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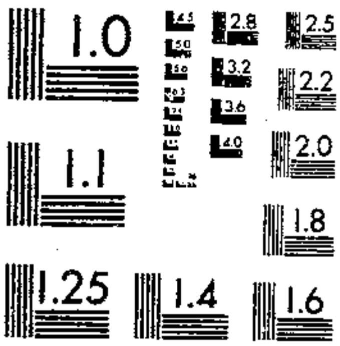

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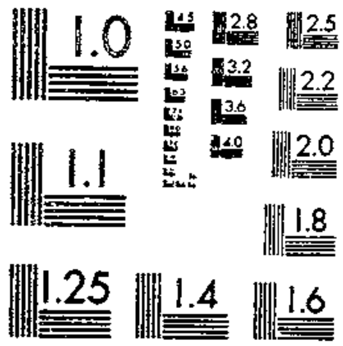

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SOME RESULTS OF INBREEDING GRADE GUERNSEY AND GRADE HOLSTEIN-FRIESIAN CATTLE

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PURPOSE, PLAN, AND PROGRESS OF THE INVESTIGATION

The original purpose of this investigation in inbreeding grade cattle was to determine whether a good dairy herd could be bred up from an ordinary one by the use of only one good bull. The plan was to mate all the female offspring with their own sire throughout his entire useful life. The investigation was started in 1912 at the United States Dairy Experiment Station at Beltsville, Md. In that year 16 cows of mixed breeding and of only average production were purchased for the experiment. The appearance of these cows indicated the presence of Shorthorn, Angus, Hereford, and Jersey breeding. A well-bred Guernsey bull, Imp. Prince Billy of Rich Neck 17799, was purchased to mate with them. In the next year 11 grade Jersey cows, which were somewhat higher producers than the cows in the original purchase, were added to the herd; and at about the same time a registered Holstein-Friesian bull, Johan Woodcrest Lad 11th 103987, was purchased. Inasmuch as the results of such a breeding experiment would depend largely upon the individuality of the bull used, it was thought best to have two bulls of different breeds and to mate some of the cows with one bull and some with the other; but in each case to mate the female offspring with their own sire for successive generations.

The investigation proceeded substantially as planned until the herd became infected with infectious abortion. This disease appeared in 1914, and in 1918 had become so severe that an effort was made to check it by disposing of the affected animals. The disease, coupled with the efforts to eradicate it, nearly terminated the experiment. The females of the Guernsey group were breeding with such uncertainty that it was decided to discontinue the work with that breed. Enough females of the Holstein group were salvaged to warrant continuing the experiment with this breed.

When the Holstein sire, Johan Woodcrest Lad 11th, became impotent, a fair start had already been made in the inbreeding of grade Holsteins. As no injurious results from the practice were yet apparent, it was decided to continue close inbreeding for the purpose of determining its effects upon the health, size, and production of the cattle. The second sire used in the Holstein group was an 87.5 per cent inbred son of the first sire, Johan Woodcrest Lad 11th. The third sire was a 75 per cent inbred son of the second sire. The fourth sire was the result of mating the third sire back to his own dam, and he is still in service. The plan has been to select for service those bulls most intensely inbred.

As used in this publication, the terms "50 per cent daughter of a bull," and "50 per cent son of a bull," mean the offspring obtained when the bull is mated with a cow that is either unrelated or only distantly related to him. A 75 per cent daughter or son of a bull is the result of mating the bull with one of his 50 per cent daughters, and an 87.5 per cent daughter or son of a bull is the result of mating him with one of his 75 per cent daughters.

The offspring of unrelated parents are referred to as "outbred" animals, and the offspring of parents so closely related as a sire and daughter or brother and sister are referred to as "inbred."

Most of the cows with which the second Holstein sire was mated were 50 per cent outbred daughters and 75 per cent inbred daughters of the first Holstein sire, while the second sire himself was an 87.5 per cent inbred son of the first sire. For this reason the terms 50 and 75 per cent, as applied to the daughters of the second sire that were out of his half-sisters, fail to express the full extent of the inbreeding.

The results of this investigation are measured by: (1) Birth weight and normality of calves; (2) weight at maturity; and (3) production of milk and butterfat. For the experiment with Holstein sires additional data are presented on the number of services required for conception, the growth and vigor of calves, and the vigor of cows.

In order to bring all this information to a comparable basis, it was necessary to use certain correction factors: (1) To make the birth weights of grade Holstein calves from immature dams comparable to those of calves from mature dams, 4 pounds was added to the birth weight of each of the calves from 2-year-old dams. (2) To make the birth weights of the bull calves comparable to those of the heifer calves (the number of calves was insufficient to justify a study of each sex), 7 pounds was deducted from the birth weight of each of the bull calves.

These correction factors were determined from data collected in this experiment, and were found to be the same as those obtained in the study conducted by this bureau at its Huntley, Mont., Experiment Station,[1] on factors influencing variation in weight of dairy cows and calves.

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[1] MOSELEY, T. W., STUART, D., and GRAVES, R. R. DAIRY WORK AT THE HUNTLEY FIELD STATION, HUNTLEY, MONT., 1918-1927. U. S. Dept. Agr. Tech. Bul. 116: 24-29. 1929.

Sufficient data from which to prepare similar correction factors for the grade Guernseys were not obtainable. The correction factors for this breed were adapted from those used for the Holsteins by assuming figures approximately proportional to the birth weights of the calves of the two breeds. Three instead of 4 pounds was added to the birth weight of calves from 2-year-old dams, and 5 instead of 7 pounds was deducted from the birth weight of bull calves.

The average body weights of the cows during lactation were determined by averaging weights taken 3, 4, and 5 months after calving if the cow was under official-test conditions, or 6, 7, and 8 months after calving if she was in the general herd. These weights were intended to represent a period when the cows were in good milking condition, but before they were heavy with calf. As the cows under official-test conditions were fed more liberally than those in the general herd, they gained in weight more rapidly after calving, and it was necessary to take their weights earlier in the stage of lactation than those of the cows kept in the general herd. In figuring the weights of young cows to maturity, the following age-correction factors prepared from records obtained in this investigation were used:

For cows 2 to 3 years old multiply the weight by 1.20
For cows 3 to 4 years old multiply the weight by 1.11
For cows 4 to 5 years old multiply the weight by 1.06
For cows 5 to 6 years old multiply the weight by 1.02

Most of the production records in this investigation were made either with immature cows or with cows kept under herd conditions rather than under official-test conditions. It was necessary, therefore, to correct the production records for both of these factors. All of the grade Guernseys and some of the grade Holsteins, as well as the foundation stock from which they sprang, were kept under herd conditions. In figuring to maturity the production records of all these animals kept under herd conditions the age-correction figures of Clark [2] for Holsteins and Guernseys were used. In correcting for age, the production records of grade Holsteins kept under test conditions, unpublished figures prepared in the Bureau of Dairy Industry were used. The age-correction factors applied for such cows when exactly 2, 3, 4, 5, and 6 years old at time of calving were: 1.40, 1.21, 1.10, 1.04, and 1.00, respectively, with monthly gradations for intermediate ages.

In addition to correcting the production records for age, it was also necessary, as just stated, to convert those records made under herd conditions to an equivalent of those made under official-test conditions. In a previous investigation,[3] it was found that cows kept under the official-test conditions used at the Beltsville station, gave 50 per cent more milk and butterfat than they did when kept under ordinary herd conditions. Therefore, the herd records given herein, after being corrected for age of cow, were converted to the equivalent of test records by applying the factor 1.50.

EFFECTS OF INBREEDING GRADE GUERNSEYS

The Guernsey bull Imp. Prince Billy of Rich Neck 17799, used in this work, was by Billy's France of the Isle 21183, and out of Froome's

[2] CLARK, R. S. THE CORRELATION BETWEEN CHANGES IN AGE AND MILK PRODUCTION OF DAIRY COWS UNDER OTHER THAN OFFICIAL TESTING CONDITIONS. Jour. Dairy Sci. 7:552. 1924.

[3] WOODWARD, T. E. INFLUENCE OF TWO PLANES OF FEEDING AND CARE UPON MILK PRODUCTION. Jour. Dairy Sci. 10:283-291. 1927.

Queen 28706, a cow with an advanced registry record of 13,902 pounds of milk and 716 pounds of butterfat. A photograph of this bull is shown in Plate 1 (in pocket) along with those of five foundation cows, their daughters and granddaughters.

BIRTH WEIGHT OF CALVES

The average birth weight of the 50 per cent daughters of the Guernsey bull, and the average birth weight of his 75 per cent calves from these 50 per cent daughters are presented in Table 1. Also, the average birth weight of three of his 75 per cent daughters is compared with the average birth weight of his 87.5 per cent calves out of these three daughters.

TABLE 1.—*Average birth weights of 75 and 87.5 per cent calves*[1] *compared with the average birth weights of their dams, all by the Guernsey bull*

Description of calves	Calves	Average birth weight	Description of dams	Dams	Average birth weight	Calf and dam comparisons
	Number	*Pounds*		*Number*	*Pounds*	*Number*
75 per cent	22	65.8	50 per cent daughters[2]	12	69.9	22
87.5 per cent	3	61.0	75 per cent daughters	3	63.7	3

[1] Corrected for age of dam and sex of calf.
[2] Birth weights of dams of these daughters unknown.

Table 1 shows that there was a small but consistent decline in the birth weight of the calves in this group as the inbreeding became more intense. Another matter, however, must be considered in interpreting these data. Of the twelve 50 per cent daughters in this table, eight were out of dams of indiscriminate breeding. It may be possible that these eight dams had some "large-breed" ancestry and carried an inheritance for greater weight at birth than that carried by the Guernsey bull, in which case it would be expected that mating them with this bull for successive generations would decrease the average birth weight of the calves. On the other hand, the four remaining 50 per cent daughters were out of grade Jersey cows, which no doubt carried an inheritance for smaller calves at birth than that carried by the Guernsey bull. These four grade Jersey daughters had an average birth weight of 70 pounds and gave birth to eight 75 per cent calves with an average birth weight of 61.6 pounds. Two of these 75 per cent daughters had an average birth weight of 63 pounds, and gave birth to two 87.5 per cent calves with an average birth weight of 61 pounds. Therefore, inbreeding decreased the birth weights of the offspring from the four grade Jerseys, although the use of the Guernsey bull probably would normally tend toward heavier calves.

NORMALITY OF CALVES AT BIRTH

A number of deformed calves resulted from mating the Guernsey bull to his daughters. Table 2 shows the total number of calves sired by this bull, and the number of normal calves, abortions, deformed and dead calves, and normal still-born calves, from the foundation cows and from his 50 per cent daughters out of these foundation cows.

TABLE 2.—*Reproduction record of cows mated with the Guernsey bull*

Description of dams	Cows mated	Recorded calvings	Normal calves	Abortions	Calves deformed and dead	Calves normal in conformation but dead
Foundation cows	21	57	51	6	0	0
50 per cent daughters of Guernsey bull	23	48	22	19	6	1

The large increase in number of abortions by the 50 per cent daughters as compared with the foundation cows can be attributed partly, if not wholly, to the prevalence of infectious abortion in the herd.

All the deformed calves either were dead at birth or died within a few hours. The anatomical abnormalities of a typical deformed calf are described by the veterinarian in charge of the herd, as follows:

This specimen showed a compound curvature of the spine. The bodies of dorsal vertebræ were compressed laterally, resulting in a lateral curvature. The bodies of lumbar vertebræ showed anterior compression, resulting in posterior curvature. The lateral processes and spinous processes were modified somewhat in conformity to the changed positions which they assumed as a result of the modification of the body formation. The intravertebral foramina were lessened in diameter upon concavity of the curvatures which would have resulted in an impingement upon the nerves issuing from the spinal cord through them. The long bones of both anterior and posterior limbs showed marked curvatures with the convexities laterally away from the median line. The humerus and femur of each limb were abnormally shortened. The extremities of these long bones were enlarged. The skull showed a general shortening and widening with a permanent bulging of the frontal bones.

This description agrees closely with the appearance of deformed calves examined by Wriedt,[4] who states that "these calves had greatly foreshortened heads and upper jawbone, and stumpy, crooked legs which could not support the animal's weight." Wriedt concludes that this type of deformity is caused by a double dose of a Mendelian recessive factor.

It is probable that none of the foundation cows in the herd at Beltsville carried this recessive factor. In that case, approximately one-half of the daughters by Prince Billy of Rich Neck and out of the foundation cows would receive this factor from their sire. When this bull was bred back to his own daughters, the normal expectancy would be that approximately one-eighth of his inbred calves would receive the factor that causes this type of deformity, both from their sire and their dams, and would be deformed. Table 2 shows that out of 48 inbred calves by Prince Billy of Rich Neck 6 were deformed. This is the number that was to be expected according to the Mendelian ratio, where this deformity is caused by a double dose of a recessive factor, and confirms Wriedt's findings and observations.

MATURE WEIGHT OF COWS

The 12 foundation cows produced 18 daughters for which body weights are available. The average weight of the foundation cows was 934 pounds, and that of the 18 daughters was 1,077 pounds. In order to make a better comparison of the weights of foundation

[4] WRIEDT, C., HEREDITY IN LIVE STOCK. p. 72. London. 1930.

cows, 50 per cent daughters, and 75 per cent daughters, Table 3 was prepared, including only those foundation cows having both daughters and granddaughters.

TABLE 3.—*Weights of five foundation cows, and of their daughters and granddaughters by the Guernsey bull*

Item	Cows	Average weight
	Number	*Pounds*
Foundation cows	5	993
Daughters [1]	5	1,131
Granddaughters [2]	6	956

[1] 50 per cent daughters of the Guernsey bull.
[2] 75 per cent daughters of the Guernsey bull.

As the foundation cattle were from an average farm herd, it is not unlikely that conditions under which they were raised made them smaller than they would have been if raised under more favorable conditions of feeding and management. The average weight of five foundation cows of mixed breeding (993 pounds) is a little less than the average weight of Guernsey cows. For these reasons the increase in weight shown by the 50 per cent daughters of the bull over their dams was to be expected. Every one of the six 75 per cent daughters of the Guernsey bull, however, was smaller than her dam. The average weight of these six 75 per cent daughters was 175 pounds less than the average weight of their dams, which were 50 per cent daughters of the Guernsey bull. This large decline can not be explained on any grounds other than the effects of inbreeding.

PRODUCTION OF MILK AND BUTTERFAT

All production records given in this report were made under ordinary herd conditions. If a cow had more than one lactation record, the one that was highest when figured to maturity was used. The records were either for complete lactation periods or for the first 365 days of prolonged lactations. The records of 12 foundation cows and of their daughters by the Guernsey bull are compared in Table 4, and a comparision of the records of 5 foundation cows with those of 50 per cent daughters and of 75 per cent daughters of this bull is shown in Table 5.

Table 4.—*Milk and butterfat records of foundation cows and of the 50 per cent daughters of the Guernsey bull*

Foundation cows					50 per cent daughters				Increase (+) or decrease (−) of daughters over dams		
Cow No.	Predominating blood	Milk	Butterfat		Cow No.	Milk	Butterfat		Milk	Butterfat	
		Pounds	*Per cent*	*Pounds*		*Pounds*	*Per cent*	*Pounds*	*Pounds*	*Per cent*	*Pounds*
1	Shorthorn	3,770	4.11	155	33	6,378	4.78	305	+2,608	+0.67	+150
1	do	3,770	4.11	155	41	4,693	5.60	203	+923	+1.49	+108
1	do	3,770	4.11	155	56	5,016	4.67	234	+1,246	+.56	+79
2	Jersey	8,184	4.73	387	40	744	4.70	35	−7,440	−.03	−352
5	Shorthorn	6,004	3.43	206	54	9,929	3.86	383	+3,925	+.43	+177
8	Guernsey	6,085	4.22	257	39	5,319	5.32	283	−766	+1.10	+26
8	do	6,085	4.22	257	66	5,297	5.25	278	−788	+1.03	+21
9	Shorthorn	5,501	4.11	226	52	6,120	4.75	291	+619	+.64	+65
12	Jersey	5,749	4.21	242	43	6,021	4.58	276	+272	+.37	+34
12	do	5,749	4.21	242	57	[1] 6,650	4.62	307	+901	+.41	+65
14	Shorthorn	6,064	4.90	297	48	7,895	4.41	348	+1,831	−.49	+51
14	do	6,064	4.90	297	61	6,610	5.17	342	+546	+.27	+45
17	Jersey	6,877	5.16	355	44	5,888	4.60	271	−989	−.56	−84
17	do	6,877	5.16	355	60	6,744	5.34	360	−133	+.18	+5
17	do	6,877	5.16	355	84	7,740	4.78	370	+863	−.38	+15
21	do	10,431	4.56	476	58	5,840	4.90	286	−4,591	+.34	−190
21	do	10,431	4.56	476	71	7,535	4.38	330	−2,896	−.18	−146
24	do	8,224	4.17	343	47	8,302	4.81	399	+78	+.64	+56
24	do	8,224	4.17	343	81	5,399	4.70	254	−2,825	+.53	−89
27	do	6,672	4.09	273	49	8,069	4.56	368	+1,397	+.47	+95
32	Holstein	9,549	4.43	423	53	7,035	4.65	327	−2,514	+.22	−96
Average		6,712	[2] 4.45	299		6,344	[2] 4.74	300			
Difference in averages									−368	+.29	+1
Average, omitting No. 2 and her daughter		6,639	4.43	294		6,324	[2] 4.74	314			
Difference in averages									−15	+.31	+20

[1] Estimated from a 6-month record.
[2] Percentage based on the averages.

Table 5.—*Milk and butterfat records of five foundation cows and of the 50 per cent daughters and 75 per cent daughters of the Guernsey bull*

Foundation cows				50 per cent daughters				75 per cent daughters			
Cow No.	Milk	Butterfat		Cow No.	Milk	Butterfat		Cow No.	Milk	Butterfat	
	Pounds	*Per cent*	*Pounds*		*Pounds*	*Per cent*	*Pounds*		*Pounds*	*Per cent*	*Pounds*
1	3,770	4.11	155	33	6,378	4.78	305	90	5,887	5.61	330
5	6,004	3.43	206	54	9,929	3.86	383	99	7,364	4.66	343
12	5,749	4.21	242	57	6,650	4.62	307	89	7,053	5.47	386
21	10,431	4.56	476	71	7,535	4.38	330	95	5,597	4.56	255
24	8,224	4.17	343	81	5,399	4.70	254	93	8,877	4.60	[illegible]
Average	6,836	[1] 4.16	284		7,178	[1] 4.40	316		6,953	[1] 4.95	344

[1] Percentage based on the averages.

Although 15 of the 21 daughters of the foundation cows produced more butterfat than their dams, the average increase was only 1 pound. One peculiar individual, cow 40 (Table 4) had much to do with bringing down the average of the daughters. As this cow was apparently in perfect health there appeared to be no justification for excluding her record. If the record of this cow and that of her dam were omitted, the average production of milk by the daughters would be about the same as that by the dams and the increase in butterfat would be 20 pounds.

These tables show that the successive matings with the Guernsey bull lowered the production of milk and increased the percentage of butterfat, resulting in a small increase in total butterfat. Three of the five 75 per cent daughters produced more butterfat than their dams; the average increase over their dams was 28 pounds.

In percentage of butterfat the five foundation cows ranged from 3.43 to 4.56 per cent, a difference of 1.13 per cent. (Table 5.) The outbred daughters ranged from 3.86 to 4.78 per cent, a difference of 0.92 per cent. Both the low and the high percentages were increased. The inbred daughters ranged in percentage of butterfat from 4.56 to 5.61, a difference of 1.05 per cent. Both the low and the high percentages were markedly increased. It appears that this sire was able to raise the level of the butterfat test in his outbred daughters and, through the concentration of his inheritance, to raise it still further in his inbred daughters, although the variability was not greatly decreased. The average percentage of butterfat for the five foundation dams was 4.16, the average for their five outbred daughters was 4.40, and the average for the five inbred daughters was 4.95 per cent.

COLOR MARKINGS

The Mendelian behavior of spotting is illustrated in the color patterns of the daughters of this Guernsey sire from cows of broken and solid color. Cow 1, in Plate 1, was a grade roan Shorthorn. The roan color was eliminated in one cross. All the foundation cows of solid color had offspring of solid color in the first generation and all but one of the inbred cows that descended from foundation cows of solid color were of solid color. It is known that spotting is recessive to solid color. Apparently these foundation cows were pure in their inheritance for the factors determining solid color, and, therefore, could not transmit the inheritance for spotting to any of the first-generation heifers; and since the inheritance for solid color is dominant, these first-generation daughters would be of solid color regardless of whether they received an inheritance for spotting from their sire. On the other hand, this sire carried very little white for a Guernsey. Except for some white on the belly and on one leg he was of solid color. Ordinarily it would be expected that more of the inbred daughters would be spotted but it is entirely possible for the spotting to crop out in only one of this limited number of inbred daughters, even if the sire is transmitting spotting to all his offspring. That he did transmit the character for broken color is shown by the fact that both his outbred and inbred daughters from the spotted foundation cow 23 are broken colored.

EFFECTS OF INBREEDING GRADE HOLSTEINS

BREEDING OF BULLS USED

The first Holstein bull used in this work, sire 1, Johan Woodcrest Lad 11th 103987, was by Johan Woodcrest Lad 52145 and out of Lillian Walker Nudine 16229, a cow with an advanced-registry record of 16,229 pounds of milk and 518 pounds of butterfat at the age of 2 years and 4 months.

The second bull used, sire 2, was an 87.5 per cent son of sire 1. Photographs of sire 1 and sire 2 appear in the illustrated pedigree of sire 2 shown in Plate 2. (In pocket.)

The third bull used, sire 3 (pl. 3, in pocket), was a 75 per cent son of sire 2. Sire 3 died of bloat at the age of 2 years and 3 months.

The fourth bull, sire 4, now in service, is the result of mating sire 3 with his own dam.

BREEDING OF FOUNDATION COWS

The immediate ancestry of the first eight cows listed below is unknown. The opinion on their breeding is based upon their appearance. The next six cows were by sires of known breeding.

Cow No.	Breeding	Cow No.	Breeding
7	Jersey-Shorthorn.	29	Grade Holstein.
18	Grade Jersey.	33	Grade Guernsey.
20	Do.	34	Grade Jersey.
21	Do.	84	Do.
23	Do.	93	75 per cent inbred Guernsey.
25	Do.	A-13	Grade Holstein.
A-6	Grade Holstein.		
A-7	Do.		

Photographs of these cows along with those of their offspring by sire 1 and sire 2 are shown in Plates 4 and 5. (In pocket.)

SERVICES REQUIRED FOR CONCEPTION

Complete service records of the animals in this experiment have been kept for a number of years. The average number of services per conception for the animals of varying degrees of inbreeding for the period from January 1, 1923, to July 1, 1930, is given in Table 6.

TABLE 6.—*Services required for conception by cows with different intensities of inbreeding*

Intensity of inbreeding	Cows served	Average services per conception
Cows served by sire 2, an 87.5 per cent son of sire 1:		
50 per cent daughters of sire 1	6	[1] 4.4
75 per cent daughters of sire 1	5	2.6
87.5 per cent daughter of sire 1	1	1.3
Cows served by sire 2 or sire 3, the latter being a 75 per cent son of sire 2:		
Cows unrelated to these sires	6	2.8
50 per cent daughters of sire 2	19	2.7
75 per cent daughters of sire 2	9	2.4

[1] If the record of 1 cow served 14 times were omitted the average would be 2.4.

Table 6 shows that the inbreeding of these cows did not adversely affect the readiness with which they conceived; in general, the average number of services per conception decreased slightly as the intensity of inbreeding increased. Compared with the other cows at the Beltsville station, the cows in this experiment required fewer services per conception.

GESTATION AND NORMALITY OF CALVES

Since January 1, 1926, more complete gestation and calving records than formerly have been kept. In the period from that date to March 14, 1931, 104 calves in this experiment were born. Of these 89 were inbred and 15 outbred. All the outbred calves were normal in every way. Of the inbred calves, however, 4 were carried full time but were born dead, 1 fetus was mummified, and 3 were abortions (not infectious). Thus 9 per cent of the gestations in which inbreeding was a factor terminated abnormally.

Comparable figures for 126 outbred registered Holstein calves in the general herd are: 112 normal, 9 carried full gestation period but born dead, 2 mummified fetuses, and 3 abortions (not infectious), or 11 per cent of the gestations terminated abnormally.

If the results from the grade herd only are considered, inbreeding appears detrimental. On the other hand, if the inbred grades are compared with the outbred registered Holsteins, little difference in the efficiency of breeding as regards gestation and normalcy of calves is found.

Only one deformed inbred calf has been produced. This was some years previous to the period stated above. The calf was the result of mating sire 1 with one of his 50 per cent daughters. The posterior part of the spinal column, including the tail, was missing and the calf was dead at birth. The deformity was entirely unlike the "bulldog" calves described in the discussion of the inbred Guernseys. As there was only one deformed calf, and as it was less intensely inbred than many of the calves born subsequently, it does not seem reasonable to attribute this one case to inbreeding.

BIRTH WEIGHT OF CALVES

The intensity of inbreeding and the average birth weights of the calves are shown in Table 7. The birth weights of only three of the foundation cows are known.

TABLE 7.—*Birth weights of grade Holstein calves, outbred and of various degrees of inbreeding*

Group	Calves	Dams	Calf and dam comparisons	Average birth weight	
				Calves	Dams
	BY SIRE 1		Number	Pounds	Pounds
A	50 per cent calves (outbred)	Foundation cows	4	84	71
B	75 per cent calves (inbred)	50 per cent daughters of sire 1 (outbred)	21	85	82
C	87.5 per cent calves (inbred)	75 per cent daughters of sire 1 (inbred)	3	86	68
	BY SIRE 2 [1]				
D	50 per cent calves (outbred)	Cows unrelated to sire 2	10	87	69
D 1	75 per cent calves (inbred)	50 per cent daughters of sire 2 (outbred) (see D).	9	80	87
E	50 per cent calves (inbred)	50 per cent daughters of sire 1 (outbred).	15	93	82
E 1	75 per cent calves (inbred)	Daughters of sire 2 from outbred daughters of sire 1 (see E).	8	86	103
F	50 per cent calves (inbred)	75 per cent daughters of sire 1 (inbred)	12	79	82
F 1	75 per cent calves (inbred)	Daughters of sire 2 from inbred daughters of sire 1 (see F).	8	71	85
G	50 per cent calves (inbred)	87.5 per cent daughter of sire 1 (inbred)	4	75	93
	BY SIRE 3 [2]				
H	50 per cent calves (inbred)	3 daughters of sire 1; 14 daughters of sire 2.	17	68	87

[1] An 87.5 per cent son of sire 1. [2] A 75 per cent son of sire 2.

Because of the difficulty of showing clearly the breeding of the calves shown in Table 7, the diagrams in pedigree form have been prepared for each group of calves. (See pages 12 to 18.) The group designation on the left side of each pedigree corresponds to the similar group designation of the calves shown in Table 7.

In interpreting the data presented in Table 7 the effect of breed must be considered. The outbred calves both by sire 1 and sire 2 of Holstein breeding were much larger at birth than were their dams. This was to be expected in view of the fact that Jersey and Guernsey blood predominated in the dams. In the calves by sire 1 the birth weights show a progressive increase with increase in percentage of Holstein breeding from successive matings of sire 1 with his own daughters. This is what would ordinarily be expected if the inbreeding had no adverse influence. However, the greatest average birth weight of any of the three groups of calves by sire 1 was 86 pounds, which is somewhat less than the normal birth weight of registered Holstein calves. At the Bureau of Dairy Industry station at Huntley, Mont., 79 Holstein calves had an average birth weight of 92.5 pounds (using the same correction factors as in this investigation); at the station at Ardmore, S. Dak., 17 heifers had an average birth weight of 90 pounds, the same as 23 heifers at the University of Missouri; and at Beltsville, Md., 27 heifers averaged 97 pounds at birth. The average for the 146 calves is about 93 pounds, which may be considered as fairly close to the average for the breed.

The birth weights of the calves by sire 1 show the contrasting influences of breed, size, and inbreeding. The outbred daughters are much smaller than is normal for the Holstein breed because of the influence of the inheritance for smaller size possessed by the foundation dams in which Jersey breeding predominated. Of the four foundation cows mated to sire 1 (Table 7), for which an average birth weight of 71 pounds is given, one was a grade Holstein, one was a grade Guernsey, and two were grade Jerseys. Somewhat the same proportion of these three breeds is found in all the foundation cows or dams of the 50 per cent daughters of sire 1 given in group B. As the percentage of Holstein breeding increases the birth weight of the calves increases, showing that size is controlled by multiple factors, but even the calves carrying 87.5 per cent Holstein breeding are still considerably smaller at birth than is normal for the Holstein breed. This failure of the calves carrying 87.5 per cent Holstein breeding to reach the normal size for the breed might be ascribed to three things: (1) Some of the factors for smaller size that were received from the foundation dams may still be present; (2) the influence of inbreeding (these calves are the result of three crosses to sire 1); (3) sire 1 may have possessed an inheritance for size at birth that was below the average for the breed.

The calves by sire 2 (Table 7), both those out of cows unrelated to him and those out of 50 per cent daughters of sire 1, were larger at birth than their dams were at birth, but this relationship did not hold true as the inbreeding became more intense. The 10 foundation dams of the outbred calves of sire 2 comprised 3 grade Holsteins, 3 grade Guernseys, and 4 grade Jerseys. When the inbred daughters of sire 1, designated in Table 7 as 75 and 87.5 per cent daughters, were mated with sire 2, the calves had an average birth weight lower that that of their dams. Three dams produced the eight calves in the E1 group. The dam of four of the calves had a birth weight of 107 pounds, the dam of three of the calves had a birth weight of 98 pounds, and the third dam had a birth weight of 105 pounds. The 75 per cent calves by sire 2 and out of dams that were not related to sire 1 also had a lower birth weight than their dams.

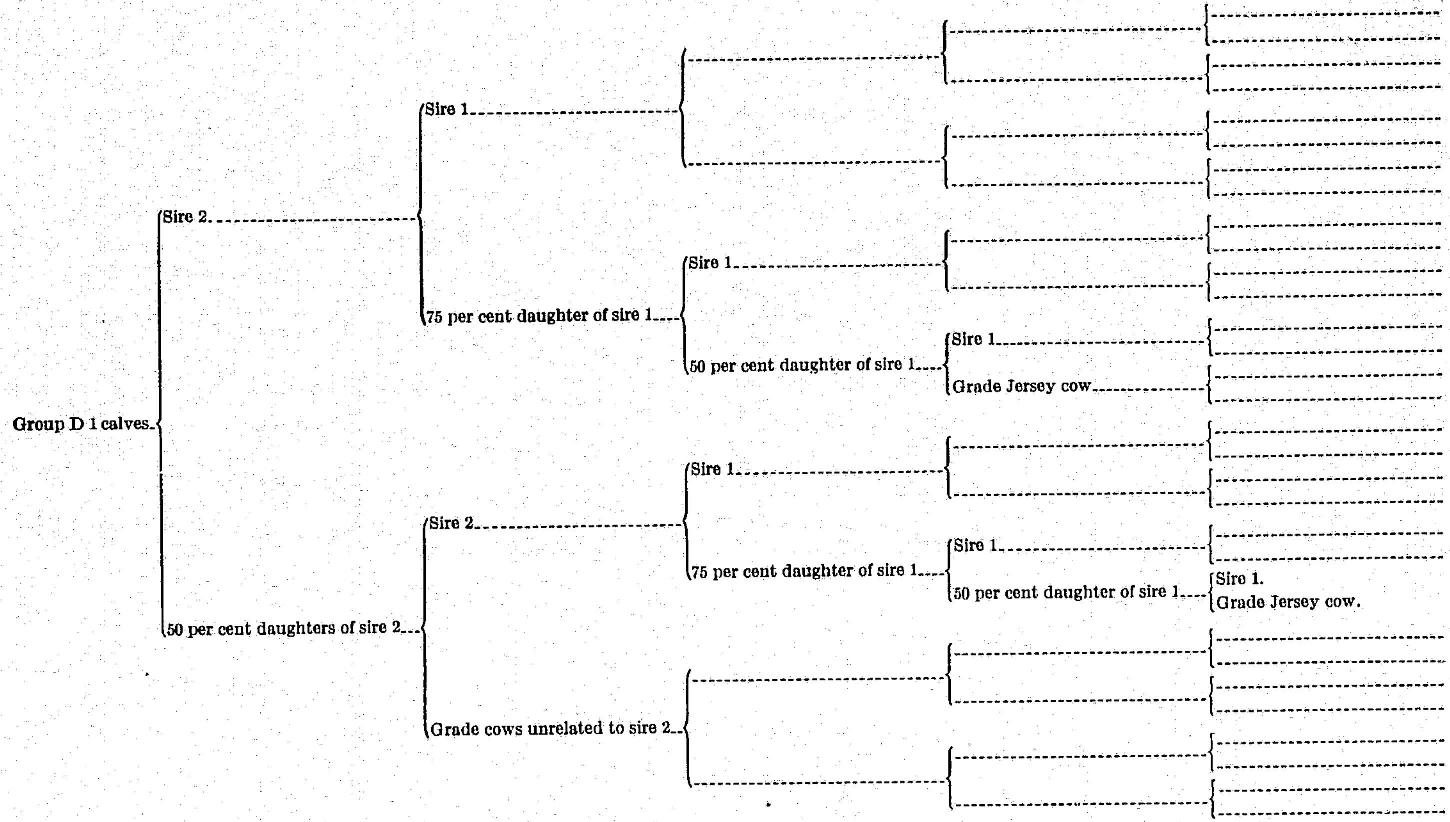
- Group A calves
  - Sire 1.
  - Grade foundation cows.

- Group B calves
  - Sire 1
  - 50 per cent daughters of sire 1
    - Sire 1.
    - Grade foundation cows.

- Group C calves
  - Sire 1
  - 75 per cent daughters of sire 1
    - Sire 1
    - 50 per cent daughters of sire 1
      - Sire 1.
      - Grade foundation cows.

- Group D calves
  - Sire 2
    - Sire 1
    - 75 per cent daughter of sire 1
      - Sire 1
      - 50 per cent daughter of sire 1
        - Sire 1.
        - Grade Jersey cow.
  - Grade cows unrelated to sire 2

- Group E calves
  - Sire 2
    - Sire 1
    - 75 per cent daughter of sire 1
      - Sire 1
      - 50 per cent daughter of sire 1
        - Sire 1.
        - Grade Jersey cow.
  - 50 per cent daughters of sire 1
    - Sire 1
    - Grade foundation cows


Group D 1 calves
Sire 2
Sire 1
75 per cent daughter of sire 1
Sire 1
50 per cent daughter of sire 1
Sire 1
Grade Jersey cow
50 per cent daughters of sire 2
Sire 2
Sire 1
75 per cent daughter of sire 1
Sire 1
50 per cent daughter of sire 1
Sire 1.
Grade Jersey cow.
Grade cows unrelated to sire 2

Group E 1 calves.
- Sire 2
  - Sire 1
  - 75 per cent daughter of sire 1
    - Sire 1
    - 50 per cent daughter of sire 1
      - Sire 1
      - Grade Jersey cow
- 50 per cent daughters of sire 2
  - Sire 2
    - Sire 1
    - 75 per cent daughter of sire 1
      - Sire 1
      - 50 per cent daughter of sire 1
        - Sire 1.
        - Grade Jersey cow.
  - 50 per cent daughters of sire 1
    - Sire 1
    - Grade foundation cows

- Group G calves
  - Sire 2
    - Sire 1
    - 75 per cent daughter of sire 1
      - Sire 1
      - 50 per cent daughter of sire 1
        - Sire 1.
        - Grade Jersey cow.
  - 87.5 per cent daughter of sire 1
    - Sire 1
    - 75 per cent daughter of sire 1
      - Sire 1
      - 50 per cent daughter of sire 1
        - Sire 1.
        - Grade foundation cow.

- Group F calves
  - Sire 2
    - Sire 1
    - 75 per cent daughter of sire 1
      - Sire 1
      - 50 per cent daughter of sire 1
        - Sire 1.
        - Grade Jersey cow.
  - 75 per cent daughters of sire 1
    - Sire 1
    - 50 per cent daughters of sire 1
      - Sire 1
      - Grade foundation cows

Group F 1 calves.
- Sire 2.
  - Sire 1.
  - 75 per cent daughter of sire 1.
    - Sire 1.
    - 50 per cent daughter of sire 1.
      - Sire 1.
      - Grade Jersey cow.
- 50 per cent daughters of sire 2.
  - Sire 2.
    - Sire 1.
    - 75 per cent daughter of sire 1.
      - Sire 1.
      - 50 per cent daughter of sire 1.
        - Sire 1.
        - Grade Jersey cow.
  - 75 per cent daughters of sire 1.
    - Sire 1.
    - 50 per cent daughters of sire 1.
      - Sire 1.
      - Grade foundation cows.

Group H calves:

- Sire 3
  - Sire 2
    - Sire 1
    - 75 per cent daughter of sire 1
      - Sire 1
      - 50 per cent daughter of sire 1
        - Sire 1.
        - Grade Jersey cow.
  - 50 per cent daughter of sire 2
    - Sire 2
      - Sire 1
      - 75 per cent daughter of sire 1
        - Sire 1.
        - 50 per cent daughter of sire 1.
    - 75 per cent daughter of sire 1
      - Sire 1
      - 50 per cent daughter of sire 1
        - Sire 1.
        - Grade Holstein cow.
- 50 and 75 per cent daughters of sire 2.
  - Sire 2
    - Sire 1
    - 75 per cent daughter of sire 1
      - Sire 1
      - 50 per cent daughter of sire 1
        - Sire 1.
        - Grade Jersey cow.

The calves by sire 2, shown in groups F1, E1, G, F, and E in Table 7, are the most intensely inbred, the intensity of inbreeding being approximately in the order given here. It is impossible to present accurately the degree of inbreeding in any group because the grade foundation dams may appear in the sire's and dam's ancestry a different number of times for different individuals within a group. In Table 8, which shows the variation in weight of calves by sire 2, according to the intensity of inbreeding, is shown the coefficient of inbreeding as calculated by the Wright method based on the appearance of the sires in the pedigree alone; the number of times that sire 1 appears in the pedigree (sire 1 being the individual whose inheritance is most concentrated), and the percentage of grade breeding remaining on the sire's and dam's side of the average pedigree representing these different groups.

TABLE 8.—*Variation in weight of calves by sire 2 according to intensity of inbreeding*

Group	Wright's coefficient of inbreeding	Times sire 1 appears	Grade breeding remaining on—		Average weight of calves	Average weight more (+) or less (−) than that of dams
			Sire's side of pedigree	Dam's side of pedigree		
	Per cent	*Number*	*Per cent*	*Per cent*	*Pounds*	*Pounds*
F1	50.8	8	12.5	18.75	71	−14
E1	45.3	7	12.5	31.25	86	−17
G	40.3	6	12.5	12.5	75	−18
F	32.8	5	12.5	25	79	−3
E	21.0	4	12.5	50	93	+11

Except among the calves in group E1, there is a tendency for the calves to be smaller at birth as the degree of inbreeding becomes more intense. As has been explained the eight calves in E1 group were all out of three dams who were themselves larger at birth than the average for the breed. The decline in weight in this group, however, is second only to that of the calves in group G. The four calves in group G are all out of the same dam and her average birth weight, 93 pounds, was considerably higher than that of the other 87.5 per cent daughters of sire 1.

The decrease in birth weight of the calves by sire 3, shown in Table 7, is marked. Of 17 calves by this sire not one had a birth weight greater than that of its dam. Whether a part of this decrease might be due to an inherent character of sire 3 to beget small calves can not be determined definitely from the data available. There is evidence, however, that he can sire calves of good size; in the one case in which he was mated with an unrelated cow, the calf weighed 98 pounds. The same cow when mated with sire 2 had a calf weighing 97 pounds. It would appear that the very low average birth weight of his calves (68 pounds), as compared to that of their dams (87 pounds) as shown in Table 7, must be attributed to inbreeding.

Additional data on two cows, each mated with a different bull, tend to strengthen the conclusion that intense inbreeding may result in lower birth weight of calves. Cow A–26, shown in Plate 4, was mated with an unrelated registered Holstein bull and had a calf weighing 90 pounds; the same cow when mated with her own sire

(sire 2 of this experiment) had a calf weighing 72 pounds; and when she was mated with her son, by the same sire, the resulting calf weighed 63 pounds. Cow 94, shown in Plate 4, a 75 per cent daughter of sire 1, was mated twice with sire 1 and produced two calves with an average weight of 82 pounds; the same cow when mated with her son by the same sire produced three calves with an average weight of 76 pounds.

MORTALITY OF CALVES

Of the 54 normal female calves born in the Holstein group of this experiment in the 10 years ended January 1, 1931, 41 were inbred and 13 outbred. All the outbred calves lived for a year or more but 5 of the inbred calves died. One died of navel infection, 1 of pneumonia, and 3 of pneumonia with complications. Of the 89 outbred registered Holsteins born in the Beltsville experimental herd during the same period, only 2 died before reaching the age of 1 year. One died of pneumonia, the other of digestive troubles.

As all the grade calves that died were inbred and as the percentage of mortalities was somewhat greater with the inbred grades than with the outbred registered Holsteins, the indications are that the inbred calves lacked the vitality of the outbred calves. However, some consideration should be given to the fact that three of the five deaths among the grades occurred during an epidemic of pneumonia; that the number of inbred calves was relatively large at the time; and that one death was the result of navel infection.

RATE OF GROWTH OF CALVES

Table 9 shows the weights, at various ages, of daughters of sire 1 and sire 2, and certain dam-and-daughter comparisons are included for sire 2. This table also gives the weights of registered Holstein calves at Beltsville and other stations.

TABLE 9.—*Weights of outbred and inbred daughters of sires 1 and 2 and of calves from other herds at various ages up to 2 years*

DAUGHTERS OF SIRE 1

Group	Breeding or herd	Animals	Average weight at age of— 3 months	6 months	12 months	24 months
		Number	*Pounds*	*Pounds*	*Pounds*	*Pounds*
A	50 per cent daughters (outbred)	4	169	321	570	921
B	75 per cent daughters (inbred)	[1] 6	157	307	541	938
C	87.5 per cent daughter (inbred)	1	173	327	616	......
	DAUGHTERS OF SIRE 2[2] AND THEIR DAMS					
D	50 per cent daughters (outbred)	9	195	355	630	[3] 1,034
D1	75 per cent daughters (inbred)	3	201	371	625	[4] 1,011
	Dams, Group D cows (outbred)	3	190	363	628	[4] 1,062
E	50 per cent daughters (inbred)	4	193	356	610	1,042
E1	75 per cent daughters (inbred)	2	189	333	615	993
	Dams, Group E cows (inbred)	2	190	351	580	1,080
F	50 per cent daughters (inbred)	5	160	320	565	974
	Dams, 75 per cent daughters of sire 1 (inbred)	4	155	312	562	943
F1	75 per cent daughters (inbred)	2	171	313	575	997
	Dams, group F cows (inbred)	2	168	331	556	982

[1] 2 of 6 calves were fed a milk substitute.
[2] An 87.5 per cent son of sire 1.
[3] 8 animals for 24 months age.
[4] 2 animals for 24 months age.

TABLE 9.—*Weights of outbred and inbred daughters of sires 1 and 2 and of calves from other herds at various ages up to 2 years*—Continued

REGISTERED OUTBRED HOLSTEIN-FRIESIAN CALVES FROM OTHER HERDS [5]

Group	Breeding or herd	Animals	Average weight at age of—			
			3 months	6 months	12 months	24 months
		Number	*Pounds*	*Pounds*	*Pounds*	*Pounds*
	Beltsville, Md.	27	197	360	627	1,056
	Huntley, Mont.	16	230	425	721	1,071
	Ardmore, S. Dak.	17	238	403	590	973
	University of Missouri	23	200	349	563	341

[5] From U. S. Dept. Agr. Tech. Bul. 116. (See footnote 1, p. 2.)

With the daughters of sire 1 there has been no apparent slackening of the rate of growth as a result of inbreeding. This statement also applies to the daughters of sire 2, if limited to dam-and-daughter comparisons. However, if the nine outbred daughters of sire 2 out of dams unrelated to him are taken as the basis of comparison, the more closely inbred calves were in general smaller than the outbred calves at the different ages given in Table 9. These inbred grade heifers are in fact not so much smaller than the registered heifers at the Beltsville station at 2 years of age as they were at birth. The calves in F1 group were 26.8 per cent smaller at birth, while the two animals that have reached 2 years of age are only 5.6 per cent smaller at that age than the average of the registered heifers. The calves in the E1 group were 11.3 per cent smaller at birth and the two animals that have reached 2 years of age were only 6 per cent smaller than the average 2-year-old registered heifer. The calves in the F group were 18.6 per cent smaller at birth and only 7.8 per cent smaller at 2 years of age. These data may be somewhat misleading because of the small number of the grade heifers on which weights at 2 years of age are available. The rate of feeding of the registered calves and the inbred grade calves at Beltsville was the same.

Other evidence that inbreeding is affecting the rate of growth is shown in Table 10. During a short period during which sire 2 was not in active service some of the inbred cows were mated with unrelated, registered Holstein bulls. Cows A–26 and A–36 gave birth to heifer calves A–55 and A–54, respectively. These two outbred heifers exceeded their inbred dams in birth weight and rate of growth. At 2 years of age they averaged 161 pounds more than their dams at the same age. All the individual weights of inbred heifers used in preparing the average weights in Table 9 were smaller than those of these two outbred heifers.

TABLE 10.—*Weights of outbred heifers and their inbred dams at various ages up to 2 years*

Breeding and cow No.	At birth	3 months	6 months	12 months	24 months
Outbred heifers:	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
A-55	90	228	439	760	1,214
A-54	80	208	387	682	1,114
Average	85	218	413	721	1,164
Inbred dams:					
A-26	68	164	343	615	1,052
A-36	78	183	322	608	954
Average	73	173	332	611	1,003

MATURE WEIGHT OF COWS

The effect of intensive inbreeding on the size of the cows at maturity is indicated in Table 11, which presents data on the foundation cows and progeny of the first and second Holstein sires used, arranged as dam-and-daughter comparisons.

TABLE 11.—*Effects of intensive inbreeding on mature weights of cows in the Holstein group*

Group	Daughters	Dams	Daughter-dam comparisons	Average mature weight	
				Daughters	Dams
	Daughters of sire 1:			*Pounds*	*Pounds*
A	50 per cent daughters (outbred)	Foundation cows (outbred)	[1] 11	1,176	944
B	75 per cent daughters (inbred)	50 per cent daughters (outbred)	7	1,144	1,163
C	87.5 per cent daughter (inbred)	75 per cent daughter of sire 1 (inbred).	1	1,220	1,024
	Daughters of sire 2: [2]				
D	50 per cent daughters (outbred)	Cows unrelated to sire 2 (outbred).	[3] 9	1,275	1,049
D 1	75 per cent daughter (inbred)	D cow (outbred)	1	1,226	1,264
E	50 per cent daughters (inbred)	50 per cent daughters of sire 1 (outbred).	4	1,313	1,203
E 1	75 per cent daughter (inbred)	E cow (inbred)	1	1,321	1,274
F	50 per cent daughters (inbred)	75 per cent daughters of sire 1 (inbred).	6	1,191	1,163
F 1	75 per cent daughter (inbred)	F cow (inbred)	1	1,135	1,278

[1] Of these 11 foundation cows, 7 were grade Jerseys, 1 was a grade Holstein, 1 was a grade Guernsey, and 2 were animals of mixed breeding.
[2] An 87.5 per cent son of sire 1.
[3] Of these 9 foundation cows, 4 were grade Guernseys, 3 were grade Holsteins, and 2 were grade Jerseys.

A large increase in weight resulted from the mating both of sire 1 and sire 2 with unrelated cows which were naturally much smaller than cows of the Holstein breed. It might be expected, also, that the next generation of daughters would show a moderate increase in size, provided some factor other than breed did not prevent such an increase. The fact that the body weights do not consistently show a further increase after the first generation indicates that inbreeding may have had a tendency to reduce the size. The dam-and-daughter comparisons show that many of the daughters were heavier than their dams, still, on the whole, there was no material change in body weights after the first generation of mating with unrelated cows. The average weight of 44 registered Holsteins raised at the Beltsville station was 1,352 pounds. It will be noted that all of the groups in Table 11 averaged considerably less than 1,352 pounds.

THE VIGOR OF COWS

With the exception of one or two cows, the inbred cows of the Holstein group have not been lacking in vigor. Cow A–28, shown in Plate 4, was the product of mating sire 2 back to his dam. She was not only subnormal in size but was also a delicate feeder. Cow 97, the 75 per cent daughter of sire 1, shown in Plate 6 (in pocket) was somewhat undersized and subject to fits. That inbreeding had anything to do with her condition is questionable. When bred back to her own sire she produced a daughter that attained normal size and was otherwise normal. An outbred registered Holstein cow at Beltsville, that is unrelated to cow 97, has presented a parallel condition. It is possible that a double dose of a recessive factor may have been the cause of this condition in both cow 97 and the unrelated registered cow. In that case, however, more of the inbred daughters of sire 2 should have shown this peculiarity.

PRODUCTION OF MILK AND BUTTERFAT

As none of the bulls used in this investigation were proved bulls at the time they were put into service, it was not known whether they had the ability to transmit high production of milk and butterfat to their daughters. A decrease in production of the daughters as compared with their dams, therefore, would not necessarily prove that inbreeding was detrimental unless such decrease was the result of diminished size or vigor. On the other hand, an increase in production would show two things: (1) That the bulls transmitted high production; and (2) that inbreeding did not result in marked diminution of vigor, otherwise the increase in production could not have been manifested.

RECORDS OF THE DAUGHTERS OF SIRE 1

The milk and butterfat records of outbred and inbred daughters of sire 1 and of the foundation cows to which he was mated are given in Table 12. The table is so arranged that the production records of successive generations of females can be followed across the page from left to right. For example, cow 20, one of the foundation cows, is the dam of cow 63, an outbred or 50 per cent daughter of sire 1; cow 63 is the dam of cow 97, an inbred 75 per cent daughter of sire 1, and she in turn is the dam of the inbred cow A–11, an 87.5 per cent daughter of sire 1. Photographs of these four cows are shown in Plate 6.

The use in this experiment of a number of foundation cows in which Jersey and Guernsey blood predominated makes it necessary to consider the effect of inherent breed differences as well as the influence of inbreeding on the milk and butterfat production of successive generations. Of the seven 75 per cent inbred daughters of sire 1 (Table 12), five had granddams in which Jersey breeding predominated and the other two were from a common granddam in which Holstein breeding predominated. There was an average increase in milk yield and an average decrease in percentage of butterfat for both the outbred and the inbred daughters. This would be the result expected from crossing a Holstein sire on grade Jersey cows.

TABLE 12.—*Production records* [1] *of outbred and inbred daughters of sire 1 and their dams*

Foundation cows					Outbred daughters (50 per cent)[2]				Inbred daughters (75 per cent)[2]				Inbred daughters (87.5 per cent)[2]			
Breeding	Cow No.	Milk	Butterfat		Cow No.	Milk	Butterfat		Cow No.	Milk	Butterfat		Cow No.	Milk	Butterfat	
		Pounds	*Per cent*	*Pounds*		*Pounds*	*Per cent*	*Pounds*		*Pounds*	*Per cent*	*Pounds*		*Pounds*	*Per cent*	*Pounds*
Grade Jersey	20	6,350	4.23	269	63	11,213	3.24	363	97	17,033	3.09	526	A-11	17,423	3.28	571
Do	20	6,350	4.23	269	63	11,213	3.24	363	94	19,930	3.17	632				
Do	18	8,919	5.36	478	46	10,196	4.46	455	79	9,601	4.44	430				
Do	21	15,647	4.56	714	91	19,926	3.91	779	A-9	15,241	3.52	536				
Do	23	9,308	4.17	388	82	18,131	3.68	667	A-2	19,682	3.49	687				
Grade Holstein	29	17,416	4.18	728	51	19,073	3.78	721	A-3	17,106	3.61	618				
Do	29	17,416	4.18	728	51	19,072	3.78	721	87	17,325	3.66	634				
Average		11,629.4	[3] 4.39	510.5		15,546.1	[3] 3.73	581.3		16,572.5	[3] 3.50	580.4		[4] 17,423	[4] 3.28	[1] 571

[1] All records have been calculated to a mature basis.

[2] All five of the 50 per cent daughters, three of the seven 75 per cent daughters, and the one 87.5 per cent daughter exceeded their dams in milk production. Three 50 per cent daughters, three 75 per cent daughters, and the one 87.5 per cent daughter exceeded their dams in butterfat production. All 50 per cent and 75 per cent daughters were exceeded by their dams in percentage of butterfat. The 87.5 per cent daughter exceeded her dam in percentage of butterfat.

[3] Percentage based on averages.

[4] Average based on the record of 1 cow.

The outbred daughters were still higher in percentage of butterfat than was inherent for their sire, as is shown by the fact that when they were mated back to their own sire their inbred daughters were all lower in percentage of butterfat. While there was an average increase in milk yield in the three groups, that of the 75 per cent daughters was principally due to the very large increase of the two cows, 97 and 94. These were full sisters descended from cow 20, the lowest producer in the herd. Of the seven 75 per cent inbred daughters of sire 1, only three were better than their dams in milk yield and in production of butterfat. The one 87.5 per cent inbred daughter of sire 1 was better than her dam in milk yield, percentage of butterfat, and total production of butterfat. The 75 per cent inbred daughters, with the exception of cow 79, are quite uniform in milk yield. Here, as in the Guernsey inbreeding data, is a clear indication that there are a number of hereditary factors influencing the total yield of milk and the percentage of fat. This is shown by the increase in milk yield of the daughters and granddaughters of grade Jersey foundation cows with each succeeding generation of Holstein inheritance and also a corresponding decrease in the percentage of butterfat. The highest butterfat test among the foundation cows, that of cow 18, was 5.36 per cent. In this case the actual test was evidently an accurate indication of the inheritance for a high percentage of butterfat that she transmitted to her daughter, cow 46. Although the butterfat test of cow 46 is much lower than that of her dam, because of the modifying influence of the hereditary factors that she received from her Holstein sire, her test is still much higher than that of her Holstein half sisters who are out of lower-testing dams. She in turn has passed along some of the factors for a high test that she received from her dam, cow 18, to her own daughter, cow 79. This latter cow, while somewhat lower in test than her dam, is considerably higher in percentage of butterfat than her inbred sisters. The relatively low milk yield of her grade Jersey granddam has also persisted through the two crosses of Holstein inheritance.

The production records of additional outbred daughters of sire 1, which do not have inbred daughters, are compared with those of their dams in Table 13. Their photographs are shown in Plate 5.

TABLE 13.—*Production records of foundation cows and of their 50 per cent daughters [1] by sire 1*

Foundation cows					Outbred daughters (50 per cent)			
Breeding	Cow No.	Milk	Butterfat		Cow No.	Milk	Butterfat	
		Pounds	*Per cent*	*Pounds*		*Pounds*	*Per cent*	*Pounds*
Grade Jersey	7	10,367	4.09	424	50	14,660	3.83	561
Do	7	10,367	4.09	424	64	15,313	3.84	588
Do	23	9,308	4.17	388	45	11,529	4.29	495
Do	25	9,821	4.40	432	67	15,379	3.83	589
Grade Guernsey	33	13,284	4.70	624	A-14	11,733	3.86	453
Grade Jersey	34	7,036	4.76	335	88	16,728	4.30	719
Average		10,031	[2] 4.37	438		14,224	[2] 3.99	568
Average [3] of 11 paired records [4]		10,711	4.42	473		14,898	3.90	581

[1] All records have been calculated to a mature basis.
[2] Percentage based on averages.
[3] Out of 11 paired records, 10 outbred daughters exceeded their dams in milk production, 8 exceeded their dams in butterfat production, and 1 exceeded her dam in percentage of butterfat.
[4] Includes records of the 5 outbred daughters in Table 12.

The coefficients of variability in yield of milk, percentage of butterfat, and total production of butterfat for the three generations of cows in Table 12 are shown in Table 14. The relative degree of variation both in milk yield and butterfat yield is greatest in the foundation cows and least in the inbred daughters. In percentage of butterfat, the relative degree of variation is greatest in the inbred daughters and only a little less in the outbred daughters than in the foundation dams.

TABLE 14.—*Coefficients of variability for the average milk and butterfat records of daughters of sire 1 and their dams*

Group	Coefficient and probable error for—		
	Yield of milk	Percentage of butterfat	Yield of butterfat
Foundation cows	30.40±5.02	8.45±1.21	30.40±5.02
50 per cent outbred daughters of sire 1	21.61±3.11	8.25±1.19	21.58±3.10
75 and 87.5 per cent inbred daughters of sire 1	17.96±3.03	11.13±1.88	13.09±2.21

Sire 1 had five registered daughters with production records made in the Beltsville, Md., and Huntley, Mont., experiment station herds. These records are given in Table 15 for comparison with the records of his inbred grade daughters, especially for percentage of butterfat.

TABLE 15.—*Production records of five registered daughters of sire 1*

Cow No.	Age		Milk	Butterfat	
	Yrs.	*Mos.*	*Pounds*	*Per cent*	*Pounds*
216	4	1	15,946	3.24	518
222	4	7	13,317	3.42	456
212	4	2	8,855	3.70	[1] 328
214 [2]	2	2	17,843	3.05	546
	5	7	16,308	3.36	548
220	2	8	10,593	3.36	559
Average			14,204	3.39	482

[1] Herd test.
[2] Only the mature record of cow 214 included in the average.

The average of 3.39 per cent of butterfat for these five registered daughters of sire 1, as compared to 3.50 per cent for his inbred grade daughters, apparently indicates that the latter show some influence of their higher-testing granddams.

From the summarized data on sire 1 and his offspring it seems that this sire carried no undesirable factors which would cause his daughters, if they had received a double dose of such factors, to be deficient in vigor or malformed. It appears, however, that he did possess an inheritance for a considerable range in milk yield and in percentage of butterfat.

RECORDS OF THE DAUGHTERS OF SIRE 2

The production records of the daughters of sire 2 are shown in Table 16.

TABLE 16.—*Production records of inbred and outbred daughters of sire 2 and of their dams and granddams*

[All records calculated to maturity]

Foundation cows					50 per cent daughters of sire 1				75 per cent daughters of sire 1				50 per cent daughters of sire 2				75 per cent daughters of sire 2			
Breeding	Cow No.	Milk	Butterfat		Cow No.	Milk	Butterfat		Cow No.	Milk	Butterfat		Cow No.	Milk	Butterfat		Cow No.	Milk	Butterfat	
		Pounds	*Per cent*	*Pounds*		*Pounds*	*Per cent*	*Pounds*		*Pounds*	*Per cent*	*Pounds*		*Pounds*	*Per cent*	*Pounds*		*Pounds*	*Per cent*	*Pounds*
Group 1: [1]																				
Grade Guernsey	84	11, 219	4. 79	537									[2] A-30	16, 818	3. 61	607				
Grade Guernsey (75% inbred)	93	13, 086	4. 81	658									[2] A-27	18, 853	3. 99	752	A-43	20, 928	3. 58	750
Grade Holstein	A-6	14, 232	3. 96	564									[2] A-15	15, 416	3. 40	524	A-50	12, 881	3. 61	466
																	A-51	17, 378	3. 36	585
Do	A-7	16, 461	4. 35	716									[2] A-32	19, 229	3. 28	631				
Do	A-13	16, 934	3. 93	666									[2] A-40	21, 245	3. 88	824				
Average	------	14, 506	4. 33	628									------	18, 312	3. 65	668				
Group 2: [3]																				
Grade Jersey	7	10, 367	4. 09	424	64	15, 313	3. 84	588					[4] A-20	14, 551	3. 51	511	A-36	20, 800	3. 50	728
Do	7	10, 367	4. 09	424	64	15, 313	3. 84	588					[4] A-37	19, 903	3. 58	713				
Do	7	10, 367	4. 09	424	64	15, 313	3. 84	588					[4] A-42	19, 466	3. 45	672				
Do	21	15, 647	4. 56	714	91	19, 926	3. 91	779					[4] A-19	22, 089	3. 34	738	A-53	20, 072	3. 57	717
Average	------	11, 687	4. 25	496	------	16, 466	3. 86	636					------	19, 000	3. 47	658				
Group 3: [5]																				
Grade Jersey	20	6, 350	4. 23	269	63	11, 213	3. 24	363	94	19, 930	3. 17	632	A-28	15, 405	3. 57	550				
Do	23	9, 308	4. 17	388	82	18, 131	3. 68	667	A-2	19, 682	3. 49	687	A-21	17, 615	3. 18	560	A-45	18, 307	2. 80	512
Do	23	9, 308	4. 17	388	82	18, 131	3. 68	667	A-2	19, 682	3. 49	687	A-30	15, 606	3. 26	509				
Grade Holstein	29	17, 416	4. 18	728	51	19, 072	3. 78	721	A-3	17, 106	3. 61	618	A-26	25, 434	3. 36	855				
Grade Jersey	21	15, 647	4. 56	714	91	19, 926	3. 91	779	A-9	15, 241	3. 52	536	A-25	21, 394	3. 38	723	A-52	16, 113	3. 52	568
Do	21	15, 647	4. 56	714	91	19, 926	3. 91	779	A-9	15, 241	3. 52	536	A-38	13, 906	3. 23	449				
Average	------	12, 279	4. 34	533	4	17, 733	3. 73	662	4	17, 814	3. 46	616	6	18, 227	3. 33	608				

[1] All five of the 50 per cent daughters and two of the three 75 per cent daughters exceeded their dams in milk production. Three of the five 50 per cent daughters and one of the three 75 per cent daughters exceeded their dams in butterfat production. All five of the 50 per cent daughters and two of the three 75 per cent daughters were exceeded by their dams in percentage of butterfat.

[2] Out of foundation cows.

[3] Both of the 50 per cent daughters of sire 1, three of the four 50 per cent daughters of sire 2, and one of the two 75 per cent daughters of sire 2 exceeded their dams in milk production. Both of the 50 per cent daughters of sire 1, two of the four 50 per cent daughters of sire 2, and one of the two 75 per cent daughters of sire 2 exceeded their dams in butterfat production. All of the 50 per cent daughters of sires 1 and 2, and one of the two 75 per cent daughters of sire 2 were exceeded by their dams in percentage of butterfat.

[4] Out of 50 per cent daughters of sire 1.

[5] All four of the 50 per cent daughters of sire 1, two of the four 75 per cent daughters of sire 1, two of the six 50 per cent daughters of sire 2, and one of the two 75 per cent daughters of sire 2 exceeded their dams in milk production. Three of the four 50 per cent daughters of sire 1 and two of the six 50 per cent daughters of sire 2 exceeded their dams in butterfat production. Two of the four 75 per cent daughters of sire 1 and both of the 75 per cent daughters of sire 2 were exceeded by their dams in butterfat production. All of the four 50 per cent and all of the four 75 per cent daughters of sire 1 and five of the six 50 per cent and one of the two 75 per cent daughters of sire 2 were exceeded by their dams in percentage of butterfat.

In Table 16 the cows have been arranged in three groups. Group 1 shows the daughters by sire 2 out of foundation cows. Group 2 shows the daughters of sire 2 out of the 50 per cent outbred daughters of his own sire, sire 1. Group 3 shows the daughters of sire 2 out of his own sire's 75 per cent inbred daughters. Of the 5 foundation cows in group 1 mated with sire 2, 3 were grade Holsteins that probably carried the inheritance of some higher-testing breed; and the other 2 were grade Guernseys. One of these, cow 93, was a 75 per cent inbred daughter of the Guernsey sire used in the work on inbreeding grade Guernseys. The 4 foundation cows in group 2, granddams of the 4 daughters of sire 2 that were out of outbred daughters of sire 1, were all grade Jerseys. The 6 daughters of sire 2 that were out of inbred daughters of sire 1 were descended from the foundation cows in group 3, all of Jersey breeding except cow 29, a grade Holstein.

The five outbred daughters of sire 2 out of the grade Holstein and Guernsey foundation cows (group 1) all exceeded their dams in milk yield, although the latter had uniformly high records; but, like the outbred daughters of sire 1 from grade Jersey foundation cows, all were lower than their dams in percentage of butterfat. Three exceeded their dams in pounds of butterfat. Cow A–43, one of the three 75 per cent daughters of sire 2 in this group, has completed her record as a 2-year-old, with 20,928 pounds of milk and 750 pounds of butterfat, computed to a mature basis. As compared with her dam, she produced considerably more milk, a lower percentage of butterfat, and about the same total amount of butterfat. The granddam of this inbred heifer was a 75 per cent inbred daughter of the Guernsey sire discussed in this publication. These three generations of cattle show the typical decline in percentage of butterfat and the increase in milk-yield which takes place as the percentage of Holstein inheritance increases and the percentage of Guernsey inheritance decreases.

The two 75 per cent inbred daughters by sire 2 out of cow A–15 (group 1) which have completed their production records as 2-year-olds, are twin sisters. Apparently they are unlike twins in so far as color markings, level of milk yield, and percentage of butterfat are concerned. One produced 4,497 pounds more milk and 119 pounds more butterfat than the other, although the latter was the higher in percentage of butterfat by 0.25 per cent. One produced more milk and butterfat than the dam, and the other produced less than the dam. Here is another illustration of the fact that inbreeding will not result in a like level of production in the offspring if the sire to which they are inbred is himself heterozygous for level of production. Two of the three inbred daughters of sire 2 in this group are better than their dams in milk yield, two are below their dams in percentage of butterfat, and one is better, one poorer, and one approximately the same as the dam in yield of butterfat.

Of the 4 daughters of sire 2 (group 2) that are out of outbred daughters of sire 1, 3 are full sisters, A–20, A–37, and A–42. These 3 cows were all lower than their dam in percentage of butterfat, but 2 of them exceeded their dam in milk and 2 in butterfat yield. Cow A–20, the poorest producer of the 3, is the dam of cow A–36, a 75 per cent inbred daughter of sire 2. The latter showed a marked increase over her dam in both milk and butterfat yield. The other 75 per cent inbred daughter of sire 2 (A–53) in this group has three generations of high-producing dams in her immediate ancestry. In each of these previous generations the Holstein daughters had shown an increase in milk yield and a decline in butterfat percentage from their Jersey foundation dam and granddam. In this 75 per cent inbred daughter of sire 2, representing the third successive cross of these Holstein sires, there is a slight increase in percentage of fat. Both of the 75 per cent daughters of sire 2 in this group are very high producers.

Group 3 in Table 16 is the most interesting since it shows the closest inbreeding. The six 50 per cent daughters of sire 2 in this group are out of four 75 per cent inbred daughters of sire 1. If average production of butterfat alone were considered in this group of four direct generations of cows, one might conclude that the inbreeding in the last two generations was resulting in a gradual decline in production. The average yield of butterfat for the foundation cows in this group was 533 pounds. The highest average, 663 pounds, was from the outbred daughters of sire 1, followed by an average of 616 pounds for the inbred daughters of sire 1, and 608 pounds for the 50 per cent (inbred) daughters of sire 2. These averages, however, include duplicate records for 2 foundation cows, 2 outbred daughters, and 2 inbred daughters of sire 1, because there were 2 pairs of full sisters in the fourth generation—the daughters of sire 2. If these duplicate records are excluded, the averages for production of milk, percentage of butterfat, and pounds of butterfat are: For the foundation cows, 12,180 pounds of milk, 4.31 per cent butterfat, and 525 pounds of butterfat; for the outbred daughters of sire 1, 17,086 pounds of milk, 3.70 per cent butterfat, and 632 pounds of butterfat, and for the inbred daughters of sire 1, 17,989 pounds of milk, 3.43 per cent butterfat, and 618 pounds of butterfat. The figures for the 50 per cent daughters of sire 2 are as given in the table, 18,227 pounds of milk, 3.33 per cent butterfat, and 608 pounds of butterfat. Excluding these duplicate records does not affect the relative ranking of the different generations in butterfat yields, though it does considerably reduce the difference between the outbred and the inbred daughters of sire 1 in butterfat yield. There is an increase in average yield of milk for each of the three generations of Holstein inheritance notwithstanding the increase in intensity of inbreeding. The decline in average butterfat yield is caused by the decline in percentage of butterfat. The decline in percentage of butterfat is caused by the increasing influence of the low-butterfat-percentage inheritance of these two Holstein sires and by the lessening influence of the high-butterfat-percentage inheritance of the foundation cows.

The 4 outbred daughters of sire 1 (group 3) were all better than their dams in milk yield by a wide margin, and all 4 were lower in percentage of butterfat. The milk yield of the 2 daughters of the 2 lowest-producing foundation cows was almost twice that of their dams. In the next generation only 2 of the 4 inbred daughters were better in milk yield that their outbred dams; the daughters of the 2 poorer cows gave more milk, but the daughters of the 2 better cows gave less milk than their dams. On the whole, it appears that the inbred daughters of sire 1 in this group did not quite hold their own. Two of the 4 were better in milk yield and pounds of butterfat, and all 4 were poorer in percentage of butterfat.

Of the 6 daughters by sire 2 which were out of these 4 inbred daughters of sire 1 (group 3), only 2 were better than their dams in milk and butterfat yield, but these 2 exceeded their dams by a sufficient margin to raise the average for the 6 daughters over that of the dams. There are 2 pairs of full sisters among these 6 daughters.

Both of the daughters of cow A–2 were lower than their dam in milk yield, percentage of butterfat, and pounds of butterfat. One of the 2 daughters of cow A–9 was considerably better, and the other considerably poorer, in milk and butterfat yield than her dam. On the whole, the records of these 6 daughters of sire 2, with milk yields ranging from 13,906 pounds to 25,434 pounds, are sufficiently high so that it does not seem that the relatively low production of 4 of them should be attributed to any weakened vigor of constitution resulting from inbreeding. Rather, it would appear that their comparatively low production is due to a heterozygous make-up for the factors determining varying levels of milk yield possessed by sires 1 and 2, and also to an inheritance for lower percentages of butterfat. Two inbred daughters of sire 2 that have completed their test are included in group 3. In some respects they are the most closely inbred animals shown in this study. Cow A–45, the inbred daughter of cow A–21, produced 18,307 pounds of milk and 512 pounds of butterfat. Her milk yield is greater than that of her dam, but the percentage of butterfat is considerably lower, resulting in a smaller amount of butterfat. The milk of this cow is lower in percentage of butterfat than that of any other daughter of sire 2. This cow (as her picture shows in Plate 4) at the age of 2 years was somewhat smaller and more refined in type than the other inbred daughters of sire 2, although she has since shown considerable development in form. Cow A–52, the other inbred daughter of sire 2 in this group, is considerably below her dam in both milk and butterfat production, but higher in percentage of butterfat.

Of the seven 75 per cent inbred daughters of sire 2 in these three groups, 4 are better than their dams in milk yield, 3 are better in percentage of butterfat and 2 are better and 1 is practically equal to her dam in butterfat yield. The average milk yield is a little greater than that of the dams, 18,068 pounds as compared to 17,905 pounds; but the average percentage of fat and the average fat yield are about the same.

There is no indication in the records or in the physical appearance of any of these inbred daughters of sire 2, except possibly in the case of cows A–28 and A–45, that producing capacity is being affected by loss of size or constitutional vigor as a result of inbreeding.

COLOR MARKINGS

Plate 4 shows that the first-generation cross with solid-color foundation cows did not bring out the characteristic Holstein spotting, nor did it breed the black off the legs below the knees and hocks. The first-generation cross with the broken-colored cow 23, however, did bring out the characteristic Holstein color markings, although some black was left below the knees. In most cases it has taken two or more crosses of Holstein breeding to bring out the spotting and to take off the black color from below the knees and hocks. In all cases the black of the Holstein has been dominant over red and all shades of fawn.

SUMMARY

In this inbreeding experiment grade dairy cows of mixed breeding and average production were mated to a good registered bull and the female offspring were mated back to their own sire for successive generations. The experiment in inbreeding Guernsey cattle was limited to the foundation Guernsey sire and two generations of daughters. The experiment with Holsteins was carried on through several generations of inbred sons and grandsons of the first Holstein sire used, as well as daughters of these sires, and is being continued with the object of obtaining more definite and pronounced results.

With grade Guernseys it was found that: The birth weight of calves decreased as inbreeding became more intense. A few of the inbred calves were deformed at birth, the deformity apparently being due to a double dose of a recessive Mendelian factor which causes a definite type of deformity. The mature weight of the cows was reduced by inbreeding. The average milk production of both the 50 per cent and the 75 per cent daughters of the bull was about the same as that of the foundation cows, but on account of a progressive increase in the percentage of butterfat the 50 per cent daughters produced slightly more butterfat than their dams and the 75 per cent daughters produced somewhat more than did the 50 per cent daughters. The variations between the individuals in the production of milk and pounds of butterfat was less with the 50 per cent daughters than with the foundation cows and still less with the 75 per cent daughters.

With grade Holsteins it was found that: Inbreeding caused no decline in fertility, as judged by the services required for conception. The number of abortions and the normality of calves at birth did not appear to have been affected by inbreeding. The birth weights of the more intensely inbred calves were reduced to a marked extent. The mortality of calves after birth was greater with the inbred grades than with either the outbred grades or registered Holsteins, indicating a probable lack of vigor. Intensive inbreeding appears to depress the rate of growth of calves, although daughters of sire 1 showed no adverse effects in this respect. The mature inbred cows were considerably below the average mature weight of registered Holsteins raised under the same environmental conditions, but not proportionately so small as at birth. The production of milk increased and the percentage of butterfat decreased with the successive sire-daughter matings. The greatest improvement in the production of both milk and butterfat was in the first generation of outbred daughters; the increase in production of butterfat by succeeding generations of inbred daughters failed to equal that of the first generation. A concentration of the inheritance of sire 1 in his offspring reduced the coefficient of variability in yields of both milk and butterfat but not in percentage of butterfat. The birth weights of calves and the weights of mature cows were not depressed so markedly in the inbred Holsteins as they were in the inbred Guernseys.

In this experiment a bull that proved to possess an inheritance for a high level of milk production, mated with ordinary grade cows, brought about a big increase in production in the first-generation daughters. Subsequent improvement through inbreeding was slow. It is possible to obtain a good producing herd in one generation by the use of a sire that has proved his ability to transmit high production. Probably the hereditary make-up of the bull will influence production more than the system of breeding. Only a few sires have been used in this investigation and the number of cows available for comparison is small in many cases. While the data presented show some very definite trends and contribute information of value in the general study of the effects of inbreeding, it is not unlikely that results of close inbreeding with other sires would differ somewhat from those recounted here, depending upon the hereditary make-up of the sire used.

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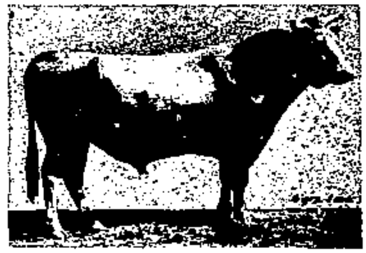
Imp. Prince Billy of Rich Neck 17799



Imp. Prince Billy of Rich Neck 17799

FOUNDATION COWS | 50 PER CENT DAUGHTERS | 75 PER CENT DAUGHTERS

Mature weight, 990 lbs.
Milk, 3,370 lbs.; Butterfat, 4.11%, 155 lbs.

Mature weight, 1,137 lbs.; at birth, 74 lbs.
Milk, 6,378 lbs.; Butterfat, 4.78%, 305 lbs.

Mature weight, 1,088 lbs.; at birth, 74 lbs.
Milk, 5,887 lbs.; Butterfat, 5.61%, 330 lbs.

Mature weight, 1,263 lbs.
Milk, 6,004 lbs., Butterfat, 3.43%, 206 lbs.

Mature weight, 1,189 lbs.; at birth, 65 lbs.
Milk, 9,929 lbs., Butterfat, 3.86%, 383 lbs.

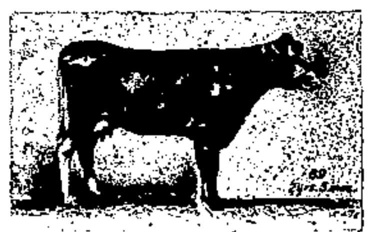
Mature weight, 868 lbs.; at birth, 69 lbs.
Milk, 7,364 lbs., Butterfat, 4.66%, 343 lbs.

Mature weight, 905 lbs.
Milk, 5,749 lbs.; Butterfat, 4.21%, 242 lbs.

No picture available

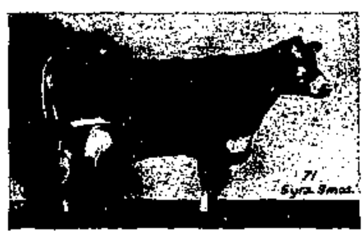
57

Weight at birth, 68 lbs.
Milk, 6,650 lbs.; Butterfat, 4.62%, 307 lbs.



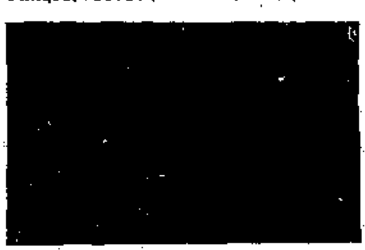
Mature weight, 907 lbs.; at birth, 62 lbs.
Milk, 7,053 lbs.; Butterfat, 5.47%, 386 lbs.

Mature weight, 1,006 lbs.
Milk, 10,431 lbs.; Butterfat, 4.56%, 476 lbs.



Mature weight, 1,114 lbs.; at birth, 68 lbs.
Milk, 7,535 lbs.; Butterfat, 4.38%, 330 lbs.

Mature weight, 878 lbs.; at birth, 71 lbs.
Milk, 5,597 lbs.; Butterfat, 4.56%, 255 lbs.



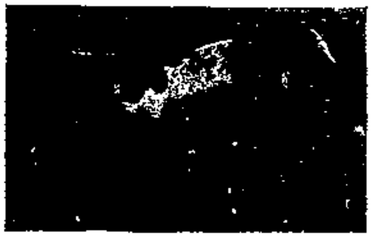
Mature weight, 814 lbs.
Milk, 8,224 lbs.; Butterfat, 4.17%, 343 lbs.

Mature weight, 1,168 lbs.; at birth, 70 lbs.
Milk, 5,399 lbs.; Butterfat, 4.70%, 254 lbs.

Mature weight, 955 lbs.; at birth, 56 lbs.
Milk, 8,877 lbs.; Butterfat, 4.60%, 408 lbs.

THE GUERNSEY GROUP

Imp. Prince Billy of Rich Neck 17799, with five foundation cows and two generations of his daughters.



Sire 2
87.5 per cent son of Sire 1

Sire 1. Registered Holstein
Johan Woodcrest Lad 11th 103987

Mature weight, 1,186 lbs.; at birth, 69 lbs.
Milk, 19,930 lbs.; Butterfat, 3.17%, 632 lbs.

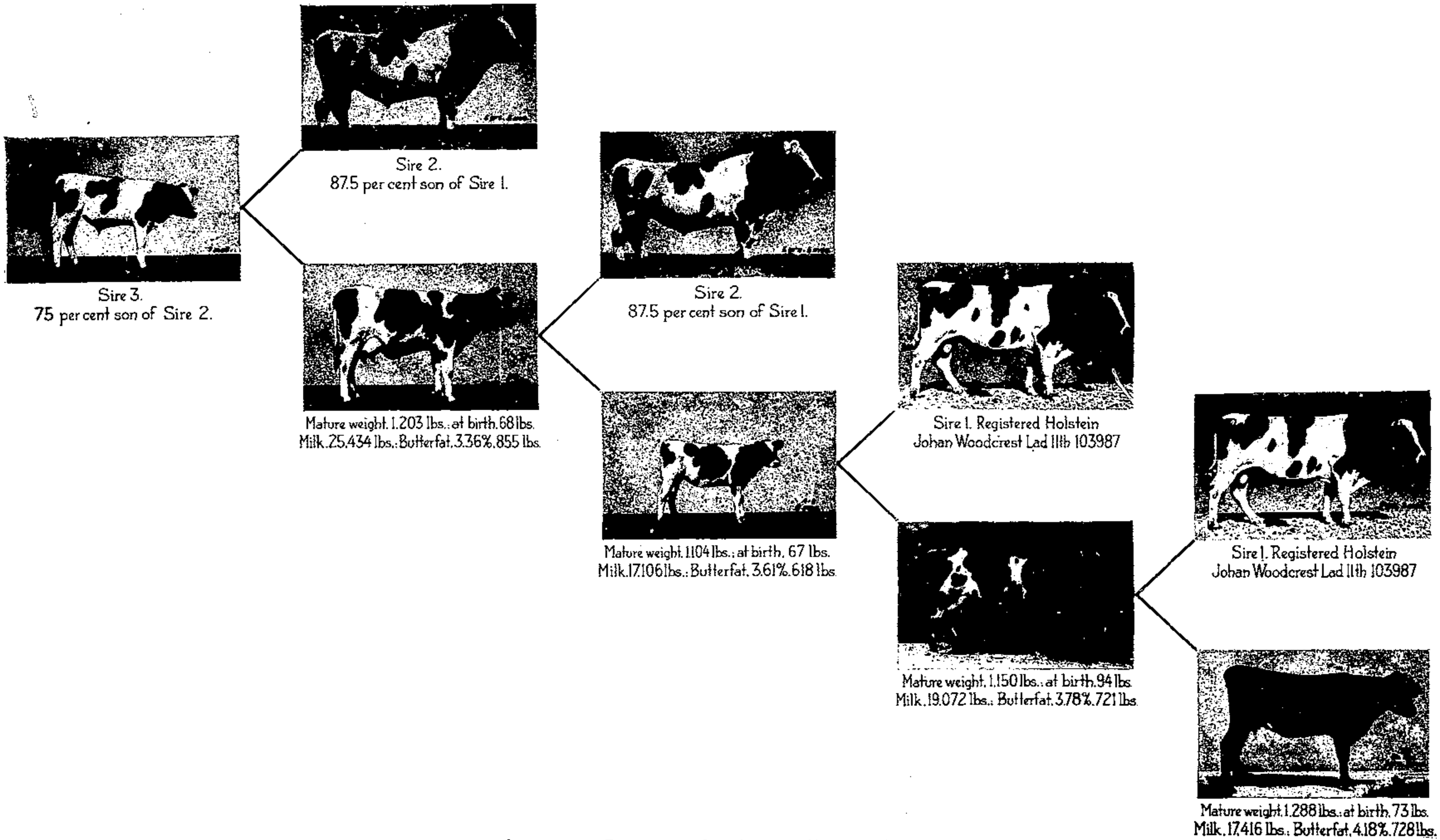
Sire 1 Registered Holstein
Johan Woodcrest Lad 11th 103987

Mature weight, 1,038 lbs.; at birth, 70 lbs.
Milk, 11,213 lbs.; Butterfat, 3.24%, 363 lbs.

Sire 1 Registered Holstein
Johan Woodcrest Lad 11th 103987

Mature weight, 821 lbs.
Milk, 6,350 lbs., Butterfat, 4.23%, 269 lbs.

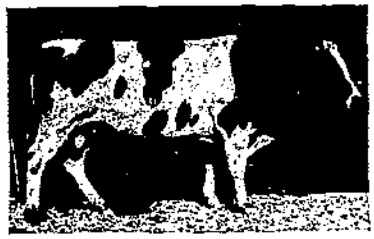
ILLUSTRATED PEDIGREE OF SIRE 2 OF THE HOLSTEIN GROUP



ILLUSTRATED PEDIGREE OF SIRE 3 OF THE HOLSTEIN GROUP

PLATE 4

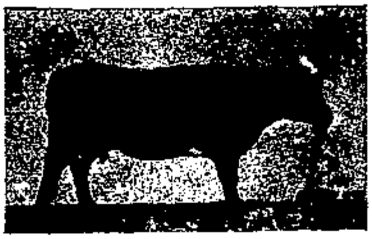
FOUND AT END OF BULLETIN.



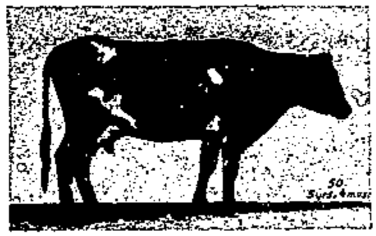
Johan Woodcrest Lad 11th 103987

FOUNDATION COWS

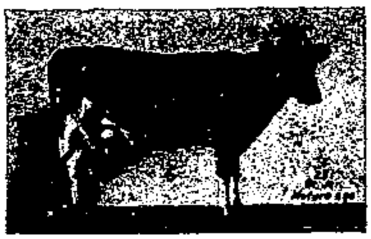
50 PER CENT DAUGHTERS



Mature weight, 984 lbs.
Milk, 10,367 lbs.; Butterfat, 4.09%, 424 lbs.

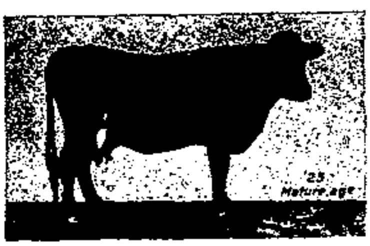


Mature weight, 1,169 lbs.; at birth, 95 lbs.
Milk, 14,660 lbs.; Butterfat, 3.83%, 561 lbs.

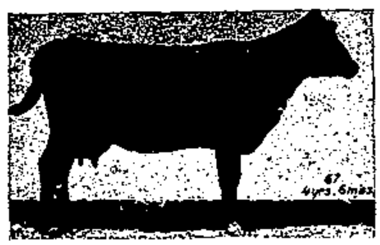


Mature weight, 783 lbs.
Milk, 9,308 lbs.; Butterfat, 4.17%, 388 lbs.

Mature weight, 1,147 lbs.; at birth, 85 lbs.
Milk, 11,529 lbs.; Butterfat, 4.29%, 495 lbs.



Mature weight, 790 lbs.
Milk, 9,821 lbs.; Butterfat, 4.40%, 432 lbs.

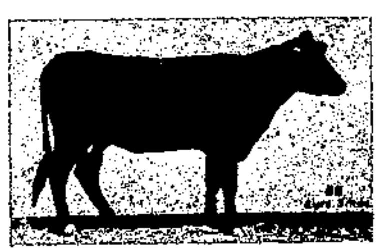


Mature weight, 1,084 lbs.; at birth, 56 lbs.
Milk, 15,379 lbs.; Butterfat, 3.83%, 589 lbs.

Mature weight, 1,137 lbs.; at birth, 74 lbs.
Milk, 13,284 lbs.; Butterfat, 4.70%, 624 lbs.

Mature weight, 1,249 lbs.; at birth, 98 lbs.
Milk, 11,733 lbs.; Butterfat, 3.86%, 453 lbs.

Mature weight, 907 lbs.; at birth, 69 lbs.
Milk, 7,036 lbs.; Butterfat, 4.76%, 335 lbs.

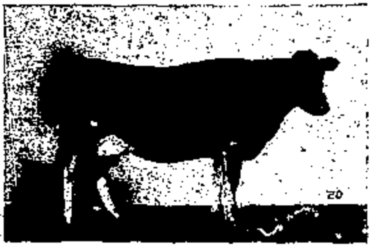


Mature weight, 1,158 lbs.; at birth, 68 lbs.
Milk, 16,728 lbs.; Butterfat, 4.30%, 719 lbs.

ADDITIONAL OUTBRED DAUGHTERS OF SIRE 1, AND THEIR DAMS

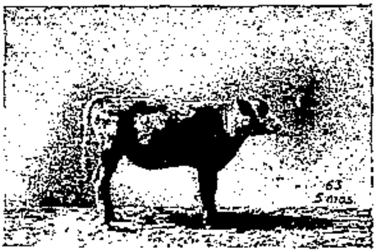
These daughters have no female progeny in the experiment.

FOUNDATION COW



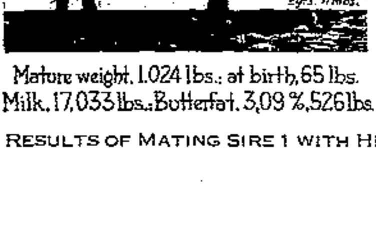
Mature weight, 821 lbs.
Milk, 6,350 lbs.; Butterfat, 4.23%, 269 lbs.

50 PER CENT DAUGHTER



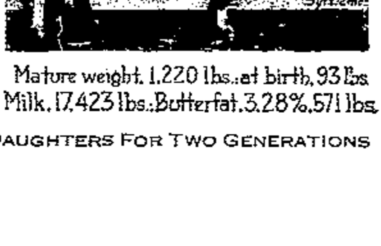
Mature weight, 1,038 lbs.; at birth, 70 lbs.
Milk, 11,213 lbs.; Butterfat, 3.24%, 363 lbs.

75 PER CENT DAUGHTER



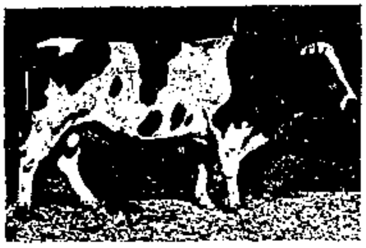
Mature weight, 1,024 lbs.; at birth, 65 lbs.
Milk, 17,033 lbs.; Butterfat, 3.09%, 526 lbs.

87.5 PER CENT DAUGHTER



Mature weight, 1,220 lbs.; at birth, 93 lbs.
Milk, 17,423 lbs.; Butterfat, 3.28%, 571 lbs.

RESULTS OF MATING SIRE 1 WITH HIS DAUGHTERS FOR TWO GENERATIONS

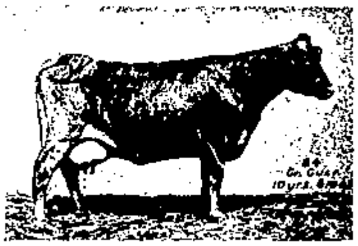


Sire 1. Registered Holstein
Johan Woodcrest Lad 11th 103987
50 PER CENT DAUGHTERS

Sire 1. Registered Holstein
Johan Woodcrest Lad 11th 103987
75 PER CENT DAUGHTERS

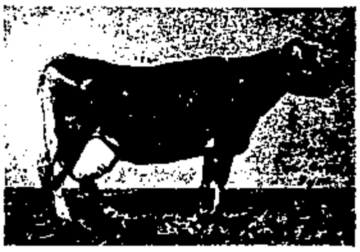
Sire 2. An 87.5 p
of Sire
50 PER CENT D

FOUNDATION COWS



Mature weight, 942 lbs.
Milk, 11,219 lbs.; Butterfat, 4.79%, 537 lbs.

Mature weight, 1,236
Milk, 16,818 lbs.; Butte



Mature weight, 955 lbs.; at birth, 56 lbs.
Milk, 13,686 lbs.; Butterfat, 4.81%, 658 lbs.

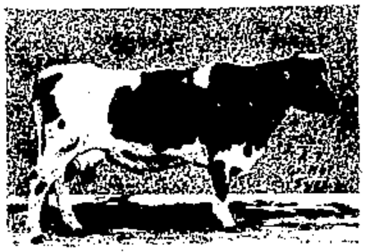
Mature weight, 1,264 l.
Milk, 18,853 lbs.; Butte

No picture available

4-6
Gr. Hol

Mature weight, 1,062 lbs.
Milk, 14,232 lbs.; Butterfat, 3.96%, 564 lbs.

Mature weight, 1,325 lb
Milk, 15,416 lbs. Butterf



Mature weight, 1,137 lbs.
Milk, 16,461 lbs.; Butterfat, 4.35%, 716 lbs.

Mature weight, 1,427 l
Milk, 19,229 lbs. Butte

Mature weight, 1,225 lbs.; at birth, 87 lbs.
Milk, 16,934 lbs.; Butterfat, 3.93%, 666 lbs.

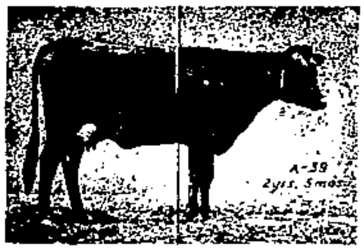
Mature weight, 1,316 lb
Milk, 21,245 lbs.; Butte

...tered Holstein
... Lad 11lb 103987
...T DAUGHTERS

Sire I. Registered Holstein
Johan Woodcrest Lad 11lb 103987
75 PER CENT DAUGHTERS

Sire 2. An 87.5 per cent son
of Sire I.
50 PER CENT DAUGHTERS

Sire 2 An 87.5 per cent son
of Sire I.
75 PER CENT DAUGHTERS



Mature weight, 1,236 lbs.; at birth, 78 lbs.
Milk, 16,818 lbs.; Butterfat, 3.61%, 607 lbs.

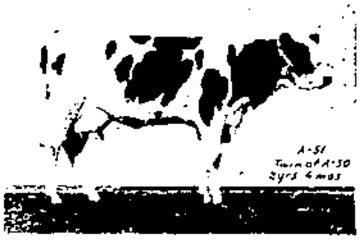
Mature weight, 1,264 lbs.; at birth, 82 lbs.
Milk, 18,853 lbs.; Butterfat, 3.99%, 752 lbs.

Mature weight, 1,235 lbs.; at birth, 77 lbs.
Milk, 20,928 lbs.; Butterfat, 3.58%, 750 lbs.

Mature weight, 1,325 lbs.; at birth, 91 lbs.
Milk, 15,416 lbs.; Butterfat, 3.40%, 524 lbs.

Mature weight, 1,135 lbs.; at birth, 66 lbs.
Milk, 7,513 lbs.; Butterfat, 3.58%, 269 lbs. (195 days)

Mature weight, 1,427 lbs.; at birth, 96 lbs.
Milk, 19,229 lbs.; Butterfat, 3.28%, 631 lbs.

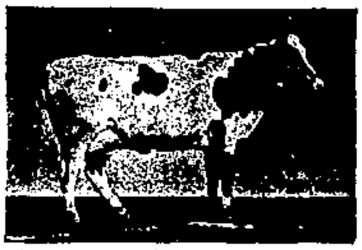


Mature weight, 1,230 lbs.; at birth, 70 lbs.
Milk, 10,992 lbs.; Butterfat, 3.28%, 360 lbs. (189 days)

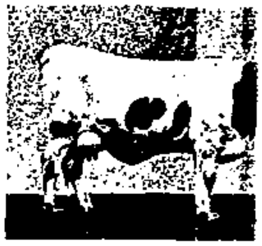
Mature weight, 1,316 lbs.; at birth, 89 lbs.
Milk, 21,245 lbs.; Butterfat, 3.88%, 824 lbs.

Mature weight 1,137 lbs.
Milk 16,461 lbs.: Butterfat 4.35% 716 lbs.

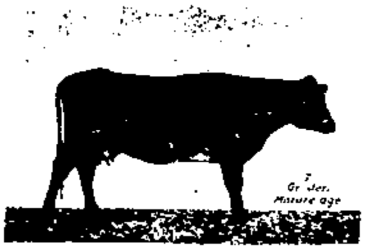
Mature weight 1,427 lbs.: at
Milk 19,229 lbs.: Butterfat 3



Mature weight 1,225 lbs.: at birth 87 lbs.
Milk 16,934 lbs.: Butterfat 3.93% 666 lbs.



Mature weight 1,316 lbs.: at b
Milk 21,245 lbs.: Butterfat 3.



Mature weight 984 lbs.
Milk 10,367 lbs.: Butterfat 4.09% 424 lbs.

Mature weight 1,173 lbs.: at birth 85 lbs.
Milk 15,313 lbs.: Butterfat 3.84% 588 lbs.

Mature weight 1,274 lbs.: a
Milk 14,551 lbs.: Butterfat

Mature weight 984 lbs.
Milk 10,367 lbs.: Butterfat 4.09% 424 lbs.

Mature weight 1,173 lbs.: at birth 85 lbs.
Milk 15,313 lbs.: Butterfat 3.84% 588 lbs.

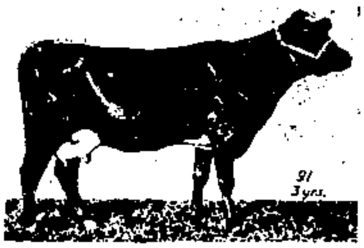
Mature weight 1,314 lbs.: a
Milk 19,903 lbs.: Butterfat

Mature weight 984 lbs.
Milk 10,367 lbs.: Butterfat 4.09% 424 lbs.

Mature weight 1,173 lbs.: at birth 85 lbs.
Milk 15,313 lbs.: Butterfat 3.84% 588 lbs.

Mature weight 1,328 lbs.:
Milk 19,466 lbs.: Butterfat.

Mature weight 1,006 lbs.
Milk 15,647 lbs.: Butterfat 4.56% 714 lbs.

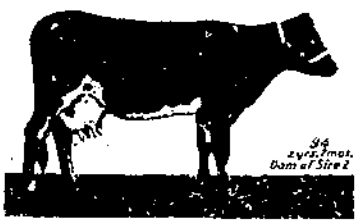


Mature weight 1,295 lbs.: at birth 76 lbs.
Milk 19,926 lbs.: Butterfat 3.91% 779 lbs.

Mature weight 1,338 lbs.: at
Milk 22,082 lbs.: Butterfat 3.

Mature weight 821 lbs.
Milk 6,350 lbs.: Butterfat 4.23% 269 lbs.

Mature weight 1,038 lbs.: at birth 70 lbs.
Milk 11,213 lbs.: Butterfat 3.24% 363 lbs.



Mature weight 1,186 lbs.: at birth 69 lbs.
Milk 19,930 lbs.: Butterfat 3.17% 632 lbs.

Mature weight 1,039 lbs.: at
Milk 15,405 lbs.: Butterfat 3.

Mature weight,1,427 lbs.:at birth,96 lbs.
Milk,19,229 lbs.:Butterfat,3.28%,631 lbs.

Mature weight,1,230 lbs.:at birth,70 lbs.
Milk,10,992 lbs.:Butterfat,3.28%,360 lbs.(189 days)

Mature weight,1,316 lbs.:at birth,89 lbs.
Milk,21,245 lbs.:Butterfat,3.88%,824 lbs.

lbs.:at birth,85 lbs
erfat,3.84%,588 lbs.

Mature weight,1,274 lbs.:at birth,107 lbs.
Milk,14,551 lbs.:Butterfat,3.51%,511 lbs.

Mature weight,1,321 lbs.:at birth,82 lbs.
Milk,20,800 lbs.:Butterfat,3.50%,728 lbs

lbs.:at birth,85 lbs.
rfat,3.84%,588 lbs.

Mature weight,1,314 lbs.:at birth,105 lbs.
Milk,19,903 lbs.:Butterfat,3.58%,713 lbs.

lbs.:at birth,85 lbs.
rfat,3.84%,588 lbs.

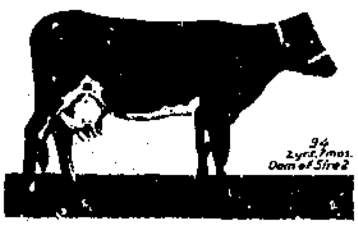
Mature weight,1,328 lbs.:at birth,97 lbs
Milk,19,466 lbs.:Butterfat,3.45%,672 lbs.

lbs.:at birth,76 lbs.
erfat,3.91%,779 lbs.

Mature weight,1,338 lbs.:at birth,98 lbs.
Milk,22,082 lbs.:Butterfat,3.34%,738 lbs.

Mature weight,1,195 lbs.:at birth,90 lbs.
Milk,12,023 lbs.:Butterfat,3.47%,417 lbs.(195 days)

lbs.:at birth,70 lbs.



Mature weight,1,186 lbs.:at birth,69 lbs.

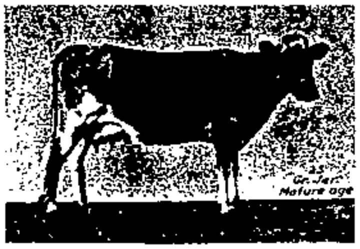
Mature weight,1,039 lbs.:at birth,70 lbs.

Mature weight, 821 lbs.
Milk, 6,350 lbs.; Butterfat, 4.23%, 269 lbs.

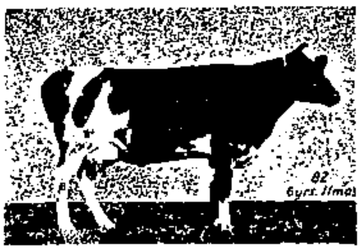
Mature weight, 1,038 lbs.; at birth, 70 lbs.
Milk, 11,213 lbs.; Butterfat, 3.24%, 363 lbs.

Mature weight, 1,186 lbs.; at birth, 69 lbs.
Milk, 19,930 lbs.; Butterfat, 3.17%, 632 lbs.

Mature weight, 1,039 lbs.; a
Milk, 15,405 lbs.; Butterfat



Mature weight, 783 lbs.
Milk, 9,308 lbs.; Butterfat, 4.17%, 388 lbs.

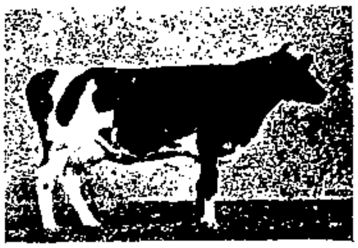


Mature weight, 1,158 lbs.; at birth, 80 lbs.
Milk, 18,131 lbs.; Butterfat, 3.68%, 667 lbs.

Mature weight, 1,153 lbs.; at birth, 98 lbs.
Milk, 19,682 lbs.; Butterfat, 3.49%, 687 lbs.

Mature weight, 1,278 lbs.;
Milk, 17,615 lbs.; Butterfat,

Mature weight, 783 lbs.
Milk, 9,308 lbs.; Butterfat, 4.17%, 388 lbs.



Mature weight, 1,158 lbs.; at birth, 80 lbs.
Milk, 18,131 lbs.; Butterfat, 3.68%, 667 lbs.

Mature weight, 1,153 lbs.; at birth, 98 lbs.
Milk, 19,682 lbs.; Butterfat, 3.49%, 687 lbs

Mature weight, 1,252 lbs.;
Milk, 15,606 lbs.; Butterfa

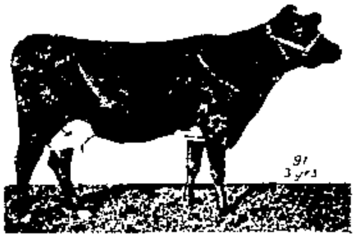
Mature weight, 1,288 lbs.; at birth, 73 lbs.
Milk, 17,416 lbs.; Butterfat, 4.18%, 728 lbs.

Mature weight, 1,150 lbs.; at birth, 94 lbs
Milk, 19,072 lbs.; Butterfat, 3.78%, 721 lbs.

Mature weight, 1,104 lbs.; at birth, 67 lbs.
Milk, 17,106 lbs.; Butterfat, 3.61%, 618 lbs.

Mature weight, 1,203 lbs.
Milk, 25,434 lbs. Butterfa

Mature weight, 1,006 lbs
Milk, 15,647 lbs., Butterfat, 4.56%, 714 lbs

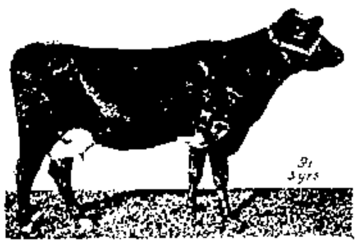


Mature weight, 1,295 lbs., at birth, 76 lbs
Milk, 19,926 lbs., Butterfat, 3.91%, 779 lbs

Mature weight, 1,190 lbs.; at birth, 93 lbs.
Milk, 15,241 lbs.; Butterfat, 3.52%, 536 lbs

Mature weight, 1,194 lbs.
Milk, 21,394 lbs. Butterfa

Mature weight, 1,006 lbs.
Milk, 15,647 lbs.; Butterfat, 4.56%, 714 lbs



Mature weight, 1,295 lbs., at birth, 76 lbs
Milk, 19,926 lbs., Butterfat, 3.91%, 779 lbs

Mature weight 1,190 lbs.; at birth, 93 lbs
Milk, 15,241 lbs., Butterfat, 3.52%, 536 lbs

Mature weight, 1,276 lbs.
Milk, 13,906 lbs. Butterf

DIREC[illegible] GENERATIONS OF COWS OF THE HOLS[illegible] GROUP

First column: left to right, grade foundation cow [illegible] 50 per cent [illegible] of the foundation cow [illegible] foundation cows [illegible] 50 and 75 per cent [illegible] column, 75 per cent [illegible]

3 lbs.:at birth,70 lbs.
rfat,3.24%,363 lbs.

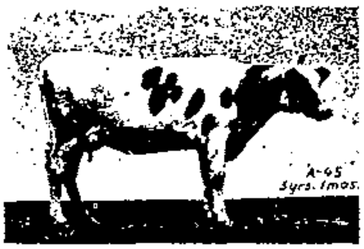
Mature weight,1,186 lbs.:at birth,69 lbs.
Milk,19,930 lbs.:Butterfat,3.17%,632 lbs.

Mature weight,1,039 lbs.:at birth,70 lbs.
Milk,15,405 lbs.:Butterfat,3.57%,550 lbs.

3 lbs.:at birth,80 lbs.
rfat,3.68%,667 lbs.

Mature weight,1,153 lbs.:at birth,98 lbs.
Milk,19,682 lbs.:Butterfat,3.49%,687 lbs.

Mature weight,1,278 lbs.:at birth,95 lbs.
Milk,17,615 lbs.:Butterfat,3.18%,560 lbs.



Mature weight,1,158 lbs.:at birth,78 lbs.
Milk,16,583 lbs.:Butterfat,2.74%,455 lbs.(325 days)

s.:at birth,80 lbs.
rfat,3.68%,667 lbs.

Mature weight,1,153 lbs.:at birth,98 lbs.
Milk,19,682 lbs.:Butterfat,3.49%,687 lbs.

Mature weight,1,252 lbs.:at birth,90 lbs.
Milk,15,606 lbs.:Butterfat,3.26%,509 lbs.

bs.:at birth,94 lbs
rfat,3.78%,721 lbs.

Mature weight,1,104 lbs.:at birth,67 lbs.
Milk,17,106 lbs.:Butterfat,3.61%,618 lbs.

Mature weight,1,203 lbs.:at birth,68 lbs
Milk,25,434 lbs.:Butterfat,3.36%,855 lbs

bs.:at birth,76 lbs
erfat,3.91%,779 lbs

Mature weight,1,190 lbs.:at birth,93 lbs.
Milk,15,241 lbs.:Butterfat,3.52%,536 lbs

Mature weight,1,194 lbs.:at birth,89 lbs
Milk,21,394 lbs.:Butterfat,3.38%,723 lbs

Mature weight,1,285 lbs.:at birth,75 lbs
Milk,10,365 lbs.:Butterfat,3.41%,353 lbs.(215 days)

lbs.:at birth,76 lbs
rfat,3.91%,779 lbs

Mature weight,1,190 lbs.:at birth,93 lbs
Milk,15,241 lbs.:Butterfat,3.52%,536 lbs

Mature weight,1,278 lbs.:at birth,82 lbs.
Milk,13,906 lbs.:Butterfat,3.23%,449 lbs.

DIREC[illegible] GENERATIONS OF COWS OF THE HOLS[illegible]N GROUP

[illegible]cent daughter of [illegible] of the foundation cows; third column, 75 per cent daughter of [illegible] fifth column, 75 per cent daughters of sire 2 out of his 50 per cent daughters. The complete [illegible]

END