

IMPORTANCE OF BODY CONFORMATION IN PREDICTING
LONGEVITY AND WEARABILITY OF DAIRY COWS

by

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INTRODUCTION

Although milk production and body conformation receive primary selection emphasis when choosing sires in a dairy breeding program, many dairymen feel that some appraisal value should be given to longevity or wearability as an economically important trait. However, direct selection emphasis on longevity would not be effective since heritability estimates for herd life are small and little genetic progress could be expected. Another complication arises because, to be effective, an appraisal of the transmitting ability of longevity for a sire would have to be made while the sire was still available for heavy service. This would be difficult if the appraisal was based on progeny performance since adequate progeny test results for longevity would not be available for almost a decade after the sire was first placed in active service.

To include longevity in a breeding program, its relationships with other economically important traits must be known. Most previous studies on herd life have indicated a positive association between milk production and herd life and considered milk production as the most important trait in determining longevity. However, it has been hypothesized that conformation characteristics also have a strong influence on longevity. Some aspects of type may be more valuable indicators of longevity than others or the type traits as a group may be more important. Therefore, the purpose of this study was to

determine the relative importance of body conformation in predicting longevity and wearability among daughters of sires with varying genetic abilities for milk yield.

LITERATURE REVIEW

Heritability of Conformational Traits

Estimates of the heritability of final classification score in dairy cattle have ranged from .14 reported by Harvey and Lush (17) in Jerseys to .35 reported by Johnson and Fourt (18) in Brown Swiss. Barousek et al. (5) reported a heritability of .28 in Guernseys while final rating heritabilities of .28, .31, and .18 were given for Ayrshires by Tyler and Hyatt (35), Freeman and Dunbar (12), and Butcher et al. (6), respectively.

Heritability estimates for type traits of Holstein-Friesian cattle based on official Holstein-Friesian Association of America (HFAA) data and unofficial data have been similar.* These estimates are summarized in Tables 1 and 2. Stone et al. (33) reported an early estimate of heritability of final score of .21 using Canadian data. O'Bleness et al. (27) in another early study, found heritability estimates for 27 type appraisal traits. Depth of barrel, udder texture, strength of udder attachment, and depth of udder had relatively high estimates. Norman and Van Vleck (25) analyzed over 16,000 type appraisals of artificial insemination sired cows and found low heritabilities for most traits. Body weight .40, upstandingness .39, sharpness .21, depth of body .17, strength of rear attachment .16, rear teat spacing .16,

* All reports referred to, hereafter, will be on studies of Holstein-Friesian cattle unless otherwise stated.

TABLE 1. Heritability Estimates of Type Traits from Studies with Official Holstein-Friesian Association Data

Trait	Author					
	Cassell et al. (10)	Legates (20)	Rennie et al. (30)	Hansen et al. (15)	Wilcox et al. (43)	Mitchell et al. (23)
Final Score	.31		.19	.26	.24	.20
General Appearance	.29		.27	.21	.29	.19
Dairy Character	.19		.22	.20	.50	.09
Body Capacity	.27		.31	.24	.66	.12
Mammary System	.22		.17	.27	.22	.18
Stature	.51	.55				
Head	.10	.17				
Front End	.12	.24				
Back	.23	.18				
Rump	.25	.29				
Hind Legs	.15	.10				
Feet	.11	.14				
Fore Udder	.21	.26				
Rear Udder	.21	.24				
Udder Support	.21	.15				
Udder Quality	.00	.08				
Teats	.31	.22				

TABLE 2. Heritability Estimates of Type Traits from Studies with Unofficial Holstein data.

Trait	Author			
	Norman and Van Vleck (25)	Aitchison et al. (1)	White et al. (40)	O'Bleness et al. (27)
Body Capacity	...	.34	...	...
Head	.12	...	...	.15
Front End	...	.25	.33	...
Back	.09	.23	.19	...
Rump	.17	.22	...	...
Hind Legs	.14	.33	.26	.08
Fore Udder	.16	.26	.20	.16
Rear Udder	.10	.26	.22	.30
Udder Support	.09	.20	.13	...
Udder Quality	.06	...	...	.28
Teats	.10	...	.08	...
Upstandingness	.39	.39	...	...
Sharpness	.21	...	...	.10
Shoulders	.16	...	.11	.10
Pasterns	.13	...	.15	.12
Depth of Body	.17	.36	.25	.33
Depth of Udder	.15	...	.30	.22

and depth of udder were among the highest estimates. Aitchison et al. (1) determined estimates on 13 type traits which ranged from .39 for up-standingness to .20 for udder support. Heritabilities of 22 components of type scored on an objective scale were analyzed by White et al. (40). Body traits ranged from .33 for chest to .11 for shoulders while udder traits ranged from .51 for shape of fore teats to .08 for teat placement.

Most heritability estimates from official HFAA data were in relatively good agreement. In two early studies, Mitchell et al. (23) found estimates for final score and scorecard traits ranging from .20 for final score to .09 for dairy character while Wilcox et al. (43) had estimates ranging from .66 for body capacity to .22 for mammary system. Later studies by Hansen et al. (15), whose estimates ranged from .27 for mammary system to .20 for dairy character, and Rennie et al. (30) with estimates from .31 for body capacity to .17 for mammary system were similar.

Heritabilities of the descriptive type traits instituted by HFAA in 1967 have been estimated by Legates (20) and Cassell et al. (10). Heritabilities of these traits as scored were comparable to those as per cent "desirable" in both studies. Legates (20) estimates ranged from .55 for stature to .08 for udder quality, whereas Cassell et al. (10), after adjusting for nonnormal distribution, estimated heritabilities ranging from .51 for stature to .00 for udder quality. Although some of the descriptive trait heritabilities were low (head, hind legs, feet, and udder quality), some of the individual subtraits

have been reported highly heritable by LaSalle et al. (19) and Van Vleck (37). The descriptive trait heritabilities were similar to those reported from unofficial Holstein data (1, 25, 27, 40).

Heritability of Longevity Traits

Casida and Chapman (8) reported a correlation of .157 between daughter and dam for length of time in herd, perhaps indicating some degree of heritability. Estimates of heritability of longevity or length of herd life, measured in a variety of ways, have been reported ranging from .49 to zero. Perhaps some of the variation is explained by most early reports having been based on data from one or a few herds with sires used entirely in a single herd. Later studies used more extensive data utilizing more cows in many herds.

In an early study on one herd, Wilcox et al. (42) estimated the heritability of herd life in terms of the number of successful parturitions to be .37. Parker et al. (28) also using a single herd's data, found estimates of heritability of age at last calving prior to disposal not significantly different from zero. Intrasire regression of daughters on dam and paternal half-sib estimates for the heritabilities of milk production per day of productive life (.28, .49) and length of productive life (.00, .39) were determined by Evans et al. (11).

White and Nichols (41) defined longevity as age at calving at the start of the last complete lactation and number of completed lactations. Their heritability estimates were .14 and .13, respectively, which were in agreement with Plowman and Gaalaas (29) whose estimated

heritability for age at calving at the start of the last complete lactation was .148. Miller et al. (21), utilizing extensive DHIA data, reported heritabilities of herd life (number of lactations truncated) ranging from .04 to .10 in ten opportunity groups.

Salazar (31) estimated the heritability of lifetime production and production per day of productive life as $.20 \pm .11$ and $.58 \pm .12$, respectively. Comparable estimates were found by Hargrove et al. (16) with heritabilities of .18 for lifetime production, .14 for number of lactations initiated, and .15 for productive life (the period from first calving to disposal). Very little genetic progress would be expected from direct selection for longer herd life with heritabilities as low as those estimated in the literature.

Genetic and Phenotypic Relationships Among Conformational Traits

Early estimates of the correlations among final score and the scorecard traits were reported by Mitchell et al. (23) and showed little variation among three stratified production levels. All phenotypic and genetic correlations were positive with the highest correlations between final score and other traits. The correlations between final score and the scorecard traits ranged from .53 to .39 (phenotypic) and .96 to .31 (genetic). Similar relationships were reported in a later study by Hansen et al. (15). Phenotypic correlations were highest between final score and the scorecard traits with a range of .87 (final score with general appearance and mammary system) to .34 (body capacity with mammary system). Genetic correlations followed

the same pattern ranging from .86 (final score with mammary system) to .18 (dairy character and mammary system).

Phenotypic correlations among type traits reported by Atkison et al. (3) agreed with other reports. They ranged from .86 (final score with general appearance) to .30 (dairy character with feet and legs).

Allaire and Henderson (2), in a type appraisal study of eleven conformation characteristics and milk production found low phenotypic correlations between the type appraisal traits. The correlations ranged from .415 (strength of fore udder attachment with strength of rear udder attachment) to -.132 (depth of body with depth of udder).

Miller et al. (22) reported phenotypic correlations among the descriptive type traits of the HFAA classification system. The highest correlation was .55 between fore udder and rear udder and the lowest, .07 between stature and teat size and placement.

Cassell et al. (10) in a study of genetic and phenotypic relationships among type traits reported that final score was highly and positively correlated genetically with all scorecard and descriptive traits. The estimates ranged from .93 (general appearance) to .40 (feet). There were sizable genetic correlations between stature and front end, front end and rump, among all of the descriptive udder traits, and among the scorecard traits. However, the correlations between the descriptive traits were, generally, not large implying that most are partially independent.

Genetic and Phenotypic Relationships Among
Conformational and Production Traits

In an early study of official HFAA classification data and milk yield, Touchberry (34) reported a phenotypic correlation of .18 and a genetic correlation of zero between type score and milk production.

Mitchell et al. (23) using official HFAA milk and type records, reported high genetic correlations between dairy character and milk production (ranging from .82 to .61 over three stratified groups) with most other genetic correlations between type traits and production low and not significant. Phenotypic correlations were low, ranging from .25 to .02. These were similar to phenotypic relationships reported by Wilcox et al. (43) on one herd which ranged from .20 for dairy character to .07 for rump. Genetic correlations ranged from .16 for mammary system to .08 for final score. Atkison et al. (3) reported phenotypic correlations between milk production and type traits ranging from .36 with dairy character to -.02 with fore udder.

Low phenotypic relationships have been reported between unofficial type data and DHI milk production records. Allaire and Henderson (2), correlating herdmate milk deviations and type traits, reported relationships ranging from .17 with dairy character to -.15 with udder depth. Aitchison et al. (1) reported phenotypic correlations ranging from .06 with front end to .09 with body capacity. Norman and Van Vleck (26) utilized first lactation production records and unofficial type appraisals to report low phenotypic correlations ranging from .27 (depth of udder) to -.10 (strength of fore udder attachment). Estimates of

genetic correlations lacked precision and ranged from 1.48 (forward slope with fore udder) to $-.71$ (milk production with strength of fore udder attachment).

The recent approach to evaluating relationships between milk and type has been to utilize sire progeny test averages (predicted difference milk, per cent "desirable" for the descriptive traits, and daughter averages for scorecard traits and final score). Grantham et al. (14) interpreted such correlations as predominately genetic due to large daughter numbers per sire (Moen, 24). All correlations between milk and type were negative except dairy character. A study by Miller et al. (22) reported similar results with phenotypic correlations generally negative with a range from $.07$ with head to $-.18$ with udder support. Descriptive type appeared to have limited value in predicting sire breeding value for milk production. However, the udder type traits were the most useful of the 12 descriptive traits for predictive purposes.

Genetic and Phenotypic Relationships Among Production and Longevity Traits

Reports in the literature indicate that length of herd life and lifetime productions are highly phenotypically and genetically correlated with first lactation milk production.

Gaalaas and Plowman (13) reported the simple correlation between final age (age at calving at start of last complete lactation) and first lactation production of $.179$. However, there apparently was a large variation in emphasis given production when selecting daughters of

sires to remain in the herd.

Negative phenotypic correlations were reported by Hargrove et al. (16) between age at first calving and the number of lactations (-.09), productive life (-.07), total days in milk (-.07), and lifetime production (-.05). Phenotypic correlations between first lactation and lifetime production, lifetime production and number of lactations, and lifetime production and productive life were .48, .95, and .97, respectively. Genetic correlations between first lactation production with number of lactations and productive life were .63 and .76. White and Nichols (41) found correlations between first lactation production with age at last calving and number of lactations completed of .254 and .216, respectively.

Parker et al. (28) reported that age at last calving prior to disposal was significantly correlated with first lactation production (.176). Phenotypic correlations between herd life (number of lactations completed) and milk production reported by Miller et al. (21) ranged from .25 to .19 over opportunity groups. This was in agreement with Van Vleck (36) who found that cows with high first lactation production produced more than their herdmates in later lactations and had a higher survival rate in each of the first four lactations.

Evans et al. (11) reported correlations between first lactation production with production per day of productive life (.45), age at disposal (.22) and length of productive life (.22). Phenotypic correlations between milk yield (herdmate deviation) with lifetime production (.34) and number of lactations (.20) were reported by Norman

and Van Vleck (26). The genetic correlation of .90 between first lactation milk and number of lactations was higher than other reports (16, 21), but tended to illustrate the emphasis on production in early life.

Carter (7) studied the relation of production with the percentage of a sire's daughters having 2, 4, or 6 lactations. Percentage having two lactations was highly correlated with production (.41), percentage having four lactations (.78), and percentage having six lactations (.72). Van Vleck et al. (38) concluded that milk production was the most important trait in determining average longevity in daughters of artificial insemination sires in New York Holsteins on DHI testing. All correlations were calculated using sire averages as observations. First lactation milk was highly correlated with longevity measures: percentage survivals through two lactations (.36), percentage survival through three lactations (.45), and percentage survival through four lactations (.54)

Relationships Among Conformation Traits and Longevity Traits

Berger et al. (4) reported that certain type traits had important emphasis on length of herd life (months of productive life and number of lactations). Nonsignificant partial regression coefficients for herd life on type score suggested lack of predictive value for individual type traits; however, their relative contributions to variation in herd life were important.

Specht et al. (32) reported that the relationship between final score and herd life was apparently small. The phenotypic evaluation between first classification score and herd life (times classified) was .2. The regression of herd life on first lactation score was .1 implying 1.7 months increased herd life for every point increase in final score. Correlations between individual type traits and herd life were essentially the same as that for final score and herd life. Higher correlations were reported by Evans et al. (11) between final score and age at disposal (.38) and final score and lifetime production (.36).

Van Vleck and Norman (39) associated type traits with reasons for disposal and concluded that few of the type traits measured before 49 months of age had any value in predicting reasons for disposal. This suggested that type traits measured in the first lactation would have only limited value in selection for longevity. However, Van Vleck et al. (38), in a study to determine the relationship between daughter averages for type traits and average daughter longevity for sires used in artificial insemination, reported that the body and udder traits were nearly as valuable as milk yield in first lactation in determining longevity. This was substantiated by a later report by Norman and Van Vleck (26) in which first lactation production variables and all type appraisal traits combined appeared to have equal predictive value for number of lactations; although type traits appraised in first lactation were not as effective predictors of lifetime production as first lactation production variables.

MATERIALS AND METHODS

Source of Data

The body conformation data used in this study were obtained from the Holstein-Friesian Association of America official classification records on Registered Holstein cows inspected between January, 1967 and June, 1974. Over a million individual records were obtained and edited to avoid multiple observations on individual cows (the earliest record for each cow in the data set was used), to remove records of males, to remove records of cows "checked" (scores not raised on a particular inspection date), and to delete all records with incomplete information or obviously erroneous type scores. This editing procedure resulted in 448,331 records, representing a single valid observation on each cow in the data set.

Included in each record was an evaluation of overall body conformation (final score) with a coded rating for each of the scorecard traits (general appearance, dairy character, body capacity, and mammary system) plus a coded evaluation for twelve individual elements of descriptive type (stature, head, front end, back, rump, hind legs, feet, fore udder, rear udder, udder support and floor, udder quality, and teat size and placement). Numerical ratings for final score were recorded: Excellent, 90 to 100; Very Good, 85 to 89; Good Plus, 80 to 84; Good, 75 to 79; Fair, 65 to 74; and Poor, 64 or lower. Scorecard traits were scored on a numerical code of 1--Excellent to 6--Poor.

The descriptive traits were assigned coded values (range 1 to 5) for each trait.

The final score and scorecard traits were age adjusted by the age adjustment factors reported by Cassell (9). However, due to the discrete and nonlinear coding of most of the descriptive traits, they were not age adjusted.

Records of cows which were the offspring of sires having a minimum of 20 daughters in 10 herds were chosen. These minimum requirements were applied to increase the accuracy of the progeny tests for type used in this study. A total of 1493 sires met these requirements.

To determine the relationship between body conformation and longevity, production information on the sires which met the type requirements was added to the data set. This information was obtained from the U.S. Department of Agriculture DHIA milk production record files for the period between January 1960 and May 1974. Individual lactation records of daughters of the 1493 sires were chosen from over six million records in the files. Included in each record were cow registration information, birth date, calving date, sire and dam registration information, herd code, and production information on a 2X-mature equivalent basis for a complete lactation.

To be included in this study, a cow must have been born before June, 1967 and have started her first lactation by 36 months of age. Cows which met these requirements were considered to have had the opportunity to complete four lactations (assuming a maximum first

calving age of 36 months, with 15 month maximum calving intervals).

Only daughters from herds on continuous test were included. A herd was considered on continuous test if there were lactation records for that herd completed by June, 1969 with more records reported annually from the year the herd began testing through 1973 with at least one record completed after March, 1973 (as the herd was considered on test during the last 15 month calving interval). To be included a sire had to have at least 30 daughters meeting the production requirements. An additional production data set was created under the same guidelines except that a time cutoff to allow cows the chance to complete five lactations was used (cows born prior to March, 1966 were considered).

The progeny test for production or predicted difference milk (PDM) for sires was obtained from the November, 1974 USDA DHIA Sire Summary. Only sires which had met the type and production record requirements and were listed in the DHIA Sire Summary were kept in the data set. A total of 788 sires met all requirements in the group allowed the chance to complete four lactations. These sires averaged 284 daughters with type information and 200 daughters with milk production records. There was a total of 223,713 type classified daughters and over 610,000 production records on 157,600 production daughters.

The group allowed the chance to complete five lactations contained 527 sires with 136,019 type classified daughters and 101,342 production daughters with over 460,000 lactation records.

Development of Progeny Test Data

The daughter classification records were used to determine the progeny tests for body conformation for each sire. The progeny tests for type consisted of a predicted difference type (PDT), daughter averages for the scorecard traits, plus the percentage of daughters "desirable" in each of the descriptive type categories for each sire. A descriptive trait was considered "desirable" if coded 1 or 2 for all traits except udder support and floor for which 1 was desirable.

The predicted difference type (PDT) was obtained using the formula:

$$PDT = b[p(\bar{P}-\bar{B}) - .5h^2(\bar{D}-\bar{B})]$$

\bar{P} = age adjusted average progeny score

\bar{B} = breed average final score

.5 = biological relationship between daughter and dam

\bar{D} = age adjusted average dam score

$$b = Nh^2 / (4 + (N-1)h^2 + \frac{4\sum n_i(n_i-1)}{N} c^2) = \text{repeatability of PDT}$$

N = total numbers of daughters with classified dams

h^2 = heritability for single classification scores = .30

n_i = number of daughters in the i^{th} herd

c^2 = nongenetic correlation between paternal sisters in same herd = .15

The values for b , \bar{P} , \bar{B} , and \bar{D} were calculated from the type records. Breed average final score was found to be 80.058. For daughters with dam records unavailable, breed average final score was substituted for dam final score in calculating \bar{D} 's.

The progeny tests for longevity consisted of four lifetime traits

calculated for each sire's progeny. The individual lactation records were used to calculate the percentage of daughters completing at least four lactations plus daughter averages for lifetime production, age at last calving, and production per day of productive life. The formula devised by Salazar (31) for calculating production per day of productive life (PDL) was used.

$$\text{PDL} = \text{LTP}/\text{TDH}$$

PDL = production per day of productive life

LTP = lifetime production

TDH = total days in herd after 27 months

$$\text{TDH} = (\text{DAL} + \text{DPL}) - \text{CF}$$

DAL = age in days at last calving

DPL = days in production for last lactation

CF = correction factor: $30.5 \times 27.0 = 823.5$

30.5 = average days per month

27.0 = age standard for initiation of the first lactation

A percentage of daughters completing at least five lactations was calculated for the 527 sires group instead of a percentage completing four lactations.

Statistical Procedure

Simple correlations between progeny tests for body conformation, longevity and PDM were calculated and can be interpreted as genetic correlations due to large numbers of daughters. Moen (24) has shown that unless the heritabilities of two traits differ greatly, the

phenotypic correlation between means of daughters of sires for two traits approaches the genetic correlation between the traits as the number of daughters becomes large. Further justification for considering these correlations genetic was given by Grantham et al. (14). In a study using similar data on body conformation, the simple correlations among progeny tests for final score and other traits differed very little from genetic correlations derived by Cassell et al. (10) from the same data set.

Multiple regression analysis of the longevity traits with the descriptive traits, scorecard traits, PDT, and PDM as the independent variables were evaluated. The statistical model used was:

$$Y_i = \mu + b_1 X_{1i} + b_2 X_{2i} + \dots + b_n X_{ni} + e_i$$

Y_i = longevity trait

μ = mean

$b_1 \rightarrow b_m$ = regression coefficients of longevity on the specific type traits

$X_{1i} \rightarrow X_{ni}$ = type traits

e_i = error term

Eleven different models were used (Figure 1) to determine which traits would be the most valuable in predicting longevity.

Stratified Groups by PDM

The 788 sires were divided into groups according to their predicted difference milk values. Nine groups were formed based on 300 lb. stratification levels (sires with PDM above +900, from +601 to +900, +301 to +600, +1 to +300, -299 to 0, -599 to -300, -899 to -600,

Model

- 1 LTP PDL AGE PCT = ST HD FE BK RP HL FT FU RU US QY TT
- 2 LTP PDL AGE PCT = ST HD FE BK RP HL FT FU RU US QY TT PDT
- 3 LTP PDL AGE PCT = GA DC BC MS PDT
- 4 LTP PDL AGE PCT = GA DC BC MS
- 5 LTP PDL AGE PCT = PDM FSCO
- 6 LTP PDL AGE PCT = GA DC BC MS PDT PDM
- 7 LTP PDL AGE PCT = GA DC BC MS PDM
- 8 LTP PDL AGE PCT = PDM PDT
- 9 LTP PDL AGE PCT = ST HD FE BK RP HL FT FU RU US QY TT PDT PDM
- 10 LTP PDL AGE PCT = ST HD FE BK RP HL FT FU RU US QY TT PDM
- 11 LTP PDL AGE PCT = PDM

Abbreviations of elements of multiple regression models

LTP [*] = lifetime production	ST ^{**} = stature
PDL [*] = production per day of productive life	HD ^{**} = head
AGE [*] = age at last calving	FE ^{**} = front end
PCT = percentage of daughters completing four lactations	BK ^{**} = back
PDT = predicted difference type	RP ^{**} = rump
PDM = predicted difference milk	HL ^{**} = hind legs
FSCO [*] = final score	FT ^{**} = feet
GA [*] = general appearance	FU ^{**} = fore udder
DC [*] = dairy character	RU ^{**} = REAR UDDER
BC [*] = body capacity	US ^{**} = udder support and floor
MS [*] = mammary system	QY ^{**} = udder quality
	TT ^{**} = teat size and placement

* expressed as age adjusted daughter averages

** expressed as percentage of daughters desirable for the trait

Figure 1. Multiple regression models used to predict longevity.

-1199 to -900, and below -1199). Simple correlations between progeny tests for all traits were calculated for each group and multiple regression analyses using the first four models in Figure 1 were evaluated.

The group of 527 sires with daughters allowed the chance to complete five lactations underwent the same analysis as the 788 sires with the exception that a percentage completing five lactations was inserted wherever the value for percentage completing four lactations was used previously.

RESULTS AND DISCUSSION

Means and standard deviations of all conformation, production, and longevity traits for the overall group of sires and for sire groups stratified by PDM are presented in Tables 3, 4, and 5. The daughter averages for type traits in the overall group were very similar to those reported by Grantham et al. (14), Cassell et al. (10), and Miller et al. (22). The average PDM for the 788 sires was lower than those reported by Grantham et al. (14) of -22 kg and 11 kg and by Miller et al. (22) of 100 kg.

There were few reports in the literature to compare with the overall group means for the longevity traits. However, Hargrove et al. (16) reported average lifetime milk production (LTP) of 45,876.6 lb. when allowing a 52-month production period. This was much lower LTP than this study which allowed 60 months. The average percentage of daughters completing four lactations (PCT 4) was very similar to that reported by Van Vleck et al. (38) of 46.2 per cent. The 788 sires had averages of 284 classified daughters and 200 daughters with production records.

For the sire groups stratified by PDM, average PDT generally increased as PDM levels were decreased. This is a reflection of the negative relationship between PDT and PDM (14). It also

TABLE 3. Means and Standard Deviations of Type Traits

PDM Group	N	FSCO	GA	DC	BC	MS	ST	HD	FE	BK
All	788	80.1 ± .3	3.5 ± .3	2.3 ± .1	2.3 ± .2	3.6 ± .3	82 ± 10	49 ± 11	82 ± 7	77 ± 8
Above +900	24	80.2 ± .4	3.6 ± .3	2.2 ± .1	2.4 ± .2	3.6 ± .3	83 ± 8	48 ± 9	82 ± 7	73 ± 11
+601 → +900	48	80.1 ± .3	3.6 ± .3	2.2 ± .2	2.4 ± .2	3.7 ± .3	81 ± 12	47 ± 10	81 ± 8	74 ± 8
+301 → +600	102	80.1 ± .3	3.6 ± .3	2.2 ± .1	2.4 ± .2	3.6 ± .3	82 ± 11	50 ± 10	82 ± 7	76 ± 8
+1 → +300	144	80.1 ± .4	3.5 ± .3	2.3 ± .1	2.4 ± .2	3.6 ± .3	80 ± 10	48 ± 11	82 ± 7	76 ± 9
-299 → 0	166	80.1 ± .3	3.5 ± .3	2.3 ± .1	2.3 ± .2	3.6 ± .3	82 ± 10	50 ± 10	82 ± 7	77 ± 8
-599 → -300	149	80.2 ± .3	3.4 ± .3	2.3 ± .1	2.3 ± .2	3.5 ± .3	82 ± 10	49 ± 11	83 ± 7	77 ± 8
-899 → -600	92	80.2 ± .3	3.4 ± .3	2.3 ± .1	2.3 ± .2	3.5 ± .3	83 ± 10	50 ± 10	83 ± 6	79 ± 7
-1199 → -900	39	80.3 ± .3	3.3 ± .3	2.3 ± .1	2.2 ± .2	3.4 ± .3	85 ± 10	52 ± 10	84 ± 6	80 ± 7
Below -1199	24	80.2 ± .4	3.3 ± .3	2.4 ± .1	2.2 ± .3	3.4 ± .2	87 ± 10	51 ± 14	84 ± 6	76 ± 10

TABLE 4. Means and Standard Deviations of Type Traits

PDM Group	N	RP	HL	FT	FU	RU	US	QY	TT
All	788	55 ± 13	37 ± 10	63 ± 10	54 ± 12	59 ± 11	61 ± 12	89 ± 5	64 ± 12
Above +900	24	49 ± 13	37 ± 9	63 ± 10	53 ± 13	59 ± 11	63 ± 14	90 ± 3	64 ± 13
+601 → +900	48	47 ± 12	36 ± 9	62 ± 8	49 ± 13	59 ± 11	61 ± 12	90 ± 3	64 ± 11
+301 → +600	102	50 ± 12	35 ± 10	61 ± 9	50 ± 12	55 ± 12	61 ± 11	89 ± 4	64 ± 12
+1 → +300	144	54 ± 13	36 ± 9	63 ± 9	52 ± 11	58 ± 11	60 ± 12	89 ± 5	64 ± 12
-299 → 0	166	55 ± 12	36 ± 9	63 ± 9	54 ± 11	59 ± 11	61 ± 12	89 ± 5	64 ± 12
-599 → -300	149	55 ± 12	37 ± 9	63 ± 10	57 ± 13	61 ± 10	62 ± 13	89 ± 4	65 ± 12
-899 → -600	92	59 ± 12	39 ± 11	63 ± 10	57 ± 12	60 ± 13	62 ± 13	89 ± 5	64 ± 12
-1199 → -900	39	63 ± 13	41 ± 10	65 ± 10	60 ± 10	62 ± 14	63 ± 15	89 ± 7	65 ± 12
Below -1199	24	60 ± 10	38 ± 10	67 ± 8	60 ± 9	60 ± 9	62 ± 11	87 ± 8	64 ± 10

TABLE 5. Means and Standard Deviations of Type, Production and Longevity Traits

PDM Group	N	PCM	PDT	LTP	PDL	AGE	PCT 4	# daughters	
								Type	Production
All	788	-136 ± 559	-.3 ± 1.1	55,919 ± 8,236	44.4 ± 6.7	60.1 ± 5.7	48.4 ± 9.1	284 ± 448	200 ± 277
Above +900	24	1,099 ± 165	-.6 ± 1.3	67,746 ± 5,776	49.9 ± 6.2	61.7 ± 3.8	52.7 ± 6.7	699 ± 924	332 ± 526
+601 → +900	48	738 ± 82	-.9 ± 1.3	62,152 ± 7,995	48.4 ± 5.6	61.6 ± 6.9	52.1 ± 8.5	450 ± 469	288 ± 350
+301 → +600	102	435 ± 88	-.6 ± 1.2	60,889 ± 7,816	47.2 ± 6.8	61.6 ± 5.1	52.3 ± 8.8	344 ± 508	251 ± 397
+1 → +300	144	140 ± 88	-.5 ± 1.1	58,195 ± 6,419	45.4 ± 6.1	61.1 ± 5.3	50.0 ± 8.7	278 ± 420	213 ± 243
-299 → 0	166	-156 ± 88	-.3 ± 1.0	55,889 ± 6,169	43.6 ± 8.4	60.6 ± 5.1	48.7 ± 7.3	235 ± 356	180 ± 216
-599 → -300	149	-442 ± 82	-.1 ± 1.1	53,791 ± 6,649	43.4 ± 4.8	59.4 ± 5.3	47.0 ± 8.1	291 ± 499	186 ± 252
-899 → -600	92	-712 ± 83	.1 ± 1.0	50,558 ± 8,320	41.9 ± 4.2	58.2 ± 6.6	44.9 ± 10.9	193 ± 303	156 ± 186
-1199 → -900	39	-1,035 ± 85	.3 ± 1.0	49,550 ± 7,889	41.9 ± 6.4	57.4 ± 6.4	42.4 ± 10.2	136 ± 204	98 ± 105
Below -1199	24	-1,500 ± 249	.3 ± 1.1	44,180 ± 6,101	40.1 ± 5.2	54.7 ± 5.1	39.0 ± 7.9	197 ± 219	162 ± 264

implies that sires were selected and daughters were kept in the herd for different reasons. Probably more emphasis was placed on milk when the high PDM sires were used while daughters of low PDM sires remained in the herd for reasons other than milk production.

Although there was little difference in the average daughter final scores among the stratified groups, definite trends were evident for the scorecard traits. Daughter averages for general appearance, body capacity, and mammary system decreased as the PDM level decreased implying that daughters of low PDM sires scored better for these categories, on the average, than did daughters of the high PDM sires. However, daughter averages for dairy character increased as PDM levels decreased implying the higher PDM sires produced daughters of better dairy character than the lower PDM sires. This perhaps explains the lack of change in daughter average final score over groups. Since final score is a composite of the four scorecard traits, the improvement in scores for general appearance, body capacity, and mammary system could be offset by a poorer score for dairy character, thus resulting in a similar final score.

Definite trends were also observed in the descriptive traits. Each PDM group was expressed as average percentage of daughters "desirable for all sires in the group. Back, rump, and fore udder showed increases from high PEM to low PDM groups.

Stature, head, front end, hind legs, and feet varied little from group to group except for the lower two groups (-900 and below) where definite increases in percentage "desirable" daughters were evident. There was only a slight increase for rear udder as PDM levels decreased while udder support, udder quality, and teat size and placement showed practically no differences among groups.

The means for the longevity traits relate the importance of PDM to daughter herd life. Lifetime production ranged from 44,180 lb. for the lowest sire group to 67,746 lb. for the highest group. Likewise PDL increased at ascending PDM levels, ranging from a low of 40.1 lb./day to 49.9 lb./day. Means for age at last calving increased in the negative PDM sire groups, but plateaued at just above 61 months for the positive PDM sire groups. This plateau effect was previously reported by White and Nichols (41). In their study, the number of lactations completed and age at last calving differed very little after the level of first lactation production reached 11,000 lb. milk and 450 lb. fat. For this study, the plateau effect was evident for groups ranging in LTP from 58,195 lb. to 67,746 lb. The percentage completing four lactations showed a similar plateau for the highest three PDM groups centering around 52.5%. The lower groups' means declined as the PDM level decreased.

Correlations Between Conformation,
Production, and Longevity

Genetic correlations between progeny test averages for type traits, milk production, and longevity traits for the 788 sires are presented in Table 6. The relationship between predicted difference type (PDT) and the descriptive traits were highly significant and positive ranging from .67 (fore udder and rear udder) to .31 (udder quality). There was a positive relationship between PDT and the scorecard traits also. Since the scorecard traits are rated on a scale of 1 for excellent to 6 for poor, the signs on the correlations were reversed to indicate relationships between traits. These ranged from .91 for general appearance to .57 for dairy character.

Most of the relationships between PDM and the type traits were highly significant and negative except for dairy character which was a significantly positive relationship (.27). Slightly higher correlations of .38 and .41 between PDM and dairy character were reported by Grantham et al. (14). Van Vleck and Norman (39) estimated a genetic correlation between sharpness and milk production of .34. Allaire and Henderson (2) reported a phenotypic correlation of .17 between dairy character and herdmate deviation for milk in Holsteins. The negative relationships between PDM and the other scorecard traits (general appearance, body capacity and mammary system) agreed with results of Grantham et al. (14) who reported correlations ranging from -.16 to -.13 and -.24 to -.21. However, these results disagreed with earlier research (23, 43).

TABLE 6. Correlations Among Traits for All Sires

N = 788

Trait	GA	DC	BC	MS	ST	HD	FE	BK	RP	HL	FT	FU	RU	US	QY	TT	PDT	PDM	LTP	PDL	AGE	PCT 4
PDT	.91	.57	.78	.86	.59	.48	.60	.35	.56	.55	.42	.67	.67	.49	.31	.43		-.27	-.05	-.08	.04	-.07
PDM	-.32	.27	-.27	-.26	-.11	-.06	-.11	-.15	-.27	-.12	-.08	-.25	-.15	-.05	.04	-.01	-.27		.53	.33	.26	.34
LTP	-.10	.18	-.12	-.02	.06	.01	.01	-.05	-.16	.03	.03	-.02	.03	.15	.20	.14	-.05	.53		.40	.64	.85
PDL	-.10	.08	-.03	-.07	.10	-.15	-.06	-.06	-.23	-.04	-.01	.01	-.04	.19	.18	.09	-.08	.33	.40		-.25	.22
AGE	.02	.15	-.09	.04	-.07	.21	.09	.05	.13	.09	.04	-.04	.09	-.10	-.01	.03	.04	.26	.64	-.26		.66
PCT 4	-.12	.04	-.17	-.01	.03	-.03	-.04	-.03	-.16	-.01	.00	.02	.02	.16	.19	.14	-.07	.34	.85	.22		.66

^aAll correlations with absolute values greater than .06 are significant at the .05 level and .08 at the .01 level.

The longevity traits and PDT were lowly correlated with only production per day of productive life or PDL (-.08) and PCT 4 (-.07) significant ($P < .05$). The relationship between the longevity traits and PDM were highly significant ($P < .01$) and positive. This was in agreement with earlier reports relating first lactation milk production with longevity traits. White and Nichols (41) reported simple correlations of .216 between first lactation milk production and number of lactations completed and .254 between first lactation milk production and age at last calving. Hargrove et al. (16) estimated genetic correlations between first lactation milk and lifetime production (.85), number of lactations (.62), and productive life (.176). Van Vleck et al. (38) calculated a correlation somewhere between phenotypic and genetic of .54 between first lactation milk and percentage of daughters completing four lactations.

Most relationships among the longevity traits were large, positive, and in agreement with previous studies (7, 16, 38). PCT 4 was highly correlated with LTP (.85) and age at last calving, hereafter, referred to as AGE (.66). LTP and AGE were also highly correlated (.65). Correlations among these traits were expected to be high since the traits are all expressions of herd life. These relationships agree with Van Vleck et al. (38) who reported correlations of .62 between percentage completing two lactations and percentage completing four lactations and .79 between percentage completing three lactations and percentage

completing three lactations and percentage completing four.

Hargrove et al. (16) reported high phenotypic correlations between lifetime production and the number of lactations initiated (.95), lifetime production and productive life (.97), and number of lactations initiated and productive life (.97). In an earlier report, Carter (7) gave correlations between the percentage of a sire's daughters having two lactations and those having four and six (.78 and .72, respectively).

PDL was a different kind of expression of lifetime performance. It was moderately, positively correlated with LTP (.40) and PCT 4 (.22). However, a negative relationship existed between PDL and AGE (-.25).

The longevity traits were lowly correlated with the score-card and descriptive traits. Correlations with lifetime production ranged from -.12 for body capacity to .20 for udder quality. Relationships with PDL ranged from -.23 for rump to .19 for udder support. Head had the highest correlation with age at last calving of .21 and udder support had the lowest of -.10. Correlations with percentage completing four lactations ranged from -.17 for body capacity to .19 for udder quality. Although the relationship between individual type traits and longevity apparently is small, the combined effect of the type traits is possibly more important.

Correlations among all traits for the 527 sires in the five lactation data set are in Appendix Table 13. Results for the five lactation set were similar to the four lactation set.

Predictive Mechanisms for Longevity

Results of analyses of eleven multiple regression models for predicting longevity traits from progeny test averages for type traits, predicted difference type, and predicted difference milk are shown in Tables 7 through 11. An assortment of independent variables were used in the regression equation to compare the relative importance of the scorecard traits, descriptive traits, PDT, PDM, and final score as predictive mechanisms for the longevity traits.

The multiple correlation coefficients squared (R^2) are given in Table 7. For predicting lifetime milk production, PDM ($R^2 = .28$) in Model 11 was more than twice as important as the scorecard traits (Model 4), descriptive traits (Model 1), or type traits combined with PDT (Models 2 and 3). PDM alone was almost equivalent to PDM and PDT (Model 8). The importance of PDM as the main source of variation can be seen by comparison of models containing PDM as an independent variable with models containing only type traits as independent variables. Of all models, the best ones for predicting lifetime production were Models 9 and 10 ($R^2 = .34$). Of the models with only type traits as independent

TABLE 7. Multiple Correlations Coefficients Squared (R^2) Between Longevity Traits and Type and Production Traits for All Sires (788)

Model	Longevity Traits			
	LTP	PDL	Age	PCT 4
1	.10 _{.32}	.12	.10 _{.32}	.09 _{.30}
2	.12 _{.35}	.13	.10 _{.32}	.11 _{.33}
3	.11	.04	.07	.06
4	.11	.04	.06	.06
5	.29 _{.54}	.12	.07	.11
6	.30	.12	.12	.14
7	.30	.12	.12	.14
8	.30 _{.53}	.11	.08 _{.28}	.11 _{.33}
9	.34 _{.58}	.21	.18 _{.42}	.18 _{.42}
10	.34 _{.58}	.20	.18 _{.42}	.17 _{.41}
11	.28 _{.53}	.11	.07 _{.26}	.12 _{.35}

TABLE 8. Weights of Components for Predicting Lifetime Production

Model	PDM	PDT	FSCO	GA	DC	BC	MS	ST	HD	FE	BK	RP	HL	FT	FU	RU	US	QY	TT
1								5 .048	5 .048	3 .033	1 -.008	17 -.180	4 .041	0 .005	24 -.246	4 .045	6 .059	15 .158	16 .167
2		23 -.361						9 .143	5 .078	5 .073	0 .007	6 -.093	5 .086	1 .015	11 -.168	7 .112	5 .080	10 .154	13 .209
3		10 .091		32 -.300	37 .343	15 -.140	6 .053												
4				32 -.264	42 .351	15 -.123	11 .094												
5	90 .542		10 .062																
6	64 .568	11 .095		1 .013	2 -.021	11 -.092	11 -.092												
7	68 .568			6 .050	1 -.013	9 -.075	16 .134												
8	85 .561	15 .100																	
9	37 .515	16 -.225						10 .131	2 .027	2 .028	1 .016	0 -.003	6 .076	1 .012	0 -.002	5 .072	4 .055	7 .099	9 .117
10	51 .526							7 .072	1 .007	0 .002	1 .007	5 -.055	5 .048	0 .005	4 -.047	3 .030	4 .042	10 .100	9 .089
11.	.534																		

TABLE 9. Weights of Components for Predicting Production Per Day of Productive Life

Model	PDH	PDT	FSCO	GA	DC	BC	MS	ST	HD	FE	BK	RP	HL	FT	FU	RU	US	QY	TT
1								15 .137	10 -.097	1 -.008	1 .011	20 -.187	1 .012	0 .003	13 -.122	5 -.047	16 .148	9 .089	9 .083
2		20 -.239						17 .200	7 -.077	2 .019	2 .021	11 -.129	4 .042	1 .010	6 -.071	0 -.004	14 .162	7 .087	9 .110
3		18 -.171		30 -.284	21 .202	19 .175	12 .114												
4				49 -.394	26 .187	20 .143	5 .038												
5	80 .340		20 .085																
6	36 .353	17 -.168		9 -.089	3 -.024	21 .204	14 .138												
7	45 .353			20 -.154	5 -.039	22 .173	8 .063												
8	97 .332	3 .009																	
9	24 .295	13 -.161						16 .193	9 -.107	1 -.007	2 .026	6 -.078	3 .036	1 .008	2 .024	2 -.026	12 .148	4 .055	5 .058
10	29 .303							14 .150	12 -.121	2 -.026	2 .019	11 -.115	2 .016	0 .003	1 -.007	5 -.056	13 .138	5 .056	4 .038
11	.329																		

TABLE 10. Weights of Components for Predicting Age at Last Calving

Model	PDM	PDT	FSCO	GA	DC	BC	MS	ST	HD	FE	BK	RP	HL	FT	FU	RU	US	QY	TT
1								13	18	5	2	1	3	0	14	13	15	7	9
								-.140	.193	.051	.026	.015	.036	.002	-.152	.140	-.159	.081	.096
2		8						9	16	5	3	3	4	0	11	13	12	7	9
		-.102						-.113	.201	.063	.030	.040	.048	.005	-.130	.159	-.153	.080	.108
3		27		7	18	37	11												
		.275		.067	.183	-.383	-.114												
4				24	29	46	1												
				.173	.208	-.332	.009												
5	88		12																
	.259		-.035																
6	23	22		18	0	29	8												
	.288	.277		.226	-.001	-.359	-.094												
7	29			34	3	31	3												
	.288			.332	.024	-.308	.029												
8	71	29																	
	.296	.122																	
9	23	2						10	14	3	3	7	3	0	3	11	13	4	4
	.297	-.024						-.121	.171	.037	.036	.092	.043	.003	-.035	.136	-.167	.048	.055
10	24							10	14	3	3	7	3	0	3	11	14	4	4
	.298							-.127	.169	.034	.035	.086	.040	.002	-.039	.132	-.169	.049	.052
11	.264																		

TABLE 11. Weights of Components for Predicting Percentage Completing Four Lactations

Model	PDM	PDT	FSCO	GA	DC	BC	MS	ST	HD	FE	BK	RP	HL	FT	FU	RU	US	QY	TT
1								1	3	2	5	20	0	2	20	4	10	17	16
								.009	.029	-.017	.040	-.172	-.001	.014	-.164	.032	.085	.142	.136
2		28						8	4	2	4	5	3	2	6	7	8	10	13
		-.392						.113	.061	.027	.056	-.072	.049	.025	-.079	.104	.108	.138	.182
3		7		23	22	31	17												
		.052		-.163	.159	-.220	.121												
4				21	25	32	22												
				-.143	.164	-.210	.145												
5	96			4															
	.334			-.013															
6	42	6		5	9	21	17												
	.371	.054		.041	-.078	-.189	.147												
7	43			7	9	21	20												
	.371			.062	-.074	-.179	.171												
8	95	5																	
	.341	.018																	
9	22	24						8	2	0	5	2	3	2	1	6	7	8	10
	.212	-.315						.106	.032	.001	.061	-.026	.043	.023	.015	.082	.094	.107	.129
10	35							3	0	4	6	11	0	2	5	3	9	12	10
	.308							.023	.004	-.035	.049	-.098	.003	.014	-.048	.024	.075	.109	.091
11	.336																		

variables, Model 2 with descriptive traits plus PDT accounted for slightly more variation than the others.

Predicted difference milk was much less accurate in predicting production per day of productive life. Model 9 accounted for the most variation ($R^2 = .21$). Model 2 was again the best of the type traits models (1-4). This model of descriptive traits plus PDT accounted for slightly more variation than all other models except 9 and 10. However, PDT apparently accounts for little of the variation since its exclusion decreases R^2 only slightly (compare Models 1 and 2, 3 and 4, 6 and 7, and 9 and 10). Therefore, the descriptive traits combined are equivalent or better predictors of PDL than the scorecard traits, PDM, PDT, or combinations of these traits.

For predicting age at last calving, the descriptive traits again appeared to be the most effective combination of type traits. They also accounted for more of the variation than PDM. However, the scorecard traits when combined with PDM had a slightly higher R^2 value. The best combination of traits appeared to be the descriptive traits plus PDM which had an R^2 value of .18.

Predicted different milk exceeded all four type models as a predictor of percentage of daughters completing four lactations ($R^2 = .12$). This was in agreement with Van Vleck et al (38) who reported that milk production was the most important trait in determining longevity to four lactations. The descriptive traits plus

PDT was just slightly lower ($R^2 = .11$) and was the best of the type models. However, Model 9 accounted for the most variation ($R^2 = .18$) and was a combination of descriptive traits, PDT, and PDM. This shows that the traits were not independent. Although there were differences in the data used in this study and in that used by Van Vleck et al. (38) in the grouping of traits for regression analyses, and in the magnitude of R^2 values obtained, certain comparisons between the two studies can be made. The New York study reported that milk was the most important trait ($R^2 = .28$). Udder traits ($R^2 = .23$), body traits ($R^2 = .17$), and management traits ($R^2 = .04$) followed in importance. When all the traits were combined in a regression equation, the R^2 was .69. For this study, the order of importance was headed by PDM ($R^2 = .12$), followed by the descriptive traits ($R^2 = .09$), the scorecard traits ($R^2 = .06$), and PDT. Predicted difference type apparently accounted for very little of the variation.

How well conformation traits predict longevity depends on how longevity is defined. The four longevity traits defined in this study are all a reflection of herd life. R^2 values for all four bordered around .10 when the descriptive traits were used with or without PDT in the regression equation. Values were lower for the scorecard traits with the exception of lifetime production. Predicted difference milk appeared to be a more important trait for predicting lifetime production and the percentage completing four lactations while the combined descriptive traits outranked

PDM for predicting production per day of productive life and the age at last calving. Apparently the most effective predictive model for all four longevity traits was a combination of the descriptive traits, PDT, and PDM.

The R^2 values for the 527 sires in the five lactation data set are in Appendix Table 14. The magnitude of the values are less than the R^2 values for the four lactation data set.

Standard Partial Regression Coefficients for the Longevity Traits

Weights of the components of the regression models are given in Tables 8 through 11. These are expressed as the standard partial regression coefficients and as the percentage of the sum of the absolute value of all components. The standard partial regression coefficients indicate the relative importance of the independent variables in the models.

For predicting lifetime production, the largest positive standard partial regression coefficients (Table 8) in models containing the descriptive traits were associated with teat size and placement, udder quality, and stature. The largest negative coefficients were associated with fore udder and rump. The five udder traits accounted for from 25 to 65% of the accounted variation by the model in models containing descriptive traits while hind legs and feet accounted for only from 4 to 7%. In models containing the scorecard traits without PDM, dairy character was associated with the largest positive coefficients and general

appearance was associated with the largest negative coefficients. However, when PDM was included in the models, mammary system accounted for the largest positive coefficients of the scorecard traits and body capacity accounted for the largest negative coefficients.

In the LTP models which have PDM as an independent variable, it accounted for the largest portion of the accountable variation and was from two to six times more important than PDT in models containing both variables. The importance of PDM was shown by comparison of Models 1 and 10. Fore udder and rump were the most important traits in Model 1, but when PDM was added to the descriptive traits in Model 10, their standard partial regression coefficients were greatly reduced. Most of the variation accountable to fore udder and rump in Model 1 was accountable to PDM in Model 10 illustrating the closeness of association between PDM and fore udder and rump. The same type of association existed between PDM and dairy character. In Model 4, dairy character accounted for 42% of the variation attributed to the model while in Model 7, dairy character accounted for only 1% and PDM for 68% reflecting the positive correlation between PDM and dairy character. PDT was associated with a negative standard partial regression coefficient when included in descriptive trait models, but when PDT was included in models with scorecard traits or PDM alone the coefficients were positive.

The standard partial regression coefficients for predicting LTP imply that daughters which classified well for such categories as dairy character, teat size and placement, udder quality, and stature should have a greater lifetime production than daughters with poorer type in these categories. However, daughters with poorer type ratings for fore udder, rump, and general appearance should have greater LTP than daughters with higher classification ratings in these categories.

Production per day of productive life models were similar (Table 9) to LTP models. In models containing the descriptive traits, the largest positive standard partial regression coefficients were associated with udder support and stature. Highest negative values were associated with rump, head, and fore udder. The combined variation of the udder traits accounted for the models ranged from 25 to 52%. In scorecard trait models, general appearance was associated with the largest negative coefficients while dairy character had the largest positive coefficients in Models 3 and 4 and body capacity had the largest positive coefficients of the scorecard traits in Models 6 and 7.

PMD was the predominant independent variable in Models 5 through 10 and was 32 times more important in explaining PDL in Model 8 than was PDT. Negative standard partial regression coefficients were associated with PDT for Models 2, 3, 6, and 9 while the coefficient for Model 8 was slightly positive. PDM

accounted for variation in Model 10 that was attributed to fore udder, and rump in Model 1 implying an association between the traits. Dairy character is a similar example in Models 4 and 7. On the other hand, traits such as stature and body capacity change little due to inclusion of PDM in the PDL models.

For predictive purposes, daughters classifying well for such categories as body capacity, udder support, and stature should tend to have greater PDL than daughters classifying poorly in these categories. On the other hand, daughters classifying poorly in general appearance, rump, head, and fore udder should tend to have greater PDL than higher classifying daughters in these traits.

The important descriptive traits in predicting age at last calving (Table 10) were head and rear udder (with positive coefficients) and fore udder, udder support, and stature (with negative coefficients). Combined udder trait variation accounted for by the models ranged from 35 to 58% and hind legs and feet ranged from 3 to 4%. General appearance (with positive coefficients) and body capacity (with negative coefficients) were generally the most important scorecard traits. In Model 7, general appearance and body capacity each accounted for more variation than PDM. PDL was almost equal in importance with PDM in Model 6 while body capacity was the most important trait in the model. The relationship among PDM and fore udder (Models 1 and 10) and dairy character (Models 4 and 7) also held true for AGE models. A lack of relationship was evident between PDM and stature.

Therefore, daughters which are highly rated on the descriptive traits of head and rear udder and the scorecard trait, generally appearance, are more likely to reach an older AGE than daughters rating poorly. However, daughters which receive poor classification scores in the categories of fore udder, udder support, stature, and body capacity should tend to reach older AGE's than daughters rating high in these traits.

For predicting the percentage completing four lactations, the largest standard partial regression coefficients (Table II) in descriptive trait models were associated with udder quality, teat size and placement, udder support (all positive), and fore udder, and rump (both negative). The combined variation of the udder traits accounted for by the models for PCT 4 ranged from 32 to 67% and feet and hind legs accounted for 2 to 5% of the variation.

PDM was again the most important variable in the models which included it. The relationship between PDM and type traits was also evident for PCT 4. BY adding PDM to the descriptive traits, the importance of fore udder and rump as predictors were greatly reduced. Likewise, the addition of PDM to the scorecard traits greatly reduced the importance of dairy character changing the standard partial regression coefficient for dairy character from a positive to a negative value.

In models containing the scorecard traits, body capacity was associated with the largest negative coefficients while dairy

character (Models 3 and 4) and mammary system (Models 6 and 7) were associated with the largest positive coefficients. Van Vleck et al. (39) reported udder edema, deep body, milk yield, and medium upstandingness as traits associated with the largest positive standard partial regression coefficients in a model predicting the percentage completing four lactations. Traits reported associated with the largest negative coefficients were fore udder attachment, udder halving, and deep udder.

Therefore, the standard partial regression coefficients for the longevity traits imply that daughters of sires which classify well for such categories as dairy character, mammary system, udder quality, udder support, teat size and placement, and stature should have a longer herd life than daughters with poorer type in these categories. On the other hand, daughters with poorer type ratings for fore udder and rump should have a longer herd life than daughters with higher classification ratings. Feet and hind legs were of little importance when predicting longevity. The coefficients indicated that daughters of sire with high predicted difference milk have greater longevity than daughters of low PDM sires. This was in general agreement with previous studies (21, 36, 38, 41) which indicated that high first-lactation producers, as a group, stay in the herd longer than low producers. The coefficients associated with PDT varied greatly. Some were lowly positive while others were large negative values. Part of this

discrepancy could be due to the negative relationship between PDT and PDM or to interrelationships with the other categories.

Weights of the components of the regression models for the five lactation data set are in Appendix Tables 19 through 22. Results are similar to the four lactation set.

Stratified Sire Groups by PDM

Correlations between progeny test averages for type traits, milk production, and longevity traits for the stratified sire groups are presented in Appendix Tables 1 through 9. The relationships were in general agreement with those of the overall group presented in Table 6.

Multiple correlation coefficients squared for the stratified sire groups associated with Models 1 through 4 are presented in Tables 12 through 15. A distinct pattern existed among the R^2 values for the stratified sire groups and was consistent for all four longevity traits in each of the models of type traits. For Models 1 and 2 which contain the descriptive traits as independent variables, the R^2 values were very large for the highest PDM group (above +900) and declined as PDM level declined. The smallest R^2 values were associated with the sire groups between the +300 and -599 PDM levels. R^2 values for the PDM groups below these levels increased as PDM decreased until the coefficients squared for the below -1199 group were comparable with the above +900 group. Models 3 and 4 which contained the scorecard traits

TABLE 12. R^2 Values for Stratified Groups Using Model 1

PDM Group	N	LTP	PDL	AGE	PCT 4
Above +900	24	.59	.64	.52	.43
+601 → +900	48	.28	.37	.34	.29
+301 → +600	102	.20	.09	.19	.27
+1 → +300	144	.18	.34	.11	.17
-299 → 0	166	.12	.03	.16	.09
-599 → -300	149	.08	.20	.20	.06
-899 → -600	92	.16	.29	.24	.14
-1199 → -900	39	.41	.48	.41	.48
Below -1199	24	.30	.58	.53	.53

TABLE 13. R^2 Values for Stratified Groups Using Model 2

PDM Group	N	LTP	PDL	AGE	PCT 4
Above +900	24	.64	.69	.52	.46
+601 → +900	48	.32	.37	.39	.29
+301 → +600	102	.20	.11	.19	.27
+1 → +300	144	.19	.34	.12	.17
-299 → 0	166	.13	.03	.16	.10
-599 → -300	149	.10	.21	.20	.11
-899 → -600	92	.18	.29	.25	.20
-1199 → -900	39	.41	.48	.42	.48
Below -1199	24	.30	.58	.54	.53

TABLE 14. R^2 Values for Stratified Groups Using Model 3

PDM Group	N	LTP	PDL	AGE	PCT 4
Above +900	24	.14	.16	.18	.14
+601 → +900	48	.16	.18	.08	.11
+301 → +600	102	.03	.03	.06	.04
+1 → +300	144	.04	.06	.04	.05
-299 → 0	166	.06	.02	.06	.05
-599 → -300	149	.05	.08	.13	.06
-899 → -600	92	.18	.05	.18	.21
-1199 → -900	39	.40	.07	.40	.38
Below -1199	24	.20	.25	.32	.26

TABLE 15. R^2 Values for Stratified Groups Using Model 4

PDM Group	N	LTP	PDL	AGE	PCT 4
Above +900	24	.14	.15	.16	.08
+601 → +900	48	.13	.15	.01	.07
+301 → +600	102	.01	.03	.05	.04
+1 → +300	144	.04	.06	.04	.05
-299 → 0	166	.06	.02	.06	.05
-599 → -300	149	.04	.07	.12	.06
-899 → -600	92	.14	.04	.13	.18
-1199 → -900	39	.38	.07	.38	.38
Below -1199	24	.17	.25	.31	.20

showed generally the same pattern except that the magnitude of the values was smaller. A possible explanation for this pattern was that the closeness of association between the high and low PDM levels and the longevity traits occurred for different reasons. Perhaps the daughters of sires in the upper PDM sire groups remained in the herd longer, predominantly because of their milk production, whereas, daughters of sires in the lower PDM groups were kept due to reasons other than milk production; mainly due to conformation.

R^2 values for the five lactation data sets stratified sire groups associated with Models 1 through 4 are presented in Appendix Tables 15 through 18. In general, larger R^2 values were associated with the five lactation data set than the four lactation data set.

CONCLUSIONS

Predicted difference milk was the most important trait in predicting the longevity of daughters of Holstein-Friesian sires. The relationship between individual type traits and longevity was apparently small since the longevity traits: lifetime production, production per day of productive life, age at last calving, and percentage completing four lactations were lowly correlated with predicted difference type, the descriptive traits, and the scorecard categories.

However, the combined effect of conformation traits was more important. PDM was the best predictor of LTP, being more than twice as effective as the best type traits model composed of PDT plus the descriptive categories. For PDL and AGE, the combined descriptive traits were a more effective predictor than PDM; although for PCT 4, PDM was a slightly better predictor than the descriptive traits plus PDT model.

The most important descriptive traits in the predictive model were udder quality, teat size and placement, udder support, fore udder, and rump. The latter two traits were negatively related to longevity (poorer type ratings for these traits imply a longer herd life).

SUMMARY

Type data for this study was provided by the Holstein-Friesian Association of America, which made available all type classification records on Registered Holstein cows inspected between January, 1967 and June, 1974. Included in the classification data were results on final score, the scorecard traits: general appearance, dairy character, body capacity, and mammary system, and the descriptive categories: stature, head, front end, back, rump, hind legs, feet, fore udder, rear udder, udder support and floor, udder quality, and teat size and placement. Production data was obtained from the United States Department of Agriculture DHIA milk production records for the period between January, 1960 and May, 1974. Each record contained cow registration information, birth date, calving date, sire and dam registration information, herd code, and 2X-mature equivalent complete lactation information.

Sire progeny tests were calculated from the data set to determine the relationship between body conformation and longevity. These progeny tests consisted of predicted difference type (PDT), daughter averages for the scorecard traits, the percentage of daughters "desirable" in each descriptive trait, plus daughter averages for lifetime production (LTP), production per day of productive life (PDL), age at last calving (AGE), and percentage completing four lactations (PCT 4). The predicted difference milk (PDM) for each sire was obtained from

the November, 1974 USDA DHIA Sire Summary. A total of 788 sires with 223,713 daughters with type classification records and 157,600 daughters with over 610,000 production records comprised the data set.

Genetic correlations between progeny test averages for PDT and the descriptive traits were highly significant and positive ranging from .67 (fore udder and rear udder) to .31 (udder quality). The scorecard traits were also positively correlated with PDT and highly significant. Most of the relationships between PDM and the type traits were highly significant and negative except for dairy character which was significantly positive (.27).

The longevity traits and PDT were lowly correlated with only PDL (-.08) and PCT 4 (-.07) significant ($P < .05$). The relationship between the longevity traits and PDM were highly significant ($P < .01$) and positive. Most relationships among the longevity traits were highly significant ($P < .01$) and positive. PCT 4 was highly correlated with LTP (.85) and AGE (.66). LTP and AGE were similar (.64). PDL was moderately, positively correlated with LTP (.40) and PCT 4 (.22). However, a negative relationship existed between PDL and AGE (-.25).

The relationship between individual type traits and longevity apparently is small. The longevity traits were lowly correlated with the scorecard and descriptive traits. Correlations ranged from -.23 between PDL and rump to .21 between AGE and head.

An assortment of independent variables were used in eleven multiple regression equations to compare the relative importance of

the scorecard traits, descriptive traits, PDT, PDM, and final score as predictive mechanisms for the longevity traits. PDM apparently was the most important trait for predicting herd life when defined as LTP or PCT 4. However, the combined descriptive traits had a larger R^2 value than PDM for predicting PDL and AGE. R^2 values for all four longevity traits bordered around .10 when the descriptive traits were used in the regression equation. Values were lower for the scorecard traits with the exception of LTP. With such small R^2 values, one would expect only limited success in a selection program based on longevity. Apparently, the most effective predictive model for all four longevity traits was a combination of the descriptive traits, PDT and PDM.

Standard partial regression coefficients for the longevity traits indicated that daughters of sires which classify well for such categories as dairy character, mammary system, udder quality, udder support, teat size and placement, and stature should have a longer herd life than daughters with poorer type in these categories. On the other hand, daughters with poorer type ratings for fore udder and rump should have a longer herd life than higher classifying daughters in these traits.

When PDM and the type traits were regressed on the longevity traits for sire groups stratified by PDM, a distinct pattern developed for the R^2 values for the stratified groups and was consistent for all four longevity traits. The R^2 values were large for the highest PDM group (above +900) and declined as PDM level declined. Smallest

values were associated with the sire groups between the +300 and -599 PDM levels. Below these levels, R^2 values increased as PDM decreased until the coefficients squared for the below -1199 group were comparable with the above +900 group. A possible explanation was that the closeness of associations between the high and low PDM levels and the longevity traits occurred for different reasons. Perhaps daughters of sires in the upper PDM sire groups had greater longevity, predominantly because of their milk production, whereas daughters of low PDM sires were kept due to reasons other than milk production; mainly due to conformation.

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TABLE 1. Correlations Among Traits for Sires in PDM Above +900

N = 24

Trait	GA	DC	BC	MS	ST	HD	FE	BK	RP	HL	FT	FU	RU	US	QY	TT	PDT	PDM	LTP	PDL	AGE	PCT 4
PDT	.96	.74	.78	.83	.53	.84	.72	.51	.65	.79	.62	.71	.62	.63	.51	.43		.43	.28	.16	.14	-.02
PDM	.37	.49	.37	.39	.24	.36	.43	.25	.35	.29	.14	.23	.47	.35	.11	.10	.43		.47	.41	-.08	.07
LTP	.23	.29	.19	.27	.29	.43	.23	.04	.23	.26	.11	.26	.34	.27	.19	.24	.28	.47		.73	-.07	.39
PDL	.09	.17	.11	.22	.21	.20	.13	.02	.02	.12	-.02	.29	-.04	.31	-.02	.26	.16	.41	.73		-.68	.02
AGE	.22	.18	.19	-.03	.13	.20	.18	.19	.36	.10	.13	-.18	.19	-.23	.10	-.16	.14	-.08	-.07	-.68		.38
PCT 4	-.07	-.07	-.18	.06	.16	.12	-.11	.12	-.18	-.16	-.34	.05	.02	.11	.33	.01	-.02	.07	.39	.02	.38	

^bAll correlations with absolute values greater than .40 are significant at the .05 level and .61 at the .01 level.

TABLE 2. Correlations Among Traits for Sires in PDM Group +601 -- +900

N = 48

Trait	GA	DC	BC	MS	ST	HD	FE	BK	RP	HL	FT	FU	RU	US	QY	TT	PDT	PDM	LTP	PDL	AGE	PCT 4
PDT	.75	.80	.79	.86	.59	.60	.59	.36	.52	.80	.63	.65	.63	.42	.51	.46		.12	.30	.23	.13	.12
PDM	.12	.20	.02	.13	-.20	.23	.24	-.03	.22	.31	.09	.01	.08	-.10	-.06	.30	.12		.10	.06	.07	.11
LTP	.21	.23	.21	.30	.28	.30	.06	.26	.08	.15	.17	.17	.28	.06	.27	.17	.30	.10		.08	.74	.80
PDL	.18	.30	.16	.27	.35	.19	.08	-.08	.07	.07	.12	.30	.28	.52	.32	.18	.23	.06	.08		-.57	-.19
AGE	.08	.05	.09	.07	-.01	.14	.04	.28	.05	.10	.04	-.07	.02	.36	-.06	.04	.13	.07	.74	-.57		.75
PCT 4	.02	.02	.07	.14	.20	.16	-.03	.24	-.04	.06	.09	.10	.15	-.02	.21	.14	.12	.11	.80	-.19	.75	

^aAll correlations with absolute values greater than .29 are significant at the .05 level and .41 at the .01 level.

TABLE 3. Correlations Among Traits for Sires in PDM Group +301 -- +600

N = 102

Trait	GA	DC	BC	MS	ST	HD	PE	BK	RP	HL	FT	FU	RU	US	QY	IT	PDT	PDM	LTP	PDL	AGE	PCT 4
PDT	.93	.77	.74	.85	.58	.53	.59	.41	.57	.54	.40	.64	.57	.53	.35	.42		-.18	-.06	-.06	.12	-.12
PDM	-.14	-.04	-.14	-.11	-.19	-.07	-.05	-.05	-.02	.01	.01	-.18	.10	-.01	-.07	-.22	-.18		.01	.17	-.08	0.03
LTP	-.09	-.10	-.10	-.05	.08	-.05	-.15	-.15	-.26	.10	.17	.00	.01	.12	.27	.02	-.06	.01		.43	.49	.80
PDL	-.02	-.07	.04	-.12	.16	-.14	-.04	-.06	-.12	.06	.03	-.02	-.01	.06	.12	.01	-.06	.17	.43		-.38	.24
AGE	.04	.10	-.04	.17	-.05	.26	.00	-.08	.05	.06	.20	.08	.17	.03	.11	.06	.12	-.08	.49	-.38		.54
PCT 4	-.15	-.14	-.18	-.08	.01	-.11	-.23	-.21	-.32	.05	.19	-.06	.00	.14	.21	-.01	-.12	-.03	.80	.24	.54	

^dAll correlations with absolute values greater than .18 are significant at the .05 level and .25 at the .01 level.

TABLE 4. Correlations Among Traits for Sires in PDM Group +1 -- + 300

N = 144

Trait	GA	DC	BC	MS	ST	HD	FE	BK	RP	HL	FT	FU	RU	US	QY	TT	PDT	PDM	LTP	PDL	AGE	PCT 4
PDT	.92	.74	.79	.83	.62	.40	.61	.35	.62	.48	.34	.62	.69	.41	.25	.38		-.03	.04	.01	.04	-.11
PDM	-.03	-.05	-.07	.03	.00	.07	.01	-.11	.00	-.01	.06	.03	.01	.02	-.12	.10	-.03		.11	.00	.09	.08
LTP	-.03	-.04	-.04	.12	.17	-.16	-.06	-.03	-.11	-.02	.02	.17	.06	.29	.31	.27	.04	.11		.41	.46	.33
PDL	-.05	-.03	.02	.08	.20	-.27	-.15	-.12	-.31	-.13	.05	.18	.05	.38	.33	.26	.01	.00	.41		-.56	.15
AGE	.05	.01	-.06	.04	-.08	.14	.10	.12	.20	.14	-.03	-.04	-.01	-.16	-.08	.00	.04	.09	.48	-.56		.58
PCT 4	-.14	-.16	-.17	.00	.01	-.18	-.17	-.02	-.16	-.09	-.05	.06	-.11	.21	.26	.20	-.11	.08	.83	.15	.58	

*All correlations with absolute values greater than .16 are significant at the .05 level and .24 at the .01 level.

TABLE 5. Correlations Among Traits for Sires in PDM Groups -299 -- 0

N = 166

Trait	GA	DC	BC	MS	ST	HD	FE	BK	RP	HL	FT	FU	RU	US	QY	TT	PDT	PDM	LTP	PDL	AGE	PCT 4
PDT	.90	.70	.77	.86	.56	.45	.58	.35	.45	.56	.43	.65	.70	.49	.33	.45		-.10	.06	-.07	.12	.04
PDM	-.11	.10	-.07	-.11	.03	.04	.00	-.13	-.08	-.13	-.03	-.06	-.08	-.02	-.01	.02	-.10		.17	.09	.05	.05
LTP	.03	.19	.01	.07	.19	-.05	.15	.04	.00	.04	-.02	.03	.05	.19	.17	.11	.06	.17		.13	.62	.87
PDL	-.03	-.08	-.03	-.09	-.07	.02	.09	-.04	.03	-.09	.01	.04	-.02	-.06	.02	.01	-.07	.09	.13		-.16	.06
AGE	.11	.21	.03	.12	-.03	.25	.19	.16	.29	.08	-.04	-.05	.10	-.07	.05	.03	.12	.05	.62	-.16		.58
PCT 4	.00	.12	-.05	.08	.15	-.04	.10	.10	-.02	-.03	-.06	.06	.04	.19	.16	.13	.04	.05	.87	.06	.58	

^fAll correlations with absolute values greater than .15 are significant at the .05 level and .20 at the .01 level.

TABLE 6. Correlations Among Traits for Sires in PDM Group -599 -- -300

N = 149

Trait	GA	DC	BC	MS	ST	HD	FE	BK	RP	HL	FT	FU	RU	US	QY	TT	PDT	PDM	LTP	PDL	AGE	PCT 4
PDT	.91	.62	.73	.87	.56	.50	.57	.34	.54	.58	.50	.64	.70	.57	.46	.48		-.05	.12	.01	.11	.03
PDM	-.07	.04	-.09	-.12	-.09	.05	-.08	-.03	.08	.03	-.02	-.11	-.14	-.17	-.13	.07	-.05		-.08	-.14	.04	-.12
LTP	.16	.01	.05	.12	.10	.18	.17	.14	.07	.18	.11	.16	.13	.14	.15	.11	.12	-.08		.34	.63	.26
PDL	-.01	-.09	.11	.06	.15	-.24	.03	.04	-.17	-.03	-.04	.16	.10	.27	.25	.11	.01	-.14	.34		-.48	.19
AGE	.16	.12	-.06	.07	-.02	.36	.12	.10	.23	.19	.11	.02	.06	-.11	-.05	-.02	.11	.04	.63	-.48		.62
PCT 4	.05	-.10	-.08	.07	.04	.12	.08	.09	.00	.10	.07	.15	.10	.15	.13	.09	.03	-.12	.86	.19		.62

⁹All correlations with absolute values greater than .16 are significant at the .05 level and .22 at the .01 level.

TABLE 7. Correlations Among Traits for Sires in PDM Group -899 -- -600

N = 92

Trait	GA	DC	BC	MS	ST	HD	FE	BK	RP	HL	FT	FU	RU	US	QY	TT	PDT	PDM	LTP	PDL	AGE	PCT 4
PDT	.88	.63	.83	.86	.59	.53	.57	.14	.46	.46	.34	.67	.63	.48	.45	.54		-.27	.18	.10	.13	.09
PDM	-.26	.01	-.26	-.26	-.17	-.21	-.13	-.05	-.15	-.05	-.07	-.22	-.22	-.05	-.06	-.12	-.27		-.10	-.03	-.07	-.14
LTP	.09	-.05	-.02	.25	.04	.15	.14	.02	.11	.11	.09	.26	.32	.25	.10	.29	.18	-.10		.20	.82	.90
PDL	.07	.04	.15	.12	.29	-.03	-.11	.15	-.21	.07	.03	.16	.05	.33	.20	.14	.10	-.03	.20		-.34	.13
AGE	.08	-.04	-.09	.19	-.15	.15	.20	-.04	.22	.16	.04	.16	.29	.03	-.03	.20	.13	-.07	.82	-.34		.78
PCT 4	.00	-.13	-.13	.20	.02	.07	.08	.00	.02	.14	.08	.27	.24	.26	.08	.31	.09	-.14	.90	.13	.78	

^hAll correlations with absolute values greater than .20 are significant at the .05 level and .26 at the .01 level.

TABLE 8. Correlations Among Traits for Sires in PDM Group -1199 -- -900

N = 39

Trait	GA	DC	BC	MS	ST	HD	FE	BK	RP	HL	FT	FU	RU	US	QY	TT	PDT	PDM	LTP	PDL	AGE	PCT 4
PDT	.89	.40	.17	.88	.70	.28	.49	.28	.40	.41	.27	.68	.71	.62	.32	.58		-.27	.34	.04	.31	.34
PDM	-.28	-.13	-.16	-.22	-.26	.03	-.22	-.03	-.11	-.15	-.07	-.15	-.21	-.30	-.13	-.10	-.27		-.02	.06	-.07	-.12
LTP	.45	.26	.09	.43	.19	.19	.39	.02	.00	.30	.31	.41	.30	.43	.41	.35	.34	-.02		-.48	.58	.85
PDL	.04	.23	.03	.05	.08	-.25	.13	.04	-.26	-.06	-.15	.18	-.18	.36	.35	.39	.04	.06	.48		-.41	.29
AGE	.41	.05	.08	.37	.14	.43	.29	.05	.33	.30	.41	.20	.48	.07	.01	-.04	.31	-.07	.58	-.41		.60
PCT 4	.36	.12	.00	.47	.13	.10	.37	-.05	.00	.15	.21	.39	.34	.46	.49	.40	.34	-.12	.85	.29	.60	

¹All correlations with absolute values greater than .32 are significant at the .05 level and .40 at the .01 level.

TABLE 9. Correlations Among Traits for Sires in PDM Group Below -1199

N = 24

Trait	GA	DC	BC	MS	ST	HD	FE	BK	RP	HL	FT	FU	RU	US	QY	TT	PDT	PDM	LTP	PDL	AGE	PCT 4
PDT	.85	.64	.75	.90	.71	.40	.71	.12	.46	.45	.35	.66	.75	.45	-.01	.29		.12	.33	.13	.37	.33
PDM	.08	.34	-.13	.24	-.11	.11	.04	.14	.03	-.01	.12	.16	.11	.05	-.19	.21	.12		.51	.09	.46	.39
LTP	.33	.33	.32	-.35	.21	.20	.36	.06	.30	.20	.23	.15	.10	-.01	-.15	.30	.33	.51		.38	.62	.83
PDL	.03	.08	.31	-.05	.30	-.18	.26	.00	-.11	.03	.05	.05	-.06	.32	.20	.24	.13	.09	.38		-.39	.41
AGE	.41	.41	.11	.44	.00	.45	.28	.22	.43	.29	.24	.26	.30	-.22	-.32	.15	.37	.46	.62	-.39		.47
PCT 4	.34	.35	.20	.43	.30	.03	.43	.16	.16	.30	.07	.19	.10	.02	-.03	.27	.33	.39	.83	.41		.47

†All correlations with absolute values greater than .40 are significant at the .05 level and .61 at the .01 level.

APPENDIX TABLE 10. Means and Standard Deviations of Type Traits

PDM Group	N	FSCO	GA	DC	BC	M,S	ST	HD	FE	BK
All	527	80.1 ± .3	3.5 ± .3	2.3 ± .1	2.4 ± .2	3.6 ± .3	80 ± 11	50 ± 11	82 ± 7	77 ± 8
Above +900	18	80.1 ± .4	3.6 ± .3	2.2 ± .1	2.4 ± .2	3.7 ± .3	83 ± 8	47 ± 9	83 ± 7	72 ± 12
+601 → +900	28	80.1 ± .3	3.7 ± .3	2.2 ± .1	2.4 ± .2	3.7 ± .3	78 ± 12	47 ± 11	81 ± 9	74 ± 8
+301 → +600	68	80.1 ± .2	3.6 ± .3	2.2 ± .2	2.4 ± .2	3.7 ± .3	79 ± 11	49 ± 11	82 ± 8	76 ± 8
+1 → +300	111	80.0 ± .3	3.6 ± .3	2.3 ± .1	2.4 ± .2	3.7 ± .3	78 ± 10	49 ± 12	82 ± 6	76 ± 9
-299 → 0	116	80.1 ± .3	3.5 ± .3	2.3 ± .1	2.3 ± .2	3.6 ± .3	81 ± 11	50 ± 10	82 ± 7	77 ± 8
-599 → -300	100	80.2 ± .3	3.5 ± .3	2.3 ± .1	2.3 ± .2	3.5 ± .3	81 ± 10	50 ± 11	83 ± 7	78 ± 7
-899 → -600	59	80.1 ± .3	3.4 ± .3	2.3 ± .1	2.3 ± .2	3.5 ± .3	81 ± 10	51 ± 10	84 ± 6	79 ± 8
-1199 → -900	19	80.3 ± .3	3.3 ± .3	2.3 ± .1	2.3 ± .2	3.4 ± .4	83 ± 11	53 ± 7	84 ± 6	80 ± 6
Below -1199	8	80.1 ± .3	3.3 ± .3	2.4 ± .1	2.3 ± .3	3.4 ± .2	82 ± 14	54 ± 14	83 ± 5	81 ± 6

APPENDIX TABLE 11. Means and Standard Deviations of Type Traits

PDM Group	N	RP	HL	FT	FU	RU	US	QY	TT
All	527	55 ± 12	36 ± 10	62 ± 9	52 ± 12	57 ± 11	59 ± 12	89 ± 5	63 ± 12
Above +900	18	49 ± 12	36 ± 9	63 ± 10	49 ± 12	58 ± 11	59 ± 13	90 ± 3	61 ± 13
+601 → +900	28	48 ± 11	35 ± 10	62 ± 8	44 ± 11	53 ± 10	56 ± 12	89 ± 3	64 ± 12
+301 → +600	68	50 ± 12	34 ± 11	61 ± 10	48 ± 11	54 ± 12	58 ± 10	89 ± 4	63 ± 12
+1 → +300	111	54 ± 12	36 ± 8	62 ± 9	50 ± 11	50 ± 10	58 ± 11	88 ± 5	63 ± 12
-299 → 0	116	57 ± 12	35 ± 9	61 ± 10	53 ± 12	58 ± 11	59 ± 11	89 ± 5	62 ± 13
-599 → -300	100	56 ± 11	36 ± 9	63 ± 9	56 ± 13	60 ± 10	60 ± 13	89 ± 4	65 ± 12
-899 → -600	59	60 ± 12	38 ± 11	63 ± 10	55 ± 12	59 ± 13	58 ± 12	88 ± 5	61 ± 12
-1199 → -900	19	64 ± 11	43 ± 12	68 ± 9	60 ± 10	62 ± 15	62 ± 17	89 ± 7	64 ± 14
Below -1199	8	60 ± 11	42 ± 7	68 ± 6	62 ± 10	59 ± 11	57 ± 13	86 ± 4	64 ± 10

TABLE 12. Means and Standard Deviations of Type, Production, and Longevity Traits

PDM Group	N	PDM	PDT	LTP	PDL	AGE	PCT 5	# Daughters	
								Type	Production
All	527	-93 ± 508	-.4 ± 1.2	56,275 ± 8,982	41.9 ±	62.5 ± 6.7	34.6 ± 9.6	258 ± 421	192 ± 257
Above +900	18	1,096 ± 168	-.7 ± 1.3	66,326 ± 7,319	47.4 ± 4.6	65.5 ± 5.3	40.3 ± 9.2	548 ± 943	262 ± 294
+601 → +900	28	731 ± 83	-1.1 ± 1.2	63,574 ± 6,532	44.7 ± 3.5	66.0 ± 6.2	37.8 ± 8.5	357 ± 403	296 ± 353
+301 → +600	68	433 ± 88	-.8 ± 1.2	60,822 ± 7,583	44.7 ± 6.5	63.9 ± 5.0	37.9 ± 8.4	335 ± 536	245 ± 410
+1 → +300	111	137 ± 84	-.7 ± 1.1	57,569 ± 6,942	42.8 ± 4.2	63.1 ± 5.4	35.0 ± 9.2	287 ± 446	190 ± 200
-299 → 0	116	-158 ± 87	-.4 ± 1.1	56,497 ± 6,660	41.1 ± 15.4	63.0 ± 4.8	35.2 ± 7.4	189 ± 263	177 ± 221
-599 → -300	100	-441 ± 82	-.2 ± 1.1	53,706 ± 7,360	41.0 ± 4.4	61.6 ± 5.6	32.8 ± 8.2	266 ± 420	173 ± 225
-899 → -600	59	-705 ± 71	0.0 ± 1.0	49,000 ± 12,022	38.5 ± 6.4	59.2 ± 12.3	30.2 ± 14.3	153 ± 172	150 ± 159
-1199 → -900	19	-1,010 ± 67	.4 ± 1.3	51,553 ± 10,958	40.3 ± 9.4	60.6 ± 6.7	32.6 ± 9.9	133 ± 226	96 ± 93
Below -1199	8	-1,308 ± 41	.1 ± 1.1	45,266 ± 4,236	36.8 ± 3.2	58.7 ± 3.3	28.1 ± 8.4	170 ± 262	253 ± 418

TABLE 13. Correlations Among Traits for All Sires

N = 527

Trait	GA	DC	BC	MS	ST	HD	FE	BK	RP	HL	FT	FU	RU	US	QY	TT	PDT	PDM	LTP	PDL	AGE	PCT 5
PDT	.92	.57	.77	.87	.54	.50	.60	.39	.61	.55	.42	.67	.66	.49	.31	.42		-.28	-.09	-.12	.05	-.03
PDM	-.31	.22	-.21	-.29	-.07	-.11	-.10	-.20	-.29	-.14	-.10	-.30	-.17	-.05	.03	-.02	-.28		.48	.24	.25	.26
LTP	-.11	.17	-.10	-.05	.07	-.07	.02	-.10	-.18	.01	.01	-.06	.02	.13	.21	.11	-.09	.48		.31	.76	.86
PDO	-.10	.03	-.05	-.13	.03	-.10	-.04	-.01	-.12	-.01	-.05	-.09	-.07	.02	.07	-.03	-.12	.24	.31		.05	.16
AGE	.04	.17	-.05	.08	.01	.14	.08	.00	.03	.10	.07	-.01	.12	.00	.08	.06	.05	.25	.76	.05		.81
PCT 5	-.05	.09	-.09	.02	.05	-.02	.04	-.03	-.12	.05	.04	.02	.05	.11	.20	.12	-.03	.26	.86	.16	.81	

^aAll correlations with absolute values greater than .08 are significant at the .05 level and .11 at the .01 level.

APPENDIX TABLE 14. Multiple Correlations Coefficients Squared (R^2)
between Longevity Traits and Type and Production
Traits for All Sires (527)

Model	Longevity Traits			
	LTP	PDL	AGE	PCT 5
1	.13	.04	.06	.07
2	.15	.05	.06	.09
3	.10	.03	.06	.04
4	.09	.03	.06	.04
5	.24	.06	.07	.07
6	.25	.06	.11	.10
7	.25	.06	.11	.09
8	.24	.06	.08	.07
9	.30	.08	.12	.14
10	.29	.08	.12	.12
11	.23	.06	.06	.07

APPENDIX TABLE 15. R^2 Values for Stratified Groups Using Model 1.

PDM Group	N	LTP	PDL	AGE	PCT 5
Above +900	18	.87	.59	.68	.73
+601 → +900	28	.49	.40	.46	.48
+301 → +600	68	.30	.14	.15	.27
+1 → +300	111	.23	.23	.17	.23
-299 → 0	116	.30	.06	.29	.25
-599 → -300	100	.16	.23	.24	.15
-899 → -600	59	.21	.19	.18	.21
-1199 → -900	19	.92	.83	.59	.80
Below 1199	8	-	-	-	-

APPENDIX TABLE 16. R^2 Values for Stratified Groups Using Model 2

PDM Group	N	LTP	PDL	AGE	PCT 5
Above +900	18	.91	.60	.74	.82
+601 → +900	28	.49	.45	.47	.48
+301 → +600	68	.30	.17	.16	.28
+1 → +300	111	.27	.25	.18	.26
-299 → 0	116	.31	.07	.29	.27
-599 → -300	100	.20	.23	.25	.19
-899 → -600	59	.21	.19	.18	.21
-1199 → -900	19	.93	.94	.75	.80
Below -1199	8	-	-	-	-

APPENDIX TABLE 17. R^2 Values for Stratified Groups Using Model 3

PDM Group	N	LTP	PDL	AGE	PCT 5
Above +900	18	.21	.11	.16	.13
+601 → +900	28	.16	.09	.15	.13
+301 → +600	68	.05	.10	.09	.06
+1 → +300	111	.03	.04	.05	.05
-299 → 0	116	.10	.04	.12	.06
-599 → -300	100	.02	.12	.15	.05
-899 → -600	59	.04	.07	.07	.05
-1199 → -900	19	.63	.45	.64	.53
Below -1199	8	.34	.60	-	.49

APPENDIX TABLE 18. R^2 Values for Stratified Groups Using Model 4

PDM Group	N	LTP	PDL	AGE	PCT 5
Above 900	18	.19	.10	.16	.10
+601 → +900	28	.14	.07	.14	.13
+301 → +600	68	.04	.09	.07	.06
+1 → +300	111	.03	.04	.05	.04
-299 → 0	116	.09	.04	.12	.06
-599 → -300	100	.02	.12	.14	.04
-899 → -600	59	.03	.05	.04	.03
-1199 → -900	19	.61	.45	.49	.47
Below 1199	8	.32	.56	.97	.48

TABLE 19. Weights of Components for Predicting Lifetime Production

Model	PDM	PDT	FSCO	GA	DC	BC	MS	ST	HD	FE	BK	RP	HL	FT	FU	RU	US	QY	TT
1								6	3	6	4	15	4	1	23	6	5	14	13
								.081	-.032	.076	-.049	-.188	.049	-.012	-.291	.069	.060	.179	.165
2		21						10	0	6	2	6	6	0	13	8	5	10	13
		-.346						.165	.001	.106	-.030	-.099	.091	.001	-.212	.130	.081	.173	.208
3		27		18	35	1	19												
		-.279		-.188	.361	-.016	.193												
4				39	44	9	8												
				-.296	.339	-.066	.065												
5	85		15																
	.490		.087																
6	43	19		6	7	4	19												
	.479	-.209		.070	.077	-.046	.210												
7	65			1	8	11	15												
	.482			-.009	.058	-.084	.114												
8	91	9																	
	.497	.051																	
9	30	16						9	1	4	0	2	6	0	2	7	3	10	8
	.437	-.261						.136	-.021	.058	.002	-.025	.084	.005	-.034	.106	.042	.140	.124
10	38							6	4	3	1	8	5	0	8	5	2	12	8
	.447							.072	-.046	.034	-.012	-.090	.052	-.005	-.090	.060	.026	.144	.090
11	.483																		

TABLE 20. Weights of Components for Predicting Production Per Day of Productive Life

Model	PDM	PDT	FSCO	GA	DC	BC	MS	ST	HD	FE	BK	RP	HL	FT	FU	RJ	US	QY	TT
1								10	9	3	6	18	4	8	19	2	6	15	0
								.062	-.055	.019	.034	-.106	.024	-.048	-.118	-.011	.034	.090	-.002
2		25						14	4	5	5	6	6	5	8	3	6	10	3
		-.215						.114	-.034	.038	.046	-.051	.051	-.040	-.069	.027	.047	.086	.025
3		45		7	30	16	2												
		-.219		-.035	.145	.078	-.011												
4				30	32	10	28												
				-.120	.127	.038	-.112												
5	96			4															
	.241			.009															
6	39	32		15	2	11	1												
	.224	-.187		.086	.012	.064	-.003												
7	62			4	1	9	24												
	.226			.015	-.004	.031	-.089												
8	81	19																	
	.224	-.054																	
9	25	20						12	5	2	7	2	6	4	2	2	3	8	2
	.213	-.174						.100	-.045	.014	.062	-.014	.047	-.038	.018	.015	.028	.070	-.016
10	32							8	9	0	8	8	4	7	3	2	2	11	6
	.219							.058	-.062	-.001	.052	-.058	.026	-.045	-.020	-.016	.017	.072	-.038
11	.240																		

TABLE 21. Weights of Components for Predicting Age at Last Calving

Model	PDM	PDT	FSCO	GA	DC	BC	MS	ST	HD	FE	BK	RP	HL	FT	FU	RU	US	QY	TT
1								4 -.042	13 .123	4 .041	1 -.007	7 -.065	5 .050	3 .025	18 -.176	15 .148	9 -.092	11 .105	10 .101
2		10 -.111						1 -.015	13 .133	5 .051	0 -.001	3 -.036	6 .064	3 .030	14 -.150	16 .168	8 -.085	10 .103	10 .115
3		12 -.097		14 .110	30 .239	30 -.239	14 .110												
4				12 .072	37 .231	41 -.256	10 .065												
5	79 .259		21 .070																
6	27 .284	5 -.056		25 .263	7 .070	25 -.257	11 .120												
7	30 .285			25 .242	7 .065	28 -.267	10 .094												
8	69 .291	31 .133																	
9	26 .277	5 -.058						3 -.034	11 .119	2 .020	2 .019	1 .011	6 .060	3 .032	3 -.038	14 .153	10 -.110	8 .082	6 .062
10	28 .279							5 -.048	11 .114	2 .015	2 .016	0 -.003	5 .052	3 .030	5 -.050	14 .143	11 -.113	8 .083	6 .055
11	.253																		

TABLE 22. Weights of Components for Predicting Percentage Completing Five Lactations

Model	PDM	PDT	FSCO	GA	DC	BC	MS	ST	HD	FE	BK	RP	HL	FT	FU	RU	US	QY	TT
1								4 .034	1 -.008	6 .052	0 .000	20 -.166	6 .049	1 .011	17 -.138	7 .060	2 -.016	21 .173	15 .125
2		27 -.356						9 .121	2 .025	6 .083	2 .020	6 -.074	7 .093	2 .025	4 -.056	9 .123	0 .005	13 .166	13 .170
3		33 -.277		2 .021	24 .206	14 -.117	27 .225												
4				16 -.086	35 .184	31 -.167	18 .098												
5	79 .268		21 .072																
6	25 .279	22 -.236		16 .171	4 .040	12 -.135	21 .235												
7	41 .282			12 .082	3 .019	26 -.177	18 .126												
8	86 .274	14 .043																	
9	17 .231	23 -.311						8 .105	1 .014	4 .058	3 .037	3 -.035	7 .089	2 .027	3 .038	8 .111	1 -.015	11 .149	9 .126
10	28 .243							3 .029	2 -.016	3 .030	2 .020	13 -.112	6 .050	2 .015	3 -.029	6 .055	4 -.035	18 .154	10 .085
11	.262																		

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the scanned document**

IMPORTANCE OF BODY CONFORMATION IN PREDICTING
LONGEVITY AND WEARABILITY OF DAIRY COWS

by

Samuel Morton Catron

(ABSTRACT)

Official type classification data recorded by the Holstein-Friesian Association of America from January, 1967 to June, 1974 and DHIA production data recorded by the U.S. Department of Agriculture from January, 1960 to May, 1974 were evaluated as progeny tests to ascertain the relationship between body conformation and longevity and wearability of dairy cows. Data for 788 sires with at least 20 daughters in 10 herds with classification information and at least 30 daughters with production information was used.

Means for type and production were daughter final score 80.1, predicted difference milk (PDM) -136, lifetime production 55,919 lb., production per day of productive life (PDL) 44.4 lb/day, age at last calving (AGE) 60.1 mo., and percentage completing four lactations, 48.4%.

Correlations between PDT and scorecard and descriptive traits were positive and highly significant ($P < .01$). Most of the relationships between PDM and type traits were negative and highly significant ($P < .01$) with the exception of dairy character which was positive

(.27). Longevity traits were lowly correlated with PDT and generally negative but were highly positively correlated with PDM. Correlations were low between longevity traits and descriptive and scorecard traits ranging from $-.23$ between PDL and rump to $.21$ between age and head.

Regression of type and production traits on longevity traits indicated that PDM was the best predictor of LTP ($R^2 = .28$) and PCT 4 ($R^2 = .12$); however, the combined descriptive traits are the best predictor of PDL ($R^2 = .12$) and AGE ($R^2 = .10$). The best type indicators of longevity appeared to be dairy character, mammary system, udder quality, udder support and floor, teat size and placement, stature, fore udder, and rump.

DAMS or Adjusted SCORE	DAU AVE SCORE	# of SIRES			AVE #DAU/BULL			DAM AVE SCORE	P D T		
	SCORE	TOTAL	+	-	TOTAL	+	-	SCORE	TOTAL	+	-
77.01-78.00	77.38	1	0	1	51.0	—	51.0	77.24	-1.72	—	-1.72
78.01-79.00	77.86	13	0	13	94.8	—	94.8	78.65	-1.93	—	-1.93
79.01-80.00	79.01	98	11	87	138.0	102.7	142.5	79.61	-1.07	+0.67	-1.30
80.01-81.00	80.19	192	81	111	246.1	312.3	197.8	80.48	-0.18	+0.59	-0.73
81.01-82.00	80.93	68	42	26	272.0	304.9	219.0	81.42	+0.36	+0.84	-0.42
82.01-83.00	81.50	21	17	4	273.0	321.0	69.3	82.32	+0.75	+1.01	-0.36
83.01-84.00	81.28	3	2	1	114.0	139.0	64.0	83.08	+0.47	+0.92	-0.41
84.01-85.00	83.71	2	2	0	82.0	82.0	—	84.68	+2.25	+2.25	—

10/0

CORR.
.390

REGR.
.193

CORR.
.566

REGR.
.676

DAMS Age Adjusted SCORE	DAUGHTERS AVE. SCORE	NUMBER of SIREs			AVE. # DAU. / SIRE			DAMS AVE. SCORE	AVE. P D T		
		TOTAL	+PDT	-PDT	TOTAL	+PDT	-PDT		TOTAL	+	-
-75.00	75.74	7	0	7	12.3	-	12.3	73.16	-1.02	-	-1.02
5.01 - 76.00	78.38	11	3	8	12.2	13.7	11.6	75.54	-0.44	+0.15	-0.66
76.01 - 77.00	78.22	21	5	16	13.8	12.2	14.3	76.52	-0.48	+0.23	-0.69
77.01 - 78.00	78.72	47	8	39	17.9	15.0	18.5	77.58	-0.50	+0.45	-0.69
78.01 - 79.00	78.86	150	45	105	25.0	15.4	29.1	78.55	-0.61	+0.40	-1.06
79.01 - 80.00	79.43	416	120	296	47.6	27.0	55.9	79.57	-0.53	+0.41	-0.91
80.01 - 81.00	80.14	523	214	309	102.5	129.4	83.8	80.51	-0.16	+0.51	-0.63
81.01 - 82.00	80.64	372	194	178	64.9	80.9	47.5	81.47	+0.07	+0.58	-0.49
82.01 - 83.00	81.45	184	135	49	45.9	55.4	19.6	82.43	+0.35	+0.59	-0.32
83.01 - 84.00	81.54	81	56	25	19.3	20.6	16.4	83.39	+0.31	+0.61	-0.37
84.01 - 85.00	82.56	43	36	7	18.9	20.4	11.0	84.41	+0.64	+0.81	-0.23
85.01 -	83.01	22	20	2	15.2	15.6	12.0	85.61	+0.75	+0.85	-0.17

150/2

DAMS Age Adjusted SCORE	DAU AVE SCORE	# of SIRES			AVE. # DAU/BULL			DAM AVE SCORE	P D T			CORR. .593	REGR. .839
		TOTAL	+	-	TOTAL	+	-		TOTAL	+	-		
78.00 - 79.00	76.04	1	0	1	284.0	-	284.0	78.90	-3.89	-	-3.89		
79.01 - 80.00	78.98	33	3	30	256.6	200.3	262.2	79.70	-1.21	+0.37	-1.37		
80.01 - 81.00	80.33	87	41	46	436.0	527.2	354.7	80.53	-0.06	+0.65	-0.69		
81.01 - 82.00	80.95	35	24	11	443.4	463.8	400.0	81.43	+0.39	+0.75	-0.39		
82.01 - 83.00	81.58	9	9	0	526.9	526.9	-	82.35	+0.87	+0.87	-		
83.01 - 84.00	82.14	1	1	0	209.0	209.0	-	83.12	+1.27	+1.27	-		

100/2

78.01 - 79.00	77.20	5	0	5	147.0	-	147.0	78.71	-2.65	-	-2.65		
79.01 - 80.00	78.95	47	4	43	217.9	182.8	221.1	79.70	-1.22	+0.59	-1.39		
80.01 - 81.00	80.30	124	54	70	340.7	429.0	272.6	80.49	-0.09	+0.64	-0.65		
81.01 - 82.00	81.01	50	34	16	347.2	363.1	313.3	81.46	+0.44	+0.86	-0.47		
82.01 - 83.00	81.67	10	10	0	484.5	484.5	-	82.32	+0.95	+0.95	-		
83.01 - 84.00	82.14	1	1	0	209.0	209.0	-	83.12	+1.27	+1.27	-		

CORR.
.595

REGR.
.856

DAMS Age Adjusted SCORE	DAUGHTERS AVE. SCORE	NUMBER OF SIRES			AVE. # DAV. / SIRE			DAMS AVE. SCORE	AVE. P D T		
		TOTAL	+PDT	-PDT	TOTAL	+PDT	-PDT		TOTAL	+	-
-75.00	75.74	7	0	7	12.3	-	12.3	73.16	-1.02	-	-1.02
5.01 - 76.00	78.38	11	3	8	12.2	13.7	11.6	75.54	-0.44	+0.15	-0.66
76.01 - 77.00	78.22	21	5	16	13.8	12.2	14.3	76.52	-0.48	+0.23	-0.69
77.01 - 78.00	78.72	47	8	39	17.9	15.0	18.5	77.58	-0.50	+0.45	-0.69
78.01 - 79.00	78.86	150	45	105	25.0	15.4	29.1	78.55	-0.61	+0.40	-1.06
79.01 - 80.00	79.43	416	120	296	47.6	27.0	55.9	79.57	-0.53	+0.41	-0.91
80.01 - 81.00	80.14	523	214	309	102.5	129.4	83.8	80.51	-0.16	+0.51	-0.63
81.01 - 82.00	80.64	372	194	178	64.9	80.9	47.5	81.47	+0.07	+0.58	-0.49
82.01 - 83.00	81.45	184	135	49	45.9	55.4	19.6	82.43	+0.35	+0.59	-0.32
83.01 - 84.00	81.54	81	56	25	19.3	20.6	16.4	83.39	+0.31	+0.61	-0.37
84.01 - 85.00	82.56	43	36	7	18.9	20.4	11.0	84.41	+0.64	+0.81	-0.23
85.01 -	83.01	22	20	2	15.2	15.6	12.0	85.61	+0.75	+0.85	-0.17

1.942

b: +.14