CURRENT STATUS OF MANAGEMENT FACTORS WHICH INFLUENCE GENETIC PROGRESS IN THE MICHIGAN HOLSTEIN POPULATION

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ABSTRACT

CURRENT STATUS OF MANAGEMENT FACTORS WHICH
INFLUENCE GENETIC PROGRESS IN THE
MICHIGAN HOLSTEIN POPULATION

By

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Progress by selection for a trait is determined by the genetic variation in the specie under study, the accuracy and intensity of selection with which the parents of offspring are chosen. The rate of progress is determined by generation interval.

A number of nongenetic factors tend to have some influence on the accuracy and intensity of selection and generation interval. The purpose of this study is to examine the following identifiable factors: population size, superiority of the bulls in use, calf mortality, cow removals, calving interval, generation interval, sire usage levels, useful life span of tested bulls in AI, and progeny testing levels.

Data were obtained by a questionnaire survey of four bull studs. Also, data were obtained from in-progress DHIA records, pedigrees of young sires, USDA sire summaries,

Holstein herd books and current research by Spike (1972), Erickson, et al. (1972), Erickson (1972), Speicher (1972), and Oxender (1972).

It was found that the Michigan Holstein cow population was 425,700 with 18 percent on official test. Cows identified by sire represented 56.8 percent of those on test. Sixty percent of Michigan Holsteins are bred artificially, 62 percent of which were sired by bulls proven to be above breed average. Based on USDA summaries of 1158 bulls, AI sires of cows in the current herd had an average predicted difference (PD) superiority of 144 and seven pounds for milk and fat, respectively. Sires of calves in high producing herds (17,694 pound average of milk) had an average PD for milk of plus 808 pounds. In herds with near breed average levels (13,397) of milk production, sires of calves had an average PD for milk of plus 694 pounds.

Thirty percent of all dairy cows left the herd annually and were replaced by 30 heifers per 100 cows successfully bred.

The average calving interval for Michigan Holsteins over a 13 year period was 395 days.

Generation intervals for sires of sires, dams of sires, sires of herd replacements, dams of herd replacements were eleven, 7.5, nine, and 4.3, respectively.

Two percent of the artificially inseminated Holstein cows were used in progeny test programs. Proven bulls in the artificial breeding program bred 7,614 cows each and remained in the stud four years during their useful life.

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INTRODUCTION

One goal of the dairyman is to improve the genetic level of his herd. Several important management decisions influence how rapidly and by how much the genetic level of a dairy herd can be raised. Increasing the average production depends on replacing the present herd with animals that are genetically superior to their dams.

How much improvement can be made depends on three things:

1. genetic variation
2. accuracy of the criterion for selection
3. intensity of selection.

Generation intervals determine how rapidly the improvement is made. Researchers have calculated the maximum progress possible within the biological limitations of the animal to be approximately three percent of the average yield [Robertson and Rendel (1950)]. It is not likely that maximum progress will ever be achieved because of the diffuse nature of the decision-making group and the economic objectives held at certain levels of the decision process.

The importance of certain factors which influence progress is not always clear to management. Additive genetic variation is not directly influenced by day to day management practices. Selection intensity, accuracy of the criterion for selection and generation intervals are reflective of several routine management decisions.

The purpose of the present study is to evaluate the current status of the following nongenetic parameters in Michigan which influence the rate of genetic progress;

1. Population size
2. Cows on official test
3. Cows on official test identified by sire
4. Fractions of bulls available which are predicted plus and minus
5. Superiority of bulls in use
6. Available herd replacements
7. Percentage of cow removals
8. Calving interval
9. Generation interval
10. Sire utilization
11. Progeny testing

Have these nongenetic parameters influencing genetic progress changed for the Michigan population since Specht's 1957 thesis work? If there have been changes, what has changed? What are the management factors which have brought about the changes? What needs to be done to correct improper or incorrect management practices of the AI units and the dairy farms. To the extent possible, these questions will be discussed in the body of the thesis.

Findings should be useful to university extension personnel in recognizing particular areas in need of emphasis, and for assisting dairymen and AI units in obtaining maximum progress by selection.

REVIEW OF LITERATURE

Theoretical Basis for Progeny Testing

It has already been mentioned that there are four basic factors determining the rate at which genetic progress can be made. Prior to entering into a discussion of the management factors related to them, it is appropriate to analyze briefly the relationship between these four factors in the formula for the calculation of rate of genetic improvement as outlined by Dickerson and Hazel (1944). The general formula is $\Delta G = \frac{\Delta P}{T}$ where: ΔG = average annual genetic gain

ΔP = average genetic superiority of parents of offspring

T = time in years (average age of parents).

Average genetic superiority of those animals selected to be parents has four sources in a large, artificially inseminated population. Robertson and Rendel (1950) referred to the four sources as:

1. Dams of replacements
2. Dams of bulls
3. Sires of bulls
4. Sires of replacements

Genetic superiority must be calculated for each of these sources and is arrived at in the following manner: ΔS or $\Delta D = (\bar{i}) r_{GI} \sigma_G$ where:

$(\bar{I})$ = selection differential in standard deviation units

(r_{GI}) = accuracy (correlation between transmitting ability and apparent merit)

σ_G = variation (the standard deviation of transmitting ability).

Skjervold and Langholz (1963) suggest one additional factor for the formula--a coefficient to correct for the rate of inbreeding.

Robertson and Rendel (1950), in their discussion of the use of progeny testing with artificial insemination, assumed the standard deviation of genotypic value for 305-day yield to be ten percent of the average yield $(\bar{Y})$. Specht (1957) reported that the genetic standard deviation $(0.10\bar{Y})$ was almost exactly the same in estimates from Michigan data as that assumed by Robertson and Rendel. Genetic improvement is dependent on genetic variation.

Additive genetic variation is that portion of the phenotypic variation which can be transmitted from parents to offspring. The correlation between a sire's transmitting ability and his apparent merit (r_{GI}) is the square root of the index used to measure heritability. Once the selection differential has been found from tables [Pearson (1931) or Nanson (1967)], it is reduced to reflect the inaccuracy by multiplying by r_{GI}, the coefficient of accuracy.

Heritability of milk production has been estimated to be 0.25 (Robertson and Rendel, 1950; Specht, 1957; Deaton, 1964).

Because of culling which takes place in second and later lactations, Rendel and Robertson (1950) demonstrate that heritability becomes dependent on the number of records; and based on that, use the following formula to determine genetic superiority of cows:

$$I_{CC} = \Sigma n h_1^2 \ (Y_1 - \bar{Y})$$

where: h_1^2 = heritability based on 1 lactations

$\bar{Y}$ = mean of the first lactations of the whole group

Y_1 = mean of the lactations

n = number of daughters of each cow.

Since one cannot observe the important economic traits in the dairy sire, information from his progeny is relied upon as an indicator of his genetic worth.

Dickerson and Hazel (1944) reported that for a population of 120 cows, progeny testing yielded slightly less progress than with mass selection. Robertson and Rendel (1950), with some variation of treatment, found "a very slight advantage with progeny testing in the case of 305-day yield in a herd of 120 cows." Specht (1957) found progeny testing equal to mass selection in a fifty cow herd sampling two, three, and four young sires on fifty, forty, and sixty percent of the cows, respectively.

As pointed out by Specht (1957) and others, the two basic limitations to progeny testing in a small herd are, first, the number of bulls that can be tested is small, which limits selection, and second, only a small number of cows is left to breed to tested bulls when so many are bred to young bulls. It is also obvious that the high environmental correlation between records of daughters and herdmates as well as the limited number of herdmates and the small number of herdmates calving in the same season limit the accuracy of the proof of the young sire. According to Specht (1957) 6.66 percent of the cows in a Michigan study were on official test. Thompson and Freeman (1971) used 0.15 as the faction of the population tested.

Effective Population Defined

Two major factors influence the population which is "effective" for progeny testing. As previously mentioned, the sire is evaluated on the basis of the performance of his female offspring. In order to do that his offspring must be correctly evaluated. Production testing represented by DHI programs in the United States is the method used in the evaluation of the production of the offspring. For this reason cows not on test are not useful for sire evaluation. The other limiting factor is records of cows on test which lack sire identification.

A related but somewhat different problem is that of misidentification. Van Vleck (1970), studied the effects of misidentification in estimating the paternal sib correlation. He concluded that misidentification of the sire can lead to substantial underestimation of heritability from the intra-sire correlation.

Further research reported by Van Vleck (1970) led to conclusions that biases in evaluation of sires will result from misidentified records in estimating the sire and environmental variances, and that genetic progress will be underestimated from misidentified records.

Genetic Trends

During the past decade several researchers have studied annual genetic progress for various herds and populations. Palmer, et al. (1972), reported mean annual phenotypic, genetic and environmental trends in milk production of 23.4 ± 4.6 kg, 37.5 ± 6.4 kg, and -14.0 kg, respectively, in a Florida experiment station Jersey herd. Dillon, et al. (1955), reported a mean change in average real producing ability between years of 706 pounds. The latter study was based on records from the University of Illinois dairy herd from 1901-1954. They concluded that the average real producing ability in this herd had changed very little since it was founded. Arave and Laben (1963) studied twelve privately owned Jersey herds with environmental conditions representative of central California conditions. They reported variation between herds of from 16.4 ± 54.8 to 186.2 ± 30.1 lb. when FCM yield, corrected for year effects was regressed on year. In only one herd was this regression reported to be nonsignificant, indicating significant positive trends in eleven herds.

Burnside and Legates (1967), investigated genetic trends using first lactation Holstein Herd Improvement Registry records reported in 335 herds from 1953 through 1961. Few of the records studied were those of artificially sired individuals. The estimated annual genetic improvement was reported as being from 0.75 to 0.92 percent of the mean milk yield. This approaches the expected rate of improvement (0.01 $\bar{Y}$ for closed herds) reported by Rendel and Robertson (1950) and Specht (1957).

Table 1 and Table 2, adapted from McDaniel (1968), illustrate gains possible and gains achieved.

Table 1. Annual genetic gains possible through AI.

Source	Percent[a]	Actual (lb)
Hickman	.86 to 2.36	120 to 330
Johannson	1.00 to 2.00	140 to 280
Skjervold	1.50[b]	210
Specht	1.70 to 2.30	238 to 322
Thompson	2.11 to 2.21	-- --

[a]Percent of mean annual production.
[b]Assumes considerable selection for other traits.

Fractions of AI Sires which are Plus and Minus

McDaniel (1968) noted that one of the reasons why the superiority of AI has not been as great as it promised

Table 2. Observed annual genetic gains in populations and herds of dairy cattle.

Source	Milk	Fat
	%/yr	%/yr
Populations		
Burnside (1964)*	.83	--
Van Vleck (1961, Non AI)*	.37	.44
Van Vleck (1961, AI)*	.48	.65
Systrad (1966)	.67	--
Single Herds		
Branton (1967)	1.09	.74
Burnside (1967) (Ayr)	1.30	1.70
Burnside (1967) (Hol)	0.00	.32
Gaalaas (1967)	-.18	.32
Gacula (1965)	1.09	.21
Legates (1966)	1.25	1.21

*Data developed from those presented in source.

to be is because a substantial portion of the proven bulls in AI service are known to transmit below breed average milk production. McDaniel used the following table to summarize the percent of proven AI sires available which are plus and minus (Table 3).

Available Herd Replacements

Johnson, et al. (1970), in a study of calf losses in Illinois Dairy Herd Improvement herds reported the average loss of female Holstein calves at 13.1 percent

Table 3. Proven sires available through AI January 1, 1968.

Below Breed Average		Above Breed Average	
PD Milk	Proven Bulls	PD Milk	Proven Bulls
(lb)	(%)	(lb)	(%)
-1 to -99	10.77	1 to 99	8.32
-100 to -199	6.24	100 to 199	9.91
-200 to -299	4.90	200 to 299	12.21
-300 to -399	4.65	300 to 399	6.85
-400 to -499	3.92	400 to 499	6.24
-500 to -599	2.08	500 to 599	6.61
-600 to -699	2.20	600 to 699	3.55
-700 to -799	.86	700 to 799	3.43
-800 or below	1.10	800 to 899	2.08
		900 to 999	1.47
		1000 or more	2.69
Total	36.72		65.27

*Based on studs reporting number of services to individual bulls.

annually. There was a decline in the percent loss as the average milk fat production increased.

The New Zealand Dairy Board (1970-1971) summarized calf losses as a distribution of herds by main cause of loss. Thirty-six percent of the herds reported scours as the main cause. Forty-four percent (nearly one half) reported that the main cause was either unknown (23 percent) or "other" (21 percent) than those mentioned specifically. Eelven, six, and three percent reported worms, salmonella and redwater as their respective main causes. A void exists in the scientific literature concerning calf losses and their causative factors.

In artificially inseminated (AI) populations, selection on both the male and female sides are dependent on the number of heifers which survive and calve. As a comparison to the extreme case in which all heifers born (50%) survive until they calve are the 0.35 to 0.40 mature heifers produced per cow in the herd per year as reported by Rendel and Robertson (1950) (implies that 70-80% of all heifer calves born calve in the same herd).

Cow Removals

Andrus, *et al*. (1970), in a study of Iowa dairy herds, reported that the average herd life expectation was 3.12 years for all cows from herds actively enrolled in the production recording program. Cows from inactive herds averaged 3.09 years of herd life expectancy. It was reported that the differences between herds actively testing and those no longer active were significant.

White and Nichols (1965) studied the relationship between first lactation, later performance, and length of herd life in Holstein-Friesian cattle. Average ages at first and last calving were reported as 27.03 ± 3.28 and 58.84 ± 17.77, respectively. They reported a correlation of 0.216 between first lactation M.E. milk and number of lactations completed. This was significant at the one percent level. Also significantly correlated ($P < 0.01$) were first lactation M.E. milk and age at last calving ($r = 0.254$).

Another study by White and Nichols (1965) revealed 36.9 percent of cow removals were for low production. A brief table compares these results with those of other researchers (Table 4).

Table 4. Percent cows culled for low production.

Source	Percent cows culled for low production
White and Nichols	36.9
Asdell	33.5
O'Bleness, Van Vleck	27.1
Baltzer	41.1
Seath	30.5

Burnside, et al. (1971), reported that reporduction (13-24 percent) and low milk production (16-28 percent) were major causes of voluntary herd removals in Canadian herds. It was also reported that young cows were culled more heavily for low production than their older herdmates. This was offset, however, by increases in the percentages of older cows removed for reporduction, diseases, and weaknesses in udders. Burnside, et al. (1971), considered any given reason associated with one percent or more of total annual cow removals to be economically important. Percent first lactation cullings were lower for the Holstein breed (22 percent) than for the Ayrshire breed (37.2 percent).

Batra, et al. (1971), reported that in Canadian herds of constant size, production level increases were associated with increases in percent sold for breeding purposes and increases in percent sold for beef becuase of poor type ($P < 0.01$). Herd size had no effect on cow disposals. They concluded that increases in the level of milk production lead to increases in the percentage of the herd inventory that changes each year in pedigree herds of constant size.

According to Asdell (1951), the net loss of DHIA cows to the industry is 16.8 percent annually. Fifty percent of the cows in DHIA herds were reported to have been removed for reasons other than for dairy sales in a little over three years. It was concluded that 3.5 years of productive life, as an average is substantially correct, taking into consideration that in each year some of the culling is among the new cows introduced as replacements.

Parker, et al. (1960), reported that differences in longevity between individual cows are determined largely by nongenetic influences. It was pointed out that cows which die young leave less offspring than those which remain in the herd longer. This they referred to as automatic selection for longevity.

Parker's study also indicated that no deleterious effects on longevity need be expected by concentrating selection of progeny tested sires on the basis of first lactation production records of their daughters. Non-breeders were reported as accounted for 33.4 percent of all Holstein cow disposals from 1918 to 1958. In addition to T.B. and bangs reactors; udder trouble, infections, and abortions were reported to be important reasons for disposal.

Fosgate (1965) reported that for a herd of registered Jerseys, the average age in years and the number of lactations completed by all cows at the time of disposal were 6.79 and 3.43, respectively.

Allaire and Henderson (1966) studied 34,000 lactations made by cows in 464 New York herds on continuous test from 1957-1962. Using 1957-1960 averages they reported 0.788, 0.755, 0.717, and 0.672 as the fractions remaining in the herd after the first, second, third and fourth lactations, respectively. These represent animals selected during each of the first four lactations. When these figures are converted to represent removals during each lactation, they create a useful comparison with those of various workers in a table adapted from Specht (1967) (Table 5).

Calving Interval

Pelissier (1970) analyzed breeding records of 5,000 cows in ten herds to determine factors contributing to low

Table 5. Cow removals during the first four lactations.

Lactation	Specht (1957)	Rendel, et al. (1951)	Seath (1940)		Asdell (1951)		Allaire Henderson (1966)
			Iowa	Kansas	Kansas	N.Y.	
1	25.2[a]	27.7[a]	28.1[a]	31.6[a]	12.6[a]	6.0[a]	21.2[a]
2	27.2	35.4	31.3	30.4	15.5	17.2	24.5
3	26.2	35.2	23.2	27.2	23.1	26.4	28.3
4	28.5	32.2	25.0	26.8	29.2	35.0	32.8

[a]Percent of cows removed each lactation of those surviving previous culling.

breeding efficiency in dairy herds. An average of 2.67 services was required per conception with 43.3 percent representing conception on first service. Four or more services were required by 18.3 percent of the cows. Those cows sold open or conceiving too late to remain in the herd represented 12.7 percent.

One of every six heat periods was reportedly either missed or not recorded subsequent to the first recorded heat period. Recorded heat periods are summarized by days after calving in Table 6.

Table 6. Percent of heat periods recorded of those not previously recorded by days after calving.

Days after calving	<60	60	90	120
Percent with heat period recorded	65.5	34.5	11.9	3.9

It was concluded that the large number of cows open for an excessive period was primarily the cumulative result of low conception rates and a high incidence of missed heat periods.

Sweden (1968) reported 62.9 percent 56 day nonreturn rate to last insemination.

In its annual report for 1970-1971, the New Zealand Dairy Board reported an average of 27 calves per 100 cows were reared as dairy replacements. This corresponds exactly with the number reared in 1969-1970. The average number of calves per 100 cows in milk dropped from 30 calves per 100 cows in 1968-1970 to 25 calves in 1970-1971. The average number of dairy heifers born in 1969 was two lower than in 1969-1970.

Specht (1957), on the basis of information from 269 Holstein DHIA herds in Michigan, estimated that 70 percent of all heifers ultimately enter the milking herd. The number of heifers useful for progeny testing is further restricted by the portion not having positive sire identification. Specht (1957) stated that his figure (47 percent of all identified heifer calves enter the same herd as first calvers) agreed closely with the 1956 findings of the New Zealand Dairy Board (23 heifers will freshen in the same herd for each 100 cows in calf). To account for the normal sex ratio, the latter figure must be doubled.

Generation Intervals

Generally r_{GP} (correlation between genotype and phenotype) increases with age as more information is available, but progress is also a function of generation interval and the ratio of $\frac{r_{GP}}{T}$ determines progress if age increases both r'_{GP} and the length of generation intervals T'. Increased genetic progress can be expected only if $\frac{r'_{GP}}{T'}$ exceeds $\frac{r_{GP}}{T}$.

Of special interest to the dairyman is his own progress with reference to the progress which he could be making. In a 200-cow herd, Specht (1957) showed graphically that genetic improvement with progeny testing was maximized by saving one of four young sires sampled when 25 percent or more of the cows are bred to young sires. Annual genetic improvement reached 1.4 percent of the average yield when approximately 80 percent of the cows were bred to young sires. An additional 0.45 percent in improvement was realized annually with progeny testing in an AI population of 150,000 cows (10,000 tested) saving five to fifty sires sampled on fifty percent of the cows (tested). Thompson, et al. (1971), using four methods of sire selection, evaluated the genetic gain expected from four methods of sire selection:

1. The use of young, untested bulls, all of which are replaced annually.
2. The use of young, untested bulls replaced annually, all sired by progeny tested sires.
3. The use of naturally proven bulls.
4. The use of pedigree selection combined with progeny testing.

Differences in the amounts of genetic progress possible among the various methods of sire selection in the model used by Thompson and Freeman are largely reflections of the generation intervals of the sires. The generation intervals used by Thompson and Freeman (1971) are presented in Table 7.

From this work they concluded that the use of young, untested bulls, sired by progeny tested bulls resulted in more rapid genetic gain than progeny testing in small populations (between 5,000 and 20,000 first services per year).

Table 7. Generation intervals used by Thompson and Freeman in evaluation of four plans of sire selection.

Source	Plan A	Plan B	Plan C	Plan D
L_{BB}	2.5	6.0	8.4	8.0
L_{BC}	2.5	2.5	8.4	8.0
L_{CB}	4.75	4.75	4.75	4.75
L_{CC}	4.75	4.75	4.75	4.75

Progeny testing resulted in more rapid gain in large populations, and in all population sizes when usage rates were low. For a population of 100,000, annual genetic progress was maximized using selection method D above with 15,000 first services per bull, selection at the five percent level, and sixty daughters per young bull.

The importance of the differences in progress achieved under the various plans should not be minimized. Another important question is, what is the most efficient method of identifying young sires which have the greatest genetic potential. In 1969 Van Vleck reported three pedigree sources as having primary importance. Van Vleck and Carter (1972), by weighting these three pedigree sources of inheritance, computed estimated daughter superiority (EDS). Daughter superiority estimated as predicted difference (PD) or sire comparison (SC) was then regressed on the pedigree estimate of daughter superiority. Accuracy of the method used, as indicated by simple correlations between EDS and PD or SC, was at or near the thirty percent level for both bull studs included in the survey. It was found that on the average, about 0.61 units of PD or SC result from the increase of one unit of EDS. They concluded that selection of high EDS young bulls is a very effective method of gathering a superior group of young bulls for further sampling in AI.

Useful Life Span of Tested Bulls in AI

According to Specht and McGilliard (1960) the generation interval decreases 0.5 year for each ten percent increase in the number of cows bred to young sires.

Roman, et al. (1969), studied the tenure of bulls from 1940 to 1964. Bulls were reported by ages at entry and disposal, and unadjusted and adjusted tenure. Findings for the Holstein breed are reported in Table 8. These ages agree with Becker and Arnold (1953), especially those ages and the length of tenure for corresponding years. While the age at entry remained nearly constant over time, age at disposal as well as tenure for all categories increased over time.

Roman, et al. (1969), reported that data from Germany showed 40.6 percent of 1,013 bulls discarded for low fertility. Over 38 percent of a different sample of

Table 8. Tenure of Holstein dairy bulls in AI.

Period	No. Sires	Age at Entry	Age at Disposal	Tenure (yrs)		
1940-49	703	5.31	7.26	1.95[a]	2.05[b]	2.05[c]
1950-54	946	4.78	7.90	3.12	3.13	3.12
1955-59	1067	4.40	8.36	3.96	3.90	3.92
1960-64	733	4.47	8.80	4.33	4.29	4.30

[a]Unadjusted.

[b]Adjusted for age at entry on an individual breed basis.

[c]Adjusted for age at entry, removing year effects.

sires were reportedly culled for the same reason. In their 1969 study of 8,887 North American sires of six dairy breeds leaving artificial service during 1939 through 1964, Roman, et al., reported the following reasons for disposal and their respective intensities in Table 9. Among the Holstein bulls, 7.9 percent were culled for old age and 2.8 percent for red factor.

Freeman (1970), reported that the average selection intensity from 1951 through 1954 was 35 percent in a bull stud which operates in the North Eastern United States. Of the 196 young sires brought to the AI center, 23.5 percent were not alive at the time of selection. Six percent of these were discarded during the course of the progeny test.

Becker and Arnold (1953) analyzed tenure and turnover for 189 desirable dairy bulls in artificial studs,

Table 9. Percent of sire removals by reason.

Reason		Intensity
Repro. inefficienty		36.3
Char. or performance of Daus.		15.8
low milk prod.	9.7	
poor type	2.5	
inbreeding	1.6	
other	2.0	
Diseases and infection		14.3
Problem-semem collection		11.8
Accidents or injury		4.2
Consolidation of studs		6.8
Poor type (bull's own)		1.2
Other reasons		9.6

born before January 1, 1937. Twenty-six started artificial service between two and 5.9 years of age, 121 others at six to 9.9 years and 42 at ten to fifteen years. For all 189 bulls, the average tenure was 2.68 years. Later work by Becker and Arnold (1957) showed 56, 31, and 13 percent of the culling of desirable bulls was for reasons connected with reproduction, physical defects, and diseases, respectively. Of the 691 bulls included in the 1957 study, all of which were born before 1940, 25 percent were used less than one year, 21 percent from one to two years, 17 percent from two to three years, 11 percent from three to four years.

It was stated in the 1970-1971 annual report of the New Zealand Dairy Board that 80 percent of the bulls in an intake can be expected to be alive when selection is made. In New Zealand bull centers, intensity of selection increased during the period 1953 to 1970.

SOURCES OF DATA

In-progress DHIA records for February 15, 1972 were used to develop a profile of the average Holstein cow milked on that day. Her age was computed on the basis of 124,329 cows. Sires of 33,419 cows having official records (those identified by sire and in milk at least 45 days) were identified from the records mentioned above. Of these, 20,678 were sired by a total of 1158 sires which were summarized after April, 1967. The USDA sire summaries were used to obtain the birth dates and the latest summary for fat and milk of all 1158 sires. All bulls having a stud code with their last summary were classified AI. AI and natural bulls were then stratified into plus and minus.

Ages of sires and dams of young sires entering three artificial insemination units from 1969 to 1971 were arrived at in the following manner. Pedigrees for all young bulls entering the three studs in the stated time period were solicited and received. The registration numbers for the sire and dam were obtained from the pedigree of each bull and used to locate their birth dates in their respective Holstein herd books. Identification of each young sire along with his birth date and the birth dates of his parents were punched on computer cards and the ages of the parents at the time the young bull was born were computed.

A questionnaire survey (see Appendix) was conducted of four bull studs which breed 90 percent of the artificially bred population in Michigan to determine the current status of progeny testing in Michigan. Progeny testing estimates are based on the number of first services per stud in Michigan. Responses of varying degrees of clarity were received from three of the organizations which bred an estimated 83 percent of the Michigan Holstein population in 1971.

Recent research of Spike (1972), Erickson (1972), and Erickson, et al. (1972) were sources of information about calving interval, sire selection decisions, and superiority of bulls currently in use. Michigan calf mortality data is based on research findings reported by Speicher (1972), and Oxender (1971).

RESULTS AND DISCUSSION

Available Herd Replacements

Specht (1957) used 70 percent as the fraction of all heifer calves born that are available as herd replacements. For purposes of the present study, an estimate of the number of available herd replacements was desired. The following formula was developed.

$$\frac{\left[\frac{(NC_1L)}{2}\right] C_2}{I} \quad \text{or} \quad \frac{\frac{(130x.85x.85)}{2} \text{ x } .90}{1.08} = 39$$

where: N = cows bred per 100 cows in the milking herd

C_1 = percent bred which calve

L = percent of calves which live to breeding age

2 = to account for normal sex ratio

C_2 = percent of heifers reaching breeding age which also reach the milking herd

I = calving interval.

All heifers available as herd replacements (39) expressed as a percentage of heifer calves born $(\frac{(130x.85)}{2}=55)$ results in 70.9 percent, or essentially the 70 percent Specht (1957) used in his thesis.

Another basis which might be used to estimate the number of available herd replacements is cow removal levels.

One limitation is that cows sold for dairy purposes are either replacing cull cows in some other herd or enlarging the size of some other herd.

Meadows (1968) refers to heifers not reaching the milking string as "cow wastage." He cited McGilliard's data as indicating that for each 100 cows successfully bred, 30 heifers reach the milking string. Meadows also cited Pelissier's reported 32 daughters reaching the milking string from every 100 cows based on California DHIA data.

Reducing calculations made earlier in this section to represent heifers reaching the milking string per 100 cows successfully bred [$(\frac{100}{130}) = .77$] an estimate which agrees exactly with McGilliard's data is found ($.77 \times 39 = 30$).

Still another approach may be used to estimate heifers born which reach the milking string. If an accurate count were made of all first lactation females, the number of available herd replacements should be the same except for any culling which might have taken place. This was done as part of the present study by examination of lactation codes of cows on the IPR file. Slightly more than 27 percent of the cows were found to be in their first lactation. Pennsylvania, in the 1968 Dairy Reference Manual, reported that in a herd of 100 cows there are 23 first calf heifers.

Calf mortality is the one most important factor determining the number of heifers available as herd replacements. According to Speicher (1972) several factors influence calf mortality. Calf mortality is higher in Southern Michigan (15 percent) than in Northern Michigan (12 percent). During the summer months calf losses are lower (10.3 percent) than for winter months (17.1 percent). Annual calf losses increase as herd size increases. The greatest period of hazard to the calf that was alive at birth came during the first week. No significant differences were noted between the breeds, but Jersey and Guernsey herds had slightly higher calf losses than did Holstein herds. Stanchion, switch, loose, and free stall housing systems were compared. Losses were higher in loose (15.1 percent) and free stall housing (14.2 percent) than in stanchion (12.0 percent) and switch (11.3 percent).

Several management practices were also discussed. Higher calf losses were reported by dairymen who turned calf care over to hired labor. Feeding of colostrum within the first five hours after birth helped reduce calf losses. Survival rates were higher for calves kept in individual pens. Oxender, et al. (1972), reported an average calf loss for the state of Michigan of 17.6 percent. Herds used in the survey were reportedly larger than the average for Michigan at the time of the study.

Percentage of Cow Removals

Cow turnover influences genetic progress in several ways. The female generation interval is greatly dependent on how many cows are culled and at what stages. Selection achieved by the dairyman during two phases of the cow removal process are important in determining genetic improvement which can be made. Phase I might be considered selection of replacement animals which, as evidenced in the immediately preceding section, is reduced by sterility, abortions, losses of females which have not freshened, and calf death losses. The second phase, then, is the selection achieved by voluntarily culling as large a portion of the cows as possible. Discussion in this section will deal mainly with phase 2. In Table 12 is a comparison of recent (June 9, 1972 IPR files) cow removals with 1968 Michigan DHIA removals and 13 year Michigan DHIA removal averages.

Some of the questions pertinent to the present study are: changes which have taken place over time, levels of involuntary culling, and factors which contribute most to involuntary culling levels. Percent removals for the various categories are very similar for those from the current IPR file and those from the 1968 DHIA records. Important differences exist between current removals and those in the thirteen year average. The decrease in involuntary culling levels is an outstanding characteristic of the differences between these two sets of data. Since death

Table 10. Dairy cow removals reported by Michigan DHIA.

	June 1972	June 1972	13 Year Ave.[a]	1968 DHIA	1968 DHIA
	No.	Percent of total removals			% of pop.
Sold - dairy	481	8.61	9.44	8.01	1.91
cull cow	3197	57.25	48.21	56.07	13.39
physical injury	250	4.48	8.16	5.47	1.31
mastitis	346	6.20	6.14	4.62	1.10
bangs	6	.11	.84	.09	.02
temperament	50	.99	--	.85	.20
hard milker	18	.32	1.45	.56	.13
sterility	830	14.86	16.56	16.40	3.92
old age	60	1.07	--	1.51	.36
hardware	28	.50	--	.57	.14
other	--	--	3.71	--	--
Died - milk fever	57	1.02	.77	.85	.20
acetonemia	20	.36	.26	.19	.05
hardware	35	.63	.77	.51	.12
bloat	5	.09	.52	.22	.05
accident	73	1.31	1.78	1.60	.38
old age	10	.18	.23	.16	.04
forage poisoning	1	.02	--	.15	.04
penumonia	7	.13	--	.24	.06
lukemia	1	.02	--	.11	.03
claving trouble	109	1.95	1.17	1.82	.43
Percent Died		5.69	5.50	5.85	1.40
Involuntary cull (percent)		34.14	35.92	42.35	--

[a] 1955-1968 Michigan DHIA records.

losses are similar, the difference must be in the sold category. Physical injury was responsible for more than three percent of the difference between the thirteen year average and the current status as indicated by the June, 1972 study. In the present study, sterility claimed nearly two percent less cows than reported in earlier DHIA data. An additional 2.14 percent were culled for "other" reasons in the thirteen year average as compared to the current level (old age and "hardware" disease were combined for purposes of this comparison).

According to Burnside, et al., any reason which accounts for greater than a one percent loss is an economically important one. Physical injury, mastitis, sterility, and death losses each represent more than one percent of the cows in the 1968 DHIA cow population. Sterility, physical injury, and mastitis are the three causes over which dairymen would be expected to have greater amounts of control. Based on the 1972 IPR data, losses due to sterility appear to have declined since 1968. Mastitis losses were lower in 1968 than they are currently. Based on the thirteen year DHIA averages, total removals in Michigan represent thirty percent of the cows in the herd annually.

It is unlikely that too much emphasis will ever be placed on reducing involuntary losses to effect an increase in voluntary culling levels. The same argument applies to both replacement heifers and cows in the milking herd.

Calving Interval

Calving interval reflects the management level of the dairyman, as much as, or possibly more than, any other factor discussed herein. Not only is it a reflection of heat detection, but also of general herd health, reproductive tract health, and the nutritional program. From a management point of view, it is as much a question of having the cow bred at the right time as it is of detecting heat accurately. Spike (1972) found that the average calving interval for Michigan Holsteins over a thirteen year period (1953-1966) was 395 days.

Length of calving interval influences genetic progress in at least three ways:

1. Long calving intervals lengthen the generation interval.
2. The rate at which herd replacements come into the herd is decreased by long calving intervals.
3. Voluntary culling levels are reduced as the rate at which herd replacements coming into the herd decreases.

Generation Intervals

As implied by the heading to this section, dairy breeders must be concerned about the ages of more than one group of animals. Robertson and Rendel (1950) outlined the four sources of parents for the next generation as sires of sires, sires of herd replacements, dams of sires and dams of herd replacements.

Vinson and Freeman (1972) reported average ages for sires and dams of young bulls of 136 months and 87.9 months, respectively. No ages were reported for parents from the other two sources.

Ages of dams of herd replacements were taken from IPR files on two different days. Average ages were found to be 51.96 and 52.15 months for groups of 125,706 and 124,329 Holstein cows, respectively. Fifty-two months is an appropriate average age to use for Holstein dams of herd replacements.

Sires listed by four AI organizations, in 1972 catalogues, were used to compute the age of sires of herd replacements. It is clear that differences do exist between the breeding organizations included in this study. An average age of over nine years was calculated for available sires in four bull studs.

Pedigrees of young sires entering three AI organizations between 1969 and 1971 were used to compute average ages of sires and dams of young sires. Results are listed by stud in Table 11. Ages of sires and dams agree well with ages reported by Vinson and Freeman (1972). Ages point up a dramatic change which has occurred since Specht's 1957 work. The nature of the formula for computation

Table 11. Average ages of sires of herd replacements.

Stud	No. of Bulls	Ave. Age in Months	Range
A	40	108.4	64-185
B	27	116.1	75-195
C	26	117.5	78-181
D	45	99.8	67-138
Overall	138	108.8	

of genetic progress is such that doubling the generation interval, for instance, requires that accuracy in the computation of breeding values be increased two fold in order to continue to make the same amount of progress as before the increase occurred in the generation intervals. A greater increase in generation interval than in accuracy creates negative progress. Almost too obvious to require mention, is the fact that this is a serious problem and will receive much attention from AI organizations in the coming decade.

Current Michigan Holstein Population

A knowledge of the cow population is necessary, not only from the standpoint of the number of inseminations required, but also from the standpoint of the number of young bulls which must be tested annually.

Table 12. Average ages of dams and sires of young bulls entering three studs between 1969 and 1971.

	Stud					
	A		B		C	
	N_1	$\overline{X}$(yr-mo)	N_2	$\overline{X}$(yr-mo)	N_3	$\overline{X}$(yr-mo)
Bull	107	2-07	144	2-02	61	1-10
Sire	107	12-10	144	14-03	61	12-11
Dam	107	9-11	144	10-01	61	9-00
Sire-Bull	107	10-03	144	12-00	61	11-00
Dam-Bull	107	7-03	144	7-10	61	7-02
Total (sire-bull+ dam-bull)		17-06		19-10		18-02
Overall totals and averages		N_{total}		$X_{overall}$ (yr-mo)		$\overline{X}_{overall}$ (months)
Sire-Bull		312		11-03		134.87
Dam-Bull		312		7-07		90.17

According to the July, 1972 Michigan Agricultural Statistics, the dairy cow population (milk cows and heifers that have calved) was 473,000 at the beginning of the year. Changes in the dairy cow population which have occurred during the past three years are reflected in the following figures taken from the 1972 version of Michigan Agricultural Statistics.

Table 13. Michigan milk cows* by year.

	Year			
	1969	1970	1971	1972
Milk cows	469,000	462,000	463,000	473,000

*Milk cows and hiefers that calved.

According to Speicher (personal communication) Holsteins constitute 86.9 percent of the Michigan dairy cow population. Ninety-two and 93 percent of the cows on the in-progress record (IPR) file were Holstein on two different dates. Speicher's figure would indicate that a smaller proportion of the cows of the minor breeds are on test than are Holsteins. For the present study 90 percent is used as the fraction of the dairy cow population represented by Holsteins or 425,700.

Effective Population for Progeny Testing

The 1971 DHIA annual summary reported 85,931 cows on official test. Holsteins on official test represent

18.1 percent of all Holsteins.

A surprising proportion of grade Holstein cows are not correctly identified by sire. It was reported by USDA (1971) that of 1,907,042 lactation records submitted, 849,506 were used for genetic evaluations of bulls and cows. Ninety-two percent of the 44.55 percent rejected records were records of grade cows lacking sire identification. The May, 1971 run by USDA found ninety percent of 45.76 percent rejected for the same reason.

Table 14. Percent DHI cows identified by sire.*

Cows with sire identification	States		
	1968	1969	1970
%	No.	No.	No.
90 or more	0	0	0
80 - 89	2	2	3
70 - 79	8	8	6
60 - 69	10	12	15
50 - 59	17	10	11
40 - 49	8	15	12
30 - 39	4	2	2
20 - 29	0	0	0
10 - 19	0	0	0
1 - 9	1	0	0
Less than 1	0	1	0
U.S. average %	59.0	57.1	59.1

*Table adapted from USDA DHI letter.

According to USDA (1971) only 56.8 percent of the official Michigan DHI records reported in 1970 had valid sire identification. The above table from USDA shows how Michigan ranks in relation to other states and the national trend over three years is also shown.

The current estimate of the Michigan population effective for progeny testing is 43,762 Holstein cows.

Stratification of Michigan Holstein Population by AI and Nat.

In Figure 1, adapted from the June-July, 1971 issue of the USDA DHI newsletter, the trend in the percent of U.S. dairy cows bred by AI since 1945 is shown. In the same newsletter it was reported that 46.7 percent of all Michigan dairy cows and bred heifers were bred artificially in 1970. In this study 46,376 Michigan in progress records having method of breeding descriptions other than unknown, showed 65.1 percent bred artificially. Based on 1972 USDA estimates of first-services in Michigan, 59.1 percent of the Holstein population is bred artificially. Sixty percent is assumed in the present study to represent the fraction of the population bred artificially.

Fractions of AI and Natural which are Plus and Minus

Sires (summarized since April, 1967) of cows on the IPR file which were in milk at least 45 days, were analyzed

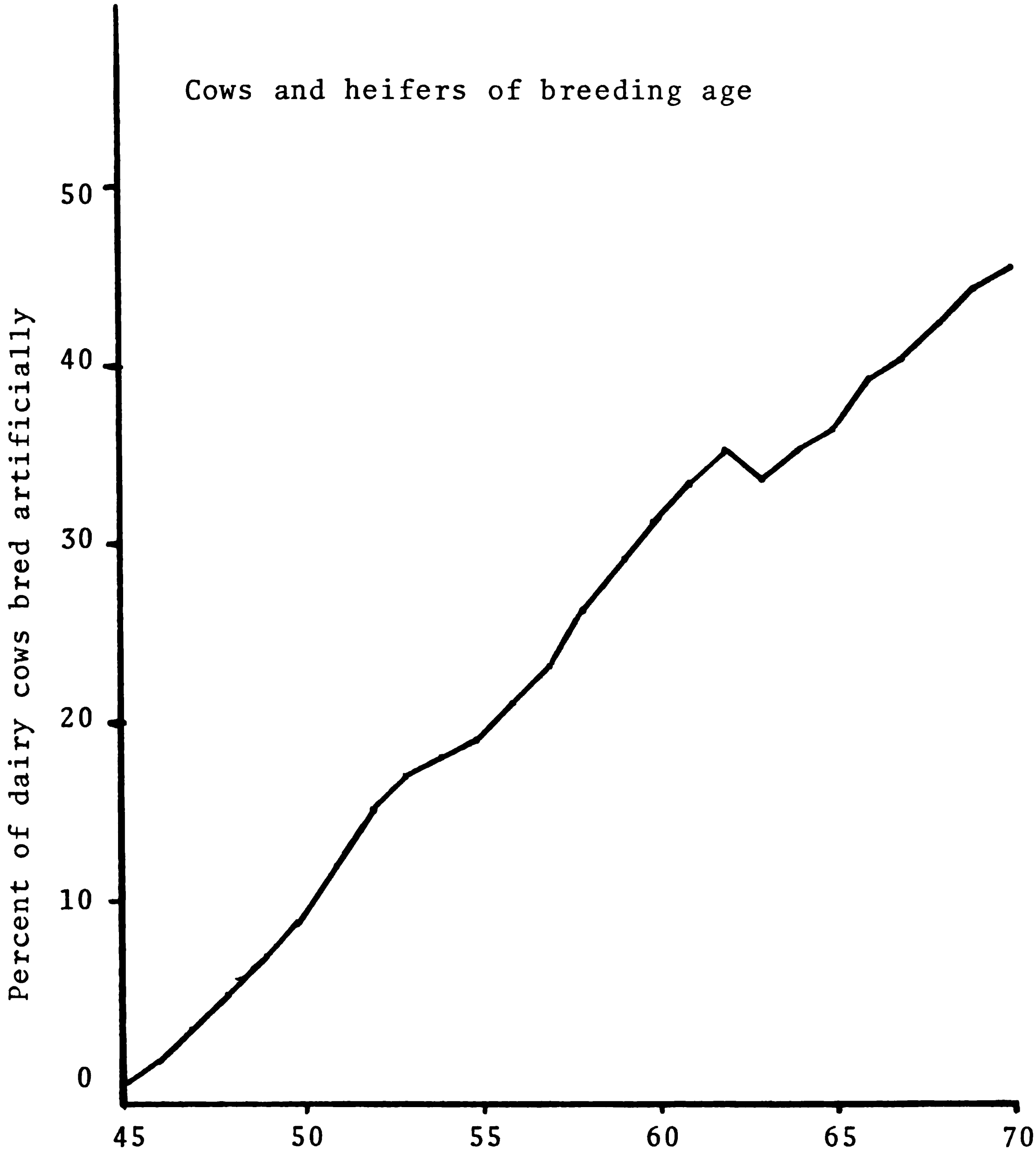

Figure 1. Yearly trends in the percentages of U.S. dairy cows bred by AI since 1945.

to determine the fractions of plus and minus sires in each of the strata discussed in the immediately preceding section. Forty-six percent of the bulls analyzed were not identified by stud code in the annual USDA-DHIA Sire Summary List containing their most recent summary. These bulls were assumed to be natural while the remaining 54 percent were known to be in bull studs at the time of their latest summarization.

Five hundred ninety-nine active AI Holstein bulls were listed by USDA based on PD rankings with 200 pound intervals. Percentages were calculated and are presented in Table 15 along with the USDA data.

Table 15. Number of bulls by 200 pound PD intervals.

	USDA		AI[a]		NAT[a]	
	No.	%	No.	%	No.	%
1000 and up	36	6	27	4	--	--
800 to 999	42	7	38	6	2	1
600 to 799	83	14	54	10	7	1
400 to 599	86	14	66	11	29	5
200 to 399	101	17	87	14	64	12
0 to 199	95	16	84	13	151	28
-1 to -199	69	11	90	14	138	26
-200 to -399	56	9	80	13	90	17
-400 to -599	18	3	46	7	37	7
-600 to -799	5	1	27	4	11	2
-800 to -999	5	1	8	1	5	1
-1000 and less	3	1	17	3	--	--
Totals	599	100	624	100	534	100

[a]Based on current Michigan study.

The following general interpretation of the data was made by USDA.

> A zero predicted difference in the table indicates that a sire with zero PD, used in breed average herds, has about half of his daughters above and about half below breed average. He can be expected to transmit somewhat less than breed-average production to his future progeny because of genetic improvement across years. In general, the bulls with minus PD's sire daughters more than 50 percent of which are below breed average in production. The bulls with higher PD's are expected to sire daughters with higher production than bulls with lower PD's regardless of herd production level.

The current study included 1158 bulls. There were slightly fewer natural sires with positive proofs than with negative proofs; however, those bulls having positive proofs sired a greater number of the naturally sired cows than did those sires having negative proofs. Among the AI sires, a greater percentage of the bulls were plus (57 percent) than minus. A greater percentage of the AI daughters were also from positive bulls (62 percent) than from negative bulls.

A summary of plus and minus sires and of daughters of the same for AI and natural is presented in Table 16.

Table 16. Percent plus proven AI and natural sires and daughters of the same.

	Plus proven sires		Daughters of plus proven sires	
	No.	%	No.	%
Natural	253	47	1785	57
AI	356	57*	10864	62*

*% + AI sires and % daughters of + AI sires were significantly different from natural at the .001 level.

In Table 13 it is interesting to note that while a difference of nearly ten percentage points existed between plus proven AI sires and natural sires in the same category, only a five percentage point difference existed when differences between the fractions of AI and natural daughters from plus proven bulls were measured. It is also noteworthy that daughters of minus proven AI sires represent the smallest portion of either of the two strata.

Superiority of Bulls in Use

Genetic improvement in the population depends on the use of selection procedures which identify superior sires and the differential use of sires.

Data presented in the immediately preceding section represent sire selection decisions made by dairymen nearly one generation of cows earlier or approximately four years ago. The average superiority for milk and fat of natural sires included in this study were +24 lb. and -1 lb., respectively (averages weighted by number of daughters for each sire). For AI sires the average superiority for milk and fat were +168 lb. and +6 lb., respectively.

According to data presented in the March, 1972 USDA DHI newsletter, the weighted, average predicted difference for milk and fat of active AI sires were +318 and +8, respectively. Only in the Holstein breed were the weighted predicted differences greater than the unweighted ones.

Researchers at USDA concluded that for those breeds other than Holstein "this indicates selection for traits other than yield and income." Other considerations related to selection intensity for sires will be discussed in a later section.

A 1971 survey of Michigan dairy farmers by Erickson, et al. (1972), revealed that farmers were using sires with predicted differences for milk of +826.3 and +822.3 for grade and registered herds, respectively. Based on a more recent survey, Erickson (1972) reported for sires of calves born in the last year, predicted differences of +808 in herds with high levels (17,694) of milk production and +694 in herds with near breed average levels (13,397) of milk production. Of particular interest at this point is the agreement between responses to Erickson's earlier questionnaire and the response of owners of herds with high levels in the more recent survey. There is an apparent, however small, upward bias in the average response to the earlier survey. A strong trend toward the selection of higher predicted difference bulls is indicated.

Average predicted differences for milk and fat were calculated for sires available to Michigan dairymen through four studs. Active bulls listed in the 1972 bull books were used for the calculations. Results are summarized in Table 17.

Table 17. Average PD's for milk and fat for available sires.

Stud	No. Bulls	Ave. PD* milk	Range milk	Ave. PD* fat	Range fat
A	40	414.0	-345 to 1892	12.3	-13 to 79
B	27	643.2	-82 to 1355	20.8	-6 to 55
C	26	543.1	-149 to 1268	17.7	-2 to 52
D	45	753.8	197 to 1906	24.7	3 to 62

*Based on 1971 Sire Summary List.

Differences of 339.8 pounds of milk and 12.4 pounds of fat existed between the average predicted differences of the high and low organizations. The overall average predicted differences for milk and fat were 593.97 and 19.02, respectively.

Useful Life Span of Tested Bulls in AI

A survey was conducted of four bull studs which provided semen for 86.3 percent of the AI services to Michigan dairy cows in 1971. There are three general stages of culling in the life of an AI bull after he enters a stud:

1. Progeny test
2. Waiting for results from the progeny test
3. Active service.

The stages listed above are used for convenience sake, recognizing that many differing programs exist.

Removal rates for each of the stages were requested on a questionnaire. Table 18 summarizes the findings from the four studs referred to for removals at two of the stages.

Table 18. Removal rates of bulls in AI.

Stud	Testing Period (% saved)	Waiting Period (% saved)	% of permanent stud replaced annually
A	99.5	70[a]	10-15
B	95	[b]	15-30
C	100	80	15-20

[a]Based on paper presented to ADSA, 1970, by Walton.
[b]Stud has no waiting period.

Sires in active service require a different approach. Ten to 33 percent must be replaced each year with responses for the individual studs (Table 18) differing, especially in their upper limits. For purposes of this study, based on New Zealand data (1970), current generation intervals, Becker and Arnold (1953), and responses to the current survey, four years will be assumed to be the average useful life span of tested bulls in AI.

Sire Utilization

Norman, *et al*. (1970) reported on "utilization of AI bulls in the United States in 1968." The report was based on data supplied by 26 organizations on the source of semen for 5,994,583 inseminations or 93 percent of all dairy to dairy services to AI bulls in the United States in 1968.

Number of bulls and the total of inseminations are given for the Holstein breed by type of service in Table 19, adapted from Norman, et al. The further breakdown to inseminations by type of service and usage levels helps clarify the intensity with which bulls are used. It is noteworthy that a mere four percent of the inseminations were in the progeny test category.

Table 19. Holstein bulls and inseminations by type of service.

Bulls				Services*			
Regular	Special Mating	Progeny Test	All	Regular	Special Mating	Progeny Test	All
Number							
628	72	354	1,054	4,781,400	53,352	181,493	5,016,245
Percent							
60	7	34	100	95	1	4	100

*Based on the average number of ampules required per breeding.

USDA also reported usage levels within the various categories. Only three percent of the regular-service sires are being used at near-optimum levels. THE USDA reported that one Holstein bull had 61,835 services while the average for Holsteins in regular service averaged 7,614 services per bull.

Norman, et al. (1970), also reported that 1967 New Zealand data showed ten young Jersey bulls which were used as extensively as possible averaging 43,188 inseminations, the maximum for any one bull being 59,451 inseminations.

The USDA reported that elimination of the lowest 43 percent of the bulls active in AI (based on production) would have been possible at 10,000 inseminations per regular service bull. Since this figure is for all breeds, it is biased upward (Holstein bulls had higher usage levels than bulls of the minor breeds) but is, non-the-less indicative of the genetic importance of usage levels. Mention should be made at this point of the possible implications of inbreeding when fewer sires are used. It is conceivable that sampling more young bulls, using more pedigree selected young bulls to sire herd replacements and limited (e.g., 50,000 inseminations per bull) use of bulls in the latter group as well as importation of semen will eliminate any serious threat of extensive inbreeding.

Minimum Number of Tested Bulls Needed

Realization of the largest possible selection differential is contingent on the use of a minimum number of tested bulls. This assumes that the bulls are accurately ranked and that the best bulls are selected. Given that the Michigan Holstein population consists of 425,700 cows, that 60 percent of the cows are bred artificially, that 1.7 services are required per conception, and that 20 percent of the cows are bred to young, untested bulls (Legates, 1971) the minimum number of services needed is 374,371. If tested bulls can be expected to provide semen for 60,000 inseminations (Kucker, 1972, personal communication), then 6.24 or seven bulls are needed.

According to USDA estimates of AI first services to dairy animals (279,766 dairy x .90 Holstein = 251,789) the above calculation overestimates the number of services needed (251,789 x .80 x 1.7 = 342,433) but seven bulls more than satisfy the semen requirements at this level. Utilization of AI bulls in the United States will be discussed in more detail in a subsequent section.

Based on a Holstein population of 425,700, 60 percent AI, and 7,614 services per Holstein bull in active service the number of Holstein bulls currently needed in Michigan is estimated at 34. Given that 25 percent of the bulls in the active stud are replaced annually, nine new bulls must be brought into the stud each year. To save 50, 20, and ten percent of those tested, progeny test programs should include 23, 57, and 113 bulls, respectively.

Present Progeny Testing Situation in Michigan

Van Vleck (1963) in a paper presented at the ADSA annual meeting, referred to "fixed parameters" and "other elements of the stud operation which can be adjusted." Fixed parameters include population size, testing situation, usage rate, and mortality rate. Three other elements which he referred to as adjustable are:

1. The fraction of first services to young, untested sires.
2. The number of first services to each young sire before he is removed from service to undergo a waiting period.
3. The number of young sires to sample each year.

In this section and the following emphasis will be placed on the three elements listed above.

Included in the survey of four bull studs operating in Michigan were questions related to their progeny testing activities in Michigan. Because of testing program differences and differences in the responses to the survey questionnaire, estimates of the level of progeny testing activity for two of the bull studs included in the survey are based on first services to dairy in Michigan and progeny testing levels of the other studs in the survey.

The desired parameter is the number of bulls currently being progeny tested in Michigan annually. The fraction of first services to young, untested sires and the number of first services to each young sire before he is removed from service to undergo a waiting period must be determined. The number of cows and the number of herds involved in the progeny testing program are also of interest. Results of the survey are summarized in Table 20.

Table 20. Progeny testing parameters for Michigan.

Stud	No. Cows	No. Herds	Young Sires		
			% First Services	Services Per Sire	No. of Sires Sampled
A	748[a]	25	2.63[c]	500	1.5
B	3364[a]	172	2.47	500	6.73
C	704[b]	--	2.00	500	1.4
D	284[b]	--	2.00	500	.56
Other	536	--	2.00	500[d]	1.07
				Total	11.26

[a]First services based on proportion of cows bred to young sires.

[b]Based on two percent of first services.

[c]Assumes 90 percent of first services are to Holsteins.

[d]Assumes same model as used for studs A and B.

Thompson and Freeman (1971) used three percent to represent the fraction of first services resulting in production tested daughters (fraction of population tested = 0.15, times fraction of calves which are heifers = 0.50, times fraction of heifer calves that make at least one record = 0.60). According to stud A, 40 daughters (eight percent) result from distribution of 500 ampules of semen. Stud B reported one two-year daughter record per eight ampules of semen used which is twelve percent as compared to the eight percent reported by stud A.

Progeny Testing Possible

In a preceding section "effective" population was defined as cows on test identified by sire. Based on a Holstein population of 425,700, eighteen percent on official test, 56.8 percent identified by sire, 60 percent AI, and 500 first services per young bull; 52 young sires could be tested annually if all cows were bred to young bulls. This, of course, leaves a large portion of the AI population to be bred to progeny tested bulls. One point of practicality is that at least some progeny tested bulls should ultimately be used in the "effective" population. The minimum reasonable use of tested bulls in the effective population would be for special mating purposes. Currently eleven bulls are being tested which represents 20 percent of the "effective" population.

Suggested Improvement

From the preceding section it appears that Legates expectations are being met in Michigan; however, this 20 percent represents slightly more than two percent of the artificially inseminated Holstein population.

It is not inappropriate to estimate the number of young bulls which could be sampled if: (a) testing included 100 percent of Michigan Holsteins, and (b) all cows were correctly identified by sire. Based on the present level of identification by sire, if all cows were on official test, 58 bulls could be tested. Using the current testing situation, if all cows were correctly identified by sire, approximately 18, 36, 55, and 73 young sires could be sampled breeding 20, 40, 60, and 80 percent, respectively, of the tested population to young sires. Still a third situation to consider is that of all cows on test and identified by sire. This would permit sampling of 122, 204, and 306 young bulls breeding 20, 40, and 60 percent of the population to young bulls. A brief computer program was developed. It computed the number of tested bulls needed varying; (1) percent AI, (2) percent bred to proven sires, (3) services per sire. Based on a constant annual removal rate of 25 percent, it calculated the number of replacements needed. The total number of bulls to be tested was then computed based on a constant 80 percent remaining after the waiting period and varied intensities of selection.

In Table 21 the number of young bulls to be tested is computed for two levels of percent services to tested bulls (60, 80) for varying intensities of selection. It should be noted that for low intensities of selection too few young bulls are being tested to breed the portion of the population not bred to tested bulls (40 percent and 20 percent) at current usage levels for young sires. At least two approaches or a combination of them could be used to overcome this deficit. Increasing the number of services per young, untested bull would insure greater

Table 21. Young sires to be tested varying several parameters.

Portion of population bred by AI	Bred by tested bulls	Services per sire	Tested bulls needed	Young bulls required	Selection intensity	Young sires to be tested
Percent	Percent	Number	Number	Number[a]	Fraction	Number[b]
60	60	10,000	16	4	1.0	5
60	60	10,000	16	4	.7	7
60	60	10,000	16	4	.5	10
60	60	10,000	16	4	.1	48
60	60	10,000	16	4	.01	479
60	80	10,000	21	6	1.0	7
60	80	10,000	21	6	.7	10
60	80	10,000	21	6	.5	13
60	80	10,000	21	6	.1	64
60	80	10,000	21	6	.01	638
80	80	50,000	6	2	1.0	2
80	80	50,000	6	2	.7	3
80	80	50,000	6	2	.5	4
80	80	50,000	6	2	.1	17
80	80	50,000	6	2	.01	170

[a]Based on a 25% annual removal rate.

[b]Assumes 80% survive the waiting period.

reliability of early USDA estimates of his genetic ability. By increasing the selection intensity more young bulls would be evaluated insuring selection of the very best replacements available for the permanent stud. If one combines these two factors with findings reported by Thompson and Freeman (1971) and Hunt (1972), that a greater portion of the AI population should be bred to young, untested bulls (partly because of reduced generation intervals), then the following conclusions seem appropriate:

1. More young bulls should be tested
    a. to increase selection intensity
    b. to reduce generation intervals
2. The number of services per young bull should be increased
    a. to increase reliability of proofs
    b. to reduce generation intervals
3. More cows should be on official test
    a. to permit testing of more bulls
4. More of the cows on test should be identified by sire
    a. to be useful in sire evaluation
5. Increase fertility
    a. less services to high PD bulls are wasted repeats
6. Increase the use of AI
    a. more bulls can be tested
    b. to achieve more uniform herd production levels

7. Select sires more intensely

   a. to limit the use of low PD bulls

SUMMARY

A study was conducted of the management factors which influence genetic progress and their current status in the Michigan Holstein population. The sources of primary data were pedigree records of 312 young bulls entering three studs between 1969 and 1971 and a survey questionnaire of four bull studs (75 percent response).

Secondary data was obtained from the following sources:

1. In progress DHIA records.
2. USDA sire summaries (April 1967-May 1971).
3. Holstein bull books.
4. Herd-books of the Holstein breed.

Results from research by Spike (1972), Erickson, *et al*. (1972), Erickson (1972), Speicher (1972), and Oxender (1972) represent still a third source of data.

On February 15, 1972 Michigan had 425,700 Holstein cows, averaging 13,250 pounds of milk per year. A profile of the average Holstein cow was developed.

1. She was 52 months of age at last calving.
2. It had been 395 days since she calved the last time if natural service was used or 391 days if artificially inseminated.

3. Fourteen percent of her heifer calves will die before six months of age.
4. Seventy percent of her heifer calves born are available as herd replacements.
5. There is a thirty percent chance that she will not be around to have another calf.
6. She was sired by one of 6000 possible sires.
7. Of these sires 1158 have been summarized by USDA with a weighted (by No. of daughters) PD for milk of +145 pounds.
   a. Six hundred and twenty four of these bulls are in AI with an average PD of +168 pounds.
   b. Five hundred and thirty four are natural service sires with an average PD of +24 pounds.
8. If the cow was sired naturally, she was among 1785 cows whose sires were plus proven; 10,864 cows were sired by plus proven AI bulls.
9. She will be bred to AI bulls by:

Stud	Ave. PD		No. Bulls
A	609		49
B	725		51
C	348		43
D	467		26
Overall Ave.	556	Total	169

10. The average PD milk for sires of cows and sires of calves in herds with high levels (17,694) of milk production were +374 and +808, respectively.

11. The average age of the bulls that she will be bred by is nine years.
12. AI units serving Michigan will sample approximately 175 Holstein bulls this year.
13. Enough Michigan cows will be bred to sample eleven bulls.
14. These young bulls will be from special mating with sires that are eleven years of age and dams that are eight years old.
15. The expected daughter superiority from pedigree evaluation will be approximately +1000 pounds of milk.
16. Eighteen percent of Michigan Holstens are on official test (DHIA-DHIR).
17. 56.8 percent of the cows on test are identified by sire.

Improvement of these management factors would increase the effectiveness of selection:

1. Reduce calving interval.
2. Increase fertility.
3. Reduce mastitis.
4. Reduce calf losses.
5. Increase DHIA.
6. Increase cow identification.
7. Increase AI usage.
8. Increase use of high PD bulls.
9. Test more bulls per year.

10. Save a smaller percent of tested bulls.
11. Increase breeding efficiency.
12. Reduce generation interval.

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APPENDIX

QUESTIONNAIRE

1. Proportion of Holstein population in Michigan which your organization breeds?

2. How many young sires do you sample in Michigan?

   a. No. Holstein cows in young sire testing program in Michigan.

   b. Fraction of first services to young untested sires in Michigan.

   c. Number of first services to each young sire before he is removed from service to go into waiting.

   d. Fraction of tested daughters resulting from those first services; and/or the fraction of first services resulting in production tested daughters.

3. Usage rate of sires available?

   a. Number of sires in the permanent stud.

   b. Number of services possible per sire.

4. Mortality rate?

   a. How many of the sires in the permanent stud must be replaced each year?

   b. How many of the young bulls will remain four to five years after their test matings.

5. How many (what fraction) of the original young bulls to be tested will survive the testing period? Survive the waiting period?

6. Age of young sires at the end of the testing period?

7. Age of young sires saved at end of waiting period?

COMPUTATIONAL FORMULAS

I. Minimum tested bulls needed.

$$T_m = \frac{N \times A \times P}{S}$$

where:
T_m = min. tested bulls need
A = fraction AI
P = fraction first services to proven sires
S = services per sire
N = population size

II. Young bulls needed.

$$Y_1 = T_m \times D$$

where:
Y_1 = young bulls needed
T_m = see above
D = fraction of permanent stud replaced annually

III. Young bulls to test.

$$Y_t = \frac{Y_1}{W_s \times I}$$

where:
Y_t = young bulls to test
W_s = young bulls which survive waiting
I = fraction of bulls saved of those tested

IV. Progeny testing possible.

$$T_p = \frac{N \times A \times T_o \times I_s}{S_y}$$

where:
T_p = testing possible
N = population size
A = fraction AI
T_o = fraction on official test
I_s = fraction identified by sire
S_y = services per young sire