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Dr. Lloyd V. Swanson

This study was conducted to determine the relationships among the linear type traits of rump angle, rump width, rump length, rear legs - side view, rear legs - position, rear legs - rear view, tailhead, vulva angle, mobility, pasterns, foot angle, and toes with reproductive performance (days open and times bred) in Holstein cows and to develop indices to predict reproductive performance from mathematical functions of the anatomical traits. Two trials were conducted. The first trial involved 7630 registered Holstein cows from Oregon and California. The regression analysis (R^2) showed only 1.1% of the variability of times bred and 1.3% of the variability of days open was accounted for by the rump and rear leg type traits.

In the second trial, 8155 Holstein cows, both registered and grade, were analyzed using the linear type traits of rump angle, rump width, rear legs - side view, rear legs position, rear legs - rear view and foot angle.. Grade and registered cows were analyzed separately to determine if differences in management between them would be reflected in the statistical analysis. Evaluator, lactation number (parity), season, geographic location, and the interaction of evaluator and lactation number had a significant effect on most of the type traits and

the scorecard category (General Appearance, Mammary System, Dairy Character and Body Capacity) scores examined. The effects of these variables were statistically removed and the residuals of the type traits were used in the final regression analysis. Using stepwise regression analysis, several non-significant traits were omitted from the final model. The analysis used days open and times bred as dependent variables. Lactation number, mature equivalent milk, foot angle, rump width and their respective quadratics were independent variables, as were season calved and geographic location. The regression analysis (R^2) indicated that 5.3% of the variability in days open and 4.7% of the variability in times bred in registered cows was accounted for by the type traits, foot angle and rump width, respectively, when the effects of season calved, geographic location, lactation number and mature equivalent milk were included in the model. For the grade cows the regression analysis (R^2) indicated that 3.5% of the variability in days open was accounted for by foot angle. None of the type traits examined had a significant effect on times bred. This study detected no significant influence of rump angle or rear leg-position, as described by the HFA linear classification program, on reproductive performance. However, our analysis indicated that fertility decreased as rear foot angles became more steep in grade and registered cows and as rump width increased in registered cows.

Relationships Among Rump and Rear Leg Type Traits and Reproductive Performance in Holsteins

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Redacted for Privacy

Head of Department of Animal Science

Redacted for Privacy

Dean of Graduate School

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For what glory is it, if, when ye be buffeted for your faults, ye shall take it patiently? but if, when ye do well, and suffer for it, ye take it patiently, this is acceptable with God.

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INTRODUCTION

The dairymen's main source of income is the production of milk and fat and, in some states, solids-not-fat or protein. The genetic potential for increased yields requires continued selection pressure for greater production of milk, fat and protein. This selection pressure applied to herd replacements can amount to 30% or more of the milking herd being replaced annually (Murrill, 1974).

In order to produce these replacements, cows must conceive and produce calves. The production of more calves allows for additional selection pressure on replacements for the milking herd (provided the offspring are genetically superior to their dams). We measure the cow's ability to reproduce by determining her yearly calving interval, conception rate, or days open.

The ability to manage cows so that they conceive promptly is one of the more important factors leading to overall efficiency in today's dairies. Increases in days open and times bred decrease profits in the herd.

There are many measures of reproductive efficiency in dairy herds. Veterinarians, universities, and farm advisors suggest the following goals (Britt, 1982; Falk, 1987; Morrow, 1970; Hutchinson, 1985):

Postpartum interval to first estrus	30-40 days
Postpartum interval to first breeding	70-75 days
Services per conception	1.3-1.7
30 day non-return rate	70-75%
Calving interval	12-13 months
Days open	<110 days
Percentage of cows that breed back	>85
Percentage of breedable heats detected	>60

The following questions were developed to serve as a basis for the inquiry in this study:

1. To what extent can fertility be improved by selecting for conformational traits?
2. Is there an association between the physical conformation of a cow (in particular the rump and leg traits) and fertility?
3. If there is a relationship, can we estimate a cow's reproductive efficiency by scores given to her for those conformational traits?

Because increased milk production and breeding efficiency have direct economic importance to the dairy farmer, the scientific community has an obligation to look for measures which will improve these two parameters. It is in the dairy industry's interest to explore relevant variables which may be related to and/or have an impact on milk production and/or breeding success.

A number of these factors are genetically determined and beyond the direct control of the farmer, other than the farmer's option of selecting which cows to breed and when. This selection process might possibly be determined by type traits which can be measured and which might prove to have some association with economic relevance.

The importance of this study lies in determining if some of these selected measurable traits are related to reproductive performance. The classification procedure is both time consuming and expensive. The literature to date does not present a definitive picture regarding the relationship of physical traits to reproductive performance.

Therefore, it is of significant value to the industry to determine whether, which and to what extent, physical traits may be related to efficient breeding performance. If a significant relationship exists, the application of the results of this study will apply when economically practical. It should be remembered that small percentages of improvement, when dealing with large numbers of cows, may prove to be economically desirable. If no significant results are found, our contribution to the industry may be the suggestion that perhaps other variables/characteristics, less obvious, should be explored, or that selection of type traits for improvement of reproductive performance is not warranted.

LITERATURE REVIEW

Defining Reproductive Traits

The calving interval can be divided into five parts (modified from Bell, 1984; Casida, 1971; Hinks, 1983):

1. The time interval from parturition to first postpartum estrus.
2. Earliest breeding date - This date is determined by the dairy manager. A commonly accepted program is to begin breeding at the first heat (estrus) 45 days postpartum or to wait at least 60 days for first calf heifers or cows with any calving problems. Therefore, this measure of dairy reproductive efficiency is not directly related to fertility. In addition, intentional management delays in breeding high producers may bias any relationship using this measurement.
3. Submission rate - Measures how quickly cows are bred after becoming eligible for breeding (the percentage of cows or heifers bred within a 21 day period that have already met or passed their earliest breeding date at the start of the 21 day period). This measure helps identify estrus detection problems as well as cows failing to cycle.
4. Time interval from the first breeding to the date of conception.
5. Time interval from the date of conception to the date of calving. This period will vary by breed, individual bulls, and sex of calf (Foote, 1981) and for all practical purposes is not under the control of dairymen.

The conception rate can be defined as:

1. Conception to first service or breeding
2. Overall conception rate
3. Services per conception - This number refers to the number of times a cow is bred per conception and includes cows that were culled but does not include cows which are culled before they conceive. Services per conception are higher for cows bred before 60 days post-partum (Berger et al., 1981).
4. Nonreturn rate or assumed pregnancy rate - This number reflects the number of cows bred within a defined period and not reported to come back in estrus. The nonreturn rate ignores cows culled, cows that died, cows that were bred by another stud service or cows that were mated by natural service. This method is, however, used by the artificial insemination (A.I) industry as a quick means of monitoring the efficiency of A.I. technicians and fertility of their bulls (Taylor et al., 1985).

Conception rate, especially when using artificial insemination, can also be affected by factors other than the fertility of the cow. Such factors as fertility of the semen, timing of the insemination, estrus detection accuracy, semen handling, insemination method, and several environmental stressors such as high ambient temperature, can contribute to the large degree of variation in this measurement (Britt, 1982).

Measurements such as services per conception and nonreturn rate fail to account adequately for reproductive performance of the problem cow which does not eventually conceive (Poston et al., 1962). The number of services required for previous conceptions is of no practical value in predicting the number of services required for later conceptions and is of even less value for predicting the services required for conception by the cow's progeny (Dunbar and Henderson, 1953). Because of this low repeatability, other measures, such as days open, need to be considered to more accurately define reproductive performance.

Days open measures the overall reproductive performance for the previous twelve months. Problems with fertility and/or estrus detection increase days open. Days open of 116-130 days indicates a slight problem for commercial herds, but may be desirable for breeders of registered cattle who are interested in obtaining maximal milk production records on individual cows to increase the sale value of these animals and/or their offspring (Varner et al., 1985).

Failure to detect estrus is the major cause of prolonged calving intervals (Bell, 1984; Holmann et al., 1987). Studies show that conception rates also may be poor in herds as a result of improper detection of estrus (Schermerhorn et al., 1986). Less than half of the owner-inseminator herds in this study had specific times of the day for estrous detection and a large number of those that observed their cows at specific times relied on heat detection aids to supplement their observations.

Estrous detection rates were higher for cows that produced slightly above the mean milk yield in Holsteins but in Jerseys there was a significant negative relationship between days to first ovulation and 305 day milk yield (Fonseca et al., 1983).

The inseminator needs to have a reliable predictor of the time of ovulation (Hafs, 1985). Various experimental methods, such as those of Kiddy (1979) using litmus paper, to those of Espinosa (1987) where estrus was determined by measuring electrical resistance of vaginal mucus, have helped scientists better determine the time of ovulation. However, these scientific methods have not proven to be of practical value for the dairy farmer.

Work in England (Bell, 1984) suggests that the best aid to estrus detection is measuring the morning or afternoon maximum milk temperature and comparing it with corresponding temperatures of any of the previous 15 days. This could easily be done by computer, thus reducing the laborious standing heat detection currently required.

Other more practical methods such as tail head paint or markers (Foote, 1975), pressure sensitive patches (Beerwinkle, 1974), computerized feeders identifying animals that have consumed less feed than expected (Hafs, 1985), teaser bulls (Holmann et al., 1987) and assays for progesterone in milk and blood (Mather et al., 1978; Sawyer et al., 1986) have been used to confirm estrus in dairy cows.

The most reliable sign of estrus, however, is the cow standing to be mounted (Bell, 1984; Foote, 1975). The average length of standing estrous is 15 hours in Holsteins and ranges from 2 to 30 hours. Because most sexual activity occurs between 6:00 p.m. and 6:00 a.m., heat (estrus) detection aids may significantly improve estrous detection efficiency.

From an economic standpoint, heat mount detectors and tail paint methods combined with visual observation during routine dairy chores always had the lowest cost when average wage rate exceeded $2.25/hour

(Holmann et al., 1987). Unaided visual observation with two checks/day was less expensive when labor had few alternative demands and when labor costs were less than $2.25/hour. The most expensive method (teaser bull, three times/day observations) yielded the shortest calving interval. A less expensive method (by $878/yr) using heat mount detectors and two daily observations added only 10 days to the calving interval.

Heat detection efficiency and the economics of the method used are important but the accuracy of detection should also be considered when assessing which method(s) to use. Stevenson and Britt (1977) compared accuracy with efficiency of detection using three methods. Their study showed an accuracy of detection for cows observed visually for standing estrus by the herdsman, using a heat mount detector, and using a teaser animal, as 68, 66, and 79%, respectively. Efficiencies of detections (the total observed heats divided by the total expected heats) were 51, 51, and 52%.

Dollars per day open for each method portrays visual observation as the most accurate and economical followed by the use of tail paint, heat mount detectors, teaser bulls, and prostaglandins, in that order (Holman et al., 1987).

To maintain a 12 month or 365 day calving interval, days open must be less than 80-85 days. This goal is not very practical when many dairymen wait to begin rebreeding 60 days or more postpartum. Besides the voluntary management decision on the earliest breeding date to start, post-partum days open is dependent on the following (Peters, 1984):

1. The re-establishment of normal ovarian cycles post-partum.
2. The occurrence of estrus behavior at the right time in the cycle.
3. The conception rate following the breeding.

The average national calving interval is 13.5 months (Call, 1978). In California, DHIA herds average 13.34 months (Lanka, 1985) and for Oregon DHIA herds, 13.30 months (Claypool, 1984). Some of the Mid-States have a slightly better calving interval with Minnesota averaging 12.9 months, Iowa and South Dakota 13.1 months, Arkansas, Missouri, and North Dakota 13.2 months and Illinois, Kansas, Nebraska and Oklahoma averaging 13.3 months (Reneau and Steuernagel, 1983).

Several studies claim that a calving interval of greater than 365 days (i.e. 385 days) is more profitable, (Ehlers and Allalout, 1982; Holman et al., 1984) while others suggest the traditional 12 month interval is more profitable (Call, 1978; Dijkhuizen et al., 1985). The optimum reproductive rate in livestock has been defined as "that rate which gives maximum economic profit per breeding female per breeding year" (Casida, 1971).

A lengthy calving interval results in lowered average milk production/day (due to the involution of the udder as lactation advances) and increases the cost in replacement stock (that cost which is associated with the maintenance of the dam). Too short an interval may impair milk yield as the lactation is too short.

As the postpartum interval between calving and rebreeding increases, the conception rate at first service increases and the number of services per conception declines (Gordon, 1983). Conception shows improvement with delay of breeding up until 80 days post-partum.

However, cows which fail to exhibit estrus by day 30 post-partum require more services than those that do (Thatcher and Wilcox, 1973).

High services per conception are costly. Grusenmeyer et al. (1983) estimates a loss of $1.50 per cow for each .1 service per conception over 1.5. A services per conception of 1.5 translates into a 66% conception rate. McGilliard et al. (1990) estimate a $7.70/.1 service decrease in profit/cow/year.

Shanks et al. (1978) reported that 21% of a dairyman's direct health costs are due to reproductive problems. Dijkhuizen et al. (1985) estimated a loss due to reproductive failure in Holland at 2% of the gross production value or 10% of an average dairy farmer's income (net return on labor). In a Pennsylvania study, conservative estimates of $2 cost/cow/day for cows open beyond 85 days were made (O'Connor et al., 1985). Pelissier (1982) estimated that infertility resulted in a net loss of about $116/dairy cow in the United States in 1981.

Holman et al., (1984) claimed an increase in net income of $.21 to $.40 per day open per cow as calving interval increases from 12 to 13 months. However, there was a consistently negative value (or loss) per day open ($.04 to $.23) when calving interval was increased from 13 to 15 months. In a more recent study, Schmidt (1989) reported a loss of $.18 to .60 per day open for a 15 month calving interval as compared to a 12 month interval. Others (Grusenmeyer et al., 1983; Olds et al., 1979b; Rawson, 1983; Reneau and Steuernagel, 1986) claim an increase of up to $5.00 per day per cow for intervals over 13 months.

Longevity and Culling

As calving intervals increase, the percent of cows in early lactation is reduced while short calving intervals tend to increase the proportion of dry days for the cow (Grusenmeyer et al., 1983). Both of these situations tend to reduce the total lifetime productivity of the cow.

Calving interval and herdlife (longevity) are phenotypically uncorrelated (Miller et al., 1967). Phenotypic correlation between average calving interval and first lactation milk production ranges from .19 to .21. Miller et al. (1967) reported further that cows producing more milk in their first lactation also had higher survival rates, however, the higher producers had the longest calving intervals compared with their contemporaries in the same herd.

Milk production in first lactation is more closely correlated with lifetime profit than any other trait (Young, 1985). Lifetime profit is highly correlated with days of herd life. Although high producing cows are under more stress than lower producing cows, as a group, fewer of them are culled due to low production; hence they last longer in the herd.

The average life span in dairy cattle is three and one half lactations or between 5 and 6 years (Gordon, 1983; Young et al., 1980). Reproductive problems are responsible for 20 to 50% of the cows leaving a herd (Bowden, 1982; Call, 1978; Foote, 1970; Laben, 1981; Murrill, 1974; Oltenacu et al., 1984; Pound, 1977; Silva et al., 1986; Van Doormaal et al., 1986; Westell et al., 1982; and Young et al., 1980). In most herds, reproductive problems rank second, behind low milk yield, for reasons for culling (Berger et al., 1981).

Reproductive failure causes substantial economic loss to the dairy farmer as a direct result of a decrease in yearly milk production, decrease in surplus calves for sale and indirectly due to a decrease in potential selection differential due to the reduction in replacement stock (Foote, 1970).

Looking at it from another perspective, the increase in cow disposal is costly, forcing a higher annual cost for replacements (because more are needed). In addition, there is a decrease in average herd yield, due to an increased number of cows in the lower yielding ages (2 and 3 year olds) and a decrease in the possibilities in selection and culling or rate of genetic progress for traits of economic importance.

Heritability of Reproductive Traits

Most northern European countries and Israel evaluate sires for some measure of reproductive performance. There is little or no selection for daughter fertility in the United States (Berger et al., 1981; Berger and Freeman, 1982).

Heritabilities for the reproductive traits are low in most studies, usually less than five percent (Dunbar and Henderson, 1953; Evans et al., 1964; Hansen, 1982; Miller et al., 1967; Smith and Legates, 1962). In other studies, heritability estimates of breeding efficiency were as high as .32 (Wilcox et al., 1957). A heritability of less than 5% means that less than 5% of the difference in reproductive performance is due to genetics. This compares to approximately 25% controlled by genetics for milk yield and fat and 20% for milk protein (Gaunt, 1973; White et al., 1981). Even though these traits have low heritabilities, progress can be made by selecting for type traits or other variables related to fertility. In Sweden, for example, the incidence of cystic ovaries was 10.8% in 1954. By selecting against sire lines with a high incidence of cystic ovaries, the occurrence of cysts was reduced to 5.1% in 1961 (Bane, 1968; Swedish Agriculture, 1978).

Others feel that attempting to change a trait with very low heritability is a waste of time since lowly heritable traits will not respond to selection and selection for several such traits will cause a reduction in genetic progress in other economically important trait (Cassell, 1984).

Low heritability means that phenotype does not predict genetic merit very well. However, this can partially be remedied with more information. Cassell (1984) shows an example of using multiple records to increase the heritability of a trait (Table 1). Five records on a cow make the heritability of the average of those records 0.42 compared to 0.25 when only one record was available.

Table 1. The effect of using multiple records on the heritability of the average of up to five milk records.

No. of records in the average	Heritability of average milk yield
1	0.25
2	0.33
3	0.38
4	0.40
5	0.42

From: Cassell, 1984

Reproduction and Its Antagonism with Production

Most studies show that reproductive problems tend to increase as yield increases (Foote, 1970; Hansen, 1982; Pound, 1977) in older cows. However, fertility seems to improve in first lactation cows with high production (Hansen, 1982). Perhaps the high stress of lactation in older cows has greater influence on fertility than does the positive association of milk yield and reproduction observed in younger and lower yielding cows.

Other researchers have found varied associations of high milk production and lowered fertility. Several reported an antagonistic effect between high yield and fertility (Badinga et al., 1985; Ducker and Morant 1984; Erb et al., 1985; Hansen, 1982; Olds et al., 1979) and others found no significant difference in reproductive efficiency between high and low yielding cows (Hillers et al., 1984; Slama et al., 1976). Taylor et al. (1985) noted a conception rate increase with increased herd milk production.

In contrast, Laben et al. (1982) found no antagonism between high milk production and fertility (on a herd basis), citing herds with higher average yields that averaged shorter intervals to first postpartum breeding and fewer days open. However, for the individual cow, Laben et al. (1982) noted a small but significant negative association between high yield and reproductive efficiency. This suggests that a part of the reason for the high average milk yield, better management, reflects the herds' ability to overcome this small antagonism.

Laben et al. (1982) reported days to first breeding, days to last breeding, and days open increased by .27, .80, and .61, respectively, and the number of breedings increased by .014 for each 100 kg increase in 180 day yield of fat corrected milk. This antagonism may be over shadowed by good management.

Selecting artificial insemination sires on predicted difference for milk was successful in increasing milk yield in the daughters of these bulls without significant increases in reproductive or health disorders (Shanks et al., 1978). Selection for high producing cows without conscious emphasis on fertility will not lead to a population with markedly altered reproductive abilities (Foote, 1970). Management plays the major role in maintaining optimum fertility levels (Foot, 1970; Hansen et al., 1983; Laben et al., 1982). There is a continuous natural selection against inherited factors which decrease fertility - the more severe the depression, the more intensive is the natural selection.

Environmental Effects on Fertility

Other factors influencing reproductive efficiency in cattle include nutrition, age, physical or environmental factors, season bred, and perhaps type. It is widely accepted that nutrition has a quantifying effect on dairy cow fertility. Where gross deficiencies or excesses of nutrients occur, poor reproductive efficiency is expected.

Nutrition

Deficiencies of energy and protein will delay the onset of puberty. There has been considerable research which suggests that when cows are losing weight they tend to have a lower conception rate than those gaining weight at breeding (Broster, 1973; Ducker, M.J., personal communication; Folman et al., 1973; Otterby and Linn, 1981). Peters and

Riley (1982a, 1982b) reported a longer postpartum anestrus period in cows with low bodyweights postcalving. Folman et al. (1973) concluded that an association exists between body weight changes and progesterone levels - both being reduced, in cows with poorer conception, prior to first insemination. Beal et al. (1978) observed that dietary energy restrictions influenced the corpus luteum's (CL) response to luteinizing hormone (LH) stimulation, resulting in the CL synthesizing and releasing less progesterone. Chesworth et al. (1983) also reported decreases in plasma progesterone in diets deficient in energy.

Although Ducker and Morant (1984) found no effect of dietary treatment on reproductive performance, they concluded that an increase of 15-20% metabolizable energy (ME) intake may not have been enough to affect fertility. However, they noted that with additional feeding in the first few weeks of lactation, initial milk yields may increase and therefore reduce the rate of increase in milk yield around the time of insemination, leading to an improvement in fertiltiy. Ducker and Morant (1984) did find that both yield and the rate of increase in milk yield were related to fertility. Chances of pregnancy, in their study, was lower in cows whose milk yield was high on day 21 but those whose average rate of increase in milk yield had been slowest tended to become pregnant more readily than those with lower cumulative yields.

Protein and its relationship with fertility has provided us with some interesting observations. Jordan and Swanson (1979b) and Aalseth et al. (1984), found decreased fertility in cows fed high levels (19.3%) of crude protein (CP) that could not be attributed to increased milk production or to increased body weight loss. Jordan and Swanson postulated that the excess dietary protein may act directly on the pituitary to increase the responsiveness to gonadotropin releasing hormone (1979a) or by adversely affecting the uterine environment (1983). Folman et al., (1983) suggested that high protein intake may reduce the utilization of energy in addition to the possible toxic effect of nitrogenous compounds. The high plasma levels of urea and ammonia found in cows fed high protein diets may also affect plasma progesterone levels. Cows that conceive after one insemination have significantly higher progesterone levels during the estrous cycle preceding insemination than cows that do not conceive (Folman et al., 1973).

In contrast, Blauwiekel and Kincaid (1986) found that high dietary protein did not have a significant effect on fertility. Kaim et al. (1983) concluded that lactation number or protein intake alone did not affect fertility to any great extent. It was the interaction between these two factors that reduced reproductive efficiency (Folman et al., 1983; Kaim et al., 1983) which might partially explain the difference between Blauwiekel et al. (1986) and Jordan and Swanson (1983).

In a more recent study, Ferguson and Chalupa (1989) pointed out that the solubility and degradability of the protein are important variants in conception rate. Excess degradable protein was deleterious to reproduction through toxic effects of ammonia and its metabolites on gametes and early embryos and by exacerbations of negative balances of energy.

The debate as to whether or not supplementation with β-carotene improves fertility continues. Deficiency symptoms of vitamin A include birth of dead or weak calves, a high incidence of retained placenta, and some abortions (Hemken and Bremel, 1982). Because of the role of β-

carotene as a precursor to vitamin A, suggestions as to its part in reproduction have been sought.

β-carotene supplementation significantly increased fertility when basal plasma β-carotene levels were lower than 50 μg/100 ml (Folman et al., 1983). This is in contrast to their earlier work (Folman et al., 1979) where they observed that plasma levels of β-carotene increased upon supplementation but there was no significant differences in duration of standing heat, length of estrous cycle, incidence of ovarian cysts, conception rate and plasma progesterone and LH concentrations.

Jackson (1981) noted a correlation between plasma β-carotene levels and conception. Ducker et al., (1984) reported that while normal to low supplementation of β-carotene does not affect reproductive performance or growth rate in heifers, when there is supplementation above some very high threshold concentration, fertility can be improved. However, they conclude that this level is well outside the ranges found in normal practice.

Conception rate of younger cows calving in the fall and winter was doubled by feeding additional β-carotene (Ascarelli et al., 1985). Conception rates of older cows and of younger cows calving during the spring or summer were not effected. There was also no effect of β-carotene deficiency on plasma progesterone concentration. In a more recent study, Akordor et al., (1986) cited no difference in days to first ovulation, interval from calving to first estrus, days open, total services per cow or relevant services per conception for cows supplemented with β-carotene.

Other workers found supplementation with β-carotene significantly increased plasma carotene but did not affect concentrations of luteinizing hormone, progesterone, insulin, glucose, glucagon, or reproductive measures such as days open, services per conception, days to first heat, and days to first breeding (Bindas et al., 1984; Wang et al., 1982). Wang et al. (1982) did note that the intervals from $PGF_{2\alpha}$ administration to onset of estrus, peak LH and ovulation were shorter in control heifers as compared to heifers supplemented with β-carotene. They postulated that the optimum time of insemination after $PGF_{2\alpha}$ might be influenced by the β-carotene status of the animal.

In Oregon trials (Marcek et al., 1985) supplementation with β-carotene had no significant affect on reducing the incidence of ovarian cysts in cows already receiving an adequate supply of β-carotene. This agrees with a later study (Akordor et al., 1986) where it was also noted that the incidence of endometritis and pyometra were not affected. Akordor et al. (1986) concluded that a deficiency in β-carotene was unlikely to be a concern provided that intake of vitamin A is adequate.

Higher plasma levels of copper (Cu) and magnesium (Mg) during the early postpartum period is associated with fewer days open (Kappel et al., 1984). In diets deficient in these minerals, supplementation with either Cu or Mg alone did not improve fertility over the unsupplemented group. However, the supplementation of both minerals showed significant increases in rate of conception (57% as opposed to 33% first service conception rate). Deficiency of manganese has been associated with anestrus and decreased conception rates in cattle (Maas, 1987).

High nitrate levels have also been reported to cause reproductive problems (Page, 1987). High nitrate rations depressed progesterone levels in cycling cows and those in early pregnancy. When progesterone levels are too low, pregnancy cannot be maintained or established.

Season

Most common domestic ruminants are seasonal in their breeding. Generally speaking, cows do not have a period of acyclicity relating to season, although they do exhibit a period of reduced fertility related to season. Photoperiod is one of the more readily accepted seasonal variants which has been reported to influence fertility (Taylor et al., 1985). Heifers gain at a more rapid rate and are more efficient during months of decreasing light and temperature (Hauser, 1984), thereby reaching puberty at an earlier age (Tucker, 1982). However, Tucker (1982) found photoperiod to have little effect on gonadotropin secretion and fertility.

Temperature and humidity are two other variants associated with change in season. Conception rates fall drastically in cows bred during the hot summer months (Cavestany et al., 1985; Fuquay, 1986; Jarett, 1986; Ron et al., 1984; Stott and Williams, 1962; Tucker, 1982). As maximum daily temperatures increased by 15°F from the first of June (92°F) to June 15 (107°F), the number of animals conceiving and maintaining their pregnancy dropped from 61.5 to 31.0% (Stott and Williams, 1962), indicating a high rate of embryonic mortality associated with high ambient temperature. Days open, and hence the calving interval, increase in cows bred in hot summer months (Rosenberg et al., 1977; Bulman and Lamming, 1978; McNatty et al., 1984). Cows normally resume estrous cycles by 24 days after calving (Bulman and Lamming, 1978). The length of this interval (from calving to first postpartum estrus) varied significantly with the season of calving and non-significantly with the age of the cow (i.e., lactation number) and was not related to yield.

Studies in Israel show that conception rates decrease in summer months with a significant decrease in progesterone concentrations during the luteal phase of the cycle (Rosenberg et al., 1977). Increased exposure to summer heat increases secretion of adenocorticotropin, which increases adrenal progesterone secretion, followed by decreases in preovulatory surges of LH (Tucker, 1982). Cortisol levels rise initially when cows are exposed to extreme high temperatures but then become depressed over time (Chesworth and Easdon, 1983). Some of the initial increase in glucocorticoid levels during heat stress might be as a result of a decrease in nutrient intake. High corticosteroid concentrations can inhibit the secretion of LH and thus may be a factor in the delay of normal ovarian cycles (Peters and Lamming, 1986; Matteri and Moberg, 1982; Stoebel and Moberg, 1982).

High ambient temperatures act on control centers in the hypothalamus, depressing appetite and lowering the metabolic rate. As mentioned earlier, decreased appetite (weight gain) postcalving has a significant association with decreased progesterone levels and decreased conception at first service (Folman et al., 1973). Growth rates also decreased which may delay puberty (Fuquay, 1986).

In a later study, McNatty et al. (1984) noted that seasonal differences in ovarian activity in cows was probably due to seasonal differences in gonadotropin secretion. Luteinizing hormone pulse frequency and plasma prolactin concentrations were significantly higher in spring months than in autumn and winter months. The corpora lutea were heavier and secreted more progesterone in autumn and winter than in spring (McNatty et al., 1984).

Season of calving influences the duration of postpartum anestrus; the interval is longer during the winter than during the summer (Peters and Riley, 1982a).

Functional Type

Dairymen have long argued the relative value that type has in selection or breeding programs. Type is defined as the ideal or standard of perfection that combines all the body characteristics that contribute to the usefulness of dairy animals (Trimberger et al., 1987). Some dairymen prefer to ignore type altogether while others are solely concerned with type improvement in their breeding programs. Most dairymen strive for a combination of milk yield and functional type traits in their herd selection program. Functional type traits generally include feet and legs, mammary system and dairy character. The rump and rear legs are especially important in determining mobility and, possibly, fertility. Certainly it is recognized (Ali et al., 1984) that cows with large pelvic areas are known for calving ease. Pelvic area is a moderately heritable trait (Benyshek and Little, 1982). Benyshek and Little (1982) concluded, using Simmental cattle, that selection for pelvic area may reduce dystocia. The average commercial dairyman is looking for a cow with high production capability and one that has the body and strength to sustain high milk yield over a long period of time.

Type has monetary significance at the show ring and at sales; however, specific monetary weights for components of type have been impossible to calculate (Blanchard et al, 1983) and varies considerably amongst dairy farmers (Hinks, 1983).

In 1922, leading Holstein breeders and judges met to establish models for the True-Type cow and bull (Prescott, 1973). These models represented theoretical perfection in Holstein type. In order to provide official means of comparing the conformation and characteristics of living animals with the theoretical perfection of the True-Type, a system of herd classification was created.

Since 1929, the Holstein Association has used an official type classification system in the United States (Murrill, 1974). The descriptive type traits were implemented as part of the classification program in 1967 (Cassell et al., 1973b; Grantham et al., 1974; Trimberger et al., 1987). Animals in the original classification system were placed in one of six categories: Excellent, Very Good, Good Plus, Good, Fair, and Poor. Each animal was given a numerical score representing a percentage of theoretical perfection, i.e., 100 points. In 1967, the classification program added descriptive terms including information on stature, front end, legs and feet, and mammary system (Prescott, 1973; Grantham et al., 1974). Dairymen hoped to be able to identify conformational strengths and weaknesses in individual cows and then select bulls to improve these functional traits, a system known as corrective mating.

Dickinson and Powell (1981) recommend that every cow and heifer be individually mated after the particular strengths and weaknesses of each cow or heifer and of each bull are considered. They further recommended rating bulls on their expected transmitting abilities for economically important type traits. Genetic theory indicates that it should make little difference whether certain bulls are bred to certain cows (White, 1974). White (1974) admits, however, that within a herd, corrective mating may reduce the frequencies of cows expressing undesirable traits (for certain traits).

Corrective breeding can have an affect on type and hence on overall productivity (Grantham et al., 1974; Vinson, 1980; White and Vinson, 1976). For example, selection for a strong median suspensory ligament (udder support and rear udder) contributes to longer herd life and higher lifetime yields (Young, 1985).

Van Vleck et al., (1969) describe correlations between the absence of breeding problems and descriptive type (Table 2). This partial summary table shows that nearly all the correlations are less than .25 and that there may be some but no definitive relationship between descriptive type traits and the absence of breeding problems. Van Vleck et al. (1969) did observe a relationship between reproductive problems and level rumps. In a later study, Van Vleck and Norman (1972) reported that cows with sloping rumps were culled less frequently for reproductive failure than cows with level rumps.

The categorical system of classification had the effect of introducing bias into estimates of heritability and correlation. Classifiers were reluctant to assign low scores. Variation due to evaluators was as high as 26% for final score and 48% for feet and legs (Boldman and Famula, 1985; Bowden, 1982; Lawstuen and Hansen, 1986; Smith et al., 1985). Effects of stage of lactation (Ali et al., 1984; Boldman and Famula, 1985; Bowden, 1982; Cassell et al., 1973; Murrill, 1974; Petersen et al., 1986; Rennie et al., 1974), season classified (Bowden, 1982; Hansen et al., 1969; Murrill, 1974) and age at classification were major factors affecting type score (Boldman, and Famula, 1985; Bowden, 1982; Cassell et al., 1973b; Lawstuen and Hansen, 1986; Lucas et al., 1984; Murrill, 1974; Rennie et al., 1974; Smith et al., 1985).

Table 2. Correlations between descriptive type traits and absence of breeding problems.

Hind legs (side view) (%)	
Nearly straight	.07
Intermediate	-.12
Hind legs (rear view) (%)	
Toe-out; none-to-slight	.00
Rump levelness (%)	
Nearly level, smooth pelvic arch	.01
Nearly level, notched pelvic arch	-.33
Nearly level, high pelvic arch	.17
Nearly level, high tail head	-.02
Slightly sloping, relatively smooth pelvic arch	.00
Rump rear view (%)	
High thurls, square	-.13
Intermediate thurls	.10
Heel depth (%)	
Deep	-.01
Intermediate	.07

From: Van Vleck et al., 1969.

Classifiers had a tendency to raise a cow's evaluation with age and score them higher just before or just after calving as compared to mid-lactation (White, 1974). The discrete and nonlinear nature of descriptive type traits made age adjustments impractical (Cassell et al., 1973a). The repeatability was only 0.55 when different classifiers judged the same cow at the same time (White, 1974).

Correlations between overall type appraisals and measures of longevity have been conducted using HFA's descriptive type classification program and have shown moderate positive to slight negative correlations (Grantham et al., 1974; Honnette et al., 1980b; Van Vleck et al., 1980).

In an earlier study (Berger et al., 1973), phenotypic type score was .38 to 2.94 times as important as production phenotype in determining length of herdlife. In this study some dairy herds emphasized (in their culling decisions) how their cows looked rather than how much milk they produced. Purebred breeders and dairy producers differ on traits considered most important to economic herdlife. Dairy producers give more emphasis to udder support, teat placement, rear udder height, and fore udder attachment than to the remaining traits. Purebred breeders place their major emphasis on strength, angularity, rump length, and rear udder height (Gonyon et al., 1986b).

In 1977, a committee from the National Association of Animal Breeders (NAAB) recommended a new linear means of evaluating cattle. Traits were to be scored from one biological extreme to the other on a continuous scale (Norman et al., 1983; Wilson, 1979). Thirteen appraisal traits were proposed to be a part of the new uniform functional type trait (UFTT) program adopted by the NAAB (Norman et al., 1983). On January 1, 1980, the program was adopted by the Ayrshire, Guernsey, and Jersey breeds. In January, 1981, the Milking Shorthorn and Red and White breed associations began using the program and in January 1982, the Brown Swiss Association adopted its version of UFTT. The Holstein Association finally adopted a linear system of classification in January of 1983 (Lawstuen and Hansen, 1986). In 1986 the trait list was simplified according to real economic value for milk and longevity (Holstein Association - personal communication). One purpose of the linear type scoring system was to describe a phenotype without assigning merit to a particular score (Gonyon et al., 1986a). The older "categorical system" was not meant to be used as a sire evaluation system. It's purpose was as a descriptive system to indicate the strengths and weaknesses of a particular cow (Vinson and Honnette, 1980). Researchers have suggested that the new linear classification program more accurately describes the functional traits of the animal (Norman et al., 1988).

Heritabilites of uniform functional type traits varied by breed (Norman et al., 1983) (Table 3).

Table 3. Heritabilities of uniform functional type traits by breed.

	Ayrshire	Guernsey	Jersey	Milking Shorthorn
Rear Legs (side)	.20	.13	.08	.07
Pelvic Angle	.13	.34	.29	.19
Rump Width	.16	.36	.20	.50

From: Norman et al., 1983.

Herd effect was high for most traits in Jerseys, possibly because of the use of more evaluators. One evaluator was used in both the Ayrshire and Guernsey programs whereas several evaluators were used in the Jersey program. There are vast differences in heritabilities of type traits among breeds. In general, Holsteins have a negative correlation between type and production whereas Jerseys have a positive correlation (Young, 1985). It is felt by some breeders (Lindskoog, personal communication) that Jersey type programs assign highest type scores to cows that make the commercial dairy farmer more money and the Holstein type program does not.

In comparing the NAAB linear classification program and the HFA descriptive classification system, Vinson and Pearson (1983) found that the linear system was superior to the descriptive system in measuring differences among cows in components of conformation.

Type appraisal on a linear basis over scoring in relation to an ideal is recommended because heritabilities of linear traits are slightly larger and correlations between linearly scored traits are interpreted more easily (Thompson et al., 1981). The linear system also allows the measurement of more genetic variation.

Heritabilities for conformational traits by two methods using the older Holstein descriptive system were estimated (Rennie et al., 1974; Cassell et al., 1973) which can be compared to heritabilities performed for the new linear system (Thompson et al., 1983; Holstein Association Sire Summary, 1985) (Table 4). There does not appear to be the consistent improvement in estimating heritability with the linear system as previously reported by Vinson and Pearson (1983).

Table 4. Comparative heritabilities between linear and descriptive type traits.

	Heritability		
Trait	Unadjusted data[a]	Adjusted data[c]	Linear heritability[d]
Final Score	.33	.19	.28
General Appearance	.28	.27	.24
Dairy Character (angular)	.23	.27	.24
Body Capacity	.31	.31	.26
Mammary System	.19	.17	.23
Fore Udder (attachment)	.17	.14	.15
Rear Udder	.16	.15	
Rear Udder Height			.22
Rear Udder Width			.15
Udder Depth			.26
Teat Placement	(.17)[b]	(.24)	.23
Legs and Feet	.08	.07	
Rear Leg Set, side view	(.07)	(.08)	.15
Foot Angle, heel depth	(.08)	(.11)	.15
Rump	.34	.33	
Rump Angle			.17
Rump Width			.26
Strength			.22
Stature	.55	.52	.32

[a] From: Rennie et al., 1974, descriptive type traits.
[b] From: Cassell et al., 1973, descriptive type traits.
[c] Adjusted for age, stage of lactation, season of classification and rounds of classification.
[d] From: Thompson et al., 1983, and HFA Sire Summary, 1985.

For Holsteins, correlations between all type traits except dairy character are negatively correlated (-.09 to -.36) with predicted difference for milk (PD milk) (Kliewer, 1982). Dairy character was positively correlated with PD milk (.41). However, Kliewer concluded that if type were ignored in the breed improvement program, serious functional weaknesses would increase in frequency and longevity would decline. The highest correlations were shown among the joint effects of descriptive traits, predicted difference type (PDT) and PD milk with longevity (+.58).

Lucas et al. (1984) lists additional advantages of the linear system as allowing for removal of environmental effects such as age, stage of lactation, and herd, using all data in computing the daughter average, and allowing for more complete representation of cow differences.

Approximately 10% of all U.S. dairy cows are evaluated for type in some kind of appraisal program (Annexstad, 1986; Berger et al., 1986). Some A.I. industry leaders believe we have lost considerable genetic potential in milk yield by placing too much emphasis on aesthetic type traits (Keown, 1981). Burnside et al. (1984) found sire ratings for conformation to have little predictive value for longevity.

Petersen et al. (1986) reported that genetic gain for milk yield is sacrificed if body conformation traits are emphasized in selection. They concluded that final score as well as most changes of conformation following selection for milk yield were favorable. Everett et al. (1976) showed positive trends for genetic improvement of milk yield in both the Holstein and Jersey breeds, however, the Holsteins genetically decreased in longevity while the Jerseys increased. Lifetime profit is highly correlated with days of herd life (Young, 1985).

High, wide rear udder attachments, strong udder suport and correct teat placements were associated with increases in longevity (Tigges et al., 1986; Van Vleck et al., 1969) while upstandingness, level rump and straight hind legs were negatively related to longevity. Tigges et al. (1986) concluded that the codes deemed most desirable for stature, back, rump and feet were the least profitable.

Vinson and Honnette (1980) concluded that, in all type traits except for udder support and rear udder, the more desirable codes were not associated with increases of any magnitude in longevity or lifetime milk yield. Negative correlations between final score, all components of type, and slope from hip to pins and hip to thurls, as reported by Ali et al. (1984), indicate that classifiers discriminate against sire progeny with progressively more sloping rumps even though these are indicated as contributing to easier calving. The kind of rump for which breeders are selecting may lead to cows with inferior genetic ability to stay in the herd, as shown by the negative coefficient for rump (Van Doormaal et al., 1986).

Dairy judges prefer a rump where the pin bones are slightly lower than the hooks in the belief that it results in better uterine drainage and improved health of the reproductive tract (Trimberger et al., 1987).

Cows with longer rumps and lower pin bones are genetically predisposed to easier calvings (Ali et al., 1984; Dadati et al., 1985). Dadati et al. (1985) concluded that rump score is favorably related genetically to calving ease and that it would appear that the type of rump regarded as ideal has some advantages in reproductive performance.

Variation among type traits was significant as it related to dystocia for all linear traits except teat length and foot angle (Boldman and Famula, 1985). Slightly lower linear type scores were reported for progeny from easy calving sires. Heifers tended to be shorter, more narrow in the rump, more straight hocked and less angular. Boldman and Famula (1985) concluded that the decreased rump width and smaller stature may be factors contributing to the negative-direct-maternal correlation for progeny of easy calving bulls. Negative direct-maternal correlation hypothesis states that small calves born with ease become small cows that have difficulty giving birth. Goldman and Famula (1985) found no evidence to support this theory.

Several standards or ideal types have been proposed to improve reproductive efficiency in dairy cows. One such standard describes this cow as being wide between the hip bones, thurl joints and pin bones. Lindskoog (personal communication) believes that the thurl joints should be considerably lower than the hooks and the pin bones enough lower than the thurl joints so that when the cow is standing, she will positively drain the vagina outward. She should also have a moderate set to the rear legs and a deep heel.

McFarlane (1976) describes the raising of the pinbones at the rear of the hindquarters as a factor which causes the narrowing of the vertical opening that the cow has for calving. This lessens the distance between the pelvic floor and the base of the tail. He further comments that this is one of the prime factors in dystocia. McFarlane (1976) challenges the emphasis placed in the showring for greater width between the pin bones. He stresses that the overall portions of the pelvis in the natural animal (not subjected to artificial selection) show that there is a narrowing between the rear end of the pelvis, which has a very important effect on the fetus.

The heritabilities of rump traits are much higher than heritabilities for reproductive traits. Heritabilities for rump of .21 to .33 have been reported in (Rennie et al., 1974; Cassell et al., 1973b). Heritabilities were lower for rump levelness (.10 to .13) and rump length (.9 to .13) (Smith et al., 1985). Feet and leg traits generally had the lowest heritabilities (.00 to .10). Legs are the most common occurring fault corrected (17%) in corrective matings (Berger et al., 1986). In a later study (Schaeffer et al., 1985), heritabilities for linear type traits were reported as .29 for pelvic width, .25 for pelvic angle and .16 for legs, side view.

Heritabilities for reproductive traits were summarized by Jordan (1985) as days open (.01 to .10), calving interval (.00 to .10), services per conception (.00 to .10) and dystocia (.03 to .15); and by Hinks (1983) as reproductive failure (0.05 to 0.10).

Breeders and dairy specialists have been unable to distinguish or to accurately measure genetically transmissible type traits from effects of management or other environmental factors (Hinks, 1983). This has led to selection recommendations that perhaps were based on spurious effects of preferential treatment. Consequently, culling was determined on beauty and not function.

This thesis was designed to examine the relationships among the linear type traits of rump angle, rump width, rump length, rear legs - side view, rear legs - position, rear legs - rear view, tailhead, vulva angle, mobility, pasterns, foot angle, and toes, with reproductive performance (days open and times bred) in Holsteins and to develop indices to predict reproductive performance from mathematical functions of the anatomical traits.

TRIAL ONE

Introduction

Descriptive type classification has been used for evaluating purebred Holstein cattle since 1967 (Grantham et al., 1974). Most dairymen who use this program are concerned with functional aspects of type, that is, those traits related to the cow's ability to maintain high milk production. Functional type traits generally include feet and legs, mammary system and dairy character. The rump and rear legs are especially important, being on the "business end" of the cow, in determining mobility and, possibly, fertility. Certainly it is recognized (Ali et al., 1984) that cows with large pelvic areas are known for calving ease.

Correlations between overall type appraisals and measures of longevity have been conducted using the Holstein Friesian Association's (HFA) descriptive type classification program and have shown moderate positive to slightly negative correlations (Grantham et al., 1974; Honnette et al., 1980b; Van Vleck et al., 1980). Researchers have suggested that the new linear classification program more accurately describes the functional traits of the animal. This new system does not assess the degree or condition of each functional trait.

Dairy judges prefer a rump where the pin bones are slightly lower than the hooks in the belief that it results in better uterine drainage and improved health of the reproductive tract (Trimberger et al., 1987). Reproductive performance can be measured by evaluating services per conception, days open and calving interval. A twelve-month calving interval is considered ideal but is seldom attained. However, a recent survey of Washington herds indicated that a 385-day calving interval was optimal for maximum production (Ehlers and Allalout, 1982). An average herd will have a calving interval of 13 to 13.5 months, days open averaging 100 to 115 days and about two services per conception (Claypool, 1984; Hafs et al., 1976).

Several studies have shown positive relationships between longevity and type and between lifetime production and type (Grantham et al., 1974; Honnette et al., 1980a; Honnette et al., 1980b; Van Vleck et al., 1980; Vinson and Honnette, 1980). However, none of these studies have specified the ideal type for optimum reproductive performance. Therefore, the objectives of this study were to examine relationships among the linear rump traits (vulva angle, tailhead, rump angle, rump length, rump width) and the linear rear leg traits (rear legs - side view, rear legs - position, rear legs - rear view, mobility, foot angle, pasterns and toes) with reproductive performance (days open, services per conception, and calving interval) in Holsteins and to develop indices to predict reproductive performance from mathematical functions of the anatomical traits.

Materials and Methods

Records from 350,000 lactations from Agri-Tech Analytics (ATA), Tulare, California, containing 17,294 records of registered Holstein cows were merged with 59,469 records of classifications from the HFA (see Appendix, Exhibit 6, p. 114). The merged file consisted of 10,177 records, matched by registration number. Of the matched records, only 7,630 cows had complete records. A complete record was one where a cow had a calving date in 1981, 1982, 1983, or 1984 and had a date of classification in 1983, 1984, or 1985.

Not all of the 7,630 complete records had consistently complete data. Table 5 depicts the true consistency of the matched records used in trial 1. Most (92.7%) of these records allowed for complete statistical analysis, however, 6% (461 cows) were not recorded for times bred for the previous lactation and 2.5% (194 cows) were not recorded for days open. In addition, 7.2% (550 cows) had no classifier code and 7.3% (557 cows) had no linear scores for any of the primary traits.

Table 5. Frequency of complete[a] records in final match.[b]

	Times bred	Days open	Classifier code	Complete classification of primary traits
Number	7169	7436	7080	7073
Percent	94.0	97.5	92.8	92.7

[a] Differences in frequencies mitigated by the use of missing value cards (Nie et al., 1975).

[b] Total records included 7630 cows recorded for either fertility trait, days open or times bred.

Fifteen primary traits were evaluated for all cows (Table 6). Primary traits are defined by HFA as those known to have economic value and sufficient variation that when summarized by sire provide a basis for selection. The 14 secondary traits evaluated were recorded only when biological extremes existed; thus, a significantly smaller sampling of cows were available for secondary traits. Of the 14 secondary traits, seven were analyzed with reproductive performance in this study (Table 7). Frequencies for all traits are found in Table 8a and 8b.

Table 6. Description of primary[a] linear type traits evaluated in the classification process.

Trait	High biological extreme	Low biological extreme
Stature	Extremely tall	Extremely short
Strength	Extremely strong	Extremely frail
Body depth	Extremely deep	Extremely shallow
Angularity	Extremely sharp	Coarse and thick
Rump angle	Sloped hooks to pins	Pins higher/hooks
Rump length	Extremely long	Extremely short
Rump width	Extremely wide	Extremely narrow
Rear legs, side view	Extremely sickled	Posty
Foot angle	Extremely steep	Extremely low
Fore udder attachment	Extremely strong	Extremely loose
Rear udder height	Extremely high	Extremely low
Rear udder width	Extremely wide	Extremely narrow
Udder support	Extremely strong	Broken
Udder depth	Extremely shallow	Very deep
Teat placement	Extremely close	Extremely wide

[a] Primary traits are those known to have economic value and sufficient variation that when summarized by sire provide a basis for selection.

Table 7. Frequencies for secondary linear type traits.[a]

Secondary trait	Number of Cows
Tailhead	831
Vulva angle	107
Rear leg position	717
Rear legs - rear view	1,198
Mobility	84
Pasterns	694
Toes	237

[a] Secondary traits were recorded only when biological extremes were observed.

Cows with greater than 300 days or less than 40 days open were excluded prior to the regression analysis (Laben et al., 1982). In addition the 550 cows without primary scores and the 655 cows with no dates for either calving or breeding were removed from the analysis.

Days open and times bred were the only dependent variables used. The reproductive variable, calving interval, was not used since it would have to be computed using the values recorded in the days open variable. The seven secondary traits (tailhead, vulva angle, rear leg position, rear legs - rear view, mobility, pasterns and toes) were made into indicator variables so that they could be included in the regression analysis with their limited numbers of actual recorded scores. Indicator variables (sometimes called dummy variables) are used when qualitative variables are to be used in a multiple regression model (Neter et al., 1983; Nie et al., 1975). Estimations of effects of belonging to groups or classes can be made (i.e., what effect belonging to intermediate vulva angle as compared to extremely tipped or vertical vulva classes would have on times bred or days open).

Table 8a. Frequencies for all traits using all data and data from cows in optimum fertility group.[a]

	Frequency (using all data)	Frequency (DO 85-115 & TB 1 or 2)
Classifiers	21	14
0 code classifier[b]	555	104
Stage of Lactation 1	467	112
2	17	5
0 code stage	7146	1418
Lactation No. 1st	3158	616
2nd	1911	386
3rd	1195	261
4th	1258	256
0 code lact. No.	108	16
Stature	7073	1431
Strength	7073	1431
Body Depth	7073	1431
Angularity	7073	1431
Height Front End	1091	233
Shoulders	483	104
Back	1104	213
Rump Angle	7073	1431
Rump Length	7073	1431
Rump Width	7073	1431
Tail Head	831	183
Vulva Angle	107	30
Rear Legs Side View	7073	1431
Rear Legs Position	719	158
Rear Legs Rear View	1200	253
Mobility	87	17
Foot Angle	7073	1431
Pasterns	695	147
Toes	235	40
Fore Attachment	7073	1431
Rear Udder Height	7073	1431
Rear Udder Width	7073	1431
Udder Support	7073	1431
Udder Depth	7073	1431
Fore Length	445	96
Udder Balance	1007	210
Teat Placement	7073	1431
Placement Side View	352	70
Teat Size	585	114
General Appearance	7073	1431
Dairy Character	7073	1431
Body Capacity	7073	1431
Mammary System	7073	1431
Final Score	7073	1431

Table 8a. Continued.

	Frequency (using all data)	Frequency (DO 85-115 & TB 1 or 2)
Temperament	3195	678
Milking Speed	3195	678
Mastitis Resistance	3195	678
Reproductive Performance	3195	678
Edema	3195	678
General Health	3195	678
Calving Ease	3195	678
Housing System	2347	504
Milking System	2226	478
Feeding System	2336	499
Herd Health	2282	489
Times Bred	7169	1535
Days Open	7436	1535

[a] Optimum fertility group includes cows bred 1-2x and having days open of 85-115.

[b] 0 code is used as a missing data indicator (Nie et al., 1975).

TB = Times bred; DO = days open.

Table 8b. Frequencies for environmental traits and indicator variables.

		Frequency (using all data)	Frequency (DO 85-115 & TB 1 or 2)
Season Bred	Winter	1190	248
	Spring	1901	382
	Summer	1332	244
	Fall	1346	305
Geographic Location			
	Coast	991	231
	Williamette Valley	1669	367
	San Joaquin Valley	3402	603
	Southern California	1237	279
Season Classified			
	Winter 1984	773	165
	Spring 1984	1085	170
	Summer 1984	6	2
	Fall 1984	621	112
	Winter 1985	2495	568
	Spring 1985	1206	261
	Summer 1985	376	82
	Fall 1985	625	100
Relative Height		(%)	(%)
	Extly Low	5 (.52)	1 (.48)
	Low	264 (27.5)	56 (27.59)
	Level Fr. Rump	217 (22.6)	44 (21.68)
	Intermediate	1 (.10)	0 (0)
	High	473 (49.27)	102 (50.25)
	No. Data	6539	1302
Shoulder		(%)	(%)
	Extly Winged	172 (37.97)	33 (34.74)
	Definite Open	200 (44.15)	42 (44.21)
	Nearly Tight	81 (17.88)	20 (21.05)
	No Data	7147	1431
Back		(%)	(%)
	Extly Weak	2 (.21)	0 (0)
	Weak	617 (65.64)	133 (72.28)
	Intermediate	3 (.32)	0 (0)
	Strong	318 (33.83)	51 (27.72)
	No Data	6526	1322
Tailhead		(%)	(%)
	Extly Low, Dep	4 (.48)	0 (0)
	Low	98 (11.85)	27 (14.84)
	Intermediate	2 (.24)	1 (.55)
	High	659 (79.69)	140 (76.92)
	Extly High	64 (7.74)	14 (7.69)
	No Data	6799	1352

Table 8b. Continued.

	Frequency (using all data)	Frequency (DO 85-115 & TB 1 or 2)
Vulva Angle	(%)	(%)
Extly Tipped	7 (6.54)	1 (3.33)
Def. Tipped	97 (90.65)	29 (96.67)
Intermediate	1 (.93)	0 (0)
Vertical	2 (1.87)	0 (0)
No Data	7523	1505
Rear Legs Position	(%)	(%)
Extly Far Back	7 (.97)	4 (2.53)
Too Far Back	706 (98.2)	153 (96.84)
Intermediate	1 (.14)	0 (0)
Too Far Forward	4 (.56)	1 (.63)
Extly Forward	1 (.14)	0 (0)
No Data	6911	1377
Rear Leg Rear View	(%)	(%)
Extly Hocked	17 (1.42)	3 (1.19)
Close At Hocks	1018 (84.83)	219 (86.56)
Nearly Straight	4 (.33)	1 (.40)
Straight Toe Out	89 (7.42)	18 (7.12)
Strt. No Toe Out	72 (6.00)	12 (4.74)
No Data	6430	1282
Mobility	(%)	(%)
Extly Crampy	1 (1.27)	0 (0)
Def Sign of Cramp	78 (98.73)	13 (100)
No Data	7543	1518
Pasterns	(%)	(%)
Extly Weak	13 (1.89)	2 (1.4)
Tend Toward Weak	674 (98.11)	141 (98.6)
Average or Better	6935	1388
Toes	(%)	(%)
Extly Wide Spread	5 (.07)	1 (.07)
Def Spread	222 (2.91)	34 (2.22)
Ave. or Better	7395 (97.02)	1495 (97.71)
Calving Ease	(%)	(%)
Extly Hard	4 (.13)	0 (0)
Difficult	57 (1.79)	15 (2.21)
Average	1082 (33.94)	234 (34.51)
Easy, No Assistance	1495 (46.89)	321 (47.35)
Extly Easy	550 (17.25)	108 (15.92)
No Data	4435	857

Legend: Extly = extremely; Dep = depressed; Ave = average; def = definitely; strt. = straight; TB = times bred; DO = days open; % = percent classified in each class.

The effects of season, geographic location, and lactation number were removed by using the residuals in the regression model. Five cows who were obvious outliers were removed prior to the analysis (Gill, 1986). An example of an outlier was a cow with as many as 900 days open. Both R square and adjusted R square were included in the analysis. Adjusted R square was added to correct for the large number of variables included in the model. Chances for spurious correlations increase with large numbers of variables (Nie et al., 1975).

In addition, stepwise discriminate analysis was run to statistically distinguish cows with optimum fertility (defined below), classifying them on the basis of their physical conformation. Rao's V was used as the stepwise criterion (Nie et al., 1975). Cows were classified in either optimum or non-optimum fertility groups on the basis of their discriminant coefficients and these numbers were compared to the average score for each group. Cows were placed in two groups for times bred evaluation and three groups for days open. Frequencies for the respective groups are summarized in Table 9:

Table 9. Frequencies in the discriminant analysis groups of times bred and days open.

Times bred			Days open
Bred 1-2X	3523	1663	85 to 115 days open
Bred 0[a] or >2X	2572	3798	>115 days open
		2169	<85 days open[b]

[a] Bred 0 = unrecorded breedings (n=461).
[b] Includes 194 cows with no days open recorded.

A combined group of cows with optimum fertility days open (DO) between 85 to 115 days, and times bred (TB) of 1 or 2) was also created to assess differences in mean scores for traits of cows in this group from that of the general population.

As a check of adequacy of our discriminant functions, we classified the original set of cases to see how many were correctly classified by the variables being used, using a separate linear combination of discriminating variables for each group, thus producing a probability of membership in each respective group, with each case being assigned to the group with the highest probability.

Results and Discussion

The mean scores for the 7630 cows used in trial 1 for primary traits, days open and times bred are summarized in Table 10. In the population group 5.1% of the cows had days open greater than 365 days and 2.6% had days open less than 18 days. Missing data included 461 cows (6%) with no times bred recorded and 36 cows (0.2%) with 10 or more breedings recorded.

Table 10. Mean scores of linear primary type traits.[b]

	Cows with optimum fertility[a]		Using all data	
	Mean	Std. dev.	Mean	Std. dev.
Stature	25.5	10.02	25.5	10.24
Strength	23.4	9.28	23.4	9.61
Body Depth	24.7	9.82	24.6	10.09
Angularity	27.3	10.66	27.3	10.80
Rump Angle	23.6	8.55	23.5	8.61
Rump Length	25.4	9.29	25.3	9.46
Rump Width	23.0	9.16	22.8	9.30
Rear Legs Side View	24.5	9.09	24.4	9.20
Foot Angle	22.5	8.67	22.2	8.76
Fore Attachment	22.2	9.17	22.1	9.23
Rear Udder Height	24.2	9.48	24.1	9.69
Rear Udder Width	23.5	9.65	23.3	9.75
Udder Support	24.1	8.80	23.9	8.94
Udder Depth	24.3	9.62	24.1	9.81
Teat Placement	21.8	8.18	21.7	8.36
Final Score	75.0	20.59	74.7	21.29
Times Bred	1.4	0.49	2.09	1.72
Days Open	99.0	8.7	147.7	102.9

[a] Optimum fertility group includes cows bred 1-2x and having days open of 85-115.

[b] Total group was used as a population and the optimum group was tested for inclusion in that population. In each of the cases of conformational traits the population means fell within the .95 confidence interval of the sample mean.

In the first regression analysis, with times bred as the dependent variable, the coefficient of multiple determination, denoted by R square, was low (.011). With days open as the dependent variable the R square was .013. However, several of the independent variables (rump and leg traits) were significant ($P<.05$) with reproductive performance (Table 11). Of the secondary traits, none were significant with times bred, and only vulva angle was significant ($P<.05$) with days open. Lack of significant effects may be the result of lack of statistical power to detect differences with the small number of cows analyzed. Secondary traits are evaluated for research purposes only for cows with biological extremes in those traits. One primary trait, rear legs - side view, was not significant with either of the dependent variables.

Table 11. Mean squares and F values for times bred and days open in registered Holsteins.

Source of variation	df	Times bred Mean squares	Times bred F	Days open Mean squares	Days open F
<u>Primary Traits</u>					
Rump Angle	2	6.32024	3.04*	2688.56	0.85
Rump Length	2	8.24395	3.97*	15596.22	4.95**
Rump Width	2	6.41768	3.09*	2715.96	0.86
Foot Angle	2	2.05813	0.99	14839.99	4.71**
Rear Legs, SV	2	6.01217	2.89	4098.04	1.30
<u>Secondary Traits</u>					
Rear Legs, PS	2	0.30396	0.15	754.35	0.24
Rear Legs, RV	2	4.52452	2.18	2703.68	0.86
Mobility	2	2.84805	1.37	102.05	0.03
Tailhead	2	2.85554	1.37	5538.38	1.76
Pasterns	2	2.78240	1.34	6782.50	2.15
Toes	2	5.65622	2.72	6704.07	2.13
Vulva Angle	2	1.84475	0.89	13062.31	4.15*
Residual	4772	2.07766		3149.67	

* (P<.05); ** (P<.01).
SV = side view; PS = position; RV = rear view.

The regression equations for the primary traits are summarized in Table 12:

Table 12. Summary stepwise regression analysis using all variables in the equation.

Variable	Days open	Times bred
RAN	-0.381	-0.0044
RLG	-1.424*	-0.0638***
RWD	0.587	0.0161
LFA	-1.358*	-0.0141
$(RAN)^2$	0.011	0.0003
$(RLG)^2$	0.0349**	0.0012***
$(RWD)^2$	-0.0079	-0.0001
$(LFA)^2$	0.0336**	0.0004
Constant	117.8043***	1.4993***
R Square	.0132	.011
Adjusted R Square	.009	.006

* (P<.10); **(P<.05); ***(P<.01).
Traits: RAN = rump angle; RLG, rump length; RWD, rump width; LFA, foot angle.

The regression analysis showed some associations that are counter to biological expectation (Pound, 1977; Sorensen, 1979). Although not significant, our research observed a tendency for TB to increase as the slope from hooks to pins increased (Figure 1). A rump angle score of 25 has a slight slope and at 15 the pins are slightly higher than the hooks. Figure 1 depicts such a cow with better fertility (lower TB). In another study (Pedron et al., 1989), Italian Holsteins had a tendency (also not significant) to exhibit shorter calving intervals with sloping rumps. The lack of significance in both our trial and that of Pedron et al. (1989) along with inconsistency in results suggest no meaningful relationship exists between RAN and fertility.

Our study indicated that cows with intermediate length of rump required fewer services and fewer days open than either extreme (Figures 2 and 4). Although in the past dairy judges have insisted on longer and wider rumps, our research agrees with newer proposals of intermediate length of rump for maximizing herdlife (Wilson, 1990). The significant observations for both fertility traits, in and of itself, suggests that rump length is a possible trait to use in corrective mating for improvement of fertility. However, when analyzing the adjusted R square, less than 1% of the variation in TB or DO could be explained by the regression model indicating a very weak relationship.

Although not significant, cows in our study had a tendency to exhibit more TB with increasing rump width (Figure 3). Again, this is counter to biological expectation. Dadati et al. (1985) cited easier calving with wider rumps. As dystocia increases so does DO and calving interval (Pedron et al., 1989). In addition, dystocia may result in both long anestrous periods postpartum and a decreased conception rate (Peters, 1984).

While McDaniel et al. (1984a) reported improved reproductive performance with increasing foot angle we observed cows with hooves of an intermediate angle had fewer DO than either extreme (Figure 5).

For the secondary trait, vulva angle, cows with intermediate vulva angle averaged an additional 43 days open than the average of the extremes (Table 13). However, only a very small number of cows (107, 1.4% of the total) were actually evaluated for this secondary trait. Perhaps a larger sampling may have showed a more meaningful variation in days open or times bred and should be looked at further. It does not make any sense with our present biological models to have higher fertility in a cow with an extremely tipped or flat vulva as opposed to the cow with vertical or intermediate angle.

It is an established judging principle that the position of the vulva should be vertical (H. Toone, personal communication). When the angle becomes more horizontal it is possible to accumulate significant amounts of microorganism rich soils and manure in the cow's reproductive tract (Pound, 1977). As the cow defecates, the feces fall into the vulva and vestibule, contaminating the reproductive tract. The more horizontal the angle the more prone to contamination. This is exacerbated with windsucking. Windsucking is a condition where the vulva forms an acute angle with the horizontal plane. The vulvar lips become relaxed, permitting the aspiration of air into the vagina and uterus (Zemjanis, 1970). When air is sucked into the vagina, dust and airborne bacteria may enter and infection results (Sorensen, 1979).

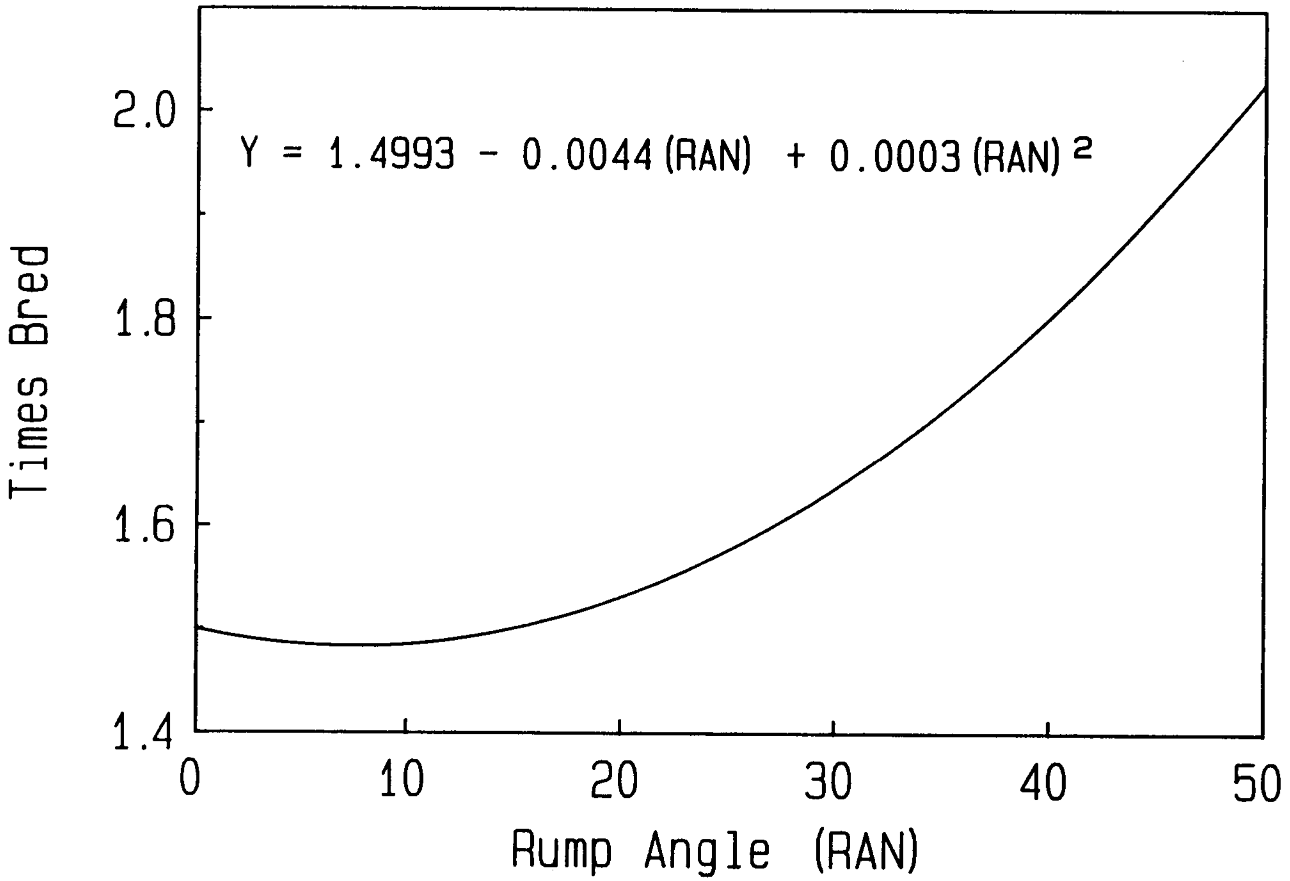

Figure 1. Relationship and the quadratic regression curve of rump angle and times bred. The linear scores of 1-50 represent pins clearly higher than the hooks and extremely sloped from hooks to pins, respectively. $P > .10$.

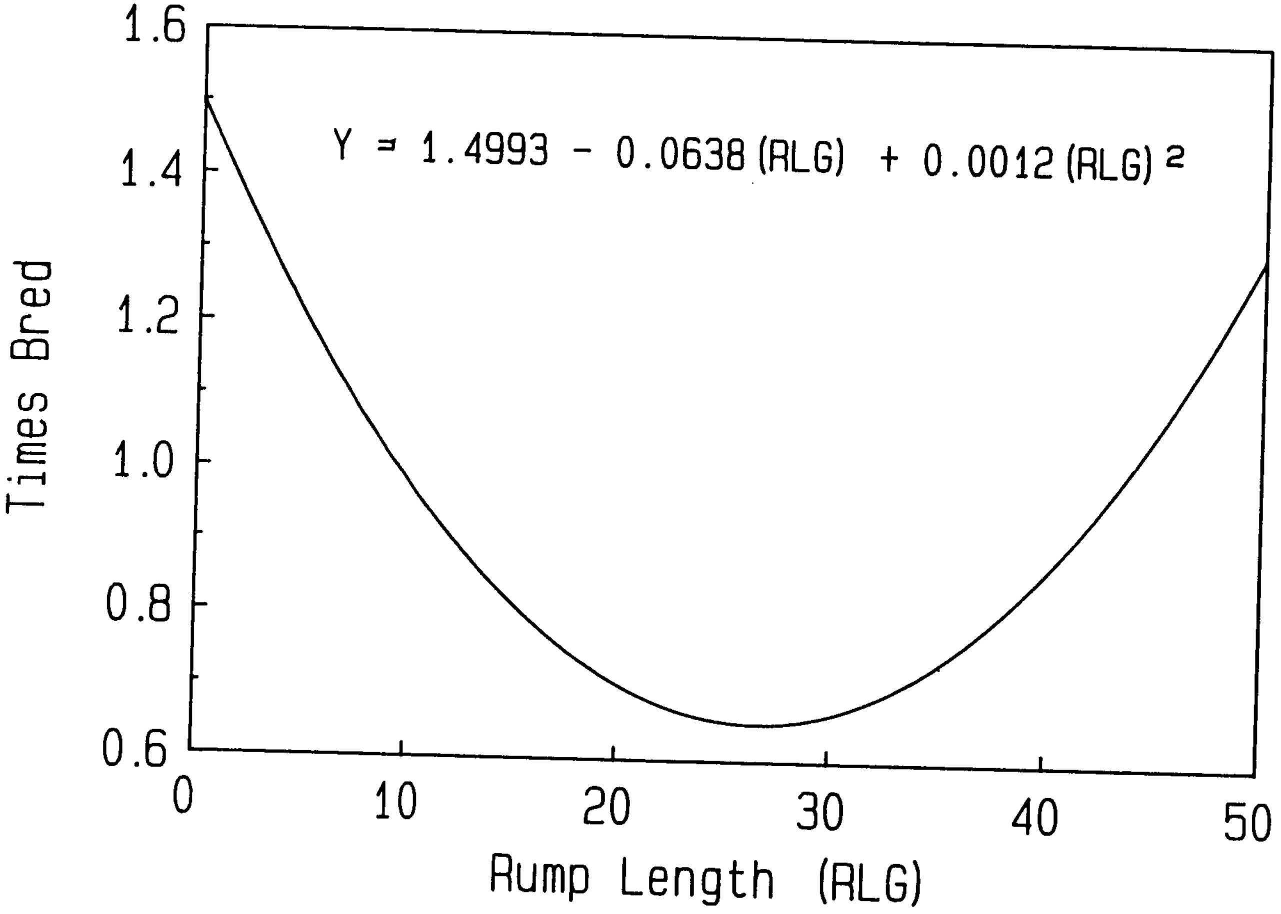

Figure 2. Relationship and the quadratic regression curve of rump length and times bred. The linear scores of 1-50 represent extremely short rump from the hooks to the pins and extremely long rump from the hooks to the pins, respectively. $P<.01$.

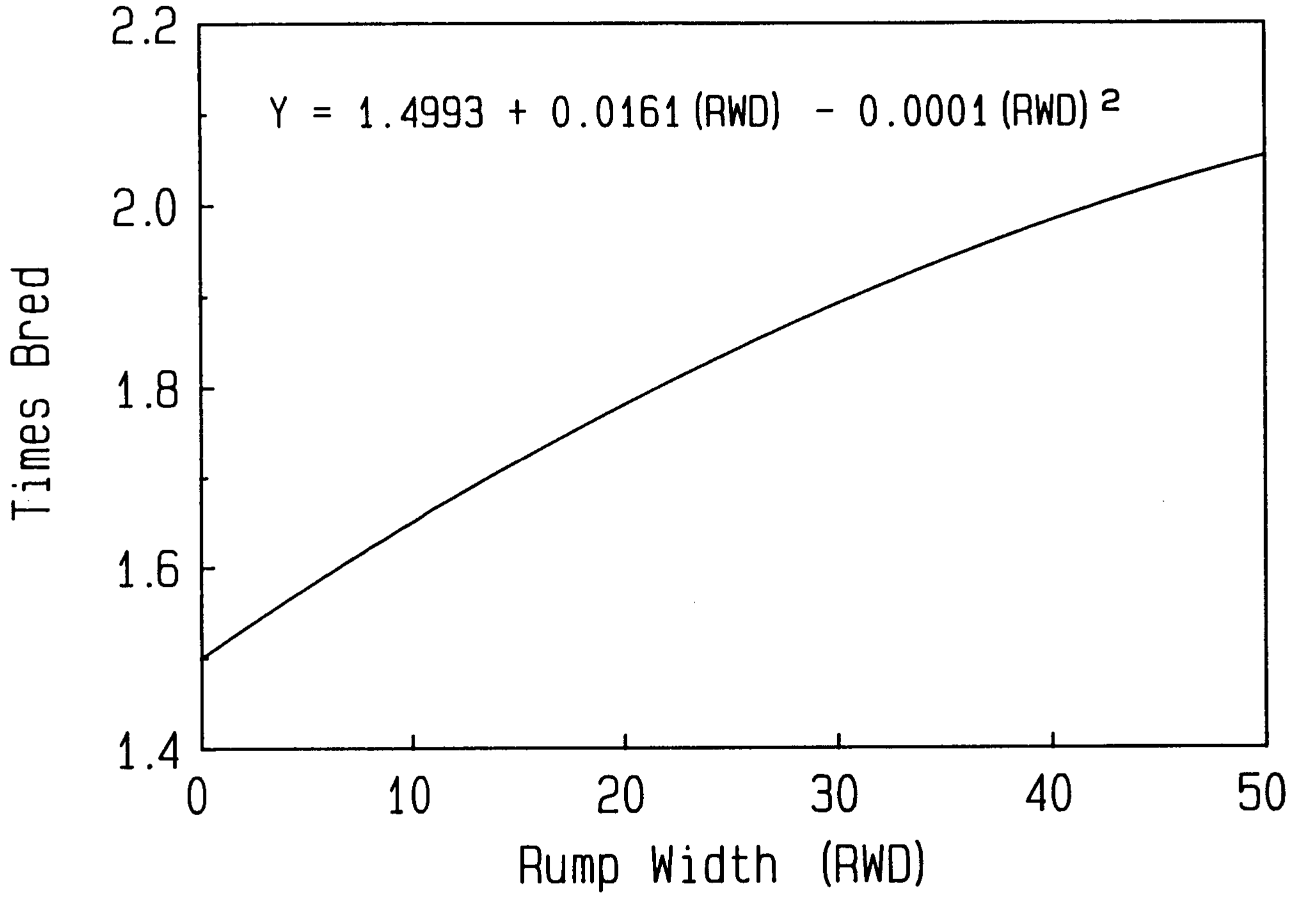

Figure 3. Relationship and the quadratic regression curve of rump width and times bred. The linear scores of 1-50 represent extremely narrow through the pelvic area and extremely wide through the pelvic area, respectively. P>.10.

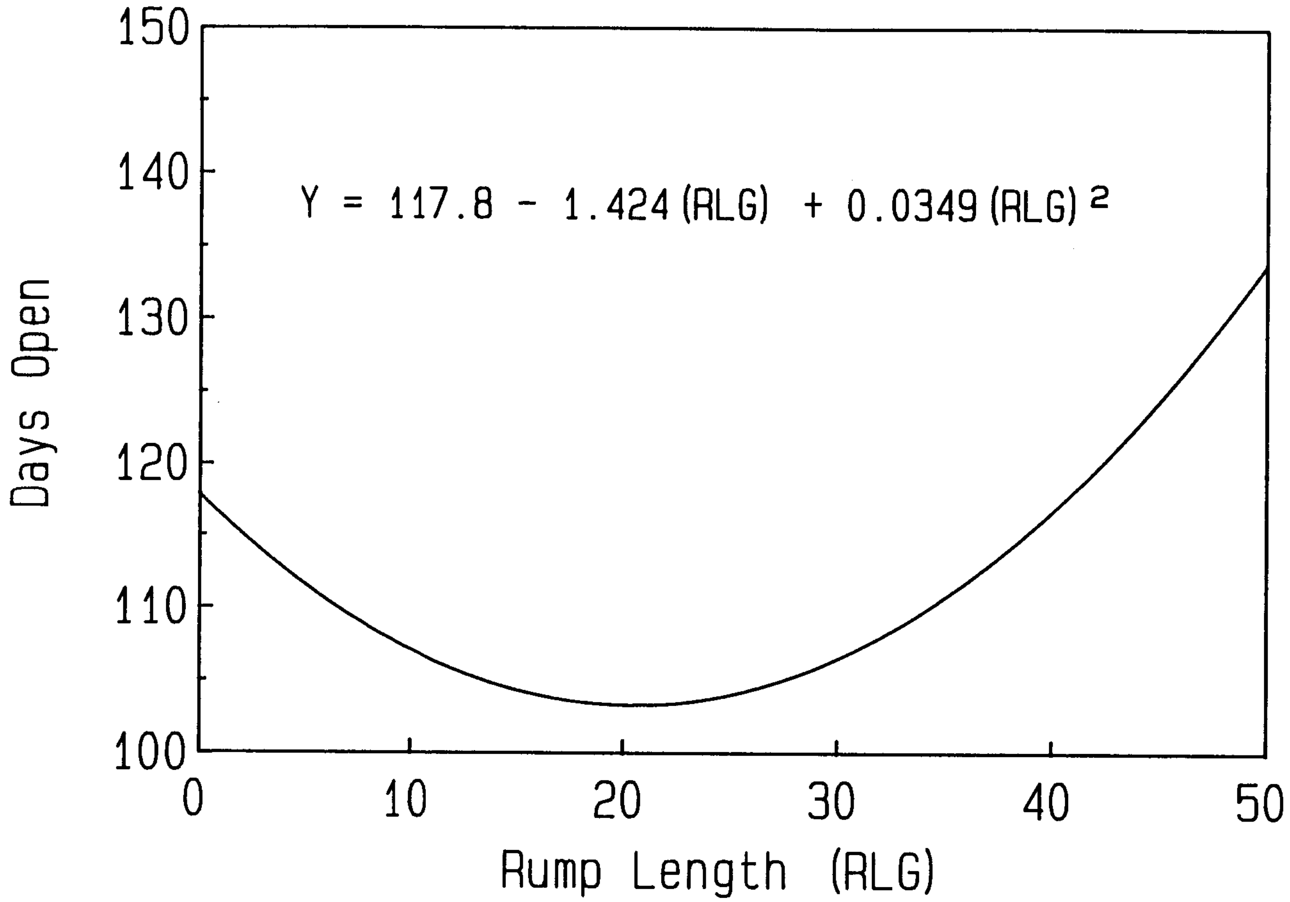

Figure 4. Relationship and the quadratic regression curve of rump length and days open. The linear scores of 1-50 represent extremely short rump from the hooks to the pins and extremely long rump from the hooks to the pins, respectively. P<.10.

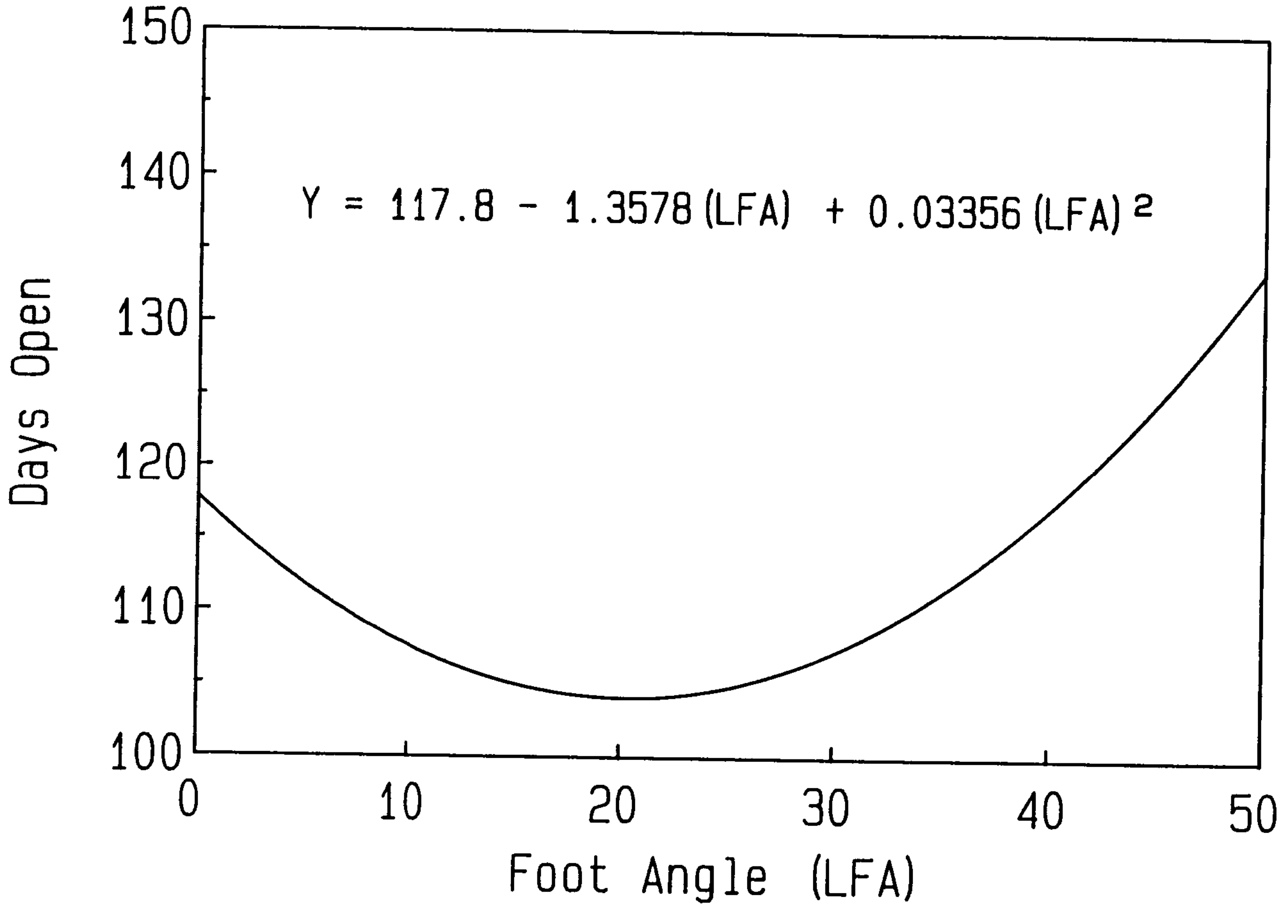

Figure 5. Relationship and the quadratic regression curve of foot angle and days open. The linear scores of 1-50 represent extremely low angle and extremely steep foot angle, respectively. P<.05.

Table 13. Days open from the mean for cows falling into one of three groups for vulva angle.[a]

	Days open
Mean Days Open = 126.75; standard deviation = 56.37	
A group = scores of 1-19 (extremely tipped or flat vulva)	-18.7
B group = scores of 20-29 (intermediate)	29.1
C group = scores of 30-50 (vertical vulva)	-10.3

[a] P<.01.

Table 14 summarizes the discriminant analysis undertaken to determine the success in predicting two breeding groups, those bred 1x or 2x and all others, using all the independent variables. The success at predicting the breeding group was 56%.

Table 14. Classification matrix showing accuracy of times bred by discriminant analysis.

Actual group	No. of cases	Predicted group membership 1	Predicted group membership 2
Group 1 Bred 1x or 2x	3523	1816 (51.5%)	1707 (48.5%)
Group 2 Zero or >2	2572	975 (37.9%)	1597 (62.1%)

% of "Grouped" cases correctly classified: 56%[a]

[a] Classification routine was able to correctly identify 56% of these cases as members of the groups to which they actually belong.

Classification results for days open were even poorer than that seen when TB was the dependent variable. Table 15 summarizes the discriminant analysis undertaken to determine the success in predicting three breeding groups; those with DO 85-115, over 115 DO and less than 85 DO, using all the independent variables. Early conception reduces profitability due to the detrimental effect of gestation on milk production. In addition, conception rate is lower in cows bred before 60 days (Hillers et al., 1984). Late conception reduces profitability because cows with longer calving intervals will be at peak milk production during a smaller portion of their productive life and produce fewer calves per unit of time (Smith et al., 1984). Although the importance of maintaining an optimum days open has been justified (Schmidt, 1989) we were unable to distinguish this optimum fertility group from that of the general population by means of discriminant analysis. The success at predicting breeding groups using DO in our study was only 36%.

Table 15. Classification matrix showing accuracy of days open by discriminant analysis.

		No. of predicted group membership		
Actual groups	Cases	1	2	3
Group 1 85-115 days	1663	475 (28.6%)	528 (31.7%)	660 (39.7%)
Group 2 Over 115 days	3798	1014 (26.7%)	1266 (33.3%)	1518 (40.0%
Group 3 Less than 85 days	2169	514 (23.7%)	662 (30.5%)	993 (45.8%)

% of "Grouped" cases correctly classified: 36%[a]

[a] Classification routine was able to correctly identify 36% of those cases as members of the groups to which they actually belong.

A problem with this type of classification procedure is that the rule of highest probability defines a very strict dividing line. A .51 probability of being optimum versus a .49 probability of being non-optimum would lead to an optimum classification. With a larger number of cows this fine line can be excluded from the grouping procedure and only cows on either extreme considered. We did not have this ability in our data set due to financial constraints. Incorporating cows from another DHI computer center would be helpful in increasing cow number.

In addition, a DO of 115 is considered optimum and one of 116 is not. The criteria set up for optimum reproductive performance may require further study so as to discriminate between poor and optimum breeding groups.

Although this study was able to predict breeding groups with a 35-56% accuracy, discriminant analysis has been shown to be statistically more appropriate than regression analysis for predicting dystocia, because distinct group classification of the dependent variable is achieved (Morrison et al., 1985). They correctly predicted 86.7% of the occurrences of dystocia, using physical conformation (pelvic height and pelvic width) as factors in their analysis. We were unable to predict reproductive performance with such accuracy in our study. Our study suggested the presence of several confounding factors (classifier effects, season, geographic location), not present in the Morrison study where all pelvic measurements were taken by a single technician, kept together in one location and examined during the same season.

Even though two of the regression equations for the primary traits were statistically significant, only 1.1% of the variation in times bred and 1.3% in days open could be explained by the regression.

Conclusion

We were unable to make any substantial conclusions with our first trial due to the unexpectedly low numbers of cows recorded for the secondary traits. Even though rump length and foot angle were significantly related to fertility, a strength of association measure, adjusted R square, indicated only a weak relationship was found. Refined techniques, methodology and the inclusion of grade cattle should be considered for further study of type and reproductive performance.

TRIAL 2

Introduction

Conformational traits traditionally have been recorded in the belief that they were correlated with production and longevity. While the differences between sire progeny groups in the production traits of milk yield and composition are based on objective measures of weight and content that can be assigned a meaningful monetary value and one that varies little from one dairy farmer to the next, type scores are more subjective and more difficult to quantify in monetary values and are of varying importance to each individual dairy farmer (Hinks, 1983).

The Holstein-Fresian Association (HFA, 1985; Pound, 1977) has advocated the ideal type for fertility as having pin bones slightly lower than the hip bones, a vulva almost vertical as viewed from the side, and a long, wide rump with a well defined pelvic arch. Some studies have verified the desirability of this phenotype (Ali et al., 1984; Honnette et al., 1980a; Philipsson, 1976), while others have failed to detect a relationship between these traits and fertility (Dadati et al., 1985; Lawstuen et al., 1988).

With the recent change by all breed associations and bull studs from a descriptive to a linear analysis of type traits (Thompson et al., 1983), we thought it important to reassess the relationship between conformation and fertility. Therefore, the objectives of this study were to determine the relationship among some specific linear type traits (rump angle [RAN], rump width [RWD], rear legs-side view [LRL], rear legs-position [LRP], rear legs-rear view [LRV], tailhead, vulva angle, mobility, pasterns, foot angle [LFA], and toes) and fertility and, if a relationship existed, to develop indices to predict reproductive performance from mathematical functions of the anatomical traits.

Materials and Methods

We began with DHI records from 200,990 cows from Agri-Tech Analytics (ATA; Tulare, CA) and linear classification records from 40,954 cows from HFA. All classification and DHI records were between June 1, 1985 and May 30, 1986.

Records deleted from HFA included those with missing or incomplete linear classification data and those whose DHI records were not recorded at ATA. Dairy Herd Improvement records were edited to exclude cows with less than 40 days open, while cows failing to conceive were assigned 300 days open (Laben et al., 1982) prior to statistical analysis. Cows were considered pregnant only if they had a breeding date followed by a calving date within a 300 day period. Records from 3,265 grade and 4,890 registered Holstein cows, all from Oregon or California, which had been linearly classified and were enrolled in an official DHI program were used after the original data bases were edited for completeness and consistency.

Grade and registered cows were analyzed separately to determine whether differences in the management traditionally provided to registered vs. grade cows would influence relationships of conformation to fertility. In preliminary analyses for both registered and grade cattle, only the regression coefficients for LFA and RWD were significant ($P<.05$) for predicting days open (DO) or times bred (TB). We were unable to complete our evaluation for the traits vulva angle, tailhead, mobility, pasterns and toes as an insufficient number of cows were classified for these traits. Furthermore, these traits had low heritabilities and/or their economic importance was questionable and thus were subsequently dropped from the HFA linear classification program. The type traits analyzed in our study were evaluated by classifiers employed by HFA, rating each trait of each cow on a scale of biological extremes (Table 16). The general scorecard categories of mammary system, dairy character, body capacity, general appearance and final score were included because of their high correlation to longevity and/or milk yield (Honnette et al., 1980a). Analysis of variance estimated the significance of evaluator, lactation number, geographic location, season calved, and the interaction of evaluator and lactation number for linear type traits and general scorecard category scores for both registered and grade cattle.

Table 16. Description of linear type traits evaluated in the classification process.

Trait	High biological extreme	Low biological extreme
Rump Angle (RAN)	Low Pins	High Pins
Rump Width (RWD)	Wide	Narrow
Rear Legs, Side View (LRL)	Sickled	Posty
Rear Legs, Position (LRP)	Forward	Back
Rear Legs, Rear View (LRV)	Straight	Toe-out
Foot Angle (LFA)	Steep	Low Angle

Multiple regression analysis used DO and TB as dependent variables. To measure the number of DO a subsequent calving or at least 300 DO was necessary. This resulted in fewer cows with information on

DO than with information on other traits. Season of parturition (winter, spring, summer, fall), geographic location (Oregon and California Coast, Willamette Valley [OR], San Joaquin Valley [CA] and Southern California), lactation number (first and second for grade cows and first, second, third, fourth and fifth or more lactations for registered cows), mature equivalent milk (ME milk), LFA, LRP, RAN, LRL, LRV, and RWD (along with their respective quadratics) were independent variables in the analysis. In addition to R square, adjusted R square was added to correct for the large numbers of variables included in the model. Chances for spurious correlations increase with large numbers of variables (Nie et al., 1975). Stepwise regression analysis was used to determine the statistically significant variables (Pagano, 1981). Dummy variables were created for the environmental traits of season, geographic location, and lactation number (Nie et al., 1975). Because the inclusion of all dummy variables created from a given nominal variable rendered the normal equations unsolvable (the kth dummy variable is completely determined by the first k-1 dummy variables entered into the regression equation) it was necessary to exclude one of the dummy variables from the regression equation.

Results and Discussion

Days open, TB and ME milk (kg) for registered and grade cattle averaged (±SD) 136 ± 69.6, 2.3 ± 1.77, 9999 ± 1646 and 125 ± 69.4, 2.2 ± 1.64 and 9706 ± 1534, respectively. Although three of twelve evaluators classified cows in one geographic location, most classified cows in two (46%), three (18%) or four (9%) locations. Evaluator effects were significant for all type traits for both registered and grade cattle.

Lactation number was significant for all type traits for registered cattle and for all traits for grade cows except LRL and LRP. Evaluator and lactation number interactions were significant for registered cows for all type traits except LFA and in grade cows for all type traits except LRL and LRP. This interaction suggests that evaluators were making unequal parity adjustments and perhaps should receive additional training. Therefore, the average effects of these environmental variables were removed by using the residuals of the type traits in the final regression analysis.

Correlations between linear type traits were estimated by Pearson product-moment correlation using both raw scores and residuals (Table 17). When using raw scores, the relationship between type traits may be obscured due to differences in environment. Correlations among residuals were consistently smaller than correlations among raw data, thus revealing a more correct relationship between type traits.

Table 17. Pearson correlation coefficients between linear traits.

	Grade/Raw	Grade/Res.	Reg./Raw	Reg./Res.
Foot Angle with				
Rear Legs, Side View	-.23***	-.18*	-.25***	-.23**
Rear Leg Position	.28***	.24**	.25***	.23**
Rear Legs, Rear View	.43***	.38***	.38***	.35***
Rump Angle	-.12	-.06	-.08	-.05
Rump Width	.19**	.14	.18*	.14
Rump Width with				
Rear Legs, Side View	-.08	-.02	-.01	-.02
Rear Leg Position	.24**	.14	.20**	.13
Rear Legs, Rear View	.33***	.22**	.29***	.22**
Rump Angle	-.13	-.08	-.19**	-.15

*(P<.10), **(P<.05), ***(P<.01)
Res. = residual; Reg. = registered

In the final equations from the stepwise regression analysis, only type traits which showed a significant relation with the dependent variables were included. This removed LRP, RAN, LRL, and LRV from the final model. For registered cows, with DO as the dependent variable, the only significant independent type variable was RWD (Table 18); as RWD increased, so did DO (Figure 6). We know of no biological explanation for this observation. Perhaps dairy farmers with registered cows allow cows with wider rumps more DO than those with narrow rumps before making culling decisions. The significance of season calved (spring) indicated that DO was longer for those cows bred in the summer months when high ambient temperatures may have influenced estrus behavior and other fertility parameters. For cows in the northern coastal area of California and the coast of Oregon, and in Southern California, DO was significantly shorter whereas cows in the Willamette Valley had significantly longer DO. The cooler temperatures along the coast most likely contributed to the shorter DO in those herds, however, we have no explanation for the small but significant reduction in DO in Southern California, other than differences in management and environment.

Table 18. Summary stepwise regression analysis using all variables (residuals) in the equation.

	Days open		Times bred	
Variable	Registered	Grade	Registered	Grade
Season				
Winter	-.06	1.82	-.03	-.02
Spring	5.37**	-2.25	.09	-.04
Summer	.48	1.77	.05	.07
Fall	-5.79	-1.34	.10	.01
Location				
Coast	-14.53***	-24.45***	-.34***	-.46***
Willamette Valley	12.15***	13.57***	-.03	-.09
San Joaquin Valley	3.64*	4.93	.17***	.16**
So. California	-1.26**	5.95	.20	.39
Lactation				
First	-11.94	3.33*	-.46**	.01
Second	-10.83	-3.33*	-.42**	-.01
Third	-7.78		-.32	
Fourth	41.28		1.69**	
Fifth+	-10.73		-.49	
ME milk (kg)	-.19x10^{-2}	.22x10^{-3}	-.43x10^{-4}	-.30x10^{-5}
ME milk^2 (kg)	.08x10^{-6}***	.31x10^{-7}	.19x10^{-8}***	.07x10^{-8}
LFA	.28	.07	.01**	.84x10^{-2}
LRP	.31	.29	.01	.01
RAN	.25	.29	.29x10^{-2}	[1]
LRL	.28	.22	-.89x10^{-3}	[1]
LRV	-.33	.11	.24x10^{-2}	-.01
RWD	.71***	-.09	-.79x10^{-4}	-.51x10^{-2}
LRL^2	-.01	.01	.12x10^{-2}	[1]
RAN^2	-.01	-.03	.56x10^{-3}	[1]
LFA^2	-.84x10^{-2}	.07**	-.59x10^{-3}	.50x10^{-2}
RWD^2	.04	-.69x10^{-2}	.71x10^{-3}	.12x10^{-3}
LRV^2	-.02	.02	-.77x10^{-3}	-.30x10^{-3}
LRP^2	[1]	.01	.89x10^{-3}	[1]
Constant	148.03***	73.19**	2.65***	1.41*
R Square	.055	.036	.049	.027
Adjusted R Square	.048	.029	.043	.021
Std. Deviation	67.94	68.33	1.73	1.62

[1] = F-level or tolerance-level insufficient for further computation.
*(P<.10), **(P<.05), ***(P<.01)

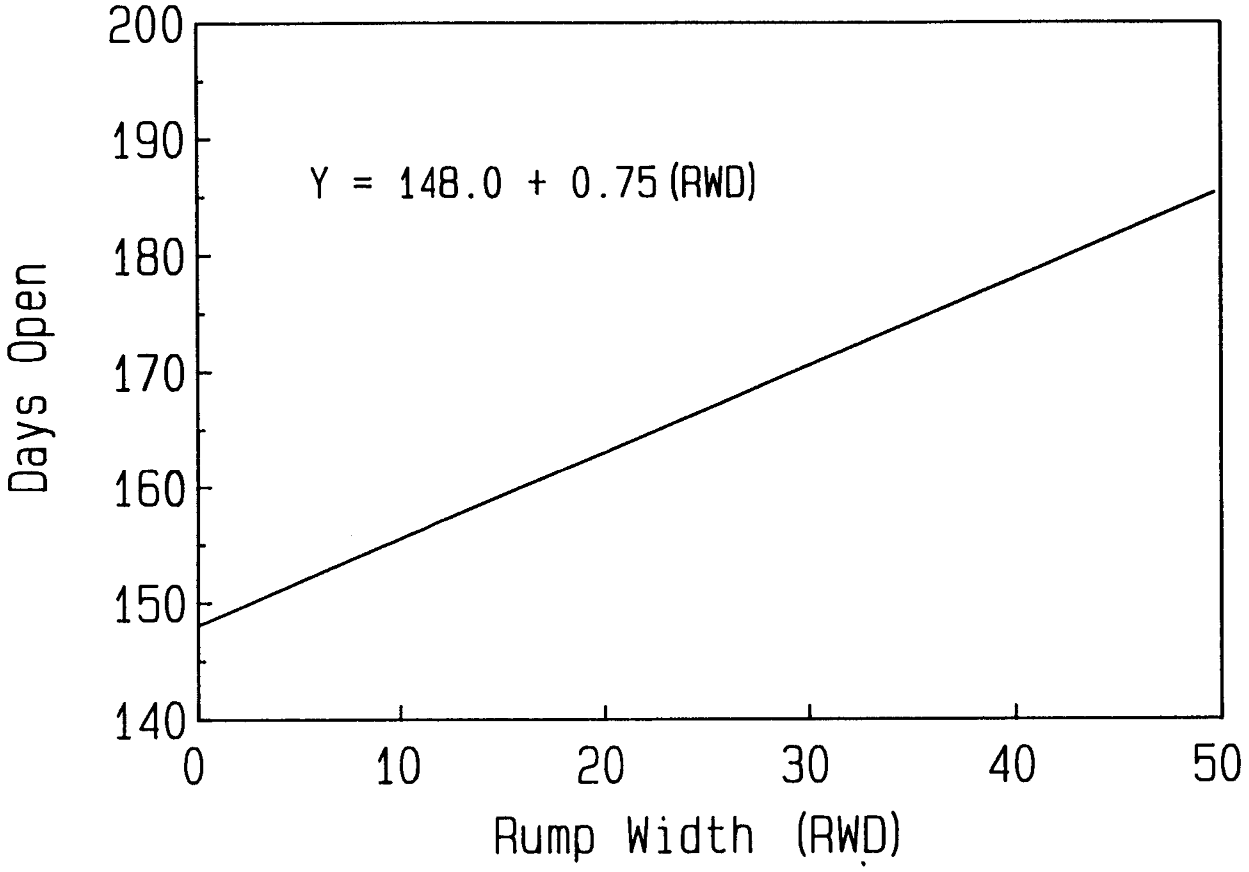

Figure 6. Relationship and linear regression of rump width and days open for registered cattle. The linear scores of 1-50 represent extremely narrow through the pelvic area and extremely wide through the pelvic area, respectively. $P<.01$.

For registered cows, with TB as the dependent variable, the only significant independent type variable was LFA; as LFA became more steep, TB increased (Figure 7). The significance of geographic location indicates that cows in the coastal areas were bred fewer times whereas those from the San Joaquin Valley were bred more times; again most likely due to differences in ambient temperature. Cows in the first and second lactations required significantly fewer TB whereas those in the fourth lactation required significantly more TB.

For grade cows, with DO as the dependent variable, the only significant independent type variable was the quadratic for LFA; days open increased more rapidly as LFA became steeper (Figure 8). While this observation corresponds with the relationship seen when TB was the dependent variable it does not agree with our first trial where intermediate LFA was associated with higher fertility (Figure 5). Cows in the coastal area had fewer DO whereas those in the Willamette Valley had more DO. There were no significant independent type variables for grade cows when TB was the dependent variable. Similar to registered cows, cows in the coastal areas were bred fewer times whereas cows in the San Joaquin Valley were bred more times.

The R^2 values indicated that 5.3% of the variability of DO and 4.7% of the variability of TB in registered cattle was accounted for by the type traits, LFA and RWD, respectively, when the independent variables of season, geographic location, lactation number, ME milk, and the quadratic for ME milk were included in the model (Table 19). For grade cattle, 3.5% of the variability of DO was accounted for by LFA in a model including the sources of environmental variation listed above. In our first trial with registered cows, and without the inclusion of the environmental variables, the R^2 values were only .011 and .013 for TB and DO, respectively, indicating a smaller contribution from type traits to DO and TB.

Low milk production, reproductive problems, and mastitis are the main reasons for dairy cattle culling (Freeman, 1984; Van Vleck and Norman, 1972). Improvement in any one of these areas should, therefore, increase the potential productive life and hence the profitability of the cow. Type is defined as the comparison of the physical appearance of an animal with that of the ideal animal as envisioned by the breed association. Type has monetary significance at the show ring and at sales; however, specific monetary weights for components of type have been impossible to calculate (Blanchard et al., 1983) and varies considerably amongst dairy farmers (Hinks, 1983).

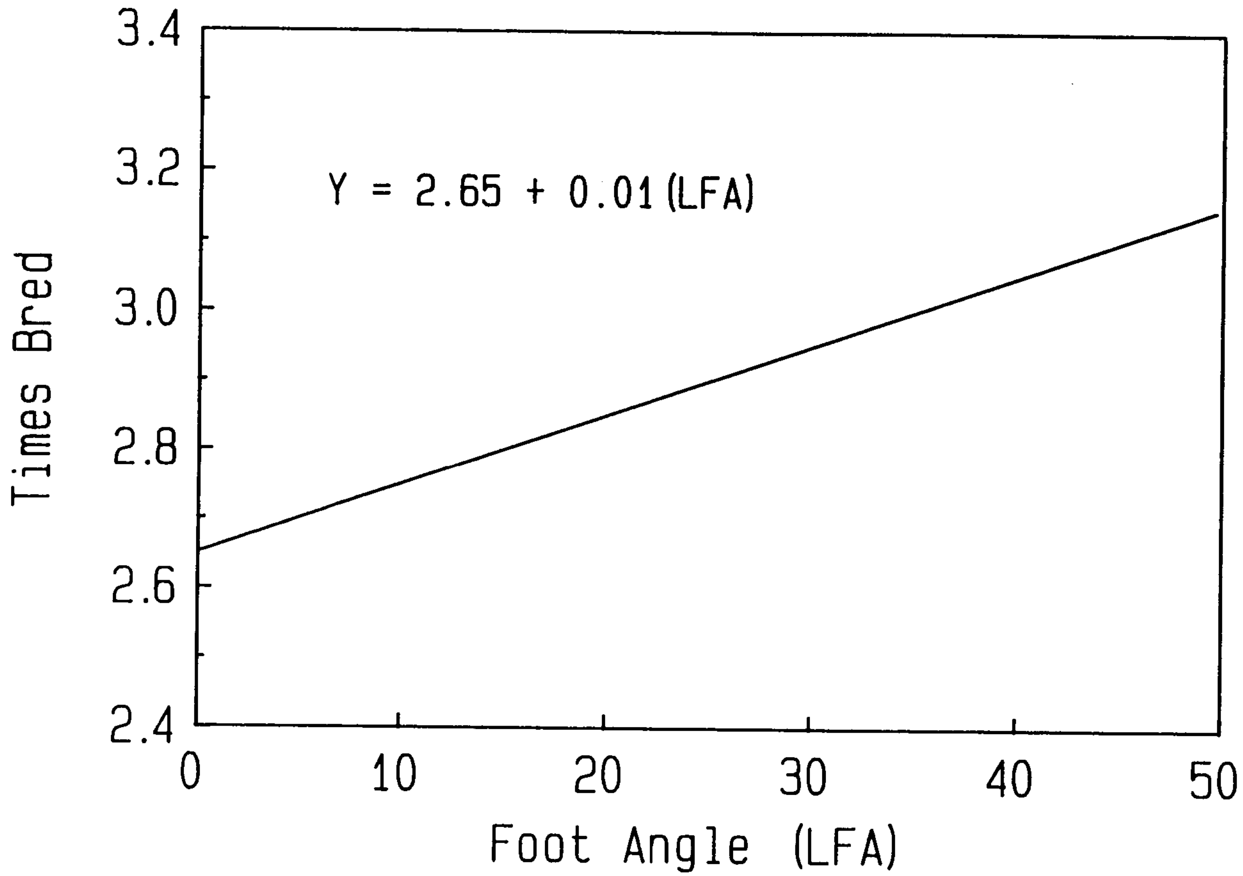

Figure 7. Relationship and linear regression of foot angle and times bred for registered cattle. The linear scores of 1-50 represent extremely low angle and extremely steep foot angle, respectively. P<.05.

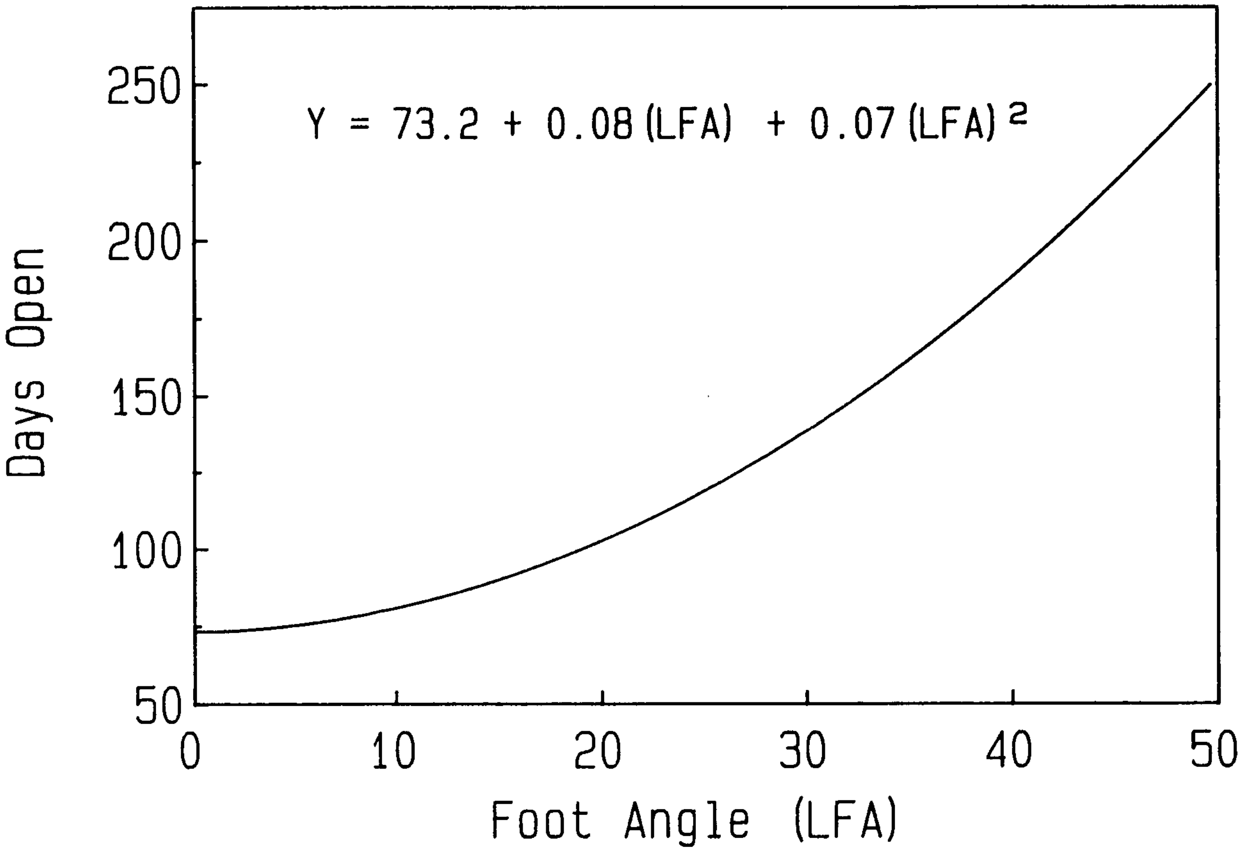

Figure 8. Relationship and quadratic regression curve of foot angle and days open for grade cattle. The linear scores of 1-50 represent extremely low angle and extremely steep foot angle, respectively. $P<.05$.

Table 19. Coefficient of determination (%) for days open and times bred when regressed for the type traits foot angle and rump width.

Statistical model	Days open	Times bred
Registered Cattle		
$u + s + g + l + M + M^2 + rwd$	5.3	
$u + s + g + l + M + M^2 + lfa$		4.7
Grade Cattle		
$u + s + g + l + M + M^2 + lfa + (lfa)^2$	3.5	

Traits: s, season; g, geographic location; l, lactation number; M, ME Milk; rwd, rump width; lfa, foot angle.

The HFA (1985; Pound, 1977), judging textbooks (Trimberger et al., 1987), some Holstein breeders (W. Lindskoog, personal communication), and a few scientific studies (Ali et al., 1984; Honnette et al., 1980; Philipsson, 1976) have proposed that a sloping rump (pin bones lower than hip bones) is advantageous to calving ease and freedom from uterine infections, the logic being that a sloping rump has a larger pelvic opening and permits easier drainage from the reproductive tract. However, with a few exceptions (Foster et al., 1989; Norman et al., 1988), others, in agreement with the present study, have also reported that the slope of the rump had little (two days shorter calving interval (Honnette et al., 1980a)) or no effect on fertility or calving ease (Dadati et al., 1985). Cassell et al. (1990) suggested higher profits from bulls siring daughters with sloped rumps based on discounted relative net income. Foster et al. (1989) found that cows with average rump width and more rear leg set survived longer whereas Rogers and McDaniel (1988) reported decreased milk yield for cows with sloping rumps. Lawstuen et al. (1988) reported that rump width and rump length, rather than rump angle, was associated with calving ease. In our study there was no biological explanation for the antagonism of rump width and foot angle with reproductive performance.

While this study found no relationship between fertility and RAN or leg position, as described by the HFA's linear classification program, this does not necessarily mean that there is no optimum RAN or rear leg set. It is possible that we have not been able to describe or evaluate these particular areas of the cow in a quantitative method that adequately depicts optimum reproductive efficiency. Perhaps, using discriminate analysis, the conformation of cows which have low and optimum TB and DO should be examined to assess possible significant type differences between them. It is also interesting that, as logical as it may seem that cows with a tipped vulva would be predisposed to uterine infections and thus less fertile, as opposed to cows with a vertical vulva angle, we failed to detect any relationship between vulva angle and fertility in our study. In fact, our preliminary analysis indicated that cows with a vertical vulva angle tended to have more DO than cows with an intermediate or tipped vulva angle.

Differences between type classification programs (i.e., A.I. organizations, breed programs, private cow mating systems) (Berger et al., 1986), and differences among dairy producers in their management of cows within each herd are difficult to correct or remove by statistical means. The HFA linear classification program was adopted to amend some of these differences. Our results confirm those of (Boldman and Famula, 1985; Schaeffer et al., 1985), where major sources of variation in type scores assigned by evaluators were accounted for by parity, stage of lactation and interactions of evaluator and lactation number. The significant interaction of evaluator and lactation number in our study agrees with those of (Thompson et al., 1981; Thompson et al., 1983). Thompson et al. (1983) reported that this interaction may be due to unequal age adjustment among evaluators when actually nonrandom sampling had occurred.

Our study found a positive association of LFA and TB; as the LFA became more steep, TB increased. This contradicts previous studies where DO were lower for cows that had steeper foot angles (McDaniel et al., 1984). Hoof traits have been associated with stayability (McDaniel et al., 1984; Van Doormaal et al., 1986). Foster et al. (1989) reported that longevity also increased as the LFA increased. Because most studies have shown the heritability of LFA to be quite low (Lawstuen and Hansen, 1987a; Rogers and McDaniel, 1989; Thomas et al., 1985; Van Doormaal and Burnside, 1987), any relationship we or others have observed are probably of little or no economic consequence, especially when studies such as those of (Cassell et al., 1990; Norman et al., 1988) failed to detect any relationship between foot angle and milk yield or net income, respectively. Herd effects do make distinct contributions to hoof morphology (Hahn et al., 1984). Perhaps this could explain the difference between our study of commercial California and Oregon herds and that of institutional herds in North Carolina (McDaniel et al., 1984). To obtain an accurate assessment of hoof morphology and its association with fertility we would need to examine cows whose feet were not trimmed or examine the frequency of foot trimming.

Diseases of the heel have been linked to shallow heels which become bruised and infected (Winkler, 1981) and which require more frequent trimming (Trimberger et al., 1987). Thus, recommending selection for shallow heel to decrease TB a relatively small amount cannot be justified. In addition, there is neither genetic nor phenotypic correlations between milk yield and LFA in Holsteins (Rogers and McDaniel, 1989). In addition to fertility traits having low to zero heritability, one of the most significant type traits related to fertility in our study, foot angle, has heritability estimates of .06 to .47, with most estimates below .15 (Hahn et al., 1984; Rogers and McDaniel, 1989). Considering the low heritabilities of reproductive traits, and the absence of any practical or biological relationship between conformation and fertility, direct selection of type traits aimed at improving reproductive performance is not warranted. However, a rejection of extreme deviants in functional type may be justified (Hinks, 1983; Petersen et al., 1986).

Significance of independent variables was different for linear type traits between grade and registered cattle. This may indicate that the classifier does not see a registered cow in the same way as a grade cow and (or) that certain managerial decisions by the dairy producer are influenced by registration status. Rogers et al. (1988) cite significant differences in correlations of survival and body traits for grade and registered cows. For example, in their study, LFA was significant to survival in registered cows but not in grade cattle. Udder traits, however, were associated with survival in both groups. Type traits were more highly related to survival in registered than in grade cows (Dentine et al., 1987a and b; Nieuwhof et al., 1989). In these studies, only in registered cows were type traits that reflected body characteristics positively correlated with longevity. These differences were not surprising since registered cows are culled at different rates and for different reasons than grade cows (Dentine and McDaniel, 1987).

Conclusion

Despite the claims of purebred breeders and breed associations, we failed to detect any biological significance between fertility and the linear type traits thought to be related to heritability. Of the environmental independent variables, geographic location had the greatest relationship to fertility. Perhaps an alternative to corrective mating of type traits for the improvement of reproductive performance may be to select for milk production and reproductive performance directly and simply accept whatever shape the cow chooses to assume.

DISCUSSION

Infertility costs the American dairy farmer a net loss of about \$116/cow/year (Pelissier, 1982) or approximately \$1.2 billion/year for the entire dairy industry. Thus, any small reduction in cow infertility could save the industry millions of dollars.

The purpose of this study was to measure any association existing between fertility and physical conformation. In order to assess this relationship we first removed all confounding factors, such as season, geographic location, milk yield and others that might contribute to the large degree of variation seen in such an analysis.

Several factors causing excessive variation in fertility in dairy cows and not considered in our study include:

1. The failure to detect estrus or the breeding of cows when not in true estrus.
2. Nutrition - deficiencies, toxicities, and interactions of various nutrients on reproductive performance.
3. Heritability of fertility.

While our study detected a significant association between fertility and conformation, the relationship was quite small. In the first trial only 1.1 to 1.3% of the variation in fertility could be accounted for by the conformation traits considered in our model. In the second trial we used a more complete model (included factors such as milk yield, season and geographic location) which only accounted for 3.5 to 4.7% of the variation in the reproductive traits of times bred and days open. This means that more than 95% of the variation in reproductive performance of dairy cows was not considered in our model. Some factor(s) other than milk yield, season bred, geographic location and physical conformation account for the majority of the variation in reproductive performance.

Days open can be severely skewed due to human error. Approximately 53% of all cows heats are undetected (Barr, 1975). A more distressing problem is that of cows being bred when not in the proper stage of the estrous cycle. Five to 60% of dairy cows bred by artificial insemination in some herds were not in estrus at the time of insemination (Smith, 1982; Reimers et al., 1985). Errors of estrus detection must be considered a potential cause of low conception rates in problem herds.

A problem in selecting for fertility traits (DO and TB) is that the heritability is extremely low (Freeman, 1984; Hansen et al., 1983b; Lawstuen et al., 1988). The major determinant of fertility is environment (White, 1974; Hansen et al., 1983a; Lawstuen et al., 1988), which is under the control of the manager (Laben et al., 1982). For example, a common reason most studies show antagonism between fertility and milk yield is that dairy producers may provide a longer postpartum interval before attempting to rebreed high-producing cows. Gill and Allaire (1976) reported optimal profit when cows averaged 124 days open. We did not consider management decisions on extension of open periods for high producing cows or for other reasons under the control of the dairy manager. These factors could have greatly distorted our results.

Although our study's primary emphasis was on measuring the association of conformational traits and reproductive efficiency in dairy cows, we observed several interesting results related to other factors influencing the variation we saw in fertility. These factors include milk yield, season bred, age or parity, grade vs. registered cows, and geographic location.

In trial 2, milk yield had the highest correlation of any traits with the two dependent variables (DO and TB) in both registered and grade cattle. Times bred and DO both increased as milk yield increased. Butler and Smith (1989) concluded that negative effects of milk yield on fertility are related to the extent of negative energy balance brought about in early lactation when dietary energy intake is deficient as compared to energy utilized for milk production. The limiting factor in the return to cyclicity in the postpartum dairy cow appears to be the lack of pulsatile luteinizing hormone (LH) secretion which is the result of negative energy balance (Terqui et al., 1982).

The significant variation we observed between season and fertility agrees with most studies evaluating environmental effects of reproductive performance (Cavestany et al., 1985; Fuquay, 1986; Ron et al., 1984; Rosenberg et al, 1977; Stott and Williams, 1962; Tucker, 1982) where DO increased for registered cows bred in the hot summer months. We saw no significant variation for TB for either grade or registered cows and cannot account for this inconsistency.

Another inconsistent finding was the relationship between age or parity and reproductive parameters. Registered cows in the first and second lactations during our second trial required significantly fewer TB while those in the fourth lactation required significantly more TB. There was no significant variation in TB amongst grade cattle nor amongst grade or registered cows when using DO as the dependent variable. Spalding et al. (1975) reported that conception declined markedly beyond 4 years with the largest drop in fertility occurring in cows 5 years of age and older. Our records included grade cows only during the first two lactations. This may account for some of the contradiction in results between grade and registered cows.

One of the reasons we ran a second trial was to use a larger data base and one where we could analyze differences in management style between registered and grade cattle and assess any affects these differences might have on fertility relationships with the type traits used in our model. In addition to finding significant differences of independent variables for the linear type traits between grade and registered cattle, we observed a significant difference in fertility between grade and registered cows. Registered cattle averaged more TB and higher DO than grade cattle. Perhaps the dairy farmer justifies breeding a registered problem cow more times and keeping an open registered cow longer because of the potential genetic worth of her offspring. Taylor et al. (1985) indicated that conception rates were 2.3% higher in grade than in registered cows, probably due to greater culling pressure for breeding efficiency in grade cattle.

Rogers et al. (1988) cite significant differences in correlations of survival and body traits for grade and registered cows. For example, in their study, foot angle was significant to survival in registered cows but not in grade cattle. Udder traits, however, were associated with survival in both groups. Our study observed RWD significantly related to DO and LFA was significantly related to TB in registered cattle only.

Other studies (Dentine et al., 1987b; and Nieuwhof et al., 1989) reported that type traits were more highly related to survival in registered cows than in grades. In these studies type traits that reflected body characteristics were positively correlated with longevity in registered but not grade cows. These differences were not surprising since registered cows are culled at different rates and for different reasons than are grade cows (Dentine et al., 1987a).

Even though the heritability estimates for milk yield are about the same for registered and grade cows (Schneider and Van Vleck, 1986), grade cows are culled more intensely than registered cows, resulting in higher average yield by maturity for remaining grades (Powel and Norman, 1986). Superiority in yield of registered cows is greater in mixed herds than in the general population which implies that registered cows receive preferential treatment within herds.

Since we did not have sufficient numbers of older grade cattle we could not accurately compare changes between registered and grade cows in milk yield by age. The averages of our grade cows during first and second lactations were slightly lower (9706 kg vs. 9999 kg) than the averages of all lactations (1st through 5th and more) for registered cows (Table 20).

Table 20. Differences between grade and registered cattle in milk yield and fertility traits.[a]

	Grade	Registered
Milk, kg	9706	9999
SD	1534	1646***
DO	124.5	136.4
SD	69.4	69.7**
TB	2.2	2.3
SD	1.6	1.8*

SD = standard deviation, DO = days open, TB = times bred.

[a] Statistical significance of differences were estimated by Student's t test: *** = $P<.001$; ** = $P<.01$; * = $P<.05$.

Although this difference in means was significant, no meaningful comparison can be made due to age differences between the two groups. Twenty-six percent of the cows in the registered group had three or more lactations, whereas all of the cows in the grade group were in their first or second lactation. Dairy records, in general, show an increase in milk yield through the fifth lactation (Anderson, 1985) which could account for some of the increase in registered over grade milk yield. Even though studies have reported higher conception in grade vs. registered cows (Everett and Bean, 1986) other research has demonstrated poorer fertility (Everett and Bean, 1986; Hillers et al., 1984) as cows increase in age. Thus, it would not be proper to compare significance between the means of the two fertility traits and declare any meaningful relationship because of the difference in parity levels between groups. We initially hoped to compare differences between registered and grade cattle and expected uneven numbers between the groups. However, we did not expect to find zero cows in the three lactations and greater group for grade cattle. This unexpected frequency severely limited any meaningful comparisons between groups.

The significant variation we observed due to geographic location was fairly consistent. Both registered and grade cows residing in the Willamette Valley had longer DO whereas those in the coastal areas of Northern California and Oregon had significantly shorter DO and lower TB. Since we did not analyze diet differences between regions we cannot comment on possibilities of nutritional effects of reproduction due to geographic dietary differences. However, it should be obvious that there are significant environmental differences between these regions, such as temperature and humidity, that have been shown to have significant effects upon both milk yield and fertility (Badinga et al., 1985; Gwazdauskas, 1985; and Hauser, 1984). Shah et al. (1989) suggested an influence of bio-meteorological factors, such as decreasing or increasing daylength and ambient temperatures on the endocrine system to explain some of the differences seen in fertility between geographical regions. Shah et al. (1989) further emphasized that amongst environmental stimuli, the level of nutrition, climate and day length are the most important parameters. Many of the managers of coastal herds evaluated in our study pasture their cows, whereas those in the Willamette Valley feed a diet heavy in corn silage. We did not evaluate diet or photoperiod parameters in our studies.

We cannot fully explain the small but significant reduction in days open in Southern California compared to the Willamette and San Joaquin Valleys. Flamenbaum et al. (1986) observed that a significant increase in milk yield and in conception rate could be realized through improved environmental management (cooling dairy cattle by inverted static sprinklers and forced ventilation). Most, if not all, of the Southern California dairy herds are provided with a large shade area per cow and many with similar, as outlined by Flamenbaum et al. (1986), forced ventilation (and some with ventilation and sprinkler cooling) systems. We cannot assume that the larger herds in Southern California are employing these ambient temperature reducing techniques to a greater extent than in the San Joaquin and Willamette Valleys. We did not take management surveys to assess this phenomenon and hence cannot make such a judgement.

One justification for a study such as ours would be to recommend the selection for a preferred type relating to optimum fertility. We were unable to determine an ideal type related to fertility from the analysis in either trial. Selection for type traits has been shown to have little effect on involuntary culling (Rogers and McDaniel, 1989). Corrective mating may result in decreased variability in type traits within a herd (White, 1974) but most studies have shown that it makes little difference (Thomas et al., 1986 and Hay et al., 1983) in progress toward improved type traits. In a controlled breeding study, Petersen et al. (1986) found that daughters of sires selected only for maximum yield (PDM) had better type scores than daughters of sires selected for both type and yield. Direct selection for calving ease is more effective than indirect selection of type traits in reducing calving problems (Dadati et al., 1985). Tigges et al. (1986) reported that selection for such type traits as feet and legs was unimportant if the goal was maximum profit.

It has already been pointed out that some of the variation in type scores for geographic location was due to evaluator effects. Evaluator effects were significant for all type traits for both registered and grade cattle. Evaluator and lactation number interactions were significant for registered cows for all type traits except LFA and in grade cows for all type traits except LRL and LRP. This interaction suggests that evaluators were making unequal parity adjustments and perhaps should receive additional training. One of the justifications to switching from a categorical system of classification to a linear system was to avoid this evaluator bias.

To evaluate relationships, if any, between type and reproductive performance, a non-biased objective measurement of these traits needs to occur. Hayes and Mao (1987) reported that angularity (dairy character) and rump angle scores increased during early lactation and then declined. Rump length and rump width linear scores decreased and then increased (although minimally) and foot angle scores decreased slightly during early lactation and then increased, with springing animals receiving the highest scores. Perhaps we would see a more objective measurement, and thus be able to evaluate more correctly any associations, if all classifications were made at the same stage of lactation and at the same age (i.e., 2 year old fresh cows).

Some of our results were difficult to explain biologically in our first trial. Cows with pins higher than the hooks required less TB than those with the hooks higher than the pins; cows intermediate in rump length required the least TB and had fewer DO than either extreme; cows having rumps narrower through the pelvic area required fewer TB than the wide-rumped cows; cows with an intermediate angled foot had fewer DO than either extreme; and cows with a vertical vulva had more DO than either the intermediate or tipped vulva. We must remember that the relationships we observed with rump angle and rump width were not significant and the association of foot angle and vulva angle with fertility was significant but very weak as demonstrated by the low R^2.

We were hoping that with a larger data base, including grade cows, we would derive a more significant explanation regarding these relationships. Trial 2 did not consider vulva angle, since it is no longer being evaluated by the HFA. The small number (107) of cows evaluated for this discrete trait (only evaluated for biological extremes) in trial 1 could have contributed to a skewed result and one in which we cannot biologically explain.

Trial 2 also excluded rump length which the HFA removed from its linear classification program. A rump intermediate in width and in slope is suggested by Wilson (1990) for maximum profitability but disagrees with earlier recommendations (Pound, 1977; Maree, 1981; and Lindskoog, 1987) where more extremes in width, length and slope were advised.

Although registered cows with an intermediate angled foot in trial 1 had fewer DO than either extreme, we observed no significant difference in foot angle scores for DO for either grade or registered cows in trial 2. There was a small but significant increase in TB in registered cows, where cows with increasing foot angles had more TB. The small increase was statistically significant but not biologically so. Even with a ten point increase in linear score for foot angle we would only see an increase of 0.10 TB and even if this were biologically significant the heritability of foot angle is low (.11) (Lawstuen et al., 1987a). Perhaps we would obtain a more significant relationship between foot angle and fertility if all cows were evaluated with natural growth of the hooves. Frequent hoof trimming and uneven wear due to concrete vs. pasture or soft ground makes it difficult to compare a cow's natural foot angle with any reproductive or productive trait.

SUMMARY AND CONCLUSION

This study demonstrated that the improvement of reproductive performance in Holstein cows has a very small relationship with physical type traits. Traits such as rump angle, rear legs - side view, rear legs - position, rear legs - rear view, tailhead, vulva angle, mobility, pasterns, and toes were not found to be significant with reproductive performance.

Although small, the physical traits of rump length, rump width and foot angle had significant relationships in predicting reproductive performance in Holstein cows. The low heritabilities of the fertility and physical type traits we examined in our study may have contributed to this limited relationship.

The environmental factors of season, geographic location, and age all had a greater effect on the reproductive performance of the cow than the type traits. The significant effect of evaluator on all type traits and the interaction of evaluator with age or parity makes our attempted model more difficult to interpret. The subjective scores that resulted from the cow evaluations may have masked what little association we might expect to see between these type traits and fertility.

No strong linear or curvilinear relationship was observed in either of our trials between the new linear type trait evaluation system and days open or times bred. Since others (Pedron et al., 1989 and Honnette et al., 1980a) succeeded in observing a higher association between physical conformation and reproductive performance using descriptive type traits, one conclusion that can be drawn is that there does not appear to be an advantage using linear type traits in obtaining a more objective analysis.

As discussed in the introduction to this study, even a small percentage of improvement, when dealing with large numbers of cows, may prove to be economically desirable. However, with large samples, very weak relationships may well be statistically significant, but have no practical significance whatsoever. Although the relationship may be real or significant it is quite weak if it can account for less than 5% of the variance in the dependent variable. Corrective mating may, in some instances, improve herdlife and milk yield, but does not appear to be an effective alternative to direct selection aimed at improved reproductive performance.

Some assumptions were made at the beginning of our study that followed others in the literature (Thompson et al., 1981). For example, we assumed that the various evaluators classified cows in the same manner. No two evaluators classified the same cow. We assumed that differences between evaluators on type for the individual cows were due to the cows having different type and not due to interrater reliability. While we observed that type traits, as they are currently evaluated by the Holstein Association, have little impact on reproductive performance, we have some recommendations for improvement in future evaluations with fertility and/or type.

Because milk yield and its components are the most economically important traits in a selection program these traits should be the primary areas to consider in corrective mating. Selecting for type traits should be limited to eliminating extreme deviants of functional type that might lessen profitability and/or herd life. Direct selection against such proven reproductive disorders as cystic ovaries and dystocia might be profitable as a secondary selection guide but should not be considered for genetic management through corrective mating of type traits.

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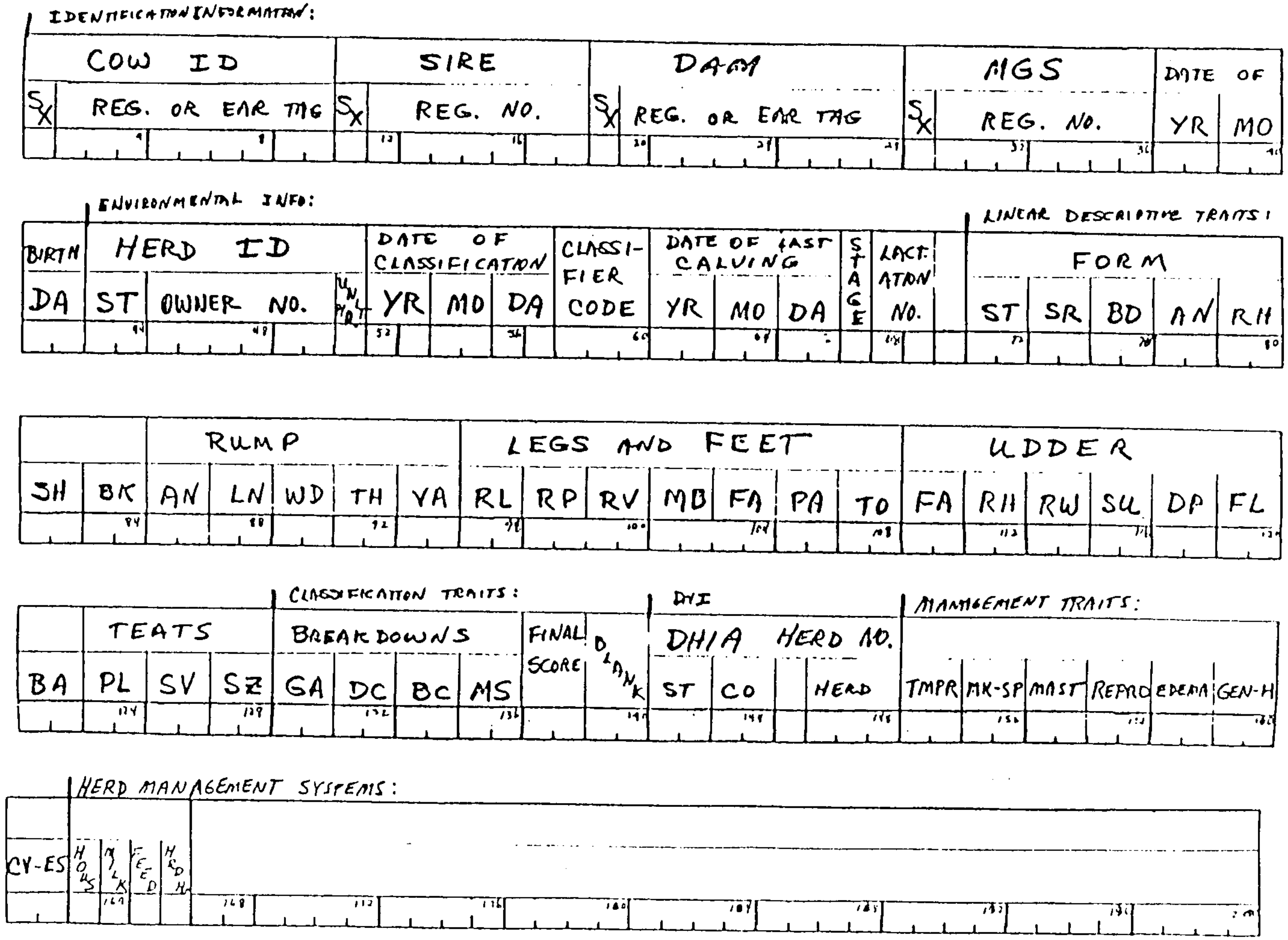
APPENDIX



IDENTIFICATION INFORMATION:

COW ID		SIRE		DAM		MGS		DATE OF	
SX	REG. OR EAR TAG	SX	REG. NO.	SX	REG. OR EAR TAG	SX	REG. NO.	YR	MO

ENVIRONMENTAL INFO:

LINEAR DESCRIPTIVE TRAITS:

BIRTH	HERD ID			DATE OF CLASSIFICATION			CLASSIFIER CODE	DATE OF LAST CALVING			STAGE	LACTATION NO.		FORM				
DA	ST	OWNER NO.	UNHRT	YR	MO	DA		YR	MO	DA				ST	SR	BD	AN	RH

		RUMP					LEGS AND FEET							UDDER					
SH	BK	AN	LN	WD	TH	YA	RL	RP	RV	MB	FA	PA	TO	FA	RH	RW	SU	DP	FL

CLASSIFICATION TRAITS:

DHI

MANAGEMENT TRAITS:

	TEATS			BREAKDOWNS				FINAL SCORE	BLANK	DHIA HERD NO.									
BA	PL	SV	SZ	GA	DC	BC	MS			ST	CO		HERD	TMPR	MK-SP	MAST	REPRO	EDEMA	GEN-H

HERD MANAGEMENT SYSTEMS:

CY-ES	HOUS	MLK	FEED	HRD H	

Exhibit 1. Holstein Friesian Association linear classification cow data research format provided for every cow classified.[a]

Legend for Exhibit 1:

MGS = maternal grand sire; Sx = sex; REG. = registration number; YR = year; MO = month; DA = day; Herd ID ST = state; Form ST = stature; SR = strength; BD = body depth; AN = angularity; RH = relative height of front end; SH = shoulder; BK = back; Rump An = angle; LN = length; WD = width; TH = tailhead; VA = vulva angle; Legs and Feet RL = rear legs, side view; RP = rear leg position, RV = rear legs, rear view; MB = mobility; FA = foot angle; PA = pasterns; TO = toes; Udder FA = fore attachment; RH = rear height, RW = rear width, SU = support, DP = depth; FL = fore udder length; BA = balance; Teats PL = placement, rear view; SV = placement, side view; SZ = teat size; GA = general appearance; DC = dairy character; BC = body capacity; MS = mammary system; CO = country; TMPR = temperament; MK-SP = milking speed; MAST = mastitis resistance; REPRO = reproductive performance; GEN-H = general health; CV-ES = calving ease; HOUS = housing system; MILK = milking system; FEED = feeding system; HRD H = herd health.

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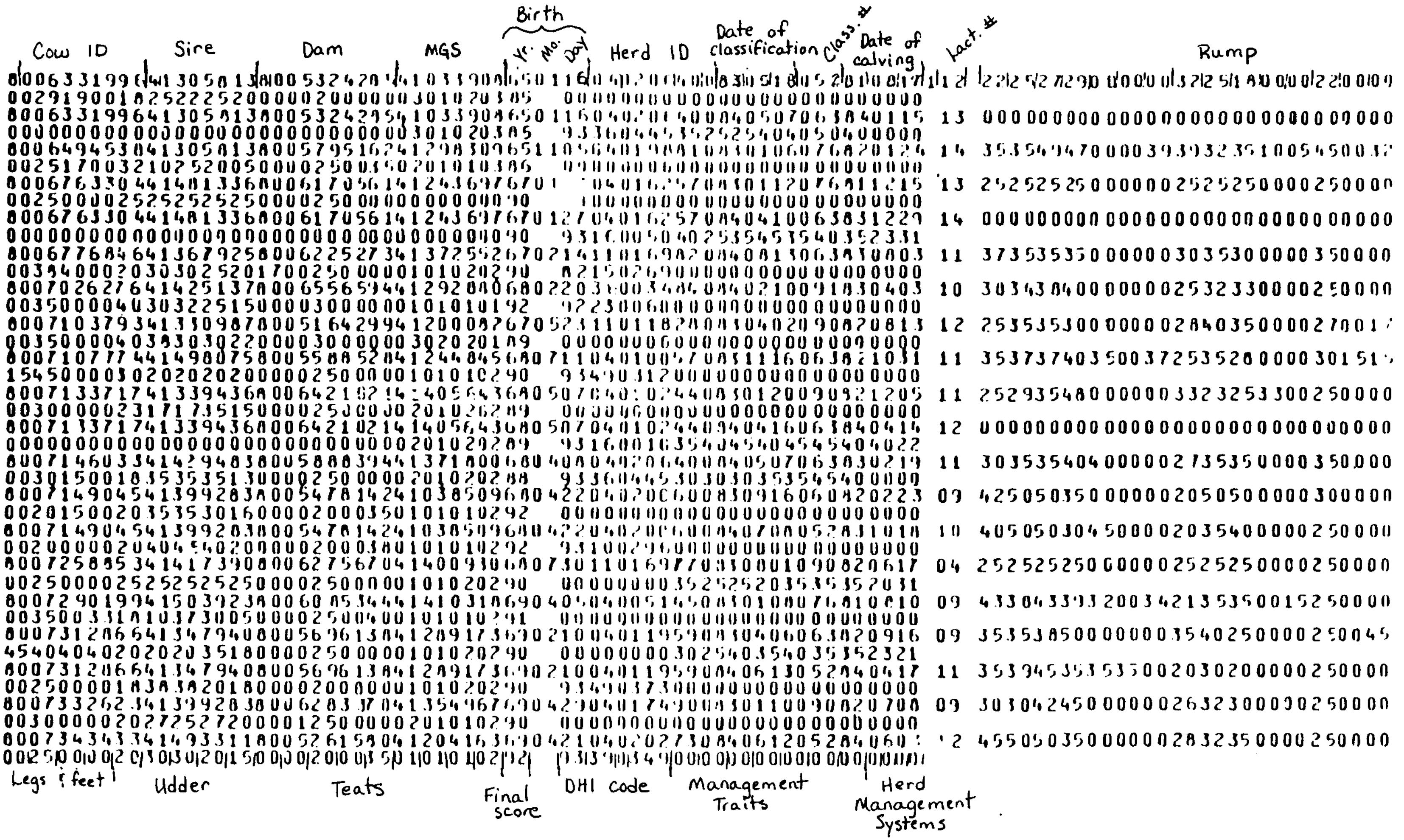
[a] Detailed description of each trait is found on page 110 of the appendix.



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```

Exhibit 2. Sample computer readout from Holstein Friesian Association registration data.[a]

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[a] Refer to pages 110 and 111 (HFA linear classification cow data research format for format design.

DESCRIPTION OF TRAITS AND MEASUREMENT SCALE

LINEAR DESCRIPTIVE TRAITS

FORM

Stature
50
45 - Extremely **tall**
40
35 - **Tall**
30
25 - Intermediate
20
15 - Short
10
5 - Extremely **short**
1

Strength
50
45 - Extremely **strong** and wide
40
35 - Very strong
30
25 - Intermediate strength and width
20
15 - Narrow and frail
10
5 - Extremely narrow and **frail**
1

Body Depth
50
45 - Extremely **deep** body
40
35 - Deep body
30
25 - Intermediate in body depth
20
15 - Shallow body
10
5 - Extremely **shallow** body
1

RUMP

Angle
50
45 - Extremely **sloped** from hooks to pins
40
35 - Moderate slope
30
25 - Slight slope, hooks to pins
20
15 - Pins slightly higher than hooks
10
5 - **Pins clearly higher** than hooks
1

Rump Length
50
45 - Extremely **long** rump, hooks to pins
40
35 - Long rump
30
25 - Intermediate in length
20
15 - Short rump
10
5 - Extremely **short** rump, hooks to pins
1

Rump Width
50
45 - Extremely **wide** through pelvic area
40
35 - Wide through pelvic area
30
25 - Intermediate width of rump
20
15 - Slightly narrow through pelvic area
10
5 - Extremely **narrow** through pelvic area
1

LEGS & FEET

Rear Legs, Side View
50
45 - Extremely **sickled** in hock
40
35 - Slightly sickle hocked
30
25 - Intermediate set in hock
20
15 - Nearly straight in hock
10
5 - **Posty** and straight legged
1

Rear leg position
50
45 - Extremely **forward**
40
35 - Too far forward
30
25 - Intermediate leg position
20
15 - Too far back
10
5 - Extremely **too far back**
1

Rear Legs, Rear View
50
45 - **Straight** with no toe out
40
35 - Straight with slight toe out
30
25 - Nearly straight, with moderate toe out
20
15 - Close at hock, clearly toes out
10
5 - Extremely "**hocked In**", severe toe out
1

UDDER

Fore Attachment
50
45 - Extremely snug and **strong** attachment
40
35 - Very strong attachment
30
25 - Intermediate strength attachment
20
15 - Loose attachment
10
5 - Extremely **loose** attachment
1

Rear Height
50
45 - Extremely **high**
40
35 - Very high
30
25 - Intermediate height
20
15 - Low
10
5 - Extremely **low**
1

Rear Width
50
45 - Extremely **wide**
40
35 - Very wide
30
25 - Intermediate width
20
15 - Narrow
10
5 - Extremely **narrow**
1

TEATS

Placement, rear view
50
45 - Extremely **close**, base of teats on inside quarter
40
35 - Placement on inside of quarter
30
25 - Centrally placed on quarter
20
15 - Placement toward outside of quarter
10
5 - Extremely **wide**, placement is on outside of quarter
1

Placement, side view
50
45 - **Too far forward**
40
35 - Forward placement
30
25 - Centrally placed
20
15 - Placement toward rear
10
5 - **Too far back**
1

Teat Size
50
45 - Extremely **large**
40
35 - Large
30
25 - Intermediate in size
20
15 - Small
10
5 - Extremely **small**
1

CLASSIFICATION TRAITS

General Appearance
Excellent
Very Good
Good Plus
Good
Fair
Poor

Dairy Character
Excellent
Very Good
Good Plus
Good
Fair
Poor

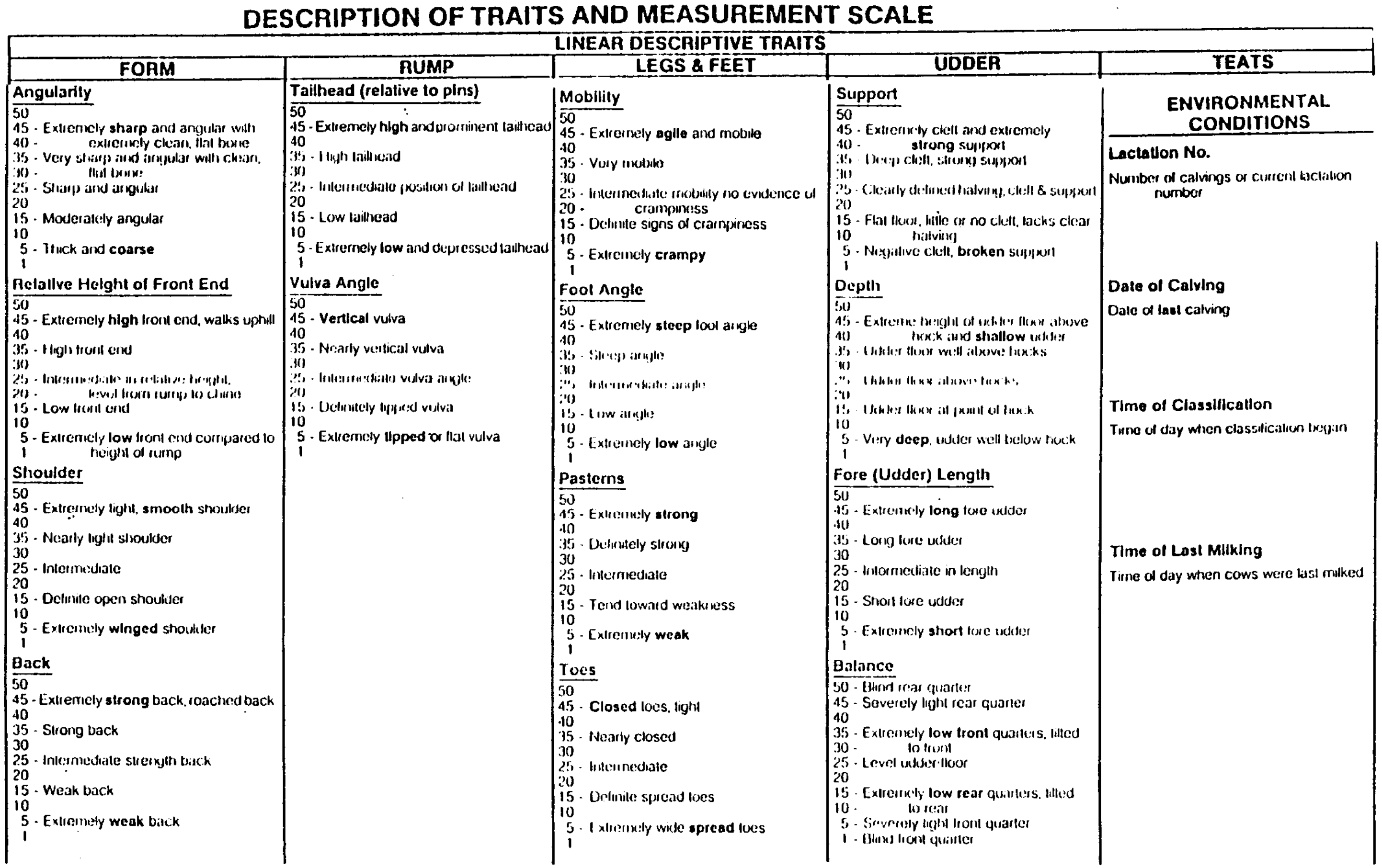
Body
Excellent
Very Good
Good Plus
Good
Fair
Poor

Mammary
Excellent
Very Good
Good Plus
Good
Fair
Poor

Final Score

Excellent	- 90 to 100 points
Very Good	- 85 to 89 points
Good Plus	80 to 84 points
Good	- 75 to 79 points
Fair	- 65 to 74 points
Poor	- 50 to 64 points

Exhibit 3. Description of traits and measurement scale for linear classification traits from the Holstein Friesian Association.



DESCRIPTION OF TRAITS AND MEASUREMENT SCALE

LINEAR DESCRIPTIVE TRAITS

FORM

Angularity
50
45 - Extremely **sharp** and angular with
40 - extremely clean, flat bone
35 - Very sharp and angular with clean,
30 - flat bone
25 - Sharp and angular
20
15 - Moderately angular
10
5 - Thick and **coarse**
1

Relative Height of Front End
50
45 - Extremely **high** front end, walks uphill
40
35 - High front end
30
25 - Intermediate in relative height,
20 - level from rump to chine
15 - Low front end
10
5 - Extremely **low** front end compared to
1 height of rump

Shoulder
50
45 - Extremely light, **smooth** shoulder
40
35 - Nearly light shoulder
30
25 - Intermediate
20
15 - Definite open shoulder
10
5 - Extremely **winged** shoulder
1

Back
50
45 - Extremely **strong** back, roached back
40
35 - Strong back
30
25 - Intermediate strength back
20
15 - Weak back
10
5 - Extremely **weak** back
1

RUMP

Tailhead (relative to pins)
50
45 - Extremely **high** and prominent tailhead
40
35 - High tailhead
30
25 - Intermediate position of tailhead
20
15 - Low tailhead
10
5 - Extremely **low** and depressed tailhead
1

Vulva Angle
50
45 - **Vertical** vulva
40
35 - Nearly vertical vulva
30
25 - Intermediate vulva angle
20
15 - Definitely tipped vulva
10
5 - Extremely **tipped** or flat vulva
1

LEGS & FEET

Mobility
50
45 - Extremely **agile** and mobile
40
35 - Very mobile
30
25 - Intermediate mobility no evidence of
20 - crampiness
15 - Definite signs of crampiness
10
5 - Extremely **crampy**
1

Foot Angle
50
45 - Extremely **steep** foot angle
40
35 - Steep angle
30
25 - Intermediate angle
20
15 - Low angle
10
5 - Extremely **low** angle
1

Pasterns
50
45 - Extremely **strong**
40
35 - Definitely strong
30
25 - Intermediate
20
15 - Tend toward weakness
10
5 - Extremely **weak**
1

Toes
50
45 - **Closed** toes, tight
40
35 - Nearly closed
30
25 - Intermediate
20
15 - Definite spread toes
10
5 - Extremely wide **spread** toes
1

UDDER

Support
50
45 - Extremely cleft and extremely
40 - **strong** support
35 - Deep cleft, strong support
30
25 - Clearly defined halving, cleft & support
20
15 - Flat floor, little or no cleft, lacks clear
10 halving
5 - Negative cleft, **broken** support
1

Depth
50
45 - Extreme height of udder floor above
40 hock and **shallow** udder
35 - Udder floor well above hocks
30
25 Udder floor above hocks
20
15 - Udder floor at point of hock
10
5 - Very **deep**, udder well below hock
1

Fore (Udder) Length
50
45 - Extremely **long** fore udder
40
35 - Long fore udder
30
25 - Intermediate in length
20
15 - Short fore udder
10
5 - Extremely **short** fore udder
1

Balance
50 - Blind rear quarter
45 - Severely light rear quarter
40
35 - Extremely **low front** quarters, tilted
30 - to front
25 - Level udder floor
20
15 - Extremely **low rear** quarters, tilted
10 - to rear
5 - Severely light front quarter
1 - Blind front quarter

TEATS

ENVIRONMENTAL CONDITIONS

Lactation No.
Number of calvings or current lactation number

Date of Calving
Date of last calving

Time of Classification
Time of day when classification began

Time of Last Milking
Time of day when cows were last milked

Exhibit 3. Description of traits and measurement scale for linear classification traits from the Holstein Friesian Association (continued).

OREGON STATE UNIVERSITY - RESEARCH TAPE

DATES ARE IN "MONTH DAY YEAR" FORMAT.

PREGNANCY CAN BE EITHER ASSIGNED BY THE COMPUTER (EST-FLAG=1)
OR ASSIGNED BY THE DAIRYMAN (EST-FLAG=0)
IF THE EST-FLAG=0, THE LISTING WILL BE BLANK

WE PROVIDE INFORMATION ON A MAXIMUM OF 15 LACTATIONS AND 15 BREED RECORDS PER COW.

TAPE IS IN;
1600 BPI
EBCDIC
LENGTH OF RECORD = 800 CHARACTERS
3 RECORDS/BLOCK
FIXED RECORD LENGTH
ONE RECORD PER COW

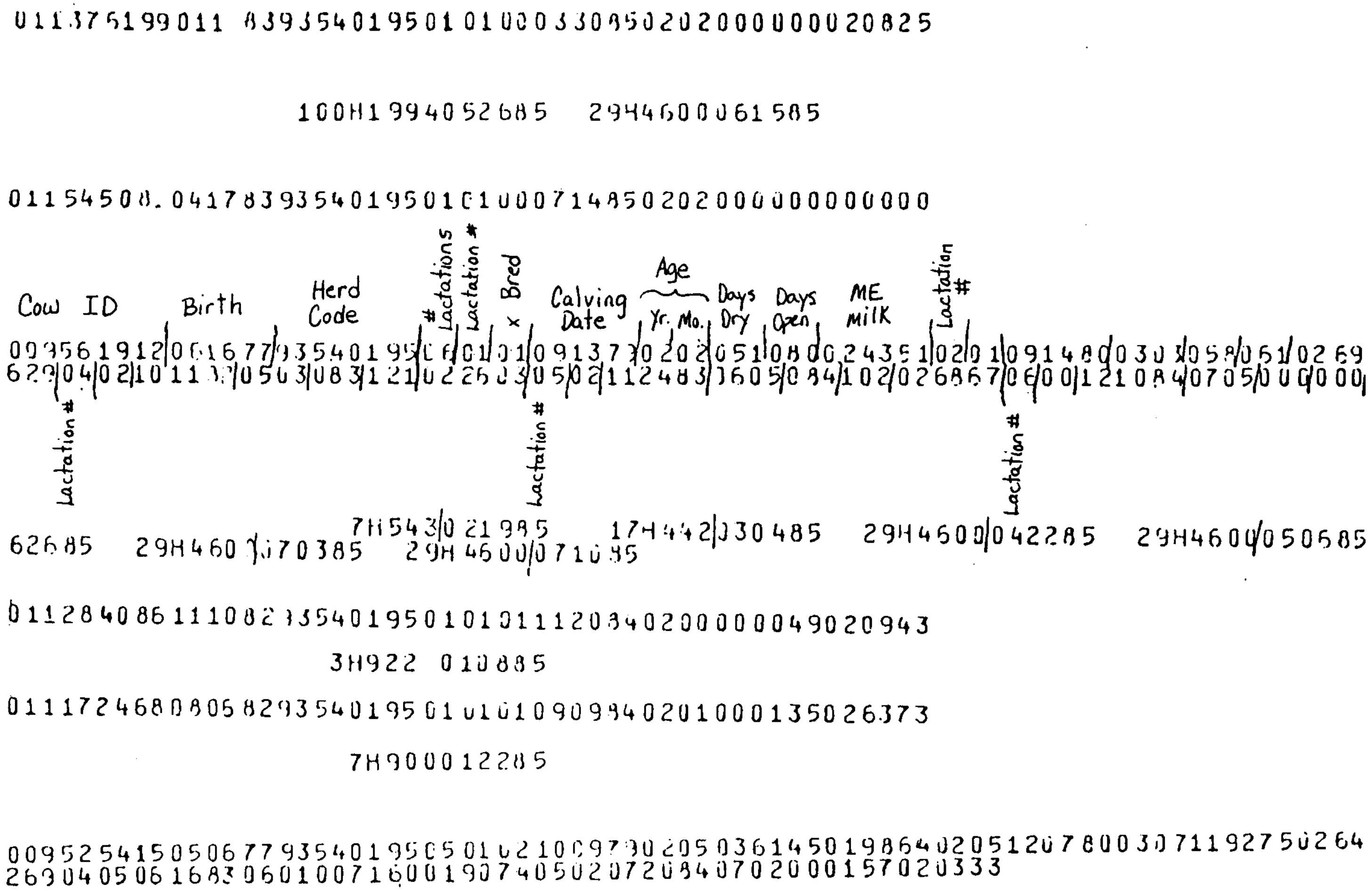
DESCRIPTION OF FIELDS;

		CHARACTERS	COLUMNS
COW REGISTRATION NUMBER	ALPHA/NUM	9	1-9
BIRTH DATE	NUMERIC	6	10-15
HERD CODE	NUMERIC	8	16-23
NUMBER OF LACTATIONS	NUMERIC	2	24-25
LACTATION DATA - UP TO 15 LACTATIONS			
LACTATION NUMBER	NUMERIC	2	26-27
TIMES BRED	NUMERIC	2	28-29
CALVING DATE	NUMERIC	6	30-35
AGE AT CALVING - YEARS	NUMERIC	2	36-37
AGE AT CALVING - MONTHS	NUMERIC	2	38-39
DAYS DRY	NUMERIC	3	40-42
DAYS OPEN	NUMERIC	3	43-44
ME MILK	NUMERIC	6	45-50
BREED DATA - UP TO 25 BREEDINGS			
SIRE USED	ALPHA/NUM	9	416-424
BREED DATE	NUMERIC	6	425-430
PREG OR OPEN FLAG	NUMERIC	1	791
PREG EST. FLAG	NUMERIC	1	792
[a] CAR CODE	NUMERIC	9	793

Exhibit 4. Format for DHI records from Agri-Tech Analytics DHI records.

---

[a] CAR CODE - condition affecting record code.



```
011376199011  839354019501 01000330850202000000020825

          100H1994052685   29H4600061585

0115450 8.04178393540195 01 01000714850202000000000000

0035619120016779354019506010109137302020510800024351020109148003030 5806102 69
62204021011370503083121022603050211248336050841020268670600121084070500000

62685    29H460 070385  7H543 021985      17H442 030485    29H4600 042285    29H4600 050585
                          29H4600 071085

011284086111082335401950101011120840200000049020943
          3H922  010885
01117246808058293540195 01 01010909840201000135026373
          7H900012285

0095254150506779354019505010210097302050361450198640205120780030711927502 64
2690405061683060100716001907405020720840702000157020333
```

Exhibit 5. Sample computer readout from Agri-Tech Analytics DHI records.

FORMAT

	FIELD	SIZE
1.	COW REGISTRATION	9
2.	DHIA NUMBER	9
3.	CHAIN NUMBER	4
4.	HERD CODE	8
5.	BIRTH DATE	6
6.	LACTATION NUMBER	2
7.	TOTAL NUMBER OF LACTATIONS	2
8.	CALVING DATE	6
9.	CAR CODE (IF SOLD DATE)	1
10.	TIMES BRED	2
11.	DAYS OPEN	3
12.	DAYS DRY	3
13.	AGE - YRS.	2
14.	AGE - MOS.	2
15.	M.E. MILK	6
16.	FILLER	5

Exhibit 6. Format for DHI records from Agri-Tech Analytics, Tulare, CA for trial 2.

Exhibit 7. Variable list for computer input for trial 1.

Var. #	Variable		Column
1.	Sex (8 = female, 4 = male)		1
2.	Cow Registration Number		2-10
3.	Sex of Sire		11
4.	Sire Registration Number		12-18
5.	Sex of Dam		19
6.	Dam Registration Number		20-28
7.	Sex of MGS		29
8.	MGS Registration Number		30-36
9.	Date of Birth (year)		37-38
10.	(month)		39-40
11.	(day)		41-42
12.	Herd I.D. (State)		43-44
13.	(owner no.)		45-50
14.	Date of Classification (year)		52-53
15.	(month)		54-55
16.	(day)		56-57
17.	Classifier Code		58-60
18.	Date of Last Calving (year)		61-62
19.	(month)		63-64
20.	(day)		65-66
21.	Stage of Lactation		67
22.	Lactation Number		68-69
	Blank		70
	Linear Descriptive Traits		
	Primary	Secondary	
23.	Stature		71-72
24.	Strength		73-74
25.	Body Depth		75-76
26.	Angularity		77-78
27.		Ht. Ft End	79-80
28.		Shoulders	81-82
29.		Back	83-84
30.	Rump Angle		85-86
31.	Rump Length		87-88
32.	Rump Width		89-90
33.		Tail Head	91-92
34.		Vulva Angle	93-94
35.	Rear Legs (side view)		95-96
36.		Rear Lgs Pos.	97-98
37.		Rr Lgs. Rr. Vw	99-100
38.		Mobility	101-102
39.	Foot Angle		103-104
40.		Pasterns	105-106
41.		Toes	107-108
42.	Fore Attachment		109-110
43.	Rear U. Height		111-112
44.	Rear U. Width		113-114
45.	Udder Support		115-116
46.	Udder Depth		117-118
47.		Fore Length	119-120
48.		Udder Balance	121-122

49.	Teat Placement (rear view)	123-124
50.	Place. side vw	125-126
51.	Teat size	127-128
	Classification Traits (breakdowns)	
52.	General Appearance	129-130
53.	Dairy Character	131-132
54.	Body Capacity	133-134
55.	Mammary System	135-136
56.	Final Score	137-138
	Blank	139-140
57.	DHIA Herd No. (State)	141-142
58.	(County)	143-144
59.	(Herd)	145-148
	Management Traits	
60.	Temperament	149-150
61.	Milking Speed	151-152
62.	Mastitis Resistance	153-154
63.	Reproductive Performance	155-156
64.	Edema (secondary)	157-158
65.	General Health (secondary)	159-160
66.	Calving Ease (secondary)	161-162
67.	Housing System	163
68.	Milking System	164
69.	Feeding System	165
70.	Herd Health	166
71.	Birth Date (month)	167-168
72.	(day)	169-170
73.	(year)	171-172
74.	Herd Code	173-180
75.	# of Lactations	181-182
76.	Lactation #	183-184
77.	Times Bred	185-186
78.	Calving Date (month)	187-188
79.	(day)	189-190
80.	(year)	191-192
81.	Age at Calving (years)	193-194
82.	(months)	195-196
83.	Days Dry	197-199
84.	Days Open	200-202
85.	ME Milk	203-208
86.	Succeeding lactations	209- (26 columns/lactation)

Created Variables

Var. #	Category Value	Column
101. Season Bred		
1. Winter	01, 02, 03	
2. Spring	04, 05, 06	
3. Summer	07, 08, 09	
4. Fall	10, 11, 12	
	if 105 is 4 or 8 then 101 = 1	
	if 105 is 1 or 5 then 101 = 2	
	if 105 is 2 or 6 then 101 = 3	
	if 105 is 3 or 7 then 101 = 4	
102. Lactation #		
1. 1st lactation	01	68,69
2. 2nd lactation	02	68,69
3. 3rd lactation	03	68,69
4. Aged Cows	04, 05, 06, 07, 08, 09, 10, 11, 12, 13	68,69
103. Geographic Variable		
1. Coast	9204,9206,9223, 9327,9308,9312, 9360	141-144
2. Willamette Valley	9203,9211,9213, 9214,9216,9218, 9220,9227	141-144
3. San Joaquin Valley	9310,9311,9315, 9316,9320,9324, 9334,9339,9350, 9354,9349	141-144
4. So. California	9336, 9342,9337	141-144
104. Season Classified		
1. Winter 1984	8401,8402,8403	52-55
2. Spring 1984	8404,8405,8406	52-55
3. Summer 1984	8407,8408,8409	52-55
4. Fall 1984	8410,8411,8412	52-55
5. Winter 1985	8501,8502,8503	52-55
6. Spring 1985	8504,8505,8506	52-55
7. Summer 1985	8507,8508,8509	52-55
8. Fall 1985	8510,8511,8512	52-55
105. Date of Last Calving		
1. Winter 1984	8401,8402,8403	61-64
2. Spring 1984	8404,8405,8406	61-64
3. Summer 1984	8407,8408,8409	61-64
4. Fall 1984	8410,8411,8412	61-64
5. Winter 1985	8501,8502,8503	61-64
6. Spring 1985	8504,8505,8506	61-64
7. Summer 1985	8507,8508,8509	61-64
8. Fall 1985	8510,8511,8512	61-64

Secondary Traits

106. Relative Height of Front End

1. Extremely low	01,02,03,04,05	79-80
2. Low front end	06,07,08,09,10, 11,12,13,14,15	79-80
3. Level from rump to chine	16,17,18,19,20	79-80
4. Intermediate in rel. height	21,22,23,24,25	79-80
5. High front end	26,27,28,29,30, 31,32,33,34,35, 36,37,38,39	79-80
6. No Data	00	79-80

107. Shoulder

1. Extremely winged shoulder	01,02,03,04,05	81-82
2. Definite open shoulder	06,07,08,09,10, 11,12,13,14,15 16,17,18,19	81-82
3. Intermediate	20,21,22,23,24, 25,26,27,28,29	81-82
4. Nearly tight shoulder	30,31,32,33,34, 35,36,37,38,39	81-82
5. No Data	00	81-82

108. Back

1. Extremely weak back	01,02,03,04,05	83-84
2. Weak back	06,07,08,09,10 11,12,13,14,15, 16,17,18,19	83-84
3. Intermediate strength back	20,21,22,23,24, 25,26,27,28,29	83-84
4. Strong back	30,31,32,33,34, 35,36,37,38,39	83-84
5. No Data	00	83-84

109. Tailhead (relative to pins)

1. Extremely low and depressed	01,02,03,04,05	91-92
2. Low tailhead	06,07,08,09,10 11,12,13,14,15, 16,17,18,19	91-92
3. Intermediate position	20,21,22,23,24, 25,26,27,28,29	91-92
4. High tailhead	30,31,32,33,34, 35,36,37,38,39	91-92
5. Extremely high tailhead	40,41,42,43,44, 45,46,47,48,49	91-92
6. No Data	00	91-92

110. Vulva Angle		
1. Extremely tipped or flat	01,02,03,04,05	93-94
2. Definitely tipped vulva	06,07,08,09,10, 11,12,13,14,15, 16,17,18,19	93-94
3. Intermediate angle	20,21,22,23,24, 25,26,27,28,29	93-94
4. Nearly vertical vulva	30,31,32,33,34, 35,36,37,38,39	93-94
5. Vertical vulva	40,41,42,43,44 45,46,47,48,49	93-94
6. No Data	00	93-94
111. Rear Leg Position		
1. Extremely too far back	01,02,03,04,05	97-98
2. Too far back	06,07,08,09,10 11,12,13,14,15, 16,17,18,19	97-98
3. Intermediate leg position	20,21,22,23,24, 25,26,27,28,29	97-98
4. Too far forward	30,31,32,33,34 35,36,37,38,39	97-98
5. Extremely forward	40,41,42,43,44 45,46,47,48,49	97-98
6. No Data	00	97-98
112. Rear Legs Rear View		
1. Extremely hocked in or toe out	01,02,03,04,05	99-100
2. Close at hocks, clearly toes out	06,07,08,09,10 11,12,13,14,15, 16,17,18,19	99-100
3. Nearly straight with moderate toe out	20,21,22,23,24, 25,26,27,28,29	99-100
4. Straight with slight toe out	30,31,32,33,34, 35,36,37,38,39	99-100
5. Straight with no toe out	40,41,42,43,44, 45,46,47,48,49	99-100
6. No Data	00	99-100
113. Mobility		
1. Extremely crampy	01,02,03,04,05	101-102
2. Def. signs crampiness	06,07,08,09,10 11,12,13,14,15, 16,17,18,19	101-102
3. No evid. of crampiness	20,21,22,23,24, 25,26,27,28,29	101-102
4. No Data	00	101-102

114. Pasterns

1. Extremely weak	01,02,03,04,05	105-106
2. Tend toward weakness	06,07,08,09,10, 11,12,13,14,15, 16,17,18,19	105-106
3. Ave.or better	00	105-106

115. Toes

1. Extremely wide spread toes	01,02,03,04,05	107-108
2. Definite spread toes	06,07,08,09,10, 11,12,13,14,15, 16,17,18,19	107-108
3. Ave. or better	00	107,108

116. Calving Ease

1. Extremely hard calver	01,02,03,04,05	161-162
2. Difficult calving	06,07,08,09,10, 11,12,13,14,15, 16,17,18,19	161-162
3. Average or intermed. calving ease	20,21,22,23,24, 25,26,27,28,29	161-162
4. Easy calving/no assist.	30,31,32,33,34, 35,36,37,38,39	161-162
5. Extremely easy	40,41,42,43,44, 45,46,47,48,49	161-162
6. No Data	00	161-162

Tape 48, Disk 001, 002

Sex of Cow	1
Cow Registration #	2-9
Bull's Name or Stud Code #	10-18
Date Bred	19-24
Succeeding breedings (15 columns/breeding)	24-220

117. Age of Cow at Classification in months
Variable 117 = (12 x Var.14 + Var. 15) - (12 x Var. 9 + Var. 10)

118. Age of Cow at Last Calving in months
Variable 118 = (12 x Var. 81 + Var. 82)

119. Calving Interval in months
Variable 119 = (279 + Variable 84)

120. Geography x Season Bred
1. Winter x Coast if V101 = 1 and V103 = 1
2. Winter x W.V. if V101 = 1 and V103 = 2

3. Winter x S.J.C . if V101 = 1 and V103 = 3
4. Winter X S.C. if V101 = 1 and V103 = 4
5. Spring x Coast if V101 = 2 and V103 = 1
6. Spring x W.V. if V101 = 2 and V103 = 2
7. Spring x S.J.V. if V101 = 2 and V103 = 3
8. Spring x S.C. if V101 = 2 and V103 = 4
9. Summer x Coast if V101 = 3 and V103 = 1
10. Summer x W.V. if V101 = 3 and V103 = 2
11. Summer x S.J.V. if V101 = 3 and V103 = 3
12. Summer x S.C. if V101 = 3 and V103 = 4
13. Fall x Coast if V101 = 4 and V103 = 1
14. Fall x W.V. if V101 = 4 and V103 = 2
15. Fall x S.J.V. if V101 = 4 and V103 = 3
16. Fall x S.C. if V101 = 4 and V103 = 4

Exhibit 8. Sample computer input for SPSS[a] program during trial 1.

COMPUTER INPUT (COMMANDS) FOR TRIAL 1

```
NUMBERED
RUN NAME            LELAND S. SHAPIRO/LLOYD SWANSON
FILE NAME           HFAMILK

VARIABLE LIST       V1 TO V56, V58 TO V85
INPUT FORMAT FIXED(F1.0,F9.0,F1.0,F7.0,F1.0,F9.0,F1.0,F7.0,4F2.0,
                   F6.0,1X,3F2.0,F3.0,3F2.0,F1.0,F2.0,1X,
                   34F2.0,2X,2F4.0,7F2.0,4F1.0,3F2.0,F8.0,8F2.0,
                   2F3.0,F6.0)

INPUT MEDIUM DISK
MISSING VALUES ALL(-9999)

IF (V80 = 83 AND V14 = 83)GR=1
IF (V80 = 82 AND V14 = 83)GR=2
IF (V80 = 81 AND V14 = 83)GR=3
IF (V80 = 84 AND V14 = 83)GR=4
IF (V80 = 84 AND V14 = 84)GR=5
IF (V80 = 83 AND V14 = 84)GR=6
IF (V80 = 82 AND V14 = 84)GR=7

IF (GR EQ 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7)GR=8

IF (V84 LE 115 AND V84 GE 85)GROUP=1
IF (V84 GT 115)GROUP=2
IF (V84 LT 85)GROUP=3
IF (V77 = 1 OR 2)SET=4
IF (V77 GT 2)SET=5
IF (V77 LT 1)SET=7
IF ((V84 GE 85 AND LE 115) AND (V77 =1 OR 2))SET=6
IF (GR = 8 AND GROUP = 1)DOPEN=1
IF (GR = 8 AND GROUP = 2)DOPEN=2
IF (GR = 8 AND GROUP = 3)DOPEN=3
IF (GR = 8 AND SET = 4)BRED=1
IF (GR = 8 AND SET = 5)BRED=2
IF (GR = 8 AN SET = 6)COWGR=1

IF (V18 = 84 AND V19 = 1 OR 2 OR 3)V105=1
IF (V18 = 84 AND V19 = 4 OR 5 OR 6)V105=2
IF (V18 = 84 AND V19 = 7 OR 8 OR 9)V105=3
IF (V18 = 84 AND V19 = 10 OR 11 OR 12)V105=4
IF (V18 = 85 AND V19 = 1 OR 2 OR 3)V105=5
IF (V18 = 85 AND V19 = 4 OR 5 OR 6)V105=6
IF (V18 = 85 AND V19 = 7 OR 8 OR 9)V105=7
IF (V18 = 85 AND V19 = 10 OR 11 OR 12)V105=8
IF (V22 = 3)V102=3
IF (V105 = 4 OR 8)V101=1
IF (V105 = 1 OR 5)V101=2
IF (V105 = 2 OR 6)V101=3
IF (V105 = 3 OR 7)V101=4
IF (V22 = 1)V102=1
```

```
IF (V22 GE 4)V102=4
IF (V22 = 2)V102=2
IF (V58 = 9204 OR 9206 OR 9223 OR 9327 OR 9308 OR 9312
    OR 9360)V103=1
IF (V58 = 9203 OR 9211 OR 9213 OR 9214 OR 9216 OR 9218
    OR 9220 OR 9227)V103=2
IF (V58 = 9310 OR 9311 OR 9315 OR 9316 OR 9320 OR 9324
    OR 9334 OR 9339 OR 9349 OR 9350 OR 9354)V103=3
IF (V58 = 9336 OR 9342 OR 9337)V103=4

IF (V14 = 84 AND V15 = 1 OR 2 OR 3)V104=1
IF (V14 = 84 AND V15 = 4 OR 5 OR 6)V104=2
IF (V14 = 84 AND V15 = 7 OR 8 OR 9)V104=3
IF (V14 = 84 AND V15 = 10 OR 11 OR 12)V104=4
IF (V14 = 83 AND V15 = 1 OR 2 OR 3)V104=5
IF (V14 = 83 AND V15 = 4 OR 5 OR 6)V104=6
IF (V14 = 83 AND V15 = 7 OR 8 OR 9)V104=7
IF (V14 = 83 AND V15 = 10 OR 11 OR 12)V104=8
IF (V14 = 85 AND V15 = 1 OR 2 OR 3)V104=9
IF (V14 = 85 AND V15 = 4 OR 5 OR 6)V104=10
IF (V27 GE 1 AND V27 LE 5)V106=1
IF (V27 GE 6 AND V27 LE 19)V106=2

IF (V27 GE 20 AND V27 LE 29)V106=3
IF (V27 GE 30 AND V27 LE 39)V106=4
IF (V27 GE 40 AND V27 LE 50)V106=5
IF (V27 = 0)V106=6
IF (V28 GE 1 AND V28 LE 5)V107=1
IF (V28 GE 6 AND V28 LE 19)V107=2
IF (V28 GE 20 AND V28 LE 29)V107=3
IF (V28 GE 30 AND V28 LE 39)V107=4
IF (V28 GE 40 AND V28 LE 50)V107=5
IF (V28 = 0)V107=6
IF (V29 GE 1 AND V29 LE 5)V108=1
IF (V29 GE 6 AND V29 LE 19)V108=2
IF (V29 GE 20 AND V29 LE 29)V108=3
IF (V29 GE 30 AND V29 LE 39)V108=4
IF (V29 GE 40 AND V29 LE 50)V108=5
IF (V29 = 0)V108=6
DO REPEAT XV=V33,V34,V36,V37,V66/
          XW=V109,V110,V111,V112,V116
IF (XV G3 1 AND LE 5)XW=1
IF (XV GE 6 AND LE 19)XW=2
IF (XV GE 20 AND LE 29)XW=3
IF (XV GE 30 AND LE 39)XW=4
IF (XV GE 40 AND LE 50)XW=5
IF (XV = 0)XW=6
END REPEAT
IF (V38 GE 1 AND LE 5)V113=1
IF (V38 GE 6 AND LE 19)V113=2
IF (V38 GE 20 AND LE 29)V113=3
IF (V38 GE 30 AND LE 39)V113=4
IF (V38 GE 40 AND LE 50)V113=5
IF (V38 = 0)V113=6
```

```
IF (V40 GE 1 AND LE 5)V114=1
IF (V40 GE 6 AND LE 19)V114=2
IF (V40 GE 20 AND LE 39)V114=3
IF (V40 GE 40 AND LE 50)V114=4
IF (V40 = 0)V114=5
IF (V41 GE 1 AND LE 5)V115=1
IF (V41 GE 6 AND LE 19)V115=2
IF (V41 GE 20 AND LE 39)V115=3
IF (V41 GE 40 AND LE 50)V115=4
IF (V41 = 0)V115=5
IF (V101 = 1 AND V103 = 1)V120=1
IF (V101 = 1 AND V103 = 2)V120=2
IF (V101 = 1 AND V103 = 3)V120=3
IF (V101 = 1 AND V103 = 4)V120=4
IF (V101 = 2 AND V103 = 1)V120=5
IF (V101 = 2 AND V103 = 2)V120=6
IF (V101 = 2 AND V103 = 3)V120=7
IF (V101 = 2 AND V103 = 4)V120=8
IF (V101 = 3 AND V103 = 1)V120=9
IF (V101 = 3 AND V103 = 2)V120=10
IF (V101 = 3 AND V103 = 3)V120=11
IF (V101 = 3 AND V103 = 4)V120=12
IF (V101 = 4 AND V103 = 1)V120=13
IF (V101 = 4 AND V103 = 2)V120=14
IF (V101 = 4 AND V103 = 3)V120=15
IF (V101 = 4 AND V103 = 4)V120=16

IF (12 X V14 + V15)-(12 X V9 + V10)=V117

IF (12 X V81 + V82)=V118

IF (279 + V84)=V119

VAR LABELS   V105 DATE OF LST CALVING/V101 SEASON BRED/
             V102 LACTATION NO/V103 GEO LOCATION/
             V104 SEASON CLASSIFIED/V106 RE. HEIGHT/
             V107 SHOULDER/V108 BACK/V109 TAILHEAD/V110 VULVA ANGLE/
             V111 REAR LEG POS./V112 REAR LEG REAR VIEW/
             V113 MOBILITY/V114 PASTERNS/V115 TOES/V116 CALVING
             EASE/V117 AGE AT CLASSIFICATION/V118 AGE AT LAST CALV/
             V119 CALVING INTERVAL/V120 GEO X SEASON BRED

VALUE LABELS V104,V105 (1)WIN’84 (2)SPR’84 (3)SUM’84 (4)FALL’84/
             V104 (5)WIN’83 (6)SPR’83 (7)SUM’83 (8)FALL’83/
             V105 (5)WIN’85 (6)SPR’85 (7)SUM’85 (8)FALL’85/
             V104 (9)WIN’85 (10)SPR’85/V101 (1)WINTER (2)SPRING
             (3)SUMMER (4)FALL/V102 (1)1ST LAC (2)2ND LAC (3)3RD LAC
             (4)AGED COWS/V103 (1)COAST (2)WILLIA. VALLEY (3)SAN
             JOAQUIN (4)SO. CALIF/V106 (1)EXTLY LOW (2)LOW (3)INTER.
             IN REL.HEIGHT (4)HIGH (5)WALKS UPHILL (6)NO DATA/
             V107 (1)EXTLY WINGED (2)DEFINITE OPEN (3)INTER.
             (4)TIGHT (5)SMOOTH (6)NO DATA/V108 (1)EXTLY WEAK
             (2)WEAK (3)INTER. (4)STRONG (5)ROACHED/V109 (1)EXTLY
             LOW (2)LOW (3)INTER. (4)HIGH (5)PROM.TAILHEAD (6)NO
```

```
DATA/V110 (1)EXTLY TIPPED (2)DEF TIPPED (3)INTER.
(4)NEARLY VERTICAL (5)VERTICAL (6)NO DATA/
V111 (1)EXTLY TOO FAR BACK (2)TOO FAR BACK (3)INTER.
(4)TOO FAR FORWARD (5)EXTLY FORWARD (6)NO DATA/
V112 (1)EXTLY HOCKED (2)CLOSE AT HOCKS (3)NEARLY STR.
(4)STRAIGHT TOE OUT(5)STR NO TOE OUT (6)NO DATA/
V113 (1)EXTLY CRAMPY (2)DEF CRAMPY (3)INTER. (4)VERY
MOBILE (5)EXTLY AGILE (6)NO DATA/V114 (1)EXTLY WEAK
(2)TEND TO WEAK (3)INTER. (4)DEF. STRONG (5)EXTLY
STRONG (6)NO DATA/V115 (1)EXTLY SPREAD TOES (2)DEF.
SPREAD (3)INTER. (4)NEARLY CLOSED (5)CLOSED TIGHT
(6)NO DATA/V116 (1)EXTLY HARD (2)DIFFICULT (3)AVG
(4)EASY, NO RES (5)EXTLY EASY (6)NO DATA/
V117 AGE OF COW AT CLASSIFICATION IN MONTHS/
V118 AGE OF COW AT LAST CALVING IN MONTHS/
V119 CALVING INTERVAL IN MONTHS/
V120 (1)WINTER X COAST (2)WINTER X W.V. (3)WINTER X
S.J.V. (4)WINTER X S.C. (5)SPRING X COAST, (6)SPRING X
W.V. (7)SPRING X S.J.V. (8)SPRING X S.C. (9)SUMMER X
COAST (10)SUMMER X W.V. (11)SUMMER X S.J.V. (12)SUMMER
X S.C. (13)FALL X COAST (14)FALL X W.V. (15)FALL X
S.J.V. (16)FALL X S.C./DOPEN (1)85 TO 115 (2)OVER 115
(3)LESS THAN 85/BRED (1)BRED ONCE OR TWICE (2)BRED
MORE THAN TWICE (3)NEVER BRED/COWGR (1)BRED 1 AND
DOPEN 1

SELECT IF(COWGR = 1)
ANOVAV30,V31,V32,V33,V34,V35,V36,V37,V38,V116 BY
V101,V102,
V103(1,4)
OPTIONS8
STATISTICSALL

ANOVAV30,V31,V32,V33,V34,V35,V36,V37,V38,V116 BY
V120(1,16)
WITH V22
OPTIONS          8
STATISTICS       ALL
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[a] SPSS - Statistical Package for the Social Sciences.