<td>.06</td>
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<td>.01</td>
<td>-.001</td>
<td>.01</td>
<td>-.10</td>
<td>-.14</td>
<td>-.10</td>
<td>.001</td>
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<td></td>
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<td>.85</td>
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of faulty milking equipment, poor milking technique, and lack of proper teat dipping. These factors, in turn, may cause mastitis. This is in agreement with the findings of Philpot et al. (1974) and Schmidt and Van Vleck (1974).

Table 11 shows the results of the multiple regression stepwise deletion analyses. The first analysis shows that month of lactation accounted for 43% of the variability in daily milk yield. Sample time influenced variation in daily milk yield by 4% while the other variables, lactation number and teat shape, had no influence. None of the above variables contributed to the variability in mastitis score.

The second analysis in Table 11 shows that only 1% of the variability in composite teat end erosion scores was due to sample time, teat shape, daily milk yield, month of lactation, and lactation number. These same variables accounted for 6% of the variability in composite CMT scores. However, only 2 to 7% of the cows during any one time period had clinical mastitis. Thus it is not surprising that none of the variables studied had much influence on clinical mastitis.

Analysis 3 in Table 11 shows that sample time accounted for 8% of the variability in somatic cell count. Daily milk yield and lactation number each accounted for 1% of the variability. Sample time and lactation number accounted for 6% of the variability in CMT scores from somatic cell counts.

Average daily milk yield decreased from the first sample time in August to the second sample time in November, then started to
### TABLE 11
MULTIPLE REGRESSION STEPWISE DELETION ANALYSES

<table>
<thead>
<tr>
<th>Analysis 1</th>
<th>Daily Milk Yield</th>
<th>Clinical Mastitis</th>
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<table>
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<th>Analysis 2</th>
<th>Composite Teat End Shape</th>
<th>Composite CMT</th>
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</thead>
<tbody>
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<td>Lact. No.</td>
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<table>
<thead>
<tr>
<th>Analysis 3</th>
<th>Somatic Cell Count</th>
<th>CMT from Somatic Cell Count</th>
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<tr>
<td>Daily Milk Yield</td>
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<tr>
<td>Month of Lact.</td>
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</tr>
<tr>
<td>Lact. No.</td>
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<td>0.01</td>
</tr>
<tr>
<td>Total</td>
<td>0.10</td>
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</tbody>
</table>

increase again by Time Period III in February. It is to be expected that cows in later lactation produce less milk; however, fresh cows coming into the herd should balance out this effect. CMT
scores followed an opposite trend, increasing in November and
decreasing by February to a level below that for August. Somatic
cell counts were not taken in August but decreased drastically from
Time Period II to Time Period III. Factors such as changes in
milking equipment, additional manpower in the parlor, and the
instigation of teat dipping all could have caused the decrease
of leucocyte counts in herd milk.

As stage of lactation increased, daily milk yield decreased
as would be expected. Cows in later lactation may also be
expected to have higher CMT scores and somatic cell counts in
their milk. This is in accord with the findings of Braund and
Schultz (1963), who found that the number of positive quarters
resulting from CMT analysis increased in the later stages of
lactation.

Gunnison Valley Dairy began in 1971 with all first calf
heifers. Results of this study show that as the animals mature,
they show higher incidences of clinical mastitis and CMT scores.

Higher producing cows showed lower CMT scores and somatic
cell counts than lower producing cows. This may result from the
lower producing cows being in later stages of lactation. Cows
with subclinical mastitis also dropped in milk production. From
a study by Forster, Ashworth, and Luedecke (1967), CMT scores of
trace, 1, 2, and 3 were associated with average decreases in milk
production by 9.0, 19.5, 31.8, and 43.7%, respectively.
Cows randomly entered either side of the milking parlor and were not assigned to a particular milking stall. Erosion of teat ends was uniform over all quarters, with no indication that milking practices or milking equipment was causing any damage to one quarter as compared to any other quarter.
SUMMARY AND CONCLUSIONS

Summary

The objectives of this study were to determine if correlations exist between teat shape and mastitis and between teat erosion and mastitis and if interrelationships exist between teat shape, teat erosion, mastitis (as measured by the CMT and somatic cell counts), and milk production.

Data were collected from the 1,000 cow milking operation at Gunnison Valley Dairy, Gunnison, Utah, during three time periods between June, 1974, and February, 1975. During Time Period I teat shapes from 997 Holstein cows were classified and composite milk samples from 1,015 Holstein cows were screened using the CMT. Teat end erosion scores from 913 Holstein cows were determined, and DHI production data were collected on all milking cows. One hundred seventy-five of the above 1,015 cows whose composite milk samples had scores of trace or higher had each quarter tested for mastitis using the CMT.

During Time Period II, teat end erosion, composite milk samples for CMT analysis, and DHI production data were collected from 879 Holstein cows. The same type of information was collected on 925 Holstein cows during Time Period III. Changes in milking equipment were made during December, 1974, which was between Time Periods II and III. Other changes at the same time included additional manpower in the milking parlor and instigation of teat dipping.
Teat shapes were categorized according to external teat end morphology. The shapes were classified as pointed, round, flat, disk, and cone. Teat end erosion was subjectively classified on a scale of zero to three, zero indicating no erosion and three indicating severe erosion. Teat erosion was defined as various epithelial lesions on the distal end of the teat caused by milking machines. In severe cases, epithelial lesions showed an eversion of the teat orifice.

No relationship between teat shape and milk or fat production was found. CMT scores during Time Periods I and II were significantly higher for cows with flat and cone shaped teat ends compared to cows with pointed, round, or disk shaped teat ends. However, in Time Period III there was no relationship between teat shape and CMT scores. CMT scores of trace, 1, 2, and 3 were reduced by a factor of 2.5 to 3.0 times in Time Period III as compared to Time Periods I and II. In Time Periods I and II there was no relationship found between teat shape and teat end erosion. However, in Time Period III, two months after the changes in milking equipment and milking procedure occurred, a significant relationship was found. At this time teat end erosion was highest for pointed teat ends, lowest for cone and flat shaped teat ends and of an intermediate degree for round and disk shaped teat ends. During all three time periods no significant relationship was found between different quarters for teat end erosion. Severe teat end erosion (score of 3) was reduced in Time Period III by 15.1 and 48.9% as compared to Time Periods I and II, respectively.
Conclusions

There were no relationships between teat shape or teat end erosion and milk or fat production. The relationship between teat end erosion and mastitis appeared to be masked by the high level of teat erosion. There was an indication that cows with flat and cone shaped teat ends were prone to higher CMT scores than cows with pointed, round, or disk shaped teat ends. Teat shape may also be related to teat end erosion. When milking equipment and practices were changed, teat end erosion was not so severe, and pointed teat ends showed the highest amount of erosion, round and disk an intermediate amount of erosion, and cone and flat the least amount of erosion. There was a high correlation between the CMT scores and scores from the somatic cell counts.

Teat end erosion, CMT scores of 1, 2, and 3, and mastitis increased in the herd from August to November, 1974, and then decreased by February, 1975. On the other hand, average daily milk yield decreased from August to November, 1974, and then increased by February, 1975.

Teat end erosion is indicative of faulty milking equipment. High CMT scores may be indicative of several factors, faulty milking equipment being one of them. There are also reports that mastitis may be caused by faulty milking equipment.

The probable cause of the fluctuation in milk production from August, 1974, to February, 1975, was due to clinical and subclinical mastitis which increased from August to November, 1974, and then
decreased sharply in February, 1975. Management changes that were made in December, 1974, undoubtedly were factors that helped to elevate teat erosion, mastitis, and low milk production.
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VITA

John Stephen Malan

Candidate for the Degree of

Master of Science

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Major Field: Dairy Science

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