Effects of Within Herd Variation on the Relationship between Genetic Evaluations and Performance of Offspring

by

Todd Richard Meinert

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APPROVED:

Ronald E. Pearson, Chairman

Bennet G. Cassell

William E. Vinson, Department Head

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(ABSTRACT)

1,032,438 Jersey and 1,162,578 Holstein official Dairy Herd Improvement Association (DHIA) records from 20,380 and 34,000 herd-years, respectively, were used to compute herd-year means and within herd-year standard deviations for individual mature equivalent (ME) milk, fat, and fat percent. These herd-year means and within standard deviations were used to stratify records into five classes. Regressions for individual daughter's modified contemporary deviation (MCD) on sire's predicted difference (PD) were calculated for each class. The within herd-year standard deviations were also used in some of the six different MCD calculations used to compute six different cow indexes (CI) for each cow and trait. The six MCDs calculated were either the current deviation, log adjusted deviation, or the deviation standardized to a constant variance in combination with either the current correction for contemporaries merit or an adjusted correction. The six different CI for each trait were compared by how accurately they predicted the son's $\overline{MCD}$ trait and the daughter's $\overline{MCD}$ trait.

The analysis of herd-year variables indicated heterogeneity of within herd-year standard deviations for milk, fat, and fat percent. Nine-fold and fourteen-fold differences in within herd-year standard deviations for Holsteins and Jerseys, respectively, for milk yield were found. Ten-fold and twelve-fold differences in within herd-year standard deviations for Holsteins and Jerseys, respectively, for fat yield were observed. Sixteen-

fold and eleven-fold differences in within herd-year standard deviations for Holsteins and Jerseys, respectively, for fat percent were found. The within herd-year standard deviations for milk and fat were moderately correlated (.4) with the herd-year mean though for fat percent the correlation (.1) was much smaller.

Regressions of daughter's MCD on sire's PD indicated that coefficients had larger ranges when stratification was by within herd-year standard deviations (.66-1.54) rather than herd-year means (.74-1.30) for all traits. This was especially evident for fat percent. "Direct" fat percent calculations of MCDs were more strongly correlated (Holsteins=.336 and Jerseys=.279) with sire's PD than the current "indirect" fat percent (Holsteins=.306 and Jerseys=.271) calculation methods.

The σ adjusted genetic merit of modified contemporaries (AGMC) MCD calculation which standardized the variance of the deviation portion of the MCD and adjusted the genetic merit of contemporaries according to the proportion of genetic differences expressed in a herd with this within herd-year standard deviation was the best MCD calculation for predicting daughter's milk and fat $\overline{MCD}$ in both breeds. This was also the best for predicting son's $\overline{MCD}$ for milk in Holsteins. However when the son-dam pairs were grouped according to the dam's CI and the sire's PD, group size and numbers of groups had a large impact on R^2 values for predicting son's $\overline{MCD}$ and the rankings of the adjustments in the son-dam pair groups. It was also found that it was important to form son-dam or daughter-dam groups using both the sire's PD and dam's CI in order to get reasonable regression coefficients for the sire's PD and the dam's CI.

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Introduction

Estimated Transmitting Abilitites (ETA) for dairy cattle are called "Predicted Differences" (PD) and "Cow Indexes" (CI) for sires and cows, respectively. They are calculated using the United States Department of Agriculture's (USDA) Modified Contemporary Comparison (MCC) which was implemented in 1974. The calculation of these ETAs assume that the within herd variance is constant for all herds. Recent research (4,8,11,14,25) has clearly demonstrated that this assumption does not hold for ETAs of milk yield. Researchers (8,11,25) have found that in genetically similar herds, selection of elite cows will favor the more variable herd. Also, studies (3,17,25) have examined the effect herd mean production level for milk and fat yield had on the relationship between sire's predicted difference (PD) and daughter's modified contemporary deviation (MCD) and found that as herd production levels increased the response to PD increased. Since the mean and the within herd variance has been found to be positively correlated (8,13), the herd mean production has been used to measure the effect of within herd variance in most of these studies. However, the association between the mean and within herd variance was far from one and looking at the direct effect of within herd variance would give a better indication on how much effect within herd variance is having on MCC genetic evaluations.

Researchers (4,15,26) have attempted log adjustments, standardization to a constant variance, and varying the heritability used from herd to herd in order to correct CI for the heterogeneous within herd variances. Results of these studies have not found a clearly effective adjustment to be used in the MCC genetic evaluations.

The objectives of this study was to quantitate the effect of within herd variance for fat percent, fat, and milk on the relationships between daughter's MCD and sire's PD for fat percent, fat, and milk, and to compare the accuracy of CI calculated from fat percent, fat and milk records adjusted for within herd variation.

Review of Literature

Estimated Transmitting Abilitites (ETA) for dairy cattle are called "Predicted Differences" (PD) and "Cow Indexes" (CI) for sires and cows, respectively. They are calculated using the United States Department of Agriculture's (USDA) Modified Contemporary Comparison (MCC) which was implemented in 1974. The utilization of these genetic estimates has caused genetic progress to increase substantially. Powell et al. (27) reported that progress for milk yield was nil to small during the 1960's, increased by approximately 39 kg per year from 1972 to 1977, and further increased to 74 kg per year from 1978 to 1983. This improvement from 1978 to 1983 represented 1.2% of the 1977 mean milk yield (27). However, this is still far below the theoretical improvement of 2% of the mean per year (28). Further increases in the accuracy of ETAs could narrow the difference between theoretical and actual genetic improvement.

Modified Contemporary Comparison Predicted Difference

Sire Predicted Difference (PD) is the most important tool used in making genetic progress in dairy cattle. Sire PDs are used in making decisions on 1) which bulls will become sires of future sires, and 2) which sires will become sires of future dams. These two genetic pathways account for over 60% of all genetic improvement made in dairy cattle (34). Therefore, it is vital that sire PDs reflect their true biological transmitting abilities.

The Modified Contemporary Comparison (MCC) PD equation for milk and fat yield is:

$$PD82 = Rpt(\overline{MCD}) + (1 - Rpt)AM \quad (7).$$

PD82 signifies the year of the genetic base used. The genetic base was set so the average genetic merit of sires of two-year-old cows calving for the first time in 1982 was zero (36). The advantage of a constant genetic base is that PDs of sires born in 1980 can be compared to PDs of sires born in 1960. If genetic improvement has been attained, then the values of the PDs will encourage the use of the younger sires.

Rpt is the repeatability or accuracy of the sire's production proof. The value of Rpt ranges from zero to one and is mostly influenced by the number of daughters, herds, and contemporaries included in the proof.

$\overline{MCD}$, the average modified contemporary deviation, is the information on the performance of a sire's daughters. It is calculated as the average difference in 305 day mature equivalent production between daughters of a bull and their modified contemporaries with an adjustment for the average genetic value of the modified contemporaries. Modified contemporaries are herdmates with a different sire that calved during the same herd-year-season.

Ancestor Merit (AM) is the portion of the PD that includes the pedigree information about the sire. Pedigree information is used to improve the accuracy and to help stabilize early, low repeatability proofs (36). Pedigree Indexes (PI) where,

$$\text{PI} = .5\,(\,PD_{sire}\,) + .25(\,PD_{mgs}\,)$$

are computed for each sire and a GA is calculated as a function of the PI. The estimate of the pedigree information is influenced by sire's birthdate and sampling program.

PDs for fat percent are calculated differently than those for milk and fat yield since MCDs are not calculated for fat percent. The PD for fat percent is calculated where,

$$\text{PD Fat Percent} = \left[\left(\frac{\text{PD Fat} + \text{BGB Fat}}{\text{PD Milk} + \text{BGB Milk}}\right) - \frac{\text{BGB Fat}}{\text{BGB Milk}}\right] \times 100 \quad (20).$$

BGB is the Breed's Genetic Base for fat and milk yield in 1982. The use of a bull's PD for milk and fat yield to obtain a PD for fat percent may not be an ideal procedure, but it used due to the added cost that would occur from calculating PDs similar to milk and fat yield.

Modified Contemporary Comparison Cow Index

Cow Indexes (CI), are used by the artificial insemination (AI) industry to identify the elite cows as potential future mothers of AI sires. This is the second most important genetic pathway and accounts for nearly one-third of all genetic improvement made in dairy cattle (34). Thus, it is critical that cows with the highest CI are genetically elite in order to maximize genetic progress.

The MCC CI for milk and fat yield implemented in 1974 resulted from the combination of the individual cow's production with the information on her sire's estimated transmitting ability using selection index weights:

$$CI = .5[w(\text{Cow's } \overline{MCD}) + (1 - w)(PD_{sire})] \quad (7).$$

Information about the cow's production is expressed as the average Modified Contemporary Deviation ($\overline{MCD}$). Prior to the calculation of each lactation's MCD, the individual cow's and her modified contemporaries' records are expressed as 305 day, 2X, mature equivalent records. This removes the fixed effects of length of lactation, times milked, region, age, and season calved (18). Each lactation's MCD can be expressed as:

$$MCD = LR - MCA + GMC \quad (7).$$

The MCD for each lactation is calculated as the difference between the cow's lactation record (LR) and the average lactation record of her modified contemporaries (MCA) adjusted by the average genetic merit of of her modified contemporaries (GMC). The GMC was the average $\overline{MCD}$ of sires' of modified contemporaries until January 1983 when the average PD of sires' of modified contemporaries replaced it (24).

Lactation weights (LACTWT) are calculated for each lactation and range in value from zero to two. The value of each LACTWT depends upon the amount of information included in each lactation's MCD. This information includes the length of the lactation, number of modified contemporaries, the number of sires of modified contemporaries, and the repeatability of the PDs of sires of modified contemporaries (7).

The $\overline{MCD}$ of a cow is computed by taking a weighted average of all her MCDs from each lactation. This is accomplished by summing the product of the LACTWT and MCD for each lactation and dividing by the sum of the LACTWT:

$$\overline{MCD} = \frac{\sum^{n}(LACTWT \times MCD)_i}{\sum^{n} LACTWT_i}$$

The selection index weight (w) is a function of the heritability of the trait, the accuracy of the genetic evaluations of her relatives, and the sum of her LACTWT. The resulting value of w theoretically maximizes the correlation between the cow's additive genotype and the index (7).

The pedigree information of the CI was expressed as the PD of the cow's sire until January 1981 when the CI of her dam was also included resulting in

$$CI = .5[w(\text{Cow's } \overline{MCD}) + (1 - w)(PD_{SIRE} + CI_{DAM})] \quad (22).$$

By including the dam's CI, data on the dam and maternal grandsire (MGS) were incorporated that increased the accuracy of CIs about the equivalent of the addition of two records on the cow.

However, if the cow's dam does not have a CI, one-half the MGS PD was used instead:

$$CI = .5[w(\text{Cow's } \overline{MCD}) + (1 - w)(PD_{SIRE} + PD_{MGS})].$$

Powell (23) in January 1984 stated that since the genetic merit of dams of modified contemporaries was ignored in the past, the CI base was unequal to the PD base. So to correct for this error, an adjustment, ADC_y , was implemented. ADC_y reflected the change in the genetic base from 1972 to 1982 and also corrected for the genetic merit of dams of modified contemporaries by using the average CI by year of calving and applying this to the birth year of the cow. By having the CI and PD relative to the same base, the prediction of the genetic merit of offspring would be more accurate.

With ADC_y implemented the CI for cows with dams having CI is

$$CI = .5[w(\text{Cow's } \overline{MCD} + ADC_y) + (1 - w)(PD_{SIRE} + CI_{DAM})] \quad (23)$$

or for cows without dams having CI is

$$CI = .5[w(\text{Cow's } \overline{MCD} + ADC_y) + (1 - w)(PD_{SIRE} + ADC_{y-5})] \quad (23)$$

ADC_{y-5} is an estimate of the genetic merit of dams of modified contemporaries five years prior to the birth of the cow.

Cow Indexes for fat percent are calculated using the same procedure utilized for PD fat percent:

$$\text{CI Fat Percent} = \left[\left(\frac{CIFat + BGBFat}{CIMilk + BGBMilk}\right) - \frac{BGBFat}{BGBMilk}\right] \times 100 \quad (24).$$

This indirect method assumes that the heritability of fat percent is the same as that of milk and fat yield. However, researchers have shown that the heritability of fat percent is larger than that of milk and fat yield (10,19). To calculate a CI for fat percent using the same procedure as milk and fat yield would require repeatabilities for sire PDs for fat percent (with the PD fat percent calculated like those for PD milk and fat), revised laction weights for fat percent, and the heritability of fat percent in order to calculate the proper selection index weights.

Within Herd Variance

The selection index weights used in calculating the CI for milk and fat yield are theoretically optimum for maximizing the relationship between a cow's genotype and her CI. However, these weights are calculated on the assumption that the within herd variance is constant for all herds. Recent research has clearly demonstrated that this assumption does not hold. Everett et al. (8) found within herd variances in 7,398 Holstein herds ranged from 250,000 kg to 3,240,000 kg of milk yield. Hill et al. (10) reported threefold differences in within herd standard deviations for milk yield in dairy cattle. Lofgren et al. (14) grouped Jersey and Holstein herd-years by within herd standard deviations for modified contemporary average milk production. Group within herd standard deviations ranged from 405 kg to 935 kg and 290 kg to 675 kg for Holsteins and Jerseys, respectively.

The heterogeneous within herd variances for all herds causes us to deal with the question: How will these heterogeneous within herd variances affect the selection of cows based on CI? Hill et al. (11) found that by using the same intensity of selection among members of two groups of equal size with the same mean but different variances will cause three-quarters of the selected animals to be taken from the more variable group. The representation depends on the magnitude of the difference in the variances and as the intensity of selection is increased the larger variance group will be even more favored. Powell et al. (26) reported that in herds with equal sire merit, higher producing herds had substantially more elite cows due to a larger standard deviation of modified contemporaries average milk yield in herds with high milk production. Everett et al. (8) discovered that in herds with equal genetic merit, ten percent of the cows qualified for elite status in 3,240,000 kg variance herds and no cows qualified for elite in 250,000 kg variance herds. It appears that large within herd variation will cause more cows to reach elite status and be selected as future AI bull mothers than in herds with small within herd variation.

Since within herd variation can have an effect on CI this creates a further problem. The dam's CI is used in calculating her daughter's CI. If the dam's CI is biased by within herd variance then the bias can be passed onto her daughter's CI. Since most dams and daughters are in the same herd, within herd variation can have a cumulative effect on CIs over several generations. The cumulative effect appears to be a real threat since Brotherstone and Hill (4) found that within herd variation for the same herd was consistent over years.

The impact of within herd variance is minimized in PD due to the variety of herds included. Daughters in low variance herds can offset daughters in high variance herds as long as sires are represented in both high and low variance herds. Within herd variance could affect initial PDs from progeny tests more than later proofs. A smaller number of herds are represented and the chance of a normal distribution of high and low variance herds is reduced.

Within herd variation can affect the differences between daughters of two bulls observed in a farmer's herd. McDaniel and Corley (17) showed that as herd milk production levels increased from low to high, variation between the proofs of forty highly proven sires increased markedly. For two bulls whose overall milk proofs differed by 1000 kg the difference in low mean herds averaged 850 kg, in the high mean herds the difference averaged 1150 kg. Powell and Norman (25) examined both milk and fat yield at ten different herd production levels and found similar results. Regressions of first lactation milk yield on sire's PD ranged from .75 to 1.49 and .71 and 1.49 from low to high mean herds for milk and fat yield, respectively. The within herd standard deviations increased from 999 kg to 1516 kg from low to high herd milk production levels. It would appear that the response to sire selection will be the greatest in the high producing herds.

Most studies have used the mean level of production to represent differences in the within herd variation. Since the mean and variance are correlated, this indirect measure of the variance may be useful. However, Everett et al. (8) found the correlation between within herd standard deviation and mature equivalent herd average for milk yield to be only .24. Similarly, Legates (13) found the correlation between within herd variance and herd average fat yield to be .46. Hill et al. (10) showed that in a study of British Fresian herds only two-thirds of the herds were classified as high-high or low-low for mean and variance. This moderate relationship between the mean and variance suggests that the direct effect of within herd variation should be examined in order to observe how genetic transmitting abilities are affected.

Causes of Differences Among Herds for Means and Variances

Herds of different production levels have been shown to respond differently to sire selection and to yield different frequencies of elite dams. The question remains: What causes these inequalities across herds?

Aisbett (1) suggested that the heterogeneous variances are an artifact of editing, selection, and culling rather than evidence that herd yield has a multiplicative effect. However, most researchers have pointed toward genetic or evnvironmental causes.

Genetic Causes Genetics could partially account for variation among herds. The Modified Contemporary Comparison (MCC) attempts to correct for genetic differences between herds by adjusting for the genetic level of modified contemporaries. However, for second and later lactation contemporaries the genetic adjustment, the PD of their sires, will be a conservative estimate of genetic level if selection has been successful.

Selection could cause further differences among herds since most herds have their own criteria for culling cows. Common selection pressure within the herd could cause cows to be more alike. Sires used within the herd are selected based on the herd's longterm goals. Each herd may have different goals which could develop the genetic uniformity in the herd (31).

Genetic differences among herds could be attributable to genetic relationships within herds. Cows frequently have maternal half sibs, daughters, and other more distantly related cows producing in the same herd-year (32). The MCC only excludes paternal half sibs as modified contemporaries so these other relationships can be included as modified contemporaries.

Many researchers have tried to calculate the proportion of the herd's mean or variance that is genetic. Schaeffer et al. (30) found that herd genetic differences accounted for only 2.05 % of the herd variance for milk yield and 12.7% for fat percentage. Robertson et al. (29) stated that in data from England and Wales 20% of the differences in production between herds was genetic in origin though this may be due to the gradual change from Dairy Shorthorn to Fresian and Ayrshire. Spike and Freeman (32) later found 10% of the differences among herd-year-seasons was genetic. Other researchers (9,21) have found similar results.

Another possible cause of heterogeneous variances is a type of genotype-environmental interaction where genetic variability is different from one environmental level to another. The ranking of sires is not affected. This is commonly referred to as differing heritability (h^2) estimates across herd mean or variance levels. A genetic model for this type of interaction uses the usual additive gene effect model with a multiplier effect caused by the environment (33).

Much work has been devoted to this topic. Early studies (16,29,35) found differing results on the relationship between h^2 estimates and production levels. In one study, Legates (13) computed h^2 estimates across herd levels for fat yield and found no significant relationship between the h^2 values and the production levels.

In more recent studies, h^2 have tended to increase as the herd mean or variance increased. VanVleck (33) reported h^2 increased from .19 to .28 and .20 to .25 for milk and fat yield respectively, from low to high herd-mate levels. Lofgren et al. (14) grouped herds by their within herd standard deviation for MCA milk yield an found h^2 increased from low to high of .178 to .206 and .254 to .371 for Holsteins and Jerseys, respectively. Hill et al. (10) grouped Fresian-Holstein herds by within herd variance and discovered h^2 estimates increased, (24.4 to 30.2), (23.6 to 28.5), and (41.3 to 45.6) for milk yield, fat yield, and fat percent, respectively, from low to high variance herds. Powell and Norman (25) reported h^2 across herd milk averages increased for milk (.11 to .23) and fat (.12 to .21) yield with increased herd production.

Environmental Causes Though some of the differences between the within herd variances could be genetic, it appears that most of the differences are environmental. In Everett's et al. study (8) genetic merit of the herds were equivalent but ten percent of the cows qualified for elite status in high variance herds while no cows qualified for elite status in low variance herds. The low variance herds had been on official DHIA test for a long period of time and had used AI sires heavily. This appears contradictory since herds that use AI heavily should be better genetically and have an equal opportunity of qualifying cows as elite. Powell et al. (26) noted similar results when considering cow evaluations at different herd yields for milk. In herds with equivalent merit of sires, the herds with the highest milk production averages had 5.4% of their cows designated elite while the herds with the lowest milk production averages had only .2% designated elite.

The MCC assumes that a cow and her modified contemporaries are treated the same. However, many dairymen feed concentrates according to production. Preferential treatment like this could potentially affect within herd variances with or without it being the dairyman's intent.

Adjustments to Correct for Within Herd Variances

The correct adjustment for normalizing records for heterogeneous within herd variances depends upon the cause of the differing variances. Lofgren et al. (15) tried several different adjustments to CI to correct for the effects of herd mean and variance for milk yield. Environmental adjustments included standardization of records to a common within herd variance (σ) and log transformations of records (LOG). These environmental adjustments assumed all differences between herds are environmental and if genetic differences are present they will be ignored. The σ adjustment was made to the portion of the MCD in the CI called the actual deviation (DEV) of cow's record from MCA as

$$\text{"}\sigma \text{ DEV"} = \left[\sigma \times \frac{(DEV - \mu_{HY})}{\sigma_{HY}}\right] + \mu_{HY}$$

where: μ_{HY} = herd-year mean for DEV

σ_{HY} = within herd-year standard deviation for DEV

σ = overall within herd-year standard deviation for DEV.

The adjusted deviation (σ DEV) was then added to the average PD of modified contemporary sires to yield the new MCD.

Lofgren's et al. (15) log transformations were analogous to the log transformations utilized in the Northeast Artificial Insemination Sire Comparison (NEAISC) procedure. Again only the DEV portion of the MCD was altered. The log DEV, a multiplicative adjustment, was equivalent to:

$$\text{"LOG DEV"} = \left[AVG \times \frac{Record}{MCA} \right] - AVG$$

where AVG is equivalent to the NEAISC average production of two year olds freshening in 1982. This value was computed so the variance of the LOG DEV equalled the variance of the unadjusted DEV. Average PD of modified contemporary sires was added to yield the LOG MCD.

The problem with log transformations as pointed out by Lofgren et al. (15) and Brotherstone and Hill (4) is that the adjustment assumes a perfect correlation of 1.00 between the herd mean and within herd variance. As pointed out earlier, this is far from true.

Material and Methods

Source of Data

Lactation records of Jersey and Holstein cows born after January 1, 1964 were obtained from the Animal Improvement Programs Laboratory (AIPL), United States Department of Agriculture (USDA). The 1,162,578 Jersey records were from 34,000 herd-years on official Dairy Herd Improvement Association (DHIA) test. The 1,612,453 Holstein records were from 48,235 herd-years on offical test with herd codes ending with the number "4". This was approximately a ten percent random sample of all Holstein herds on official DHIA test.

Individual lactation records of each cow included her registration or ear tag number; sire's and dam's identification number; herd code; year, month, and date of birth; year, month, and date of calving; code indication of usability of record for genetic evaluations; lactation number; length of lactation; mature equivalent (ME) milk and fat yield; modified contemporaries' average (MCA) ME milk and fat yield; average PD of modified contemporaries' sires; number of modified contempory sires; average repeatabilty of modified contemporary sires' PD; number of modified contemporaries; and weighting for lactation length of modified contemporaries.

The male data set, the January 1986 USDA sire summary run, was also obtained from AIPL.

Record Edits

Records were removed if the individual's ME milk or fat yield was less than or equal to zero, MCA ME milk or fat yield was less than or equal to zero, sire identification was missing, sire had no USDA PD, record was unusable for genetic evaluations, or if the herd-year size was less than ten cows passing the previous edits. Due to few herd-years occurring before 1967 and after 1982 the data set was restricted to herd-years occurring after January 1, 1967 and berfore January 1, 1983. Table 1 shows the number of herd-years and records present before and after edits.

Calculation of Herd-year Means and Within Herd-year Standard Deviations

Individual lactation records and the USDA sire summary information were merged by sire. Mean and within herd-year standard deviations were calculated for individual ME milk, fat, and fat percent; and individual ME milk, fat, and fat percent minus her sire's PD for the respective trait. Only Holstein and Jersey herd-years containing at least ten cows with usable records were included to assure reasonable herd-year standard deviations. The "individual ME trait minus her sire's PD for the trait" (ADJ trait) was an attempt to remove genetic differences between herds. For later use in the study the

Table 1. Holstein and Jersey records and herd-years before and after edits.

	Holstein		Jersey	
	Herd Years	Records	Herd Years	Records
Original	48,235	1,612,453	34,000	1,162,578
After Edits	33,585	1,490,909	20,380	1,032,438

overall mean and standard deviation of herd-year means and within herd standard deviations as well as yearly means and standard deviations of herd-year means and within herd-year standard deviations were computed for all six traits. Correlations between herd-year means and within herd-year standard deviations for all traits were calculated.

Determination of the Relationship between Sire PD and Daughter MCD in Herd-years with Different Characteristics

Stratification of Herd-years: For both breeds individual ME milk records were stratified into five equal frequency classes each year based on their unadjusted herd-year's mean for milk. This process was repeated stratifying records using herd-year means for fat and fat percent, and using the within herd-year standard deviations for milk, fat, and fat percent.

Stratification was completed for all two year olds, all three year olds, two year olds by sires having at least 500 two year old daughters in the edited data set, and three year olds by sires having at least 500 three year old daughters in the edited data set. The truncation points which were adjusted each year were different for each subset so that approximately equal class size was maintained. Number of records in each stratified subset are in Tables 2-13. Class '1' was the lowest mean or within standard deviation herd-years while class '5' was the largest mean or within standard deviation herd-years.

Impact of Herd Means and Standard Deviations on Daughter MCDs: Simple regressions of individual daughter's modified contemporary deviation for milk, fat, "direct" fat percent, and "indirect" fat percent on her sire's PD for milk, fat, and fat percent, respectively, were calculated for each stratified group within each subclass. "Indirect" fat

Table 2. Number of Holstein records in each of 5 groups where individual records were stratified by herd-year means for milk yield.

Group	All 2 yr	All 3 yr	Selected[1] 2 yr	Selected[1] 3 yr
1	110,979	74,387	42,703	21,332
2	86,465	58,991	32,973	16,331
3	102,791	70,285	42,709	22,251
4	106,811	72,322	49,396	21,293
5	134,265	88,955	41,762	25,722
Total	541,311	364,940	209,543	106,929

[1] Sires having at least five hundred daughters in the subset.

Table 3. Number of Holstein records in each of 5 groups where individual records were stratified by herd-year means for fat yield.

Group	All 2 yr	All 3 yr	Selected[1] 2 yr	Selected[1] 3 yr
1	97,134	64,819	44,326	18,721
2	93,371	62,765	31,876	18,446
3	98,829	67,137	48,566	25,606
4	113,229	77,257	36,974	16,893
5	138,748	92,962	47,801	27,263
Total	541,311	364,940	209,543	106,929

[1] Sires having at least five hundred daughters in the subset.

Table 4. Number of Holstein records in each of 5 groups where individual records were stratified by herd-year means for fat percent.

Group	All 2 yr	All 3 yr	Selected[1] 2 yr	Selected[1] 3 yr
1	113,473	74,341	43,711	21,467
2	110,732	73,257	43,381	21,580
3	117,898	80,402	46,181	23,769
4	109,793	74,551	42,697	21,934
5	89,415	62,389	33,573	18,179
Total	541,311	364,940	209,543	106,929

[1] Sires having at least five hundred daughters in the subset.

Table 5. Number of Jersey records in each of 5 groups where individual records were stratified by herd-year means for milk yield.

Group	All 2 yr	All 3 yr	Selected[1] 2 yr	Selected[1] 3 yr
1	75,038	48,391	40,210	22,869
2	62,123	41,566	32,109	19,255
3	66,282	45,443	38,360	22,919
4	67,616	45,738	40,793	24,515
5	80,031	53,210	31,863	18,650
Total	351,090	234,348	183,335	108,208

[1] Sires having at least five hundred daughters in the subset.

Table 6. Number of Jersey records in each of 5 groups where individual records were stratified by herd-year means for fat yield.

Group	All 2 yr	All 3 yr	Selected[1] 2 yr	Selected[1] 3 yr
1	63,780	40,774	42,690	24,506
2	67,343	44,835	31,234	18,550
3	64,434	43,231	40,515	23,900
4	66,996	46,253	28,492	17,202
5	88,537	59,255	40,404	24,050
Total	351,090	234,348	183,335	108,208

[1] Sires having at least five hundred daughters in the subset.

Table 7. Number of Jersey records in each of 5 groups where individual records were stratified by herd-year means for fat percent.

Group	All 2 yr	All 3 yr	Selected[1] 2 yr	Selected[1] 3 yr
1	65,794	42,732	37,913	22,152
2	70,677	46,779	38,285	22,544
3	74,807	51,074	38,874	23,735
4	74,741	49,151	38,395	22,221
5	65,070	44,611	29,867	17,555
Total	351,089	234,347	183,334	108,207

[1] Sires having at least five hundred daughters in the subset.

Table 8. Number of Holstein records in each of 5 groups where individual records were stratified by within herd-year standard deviations for milk yield.

Group	All 2 yr	All 3 yr	Selected[1] 2 yr	Selected[1] 3 yr
1	116,023	76,210	43,947	21,737
2	98,207	66,552	38,365	19,959
3	100,959	69,657	40,072	20,653
4	103,525	70,217	40,665	20,956
5	122,597	82,304	46,494	23,624
Total	541,311	364,940	209,543	106,929

[1] Sires having at least five hundred daughters in the subset.

Table 9. Number of Holstein records in each of 5 groups where individual records were stratified by within herd-year standard deviations for fat yield.

Group	All 2 yr	All 3 yr	Selected[1] 2 yr	Selected[1] 3 yr
1	126,315	79,838	47,297	22,452
2	97,386	67,363	38,430	19,894
3	115,851	78,594	45,692	23,900
4	95,969	65,496	36,658	19,045
5	105,790	73,649	41,466	21,638
Total	541,311	364,940	209,543	106,929

[1] Sires having at least five hundred daughters in the subset.

Table 10. Number of Holstein records in each of 5 groups where individual records were stratified by within herd-year standard deviations for fat percent.

Group	All 2 yr	All 3 yr	Selected[1] 2 yr	Selected[1] 3 yr
1	123,154	81,253	46,591	23,159
2	106,565	71,551	41,506	21,188
3	108,339	74,117	42,476	22,221
4	99,246	68,200	39,571	20,742
5	104,007	69,819	39,399	19,619
Total	541,311	364,940	209,543	106,929

[1] Sires having at least five hundred daughters in the subset.

Table 11. Number of Jersey records in each of 5 groups where individual records were stratified by within herd-year standard deviations for milk yield.

Group	All 2 yr	All 3 yr	Selected[1] 2 yr	Selected[1] 3 yr
1	69,368	46,134	36,883	21,170
2	57,948	43,560	30,190	20,183
3	78,927	48,147	40,797	22,033
4	65,723	44,679	33,923	20,554
5	79,124	51,828	41,542	24,268
Total	351,090	234,348	183,335	108,208

[1] Sires having at least five hundred daughters in the subset.

Table 12. Number of Jersey records in each of 5 groups where individual records were stratified by within herd-year standard deviations for fat yield.

Group	All 2 yr	All 3 yr	Selected[1] 2 yr	Selected[1] 3 yr
1	78,415	50,814	42,514	24,083
2	65,004	43,963	34,532	20,804
3	72,145	48,663	37,255	22,637
4	63,999	42,799	32,875	19,466
5	71,527	48,109	36,159	21,218
Total	351,090	234,348	183,335	108,208

[1] Sires having at least five hundred daughters in the subset.

Table 13. Number of Jersey records in each of 5 groups where individual records were stratified by within herd-year standard deviations for fat percent.

Group	All 2 yr	All 3 yr	Selected[1] 2 yr	Selected[1] 3 yr
1	78,839	51,398	41,786	24,065
2	65,100	44,437	33,239	20,093
3	75,131	50,794	39,293	23,080
4	71,090	47,471	37,728	22,732
5	60,929	40,247	31,288	18,237
Total	351,089	234,347	183,334	108,207

[1] Sires having at least five hundred daughters in the subset.

percent was the similar to the current USDA method used to calculate fat percent for sire PDs and dam CIs. "Direct" fat percent was an attempt to calculate a MCD for fat percent similar to that of milk and fat yield. Regressions were calculated as the product of the correlations between the daughter's MCD and her sire's PD and the ratio of the standard deviations of daughter's MCD and sire's PD for each stratified group within each subclass.

Single lactation MCDs for milk and fat yield were computed according to AIPL, USDA procedures (22) :

$$\text{MCD} = \text{ME Production} - \text{MCA ME Production} + \text{Modified Contemporaries' Sires'}\overline{PD}.$$

AIPL does not compute a MCD for fat percent. Thus, MCDs for fat percent were calculated in two ways: "direct" and "indirect".

"Direct" fat percent MCD was defined as

$$\text{Direct Fat Percent } \overline{MCD} =$$

$$\text{ME Fat\% -MCA ME Fat\%} + \text{Modified Contemporaries' sires'}\overline{PD}\ \%.$$

where:

$$\text{ME Fat\%} = \left(\frac{\text{Individual ME Fat Yield}}{\text{Individual ME Milk Yield}}\right) * 100$$

$$\text{MCA ME Fat\%} = \left(\frac{\text{MCA ME Fat Yield}}{\text{MCA ME Milk Yield}}\right) * 100$$

$$\begin{array}{c}\text{Modified Contemporaries'} \\ \text{Sires' } \overline{PD}\end{array} =$$

$$\left[\frac{\overline{PD}\text{Fat of Modified Contemporaries' Sires} + \text{BGB Fat}}{\overline{PD}\text{Milk of Modified Contemporaries' Sires} + \text{BGB Milk}} - \frac{\text{BGB Fat}}{\text{BGB Milk}} \right] * 100.$$

BGB was the 1982 genetic base for each breed.

This "direct" deviation came as close to obtaining a MCD like that of milk and fat yield as the data set would allow. In order to obtain a deviation exactly like those for milk and fat yield, the MCA fat percent and the average PD fat percent of modified contemporary sires would have to be recalculated using actual fat percentages of each modified contemporary and each modified contemporary's sire. Both deviations calculated for fat percent would tend to be biased downward slightly.

The "Indirect" fat percent MCD was parallel to the present USDA method of calculating PDs and CIs for fat percent:

$$\text{"Indirect" Fat\% MCD} = \left[\left(\frac{\text{MCD Fat} + \text{BGB Fat}}{\text{MCD Milk} + \text{BGB Milk}} \right) - \frac{\text{BGB Fat}}{\text{BGB Milk}} \right] * 100 \quad (20).$$

The individual's MCD for milk and fat yield replaced the CI or PD for milk and fat yield, respectively. An edit was required for this procedure due to extreme negative outliers for milk MCDs caused the denominator to be extremely small or even negative. A Jersey example in the Appendix illustrates the problem where the direct and indirect MCDs gave totally different estimates. Due to the large difference between the values of the two MCDs, all "indirect" fat percent MCDs greater than six standard deviations from the mean were removed from the data set before analysis.

Prediction of Offspring's Average MCD from Dam's Adjusted Cow Indexes

In an attempt to improve the accuracy of CIs, the removal of the effect of heterogeneous within herd variances was tried through different adjustments to the CI. The accuracy of predicting daughter's $\overline{MCD}$ for the respective trait was used to judge the value of the adjustment. The five adjustments were compared to the accuracy of predicting daughter's $\overline{MCD}$ using the present USDA CI for the trait.

Calculation of Cow Indexes for Milk and Fat Yield: The basic form of the six CI calculated for milk and fat yield were identical except when the cow's dam was not in the data set. For cows with dams in the data set the CI was

$$CI82 = .5[w(\overline{MCD} + ADC_y) + (1 - w)(PD82_{SIRE} + CI82_{DAM})] \quad (23)$$

where

w = the selection index weight,

$\overline{MCD}$ = average Modified Contemporary Deviation of the cow,

ADC_y = adjustment for genetic merit of modified contemporaries' dams,

$PD82_{SIRE}$ = Predicted Difference of cow's sire,

and $CI82_{DAM}$ = Cow Index of cow's dam.

When the dam was lacking the model was

$$CI = .5[w(\overline{MCD} + ADC_y) + (1 - w)(PD82_{SIRE} + ADC_{y-5})] \quad (23)$$

where

ADC_{y-5} = adjustment for genetic merit of modified contemporaries' dams five years prior to the birth of the cow.

The only difference between the two forms was the replacement of the dam's CI with the ADC_{y-5}. The latter CI was required so that all cows in the data set would have a starting point. It was impossible to use the maternal grandsires (MGS) PD when the dam's CI was missing, as the USDA does (23), since the data were such that if the dam's CI was missing so was the MGS identification. Cows that had dams without CI were used in calculating their daughter's CI but they themselves were removed prior to analysis. All ADC_ys used in CI calculations were those computed by Powell (23).

For each record that passed original edits, an MCD for milk and fat yield was calculated and weighted using the appropriate lactation weight as described by Dickinson et al (7). Weighted MCDs were summed over all lactations for each cow and divided by the sum of her lactation weights resulting in an average MCD ($\overline{MCD}$). In the six different CIs analyzed, the method of calculating the individual lactation MCD was the only portion of the CI that varied besides information on the dam.

Six different individual lactation MCDs were calculated for milk and fat. These six different MCD calculations were used to compute six $\overline{MCD}$ which in turn were used in computing six different CI for both milk and fat. The resulting six CI were called "Current", "Log", "σ", "Current AGMC", "Log AGMC", and "σ AGMC".

MCD Calculations used in the Current CI: The present USDA calculation of CI for milk and fat yield was called "Current CI". The MCD for each lactation was calculated as

MCD =

$$\text{ME Production} - \text{MCA ME Production} + \text{Modified Contemporaries' Sires'}\ \overline{PD}.$$

The overall $\overline{MCD}$ was computed as earlier stated and used in the CI formula.

MCD Calculations used in the Log CI: The single lactation MCDs were adjusted using log transformations identical to those performed by Lofgren et al. (14). The deviation portion of the MCD was adjusted by taking natural logs of the cow's ME record, her modified contemporaries' average ME record, and a constant (AVG) which kept the variance of the log deviation equal to the variance of the current deviation portion of the MCD.

$$R = \ln(\text{cow's record}) - \ln(\text{MCA record}) + \ln(\text{AVG}).$$

Taking the antilog of "R" and subtracting AVG yielded a new deviation equivalent to the "cow's record minus her MCA record" deviation portion of the current USDA MCD. The log deviation can also be expressed as:

$$\text{Log Deviation} = \left[\frac{(\text{AVG})(\text{Cow's Record})}{\text{MCA Record}}\right] - \text{AVG}.$$

The average PD of modified contemporaries' sires was added to the log deviation resulting in a log adjusted MCD for each lactation. Each lactation log MCD was weighted using the appropriate lactation weight described in "current" and then summed over all lactations. Dividing by the sum of the lactation weights gave log $\overline{MCD}$. The log $\overline{MCD}$ was utilized in the CI formula resulting in the "Log CI".

MCD Calculations used in the σ CI: This method of correcting for the environmental effect of heterogeneous herd-year variances standardized records to a common within herd-year standard deviation. The "deviation" or the "cow's record minus MCA record" portion of the MCD for each lactation was standardized. The average genetic merit of modified contemporaries was unaltered (as was the case in the log adjustment) so genetic differences between herds were unaffected.

The adjustment:

$$\sigma \text{ Deviation} = \left[\sigma * \frac{(DEV - u_{HY})}{\sigma_{HY}} \right] + u_{HY}$$

where:

DEV = the cow's deviation portion of her MCD (cow's record minus her MCA record).

u_{HY} = herd-year mean for the deviation portion of the MCD

σ_{HY} = within herd-year standard deviation for the cows' record minus her sires' PD

σ = overall within herd-year standard deviation for the cows' record minus her sires' PD,

was analogous to Lofgren et al. (15) standardized deviation except for σ_{HY} and σ.

The σ_{HY} and σ were the standard deviations of herd-year's cows' records minus their sires' PD whereas Lofgren's equivalent variables were the herd-year's standard deviation of cows' deviations. This alteration was conducted so possible genetic differences between herds would not be removed. The within herd-year mean for the deviation was subtracted from the cow's deviation and divided by σ_{HY} to yield a standardized deviation. The σ deviation expressed the deviation as being the number of within herd-year standard deviations above or below the herd-year mean. The adjusted deviation was multiplied by σ and the within herd-year mean for the deviation was added resulting in the

"σ deviation" which is similar in value to the deviation portion of the current USDA MCD. The average PD of modified contemporaries' sires was added to the σ deviation giving a "σ MCD" for each lactation. The σ $\overline{MCD}$ was computed by weighting the individual σ MCDs for each lactation by their appropriate lactation weight, summing these weighted σ MCDs, and dividing by the sum of the lactation weights. The σ $\overline{MCD}$ was used in the CI formula resulting in a 'σ CI'.

Adjustment of the Genetic Merit of Modified Contemporaries: In order to take into account the differences between herd-years in the amount of the sires' PD expressed in their daughters' MCDs, another adjustment to the MCD was used. In the initial phase of this study, regressions of daughter's MCD on sire's PD were computed for five classes of herd-years stratified by within herd-year standard deviations. Using the regression coefficient and average within herd-year standard deviation for each of the five classes, an overall regression equation was formed which would give the appropriate regression coefficient to use according to the magnitude of the within herd-year standard deviation. The equation was

$$\delta_{ij} = \alpha + \beta_1 \times \sigma_{HYi} + e_{ij}$$

where

δ_{ij} = the predicted regression coefficient of daughters' MCDs on sires' PD for the ith stratified class,

α_0 = the intercept,

β_1 = the slope of the ith class regression coefficient on the ith class average within herd-year standard deviation,

e_{ij} = error term.

This prediction equation was used to calculate a predicted regression coefficient for each herd-year using the herd-year's standard deviation. This predicted regression coefficient for each herd-year was multiplied times the genetic merit of modified contemporaries. The adjusted portion of the MCD was:

$$\text{Adjusted Modified Contemporaries' Sires } \overline{PD} = \beta_1 * (\text{Modified Contemporaries' Sires' } \overline{PD}).$$

This adjusted genetic merit of modified contemporaries was combined with the current, log, and σ deviation portion of each lactation's MCD yielding three additional MCDs for each lactation. For each of the MCDs, the $\overline{MCD}$ was computed by weighting the individual lactation MCDs by their appropriate lactation weight, summing these weighted MCDs, and dividing by the sum of lactation weights. The resulting $\overline{MCD}$ were called

1. "current AGMC" $\overline{MCD}$

2. "log AGMC" $\overline{MCD}$

3. "σ AGMC" $\overline{MCD}$

with AGMC representing the adjustment to the genetic merit of modified contemporaries portion of the MCD. These $\overline{MCDs}$ were implemented into the CI formula giving "current AGMC", "log AGMC", and "σ AGMC" CI.

Calculation of Cow Indexes for Fat Percent Originally it was planned to calculate cow indexes for fat percent using the same CI formula as that of milk and fat yield. The calculation of MCDs for fat percent for each lactation was to be computed as in the initial phase of this study. These MCDs would not be equivalent to those of milk and fat yield, but would have been as close as possible given the data available. However, the largest difficulty appeared when using the appropriate lactation weights and selection index weights. Both the lactation weights and selection index weights require sire repeatabilities for the trait under consideration. Presently the only repeatability calculated for USDA sire proofs is that for milk and fat yield. Due to the excessive cost of calculating repeatabilities for fat percent, this method of calculating CI for fat percent was discarded.

Like the cow indexes for milk and fat yield, six CI for fat percent were computed for each cow that passed previous edits. The CI fat percent formula decided on was the current USDA procedure:

$$\text{CI Fat Percent} = \left[\left(\frac{\text{CI Fat}_i + \text{BGB Fat}}{\text{CI Milk}_i + \text{BGB Milk}} \right) - \frac{\text{BGB Fat}}{\text{BGB Milk}} \right] * 100, \quad (24)$$

where

i = 1 to 6, with

1)Current CI

2)Log CI

3)σ CI

4)Current AGMC CI

5)Log AGMC CI

6)σ AGMC CI

BGB = 1982 Breed's Genetic Base.

Calculation of Average MCD for Fat Percent: Since the USDA does not compute a cow's $\overline{MCD}$ for fat percent and it was needed to assess the accuracy of the six cow indexes for fat percent, a method of calculating a $\overline{MCD}$ for each adjusted fat percent CI was assembled. In the initial phase of this study, single lactation MCDs for fat percent were computed. However, weighting these individual lactation MCDs by lactation weights, summing them, and dividing by the sum of the lactation weights to yield a $\overline{MCD}$ was determined to be unfeasible since the correct lactation weights were impossible to obtain without calculating sire repeatabilities for fat percent. The $\overline{MCD}$ constructed used a procedure similar to the USDA CI for fat percent. The model was

$$\overline{MCD}\text{ Fat Percent} = \left[\left(\frac{\overline{\text{MCD}}\text{ Fat}_i + \overline{\text{MCA}}\text{ Fat}}{\overline{\text{MCD}}\text{ Milk}_i + \overline{\text{MCA}}\text{ Milk}}\right) - \frac{\overline{MCA}\text{ Fat}}{\overline{MCA}\text{ Milk}}\right] * 100,$$

where

$\overline{\text{MCD}}$ Fat$_i$ = cow's ith average modified contemporary deviation for fat, where i equals "current", "log", "σ", "current AGMC", "log AGMC", or "σ AGMC",

$\overline{\text{MCD}}$ Milk$_i$ = cow's ith average modified contemporary deviation for milk, where i equals "current", "log", "σ", "current AGMC", "log AGMC", or "σ AGMC",

$\overline{\text{MCA}}$ Milk = weighted average over all lactations of modified contemporaries average milk yield,

$\overline{\text{MCA}}$ Fat = weighted average over all lactations of modified contemporaries average fat yield.

The $\overline{MCA}$ for fat and milk yield was used instead of the breed's genetic base so the $\overline{MCD}$ for fat percent would more closey resemble the $\overline{MCD}$ for milk and fat yield. This can be shown algebraically. The $\overline{MCD}$ for milk and fat yield was equivalent to the weighted averages over lactations of the cow's production, modified contemporaries' average production, and the average genetic merit of the modified contemporaries:

$$\overline{MCD} = \begin{matrix}\text{Cow's} \\ \text{Production}\end{matrix} - \begin{matrix}\text{MCA} \\ \text{Production}\end{matrix} + \begin{matrix}\text{Average PD of Modified} \\ \text{Contemporaries' Sires}\end{matrix}$$

Substituting the right hand side of this equation into the $\overline{MCD}$ fat percent equation using the "current" $\overline{MCD}$ for fat and milk yield gave:

$$\begin{matrix}\overline{MCD} \\ \text{Fat Percent}\end{matrix} = \left[\frac{\begin{matrix}\text{Cow's Fat} \\ \text{Production}\end{matrix} + \begin{matrix}\text{Average PD Fat of Modified} \\ \text{Contemporaries' Sires}\end{matrix}}{\begin{matrix}\text{Cow's Milk} \\ \text{Production}\end{matrix} + \begin{matrix}\text{Average PD Milk of Modified} \\ \text{Contemporaries' Sires}\end{matrix}} - \frac{\begin{matrix}\text{MCA Fat} \\ \text{Production}\end{matrix}}{\begin{matrix}\text{MCA Milk} \\ \text{Production}\end{matrix}} \right] * 100.$$

This held true only for the "current" and "current AGMC" $\overline{MCD}$ for fat percent which used the "current" and "current AGMC" $\overline{MCD}$ for milk and fat yield, respectively. For the "log", "σ", "log AGMC", and "σ AGMC" $\overline{MCD}$ fat percent calculations, the values for $\overline{MCA}$ would not equal the value of the $\overline{MCA}$ for fat and milk yield that replaced the breed's genetic base values for fat and milk.

The same problem existed in calculating an $\overline{MCD}$ for fat percent as existed in calculating single lactation "indirect" MCDs for fat percent. Extreme outliers for milk $\overline{MCD}$ caused the denominator of the $\overline{MCD}$ fat percent formula to be extremely small or even negative. This resulted in extreme outliers for $\overline{MCD}$ fat percent. All $\overline{MCD}$ for fat percent greater than six standard deviations from their mean were removed prior to analysis.

Method of Analysis of the Different Cow Indexes for each Trait

For the six cow indexes calculated for each trait a comparison was made to determine which CI best predicted her offspring's $\overline{MCD}$. "Best" was determined as the model that explained the most variation (largest R^2).

Daughter-Dam Pairs: Daughter's $\overline{MCD}$ for each trait and method of calculation were merged with their dam's corresponding CI for each trait and method of calculation. This data set was then merged with the Predicted Differences of the daughter's sire. For every trait and method of calculation, regressions of the dam's CI on the daughter's $\overline{MCD}$ were computed with the variation due to sires absorbed.

Son-Dam Pairs: The son's unadjusted $\overline{MCD}$ for each trait was merged with their dam's six CI for each trait. This data set was then merged with the Predicted Differences of the son's sire. The son's $\overline{MCD}$ was computed as:

$$\text{Son's } \overline{MCD} = \frac{\text{PD} - [(1 - R)\,\text{GI}]}{R}$$

where

PD = his Predicted Difference for the trait,

R = the repeatability or accuracy of his PD,

GI = the pedigree index or genetic merit of his ancestors for the trait.

It was impossible to make adjustments to this $\overline{MCD}$ like those of the daughter's $\overline{MCD}$ since only a sample of the herds was included in our Holstein data set. For every trait and method of calculating the CI, regressions of the dam's CI on the son's $\overline{MCD}$ were computed with the variation due to sires absorbed.

Grouped Daughter-Dam Pairs: In order to better detect differences between the six cow indexes for each trait, the daughter-dam pairs were assigned into groups based on their sire's PD and dam's CI. For both breeds the group increments were 15 kg for milk, 1 kg for fat, and .01 percentage points for fat percent. Within each group the means of the dams' CI, daughters' $\overline{MCD}$, and sires' PD were computed for the trait which stratified the groups and each of the six CI calculated for each trait. Using these group means for each trait and method of calculation, multiple regression models were run with the group means for the dams' CI and sires' PD being the independent variables and the group means for the daughters' $\overline{MCD}$ being the dependent variable. For each trait the R^2 were compared between the methods of calculating the CI.

Grouped Son-Dam Pairs The son-dam subset earlier analyzed was grouped based on the sire's PD and dam's CI. The group increments for milk were 125 kg and 100 kg for Holsteins and Jerseys, respectively. The group increments for fat were 5 kg and 2.5 kg for Holsteins and Jerseys, respectively. The group increments for fat percent were .05 and .025 percentage points for Holsteins and Jerseys, respectively. Grouping was done in hope of improving the chance of detecting differences between the six CI calculated for each trait. Means of the six dam's CIs, son's $\overline{MCD}$ (calculated as described before), and the sire's PD were computed for each group. These group means were used in multiple regression models calculated for each trait and method of calculation. The independent variables were the group means of the dams' CI and the sires' PD. The dependent variable was the group means of the sons' $\overline{MCD}$. R^2 were compared between the six different CI adjustments for each trait.

Results and Discussion

Herd-Year Characteristics

Overall means and standard deviations of Holstein and Jersey herd-year variables can be found in Tables 14 and 15. The range of these variables is also presented. The mininum value of 10 for herd size was to help prevent sampling from influencing within herd-year standard deviations. Of particular interest are the large ranges for within herd-year standard deviations for milk, fat, and fat percent for both breeds. The presence of heterogeneous within herd-year standard deviations for milk and fat yield agree with the observations of other researchers. Everett et al. (8) found within herd standard deviations for milk yield ranging from 500 kg. to 1800 kg.. Hill et al. (10) reported three-fold differences in within herd standard deviations for milk yield. Brotherstone and Hill (4) showed that within herd standard deviations for fat yield were heterogeneous and by assuming normality that ninety-nine percent of the herds would range from 18.4 kg to 52 kg.

Table 14. Characteristics of the 33,585 Holstein herd-years.

	$\overline{X}$	Range Mininum	Range Maximum
Herd size	41.3	10.0	1449.0
Herd ME[1] milk $\overline{X}$ (kg)	7141.9	3189.8	11533.1
Herd ME fat $\overline{X}$ (kg)	260.0	109.1	466.5
Herd ME fat% $\overline{X}$	3.66	2.57	4.74
Herd ME milk σ (kg)	1189.0	284.9	2696.1
Herd ME fat σ (kg)	43.0	10.4	107.3
Herd ME fat% σ	.35	.05	.84
Adjusted[2] Herd ME milk σ (kg)	1168.4	297.1	2606.9
Adjusted Herd ME fat σ (kg)	42.2	10.4	102.8
Adjusted Herd ME fat% σ	.34	.07	.83

1) Mature Equivalent
2) Calculated with sire′ PD subtracted from the individual's record.

Table 15. Characteristics of the 20,380 Jersey herd-years.

	$\overline{X}$	Range	
		Mininum	Maximum
Herd size	44.8	10.0	643.0
Herd ME[1] Milk $\overline{X}$ (kg)	4604.9	1652.6	7803.9
Herd ME Fat $\overline{X}$ (kg)	226.0	86.1	394.5
Herd ME Fat% $\overline{X}$	4.94	3.60	6.31
Herd ME Milk σ (kg)	831.6	200.6	2913.9
Herd ME Fat σ (kg)	39.1	10.9	130.9
Herd ME Fat% σ	.45	.09	1.03
Adjusted[2] Herd ME Milk σ (kg)	811.3	192.0	2845.6
Adjusted Herd ME Fat σ (kg)	38.3	11.3	130.4
Adjusted Herd ME Fat% σ	.43	.10	.98

1) Mature Equivalent
2) Calculated with sire' PD subtracted from individual's record.

The ranges of the within herd-year standard deviations for milk and fat yield found for both breeds were larger than those cited in the literature. A possible explanation is that more herd-years were analyzed and since they represented a sample of herd-years from throughout the United States, a larger spectrum of environments were included.

The sixteen-fold and eleven-fold differences in within herd-year standard deviations for Holsteins and Jerseys, respectively, for fat percent indicate heterogeneous within herd-year standard deviations similar to those found for milk and fat yield. No comparison of fat percent within herd-year standard deviations can be made due to lack of studies reported in the literature. It appears that the within herd-year standard deviation for milk, fat, and fat percent are not normally distributed. For the two breeds and three traits, a higher percentage of the estimates were more than three standard deviations above the mean than below the mean.

For both breeds, the adjusted within herd-year standard deviations for milk, fat, and fat percent, (her sire's PD was subtracted from each cow's production record), yielded similar overall means, standard deviations, and ranges as the uncorrected within herd-year standard deviations. The slight decrease in the mean and standard deviation with an adjustment is in agreement Brotherstone and Hill (4) who found that correcting for sire decreased the standard deviation from 5.7 kg. to 5.2 kg. for within herd standard deviation for fat yield.

Herd-year correlations for Holsteins and Jerseys are in Tables 16 and 17. The correlations between herd-year means and within herd-year standard deviations for milk and fat yield were moderate in both breeds (.4 to .5). In both breeds, the correlations for milk yield were larger than the .24 reported by Everett et al. (8), but for fat yield the correlation was in agreement with the .46 correlation calculated by Legates (13). Correlations between herd-year means and standard deviations for fat percent were much smaller (<.16). The difference between the correlations of the herd-year mean and within herd-year standard deviation for milk, fat yield, and fat percent is of interest. One possible explanation is that as dairymen increased their management practices to increase herd mean production, the within herd-year standard deviations of the lower heritable traits (milk and fat yield) would increase more than those of the more highly heritable fat percent due to a larger proportion of the total variance being environmental variance. Another possibility can be found from Aisbett's (1) simulation study which postulated that correlations between the herd mean and within herd standard deviation are caused by a function of days in milk, as well as selection on production. Using the interpretation of Aisbett's study it would appear that in our data set dairymen selected cows within herd on milk and fat yield more intensely than for fat percent.

For both Holstein and Jersey data sets the correlations between adjusted within herd-year standard deviations and unadjusted within herd-year standard deviations for each trait were high and indicates that genetic differences between herds contributes only a small amount to the heterogeneity of within herd-year standard deviations.

The correlations of herd size with herd-year mean milk yield for both breeds are in agreement with the correlations of .19 and .28 observed by Powell et al. (26) and Everett et al. (8) , respectively. Correlations of herd size and fat yield variables were very similar to those for milk. Correlations of herd size and fat percent variables were much smaller indicating that herd size has little association with herd-year fat percent variables.

Characteristics of Lactations

Means and standard deviations of characteristics of first, second, selected first, and selected second lactations for Holsteins and Jerseys are in Tables 18 and 19. Selected groups consisted of daughters of sires with at least 500 first or second lactation daugh-

Table 16. Correlations between Holstein herd-year variables.

	Herd ME[1] Milk $\overline{X}$	Herd ME Fat $\overline{X}$	Herd ME Fat% $\overline{X}$	Herd ME Milk σ	Herd ME Fat σ	Herd ME Fat% σ	Adjusted[2] Herd ME Milk σ	Adjusted Herd ME Fat σ	Adjusted Herd ME Fat% σ
Herd Size	.258	.226	-.061	.224	.200	.089	.223	.199	.094
Herd ME Milk $\overline{X}$		.930	-.128	.490	.480	.178	.480	.471	.169
Herd ME Fat $\overline{X}$			.240	.423	.509	.200	.411	.498	.183
Herd ME Fat% $\overline{X}$				-.118	.103	.112	-.124	.098	.093
Herd ME Milk σ					.806	.295	.981	.798	.304
Herd ME Fat σ						.344	.797	.981	.347
Herd ME Fat% σ							.290	.338	.967
Adjusted Herd ME Milk σ								.812	.307
Adjusted Herd ME Fat σ									.347

1) Mature Equivalent
2) Calculated with sire's PD subtracted from individual's record.

Table 17. Correlations between Jersey herd-year variables.

	Herd ME[1] Milk $\overline{X}$	Herd ME Fat $\overline{X}$	Herd ME Fat% $\overline{X}$	Herd ME Milk σ	Herd ME Fat σ	Herd ME Fat% σ	Adjusted[2] Herd ME Milk σ	Adjusted Herd ME Fat σ	Adjusted Herd ME Fat% σ
Herd Size	.272	.252	-.052	.250	.233	.025	.252	.237	.025
Herd ME Milk $\overline{X}$		.935	-.154	.450	.382	-.011	.441	.377	-.038
Herd ME Fat $\overline{X}$			.200	.397	.424	.034	.387	.416	.006
Herd ME Fat% $\overline{X}$				-.107	.123	.155	-.113	.115	.151
Herd ME Milk σ					.843	.156	.973	.827	.156
Herd ME Fat σ						.169	.832	.979	.177
Herd ME Fat% σ							.142	.165	.954
Adjusted Herd ME Milk σ								.849	.157
Adjusted Herd ME Fat σ									.177

1) Mature Equivalent
2) Calculated with sire's PD subtracted from individual's record.

ters in the subset. The differences between first and second lactation for all variables were small. Standard deviations of all variables varied little from first to second lactations. Selected lactation means of MCDs for milk and fat yield were larger than those for the unselected lactations. This was expected since cows in selected subsets had sires with higher PDs. Standard deviations of MCDs for milk yield across all lactation groupings were similar to those found by Cassell et al. (5). Selected lactation means of MCDs for "direct" and "indirect" fat percent were less than those for the unselected lactations. The differences between selected and unselected lactations in "indirect" and "direct" MCDs for fat percent agree with the decrease in the mean of the sires' PD fat percent from unselected to selected lactations.

In both breeds second lactation mean ME milk and fat yields were slightly higher than those for first lacations indicating selection of cows allowed to have second records. Standard deviations of ME milk and fat yields were in close agreement between second and first lactations. The lack of a decrease in standard deviations from first to second lactation is in disagreement with other research and theory. A possible reason is that scaling is offsetting selection thus maintaining the variation. Means and standard deviations of ME fat percent were similar between first and second lactations indicating fat percent had little importance on which cows were allowed to have second lactations.

For Jerseys means of milk and fat yield MCDs decreased from first to second lactations. This was in agreement with Cassell et al. (6) who found MCDs decreased from first lactation to second lactation. The decrease in milk and fat yield MCDs can be accounted for by the means of year born, average predicted difference of contemporary sires, and the predicted difference of the sire. These means indicate that the older second lactation cows are slightly inferior to first lactation cows due to genetic trend.

Holstein means of MCDs for milk and fat yield increased slightly from first to second lactations. Standard deviations also increased from first to second lactations. The

Table 18. Characteristics of first, second, selected first, and selected second Holstein lactations.

	First		Second		Selected[1] first		Selected[1] second	
N[2]	541417		365004		209543		106929	
Trait	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ
ME[3] milk (kg)	7323.6	1600.8	7483.4	1669.3	7528.7	1607.3	7721.5	1684.0
ME fat (kg)	264.9	56.5	270.5	60.1	271.6	57.1	278.4	60.9
ME fat%	3.64	.40	3.64	.42	3.63	.40	3.63	.41
CTP[4] ME milk (kg)	7357.7	1104.7	7451.7	1071.3	7456.5	1096.3	7567.2	1063.3
CTP ME fat (kg)	265.8	39.8	270.0	39.2	269.2	39.7	274.3	39.1
CTP ME fat%	3.62	.22	3.63	.21	3.62	.22	3.63	.21
CS[5] milk (kg)	-251.1	204.1	-302.9	176.8	-221.3	198.6	-279.1	166.7
CS fat (kg)	-6.70	5.87	-6.98	4.70	-5.87	5.85	-6.30	4.58
CS fat%	.01	.02	.02	.02	.01	.02	.02	.02
Year born	73.3	4.5	72.4	4.3	73.7	4.0	72.8	3.8
Year calved	76.1	4.4	76.2	4.3	76.5	4.0	76.7	3.7
MCD[6] milk (kg)	-285.1	1289.3	-271.2	1343.2	-149.1	1303.0	-124.8	1361.0
MCD fat (kg)	-7.62	44.62	-6.47	48.22	-3.55	45.29	-2.23	48.99
DMCD Fat%[7]	.04	.38	.03	.38	.03	.37	.02	.38
'IDMCD Fat%[8]	.02	.16	.02	.17	.01	.16	.02	.17
Herd size	86.0	127.3	89.0	129.8	84.5	123.5	85.7	120.1
Herd ME milk $\bar{X}$ (kg)	7395.6	1023.1	7406.1	1020.8	7509.5	1007.4	7536.1	1007.4
Herd ME fat $\bar{X}$ (kg)	267.8	37.2	268.5	37.1	271.8	37.0	273.2	36.9
Herd ME fat% $\bar{X}$	3.65	.19	3.65	.19	3.64	.19	3.65	.19
Herd ME milk σ (kg)	1247.5	254.5	1253.0	252.6	1256.6	250.2	1262.8	246.9
Herd ME fat σ (kg)	44.7	9.3	45.1	9.2	45.2	9.2	45.5	9.0
Herd ME fat% σ	.36	.08	.36	.08	.36	.08	.36	.07
PD[9] milk (kg)	-246.4	302.9	-273.7	292.0	-125.8	279.0	-144.6	264.7
PD fat (kg)	-7.74	10.34	-8.49	10.10	-3.98	10.24	-4.32	10.06
PD fat%	.02	.10	.02	.10	.01	.10	.01	.10

1) Daughters of sires with at least 500 daughters in the subset
2) Number of lactations
3) Mature Equivalent
4) Contemporaries
5) Average Predicted Difference of contemporaries' sires
6) Modified contemporary deviation
7) Direct modified contemporary deviation calculation for fat%
8) Indirect modified contemporary deviation calculation for fat%
9) Predicted Difference

Table 19. **Characteristics of first, second, selected first, and selected second Jersey lactations.**

	First		Second		Selected[1] first		Selected[1] second	
N[2]	351189		234376		183335		108208	
Trait	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ
ME[3] milk (kg)	4749.7	1159.9	4804.9	1168.3	4879.1	1165.0	4933.3	1175.0
ME fat (kg)	231.8	55.0	235.2	56.1	235.9	55.2	238.8	56.2
ME fat%	4.92	.52	4.93	.54	4.87	.51	4.87	.53
CTP[4] ME milk (kg)	4744.5	810.4	4800.8	772.1	4797.0	807.9	4848.8	771.3
CTP ME fat (kg)	231.7	40.0	235.3	38.6	233.2	39.9	236.5	38.5
CTP ME fat%	4.89	.31	4.91	.30	4.87	.31	4.88	.30
CS[5] milk (kg)	-252.6	196.1	-274.9	168.5	-229.6	190.2	-254.1	162.7
CS fat (kg)	9.27	7.37	-9.68	6.17	-8.47	7.16	-8.98	5.96
CS fat%	.02	.03	.03	.03	.02	.03	.03	.03
Year born	72.9	4.6	72.0	4.4	73.1	4.3	72.3	4.1
Year calved	75.7	4.5	75.9	4.4	76.0	4.2	76.2	4.1
MCD[6] milk (kg)	-247.5	925.8	-270.9	932.9	-147.5	933.3	-169.7	942.8
MCD fat (kg)	-9.22	41.81	-9.81	43.48	-5.79	45.29	-6.65	43.60
DMCD fat%[7]	.05	.47	.05	.48	.02	.46	.02	.47
IDMCD fat%[8]	.03	.19	.03	.20	.02	.19	.02	.20
Herd size	88.4	94.1	91.4	94.1	84.8	89.4	88.3	89.5
Herd ME milk $\bar{X}$ (kg)	4766.7	748.5	4787.3	743.1	4828.7	742.8	4849.3	736.4
Herd ME fat $\bar{X}$ (kg)	233.3	37.3	234.4	37.1	235.2	37.2	236.0	36.8
Herd ME fat% $\bar{X}$	4.93	.28	4.93	.28	4.90	.28	4.90	.27
Herd ME milk σ (kg)	876.4	183.1	878.3	181.2	879.1	183.3	883.1	180.8
Herd ME fat σ (kg)	41.0	8.8	41.2	8.7	40.9	8.8	41.1	8.6
Herd ME fat% σ	.45	.09	.45	.09	.45	.09	.45	.09
PD[9] milk (kg)	-234.1	270.7	-249.0	262.5	-141.8	252.2	-147.3	242.6
PD fat (kg)	-8.43	10.72	-8.94	10.43	-5.34	10.41	-5.76	10.15
PD fat%	.06	.14	.06	.14	.03	.15	.03	.15

1) Daughters of sires with at least 500 daughters in the subset
2) Number of lactations
3) Mature Equivalent
4) Contemporaries
5) Average Predicted Difference of contemporaries' sires
6) MCD
7) Direct MCD calculation for fat%
8) Indirect MCD calculation for fat%
9) Predicted Difference

only slight increase in the milk and fat MCD means and the increase in the standard deviations indicate that the selection of cows allowed to have second lactations was either not practiced or was being offset by scaling. Comparing the differences in mean values of the sires' PD of milk and fat yield between first and second lactations would be an indication of selection on first lactation milk and fat yields. However, there was approximately a year difference in the mean year of birth between first and second lactations. This suggests that genetic trend is a part of the differences between first and second lactations.

Regression Coefficients across Stratified Herd-Years

In Tables 20, 21, 22, 23, 24, 25, 26, and 27 regression coefficients of daughters' MCD trait on sires' PD trait can be found for first, second, selected first, and selected second lactations stratified into quintiles based either on herd-year mean or within herd-year standard deviation of the trait. Regression coefficients were computed from the product of the correlation between the trait's MCD and PD and the ratio of standard deviations of the trait's MCD and PD. Only regression coefficients are presented in the tables though the correlations and ratios will be used in the discussion of the results which will be broken down by trait.

Milk: Correlations between MCDs and PDs are indicators of the accuracy of the relationship. These correlations were consistently higher for Jerseys ($\overline{X}$ = .286) than Holsteins ($\overline{X}$ = .229). Also, correlations for the unselected groups were generally larger than for the selected groups. This last result would have been predicted by genetic theory since the variance of PD and the covariance between PD and the average MCD

Table 20. Holstein milk regression coefficients of daughters' MCD on sire' PD for various subsets and groups of herds stratified on herd ME milk mean or within herd ME milk standard deviation.

Subset	Stratification	Regression Coefficients: Herd Classes[1] 1	2	3	4	5
First lactations	$\overline{X}$	.96	1.04	1.07	1.10	1.15
First lactations	σ	.83	.99	1.06	1.15	1.28
Second lactations	$\overline{X}$	.96	1.10	1.16	1.15	1.26
Second lactations	σ	.87	1.04	1.12	1.21	1.40
Selected[1] first lactations	$\overline{X}$	.85	1.01	1.01	1.07	1.12
Selected first lactations	σ	.74	.95	.98	1.12	1.23
Selected second lactations	$\overline{X}$	.88	1.03	1.10	1.14	1.25
Selected second lactations	σ	.84	1.01	1.07	1.16	1.33

1) Increasing quintiles within year on herd characteristic used in stratification.
2) Daughters of sires with at least 500 daughters in the subset.

Table 21. Jersey milk regression coefficients of daughters' MCD on sire' PD for various subsets and groups of herds stratified on herd ME milk mean or within herd ME milk standard deviation.

Subset	Stratification	Regression Coefficients: Herd Classes[1] 1	2	3	4	5
First lactations	$\overline{X}$	.98	1.03	1.07	1.11	1.18
First lactations	σ	.86	.98	1.04	1.15	1.29
Second lactations	$\overline{X}$	.96	1.03	1.06	1.09	1.16
Second lactations	σ	.84	.98	1.05	1.13	1.27
Selected[1] first lactations	$\overline{X}$	.93	1.00	1.05	1.08	1.13
Selected first lactations	σ	.82	.98	1.00	1.11	1.22
Selected second lactations	$\overline{X}$	.89	.98	1.00	1.06	1.13
Selected second lactations	σ	.80	.96	.98	1.07	1.21

1) Increasing quintiles within year on herd characteristic used in stratification.
2) Daughters of sires with at least 500 daughters in the subset.

Table 22. Holstein fat regression coefficients of daughters' MCD on sire' PD for various subsets and groups of herds stratified on herd ME fat mean or within herd ME fat standard deviation.

Subset	Stratification	Regression Coefficients				
		Herd Classes[1]				
		1	2	3	4	5
First lactations	$\overline{X}$	.86	.95	1.01	1.06	1.12
First lactations	σ	.75	.91	1.01	1.13	1.27
Second lactations	$\overline{X}$	.87	1.01	1.08	1.15	1.18
Second lactations	σ	.78	.97	1.07	1.18	1.37
Selected[2] first lactations	$\overline{X}$	.74	.88	.98	1.04	1.09
Selected first lactations	σ	.68	.86	.93	1.06	1.24
Selected second lactations	$\overline{X}$	.79	.94	1.03	1.13	1.20
Selected second lactations	σ	.73	.92	1.00	1.14	1.35

1) Increasing quintiles within year on herd characteristic used in stratification.
2) Daughters of sires with at least 500 daughters in the subset.

Table 23. Jersey fat regression coefficients of daughters' MCD on sire' PD for various subsets and groups of herds stratified on herd ME fat mean or within herd ME fat standard deviation.

Subset	Stratification	Regression Coefficients				
		Herd Classes[1]				
		1	2	3	4	5
First lactations	$\overline{X}$	.94	1.01	1.09	1.09	1.20
First lactations	σ	.83	.97	1.05	1.17	1.34
Second lactations	$\overline{X}$	.96	.99	1.06	1.09	1.18
Second lactations	σ	.83	.96	1.07	1.15	1.30
Selected[2] first lactations	$\overline{X}$	.88	.96	1.05	1.02	1.14
Selected first lactations	σ	.70	.92	1.01	1.12	1.24
Selected second lactations	$\overline{X}$	.88	.99	1.01	.97	1.12
Selected second lactations	σ	.79	.91	.99	1.11	1.19

1) Increasing quintiles within year on herd characteristic used in stratification.
2) Daughters of sires with at least 500 daughters in the subset.

Table 24. Holstein fat% regression coefficients of daughters' Direct MCD on sire's PD for various subsets and groups of herds stratified on herd ME fat% mean or within herd ME fat% standard deviation.

Subset	Stratification	Regression Coefficients				
		Herd Classes[1]				
		1	2	3	4	5
First lactations	$\bar{X}$	.98	1.05	1.12	1.15	1.20
First lactations	σ	.73	1.00	1.13	1.23	1.39
Second lactations	$\bar{X}$	1.05	1.13	1.16	1.20	1.26
Second lactations	σ	.79	1.04	1.16	1.31	1.50
Selected[2] first lactations	$\bar{X}$	.88	.97	1.03	1.08	1.08
Selected first lactations	σ	.68	.93	1.07	1.13	1.24
Selected second lactations	$\bar{X}$	.94	1.05	1.05	1.11	1.19
Selected second lactations	σ	.71	.95	1.04	1.26	1.36

1) Increasing quintiles within year on herd characteristic used in stratification.
2) Daughters of sires with at least 500 daughters in the subset

Table 25. Jersey fat% regression coefficients of daughters' Direct MCD on sire's PD for various subsets and groups of herds stratified on herd ME fat% mean or within herd ME fat% standard deviation.

Subset	Stratification	Regression Coefficients				
		Herd Classes[1]				
		1	2	3	4	5
First lactations	$\bar{X}$	.98	1.06	1.11	1.16	1.19
First lactations	σ	.74	1.01	1.14	1.21	1.42
Second lactations	$\bar{X}$	.99	1.11	1.19	1.21	1.30
Second lactations	σ	.77	1.06	1.17	1.30	1.54
Selected[2] first lactations	$\bar{X}$	.94	.99	1.03	1.04	1.09
Selected first lactations	σ	.68	.93	1.06	1.11	1.31
Selected second lactations	$\bar{X}$	.93	1.06	1.12	1.12	1.19
Selected second lactations	σ	.75	1.02	1.16	1.24	1.45

1) Increasing quintiles within year on herd characteristic used in stratification.
2) Daughters of sires with at least 500 daughters in the subset

Table 26. **Holstein fat% regression coefficients of daughters' Indirect MCD on sire' PD for various subsets and groups of herds stratified on herd ME fat% mean or within herd ME fat% standard deviation.**

Subset	Stratification	Regression Coefficients				
		Herd Classes[1]				
		1	2	3	4	5
First lactations	$\overline{X}$	1.02	1.04	1.10	1.10	1.11
First lactations	σ	.71	.97	1.10	1.20	1.36
Second lactations	$\overline{X}$	1.11	1.15	1.15	1.18	1.20
Second lactations	σ	.78	1.03	1.15	1.29	1.49
Selected[2] first lactations	$\overline{X}$	.91	.97	1.01	1.05	1.02
Selected first lactations	σ	.66	.89	1.04	1.11	1.23
Selected second lactations	$\overline{X}$	.99	1.08	1.06	1.09	1.15
Selected second lactations	σ	.71	.95	1.04	1.26	1.38

1) Increasing quintiles within year on herd characteristic used in stratification.
2) Daughters of sires with at least 500 daughters in the subset

Table 27. **Jersey fat% regression coefficients of daughters' Indirect MCD on sire' PD for various subsets and groups of herds stratified on herd ME fat% mean or within herd ME fat% standard deviation.**

Subset	Stratification	Regression Coefficients				
		Herd Classes[1]				
		1	2	3	4	5
First lactations	$\overline{X}$	.97	1.02	1.05	1.09	1.09
First lactations	σ	.71	.96	1.07	1.15	1.32
Second lactations	$\overline{X}$	.99	1.09	1.14	1.15	1.20
Second lactations	σ	.75	1.01	1.13	1.26	1.43
Selected[2] first lactations	$\overline{X}$	.93	.96	.97	.98	1.03
Selected first lactations	σ	.66	.89	1.01	1.06	1.24
Selected second lactations	$\overline{X}$	.93	1.04	1.07	1.08	1.12
Selected second lactations	σ	.69	.94	1.04	1.18	1.38

1) Increasing quintiles within year on herd characteristic used in stratification.
2) Daughters of sires with at least 500 daughters in the subset

would be reduced for a selected group of bulls. Differences in correlations over the stratified classes were generally small. However in Holsteins they tended to increase from class 1 to 5 while for Jerseys they tended to decrease.

The ratio of the standard deviations for MCD and PD were indicators of the magnitude of scaling present. The increase from class 1 to class 5 was greater for the stratification by within herd-year standard deviation than by herd-year mean for both breeds. Also the ratios are generally wider apart from class 1 to class 5 for Holsteins than Jerseys.

The increase in regression coefficients from low mean to high mean herds was in agreement with other research. McDaniel and Corley (17) reported that regressions of daughter-herdmate difference on PD were smaller than 1.00 for low milk yield herds and larger than 1.00 for high milk yield herds. Bonaiti and Bertaudiere (3) found that in French data, regressions of yield on transmitting ability of sire for milk was .90 for low milk mean herds and 1.14 for high milk mean herds. However, Powell and Norman (25) found larger ranges of regressions of first lactation milk yield on PD from low to high mean herds. Their regressions ranged from .75 to 1.49 and 1.14 to 1.91 from the lowest to the highest herd milk mean for Holsteins and Jerseys, respectively. These values were more variable from the lowest to highest herd mean milk yield than our results.

Fat: Correlations between MCDs and PD for fat tended to be slightly smaller than those of milk for both breeds. As with milk, correlations were larger for Jerseys than Holsteins (.253 vs .218). "Selected" lactation correlations were smaller than correlations for unselected lactations in both breeds. Differences between correlations across stratified classes were small, however, in Holsteins correlations tended to increase from class 1 to class 5 while in Jerseys they remained relatively constant across classes.

The ratio of the standard deviation for MCD and PD fat yield increased from class 1 to class 5 for both methods of stratification. However, differences in the ratios across classes were larger when stratification was on within herd-year standard deviations. Ratios were larger for Holsteins than Jerseys. As compared to the ratios for milk yield in Holsteins, fat ratios for unselected lactations were similar while selected lactations fat ratios decreased across classes. In Jerseys, ratios for fat were larger than the ratios observed for milk.

Regression coefficients of daughter's MCD on sire's PD for fat yield increased from class 1 to class 5 for stratification by herd-year fat mean as well as for stratification by within herd-year standard deviation. However, stratification by within herd-year standard deviation resulted in larger differences in regression coefficients from class 1 to class 5 for both breeds.

The increase in regression coefficients across stratified herd-year fat means was in agreement with the results observed by Powell and Norman (25) though their regression coefficients had a larger range (.71 to 1.49) from low to high fat mean herds. A possible explanation for this larger range was that their study stratified into ten groups while our study stratified into only five groups. No literature was found that examined regression coefficients across herds stratified using within herd-year standard deviation fat yield.

Fat Percent: Correlations were larger for Jerseys than Holsteins for both "indirect" (.306 vs .271) and "direct" (.336 vs .279) fat percent calculations. For both breeds, "direct" fat percent correlations were larger than those "indirect" fat percent. Correlations were smaller for selected lactations in Holsteins, however this was not evident in Jerseys. For both breeds and measures of fat percent, correlations increased from low to high classes. The difference between correlations across stratified classes were larger than those observed for milk and fat yeld. In Jerseys differences across classes were more substantial when stratification was on within herd-year standard deviations. However, the same trend was not evident in Holsteins.

The range in the ratio of the standard deviations for "indirect" or "direct" MCD and PD fat percent across classes was much smaller when stratified by herd-year mean than when stratified by within herd-year standard deviation. Ratios were larger for Holsteins than Jerseys for both "indirect" and "direct" fat percent.

The differences in the correlations and standard deviation ratios by method of stratification was evident in the ranges of regression coefficients. In both breeds and measures of fat percent, differences in regressions were small across classes stratified on herd-year means while differences were large across classes stratified by within herd-year standard deviations. The difference in fat percent coefficients across classes stratified by within herd-year standard deviations were larger than those for milk and fat yield.

No literature was found that examined regressions of daughter's fat percent on sire's PD fat percent across different herd-year characteristics. The trend of increasing regression coefficients with increasing herd-year means agrees with results of researchers for milk and fat yield.

Comparison of MCD Calculations

Since the original data set for both breeds and the 'log' and 'σ' adjustments were similar to Lofgren et al. (15), comparisons to their results will only be made if results differed in order to avoid repetition. However, it is important to note that 'current AGMC', 'log AGMC', and 'σ AGMC' were different MCD calculations than Lofgren's and fat yield and fat percent were also analyzed.

Daughter-dam Pairs

Coefficients of determination and regression coefficients from regressions of daughter's average MCD trait on dam's CI trait (with the sire absorbed) for the six methods used for computing the modified contemporary deviation are in Tables 28, 29, 30, 31, 32, and 33. Unequal number of daughter-dam pairs across methods of adjustment was due to the removal of daughter-dam pairs having fat percent MCDs exceeding six standard deviations from the mean.

Milk: Regression coefficients were near the theoretical value of one in both breeds. For Holsteins, regression coefficients were larger than one for each method of MCD calculation indicating that all methods were conservative. Coefficients were closer to one for Jerseys with MCDs computed differently than the 'Current' method being slightly smaller than one. Coefficients from regressions on CI using 'Current AGMC' was the largest in magnitude while 'σ' was the smallest in magnitude for both breeds.

Within each breed there were small differences in R^2 values across methods of computing MCDs. This was in agreement with results obtained by Powell et al. (26) and Lofgren et al. (15). R^2 values were larger in Jersys than in Holsteins. For both breeds the 'σ AGMC' had the largest R^2 value.

Fat: For Holsteins, regression coefficients were larger than one and were similar to the coefficients observed for milk yield. However, all Jersey regression coefficients were smaller than one and were less than those for milk yield. As observed for milk yield, regression coefficients were the largest for 'current AGMC' and the smallest for 'σ' in both breeds.

Table 28. **Regression coefficients and coefficients of determination from Holstein daughter-dam pairs for daughter's average MCD[1] for milk on dam's CI[1] for milk.**

MCD Method	Number Pairs	Regression Coefficient	Standard Error	R^2
Current	225,092	1.165	.014	.164
Log	224,953	1.120	.014	.166
σ	224,879	1.071	.013	.171
Current AGMC	224,879	1.180	.014	.168
Log AGMC	224,879	1.135	.014	.171
σ AGMC	224,879	1.088	.013	.175

1) Calculated using the six methods to compute the modified contemporary deviation.

Table 29. **Regression coefficients and coefficients of determination from Jersey daughter-dam pairs for daughter's average MCD[1] for milk on dam's CI[1] for milk.**

MCD Method	Number Pairs	Regression Coefficient	Standard Error	R^2
Current	169,163	1.022	.013	.180
Log	168,883	.977	.013	.184
σ	168,791	.952	.012	.188
Current AGMC	168,791	1.037	.013	.179
Log AGMC	168,791	.996	.013	.184
σ AGMC	168,791	.969	.012	.192

1) Calculated using the six methods to compute the modified contemporary deviation.

Table 30. **Regression coefficients and coefficients of determination from Holstein daughter-dam pairs for daughter's average MCD[1] for fat on dam's CI[1] for fat.**

MCD Method	Number Pairs	Regression Coefficient	Standard Error	R^2
Current	225,092	1.157	.013	.159
Log	224,953	1.116	.013	.160
σ	224,879	1.059	.012	.163
Current AGMC	224,879	1.165	.013	.160
Log AGMC	224,879	1.123	.013	.161
σ AGMC	224,879	1.068	.012	.165

1) Calculated using the six methods to compute the modified contemporary deviation.

Table 31. **Regression coefficients and coefficients of determination from Jersey daughter-dam pairs for daughter's average MCD[1] for fat on dam's CI[1] for fat.**

MCD Method	Number Pairs	Regression Coefficient	Standard Error	R^2
Current	169,163	.946	.014	.150
Log	168,883	.909	.014	.152
σ	168,791	.881	.013	.155
Current AGMC	168,791	.951	.014	.149
Log AGMC	168,791	.920	.014	.152
σ AGMC	168,791	.892	.013	.158

1) Calculated using the six methods to compute the modified contemporary deviation.

Table 32. Regression coefficients and coefficients of determination from Holstein daughter-dam pairs for daughter's average MCD[1] for fat% on dam's CI[1] for fat%.

MCD Method	Number Pairs	Regression Coefficient	Standard Error	R^2
Current	225,092	1.615	.011	.232
Log	224,953	1.600	.012	.231
σ	224,879	1.510	.011	.236
Current AGMC	224,879	1.618	.011	.234
Log AGMC	224,879	1.602	.012	.232
σ AGMC	224,879	1.517	.011	.238

1) Calculated using the six methods to compute the modified contemporary deviation.

Table 33. Regression coefficients and coefficients of determination from Jersey daughter-dam pairs for daughter's average MCD[1] for fat% on dam's CI[1] for fat%.

MCD Method	Number Pairs	Regression Coefficient	Standard Error	R^2
Current	169,163	1.416	.011	.255
Log	168,883	1.391	.011	.249
σ	168,791	1.318	.011	.255
Current AGMC	168,791	1.395	.011	.253
Log AGMC	168,791	1.373	.011	.248
σ AGMC	168,791	1.327	.011	.255

1) Calculated using the six methods to compute the modified contemporary deviation.

Within each breed and across methods of computing MCD there were small differences in R^2 values. R^2 values were smaller than those for milk yield in both breeds. However, the difference was greater in Jerseys than in Holsteins. As was the case for milk yield, the 'σ AGMC' adjustment had the largest R^2 value in both breeds. In contrast to milk, R^2 values for Holsteins were larger than for Jerseys.

Fat Percent: In both breeds regression coefficients were considerably larger than the theoretical value of one. This indicates that fat percent cow indexes are very conservative. One possible explanation is that fat percent CI are computed indirectly from milk and fat CI. The resulting CI for fat percent could be compressed since milk and fat yield heritabilities used in CI calculations are smaller than the heritability for fat percent. Another possibility could be cytoplsmic inheritance of fat percent. Bell et al. (2) found that cytoplasmic affects were most important in fat percentage, accounting for 3.5% of total variation of milk fat percentage. However, it would seem that the indirect calculation of CI for fat percent would be the most predominant cause. Regression coefficients were larger in Holsteins than Jerseys. 'Current AGMC' and 'current' had the largest regression coefficients for Holsteins and Jerseys, respectively. 'σ' had the smallest regression coefficient in both breeds as was found for milk and fat yield.

For both breeds R^2 values were larger than those observed for milk and fat yields. This would be expected since fat percent has a higher heritability than milk and fat yield. R^2 were slightly larger for Jerseys than Holsteins. Across methods of MCD calculations R^2 values were very similar as was the situation for milk and fat yield. In Holsteins the 'σ AGMC' had the largest R^2 value while 'σ AGMC', 'σ', and 'current' methods tied for the largest R^2 in Jerseys.

Son-dam Pairs

In Tables 34, 35, 36, 37, 38, and 39 coefficients of determination and regression coefficients are presented from regressions of son's average MCD trait on dam's CI trait with the sire absorbed for the six methods of computing the modifed contemporary deviation. The $\overline{MCD}$ used in the dam's CI used the six MCD methods while the son's $\overline{MCD}$ was unadjusted.

Milk: In Holsteins, regression coefficients were less than the theoretical value of .5 for all methods of calculating MCDs. This was in agreement with results observed by Powell et al. (26) and Lofgren et al. (15). However, Jersey coefficients were all closer to .5. The theoretical regression coefficient is .5 rather than 1.0 since the son's MCD is based on granddaughters of the dam. For both breeds the 'σ AGMC' had the largest regression coefficient. The smallest coefficient was the 'current' for Holsteins and the 'current AGMC' in Jerseys.

R^2 values were nearly identical across methods of calculating MCDs for both breeds. R^2 values were larger than the R^2 values for milk observed in the daughter-dam pair regressions. This would be expected since a dam's CI should be able to predict the performance of a group of relatives better than a single relative. R^2 values were larger for Jerseys than Holsteins.

Fat: For both breeds regression coefficients were less than .5 across all MCD methods. Regression coefficients were larger for Jerseys than Holsteins. 'σ AGMC' had the largest coefficient for both breeds. 'Current' and 'current AGMC' had the smallest regression coefficients in Holsteins and Jerseys, respectively.

Table 34. Regression coefficients and coefficients of determination from Holstein son-dam pairs for son's average MCD for milk on dam's CI[1] for milk.

MCD Method	Number Pairs	Regression Coefficient	Standard Error	R^2
Current	3676	.370	.036	.381
Log	3676	.372	.037	.380
σ	3676	.393	.038	.380
Current AGMC	3676	.374	.036	.381
Log AGMC	3676	.375	.037	.380
σ AGMC	3676	.395	.038	.380

1) Calculated using the six methods to compute the modified contemporary deviation.

Table 35. Regression coefficients and coefficients of determination from Jersey son-dam pairs for son's average MCD for milk on dam's CI[1] for milk.

MCD Method	Number Pairs	Regression Coefficient	Standard Error	R^2
Current	2175	.498	.040	.446
Log	2175	.518	.042	.444
σ	2175	.512	.042	.445
Current AGMC	2175	.441	.038	.441
Log AGMC	2175	.470	.040	.440
σ AGMC	2175	.522	.042	.446

1) Calculated using the six methods to compute the modified contemporary deviation.

Table 36. **Regression coefficients and coefficients of determination from Holstein son-dam pairs for son's average MCD for fat on dam's CI[1] for fat.**

MCD Method	Number Pairs	Regression Coefficient	Standard Error	R^2
Current	3676	.349	.032	.360
Log	3676	.354	.033	.359
σ	3676	.382	.035	.360
Current AGMC	3676	.350	.032	.360
Log AGMC	3676	.355	.033	.359
σ AGMC	3676	.385	.035	.360

1) Calculated using the six methods to compute the modified contemporary deviation.

Table 37. **Regression coefficients and coefficients of determination from Jersey son-dam pairs for son's average MCD for fat on dam's CI[1] for fat.**

MCD Method	Number Pairs	Regression Coefficient	Standard Error	R^2
Current	2175	.422	.039	.428
Log	2175	.442	.042	.427
σ	2175	.435	.041	.428
Current AGMC	2175	.354	.036	.423
Log AGMC	2175	.388	.039	.423
σ AGMC	2175	.445	.041	.429

1) Calculated using the six methods to compute the modified contemporary deviation.

Table 38. Regression coefficients and coefficients of determination from Holstein son-dam pairs for son's average MCD for fat% on dam's CI[1] for fat%.

MCD Method	Number Pairs	Regression Coefficient	Standard Error	R^2
Current	3676	.561	.038	.325
Log	3676	.579	.041	.324
σ	3676	.598	.043	.324
Current AGMC	3676	.554	.039	.325
Log AGMC	3676	.573	.041	.324
σ AGMC	3676	.598	.043	.323

1) Calculated using the six methods to compute the modified contemporary deviation.

Table 39. Regression coefficients and coefficients of determination from Jersey son-dam pairs for son's average MCD for fat% on dam's CI[1] for fat%.

MCD Method	Number Pairs	Regression Coefficient	Standard Error	R^2
Current	2175	.587	.037	.433
Log	2175	.611	.038	.432
σ	2175	.608	.038	.430
Current AGMC	2175	.570	.036	.432
Log AGMC	2175	.596	.037	.431
σ AGMC	2175	.610	.038	.430

1) Calculated using the six methods to compute the modified contemporary deviation.

In both breeds R^2 values were nearly identical across MCD methods. R^2 values were larger for Jerseys than Holsteins as was the situation for milk. Values of R^2 were larger than the corresponding R^2 values observed for fat yield using daughter-dam pairs.

Fat Percent: In both breeds regression coefficients were greater than the theoretical value of .5. With regression coefficients being larger than the theoretical value as was the situation in daughter-dam pairs indicates that the indirect calculation of fat percent MCD and CI was the predominant cause of larger coefficients rather than cytoplasmic inheritance. If cytoplasmic inheritance was the cause we would expect coefficients less than the theoretical value in son-dam pairs. The regression coefficient larger than .5 for the dam's CI was in disagreement with the results of Lee (12) who found a dam's CI coefficient of .415 in the prediction of registered AI son's PD fat percent. A possible explanation for this difference was that Lee was predicting the son's PD while we were predicting his $\overline{MCD}$.

Regression coefficients were slightly larger for Jerseys than Holsteins. 'σ' and 'σ AGMC' had the largest regression coefficients for Holsteins while 'log' was the largest for Jerseys. 'Current AGMC' had the smallest regression coefficient for both breeds.

Little difference in R^2 values across MCD methods was evident for both breeds. R^2 values were larger for Jerseys than Holsteins. In Holsteins R^2 values were less than those for milk and fat yield while for Jerseys they were very similar. Lower than expected R^2 values for the higher heritable fat percent as compared to those of the lower heritable milk and fat yield was in agreement with results by Lee (12) who examined at the accuracy of pedigree prediction of transmitting ability for milk an fat percent. R^2 values were larger than those observed for fat percent from daughter-dam pair regressions, but the difference was smaller than for milk and fat.

Daughter-dam Pair Groups

In Tables 40, 41, 42, 43, 44, and 45 coefficients of determination and regression coefficients are presented from the daughter-dam groups. In order to better detect differences in R^2 values across MCD calculations daughter-dam pair groups were formed. For each trait, the regression of group mean dam CI and sire PD on group mean daughter average MCD were performed. Groups were determined according to the dam's CI and sire's PD since grouping by just using the dam's CI gave unreasonable regression coefficients for the sire's PD. In addition, grouping using the sire's PD also changed the ranking of MCD methods according to their R^2 values. Also, it was found that group size and the number of groups had a large impact on R^2 values across the different MCD calculations for each breed and trait.

Milk: In both breeds and across all methods of calculating MCDs regression coefficients for sire's PD and dam's CI were near the theoretical value of one. The coefficients tended to be larger than one for Holsteins while less than one for Jerseys. Sire's PD and dam's CI regression coefficients were the smallest for 'σ' and the largest for 'current AGMC' in both breeds. This same trend was observed in the individual daughter-dam pair regressions.

For both breeds R^2 values were more variable than those from the individual daughter-dam pair regressions as was expected. However, extreme differences in R^2 values were not evident across methods of MCD calculations. For both breeds 'σ AGMC' had the largest R^2 value.

Fat: As was the situation for milk yield, regression coefficients of the sire's PD and the dam's CI were close to the theoretical value of one for both breeds and all MCD calcu-

Table 40. Regression coefficients and coefficients of determination from Holstein daughter-dam 15 kg milk groups[1] of group's mean daughter average MCD[2] for milk on group's mean dam CI[2] and sire PD for milk.

MCD Method	Number Groups	Sire PD Regression Coefficient	Sire PD Standard Error	Dam CI Regression Coefficient	Dam CI Standard Error	R^2
Current	7,836	1.072	.016	1.081	.022	.524
Log	7,781	1.046	.015	1.052	.021	.547
σ	7,646	1.000	.013	.998	.019	.568
Current AGMC	7,835	1.096	.016	1.124	.022	.543
Log AGMC	7,809	1.060	.015	1.086	.021	.553
σ AGMC	7,685	1.028	.014	1.021	.019	.577

1) Grouped using value of dam's CI and sire's PD.
2) Calculated using the six methods to compute the modified contemporary deviation.

Table 41. Regression coefficients and coefficients of determination from Jersey daughter-dam 15 kg milk groups[1] of group's mean daughter's average MCD[2] for milk on group's mean dam CI[2] and sire PD for milk.

MCD Method	Number Groups	Sire PD Regression Coefficient	Sire PD Standard Error	Dam CI Regression Coefficient	Dam CI Standard Error	R^2
Current	5,222	.987	.016	.937	.022	.595
Log	5,228	.968	.015	.880	.021	.599
σ	5,241	.939	.015	.874	.021	.593
Current AGMC	5,357	1.040	.018	.964	.023	.569
Log AGMC	5,363	1.015	.017	.923	.022	.582
σ AGMC	5,256	.959	.015	.896	.021	.603

1) Grouped using value of dam's CI and sire's PD.
2) Calculated using the six methods to compute the modified contemporary deviation.

Table 42. Regression coefficients and coefficients of determination from Holstein daughter-dam 1 kg fat groups[1] of group's mean daughter's average MCD[2] for fat on group's mean dam CI[2] and sire PD for fat.

MCD Method	Number Groups	Sire PD Regression Coefficient	Sire PD Standard Error	Dam CI Regression Coefficient	Dam CI Standard Error	R^2
Current	2,719	1.083	.021	1.116	.029	.628
Log	2,731	1.068	.020	1.073	.028	.637
σ	2,665	1.002	.018	1.013	.025	.668
Current AGMC	2,727	1.122	.021	1.137	.029	.636
Log AGMC	2,733	1.085	.020	1.080	.027	.645
σ AGMC	2,661	1.025	.018	1.018	.025	.676

1) Grouped using value of dam's CI and sire's PD.
2) Calculated using the six methods to compute the modified contemporary deviation.

Table 43. Regression coefficients and coefficients of determination from Jersey daughter-dam 1 kg fat groups[1] of group's mean daughter's average MCD[2] for fat on group's mean dam CI[2] and sire PD for fat.

MCD Method	Number Groups	Sire PD Regression Coefficient	Sire PD Standard Error	Dam CI Regression Coefficient	Dam CI Standard Error	R^2
Current	2,410	1.058	.024	.903	.032	.589
Log	2,400	1.027	.021	.822	.028	.627
σ	2,395	1.000	.020	.805	.027	.639
Current AGMC	2,466	1.112	.025	.894	.032	.581
Log AGMC	2,452	1.079	.023	.871	.030	.603
σ AGMC	2,393	1.017	.020	.841	.027	.645

1) Grouped using value of dam's CI and sire's PD.
2) Calculated using the six methods to compute the modified contemporary deviation.

Table 44. Regression coefficients and coefficients of determination from Holstein daughter-dam .01 fat% groups[1] of group's mean daughter's average MCD[2] for fat% on group's mean dam CI[2] and sire PD for fat%.

MCD Method	Number Groups	Sire PD Regression Coefficient	Sire PD Standard Error	Dam CI Regression Coefficient	Dam CI Standard Error	R^2
Current	2,034	.998	.030	1.381	.030	.630
Log	2,013	.990	.028	1.390	.029	.651
σ	2,000	.971	.029	1.320	.030	.628
Current AGMC	2,029	1.002	.030	1.381	.031	.623
Log AGMC	2,013	.984	.028	1.399	.029	.653
σ AGMC	1,996	.981	.029	1.314	.030	.628

1) Grouped using value of dam's CI and sire's PD.
2) Calculated using the six methods to compute the modified contemporary deviation.

Table 45. Regression coefficients and coefficients of determination from Jersey daughter-dam .01 fat% groups[1] of group's mean daughter's average MCD[2] for fat% on group's mean dam CI[2] and sire PD for fat%.

MCD Method	Number Groups	Sire PD Regression Coefficient	Sire PD Standard Error	Dam CI Regression Coefficient	Dam CI Standard Error	R^2
Current	3,278	.933	.021	1.169	.024	.598
log	3,232	.907	.021	1.175	.025	.593
σ	3,297	.908	.020	1.076	.023	.593
Current AGMC	3,348	.941	.021	1.104	.024	.590
Log AGMC	3,292	.921	.021	1.106	.024	.581
σ AGMC	3,301	.913	.021	1.082	.023	.591

1) Grouped using value of dam's CI and sire's PD.
2) Calculated using the six methods to compute the modified contemporary deviation.

lations. The sire's PD and dam's CI coefficients were larger than one for Holsteins. In Jerseys the sire's PD coefficient was at least one while the dam's CI coefficient was less than one for all MCD methods. For both breeds 'σ' had the smallest sire's PD and dam's CI coefficients. 'Current AGMC' had the largest sire's PD and dam's CI coefficient in Holsteins. In Jerseys 'current AGMC' and 'current' had the largest coefficients for the sire's PD and dam's CI, respectively.

R^2 values were more variable than those obtained from individual daughter-dam pair regressions. However, differences in R^2 values across methods of calculating MCDs were not extreme. In both breeds 'σ AGMC' had the largest R^2 value.

Fat Percent: For both breeds and across all MCD methods the regression coefficients of the dam's CI were larger than the theoretical value of one. This was more severe in Holsteins than Jerseys. However, the coefficients of the sire's PD were near one for Holsteins but less than one in Jerseys. This indicates that cow indexes for fat percent are conservative in both breeds while sire predicted differences for fat percent are close to the expected value in Holsteins but overestimate the sires contribution in Jerseys.

In Holsteins 'σ' and 'σ AGMC' had the smallest coefficients for the sire's PD and dam's CI, respectively. The largest coefficient was 'current AGMC' for the sire's PD while 'log AGMC' had the largest coefficient for the dam's CI. However, for Jerseys 'log' and 'σ' had the smallest coefficients for the sire's PD and dam's CI, respectively. 'Current AGMC' had the largest coefficient for the sire's PD and 'log' had the largest dam's CI coefficient.

In both breeds very small differences were evident in R^2 values across methods of calculating MCDs. These R^2 values differed less across methods than those for milk and fat yield. 'Log AGMC' had the largest R^2 value for Holsteins while 'Current' had the largest R^2 value in Jerseys.

Son-dam Pair Groups

In Tables 46, 47, 48, 49, 50, and 51, coefficients of determination and regression coefficients are presented from the son-dam groups. As was the case in the daughter-dam groups, they were divided according to the sire's PD and dam's CI rather than just the dam's CI in order to get reasonable sire's PD coefficients. Since there were fewer son-dam pairs than daughter-dam pairs fewer groups were available for analysis. It was found that an edit requiring at leat four son-dam pairs within a group was needed since these small extreme groups had a large effect on R^2 values. The importance of group size and the number of groups was evident in both breeds and for all traits.

Milk: In Holsteins, regression coefficeints were less than the theoretical value of .5 for both the sire's PD and the dam's CI. However, in Jerseys the coefficients of the sire's PD were closer to .5 while the dam's CI coefficients were much larger than .5. For both breeds the coefficients for the sire's PD and dam's CI differed just slightly across methods of calculating MCDs.

In Holsteins grouping the son-dam pairs caused R^2 values to differ across methods as expected. However, in Jerseys the difference in R^2 values across methods was smaller. 'σ AGMC' had the largest R^2 value in Holsteins. This method was also the best for milk and fat yield in both breeds when daughter-dam pair groups were analyzed. For Jerseys 'log AGMC' had the largest value though less differences were seen across methods compared to Holsteins.

Fat: Regression coefficients were near the theoretical value of .5 for the sire's PD but were much less than .5 for the dam's CI in Holsteins. However in Jerseys both sire's

Table 46. Regression coefficients and coefficients of determination from Holstein son-dam 125 kg milk groups[1] of group's mean son's average MCD for milk on group's mean dam CI[2] and sire PD for milk.

		Sire PD		Dam CI		
MCD Method	Number Groups	Regression Coefficient	Standard Error	Regression Coefficient	Standard Error	R^2
Current	57	.398	.071	.357	.080	.555
Log	58	.383	.075	.353	.086	.515
σ	59	.363	.065	.491	.076	.635
Current AGMC	57	.424	.068	.371	.074	.613
Log AGMC	57	.395	.066	.405	.076	.618
σ AGMC	58	.383	.063	.488	.075	.657

1) Grouped using value of dam's CI and sire's PD.
2) Calculated using the six methods to compute the modified contemporary deviation.

Table 47. Regression coefficients and coefficients of determination from Jersey son-dam 100 kg milk groups[1] of group's mean son's average MCD for milk on group's mean dam CI[2] and sire PD for milk.

		Sire PD		Dam CI		
MCD Method	Number Groups	Regression Coefficient	Standard Error	Regression Coefficient	Standard Error	R^2
Current	48	.506	.063	.765	.070	.864
Log	51	.511	.058	.750	.068	.877
σ	49	.482	.061	.769	.068	.853
Current AGMC	51	.491	.061	.745	.067	.852
Log AGMC	51	.544	.055	.741	.061	.882
σ AGMC	50	.499	.058	.774	.066	.867

1) Grouped using value of dam's CI and sire's PD.
2) Calculated using the six methods to compute the modified contemporary deviation.

Table 48. **Regression coefficients and coefficients of determination from Holstein son-dam 5 kg fat groups[1] of group's mean son's average MCD for fat on group's mean dam CI[2] and sire PD for fat.**

		Sire PD		Dam CI		
MCD Method	Number Groups	Regression Coefficient	Standard Error	Regression Coefficient	Standard Error	R^2
Current	62	.509	.052	.309	.057	.711
Log	56	.497	.057	.268	.065	.671
σ	56	.510	.055	.234	.064	.691
Current AGMC	61	.501	.051	.314	.055	.727
Log AGMC	57	.510	.056	.276	.063	.686
σ AGMC	55	.508	.054	.225	.065	.697

1) Grouped using value of dam's CI and sire's PD.
2) Calculated using the six methods to compute the modified contemporary deviation.

Table 49. **Regression coefficients and coefficients of determination from Jersey son-dam 2.5 kg fat groups[1] of group's mean son's average MCD for fat on group's mean dam CI[2] and sire PD for fat.**

		Sire PD		Dam CI		
MCD Method	Number Groups	Regression Coefficient	Standard Error	Regression Coefficient	Standard Error	R^2
Current	72	.556	.097	.598	.079	.603
Log	72	.588	.091	.606	.079	.638
σ	74	.596	.079	.588	.075	.665
Current AGMC	72	.594	.106	.654	.080	.611
Log AGMC	77	.578	.087	.587	.080	.616
σ AGMC	74	.527	.086	.657	.080	.640

1) Grouped using value of dam's CI and sire's PD.
2) Calculated using the six methods to compute the modified contemporary deviation.

Table 50. **Regression coefficients and coefficients of determination from Holstein son-dam .05 fat% groups[1] of group's mean son's average MCD for fat% on group's mean dam CI[2] and sire PD for fat%.**

		Sire PD		Dam CI		
MCD Method	Number Groups	Regression Coefficient	Standard Error	Regression Coefficient	Standard Error	R^2
Current	46	.580	.059	.526	.079	.764
Log	47	.516	.050	.571	.073	.798
σ	46	.535	.057	.474	.080	.747
Current AGMC	45	.584	.061	.506	.083	.752
Log AGMC	47	.533	.054	.512	.078	.767
σ AGMC	45	.528	.056	.473	.077	.748

1) Grouped using value of dam's CI and sire's PD.
2) Calculated using the six methods to compute the modified contemporary deviation.

Table 51. **Regression coefficients and coefficients of determination from Jersey son-dam .025 fat% groups[1] of group's mean son's average MCD for fat% on group's mean dam CI[2] and sire PD for fat%.**

		Sire PD		Dam CI		
MCD Method	Number Groups	Regression Coefficient	Standard Error	Regression Coefficient	Standard Error	R^2
Current	45	.356	.085	.509	.047	.790
Log	45	.438	.127	.556	.079	.632
σ	44	.531	.079	.596	.075	.789
Current AGMC	39	.373	.106	.497	.080	.828
Log AGMC	45	.408	.087	.520	.080	.609
σ AGMC	46	.510	.086	.608	.080	.756

1) Grouped using value of dam's CI and sire's PD.
2) Calculated using the six methods to compute the modified contemporary deviation.

PD and dam's CI coefficients were .5 or greater. In both breeds coefficients for the sire's PD and dam's CI differed only slightly across methods of MCD calculations.

In both breeds grouping the son-dam pairs caused larger differences in R^2 values as expected. 'Current AGMC' had the largest R^2 value for Holsteins while 'σ' had the largest R^2 value in Jerseys. These methods did not have the largest R^2 values in milk for the son-dam groups. In addition these were not the methods that had the largest R^2 value for fat yield in the daughter-dam pair groups.

Fat Percent: The sire's PD and dam's CI regression coefficients in both breeds and across all methods of MCD calculations were near the theoretical value of .5. Taking into account the standard errors of the coefficients, there were little differences in coefficients across methods of MCD calculations.

R^2 values were much more variable across MCD methods for Jerseys than Holsteins. In Jerseys 'current AGMC' had the largest R^2 value while 'log' had the largest value for Holsteins. For Holsteins 'log' was the method that gave the largest R^2 value for fat percent in the daughter-dam pair group analysis too. In Jerseys 'current AGMC' was no different than any of the other methods in the daughter-dam pair group analysis.

General Discussion of MCD Adjustments

From the results obtained in the daughter-dam pair groups it appears that 'σ AGMC' adjustment would improve the accuracy of predicting daughter's milk and fat production in both breeds. The rank for fat percent was somewhat different. However, it may be more important to be concerned with optimum transformations if the fat percent MCDs were calculted like milk and fat yield. 'Log AGMC' and 'current' MCD calculations were the best predictions of daughter's merit for fat percent. However, it is important to note that the R^2 values for fat percent varied less across MCD calculations as compared to those of milk and fat yield. The disagreement with the findings from milk and fat yield could be attributed to the construction of a $\overline{MCD}$ for fat percent and the "indirect" method of computing fat percent CI. Further studies looking at computing "direct" CI for fat percent and adjustments to the "direct" fat percent MCDs could resolve this question.

Since 'σ AGMC' was the best MCD adjustment for milk and fat yield for both breeds in the daughter-dam pair groups, we will compare 'σ AGMC' rank in the son-dam pair groups discussion. The interpretation of results from the son-dam pair groups must be done with caution due to problems with grouping son-dam pairs. Fewer son-dam pairs were available (especially for Jerseys) than daughter-dam pairs due to the selection of dam's to be bull mothers. Group size and the number of groups had a large impact on R^2 values and rankings. The edit requiring group size of four or greater was an attempt to control the influence of small outlier groups though one should interpret the results with caution. An additional problem in interpreting results was that the son's $\overline{MCD}$ was not adjusted like the MCDs used to compute the adjusted dam's CI.

There was little agreement in the best MCD calculation across breed and trait. As was the case in the daughter-dam pair groups, 'σ AGMC' predicted the offspring's $\overline{MCD}$ the best for milk in Holsteins while 'σ AGMC' was ranked third to 'log AGMC' and 'log' in Jerseys. However, in Jerseys less differences were observed across methods of MCD calculations for milk. For fat yield 'σ AGMC' was ranked second to 'σ' in Jerseys and ranked third to 'current AGMC' and 'current' in Holsteins. We have the same problem of an 'indirect' fat percent CI as well as an 'indirect' son's $\overline{MCD}$ fat percent. σ AGMC was ranked fifth to 'log' in Holsteins and ranked fourth to 'current AGMC' in Jerseys. A similar ranking of MCD calculations for fat percent was observed in the daughter-dam pair groups.

Conclusions

The analysis of herd-year variables indicated heterogeneity of within herd-year standard deviations for milk, fat, and fat percent. The within herd-year standard deviations for milk and fat were moderately associated with the herd-year mean though for fat percent the relationship was much smaller.

Regressions of daughter's MCD on sire's PD indicated that coefficients had larger ranges when stratification was by within herd-year standard deviations rather than herd-year means for all traits. This was especially evident for fat percent. "Direct" fat percent calculations of MCDs were higher correlated with sire's PD than the current "indirect" fat percent calculation methods. The standard deviations of "direct" fat percent MCDs were much larger than those of the current USDA "indirect" method.

The σ AGMC MCD calculation which standardized the deviation portion of the MCD and weighted the genetic merit of contemporaries according to the within herd-year standard deviation was the best MCD calculation for predicting daughter's milk and fat $\overline{MCD}$ in both breeds. This was also the best for predicting son's $\overline{MCD}$ for milk in Holsteins. However, predicting son's $\overline{MCD}$ had difficulties due to group size and numbers of groups had a large impact on R^2 values and rankings in son-dam pair group regressions. It was also found that it was important to form son-dam or daughter-dam groups using both the sire's PD and dam's CI in order to get reasonable regression coefficients for the sire's PD and the dam's CI.

It was important to note that no extreme differences between R^2 values were evident in any of the traits for each breed. In the prediction of the son's $\overline{MCD}$ for both milk and fat yield, breed differences were seen in the dam's CI regression coefficients. Why for Holsteins the coefficients are less than the theoretical value of .5 and in Jerseys they are larger than .5 was not known. Solving this question may give us results that could be useful in improving the accuracy of the selection of AI bull mothers.

Several of the results found in this study suggest that fat percent MCDs computed like those for milk and fat yield should be examined in future research. These results are the difference in standard deviations between "direct" and "indirect" fat percent MCD methods, the larger than expected dam's CI and sire's PD fat percent regression coefficients for both the son-dam and daughter-dam pairs, and the disagreement in the "best" MCD adjustment for fat percent as compared to milk and fat yield.

Bibliography

1. Aisbett, C. W. 1984. Association of herd means and variances is a function of edit for mininum lactation length. J. Dairy Sci. 67:702.

2. Bell, B. R., B. T. McDaniel, and O. W. Robison. 1985. Effects of cytoplasmic inheritance on production traits of dairy cattle. J. Dairy Sci. 68:2038.

3. Bonaiti, B., and L. Bertaudiere. 1982. Genotype environment interaction on milk production in cattle. I. Variation of milk yield of heifers as influenced by selection index of the father and herd level. Ann. Genet. Sel. Anim. 14:177.

4. Brotherstone, S., and W. G. Hill. 1985. Heterogeneity of variance amongst herds for milk production. Anim. Prod. 41:297.

5. Cassell, B. G., B. T. McDaniel, and H. D. Norman. 1983. Modified contemporary comparisons for first and second lactations in the same and different herds. J. Dairy Sci. 66:315.

6. Cassell, B. G., B. T. McDaniel, and H. D. Norman. 1983. Impact on culling on modified contemporary comparison sire evaluations. J. Dairy Sci. 66:1359.

7. Dickinson, F. N., R. L. Powell, and H. D. Norman. 1976. An introduction to the USDA-DHIA modified contemporary comparison. pp. 1-7 Prod. Res. Rep. 165, USDA.

8. Everett, R. W., J. F. Keown, and J. F. Taylor. 1982. The problem of heterogeneous within herd variances when identifying elite cows. J. Dairy Sci. 65 (Suppl. 1): 100 (Abstr.).

9. Freeman, A. E., and C. R. Henderson. 1959. Genetic structure of dairy cattle herds in terms of additive and dominance relationships. J. Dairy Sci. 42:621.

10. Hill, W. G., M. R. Edwards, M-K. A. Ahmed, and R. Thompson. 1983. Heritability of milk yield and composition at different levels and variability of production. Animal Prod. 36:59.

11. Hill, W. G. 1984. On selection among groups with heterogeneous variance. Anim. Prod. 39:473.

12. Lee, K. L. 1983. Genetic trend and selection practised in the registered Holstein cattle population. Unpublished Ph. D. Thesis. Dept. Anim. Sci., Iowa State University.

13. Legates, J. E.. 1962. Heritability of fat yields in herds with different production levels. J. Dairy Sci. 45:990.

14. Lofgren, D. L., W. E. Vinson, R. E. Pearson, and R. L. Powell. 1985. Heritability of milk yield at different herd means and variance for production. J. Dairy Sci. 68:2737.

15. Lofgren, D. L., W. E. Vinson, R. E. Pearson, and R. L. Powell. 1985. Adjustments to cow indexes for milk yield for effects of herd mean and standard deviation. J. Dairy Sci. 68:3301.

16. Mason, I. L., and A. Robertson. 1956. The progeny testing of dairy bulls at different levels of production. J. Agric. Sci. 47:367.

17. McDaniel, B. T., and E. L. Corley. 1967. Relationships between sire evaluations at different herdmate levels. J. Dairy Sci. 50:735.

18. Miller, P. D., B. T. McDaniel, and others. 1974. USDA-DHIA factors for standardizing 305-day lactation records for age and month of calving. U.S. Dept. Agr., Agr. Res. Serv. ARS-NE-40, 91 pp.

19. Norman, H. D., B. T. McDaniel, and F. N. Dickinson. 1971. Conflicts between heritability estimates of mature equivalent and herdmate-deviation milk and fat. J. Dairy Sci. 55:507.

20. Norman, H. D., B. G. Cassell, F. N. Dickinson, and A. L. Kuck. 1979. USDA-DHIA milk components sire summary. p. 9. Prod. Res. Rep. No. 178.

21. Pirchner, F., and J. L. Lush. 1959. Genetic and environmental portion of the variation among herds in butterfat production. J. Dairy Sci. 42:122.

22. Powell, R. L. 1978. A procedure for including the dam and maternal grandsire in USDA-DHIA cow indexes. J. Dairy Sci. 61:794.

23. Powell, R. L. 1984. Genetic base for cow evaluation. J. Dairy Sci. 67:1359.

24. Powell, R. L. 1985. Cow Evaluation Procedures. National Cooperative Dairy Herd Improvement Program Handbook Fact Sheet. H-2.

25. Powell, R. L., and H. D. Norman. 1984. Response within herd to sire selection. J. Dairy Sci. 67:2021.

26. Powell, R. L., H. D. Norman, and B. T. Weinland. 1983. Cow evaluation at different milk yields of herds. J. Dairy Sci. 66:148.

27. Powell, R. L., H. D. Norman, and G. R. Wiggans. 1985. Trends of breeding values of dairy sires and cows for milk yield since 1960. J. Dairy Sci. 68 (Suppl. 1):221.

28. Rendel, J.M., and A. Robertson. 1950. Estimation of genetic gain in milk yield by selection in a closed herd of dairy cattle. J. Genetics 50:1.

29. Robertson, A., L. K. O'Connor, and J. Edwards. 1960. Progeny testing dairy bulls at different management levels. Anim. Prod. 2:141.

30. Schaeffer, L. R., A. Kerr, and E. B. Burnside. 1982. Dairy herd genetic differences for lactation production. Can. J. Anim. Sci. 62:323.

31. Spike, P. L., and A. E. Freeman. 1977. Effect of genetic differences among herds on accuracy of selection and expected genetic change. J. Dairy Sci. 60:967.

32. Spike, P. L., and A. E. Freeman. 1978. Prediction of genetic differences among herds with estimates of breeding values. J. Dairy Sci. 61:1476.

33. Van Vleck, L. D. 1963. Genotype and environment in sire evaluation. J. Dairy Sci. 46:983.

34. Van Vleck, L. D. 1977. Theoretical and actual genetic progress in dairy cattle. Proc. of the International conference on quantitative genetics. Aug. 16-21, 1976, Iowa State University Press, Editors: Edward Pollak, Oscar Kempthorne, and Theodore B. Bailey Jr., pp. 543.

35. Van Vleck, L. D., and G. E. Bradford. 1964. Heritability of milk yield at different environment levels. Anim. Prod. 6:285.

36. Wiggans, G. R., H. D. Norman, and R. L. Powell. 1984. Dairy Herd Improvement Letter. 60:2.

Appendix

Example of Problem with Fat% MCDs

Individual ME Milk = 2090.0 kg

Individual ME Fat = 127.5 kg

MCA ME Milk = 7414.0 kg

MCA ME Fat = 315.5 kg

Average Sire PD Milk of Modified Contemporaries = 19.0 kg

Average Sire PD Fat of Modified Contemporaries = -1.5 kg

Jersey BGB for Milk = 5254.4 kg

Jersey BGB for Fat = 250.8 kg

MCD Milk = 2090.0 kg - 7414.0 kg + 19.0 kg = -5305.2 kg

MCD Fat = 127.5 kg - 315.5 kg + -1.5 kg = -189.6 kg

$$\text{Individual ME Fat Percent} = \left(\frac{127.5 \text{ kg}}{2090.0 \text{ kg}}\right) * 100 = 6.10\%$$

$$\text{MCA ME Fat Percent} = \left(\frac{315.5 \text{ kg}}{7414.0 \text{ kg}}\right) * 100 = 4.25\%$$

$$\text{Average Sire PD Fat\% of Modified Contemporaries} = \left[\left(\frac{-1.5 \text{ kg} + 250.8 \text{ kg}}{19 \text{ kg} + 5254.4 \text{ kg}} \right) - \frac{250.8 \text{ kg}}{5254.4 \text{ kg}} \right] * 100 = -.05$$

$$\text{"Direct" MCD Fat\%} = 6.10 - 4.25 + (-.05) = 1.80$$

"Indirect" MCD Fat% =

$$\left[\left(\frac{-189.6 \text{ kg} + 250.8 \text{ kg}}{-5305.2 \text{ kg} + 5254.4 \text{ kg}} \right) - \frac{250.8 \text{ kg}}{5254.4 \text{ kg}} \right] * 100 = -125.24$$

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