AN ANALYSIS OF SIRE-SON AND DAM-DAUGHTER RELATIONSHIPS FOR TYPE TRAITS IN THE HOLSTEIN DESCRIPTIVE TYPE CLASSIFICATION SYSTEM

by

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Thesis submitted to the Graduate Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Dairy Science (Genetics)

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May, 1972

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ACKNOWLEDGEMENTS

The author wishes to express his thanks to Dr. John M. White for his unselfish guidance, counsel, and assistance over the past several years. Special thanks is also due the other members of his graduate committee including Dr. W. E. Vinson, Dr. R. G. Saacke, and Dr. K. Hinkelmann for their advice during thesis preparation. Very sincere appreciation is also due Dr. R. G. Cragle and the members of the faculty and staff of the Dairy Science Department for their role in the author's education and personal development during the past several years.

The fellowship, assistance, and encouragement of the many fine graduate students and undergraduates in the Dairy Science Department has been an unforgettable and valuable part of the author's education.

Finally, heartfelt and sincere thanks are due the author's wife, whose unending support and encouragement was in large part responsible for the completion of all degree requirements.

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INTRODUCTION

Selection for some form of dairy cattle type (body conformation) has been practiced by dairymen for at least as long as selection for production traits. Breeders and researchers alike have long argued the relative emphasis the two areas should receive in selection plans. Some dairymen totally ignore type, others search for the optimal combination of functional type and production, while a third group is concerned solely with type improvement in their herds. Most dairymen, however, likely demand some portion of both. While accurate information is available on production traits, reliable information on type traits is not so readily available.

In an effort to provide more useful type information to its members and other dairymen, the Holstein Friesian Association of America instituted a new type evaluation system in 1967. Named the Descriptive Type Classification System, it was designed to provide the kind of type information desired by the strictly type conscious breeders while at the same time offering the dairyman interested in functional type traits more information than he previously had available. The system evaluates not only the scorecard breakdown, including final score, general appearance, dairy character, body capacity, and mammary system traits, but also provides information of a descriptive nature on twelve type traits not previously evaluated and a miscellaneous category.

This study was undertaken in an effort to evaluate the chances for success of selection programs based on information from the descriptive system and to examine genetic and phenotypic relationships between the various traits. The specific purposes of this study were:

1. To examine the need for and to develop and apply correction factors for the effects of age at classification where needed.
2. To determine the phenotypic and genetic correlations between traits and the heritabilities of the various traits.
3. To evaluate progeny test results for type traits and to study the relationships between sires and sons for progeny test results.

LITERATURE REVIEW

The volume of research involving dairy cattle type is quite large. Most researchers have concentrated their efforts on estimating heritabilities, environmental effects (such as herd, year, age, and stage of lactation) or on determining the phenotypic and genetic correlations between various type traits and production. Much less emphasis has been given to progeny test results for type, perhaps due to the lack of adequate field data for such research.

Environmental Effects on Type Evaluation

In early work in this area of type research, Johnson and Lush (1942), studied classification results from 229 Holstein cows in the Iowa State College herd. These researchers reported that the repeatability of type score was 0.34 for individual judges' ratings. Repeatabilities were somewhat lower in cattle under one year of age. The difference in evaluation between judges was non-significant. Changes in udder and general health of the animal were reported to be the primary cause of large changes in an animal's type score. Touchberry and Tabler (1951) supported these results by reporting small classifier differences in Holstein and Guernsey type evaluations.

One of the early papers published on age and stage of lactation effects came from Hyatt and Tyler (1948). These researchers studied classification results from 138 Ayrshire cows from 1942 to 1946. Results of the study indicated that as a cow advanced in age, inspectors had a tendency to raise her evaluation. Cows were also noted to score higher just prior to or just after calving than in mid lactation. General agreement between inspectors was noted except for the traits concerning feet, legs, and udders. The repeatability of type evaluation was 0.55 when different judges rated the same cow at the same time.

Harvey and Lush (1952) pointed out the problem of environmental correlations between type and production. They utilized a nested model which included effects due to herds, years, cows and error to remove some of the environmental causes for likeness in type evaluation results. Herd differences accounted for about 18 per cent of the total variation in type scores in both dams and daughters. It was noted by the authors that herd differences were much higher (about 44 to 48 per cent) for production traits than for type traits. Year effects were shown to account for 4.1 per cent of the variance for production traits.

McGilliard and Lush (1956) reported that differences in the type scores of Holstein cows in the Iowa State College herd due to judges were nearly zero for cows classified after calving, before and after calving, and before calving only. Year effects were moderately large (11 per cent) in the before and after calving group. Cow-year interactions which reflected true changes in type were shown to be large in all groups, but greatest in the group classified before and after calving, where cow by year interaction accounted for 31 per cent of the total variance. Judge by year interactions were shown to be small, about 5 per cent per year. The authors stated that this component was an unimportant source of error between individual cows.

In further attempts to determine environmental sources of variation in type scores, Wilcox, et al. (1957) analyzed data on Holsteins from the New Jersey Agricultural Experiment Station. Some 1,575 appraisals of 525 adult females were involved in the study. The authors reported that factors such as season, year, stage of lactation and time trends accounted for only 3.93 to 10.17 per cent of the total variance of the eight traits studied. True animal differences accounted for 41.60 to 64.79 per cent of the total variation. Inspector differences were generally small for most traits except feet and legs, which were more difficult to evaluate, with inspector differences accounting for 11.45 per cent of total variation. The per cent of variation due to inspectors for dairy character was larger than average at 5.92 per cent. In summary, the authors reported that overall rating, general appearance, and rump were the easiest traits to evaluate, while the more subjective traits such as feet and legs, dairy character, and rear udder were the most difficult and showed the least amount of agreement between judges in their appraisal. Correlation analyses substantiated the above results.

In a later study by Wilcox, et al. (1958), the effects of season, age, and stage of lactation were studied on 918 ratings of 113 Holstein cows. Season effects caused fall ratings to be lower for each trait than spring ratings. Younger animals were shown to score lower than older cows, in agreement with Hyatt and Tyler (1948). Although the trend was not general for all traits, mammary system and feet and legs scored lower in late lactation than in early and mid lactation. Dairy character ratings also declined with advancing stages of lactation.

The authors stated that adjustment factors for systematic environmental effects would seem justified to allow for more sensitive studies in the field of dairy cattle type. Substantiating work to this article was published by Wilcox, et al. (1959). Classifier, age, stage of lactation, season, and year were all evaluated in an attempt to obtain more valid estimates of type heritabilities. The data used covered a thirteen year period in the New Jersey Agricultural Experiment Station (1945 to 1957) and involved 2,708 ratings of 278 Holstein cows. Definite age effects were noted in the data. Cows also scored higher in the winter than the summer season. Stage of lactation effects indicated higher scores for overall ratings in late lactation. Dairy character scores declined in late lactation in agreement with the previous work by Wilcox, et al. (1958). Classifier differences were quite evident for fore and rear udder, rump, and feet and legs. In this particular set of data, year trends were negative. A total of 22 per cent of the within cow variation was attributed to these five factors.

The importance of herd and sire effects on type appraisal scores were demonstrated by Van Vleck (1964). The data used was part of a special type evaluation of 23,000 cows of all breeds conducted by Cornell University. Two age groups - older than and younger than 35 months of age were studied. Herd components accounted for less than 10 per cent of total variance for most body and udder traits. Paternal half-sib correlations yielded estimates of heritability of around 25 per cent for body characteristics and levelness of udder floor, depth of udder, and strength of udder attachments. The author stated that herd effects had much smaller influences on most type traits than on production traits, a conclusion reached previously by Harvey and Lush (1952). Carter, et al. (1965) using Canadian data from 29,000 Holstein first lactation classifications reported 8 per cent of the total variance to be due to between-herd differences and 7 per cent due to sire within herd differences. Heritability estimates ranged from 0.11 for general appearance to 0.35 for body capacity.

Using official Holstein classification results from 31,719 cows classified from 1950 to 1963, Specht, et al. (1967) reported that about 10 per cent of the variation in overall type score was accounted for by herd differences. Classifiers and sires accounted for 2 to 6 per cent and 5 to 8 per cent of the variation in classification results, respectively. In other work examining the effects of age, stage of lactation, appraisal date, and herd, White, et al. (1967) found that age at appraisal significantly affected several of the 22 traits involved in their North Carolina Institutional Breeding Association herds. Back, hind legs, pasterns, depth of barrel, chest, and many udder traits were shown to be affected by age. Stage of lactation affected traits such as withers, hind legs, depth of barrel, width and height of rear udder, and fore and rear udder attachment. Date of appraisal significantly affected 14 of the 22 traits and herd differences were noted in 19 traits. These four variables accounted for 3 to 24 per cent of the variation in type appraisal results. Norman and Van Vleck (1970) analyzed over 23,000 Holstein type appraisals obtained in a study performed on New York cattle by Cornell University. Their results were similar to those of White, et al. (1967) in that age and stage of lactation effects were apparent for many of 12 management, 16 body, and 21 udder ratings. Interaction between age and stage of lactation was shown to be small, however. Herd components were small (0 to 10 per cent) for all type traits and year trends were nearly nonexistent (-2 to 3 per cent). This work supported earlier findings of Hansen, et al. (1969) who also studied age and stage of lactation effects in Wisconsin Holsteins. These researchers found highly significant age and stage of lactation effects for final score and the four scorecard components, (general appearance, dairy character, body capacity, and mammary system), on 2,518 cows in 41 herds. With the exception of dairy character, all traits scored higher at the beginning and at the end of lactation than in the middle months. Dairy character scored highest in the third month of lactation and also showed significant interaction between age and stage of lactation.

The effects of age and stage of lactation on type classification results have been well known for many years and much of the previous literature has suggested the need for correction factors in both institutional and breed organization classification programs. Lush and Shrode (1950), in discussing the two common methods of determining age correction factors (the gross comparison and the paired record method), showed the inherent biases in each method. In the gross method, the older animals are usually of superior genetic merit to younger animals due to the effects of selection and correction factors based on such comparisons are biased upwards. The pairing of successive records, however, yields correction factors which are biased downward due to the incomplete repeatability of records. Johnson and Lush (1942) reported repeatabilities of type scores of 0.34 for individual judge's evaluations which emphasizes the problem with this method on type traits. Environmental time trends may further complicate correction factors. Biases in correction factors obtained by both methods must be recognized. However, Lush and Shrode (1950) pointed out that even the early correction factors for production traits (known in that day as the Kendrick factors) removed 91 per cent of the age variance. Miller (1964), in examining age correction factors for milk production by regions, found that biases due to selection (the primary cause of variation between the gross and paired method) were extreme only for the Western Midwest and Plains regions of the country. He also explained a technique for developing gross correction factors which would smooth out the curve of multiplicative correction factors. The technique involved determining a ratio between the mean production (or type score) for a particular age group and the age group chosen as a base, weighting each ratio for those ratios on either side of it, and fitting a curve by hand to the resulting data points. His results demonstrated that such gross correction factors exceeded those determined by the paired method at ages less than maturity, and were less than the paired method at ages beyond maturity. These results were in agreement with the theory expounded by Lush and Shrode (1950). Age correction factors for type developed by Kliewer (1971) ranged from 1.07 for animals scored at ages less than 24 months to 0.95 for animals scored at more than 167 months of age. Kliewer used 60 months (5 years) as a mature base in developing his factors.

Estimates of Heritability, Phenotypic and Genetic Correlations Between Type Traits

Many estimates of heritability of type characteristics may be found in the recent literature. Many of the early articles were based on type classification results from breeds other than Holstein. The justification of multi-breed estimates of heritability of type comes from the fact that heritability estimates are specific for a given population of cows at a given point in time. Breed differences should be expected and the estimates of heritability should change as selection is practiced over time. One early estimate of the heritability of type score in Ayrshire cattle came from Tyler and Hyatt (1948). Using the intra-sire regression of daughter on dam procedure, an estimate of 0.28 was obtained. Freeman and Dunbar (1955) studied 1,180 Ayrshire daughter-dam pairs on a within-herd basis and obtained an estimate of heritability of final rating of 0.31 $\pm$ 0.15. Estimates of heritability of other traits varied from 0.06 for udder attachments to 0.32 for breed character and rump and thighs. The 95 per cent confidence limits ranged from $\pm$ 0.11 to $\pm$ 0.18. These authors also obtained estimates of phenotypic and genetic correlations between various traits. Phenotypic correlations between final rating and all traits were quite high, being in excess of 0.50. The largest phenotypic correlation in the study was 0.87 between breed character and final rating. Genetic correlations were much more variable, ranging from -0.18 for feet and legs with udder, teats, veins and quality to 6.43 for general quality with udder size and shape. Such correlations, as pointed out by the authors, were beyond the range of reason and were due to sampling errors in the data. Such results testify to the difficulty in obtaining reliable genetic correlations. The authors also pointed out the possibility of considerable environmental correlations in their data, causing phenotypic correlations to be of limited value without knowledge of genetic and environmental components.

Butcher, et al. (1963) reported heritabilities, phenotypic and genetic correlations based on official classification results from 8,165 daughter - dam pairs. Year and inspector differences were ignored in the analysis and an intra-sire-herd model was used. Age correction factors were applied to the data. In general, heritability estimates for type were lower than those reported by Freeman and Dunbar (1955). The heritability of final type score was estimated at 0.18 ± 0.054. Breed character and rump and thighs were estimated at 0.22. Udder traits were much lower with heritability estimates of 0.06 for shape and size, 0.15 for attachments, and 0.07 for teats, veins, and quality. Phenotypic correlations between final type and other type traits ranged from 0.36 for head and neck and general quality to 0.62 for breed character. Genetic correlations were much less variable than the estimates of Freeman and Dunbar (1955). The maximum value was 1.00 between final type and general quality. All genetic correlations for type were positive with standard errors less than 0.10. The lowest genetic correlations were between feet and legs and other traits, ranging from 0.17 for teats, veins, and quality to 0.59 for final type. Selection on final type to improve milk fat was shown to be 2 per cent as effective as selection on one fat record alone.

Tabler and Touchberry (1956), using Jersey type scores, examined the question of whether numerical ratings of type classification results should be equidistantly separated. The normal procedure at that time was to code excellent ratings as 6, very good as 5, and so forth down to fair at 2. The scoring has been reversed since, at least for Holstein data. Using the daughter - dam procedure on 2,810 pairs, the authors determined that the coding system was quite satisfactory. The intra-sire heritability estimate derived from the study was 0.28. When a dam's record was repeated for each daughter, no significant differences in heritability estimates resulted. This work provided sound scientific reasons for coding type scores as well as repeating a dam's record if more than one daughter per dam appeared in the data.

Heritability estimates for type in Brown Swiss cattle were reported by Johnson and Fourt (1960). The data was from official classification results on 3,161 daughter - dam pairs classified from 1950 to 1953. The heritability estimates obtained ranged from 0.23 for dairy character to 0.36 for rump. The 95 per cent confidence limits ranged from $\pm$ 0.11 to $\pm$ 0.16 for all traits. Phenotypic correlations between final type and other traits ranged from 0.33 with feet and legs to 0.79 with general appearance. Feet and legs were lowly correlated phenotypically with all traits. All genetic correlations were quite high in this study generally exceeding the phenotypic correlations and ranging from 0.54 between rump and rear udder to 0.99 between dairy character and mammary system. Comparisons of this study with others was difficult, due to breed and trait differences. The only heritability estimates for type available on Guernsey cattle were presented by Berousek, et al. (1959). Using the intra-herd, intra-sire regression of daughter on dam from 1,981 pairs, an estimate of heritability of final type rating of 0.28 was obtained. This trait had a repeatability of 0.43. Other estimates of heritability ranged from 0.16 for dairy character to 0.32 for teat placement. Repeatabilities ranged from 0.20 for dairy character to 0.52 for rump.

Heritability estimates and other parameter estimates on Holstein cattle are more numerous in the literature than for other breeds. Comparisons between the results of five different authors are presented in Table 1.

Considering the differences in approach, data source, and models, previous heritability estimates were in fairly good agreement. The estimates presented by Legates (1971) were, however, considerably higher than other estimates in Table 1. While his study was done on the new Holstein descriptive type evaluation system, it is doubtful such extremely high heritability estimates would result from redefined traits.

Generally speaking, the more subjective the evaluation of a trait, the lower was the estimate of heritability. Dairy character was a trait low in heritability in most studies, within and across breeds.

TABLE 1. HERITABILITY ESTIMATES OF TYPE FROM PREVIOUS STUDIES WITH HOLSTEIN DATA.

Trait / Author	Legates	Hansen *et al.*	Wilcox *et al.*	Mitchell *et al.*	O'Bleness *et al.*
Final Score	.58	.26	.12	.20	
General Appearance	.54	.21	.14	.19	
Dairy Character	.25	.20	.17	.09	.10
Body Capacity	.46	.24	.27	.12	
Mammary System	.37	.27	.09	.18	
Stature	.51				
Head	.16				.15
Front End	.24				
Back	.20				
Rump	.29				
Hind Legs	.10				.08
Feet	.12				.12
Fore Udder	.23				.16
Rear Udder	.21				.30
Udder Support	.13				
Udder Quality	.18				.28
Teats	.23				

More objective traits such as body capacity, stature, and possibly even final score usually were more highly heritable. A heritability of final score between 0.25 and 0.30 could be considered about average for all breeds. Final score in Holsteins would appear, from prior research, to be slightly lower, provided that the results reported by Legates (1971) were inflated.

Four recent reports have presented phenotypic and genetic correlations between type traits. Most of these authors also examined the phenotypic and genetic relationships between type traits and milk and fat production. Hansen, et al. (1969) reported correlations between final score and scorecard components of type from 2,518 Holstein cows involved in their study. Phenotypic correlations were higher between final score and other components than were correlations between the other traits. This was to be expected, since final score was really a composite of the other traits. The range in phenotypic correlations was from 0.35 (body capacity with mammary system) to 0.87 (final score with general appearance and mammary system). Genetic correlations followed the same general pattern, with final score having the highest genetic correlation with other traits. All the genetic correlations were positive and ranged from 0.19 (body capacity with mammary system) to 0.86 (final score with mammary system).

Wilcox, et al. (1962) also reported phenotypic and genetic correlations between type traits on 233 Holstein cows. The small numbers involved in this study caused rather large standard errors. Results were in general agreement with Hansen, et al. (1969), with phenotypic correlations being greater than genetic correlations and highest when final score was involved. Sampling errors obscured results of genetic correlations in this study since some of the genetic correlations were greater than 1.00. Positive environmental correlations were noted in all cases. Mitchell, et al. (1961) presented phenotypic and genetic correlations from an analysis of 3,991 daughter - dam pairs from medium producing herds. These correlations were generally somewhat lower in magnitude than the estimates of other authors. Once again, the highest estimates of correlations were between final type score and other traits. All phenotypic and genetic correlations were positive, with standard errors of about 0.02 and 0.10, respectively.

Atkeson, et al. (1969) reported phenotypic correlations between type traits on 12,890 official Holstein classifications. The correlation between final score and other components ranged from 0.86 with general appearance to 0.57 with dairy character and feet and legs. The phenotypic correlations between dairy character and other traits were lower than the other traits, ranging from 0.30 with feet and legs to 0.39 with mammary system. No genetic correlations were presented in this study, but phenotypic correlations were in good agreement with other reports.

Sire-Son Relationships for Progeny Test Results

The rapid growth of progeny test information on bulls in recent years has prompted a number of studies on the relationships between a sire's progeny test and the progeny test results of his son or sons.

Practically all of these studies have dealt with production traits. This probably is due to the lack of readily available, dependable progeny test results for type traits. Several factors can affect a progeny test. Lush, et al. (1941) reported results of a study on the effect of selected mates of sires. Their findings indicated that differences in the intensity with which mates of bulls were selected would bias the sire's proof, but the bias was rarely important enough to need much correction in practice. They also pointed out, even at that early date, that herdmate comparisons could well improve the accuracy of a progeny test for production traits.

One of the first studies on results of sire-son progeny test comparisons came from Robertson (1960). Using a contemporary comparison system practiced in England and Wales, he obtained significant regressions of son on sire for milk yield in Friesian cattle. The regression obtained was below expectation by 25 per cent for milk production, but equal to expectation for fat content (b = 0.32). Selection was shown to have a small effect in improving yield for the traits in question, with improvement of one to two gallons per year for milk and 0.10 per cent annually for fat percentage.

Searle (1964) developed a method for calculating the expected (theoretical) correlation between and regression of son's proof on sire proof. According to theory, the regression of son on sire was dependent solely on the heritability of the trait and the number of daughters involved in the sire's proof. The number of daughters of the son had no effect on the expected regression. The maximum value of the expected regressions and correlations was 0.5. The correlation between son proof and sire proof was again dependent on the heritability of the trait involved. However, both the number of daughters of the son and the number of daughters of the sire affected the expected correlation.

Dickinson, et al. (1969) tested Searle's theory using sire-son pairs from all dairy breeds. For the Holstein breed, correlations and regressions for predicted difference milk were 0.27 and 0.19, for predicted difference fat 0.26 and 0.18, and for daughter - herdmate difference for milk fat per cent 0.30 and 0.37. The expected values fit the observed only for repeatabilities of sire and son in the range of 50 to 70 per cent. As repeatabilities increased, expected values were higher than observed. At lower repeatabilities, observed values exceeded the expectations. Rausch and Brum (1969) used predicted differences (PD) for production traits in Jersey sires and sons. They observed correlations and regressions of 0.29 and 0.30 for PD milk and 0.33 and 0.34 for PD fat when only the oldest son of each sire was analyzed. The correlations were lower than expectations in this analysis. However, when the average value of all sons of each sire was analyzed, observed values more nearly approached expectations.

The use of progeny test results to improve dairy cattle for particular traits has been a topic of interest to several researchers. Miller, et al. (1969) studied mean PD's of sires of sons across years in an effort to determine selection pressure for production. They noted positive trends in selection on predicted difference milk in all breeds except Brown Swiss. Holstein breeders showed a strong positive selection pressure for PD milk. The authors stated, however, that 50 per cent of the opportunity for genetic improvement between 1945 - 1960 had been wasted. As an extension of this article, Lytton, et al. (1969) examined sires of artificial insemination (A.I.) sons and sires of non-AI sons. They found, across breeds, a superiority of from 5 to 50 kg for PD milk for the sires of AI sons. They hastened to point out, however, that future sires of AI bulls could and should have even higher selection differentials when compared to sires of non-AI sons.

The usefullness of the new Holstein descriptive type evaluation system as an indicator of production and staying ability in first lactation was examined by Miller, et al. (1971). These workers reported that progeny average type was nearly independent of progeny average milk yield. Udder traits were found to be the most important of the type traits in determining staying ability and production. Rear udder seemed to be most important for predictive purposes. However, the squared multiple correlation (R^2) value for predicting breeding value for milk from progeny type was only 8.1 per cent. Therefore, the value of descriptive type classification in predicting progeny merit for milk yield is probably limited. However, the usefulness of descriptive type in predicting son's progeny performance for descriptive type traits was not examined. This topic was examined by Cassell, et al. (1971). Correlations and regressions for daughter average type and difference from expectancy ranged from 0.24 to 0.38 for sire - son pairs where the sire's record was repeated for each son and for sire- oldest son pairs. The values for per cent of daughters in desirable categories ranged from 0.23 to 0.34 for teats, udder support, udder floor, and stature. However, correlations and regressions were lower (0.07 to 0.16) for feet, rear udder attachment, rear legs, and udder quality. The authors noted that at least as much emphasis had been placed on type as on production in selecting sires of future AI bulls. These results indicated that some traits in the descriptive breakdown were of less value in selection decisions than were others. The rate of genetic progress for the lowly heritable traits would be expected to be so slow that selection for such traits would be virtually useless.

MATERIALS AND METHODS

Source of Data

In January, 1967, the Holstein-Friesian Association of America instituted a new classification program which included descriptive codes on twelve type traits and an additional miscellaneous code along with final score and scorecard component breakdown traits. The traits involved in the descriptive code system are presented in Figures 1 and 2. Final score was a numerical rating from 0 to 100 points, with the following classification ratings arising from it: excellent (90 to 100 points); very good (85 to 89 points); good plus (80 to 84 points); good (75 to 79 points); fair (65 to 74 points); and poor (64 points or less). The scorecard component traits, final classification (another expression of final score), general appearance, dairy character, body capacity, and mammary system were scored from excellent to poor. Numerical values from 1 to 6 were applied to these evaluations with 1 representing excellent down to 6 representing poor. The data for this study included over 750,000 such classification scores on registered Holstein-Friesian cows recorded from January 1, 1967 to September 30, 1971.

In accordance with the rules of the Association in effect through December, 1970, once a cow was classified at a certain level, she would never be lowered from that score, regardless of changes in her conformation. Her classification score could only be raised. This fact caused two distinct problems in the data. First, it was neces-

Terms -- General

STATURE

1. Upstanding
2. Intermediate
3. Low Set

HEAD

1. Clean-cut, well proportioned with style and strength
2. Strong-lacking style
3. Short
4. Plain and/or coarse
5. Weak

FRONT END

1. Shoulder smoothly blended, chest strong and wide
2. Medium strength and width
3. Coarse shoulder and neck
4. Narrow and weak

BACK

1. Straight full crops, strong wide loin
2. Medium strength and width
3. Low front end
4. Weak loin and/or back

RUMP

1. Long and wide, nearly level
2. Medium-width, length or levelness
3. Pins higher than hips
4. Narrow, especially at pins
5. Sloping

HIND LEGS

1. Strong clean, flat bone, squarely placed, clean flat thigh
2. Acceptable
3. Sickled and/or close at hock
4. Bone too light or refined
5. Too straight

FEET

1. Strong, well formed
2. Acceptable, with no serious faults
3. Spread toes
4. Shallow heel

Figure 1. Descriptive Type Terminology for General Traits.

Terms -- Mammary

FORE UDDER

1. Moderate length and firmly attached
2. Moderate length - slightly bulgy
3. Short
4. Bulgy or loose
5. Broken and/or very faulty

REAR UDDER

1. Firmly attached, high and wide
2. Intermediate in height and width
3. Low
4. Narrow and pinched
5. Loosely attached and/or broken

UDDER SUPPORT AND FLOOR

1. Strong suspensory ligament and clearly defined halving
2. Lack of defined halving
3. Floor too low
4. Tilted
5. Broken suspensory ligament and/or weak floor

UDDER QUALITY

1. Soft and pliable
2. Intermediate
3. Could not determine
4. Meaty

TEAT SIZE AND PLACEMENT

1. Plumb, desirable length and size and squarely placed.
2. Acceptable with no serious fault
3. Rear teats back too far
4. Wide front teats
5. Undesirable shape

TERMS - MISCELLANEOUS

1. Winged shoulder
2. Front legs toe out
3. Weak pasterns
4. Crampy
5. Small for age

Figure 2. Descriptive Type Terminology for Mammary Traits.

sary to find a classification score on each cow that was a true indication of her conformation on the day she was classified. Fortunately, the original data set contained a code for cows whose score was not raised on a particular classification date and such records could be easily deleted from the data. The second problem raised by the Association's rule against lowering previous classification scores was that many cows classified prior to January, 1967 could not be raised when classified after that date. Such cows had no descriptive type information and were of no use in the present analysis. After considering the effects of this rule it was decided to eliminate those cows scored under the old system (prior to January, 1967). This restriction to the data left over 500,000 records in the data set. The problem of multiple observations on individual cows, many of which were simply duplicates of first classification scores if the cow's score was not raised in a subsequent classification, was solved by taking the earliest classification score of each animal in the data set. This editing process along with further culling to remove records with incomplete information or obviously erroneous type scores left 336,253 records representing a single observation on each cow in the data set. This bank of data served as the source for determining age correction factors, computing daughter-dam regressions, and summarizing sire progeny test results.

Development of Age Correction Factors

The effect of age at classification on classification results has been pointed out by Hyatt, et al. (1948), Wilcox, et al. (1958), Wilcox, et al. (1959), and several others. Age correction factors have been developed by other researchers (Butcher, et al., 1963 and Wilcox, et al., 1962). Kliewer (1971) presented age correction factors based on 252,656 registered Holstein classifications. Preliminary analysis of this data showed age effects to be highly significant as a source of variation in type scores. It was felt that age correction factors were necessary to improve the accuracy and reliability of sire progeny test results and daughter-dam regressions.

Age correction factors were developed by first calculating the age of each animal at classification. All animals less than 24 months of age were coded as being 24 months old. At the other extreme, all animals older than 120 months (10 years) were coded as 120 months of age. Final classification, final score, general appearance, dairy character, body capacity, and mammary system were scored as explained previously. The actual correction factors were developed using the gross comparison method described by Miller (1964). The gross mean for each trait at each age (in two month intervals, 24 months, 26 months, etc.) was obtained. The mature base chosen was 60 months of age, the same mature base as that used by Kliewer (1971). The ratio between each age mean and the mature base was calculated by using the mature base as the denominator. Such ratios were age correction factors in themselves, but additional calculations were performed to smooth out irregularities in the factors. All ratios from 28 to 116 months of age were weighted for the two ratios on either side using arbitrary weights of 1-2-3-2-1. The number of animals in each age group was also important in this weighting process. The formula for this procedure, Miller (1964), is:

$$a_i' = \frac{\sum_{j = i-2}^{i+2} K_j N_j a_j}{\sum_{j = i-2}^{i+2} K_j N_j}$$

where a_i' is the newly formed, weighted ratio, N_j is the number of records in month of age j, and K_j is the weighting factor of 1 for i - 2, 2 for i - 1, 3 for i, 2 for i + 1 and 1 for i + 2. These weighted ratios, a_i', were then plotted and a smoothed curve was fitted by hand. The ratios for 24, 26, 118, and 120 months of age were not weighted by the formula since two ratios on either side of the ratio in question were required. The age correction factors used in this study were read directly from the resulting curve.

Figures 3 through 5 show the plots of age correction factors used. Table 2 lists the actual age correction factors. Dairy character and body capacity showed the widest range in age correction factors. The greatest amount of correction was necessary at the extremes of the age distribution. The correction factors for final score presented here are in almost perfect agreement with those developed by Kliewer (1971). He reported correction factors ranging from 1.07 for ages less than 24 months to 0.95 for cows over 167 months of age. The factors used in this study range from 1.04 for 24 months to 0.97 for

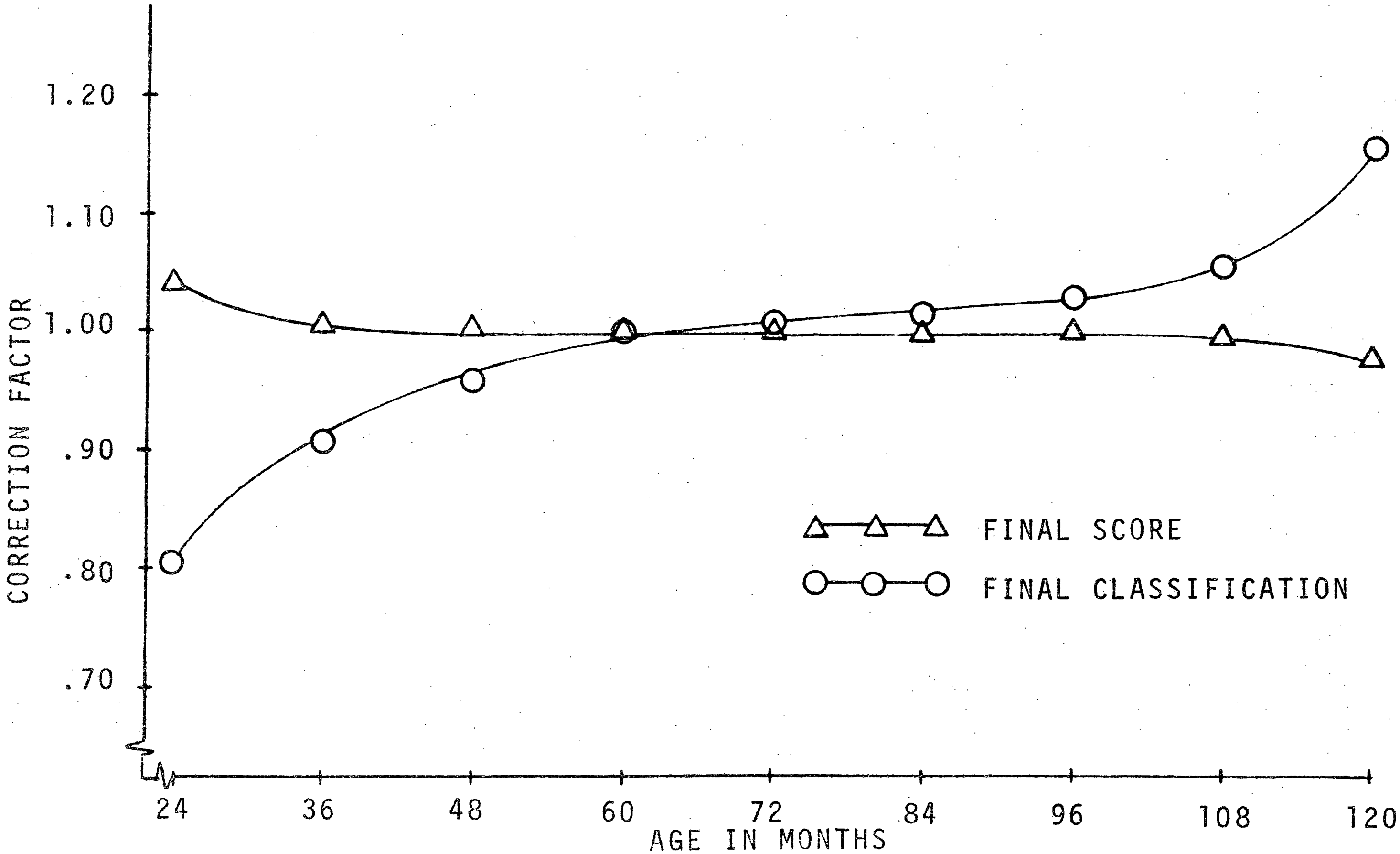

FIGURE 3. PLOT OF AGE CORRECTION FACTORS FOR FINAL SCORE AND FINAL CLASSIFICATION.

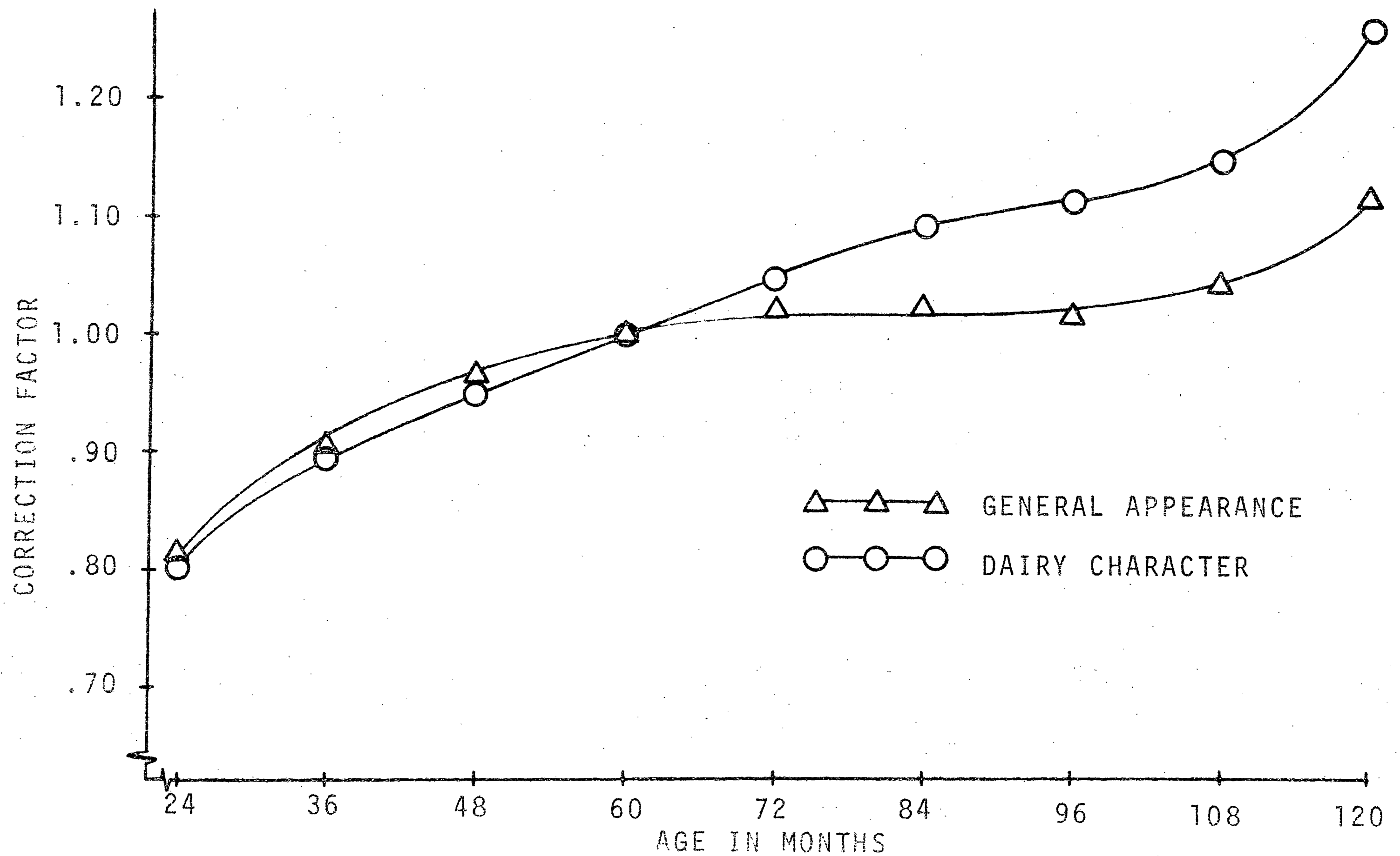

FIGURE 4. PLOT OF AGE CORRECTION FACTORS FOR GENERAL APPEARANCE AND DAIRY CHARACTER.

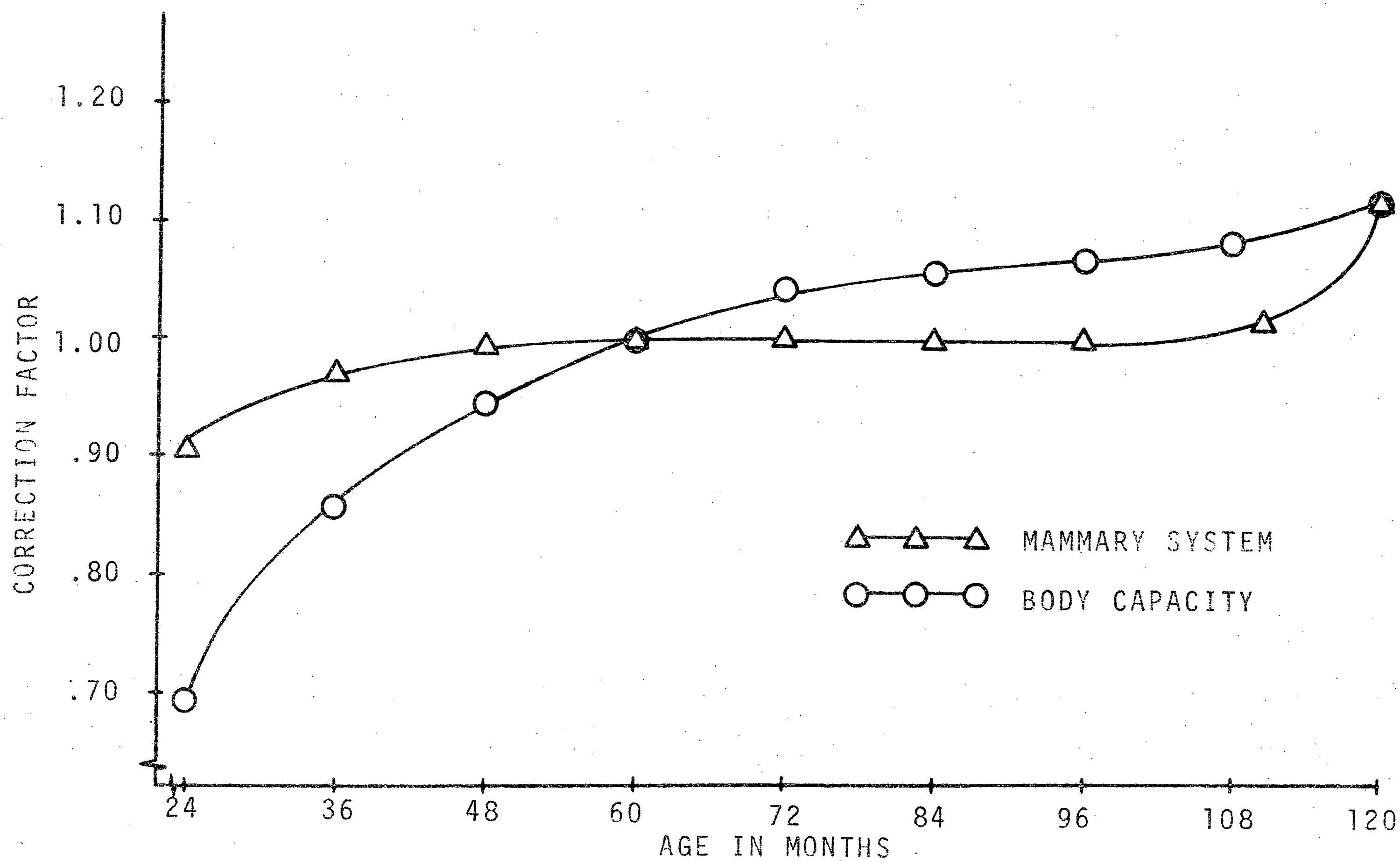

FIGURE 5. PLOT OF AGE CORRECTION FACTORS FOR BODY CAPACITY AND MAMMARY SYSTEM.

TABLE 2 . AGE CORRECTION FACTORS FOR SIX TRAITS.

Age	Score	Final Class	Gen App	Dairy Char	Body Cap	Mam Sys
24	1.04	0.81	0.82	0.81	0.69	0.91
26	1.03	0.83	0.84	0.83	0.76	0.93
28	1.03	0.86	0.86	0.84	0.79	0.94
30	1.02	0.88	0.87	0.86	0.81	0.95
32	1.02	0.89	0.89	0.87	0.83	0.96
34	1.02	0.90	0.90	0.88	0.85	0.97
36	1.01	0.91	0.91	0.89	0.86	0.97
38	1.00	0.92	0.92	0.90	0.87	0.98
40	1.00	0.93	0.93	0.91	0.89	0.98
42	1.00	0.94	0.94	0.92	0.91	0.98
44	1.00	0.94	0.95	0.93	0.92	0.99
46	1.00	0.95	0.96	0.94	0.93	0.99
48	1.00	0.96	0.97	0.95	0.94	0.99
50	1.00	0.97	0.98	0.96	0.95	0.99
52	1.00	0.98	0.99	0.97	0.96	0.99
54	1.00	0.98	0.99	0.98	0.97	0.99
56	1.00	0.99	1.00	0.98	0.98	1.00
58	1.00	0.99	1.00	0.99	0.99	1.00
60	1.00	1.00	1.00	1.00	1.00	1.00
62	1.00	1.00	1.01	1.01	1.00	1.00
64	1.00	1.01	1.01	1.02	1.01	1.00
66	1.00	1.01	1.02	1.02	1.02	1.00
68	1.00	1.01	1.02	1.03	1.03	1.00
70	1.00	1.01	1.03	1.04	1.03	1.00
72	1.00	1.01	1.03	1.05	1.04	1.00
74	1.00	1.02	1.03	1.06	1.04	1.00
76	1.00	1.02	1.03	1.07	1.05	1.00
78	1.00	1.02	1.03	1.07	1.05	1.00
80	1.00	1.02	1.03	1.08	1.05	1.00
82	1.00	1.02	1.03	1.09	1.05	1.00
84	1.00	1.02	1.03	1.09	1.06	1.00
86	1.00	1.03	1.03	1.10	1.06	1.00
88	1.00	1.03	1.02	1.11	1.06	1.00

TABLE 2 . (continued.)

Age	Score	Final Class	Gen App	Dairy Char	Body Cap	Mam Sys
90	1.00	1.03	1.02	1.11	1.06	1.00
92	1.00	1.03	1.02	1.12	1.07	1.00
94	1.00	1.03	1.02	1.12	1.07	1.00
96	1.00	1.03	1.02	1.12	1.07	1.00
98	0.99	1.03	1.02	1.13	1.07	1.00
100	0.99	1.03	1.02	1.13	1.07	1.01
102	0.99	1.03	1.02	1.13	1.07	1.01
104	0.99	1.04	1.03	1.14	1.08	1.01
106	0.99	1.05	1.03	1.15	1.08	1.02
108	0.99	1.06	1.04	1.15	1.08	1.02
110	0.99	1.06	1.05	1.17	1.09	1.03
112	0.99	1.07	1.05	1.18	1.10	1.04
114	0.98	1.09	1.06	1.19	1.10	1.05
116	0.97	1.11	1.08	1.21	1.10	1.06
118	0.97	1.14	1.09	1.24	1.11	1.08
120	0.97	1.18	1.12	1.26	1.12	1.12

120 months of age.

Even though age trends were noted for traits in the descriptive system, no correction factors were applied due to the purely descriptive nature of most of the traits. Interpretation of tenths and hundredths of units applicable to descriptive traits also presented a problem. It is possible that age correction factors for rump, for instance, would change a young cow from a 5 (sloping) to a 3.2 (pins higher than hips). This would lessen the usefulness of the descriptive system. For these reasons, age correction factors for the descriptive traits would do more harm than good.

Estimation of Heritabilities, Phenotypic, and Genetic Correlations from Daughter-Dam Relationships

The basic data source of 336,253 records was searched to locate daughter-dam pairs where two or more pairs existed in each herd. A further restriction imposed on the data was that pairs would not be included when there was more than one year difference in the age of classification of the daughter and the dam. This restriction compensated for the lack of age correction factors for the descriptive traits. Further, in cases where the dam had more than one daughter, only the youngest daughter was used to create a daughter-dam pair. Finally, if the daughter was in one herd and the dam in another, the pair was not included in the analysis. The original data yielded 30,715 pairs which satisfied these requirements.

The work of many researchers has shown the need for removing herd effects from type data prior to the estimation of heritability. Year of classification has also been shown to significantly affect type scores in some data sources. The model chosen for analysis in this study did not include effects due to years.

An analysis of variance was performed fitting herd code and year of classification of the daughter as main effects. Table 3 shows the results after equating mean squares to their expectations for daughter score. Herd effects, accounting for over 30 per cent of the variance in this trait were obviously quite important. Year of classification effects, while significant ($P < 0.01$) were responsible for less than 1 per cent of the total variance in final score of the daughter. Results were similar for other traits. The lack of any significant trend in Table 4 further demonstrates the non-importance of year effects. Tables 3 and 4 provided justification for not fitting year of classification as an effect in the model.

Table 5 is a generalized form of the analysis of variance used in the determination of heritability estimates. A total of 3,662 herds were involved in the daughter-dam analysis of the 30,715 daughter-dam pairs. This indicated an average of more than eight pairs per herd which should be sufficient for accurate estimates of heritability on a within herd basis. Prior to analysis, the daughter-dam pairs were age adjusted for the six traits mentioned previously. Descriptive traits were coded as desirable (1) or undesirable (0) and were analyzed on both an as-scored and a desirable-undesirable basis. For all descriptive traits except udder quality, a coding of 1 or 2

TABLE 3. ANALYSIS OF VARIANCE TABLE FOR DAUGHTER SCORE WITH HERD AND YEAR OF CLASSIFICATION EFFECTS INCLUDED IN THE MODEL.

Source	df	Mean Square	Component	Per Cent of Variance
Herd	3,661	37.82	5.21	30.54
Year	4	230.47	0.06	0.35
Residual	27,049	11.79	11.79	69.11
Corrected Total	30,714	14.92	17.06	100.00

TABLE 4 . MEAN OF FINAL SCORE OF DAUGHTERS AND NUMBER OF DAUGHTERS CLASSIFIED PER YEAR.

Year	Number of Daughters	Average Score of Daughters
67	10	81.50
68	1,325	79.88
69	4,834	79.78
70	12,625	79.63
71	11,921	80.01
Overall Mean	30,715	79.81

TABLE 5. FORM OF ANALYSIS OF VARIANCE USED TO DETERMINE HERITABILITIES.[a]

Source	df	$EMS_{(D)}$	$EMP_{(Dd)}$	$EMS_{(d)}$
Total	30,714			
Herd	3,661			
Residual	27,053	σ_D^2	σ_{Dd}	σ_d^2

[a] D represents dam component, d represents daughter component.

was considered desirable and all others undesirable. For udder quality, only code 1 was considered desirable. After this conversion, a total of 30 traits were analyzed in each pair. The miscellaneous code in the descriptive traits did not lend itself to analysis and was dropped from the data.

Heritability estimates were determined by doubling the within herd regression of daughter on dam. Standard errors of the heritability estimates were calculated using the following formula:

$$\sigma_h 2 = 2 \sqrt{\frac{1}{N-2} \left[\frac{\sigma^2 d}{\sigma^2 D} - b^2\right]} .$$

The value of N in this formula was the degrees of freedom for the residual source in Table 5.

Computations of the genetic correlations were performed according to the following formula:

$$r_G = \left[\frac{(ay) \cdot (xb)}{(ab) \cdot (xy)}\right]^{1/2}$$

where r_G is the genetic correlation between the two traits, (ay) is the covariance between trait 1 in the dam and trait 2 in the daughter, (xb) is the covariance between trait 2 in the dam and trait 1 in the daughter, (ab) is the covariance between trait 1 in the dam and trait 1 in the daughter, (xy) is the covariance between trait 2 in the dam and trait 2 in the daughter. Standard errors of the genetic correlations were calculated using the method described by Reeve (1955).

On certain occasions, the covariances between traits in the numerator of the genetic correlation were opposite in sign. In these instances, the genetic correlations were calculated using the following formula:

$$r_G = \frac{(ay) + (xb)}{2[(ab) \cdot (xy)]^{1/2}}$$

Covariance components were the same as those listed previously. Formulas for genetic correlations were presented by Reeve (1955).

Determination of phenotypic correlations was accomplished by separating daughter-dam pairs into two records and analyzing the resulting data set. Thus, phenotypic correlations between traits were based on 61,430 records instead of 30,715.

Sire-Son Relationships for Progeny Test Data

The 336,253 individual cows involved in this study were the offspring of 27,907 different sires. However, in order to be included in a sire-son pair, each bull was required to have a minimum of 8 daughters classified. This number should provide a reasonably accurate progeny test and satisfy the need for as many sire-son pairs as possible, especially the non-AI bulls to be described later. Progeny test results included the average daughter score for each sire for the six scorecard component traits and the 12 descriptive traits used in the daughter-dam analysis. Additionally, the per cent of daughters in the desirable categories for each of the 12 descriptive traits was calculated for each sire.

Sire-son pairs were created from the 5,598 sires with 8 or more daughters. A total of 1,872 sire-son pairs resulted. An additional code on sire records classified each sire as an artificial insemination (AI) sire or as a non-artificial insemination (Non-AI) sire. Any sire with daughters in four or fewer herds was placed in the Non-AI category, while all others were classified as AI sires. Four groups of sires and sons were created from the original 1,872 sire-son pairs. AI sires with AI sons formed the first group, AI sires with Non-AI sons the second, Non-AI sires with AI sons the third, and Non-AI sires with Non-AI sons made up the fourth group. Regressions of son progeny test on sire progeny test and correlations between the two were obtained on all 30 traits.

The analysis of sire-son relationships for all traits was performed repeating a sire's record for each of his sons. This procedure seemed acceptable in determining the relationships from the work of Cassell, et al. (1971) and Rausch, et al. (1969). Repeating a sire's record for each son allowed for use of all available sire-son pairs.

RESULTS AND DISCUSSION

Analysis of Daughter - Dam Relationships

Age correction factors were applied to the first six traits listed in Table 6. However, the non-linear nature of the descriptive traits prevented age correction of the descriptive traits and any relationships between dams and their daughters could be confused by age and selection effects in these traits. Therefore, dams were required to be within one year of their daughter's age when they were classified before the pair was included in the analysis. All age groups would still be represented in the data source, but age differences in descriptive type traits should be less of a problem with this requirement imposed.

Characteristics of Daughter - Dam Type Scores

Table 6 presents the means and standard deviations of all traits for dams, daughters, and all records combined. The average final score of dams was higher in this study than their daughters by 0.8 points. With 30,715 pairs involved in this study, such a difference, even after age correction, indicated at least some selection was practiced on final score. Final classification, general appearance, dairy character, and mammary system demonstrated the same trend. There was no difference in the scores of daughters and dams for body capacity. For the descriptive traits on an as scored basis, dams excelled daughters in head, front end, back, rump, hind

TABLE 6 . MEANS AND STANDARD DEVIATIONS OF TRAITS INVOLVED IN THE DAUGHTER-DAM ANALYSIS.

Trait	All Records	Dam Only	Daughter Only
Final Score	80.2 ± 3.7	80.6 ± 3.6	79.8 ± 3.7
Final Classification	3.1 ± .7	3.1 ± .7	3.2 ± .7
General Appearance	3.3 ± .8	3.3 ± .8	3.4 ± .8
Dairy Character	2.2 ± .5	2.1 ± .5	2.2 ± .6
Body Capacity	2.3 ± .6	2.3 ± .6	2.3 ± .6
Mammary System	3.4 ± .9	3.4 ± .9	3.5 ± .9
Stature	1.9 ± .7	1.9 ± .6	1.9 ± .7
Head	2.9 ± 1.0	2.8 ± 1.1	3.1 ± 1.0
Front End	2.1 ± .8	2.1 ± .8	2.2 ± .9
Back	2.1 ± 1.0	2.0 ± 1.1	2.2 ± 1.0
Rump	2.9 ± 1.2	2.7 ± 1.2	3.1 ± 1.2
Hind Legs	2.9 ± .9	2.7 ± .8	3.0 ± .9
Feet	2.6 ± .9	2.5 ± .9	2.7 ± 1.0
Fore Udder	2.6 ± 1.0	2.6 ± 1.0	2.6 ± 1.0
Rear Udder	2.4 ± .8	2.4 ± .8	2.5 ± .8
Udder Support	1.5 ± 1.0	1.6 ± 1.0	1.5 ± 1.0
Udder Quality	1.9 ± .6	1.9 ± .7	1.8 ± .7
Teats	2.4 ± 1.4	2.2 ± 1.4	2.5 ± 1.3
	Desirable-Undesirable categories		
Stature	.84 ± .36	.86 ± .35	.83 ± .37
Head	.47 ± .50	.54 ± .50	.40 ± .49
Front End	.83 ± .38	.86 ± .35	.80 ± .40
Back	.75 ± .43	.78 ± .42	.73 ± .44
Rump	.52 ± .50	.61 ± .49	.43 ± .50
Hind Legs	.36 ± .48	.41 ± .49	.31 ± .46
Feet	.64 ± .48	.68 ± .47	.60 ± .49
Fore Udder	.61 ± .49	.63 ± .48	.59 ± .49
Rear Udder	.62 ± .49	.65 ± .48	.59 ± .49
Udder Support	.70 ± .46	.68 ± .47	.71 ± .45
Udder Quality	.92 ± .27	.93 ± .26	.92 ± .28
Teats	.67 ± .47	.67 ± .47	.68 ± .47

legs, feet, rear udder, and teats. Daughters were superior to their dams for udder support and udder quality. Physiologically these two traits would be expected to decline in score with age, even if only one year's difference in age at classification was involved. When the descriptive traits were scored as desirable or undesirable, higher values indicated superiority. The reverse is true with scores expressed on an as-scored basis. Examination of average scores indicated that dams scored higher than daughters for all traits except udder support and teats. The degree of superiority of dams over daughters for descriptive traits, regardless of method of expression, seemed to be greater than for the first six traits in the table. Since the descriptive traits were not age adjusted, some age or selection effects could still be present in the data. With the bias of the gross comparison method of age adjustment in mind (over correction of young animals, under correction of older animals) the comparison of dam with daughter for the age - adjusted traits was probably biased in favor of younger animals while the comparisons for descriptive traits were probably biased in favor of older animals. The differences in mean final scores of dams and daughters in this study were comparable to the results of Freeman and Dunbar, (1955) who found average scores of 83.2 and 82.9 for Ayrshire dams and daughters. In their study, however, dams were more variable in final score than were daughters with standard deviations of 3.2 for dams and 3.0 for daughters. Such a situation was not true in this study, since daughters had a higher standard deviation (3.7) than dams (3.6). Butcher, et al. (1963) found dams in their study to be superior to daughters in many traits in Ayrshire cattle, in agreement with the present analysis. However, dams were reported to be a more variable group. From the standard deviations presented in Table 6, dams and daughters appeared to have quite similar degrees of variability over all traits. This would be expected, since age differences had been minimized. The average values of each trait expressed in all records were in agreement with the means presented by Legates (1971) who had the most comparable data source to the present study to be found in the literature.

Herd Effects

The analysis of variance performed on all type traits in dams and daughters showed herd effects to be a highly significant source of variation in type scores. This analysis, however, failed to demonstrate which traits were more affected by the herd in which they were expressed. Table 7 lists the per cent of total sum of squares for each trait attributable to the sum of squares among herds. This approach to estimating the importance of herd effects in various type traits was not entirely the same approach used by other authors. Others have treated herds as random effects and calculated the per cent of variance due to herds by variance component analysis.

In the present study, herd effects were greater for final score, final classification, general appearance, dairy character, body capacity and mammary system than they were for the descriptive traits.

TABLE 7 . PROPORTION OF THE SUMS OF SQUARES ATTRIBUTABLE TO HERD EFFECTS IN DAM AND DAUGHTER TYPE TRAITS.

TRAIT	% of Variation		TRAIT Desirable-Undesirable	% of Variation	
	Dam	Daughter		Dam	Daughter
Final Score	31	30	Stature	18	20
Final Class.	28	28	Head	21	21
General App.	28	28	Front End	17	20
Dairy Cha.	23	22	Back	17	17
Body Capacity	24	28	Rump	18	20
Mammary Sys.	25	22	Hind Legs	21	18
Stature	21	24	Feet	22	22
Head	22	20	Fore Udder	19	19
Front End	20	24	Rear Udder	20	21
Back	19	18	Udder Support	21	18
Rump	19	21	Udder Quality	15	15
Hind Legs	19	18	Teats	19	17
Feet	24	23			
Fore Udder	20	20			
Rear Udder	21	21			
Udder Support	18	16			
Udder Quality	21	20			
Teats	20	18			

One possible cause for this result could be that selection practices differ more among herds for these traits than for descriptive traits. Additionally, several of the traits in the descriptive categories such as back, rump, and hind legs have little association with the first six traits and selection practices on the first six traits would not change herd to herd variations in these descriptive traits. Management practices which differ from herd to herd could have affected stature and feet, causing large among herd variation. The estimates of among herd variation in this study were similar to those appearing in the literature, even in light of the differences in approach. The range of 15 to 31 per cent in this study was similar to the findings of Legates (1971), who reported herd effects of from 1 per cent for stature in 5 year olds to 35 per cent for the final score in the same age group. Herd effects on descriptive traits in this study were higher across the board than those presented by Legates (1971), due probably to the wide range of age groups in the present study. The results in Table 7 demonstrated the need to calculate heritabilities and genetic correlations on a within-herd basis. This procedure has been followed by practically all previous work in this area.

Heritability Estimates

Heritability estimates from the within-herd regression of daughter on dam for the 30,715 pairs involved in the analysis are presented in Table 8. These estimates range from a low of 0.00 for udder quality expressed as desirable-undesirable to a high of 0.38 for stature ex-

TABLE 8. HERITABILITY ESTIMATES AS DETERMINED BY THE WITHIN-HERD REGRESSION OF DAUGHTER ON DAM.

Trait	Heritability[a]	
	as scored	desirable undesirable
Final Score	.31	
Final Classification	.25	
General Appearance	.26	
Dairy Character	.15	
Body Capacity	.23	
Mammary System	.20	
Stature	.38	.23
Head	.11	.06
Front End	.11	.06
Back	.14	.13
Rump	.21	.16
Hind Legs	.07	.09
Feet	.08	.07
Fore Udder	.16	.13
Rear Udder	.17	.13
Udder Support	.13	.12
Udder Quality	.04	.00
Teats	.17	.18

[a] Standard errors were .01 for all traits.

pressed on an as-scored basis. The standard errors of the estimates were low, being 0.01 in all cases. These estimates were largely free of the effects of herds and age differences which were removed through correction factors and restrictions on the data as explained previously. These estimates were in general agreement with the findings of Hansen, et al. (1969) and Mitchell, et al. (1961) as presented in Table 1. The estimate of final classification found in this study (0.31) was slightly higher than the 0.20, 0.12 and 0.20 found by Hansen, et al. (1969), Wilcox, et al. (1962), and Mitchell, et al. (1961), respectively, but was considerably lower than the estimates reported by Legates (1971) which varied from 0.58 for three year olds to 0.71 for four year olds.

Dairy character has been shown (Table 1) to have lower heritability estimates than the other scorecard component traits. The reported value for dairy character of 0.15 from this study was in agreement with previous findings. The heritability estimate for mammary system, 0.20,was lower than the 0.27 reported by Hansen, et al. (1969), but higher than the estimate of 0.18 by Mitchell, et al. (1961) and 0.09 by Wilcox, et al. (1962). The major discrepancy noted between the results of this study and those reported in the literature, however, involves the work of Legates (1971). His estimates of heritability exceeded those of the present study in all five of the scorecard component traits. In 23 of the 24 descriptive traits, the estimate for four year olds of Legates (1971) exceeded those of the present study. General agreement was noted for most ages in udder quality expressed as desirable or undesirable where Legates reported estimates of 0.00 to 0.01. However, his estimate for five year old cows of 0.10 was well above the estimate of 0.00 from this analysis. Differences were extreme for stature, rump, and fore and rear udder. However, the ranking of traits by heritability estimates from the two studies would be quite similar. The probable cause for the observed differences could be the model used by Legates (1971). Sires, while considered cross classified with herds in his study, often had daughters in but two or three herds. Single herd sires were removed. The effect of many missing subclasses would likely bias upward the sire component of variance because of comfounding between sire and herd effects.

The estimates of heritability in this study provide reason for concern in type evaluation of certain traits of obvious economic importance. The heritability estimates of udder traits in the descriptive traits were low, indicating little likelihood of improvement through selection. The heritability estimates for hind legs and feet indicate the same problem. The udder and feet and leg traits are at least potentially related to long, productive lives in dairy cattle. The traits pointed to by the work of Miller, et al. (1971) as most related to the utility of a dairy cow were udder traits with rear udder being the most consistently useful for predictive purposes. These results do not give reason for much optimism in the improvement of several functional type traits in the Holstein descriptive classification system. The basic problem is probably the subjectivity involved in the evaluation of the traits. The more objectively measured traits such as stature and rump show considerably higher heritabilities.

Two traits in the descriptive system seem to be of little value. Head, which is only moderately heritable to begin with, is functionally of little importance. Udder quality, while functionally important, was so lowly heritable as to be of little value in a selection program. If improvement in the descriptive type classification system is to be made, as much subjectivity as possible must be removed from the evaluation of hind legs, feet, fore and rear udder, udder support and teats. Dropping head and udder quality from the program would cause little loss. If the traits are kept, they should be used for what they are - descriptive traits and not tools for selection decisions.

Phenotypic and Genetic Correlations

The formula used for calculating genetic correlations involved use of the geometric mean of two covariances in most instances in this study. However, the covariances between the two traits in dams and daughters were opposite in sign in 18 cases. These 18 pairs of traits are as follows: udder quality on an as-scored basis with head and front end on an as-scored basis; udder quality on a desirable - undesirable basis with dairy character, body capacity, mammary system, front end, hind legs, feet, fore and rear udder with all descriptive traits expressed on a desirable - undesirable basis; stature with udder support; head and feet and teats; back with feet and udder support; and rump with feet, fore udder and udder support. All of the last eight pairs were expressed on a desirable - undesirable basis.

When opposite signs occurred the arithmetic mean of the two covariances was used. The results from these two approaches have been shown to differ (Reeve, 1955), but the author was unable to determine which approach contained the least bias. Tables 9 and 10 contain genetic and phenotypic correlations and the standard errors of the genetic correlations. Standard errors of genetic correlations were quite low, usually less than 0.10. The heritability of udder quality expressed as desirable or undesirable was estimated to be zero. Since genetic correlations are not defined for non-heritable traits, a heritability of 0.01 was used in computing genetic correlations which involved this trait.

The phenotypic correlations listed in Table 9 were negative between final score and all other traits. This was to be expected, since higher scores for final score represent better type animals, while lower scores for all other traits represent better animals. Phenotypically, final score was more highly correlated with other traits than was final classification, though the results were in quite good agreement. Genetically, however, final classification was somewhat superior to final score in its correlation with other traits. The genetic correlation between final score and final classification was 1.01 ± 0.08, indicating that both traits were measures of the same thing, which, in fact, they are. The first six traits in the analysis were more highly correlated with each other genetically than they were phenotypically. General appearance was more highly correlated

TABLE 9. PHENOTYPIC AND GENETIC CORRELATIONS BETWEEN TRAITS WITH DESCRIPTIVE TRAITS EXPRESSED ON AN AS-SCORED BASIS.[a,b]

	Final Score	Final Class	Gen. App.	Dairy Cha.	Body Cap.	Mammary Sys.	Stature	Head	Front End	Back	Rump	Hind Legs	Feet	Fore Udder	Rear Udder	Udder Supp.	Udder Qual.	Teats
Final Score		1.01±.08	.93±.07	.64±.07	.81±.06	.82±.07	.70±.04	.43±.06	.79±.09	.44±.05	.58±.05	.48±.08	.40±.07	.56±.06	.62±.06	.44±.06	.52±.13	.48±.05
Final Class.	-.91		.94±.01	.61±.03	.82±.02	.82±.02	.70±.02	.46±.04	.79±.04	.47±.04	.60±.03	.69±.07	.42±.05	.60±.03	.61±.03	.44±.04	.64±.09	.49±.03
Gen. App.	-.79	.77		.57±.04	.84±.02	.60±.03	.74±.02	.43±.04	.82±.04	.51±.04	.66±.03	.49±.05	.47±.05	.35±.04	.43±.03	.27±.04	.42±.09	.30±.04
Dairy Cha.	-.47	.45	.34		.49±.04	.36±.04	.55±.03	.23±.06	.45±.06	.27±.06	.34±.04	.23±.08	.03±.07	.10±.05	.34±.05	.11±.06	.46±.11	.24±.05
Body Cap.	-.56	.53	.55	.23		.42±.04	.77±.02	.41±.05	.95±.04	.44±.04	.42±.03	.46±.06	.44±.06	.26±.04	.20±.04	.16±.05	.14±.09	.14±.04
Mammary Sys.	-.74	.72	.45	.27	.23		.31±.03	.36±.05	.45±.05	.22±.05	.37±.04	.39±.07	.32±.06	.84±.03	.80±.03	.59±.04	.74±.10	.72±.03
Stature	-.46	.44	.50	.28	.51	.18		.20±.04	.62±.04	.29±.03	.25±.03	.24±.05	.31±.05	.13±.03	.13±.03	.06±.04	.27±.07	.12±.03
Head	-.29	.28	.30	.17	.23	.18	.16		.49±.07	.24±.06	.30±.05	.10±.09	.23±.08	.24±.06	.31±.06	.12±.07	.02±.12	.07±.06
Front End	-.42	.39	.44	.21	.54	.19	.34	.29		.47±.06	.51±.05	.39±.09	.32±.08	.20±.06	.32±.06	.11±.07	.02±.12	.08±.06
Back	-.30	.29	.38	.11	.26	.14	.20	.16	.25		.34±.04	.16±.08	.11±.08	.10±.05	.10±.05	.09±.06	.09±.11	.12±.05
Rump	-.41	.40	.47	.14	.26	.25	.19	.19	.25	.26		.48±.07	.19±.06	.16±.04	.31±.04	.13±.05	.08±.09	.20±.04
Hind Legs	-.28	.27	.33	.11	.20	.16	.12	.16	.19	.10	.20		.11±.11	.22±.08	.07±.07	.13±.09	.19±.15	.21±.07
Feet	-.25	.24	.28	.08	.18	.15	.13	.12	.16	.08	.13	.24		.30±.07	.18±.07	.18±.08	.16±.14	.22±.07
Fore Udder	-.45	.44	.27	.08	.14	.60	.11	.13	.14	.11	.18	.09	.10		.50±.04	.42±.05	.56±.10	.53±.04
Rear Udder	-.50	.48	.33	.22	.18	.57	.14	.14	.18	.11	.22	.15	.12	.25		.38±.05	.58±.11	.36±.05
Udder Supp.	-.38	.36	.19	.10	.08	.46	.04	.05	.06	.04	.09	.05	.05	.25	.25		.62±.12	.42±.05
Udder Qual.	-.31	.29	.16	.17	.04	.38	.09	.09	.05	.06	.10	.05	.03	.29	.20	.24		.54±.10
Teats	-.35	.34	.19	.11	.07	.48	.05	.10	.07	.08	.12	.08	.06	.34	.19	.23	.23	

[a]Genetic correlations appear above the diagonal, phenotypic below.
[b]All phenotypic correlations significant (P <.01).

TABLE 10. PHENOTYPIC AND GENETIC CORRELATIONS BETWEEN TRAITS WITH DESCRIPTIVE TRAITS SCORED AS DESIRABLE OR UNDESIRABLE.[a]

	Final Score	Final Class	Gen. App.	Dairy Cha.	Body Cap.	Mammary Sys.	Stature	Head	Front End	Back	Rump	Hind Legs	Feet	Fore Udder	Rear Udder	Udder Supp.	Udder Qual.	Teats
Final Score		1.01±.08	.93±.07	.64±.07	.81±.06	.82±.07	.63±.05	.57±.10	.72±.07	.37±.04	.53±.03	.53±.04	.37±.05	.56±.03	.64±.03	.43±.04	.09±.14	.45±.03
Final Class	-.91		.94±.01	.61±.03	.82±.02	.82±.02	.63±.05	.59±.11	.70±.12	.40±.06	.55±.06	.55±.08	.39±.08	.59±.07	.62±.08	.43±.07	.14±.20	.45±.05
Gen. App.	-.79	.77		.57±.04	.84±.02	.60±.03	.65±.05	.54±.10	.74±.12	.43±.06	.61±.07	.59±.09	.44±.09	.36±.06	.44±.06	.24±.05	.38±.28	.27±.04
Dairy Cha.	-.47	.45	.34		.49±.04	.36±.04	.50±.06	.44±.11	.48±.12	.25±.06	.34±.06	.14±.07	.10±.08	.11±.06	.38±.07	.13±.06	-.17±.22	.20±.05
Body Cap.	-.56	.53	.55	.23		.42±.04	.68±.06	.52±.10	.81±.14	.33±.06	.48±.06	.47±.08	.42±.08	.26±.05	.21±.05	.14±.05	-.12±.18	.10±.04
Mammary Sys.	-.74	.72	.45	.27	.23		.27±.04	.41±.10	.38±.09	.17±.05	.27±.05	.36±.08	.29±.08	.85±.10	.80±.10	.59±.09	-.12±.18	.68±.07
Stature	.37	-.34	-.40	-.23	-.37	-.13		.44±.07	.41±.07	.26±.05	.29±.04	.21±.06	.26±.06	.10±.05	.17±.05	.08±.05	.25±.21	.08±.04
Head	.27	-.26	-.29	-.18	-.20	-.16	.16		.38±.13	.17±.09	.32±.08	.19±.11	.17±.12	.29±.09	.25±.09	.12±.10	.07±.33	.23±.08
Front End	.33	-.30	-.33	-.23	-.37	-.14	.23	.19		.23±.09	.53±.09	.37±.11	.31±.12	.19±.09	.27±.09	.12±.10	.19±.34	.13±.08
Back	.22	-.22	-.29	-.09	-.16	-.09	.13	.10	.12		.49±.05	.17±.07	.09±.08	.07±.06	-.01±.06	-.04±.07	.44±.33	.09±.05
Rump	.36	-.35	-.42	-.14	-.22	-.21	.14	.17	.17	.25		.65±.07	.07±.08	.01±.06	.37±.05	.05±.06	.14±.21	.25±.05
Hind Legs	.32	-.32	-.38	-.11	-.22	-.20	.10	.14	.13	.07	.17		.50±.09	.26±.07	.24±.07	.19±.08	.39±.35	.14±.06
Feet	.23	-.22	-.27	-.08	-.16	-.14	.09	.10	.11	.02	.10	.28		.24±.08	.15±.08	.28±.09	.28±.35	.19±.07
Fore Udder	.42	-.41	-.24	-.10	-.12	-.56	.07	.11	.09	.07	.13	.10	.08		.50±.06	.43±.06	.55±.35	.53±.05
Rear Udder	.44	-.43	-.29	-.21	-.15	-.52	.10	.11	.12	.06	.17	.17	.10	.21		.31±.05	.47±.34	.31±.05
Udder Supp.	.32	-.31	-.16	-.12	-.05	-.42	.04	.04	.06	.02	.07	.04	.04	.24	.20		.67±.39	.45±.05
Udder Qual.	.17	-.15	-.07	-.07	.01	-.19	.03	.05	.02	.03	.05	-.01	.00NS	.13	.05	.21		.19±.20
Teats	.30	-.29	-.15	-.08	-.05	-.43	.04	.06	.04	.06	.08	.06	.03	.30	.14	.22	.10	

[a]Genetic correlations listed above the diagonal, phenotypic below.
NS = non significant, all other phenotypic correlations significant ($P < .01$).

with final score both phenotypically and genetically than were any other traits except final classification. Body capacity and mammary system ranked next, with dairy character having the lowest phenotypic and genetic correlations with other type traits. The work of Mitchell, *et al.* (1961) was in general agreement with these results except that the relationships between dairy character and other traits were lower both phenotypically and genetically in the present study than they were in the work of Mitchell, *et al.* (1961). The phenotypic correlations presented by Atkeson, *et al.* (1969) showed substantially the same thing, with results in good agreement for all traits except dairy character. Phenotypic correlations between dairy character and body capacity and mammary system were 0.37 and 0.29 according to Atkeson, *et al.* (1969), but only 0.23 and 0.27 in the present study. Genetic correlations in the present study were 0.49 and 0.36 between dairy character and body capacity and mammary system. Mitchell, *et al.* (1961) reported values of 0.37 and 0.64 for the same traits. Their values for genetic correlations between dairy character and final score and general appearance were 0.87 and 0.65 compared to 0.64 and 0.57 in the present study.

Phenotypic and genetic correlations between descriptive traits have no comparison in the literature, since they represent the first such correlations to be calculated. A summary of the results of Table 9 for these traits seemed best accomplished in blocks of traits. For instance, the phenotypic and genetic relationships between udder traits such as fore and rear udder were generally higher than the relationships of these traits with traits not related to mammary system. Phenotypic correlations between descriptive traits and final score were less than 0.5 for all traits except rear udder. Stature, fore udder, and front end ranked next in line, with feet having the lowest phenotypic correlation with final score (0.25). The genetic correlations were similar in ranking, though higher in value. Front end had the highest genetic correlation with final score (0.79) with stature, rear udder, and rump next in line. The lowest genetic correlation with final score was feet (0.40). The lowest phenotypic correlations between traits observed were those between udder support, udder quality and teats with any other trait, though these traits had reasonably high genetic correlations with udder support, fore and rear udder and mammary system. The genetic correlation between udder quality and mammary system was quite high, indicating many of the same genes control these two traits. Udder traits as a group were highly correlated with each other. Genetic correlations with mammary system ranged from 0.84 for fore udder to 0.59 for udder support. Phenotypic correlations were lower, with a minimum of 0.19 between teats and rear udder.

The non-mammary traits such as head, back, and front end showed fewer general trends than did mammary traits. Head, for instance, was lowly correlated genetically with all traits, reaching its maximum with front end at 0.49. This trait had little phenotypic or genetic relationship with any other trait involved in the study. Front end also showed low correlations with other traits, especially the udder traits. The correlation between hind legs and feet was 0.24 phenotypically and 0.11 genetically. Any possibility of joining these two traits seems to be discouraged by this genetic correlation. Different genes appear to affect the two traits.

When the descriptive traits were coded as desirable or undesirable, (Table 10), the magnitude of correlations decreased and the standard errors of genetic correlations increased. Some negative genetic correlations involving udder quality and back with other traits appeared. Genetic correlations plus or minus standard errors included zero in many cases. Genetic correlations between final score and other traits except udder quality were similar to those in Table 9. Phenotypic correlations with final score changed somewhat, ranking rear udder and fore udder before stature with rump and front end following closely behind. No particular trait seemed to be more or less related to others from coding it as desirable or undesirable. This was to be expected since even the heritabilities for descriptive traits declined when the descriptive traits were expressed as desirable or undesirable. The reason for this is likely that the ability to discriminate between subtle differences in traits is reduced when only two scores exist. It would appear from the results of these analyses, that selection decisions made on an individual cow basis have more chance of success when the traits are expressed on an as-scored basis.

Final score seems to be the single type trait of most importance due to its high genetic relationship with other traits. If one type trait is all a breeder can use in a selection decision, the most overall improvement in the type of his dairy cattle will result from selection on final score alone. Likewise, the best opportunity to improve mammary system will be with selection decisions based on mammary system itself and not on descriptive traits such as fore and rear udder or some other component of mammary score. Genetically, mammary system seems to be controlled by essentially the same genes as udder quality. Selection decisions to improve mammary system will bring automatic improvement in udder quality. It is doubtful if selecting for udder quality alone would improve udder quality as much as selection on mammary system. The general descriptive traits appeared to be fairly independent of each other and other traits. These included head, back, rump, hind legs and feet. If improvement in these traits is desired, selection decisions should be made directly on the trait itself, though heritabilities indicated small chances of improvement in several of these traits.

Sire-Son Relationships Among Progeny Test Results

One of the important uses of descriptive information could be to provide accurate type information for progeny tests on sires. Already, much use is being made of the system in this way. The result of selection decisions based on the descriptive system have not been determined. Some knowledge as to the proportion of superiority (or inferiority) of a sire that should be reflected in his son's progeny test would be of immediate use in selecting sires of future sons.

Progeny Test Relationships

A total of 1,872 sire-son pairs were found in this data where each bull had at least eight daughters. The progeny test results evaluated were the simple mean scores for various traits or the per cent of daughters in the desirable categories for a particular trait. Age correction factors were applied to the final score, final classification, general appearance, dairy character, body capacity, and mammary system traits. None of the other traits were age adjusted, and those bulls with many older daughters would have an unfair advantage in some of these traits and a disadvantage in others due to age differences. Such a situation would likely lower sire-son relationships.

Table 11 shows the means, standard deviations, correlations and regressions among all 1,872 sire-son pairs. The average type values for daughters of sires were equal to or superior to those of the daughters of sons for all traits except udder support expressed as a desirable or undesirable trait, demonstrating the incomplete heritability of the traits. This trait was seen earlier to score higher in younger than in older cattle. The superiority of the sires for the first six traits was due to selection of those sires which were superior in transmitting ability for type and also due to selection of the sire's daughters. In the descriptive traits, age effects as well as selection pressures on sires and their daughters have an effect. As a group, the sons were somewhat more variable than the sires. The sires in this study had many more daughters in many more herds than did their sons.

TABLE 11. MEANS, STANDARD DEVIATIONS, CORRELATIONS, AND REGRESSIONS OF SON PROGENY TEST ON SIRE PROGENY TEST FOR ALL 1872 SIRE-SON PAIRS.

Trait	Sire Mean ± SD	Son Mean ± SD	Correlation	Reg ± SE
# Herds	354 ± 420	25 ± 83	-.05*	
# Daus	876 ±1131	61 ±179	-.04 NS	
Mean Age (Months)	53 ± 18	37 ± 5	.35	
Final Score	81.4 ± 1.6	80.1 ± 1.7	.27	.29 ± .02
Final Class.	2.9 ± .3	3.1 ± .3	.27	.28 ± .02
Gen App.	3.1 ± .3	3.3 ± .4	.26	.28 ± .02
Dairy Char.	2.1 ± .2	2.1 ± .2	.17	.22 ± .03
Body Cap.	2.1 ± .2	2.2 ± .3	.29	.32 ± .02
Mam. Sys.	3.2 ± .3	3.4 ± .4	.23	.25 ± .02
Stature	1.7 ± .3	1.8 ± .3	.29	.32 ± .02
Head	2.6 ± .4	2.9 ± .4	.17	.19 ± .02
Front End	1.9 ± .2	2.1 ± .3	.16	.24 ± .03
Back	1.9 ± .3	2.1 ± .4	.24	.29 ± .03
Rump	2.5 ± .4	2.9 ± .5	.23	.30 ± .03
Hind Legs	2.6 ± .2	2.8 ± .3	.12	.15 ± .03
Feet	2.4 ± .2	2.5 ± .3	.12	.18 ± .03
Fore Udder	2.5 ± .3	2.5 ± .4	.21	.28 ± .03
Rear Udder	2.2 ± .3	2.4 ± .3	.17	.21 ± .03
Udder Support	1.5 ± .2	1.5 ± .3	.25	.35 ± .03
Udder Quality	1.8 ± .2	1.8 ± .2	.16	.23 ± .03
Teats	2.2 ± .3	2.4 ± .5	.22	.31 ± .03
Per Cent of Daughters in Desirable Categories				
Stature	87.7 ± 9.7	84.7 ± 13.3	.23	.32 ± .03
Head	56.4 ± 14.7	44.5 ± 18.0	.15	.18 ± .03
Front End	87.4 ± 6.1	82.6 ± 12.6	.08	.17 ± .05
Back	79.1 ± 10.7	74.1 ± 15.3	.20	.29 ± .03
Rump	64.3 ± 12.9	49.0 ± 18.8	.21	.31 ± .03
Hind Legs	44.6 ± 12.8	34.5 ± 17.2	.13	.17 ± .03
Feet	68.1 ± 11.0	64.4 ± 16.8	.13	.19 ± .03
Fore Udder	63.3 ± 12.1	60.4 ± 17.4	.20	.29 ± .03
Rear Udder	68.7 ± 12.9	61.0 ± 18.1	.19	.26 ± .03
Udder Support	67.9 ± 10.7	71.3 ± 15.6	.24	.35 ± .03
Udder Quality	91.9 ± 4.1	92.3 ± 7.7	.09	.16 ± .04
Teats	68.7 ± 10.4	66.5 ± 17.1	.22	.36 ± .04

*Significant ($P < .05$), NS = non significant, all other correlations significant ($P < .01$).

The correlation between the number of herds or daughters of the sire and the number of herds or daughters of his son were quite low, and non-significant ($P > 0.05$). The correlation between mean daughter age was high. Sire's daughters were older than those of the son by 16 months.

The correlations between sires and sons for the first six traits ranged from a low of 0.17 for the correlation for dairy character to a high of 0.29 for body capacity. The similarity of correlations and regressions for these six traits indicated nearly equal variance in sires and sons. This was probably due to the use of age corrected records. The usefulness of these traits in predicting future performance of sons seemed quite good with the possible exception of dairy character.

The traits in the descriptive breakdown were not equally variable in sires and sons as shown by the variation in correlations and regressions in a particular trait. Both age and selection of daughters could be important here. With the traits expressed on an as-scored basis, regressions were higher for stature, back, rump, fore udder, udder support, and teats. The lowest regression among the remaining traits was for hind legs at 0.15, though head and feet were similar. Generally, correlations and regressions decreased when the per cent of daughters in the desirable categories was used. This was especially true for front end and udder quality. For other traits such as feet, fore udder, udder support, and teats, it made very little difference how the trait was expressed.

Table 12 lists the theoretical values of sire-son relationships. These expectations were developed using the formulas of Searle (1964), which includes the actual number of daughters for sires and sons, and the actual heritability of the traits found in the daughter-dam analysis. The theoretical values overestimated the observed correlations and regressions by a considerable amount in all traits except udder quality scored on a desirable-undesirable basis. The expectation for this trait was 0.00, due to the heritability estimate of 0.00. The magnitude of the deviations from expectation was quite disturbing. Others have reported deviations from expected values for similar analyses. Robertson (1960), reported observed regressions to be about 75% of expectation for milk production in British Friesians. Raush and Brum (1969) reported observed correlations and regressions to be about 80% of expected values for milk production in Jersey sires and sons. Dickinson, et al. (1969) also reported observed values which were lower than expected when pooled over all levels of repeatability. The deviations from theoretical values in the all-pairs analysis appeared to be greater than those deviations cited in the literature, though in the same direction. The most likely explanation for the calculated correlation and regression being considerably less than theoretical values would be the presence of common environmental factors associated with daughters of a bull performing in the same herd under similar conditions. Such a situation is not accounted for in Searle's (1964) theoretical values, but would act to lower the relationships between sires and sons.

TABLE 12. THEORETICAL VALUES OF CORRELATIONS AND REGRESSIONS AND DEVIATIONS FROM EXPECTATIONS FOR ALL 1872 SIRE-SON PAIRS.

Trait	Expectation		Deviation from Expectation	
	Corr.	Reg.	Corr.	Reg.
Final Score	.37	.45	-.10	-.16
Final Class.	.35	.44	-.08	-.16
General App.	.35	.44	-.09	-.16
Dairy Cha.	.30	.41	-.13	-.19
Body Cap.	.34	.43	-.05	-.11
Mammary Sys.	.33	.43	-.10	-.18
Stature	.39	.46	-.10	-.14
Head	.27	.40	-.10	-.21
Front End	.27	.40	-.11	-.16
Back	.29	.41	-.05	-.12
Rump	.33	.43	-.10	-.13
Hind Legs	.23	.37	-.11	-.22
Feet	.24	.38	-.12	-.20
Fore Udder	.31	.42	-.10	-.14
Rear Udder	.31	.42	-.14	-.21
Udder Support	.29	.41	-.04	-.06
Udder Quality	.17	.33	-.01	-.10
Teats	.31	.42	-.09	-.11
Per Cent of Daughters in Desirable Categories				
Stature	.34	.43	-.11	-.11
Head	.21	.36	-.06	-.18
Front End	.21	.36	-.13	-.19
Back	.29	.41	-.09	-.12
Rump	.31	.42	-.10	-.11
Hind Legs	.25	.39	-.12	-.22
Feet	.23	.37	-.10	-.18
Fore Udder	.29	.41	-.09	-.12
Rear Udder	.29	.41	-.10	-.15
Udder Support	.28	.40	-.04	-.05
Udder Quality	.00	.00	+.09	+.16
Teats	.32	.42	-.10	-.06

All sires and sons were coded as being AI (artificial insemination) or Non-AI sires depending on the number of herds involved in their progeny test. Four or fewer herds were designated as Non-AI proofs, while all other bulls were considered AI proven. The 1,872 sire-son pairs were then divided into four groups, AI sires with AI sons, AI sires with Non-AI sons, Non-AI sires with AI-sons, and Non-AI sires with Non-AI sons. A similar analysis to that just reported was performed on each group. The results are presented in Tables 13 through 16.

The 810 sire-son pairs which qualified in the AI-AI group are presented in Table 13. The number of daughters and herds of the sons increased considerably from the all pairs analysis. The average final score of the sires increased over the all pairs analysis from 81.4 to 81.6, indicating some selection on type. The regressions decreased in most cases. Exceptions were stature and udder support expressed on an as-scored basis and stature, rear udder, udder support, and udder quality expressed on a desirable-undesirable basis. The fact that the regressions declined when the son's daughters were exposed to a broader environment indicated that the true sire-son relationship could be lower than estimated in the all pairs analysis. The analysis revealed hind legs on an as-scored basis and front end and hind legs on a desirable-undesirable basis to be very poor indicators of a son's performance when measured in his sire's daughters.

Table 14 includes results of the AI sire-Non AI son analysis. This particular group might include sons used as clean up bulls for herds and

TABLE 13. MEANS, STANDARD DEVIATIONS, CORRELATIONS, AND REGRESSIONS OF SON PROGENY TEST ON SIRE PROGENY TEST FOR 810 AI SIRE-AI SON PAIRS.

Trait	Sire Mean ± SD	Son Mean ± SD	Correlation	Reg ± SE
# Herds	338 ± 375	56 ±120	-.06 NS	
# Daus	854 ±1033	119 ±261	-.06 NS	
Mean Age (Months)	59 ± 21	38 5	.32	
Final Score	81.6 ± 1.6	80.1 ± 1.6	.25	.24 ± .03
Final Class.	2.8 ± .3	3.1 ± .3	.25	.22 ± .03
Gen App.	3.0 ± .3	3.3 ± .3	.25	.24 ± .03
Dairy Char.	2.0 ± .2	2.1 ± .2	.15	.16 ± .04
Body Cap.	2.1 ± .2	2.2 ± .2	.29	.27 ± .03
Mam. Sys.	3.2 ± .3	3.4 ± .3	.23	.21 ± .03
Stature	1.7 ± .3	1.8 ± .2	.36	.35 ± .03
Head	2.5 ± .4	2.9 ± .3	.16	.14 ± .03
Front End	1.8 ± .2	2.1 ± .3	.14	.18 ± .05
Back	1.8 ± .3	2.1 ± .3	.29	.27 ± .03
Rump	2.4 ± .3	2.9 ± .4	.17	.22 ± .04
Hind Legs	2.6 ± .2	2.8 ± .2	.07 *	.07 ± .04
Feet	2.4 ± .2	2.6 ± .3	.13	.16 ± .04
Fore Udder	2.4 ± .3	2.6 ± .3	.18	.20 ± .04
Rear Udder	2.2 ± .3	2.4 ± .3	.20	.19 ± .03
Udder Support	1.5 ± .2	1.5 ± .3	.31	.39 ± .04
Udder Quality	1.7 ± .2	1.8 ± .2	.16	.19 ± .04
Teats	2.2 ± .3	2.4 ± .4	.24	.32 ± .05
Per Cent of Daughters in Desirable Categories				
Stature	87.3 ± 9.5	84.4 ± 11.5	.34	.40 ± .04
Head	60.2 ± 14.4	44.3 ± 13.7	.12	.12 ± .03
Front End	88.2 ± 5.5	82.0 ± 10.3	.02 NS	.04 ± .06
Back	79.7 ± 10.8	73.7 ± 12.6	.25	.29 ± .04
Rump	66.5 ± 12.2	48.6 ± 16.2	.15	.20 ± .05
Hind Legs	47.1 ± 12.8	34.8 ± 14.3	.08	.09 ± .04
Feet	69.3 ± 9.8	63.6 ± 13.3	.10	.14 ± .05
Fore Udder	64.3 ± 11.7	59.3 ± 14.1	.19	.22 ± .04
Rear Udder	71.0 ± 12.6	60.9 ± 14.3	.26	.29 ± .04
Udder Support	67.3 ± 10.5	70.9 ± 13.2	.33	.41 ± .04
Udder Quality	92.0 ± 3.7	91.8 ± 6.3	.11	.20 ± .06
Teats	69.7 ± 9.3	66.0 ± 14.5	.23	.36 ± .05

*Significant ($P < .05$), NS = non significant, all other correlations significant ($P < .01$).

TABLE 14. MEANS, STANDARD DEVIATIONS, CORRELATIONS, AND REGRESSIONS OF SON PROGENY TEST ON SIRE PROGENY TEST FOR 948 AI SIRE-NON AI SON PAIRS.

Trait	Sire Mean ± SD	Son Mean ± SD	Correlation	Reg ± SE
# Herds	410 ± 459	2 ± 1	-.002 NS	
# Daus	997 ±1230	17 ± 9	-.035 NS	
Mean Age (Months)	49 ± 15	37 ± 4	.33	
Final Score	81.2 ± 1.5	80.3 ± 1.9	.27	.33 ± .04
Final Class.	2.9 ± .3	3.0 ± .3	.28	.34 ± .04
Gen App.	3.1 ± .3	3.3 ± .4	.26	.32 ± .04
Dairy Char.	2.1 ± .1	2.1 ± .2	.17	.28 ± .05
Body Cap.	2.1 ± .2	2.2 ± .3	.27	.35 ± .04
Mam. Sys.	3.2 ± .3	3.3 ± .4	.25	.33 ± .04
Stature	1.7 ± .3	1.8 ± .3	.25	.29 ± .04
Head	2.7 ± .3	2.9 ± .5	.18	.23 ± .04
Front End	1.9 ± .2	2.1 ± .4	.15	.27 ± .06
Back	1.9 ± .3	2.1 ± .4	.21	.31 ± .05
Rump	2.5 ± .4	2.9 ± .5	.27	.39 ± .05
Hind Legs	2.6 ± .2	2.8 ± .3	.12	.19 ± .05
Feet	2.5 ± .2	2.5 ± .4	.14	.27 ± .06
Fore Udder	2.5 ± .3	2.5 ± .4	.23	.38 ± .05
Rear Udder	2.3 ± .2	2.4 ± .4	.17	.25 ± .05
Udder Support	1.5 ± .2	1.4 ± .3	.21	.34 ± .05
Udder Quality	1.8 ± .1	1.8 ± .3	.18	.35 ± .06
Teats	2.2 ± .3	2.4 ± .5	.20	.32 ± .05
Per Cent of Daughters in Desirable Categories				
Stature	88.1 ± 9.0	85.4 ± 14.3	.18	.27 ± .05
Head	53.2 ± 13.5	45.0 ± 20.7	.17	.25 ± .05
Front End	86.7 ± 5.7	83.3 ± 14.2	.10	.26 ± .08
Back	78.7 ± 9.9	74.4 ± 17.3	.17	.30 ± .06
Rump	63.0 ± 12.7	49.7 ± 20.7	.23	.38 ± .05
Hind Legs	42.5 ± 11.4	34.6 ± 19.4	.12	.21 ± .05
Feet	66.9 ± 10.0	65.0 ± 19.2	.14	.28 ± .06
Fore Udder	62.6 ± 11.3	61.4 ± 19.5	.22	.39 ± .05
Rear Udder	67.1 ± 11.9	61.5 ± 20.4	.17	.30 ± .05
Udder Support	68.6 ± 9.8	72.1 ± 17.1	.19	.34 ± .06
Udder Quality	91.6 ± 3.5	92.8 ± 8.4	.10	.24 ± .08
Teats	68.0 ± 10.3	67.0 ± 18.9	.20	.36 ± .06

NS = non significant, all other correlations significant ($P < .01$).

some animals bred for AI use that were never called to active AI service, or are currently awaiting proof. There were 948 such pairs in this data. Average type score of the sires in this group were lower (81.2 compared to 81.4) than they were in the all pairs analysis. The sons' progeny tests were made on an average of 17 daughters in two herds. The regressions of son on sire were higher in this analysis than they were in the all pairs analysis except for stature and udder support (expressed both ways). The correlations were similar to the all pairs analysis. The probable reason for higher regressions could be preferential treatment of the daughters of the sons or generally higher classification scores in herds using natural service bulls. The average final score in this group was 80.3 compared to 80.1 in the all pairs analysis. Selection of daughters to be classified could be a factor here, also. The daughters of the sons in this analysis were equal to or superior to those daughters represented in the all pairs analysis for every trait. Such an observation would hardly be due to chance alone on 948 sire-son pairs.

One of the most gratifying portions of the sire-son analysis was the lack of AI sons from non-AI proven sires. Only the 21 pairs summarized in Table 15 were found in the 1,872 sire-son pairs in the original data file. These sires averaged 21 daughters in three herds. Such a proof is hardly reliable enough to justify use of the sire in planned matings and bull studs across the country obviously recognized this. The usefulness of Table 15 is limited, except to point out the lack of significance for almost every correlation and the high standard

TABLE 15. MEANS, STANDARD DEVIATIONS, CORRELATIONS, AND REGRESSIONS OF SON PROGENY TEST ON SIRE PROGENY TEST FOR 21 NON AI SIRE-AI SON PAIRS.

Trait	Sire Mean ± SD	Son Mean ± SD	Correlation	Reg ± SE
# Herds	3 ± 1	24 ± 35	.01	
# Daus	21 ± 13	53 ± 61	.12	
Mean Age (Months)	53 ± 16	37 ± 5	.26	
Final Score	81.3 ± 1.9	80.2 ± 1.8	.24	.23 ± .21
Final Class.	2.9 ± .4	3.1 ± .4	.21	.22 ± .23
Gen App.	3.1 ± .4	3.3 ± .3	.28	.25 ± .20
Dairy Char.	2.1 ± .3	2.1 ± .3	-.25	-.27 ± .24
Body Cap.	2.2 ± .3	2.2 ± .2	.52 *	.46 ± .18
Mam. Sys.	3.2 ± .5	3.3 ± .4	.24	.19 ± .17
Stature	1.7 ± .3	1.8 ± .3	-.09	-.11 ± .27
Head	2.6 ± .5	2.9 ± .4	.17	-.13 ± .17
Front End	1.8 ± .3	2.1 ± .3	.19	.18 ± .21
Back	1.8 ± .4	2.1 ± .4	-.13	-.13 ± .22
Rump	2.6 ± .5	2.9 ± .4	.19	.15 ± .17
Hind Legs	2.5 ± .3	2.8 ± .3	.11	.09 ± .18
Feet	2.3 ± .5	2.4 ± .3	-.19	-.11 ± .13
Fore Udder	2.4 ± .4	2.6 ± .3	.37	.35 ± .20
Rear Udder	2.1 ± .4	2.3 ± .3	.04	.02 ± .16
Udder Support	1.7 ± .4	1.5 ± .4	.13	.12 ± .20
Udder Quality	1.8 ± .2	1.7 ± .2	.13	.13 ± .23
Teats	2.2 ± .5	2.2 ± .3	.43 *	.29 ± .14
	Per Cent of Daughters in Desirable Categories			
Stature	88.6 ± 13.3	81.0 ± 17.0	-.03	-.03 ± .30
Head	62.3 ± 19.8	45.5 ± 18.1	-.07	-.06 ± .21
Front End	88.7 ± 11.8	83.5 ± 10.9	.04	.04 ± .21
Back	79.6 ± 12.1	74.9 ± 15.2	-.08	-.10 ± .29
Rump	65.0 ± 16.7	51.9 ± 14.7	.31	.27 ± .19
Hind Legs	49.9 ± 21.3	36.0 ± 16.7	.24	.19 ± .17
Feet	72.4 ± 21.9	69.5 ± 12.1	-.07	-.04 ± .13
Fore Udder	66.2 ± 16.4	59.5 ± 15.9	.23	.22 ± .27
Rear Udder	73.0 ± 18.6	65.5 ± 15.0	.05	.04 ± .18
Udder Support	59.0 ± 21.3	71.6 ± 18.6	.07	.06 ± .20
Udder Quality	95.1 ± 5.0	94.9 ± 5.1	.15	.15 ± .23
Teats	71.0 ± 14.0	72.3 ± 10.4	.52 **	.39 ± .15

*Significant ($P < .05$), **Significant ($P < .01$).

errors of the regressions. Negative correlations and regressions were also noted.

The results in Table 16 concern relationships between Non-AI sires of Non-AI sons. Only 93 such pairs existed in the data, indicating that more and more breeders are turning to the AI industry for the sires of their herd bulls. The correlations and regressions in this group were more similar than in any of the previous groups. Likewise, the age of the daughters of sires and sons are much closer, differing by only 9 months. This indicated a tendency for breeders to keep sons of a herd bull before the sire had a progeny test. The correlations and regressions in this analysis were more varied than the all pairs analysis, as would be expected from the numbers involved. If there was any general trend in the results, it was toward higher correlations and regressions than in the all pairs analysis. These values, while low in dependability, could result from environmental correlations among or selection of daughters of the sire and son. Often in a group of sires and sons like this, the two would be proven in the same herd. It would be hazardous to draw too many conclusions from these results since there are only a few numbers involved.

The Importance of Type in Selecting Sires of Sons

There were 550 sires represented in the 1,872 sire-son pairs involved in the study. One sire had 157 sons while 456 sires had fewer than four sons represented in the data. In an effort to determine the importance of the several type traits in making selection decisions

TABLE 16. MEANS, STANDARD DEVIATIONS, CORRELATIONS, AND REGRESSIONS OF SON PROGENY TEST ON SIRE PROGENY TEST FOR 93 NON AI SIRE-NON AI SON PAIRS.

Trait	Sire Mean ± SD	Son Mean ± SD	Correlation	Reg ± SE
# Herds	2 ± 1	2 ± 1	.062 NS	
# Daus	23 ± 15	16 ± 8	-.041 NS	
Mean Age (Months)	46 ± 11	37 ± 5	.50	
Final Score	80.8 ± 1.9	79.5 ± 2.0	.43	.44 ± .10
Final Class	3.0 ± .4	3.2 ± .3	.41	.37 ± .09
Gen. App.	3.2 ± .4	3.4 ± .4	.41	.35 ± .08
Dairy Char.	2.1 ± .3	2.2 ± .3	.33	.34 ± .10
Body Cap.	2.1 ± .3	2.3 ± .3	.39	.37 ± .09
Mam. Sys.	3.3 ± .4	3.5 ± .4	.23 *	.23 ± .10
Stature	1.8 ± .3	1.9 ± .3	.28	.29 ± .10
Head	2.7 ± .4	3.0 ± .5	.37	.42 ± .11
Front End	1.9 ± .3	2.2 ± .4	.35	.40 ± .11
Back	1.9 ± .4	2.1 ± .4	.39	.37 ± .09
Rump	2.7 ± .4	3.1 ± .5	.32	.36 ± .11
Hind Legs	2.6 ± .3	2.9 ± .4	.34	.39 ± .11
Feet	2.5 ± .5	2.6 ± .4	.17 NS	.14 ± .08
Fore Udder	2.5 ± .4	2.6 ± .4	.28	.29 ± .11
Rear Udder	2.3 ± .3	2.5 ± .4	.16 NS	.18 ± .12
Udder Support	1.5 ± .3	1.5 ± .4	.22 *	.24 ± .12
Udder Quality	1.8 ± .3	1.8 ± .3	.10 NS	.11 ± .12
Teats	2.2 ± .5	2.5 ± .5	.30	.30 ± .10
	Per Cent of Daughters in Desirable Categories			
Stature	86.5 ± 14.8	80.3 ± 16.2	.25 *	.27 ± .11
Head	55.1 ± 18.3	42.4 ± 21.5	.33	.38 ± .12
Front End	88.3 ± 10.1	80.4 ± 13.9	.28	.37 ± .14
Back	77.7 ± 15.8	74.7 ± 16.9	.32	.34 ± .11
Rump	57.9 ± 15.9	45.6 ± 19.9	.42	.52 ± .12
Hind Legs	42.8 ± 18.2	30.8 ± 17.8	.36	.36 ± .10
Feet	68.1 ± 21.8	63.8 ± 18.6	.22 *	.19 ± .09
Fore Udder	60.5 ± 19.5	60.9 ± 21.0	.23 *	.25 ± .11
Rear Udder	64.4 ± 18.8	55.7 ± 22.2	.05 NS	.06 ± .12
Udder Support	67.4 ± 15.9	68.1 ± 18.9	.22 *	.26 ± .12
Udder Quality	92.8 ± 8.5	91.3 ± 10.0	.00 NS	.00 ± .12
Teats	67.2 ± 16.7	63.8 ± 19.8	.34	.40 ± .12

*Significant ($P < .05$), NS = non significant, all other correlations significant ($P < .01$).

concerning sires of future sons, Tables 17 through 21 were created. Sires were divided into four groups according to the number of sons they had in service. Table 17 contains daughter averages and ranges for all 550 sires and provides a base for comparison to the other groups. Daughter averages for sires with 21 or more sons in service are in Table 18, for sires having 10 to 20 sons in Table 19, for sires having 4 to 9 sons in Table 20, and for sires having 1 to 3 sons in Table 21. The fact that average final score from Table 17 was only 80.6 whereas the average was 81.4 from Table 11 (where sires were weighted by their number of sons) indicated considerable use of better type bulls. The range of values in this table must be interpreted with some cuation. Those bulls with 100 per cent of their daughters in desirable categories for descriptive traits seldom had very many daughters. The mean scores for type provide for better comparisons. One interesting feature of Table 17, however, was that not one bull in the entire study had 100 per cent of his daughters in the desirable categories for hind legs. This would indicate that either the requirements for desirable hind legs were too high, or the dairymen in this country have a long way to go in improving hind legs. Probably a little of both was true. All traits except stature, front end, and udder quality showed a fairly high degree of variability. In the case of stature, this could be a scaling effect, since there are only three codes for stature. In the instance of front end and udder quality, it was probably due to poor evaluation on the part of the classifier, since the range of per cent

TABLE 17. MEANS AND RANGES OF PROGENY TEST RESULTS FOR ALL 550 SIRES OF SONS.

Trait	Mean ± SD	Range Low	Range High
Number of Sons	3.4 ± 9.2	1	157
Number of Herds	111.8 ± 203.1	1	1857
Number of Daughters	247.9 ± 484.1	8	5321
Mean Daughter Age (Months)	51.3 ± 17.5	30	119
Final Score	80.6 ± 1.7	75.0	85.8
Final Classification	3.0 ± .3	2.0	4.1
Gen. Appearance	3.2 ± .4	2.1	4.6
Dairy Character	2.1 ± .2	1.6	3.2
Body Capacity	2.2 ± .3	1.4	3.0
Mammary System	3.3 ± .4	2.2	4.6
Stature	1.8 ± .3	1.1	2.7
Head	2.7 ± .4	1.7	4.0
Front End	1.9 ± .2	1.2	2.8
Back	1.9 ± .3	1.0	3.2
Rump	2.6 ± .4	1.3	3.8
Hind Legs	2.7 ± .2	1.6	3.6
Feet	2.5 ± .3	1.6	3.7
Fore Udder	2.6 ± .3	1.6	3.6
Rear Udder	2.3 ± .3	1.5	3.3
Udder Support	1.6 ± .3	1.0	3.0
Udder Quality	1.8 ± .2	1.1	2.8
Teats	2.3 ± .4	1.1	3.6
Per Cent of Daughters in Desirable Categories			
Stature	84.5 ± 7.8	29.0	100.0
Head	53.6 ± 15.6	9.0	100.0
Front End	86.3 ± 7.8	50.0	100.0
Back	78.1 ± 11.2	23.0	100.0
Rump	60.6 ± 15.1	16.0	100.0
Hind Legs	41.2 ± 14.1	8.0	90.0
Feet	66.5 ± 13.5	6.0	100.0
Fore Udder	59.9 ± 14.4	11.0	100.0
Rear Udder	64.8 ± 13.6	5.0	100.0
Udder Support	65.6 ± 13.7	9.0	100.0
Udder Quality	91.9 ± 5.7	50.0	100.0
Teats	65.8 ± 13.3	16.0	100.0

desirable, was from 50 to 100, for both traits and the means were high (86.3 and 91.9, respectively). The standard deviation of udder quality in the daughter-dam analysis was quite low. The low heritabilities of this trait were not hard to understand once its variability was examined.

Table 18 shows the means and ranges of traits in those thirteen bulls with 21 or more sons in the data. The ranges of number of daughters (83 to 5,321) indicated that bull studs were waiting for reliable information on a bull before they used him extensively in siring sons. It was also interesting to note that none of these sires had 100 per cent of their 83 or more daughters in the desirable categories for any of the descriptive traits. These bulls were not at the extremes in ranges seen in Table 17 except, naturally for number of sons, number of daughters, and number of herds.

Table 19 is a summary of the medium popularity bulls - those with 10 to 20 proven sons each. Some 24 such sires existed in the data. These bulls were not responsible for the extremes in ranges seen in Table 21. They were not the best in any trait (with two exceptions) nor were they the poorest. Generally, these were sound type bulls with a high percentage of daughters in desirable categories for descriptive traits. Even with a minimum of 21 daughters, some bull or bulls had 100 per cent of their daughters in the desirable categories for front end and udder quality. The regression of son on sire for these traits was low at 0.17 and 0.16, respectively.

Table 20 presents a summary of the 57 sires in the data with four

TABLE 18. MEANS AND RANGES OF PROGENY TEST RESULTS FOR 13 SIRES WITH 21 OR MORE SONS.

Trait	Mean ± SD	Range Low	Range High
Number of Sons	45.8 ± 38.0	21	157
Number of Herds	765.2 ± 544.3	68	1857
Number of Daughters	1875.3 ± 1488.1	83	5321
Mean Daughter Age (Months)	47.8 ± 13.3	37	80
Final Score	81.6 ± 1.3	79.7	83.8
Final Classification	2.8 ± .2	2.4	3.2
Gen. Appearance	3.0 ± .3	2.6	3.4
Dairy Character	2.1 ± .2	1.8	2.3
Body Capacity	2.0 ± .2	1.6	2.4
Mammary System	3.2 ± .3	2.6	3.5
Stature	1.7 ± .3	1.2	2.0
Head	2.7 ± .3	2.1	3.1
Front End	1.8 ± .2	1.6	2.1
Back	1.8 ± .3	1.5	2.6
Rump	2.5 ± .3	2.0	2.8
Hind Legs	2.7 ± .2	2.3	2.9
Feet	2.6 ± .2	2.2	2.7
Fore Udder	2.4 ± .2	2.2	2.7
Rear Udder	2.2 ± .3	1.7	2.7
Udder Support	1.5 ± .1	1.2	1.6
Udder Quality	1.8 ± .1	1.5	2.0
Teats	2.1 ± .3	1.7	2.7
Per Cent of Daughters in Desirable Categories			
Stature	88.5 ± 7.9	77.0	98.0
Head	52.3 ± 11.0	42.0	79.0
Front End	87.2 ± 4.0	81.0	92.0
Back	79.3 ± 11.6	53.0	90.0
Rump	65.3 ± 9.2	50.0	80.0
Hind Legs	48.8 ± 8.8	33.0	59.0
Feet	67.8 ± 9.2	50.0	80.0
Fore Udder	66.2 ± 6.2	55.0	77.0
Rear Udder	67.5 ± 12.2	43.0	87.0
Udder Support	69.0 ± 7.5	57.0	83.0
Udder Quality	91.4 ± 2.1	86.0	95.0
Teats	71.0 ± 6.9	58.0	84.0

TABLE 19. MEANS AND RANGES OF PROGENY TEST RESULTS FOR 24 SIRES WITH 10 TO 20 SONS.

Trait	Mean ± SD	Range	
		Low	High
Number of Sons	14.1 ± 3.0	10	20
Number of Herds	269.1 ± 273.4	3	971
Number of Daughters	581.8 ± 573.1	21	1852
Mean Daughter Age (Months)	62.3 ± 24.1	37	114
Final Score	81.9 ± 1.5	79.8	84.5
Final Classification	2.8 ± .3	2.1	3.2
Gen. Appearance	3.0 ± .3	2.4	3.5
Dairy Character	2.0 ± .1	1.8	2.2
Body Capacity	2.0 ± .2	1.6	2.3
Mammary System	3.1 ± .4	2.4	3.7
Stature	1.7 ± .2	1.4	2.1
Head	2.5 ± .4	1.7	3.0
Front End	1.8 ± .2	1.3	2.2
Back	1.7 ± .2	1.3	2.1
Rump	2.4 ± .4	1.8	3.4
Hind Legs	2.5 ± .3	1.6	3.0
Feet	3.4 ± .2	2.0	2.8
Fore Udder	2.4 ± .3	1.7	2.9
Rear Udder	2.1 ± .3	1.7	2.6
Udder Support	1.6 ± .1	1.3	1.8
Udder Quality	1.7 ± .2	1.4	1.9
Teats	2.1 ± .3	1.5	2.7
Per Cent of Daughters in Desirable Categories			
Stature	86.9 ± 7.1	71.0	97.0
Head	62.5 ± 13.5	43.0	86.0
Front End	88.9 ± 5.9	76.0	100.0
Back	82.3 ± 7.3	70.0	95.0
Rump	67.7 ± 13.0	32.0	90.0
Hind Legs	50.7 ± 14.2	33.0	90.0
Feet	72.0 ± 9.0	50.0	89.0
Fore Udder	66.0 ± 13.5	41.0	95.0
Rear Udder	73.7 ± 11.1	53.0	89.0
Udder Support	65.9 ± 7.2	47.0	77.0
Udder Quality	92.7 ± 2.8	89.0	100.0
Teats	70.1 ± 8.6	54.0	87.0

TABLE 20. MEANS AND RANGES OF PROGENY TEST RESULTS FOR 57 SIRES WITH 4 TO 9 SONS.

Trait	Mean ± SD	Range Low	Range High
Number of Sons	5.2 ± 1.4	4	9
Number of Herds	205.1 ± 251.0	8	1152
Number of Daughters	457.1 ± 553.3	18	2520
Mean Daughter Age (Months)	49.9 ± 17.3	30	119
Final Score	81.2 ± 1.6	77.3	84.5
Final Classification	2.9 ± .3	2.3	3.5
Gen. Appearance	3.1 ± .3	2.4	3.9
Dairy Character	2.1 ± .2	1.6	2.4
Body Capacity	2.1 ± .2	1.6	2.6
Mammary System	3.2 ± .3	2.6	4.0
Stature	1.7 ± .2	1.2	2.3
Head	2.7 ± .3	2.0	3.5
Front End	1.9 ± .2	1.5	2.4
Back	1.9 ± .3	1.4	3.1
Rump	2.5 ± .4	1.8	3.4
Hind Legs	2.7 ± .2	2.2	3.1
Feet	2.5 ± .2	2.0	3.0
Fore Udder	2.5 ± .3	1.9	3.3
Rear Udder	2.3 ± .2	1.8	2.7
Udder Support	1.5 ± .2	1.1	2.1
Udder Quality	1.8 ± .1	1.5	2.1
Teats	2.2 ± .3	1.6	2.9
Per Cent of Daughters in Desirable Categories			
Stature	87.5 ± 7.4	59.0	100.0
Head	54.4 ± 13.9	24.0	86.0
Front End	86.2 ± 6.1	72.0	100.0
Back	78.7 ± 10.1	31.0	95.0
Rump	63.9 ± 13.3	37.0	85.0
Hind Legs	42.3 ± 12.0	22.0	73.0
Feet	67.4 ± 10.1	41.0	88.0
Fore Udder	62.0 ± 13.8	21.0	83.0
Rear Udder	67.9 ± 10.0	46.0	94.0
Udder Support	68.5 ± 9.7	43.0	86.0
Udder Quality	90.9 ± 3.8	80.0	98.0
Teats	70.8 ± 9.9	49.0	86.0

to nine sons. Within this group were the bull or bulls with the highest mean daughter age at 119 months. The lowest scoring bull for dairy character was in this group as were bulls with 100 per cent of their daughters in desirable categories for stature and front end. A minimum of 18 daughters were involved in these percentages.

The 456 remaining sires in Table 21 with one to three sons each accounted for the extremes for all type traits except the minimum for hind legs and rear udders evaluated on an as-scored basis. Some of these bulls had average daughter ages of 119 months. This would be about the highest possible average age for a bull's daughters since all ages over 120 months were coded as being 120 months of age. The bulls in this group would be expected to be the most diversified since there were so many of them. But another reason for diversification could be that different breeders and bull studs were looking for entirely different traits in those sires with only a few sons. Some breeders might use genetically superior milk bulls with poor type scores while other breeders interested in type might use lower milk production bulls to improve type. The extreme range of type scores in this group allows for considerable conjecture, but the truest statement that could be made is that this group of sires is a catch-all for genetic ventures by all types of breeders. Some younger bulls in the process of development would be included in this group also.

Table 22, a summary of the daughter average type scores of sires of sons in Tables 17-21, is presented for ease of comparison of progeny tests. From this table, some idea of selection pressure for type

TABLE 21. MEANS AND RANGES OF PROGENY TEST RESULTS FOR 456 SIRES WITH 1 TO 3 SONS.

Trait	Mean ± SD	Range Low	Range High
Number of Sons	1.4 ± .7	1	3
Number of Herds	73.2 ± 119.8	1	849
Number of Daughters	157.7 ± 273.7	8	2669
Mean Daughter Age (Months)	51.0 ± 17.1	30	119
Final Score	80.5 ± 1.6	75.0	85.8
Final Classification	3.1 ± .3	2.0	4.1
Gen. Appearance	3.3 ± .4	2.1	4.6
Dairy Character	2.1 ± .2	1.6	3.2
Body Capacity	2.2 ± .3	1.4	3.0
Mammary System	3.4 ± .4	2.2	4.6
Stature	1.8 ± .3	1.1	2.7
Head	2.7 ± .4	1.7	4.0
Front End	1.9 ± .2	1.2	2.8
Back	1.9 ± .3	1.0	3.2
Rump	2.7 ± .4	1.3	3.8
Hind Legs	2.7 ± .2	1.7	3.6
Feet	2.5 ± .3	1.6	3.7
Fore Udder	2.6 ± .3	1.6	3.6
Rear Udder	2.3 ± .3	1.5	3.3
Udder Support	1.6 ± .3	1.0	3.0
Udder Quality	1.8 ± .2	1.1	2.8
Teats	2.3 ± .4	1.1	3.6
Per Cent of Daughters in Desirable Categories			
Stature	83.9 ± 12.6	29.0	100.0
Head	53.1 ± 15.9	9.0	100.0
Front End	86.1 ± 8.2	50.0	100.0
Back	77.7 ± 11.5	23.0	100.0
Rump	59.7 ± 15.4	16.0	100.0
Hind Legs	40.5 ± 14.3	8.0	90.0
Feet	66.1 ± 14.1	6.0	100.0
Fore Udder	59.1 ± 14.6	11.0	100.0
Rear Udder	63.9 ± 13.9	5.0	100.0
Udder Support	65.1 ± 14.5	9.0	100.0
Udder Quality	92.0 ± 6.0	50.0	100.0
Teats	64.7 ± 13.8	16.0	100.0

TABLE 22. MEANS OF PROGENY TEST RESULTS FOR SIRES WITH VARYING NUMBERS OF SONS.

Trait	All Sires 550 Sires	Over 21 Sons 13 Sires	10-20 Sons 24 Sires	4 to 9 Sons 57 Sires	1 to 3 Sons 456 Sires
Final Score	80.6	81.6	81.9	81.2	80.5
Final Class.	3.0	2.8	2.8	2.9	3.1
General App.	3.2	3.0	3.0	3.1	3.3
Dairy Char.	2.1	2.1	2.0	2.1	2.1
Body Capacity	2.2	2.0	2.0	2.1	2.2
Mammary Sys.	3.3	3.2	3.1	3.2	3.4
Stature	1.8	1.7	1.7	1.7	1.8
Head	2.7	2.7	2.5	2.7	2.7
Front End	1.9	1.8	1.8	1.9	1.9
Back	1.9	1.8	1.7	1.9	1.9
Rump	2.6	2.5	2.4	2.5	2.7
Hind Legs	2.7	2.7	2.5	2.7	2.7
Feet	2.5	2.6	3.4	2.5	2.5
Fore Udder	2.6	2.4	2.4	2.5	2.6
Rear Udder	2.3	2.2	2.1	2.3	2.3
Udder Support	1.6	1.5	1.6	1.5	1.6
Udder Quality	1.8	1.8	1.7	1.8	1.8
Teats	2.3	2.1	2.1	2.2	2.3
	Per Cent of Daughters in Desirable Categories				
Stature	85	86	87	88	84
Head	54	52	63	54	53
Front End	86	87	89	86	86
Back	78	79	82	79	78
Rump	61	65	68	64	60
Hind Legs	41	49	51	42	41
Feet	67	68	72	67	66
Fore Udder	60	66	66	62	59
Rear Udder	65	68	74	68	64
Udder Support	66	69	66	69	65
Udder Quality	92	91	93	91	92
Teats	66	71	70	71	65

on the sire side of the pedigree was evident. The basic conclusions from this table were that those bulls who sired many sons (10 or more) were above average for type. Apparently some sires in the 10 to 20 son group were too low for milk production to be used more extensively, but were so superior in type to justify some use. The average final score of this group was 81.9 compared to 81.6 for those sires of 21 or more sons.

If the sires of 10 to 20 sons could be assumed to represent "type bulls", which average scores did seem to indicate, then certain traits appeared to be quite important to type conscious breeders. These traits included stature, head, back, rump, hind legs, and fore and rear udder and perhaps front end and feet. Little emphasis seemed to have been placed on udder support in this group. If those sires with 21 or more sons could be assumed to be the bulls with a compromise between production and functional type, the importance of the traits seemed to change. For instance, head was not important in these bulls, nor was feet. But hind legs and all udder traits were quite important in these bulls. The most emphasis seemed to have been placed on hind legs, fore udder, and perhaps udder support and teats. The bulls with less than 10 sons did not seem to be part of any general trend. Their type scores were lower than those more popular bulls for most traits, once again emphasizing the importance of type on the sire side of the pedigree. Probably some of the bulls in this group were younger, good type or good production bulls who were simply not old enough to have many sons in service.

SUMMARY

Data for this study was provided by the Holstein Friesian Association of America, which made available all type classification results from January, 1967 through September, 1971. The data involved classification results on final score, final classification, general appearance, dairy character, body capacity and mammary system. The descriptive type classification system instituted in 1967 provided results for twelve additional traits. A total of 336,253 individual cows had been scored on the descriptive system after multiple records on cows had been eliminated and erroneous data edited from the original source.

Age influences were obvious for all traits in the study. However, due to the non-linear and purely descriptive nature of some of the descriptive traits, no age correction factors were applied to the descriptive traits. Final score, final classification, general appearance, dairy character, body capacity and mammary system were age adjusted using the gross comparison method of determining correction factors.

Daughter - dam pairs where only one pair existed in a herd, or where the dam and daughter differed by more than one year in age at classification were removed from the data. A total of 30,715 remaining daughter - dam pairs were used in determining heritabilities, genetic, and phenotypic correlations. A within-herd model was employed. Heritability estimates were high for most scorecard component traits, with final score highest at 0.31 ± 0.01. The one exception was dairy character at 0.15 ± 0.01. Several traits within the descriptive

traits were highly heritable, with stature being the highest at 0.38 $\pm$ 0.01. Udder quality had the lowest heritability at 0.00 $\pm$ 0.01. Phenotypic and genetic correlations between final score and all other traits were quite high. All traits dealing with mammary system were quite highly correlated with each other, but not with other traits such as front end and feet. Several of the general descriptive traits including head, front end, hind legs, and feet were found to be virtually independent of other traits, both genetically and phenotypically. Expressing the descriptive traits as desirable or undesirable in general lowered the heritabilities and phenotypic and genetic correlations and did not appear to improve the evaluation of traits on an individual cow basis.

Progeny test results expressed as the daughter mean for each trait and as the per cent of daughters in the desirable categories for descriptive traits were created from the original data. A total of 1,872 sire - son pairs were found where each bull had at least eight daughters classified. These pairs were further divided according to the type of usage each bull received. A bull with daughters in five or more herds was considered an AI (artificial insemination) bull, all others were coded as Non-AI. The correlations and regressions of son progeny test results on that of his sire were computed for all pairs, AI sires with AI sons, AI sires with Non-AI sons, Non-AI sires with AI sons, and Non-AI sires with Non-AI sons. Only 21 pairs of Non-AI sires of AI sons resulted and only 93 pairs of Non-AI sires of Non-AI sons were found. This strongly indicated that breeders were turning to popular AI bulls to sire future sons. The results of the AI sire - AI son group should have been the most reliable, since the progeny test results of these bulls involved more daughters in more herds, and 810 sire-son pairs were involved. With the exception of dairy character, the sire's progeny test result was an acceptable indicator of son's performance for all scorecard traits. Within the descriptive system, the regression of the son's progeny test on that of his sire for head, front end, hind legs, feet, rear udder, and udder quality was below 0.20, indicating that the sire progeny test results for these traits were poor predictors of son's performance when expressed by the sire's progeny test. Expressing results as the per cent of daughters in desirable categories caused head, front end, hind legs, and feet to show regressions of less than 0.20. Expressing traits in this fashion seemed advisable in bull proofs, as the correlations and regressions did not differ greatly from traits expressed on an as-scored basis and rounding errors were reduced. Theoretical correlations and regressions were generally higher than observed values and were probably due to subjective evaluation of the various traits.

A total of 550 sires were involved in the 1,872 sire-son pairs. Those bulls with many sons were superior in progeny test for type, especially for final score, hind legs, fore udder, udder support, and teats. With the exception of hind legs, all these traits showed regressions of son on sire of more than 0.20 in the AI sire - AI son group.

The usefulness of head and udder quality in the descriptive type traits seemed highly questionable based on the results of this analysis. Their omission from the program would cause little loss of useful genetic information. Subjectivity in the scoring of two important functional traits, feet and hind legs, and another general trait, front end, caused low heritability estimates. Efforts to reduce the subjective nature of these traits would greatly improve their usefulness in selection decisions.

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AN ANALYSIS OF SIRE-SON AND DAM-DAUGHTER RELATIONSHIPS FOR TYPE TRAITS IN THE HOLSTEIN DESCRIPTIVE TYPE CLASSIFICATION SYSTEM.

by

Bennet Goodman Cassell

(ABSTRACT)

Age correction factors were developed from 336,253 individual classification results and were applied to final score, final classification, general appearance, dairy character, body capacity, and mammary system. Using a within-herd model, 30,715 daughter dam pairs were analyzed to determine estimates of heritability (h^2) and genetic and phenotypic correlations. Heritability estimates were: final classification, 0.31; final score, 0.25; general appearance, 0.26; dairy character, 0.15; body capacity, 0.23; mammary system, 0.20; stature, 0.38; head, 0.11; front end, 0.11; back, 0.14; rump, 0.21; hind legs, 0.07; feet, 0.08; fore udder, 0.16; rear udder, 0.17; udder support, 0.13; udder quality, 0.04; and teats, 0.17. When traits were expressed as 1 for desirable and 0 for undesirable, h^2 estimates were lower. Genetic correlations were generally positive, ranging from 1.01 $\pm$ 0.08 between final score and final classification to -0.17 $\pm$ 0.22 between dairy character and udder quality expressed as a binomial.

Regression of the son progeny test on that of his sire indicated that head, front end, hind legs, feet, rear udder, and udder quality were poor indicators of son's performance when the sire's progeny test

result was used for selection decisions. Considerable emphasis was placed on type in selecting sires of sons, especially for final score, hind legs, fore udder, udder support, and teats, since bulls whose daughters scored high in these traits sired more future sires than other bulls.