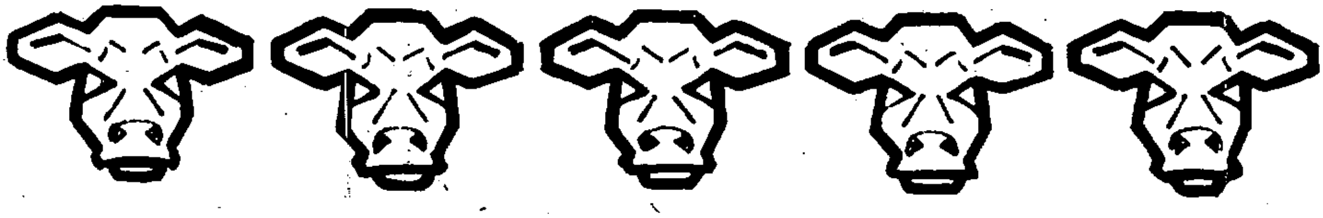
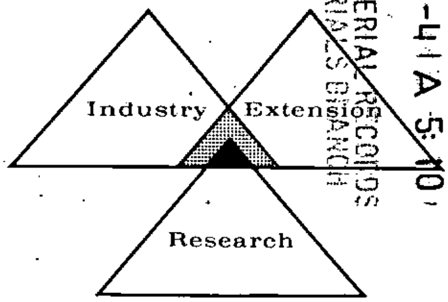
GUIDELINES FOR UNIFORM BEEF IMPROVEMENT PROGRAMS



Beef
Improvement
Federation
Recommendation



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UNITED STATES DEPARTMENT OF AGRICULTURE — EXTENSION SERVICE

Beef producers now accept objective measurements as a management tool that provides important benefits to their own operations and to the future of their industry. This acceptance is demonstrated by the fact that more than 50 organizations in the United States now provide beef improvement programs, coordinated through the Beef Improvement Federation (BIF).

This publication outlines the pattern presently used for beef cattle improvement in the United States. It is the sincere desire of all the individuals and organizations involved in preparing this publication that it will extend the usefulness of beef cattle performance testing and perpetuate its use.

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UNIFORM BEEF IMPROVEMENT PROGRAMS

FOREWORD

In the early 1930's, research was started on the use of objective measurements for evaluating beef cattle. Within a few years, it had been determined that there were a number of economically important traits that could be measured objectively. Most traits were shown to be sufficiently high in heritability to provide a sound basis for selection. Thus, the foundation for performance testing had been laid.

Performance testing has undergone thorough evaluation by researchers and producers and has been proven to be important in economical beef production. The result has been a steady increase in the use of objective measurements as a basis for beef cattle improvement. It can now be said that the economic value of performance testing has broad acceptance within the beef industry.

An indication of the emphasis being placed on performance testing in the United States is that more than 50 organizations now provide beef cattle improvement programs. To extend and further improve performance testing, these organizations and other organizations with an interest in performance testing formed the Beef Improvement Federation (BIF), on February 1, 1968. The purposes of this organization are:

1. Uniformity. To work for establishment of accurate and uniform procedures for measuring and recording data, which may be used by participating organizations, concerning the performance of beef cattle.

2. Development. To assist member organizations and/or their affiliates in developing their individual programs consistent with the needs of their members and the common goal of their recordkeeping programs.

3. Cooperation. To develop cooperation among all segments of the beef industry in compilation and utilization of performance records to improve efficiency in the production of beef.

4. Education. To encourage members to develop educational programs emphasizing the use and interpretation of performance data in improving the efficiency of beef production.

5. Confidence. To develop increased confidence of the beef industry in the economic potential of performance testing.

Member organizations include:

The Beef Cattle Improvement Associations or similar sponsoring organizations of beef cattle improvement programs of 35 or more States. These include the States containing major cattle-producing areas.

The national registry associations for 15 or more breeds of cattle. These include all breeds with the largest numbers of registrations, as well as all others in which there is a special interest in performance records.

Other national organizations: Performance Registry International, National Association of Animal Breeders, and American National Cattlemen's Association.

Associate memberships are available to organizations, firms, public agencies, or individuals interested in beef cattle performance programs.

Ex-officio member organizations are the Canadian Department of Agriculture and the Extension Service and Agricultural Research Service of the U.S. Department of Agriculture.

This publication was developed from reports of committees established by the Board of Directors of BIF. It represents an effort of this organization to extend the usefulness of beef cattle performance testing.

The guidelines in this publication are a revision of the Guidelines for Uniform Beef Improvement Programs recommended by the

Beef Improvement Federation in October 1972, which originated from the 1965 report of the former U.S. Beef Records Committee. Like the previous guidelines, this publication is the result of a cooperative effort of Extension, research, and industry. The guidelines in this publication will be reviewed periodically and updated as indicated by research, experience, and "industry economics."

The Beef Improvement Federation and the U.S. Department of Agriculture intend to show no preference for or discrimination against any individual breed of cattle or organization.

INTRODUCTION

The objective of this publication is to outline procedures for measuring and recording beef cattle performance data. A second objective is to achieve greater uniformity of terminology and methods of measuring performance traits. This is important in accomplishing rapid and accurate communication and developing cooperation among all segments of the beef industry in compiling and utilizing performance records. It is not the intent of this publication to recommend a standard program applicable to all segments of the beef cattle industry. However, the economic potential of performance testing in beef production is highly correlated with communication and cooperation.

Economic traits of beef cattle include those that contribute to both productive efficiency and desirability of product. Growth rate, feed efficiency, reproductive regularity, and carcass merit are economic traits of greatest importance. Performance testing offers those engaged in beef production a way of measuring heritable differences among their animals. Performance levels for these characteristics are related to the ability of parents to transmit desired traits to their offspring.

Differences between individual animals in traits of economic value are inherited. Thus, systematic measurements and the use of records in selection will increase the rate of genetic improvement.

Differences in the performance between individuals or groups of animals are due to either genetic or environmental causes. The observed or measured performance of each animal in each trait is the result of its heredity and the total environment in which it is produced. Genetically superior individuals can be more readily identified when the animals are maintained under the same management systems and their performance records are adjusted for known environmental differences. There are also many random or chance environmental variables which may contribute to errors in estimating breeding values of animals based on their own performance.

The importance of some of these, such as differences in fill at time of weighing, can be appreciably reduced by following appropriate and uniform procedures. The weighing conditions should be the same for all animals that are to be compared.

The rate of genetic improvement is dependent on: (1) the percentage of observed differences between animals that is due to heredity (heritability), (2) the difference between selected individuals and the average of the herd or group from which they come (selection differential), (3) the genetic association among the traits on which selection is based (genetic correlations), and (4) the average age of parents when the offspring are born (generation interval).

Records of performance are useful primarily to provide a basis for comparing cattle handled alike within a herd. Large environmental differences due to location, management, health, and nutrition are likely to exist between herds or between different management groups within herds. Genetic differences between herds do exist, but only through a carefully controlled evaluation can these differences be assessed. Guidelines for a National Sire Evaluation Program which takes herd differences into account are presented in this report. To identify high-ranking individuals within a breed, it is necessary to first identify high-ranking individuals within herds. Thus, widespread use of performance testing within herds is the first essential step to beef improvement.

The principal features of effective record of performance programs are as follows:

1. All animals of a given sex and age are given equal opportunity to perform through uniform feeding and management.

2. Systematic records of economically important traits on all animals are maintained.

3. Records are adjusted for known sources of variation, such as age of dam, age of calf, and sex.

4. Records are used in selecting replacements (bulls and heifers) and in eliminating poor producers.

5. The nutritional regime and management practices are practical and comparable to those where the progeny of the herd are expected to perform.

Fertility and the various components which contribute to it have been found to be of low heritability. However, fertility is economically the most important trait in the beef industry, and in herds where fertility is low, sizable selection differential can be achieved. Extremely low fertility or sterility are self-eliminating, but cattle of this kind need to be identified and eliminated from the herd for purely economic reasons. Thus, maintaining complete records on all cows and fertility records on bulls in breeding herds is recommended.

Replacement animals should be selected from parent stocks that have above average fertility.

Throughout this publication, the terms "weight ratio" and "gain ratio" are used to refer to the performance of an individual relative to the average of all animals in the same group. It is calculated as:

$$\frac{\text{Individual record}}{\text{Average of animals in groups}} \times 100$$

It is a useful device for quickly visualizing the relative rankings of individuals in a group. To some degree, it adjusts for environmental differences between groups. This means that two animals with equal weight ratios in two different herds or groups can be compared more validly on the basis of ratios than on the basis of actual weights. It should be emphasized, however, that the possibility of true genetic differences between herds or groups limits the usefulness of ratios for between-herd or between-group comparisons.

FARM AND RANCH PRE-WEANING AND POST-WEANING TESTING PROGRAMS

Both pre- and post-weaning growth are of primary economic importance to the beef industry. They have a direct effect on net return and are positively associated with maternal ability, efficiency of gain, and pounds of retail product. However, realized heritability for these measures of growth depends on how they are handled with respect to sex of animal and age of dam and in relation to contemporary animals. Recommendations developed for this section are based on available research information tempered by practicability in use and application. Measurements taken according to these recommendations should improve accuracy of selection for pre- and post-weaning records.

PRE-WEANING PHASE

Measurement of weaning weight (205 days). Weaning weights are obtained in order to evaluate differences in mothering ability and to measure differences in growth potential of calves. For best estimates of genetic worth for weaning weight, it is necessary to adjust individual calf records to a standard basis. It is recommended that the weaning weight be standardized to 205 days and a mature dam equivalent. It is also recommended that weights be recorded as close to 205 days as possible. The recommended range is 160 to 250 days. Calves weaned outside this range should be accounted for by a special management code and handled as a separate management group in computing 205-day weights and ratios. Records of calves in this management code should not be adjusted for age of dam, since appropriate correction factors are not available.

It is recommended that 205-day weight be computed on the basis of average daily gain from birth to weaning. This is accomplished by:

(1) Subtracting actual birth weight from actual weight at weaning (if actual birth weight is not available, substitute the appropriate standard birth weight as designated by the respective breed association for the sire breed of calf),1/

(2) Dividing by age in days at weaning, to obtain average daily gain,

(3) Multiplying the average daily gain by 205, and

(4) Adding the birth weight that was subtracted initially.

This provides an estimated 205-day weight, unadjusted for age of dam or sex of calf. This procedure is summarized by the following formula:

$$\text{Computed 205-day wt. (lbs.)} = \frac{\text{actual wt.} - \text{birth wt.}}{\text{age in days}} \times 205 + \text{birth wt.}$$

To establish a uniform procedure for computing age of dam, the following classification is recommended:

Age Range	Age of dam
21 to 33 mos.	2 year olds
34 to 46 mos.	3 year olds
47 to 59 mos.	4 year olds

To adjust for age of dam, it is recommended that the following adjustment factors be added to the computed 205-day weights for the respective age of dam for each calf.

1/ This replaces the former recommendation of using a standard birth weight of 70 lbs. for all breeds and crossbreds.

Age of dam	Additive Factors Male Calves	 Female Calves
2-year-old cows	60 lbs.	54 lbs.
3-year-old cows	40 lbs.	36 lbs.
4-year-old cows	20 lbs.	18 lbs.
5-10-year-old cows	0 lbs.	0 lbs.
11-year-old cows	20 lbs.	18 lbs.

There is substantial evidence that the additive adjustment factors listed above to adjust for age of dam are not appropriate for all breeds. For example, higher milk-producing cows (i.e., Brahmans, dairy crosses, some continental breeds, and most F_1 crosses) produce more milk than British straightbreds relative to the capacity of their calves to consume milk. Thus, these higher-milk-producing types require less statistical adjustment to approximate their production potential as mature cows. Therefore, when sufficient evidence is available demonstrating that other correction factors than the ones listed above are more appropriate for a given breed or crossbreed, their use is encouraged. However, research shows that the above-listed additive factors for age of dam more correctly adjust weaning weights than do multiplicative factors presently being used. Also, unlike multiplicative factors, additive factors do not favor heavy birth weights or "balloon" the effects on weaning weight of extra weight gain due to creep feeding. Therefore, BIF recommends the use of additive rather than multiplicative age of dam adjustment factors.

Weaning weight ratio. Records on 205-day weight and 205-day weight ratio, adjusted for age of dam on individual animals, should be reportd and/or published on the basis of each sex (within sex basis without sex adjustment). Weaning weight ratios within sex groups are calculated by dividing each individual's 205-day weaning weight adjusted for age of dam by the average of its sex group and expressing it as a percentage of its sex group average. Thus, weaning weight ratios provide a record of each individual animal's deviation from the average of its contemporaries in terms of percentage. These are useful in ranking individuals of each sex for making selections. For weight ratios to be meaningful, contemporaries should be herd mates and similar in age and should all have been exposed to the same environmental influences.

Produce of Dam Summary. A record of lifetime productivity (cow summary) is recommended. It can provide valuable information for within-herd comparisons. It can be most helpful for identifying both the lowest-producing cows to be culled and consistently high-producing cows..

No specific format is suggested, but it is recommended that the cow summary include the following information:

Measures relating to reproductive efficiency

1. Age at first calving (days)
2. Current age
3. Number of calves born (lifetime)
4. Number of calves weaned (lifetime)
5. Average age of calves when weaned

Measures relating to productivity

1. Average birth weight
2. Average weaning-weight ratio of all calves weaned
3. Average adjusted 365-day weight, weight ratio, and number of contemporaries
4. MPPA

Most Probable Producing Ability (MPPA). It is recommended that MPPA be included on Produce of Dam summaries and that ranking of dams be based on MPPA for 205-day weaning weight ratio. This is needed to compare dams which do not have the same number of calf records in their averages. For example, suppose six cows have the following records of production:

Cow	No. Calves	Avg. wn. wt. ratio	MPPA
A	1	85	94.0
B	2	88	93.2
C	4	90	92.7
D	3	110	106.7
E	4	112	108.8
F	1	115	106.0

In the example, cow A has the lowest lifetime average. However, this is for only a single calf for which environmental conditions or the calf's genetic potential for growth might have been below the average of what the cow would normally produce. One or more calves from cows B or C could also have had a record of 85 or less. All three cows are probably low producers, but use of MPPA enables more accurate culling and, in this example, indicates that cows B and C are slightly lower-producing cows than A.

MPPA for weaning weight ratio is computed by the following formula:

$$MPPA = \overline{H} + \frac{NR}{1 + (N-1)R} (\overline{C} - \overline{H})$$

where $\overline{H}$ = 100, the herd average weaning weight ratio,
N = the number of calves included in the cow's average,
R = .4, the repeatability factor for weaning weight ratio,
and $\overline{C}$ = average for weaning weight ratio for all calves the cow has produced.

MPPA of cow D in the example above is computed as follows:

$$\text{MPPA cow D} = 100 + \frac{3 \times .4}{1 + (3-1)\ .4} (110-100) = 106.7$$

POST-WEANING PHASE

Measurement of yearling weight (365 days) or long yearling weight (452 or 550 days). Yearling weight at 365 days or long yearling weight at 452 or 550 days are particularly important because of their high heritability and high genetic association with efficiency of gain and pounds of retail trimmed boneless beef produced, when cattle have been compared on a constant weight or age basis.

Yearling weight should be computed and reported separately for each sex. In on-the-farm or ranch tests, the post-weaning period should start on the date weaning weights are obtained (i.e., actual weaning weight is used as initial weight on test). Research results show that the age-of-dam effects on 365-day weight are of approximately the same magnitude as age-of-dam effects at weaning. For this reason, it is desirable to add post-weaning gains in a 160-day, post-weaning period to 205-day weaning weight, adjusted for age of dam to arrive at adjusted 365-day weight. The following formula is recommended:

$$\text{Adjusted 365-day wt.} = \frac{\text{actual final wt. - act. wn. wt.}}{\text{number of days between wts.}} \times 160$$

$$+ \text{ 205-day wn. wt. adj. for age of dam}$$

The period between weaning weight and final weight should be at least 160 days. Final weight should not be taken at less than 330 days of age for any individual animal, and the average age for each sex management group should be at least 365 days. It is recommended that the number of days between weaning and final weight be the same for all animals of the same sex in a herd. By use of this procedure, it is necessary to obtain only weaning weight and yearling weight on each animal. All growth periods in the animal's life are included by this procedure.

The procedure of using adjusted 365-day weights as a measure of yearling weight will apply primarily to herds that develop bulls on a rather high level of concentrate feeding starting at weaning time. For herds that prefer to develop bulls more slowly, a long yearling weight may be used as an alternative to adjusted 365-day weights. Likewise, it may be more practical to develop replacement heifers on a lower feeding regime. In such instances, long yearling weights may be more appropriate.

Adjusted long yearling weight (452 or 550 days) for each sex should be computed in the same manner as adjusted 365-day weight.

$$\text{Adjusted 550-day wt.} = \frac{\text{act. final wt. - act. wn. wt.}}{\text{number of days between wts.}} \times 345$$

$$+ \text{ wn. wt. (205 days) adj. for age of dam}$$

To compute 452-day weight, 247 would be substituted for 345 in the equation. For bulls grown on intermediate feed levels, adjusted 452-day weight gives a better evaluation of growth potential than 365-day weight. Taking them to 550 days on a standard ration might put them in higher condition than desired. Final weight should not be taken at less than 500 days of age when estimating 550-day weight or at less than 400 days when estimating 452-day weight.

Weight ratios. Weight ratios for either adjusted 365-day weight (yearlings), adjusted 452-day weight, or adjusted 550-day weight (long yearling) should be computed separately for each sex-management code group. Weight ratios should also be reported separately for each sex-management code group for ease of ranking individual animals of each sex in making selections.

Weight ratios for yearling weight can be biased downward if lighter calves are culled at weaning. Research has indicated that with 25 percent, 50 percent, and 73 percent culling for low weaning weight, yearling weight ratios would be underestimated by 3 percent, 6 percent, and 8 percent for each calf, respectively, if the average yearling weights of selected calves are used to compute the ratio, because the average yearling weights of selected calves would exceed those for all calves weaned.

To adjust yearling weight ratio for selection on weaning weight (or culling of lighter calves at weaning), the following formula is recommended for computing yearling weight ratio:

$$\frac{W + P}{\overline{W}_u + \overline{P}_s} \times 100$$

where W = adjusted 205-day weight of the individual,

P = the 160-day post-weaning gain of the individual = 160 x post-weaning average daily gain (247 or 345 should be substituted for 160 in computing adjusted 452- or 550-day weight ratios),

$\overline{W}_u$ = the average 205-day adjusted weight of all calves weaned contemporarily with the calf in question,

and $\overline{P}_s$ = the average 160-day post-weaning gain of all calves tested in a contemporary sex-management group.

If no calves are culled at weaning, this is the same as dividing the individual animal's adjusted 365-day weight (or adjusted 452- or 550-day weight) by the average of all animals in the sex-management code group and multiplying by 100 to express the ratio as a percentage of its sex-management code group. By keeping the averages corresponding to each calf on file, this type of indexing can be done even for noncontemporary weaning groups assembled for central tests.

Sire and group summaries for yearling weight ratio should be computed as:

$$\frac{\overline{W}_{ug} + \overline{P}_{sg}}{\overline{W}_{u} + \overline{P}_{s}} \times 100$$

where $\overline{W}_{ug}$ = the sire progeny group average 205-day adjusted weight for all calves weaned,

$\overline{P}_{sg}$ = the average 160-day post-weaning gain (247 or 345 for 452- or 550-day weights, respectively),

$\overline{W}_{u}$ = the average 205-day adjusted weight of all calves weaned contemporarily with the calf in question,

and $\overline{P}_{s}$ = the average 160-day post-weaning gain of all calves tested in a contemporary sex-management group.

REPRODUCTION

Reproduction or fertility is the most important trait in beef cattle. Breeders are urged to record reproductive performance in both the female and the male and to build this data into their herd records. They are urged to use this data in culling and selection, even though heritabilities may be low. Recommendations for this section are based on experience and limited research information. Research workers are urged to further study reproductive traits and measures for future refinement and improvements.

FEMALE

The following recommendations are made for scoring and recording traits associated with the female.

General Reproductive Performance:

1. Open or pregnant -- score 0 for open and 1 for pregnant.
2. Calving date -- record in a conventional manner but store and carry in dam summaries in Julian calendar form.
3. Calf born -- score 0 for no calf born and 1 for calf born.
4. Calf weaned -- score 0 for no calf weaned and 1 for calf weaned.
5. Age at first calving -- should be carried in dam records in days.

Birth Weight of Calf -- recorded in pounds and may be expressed as a ratio within like sex, age of dam, and management groups.

Calving Difficulty:

1. No difficulty and no assistance (score 1).
2. Minor difficulty, some assistance (score 2).
3. Major difficulty, mechanical assistance with jack or puller (score 3).
4. Caesarean section, very difficult, or other surgery (score 4).
5. Abnormal presentation (score 5).

NOTE: Score 1 through 4 may be averaged but 5 should not be included.

6. Mortality -- score 0 for live and 1 for dead. This should be scored in a separate column.

MALE

The following are recommended as guidelines for physical examinations and semen evaluation in screening yearling bulls for normal reproductive function. These recommendations are especially intended for bulls which have completed post-weaning gain test at either central test stations or on breeders' farms.

Physical Examination (very important)

1. Palpation of scrotum and its contents -- score 0 for unacceptable and 1 for acceptable.
2. Measure scrotal circumference -- record in centimeters.
3. Examine extended penis and prepuce for injury or abnormalities -- score 0 for unacceptable and 1 for acceptable.
4. Palpate internal accessory glands rectally -- score 0 for unacceptable and 1 for acceptable.

Semen Evaluation (electro-ejaculate)

1. Volume -- observation.
2. Concentration -- observation.
3. % motility -- observation.
4. Morphology*

   *Percentage primary abnormalities counted on a stained smear at 1,000 magnification. Primary emphasis should be on % normal sperm. Head and midpiece abnormalities are especially important; i.e., primary abnormality.

Most bulls with gross deficiencies or abnormalities detectd by physical examination should be culled.

Scrotal circumference measurements should be scored as actual measurements. Percent primary abnormalities may be expressed as a ratio for the group of bulls tested together.

The scrotum, penis, and rectal examinations should be recorded as acceptable or unacceptable. If unacceptable, the report should tell why.

The screening examination should be performed by experienced, competent personnel.

CENTRAL TESTING STATIONS

Central testing stations are locations where animals are assembled from several herds to evaluate differences in certain performance traits under uniform conditions. Uses of central testing stations include: (1) comparing individual performance of potential seed-stock herd sires to similar animals from other herds; (2) comparing bulls being readied for sale to commercial producers; (3) finishing steers or heifers scheduled for slaughter as part of progeny test programs for growth and carcass traits; (4) as an educational tool to acquaint breeders with record of performance, and (5) estimating genetic differences between herds or between sire progenies in gaining ability, feed conversion, conformation, and carcass characteristics.

It is important that the objectives of a central testing station be clearly defined with procedures designed to accomplish these objectives. Since specific objectives and procedures may vary with location, only general principles will be discussed here.

Bull buyers have to decide on: (1) herds from which to select bulls, and (2) which bull or bulls to buy within a herd. If bulls are raised and fed entirely on the farm or ranch where they are produced, a buyer has the difficult task of deciding how much of the apparent superiority or inferiority of bulls in a specific herd is due to feeding and/or management. Having them handled for part of their growth period under standard conditions minimizes these effects and makes the task of the buyer somewhat easier, whether he is buying commercial bulls or herd sires for a purebred herd.

Similarly, if progeny test groups of steers from different herds are fed to determine the transmitting ability of the sires for growth rate, efficiency, and carcass traits, sire comparisons are more accurate if all progeny are fed under standard conditions.

Central tests are of limited usefulness for estimating genetic differences between herds. If this is the purpose of the test, at least 5 to 10 head per herd should be tested annually, for a minimum of 3 years. The larger the herd size, the greater the number needed to adequately sample the herd. The accuracy of the tests may be improved if from 5 to 8 progeny of each sire from each herd are tested each year. This also permits the assessment of within-herd differences, as well as between-herd differences. Efforts should be made to get a representative sample of animals from each herd on test; otherwise, little real information on herd differences will be obtained. If central testing stations are

The 140-day average daily gain and gain ration are the most important figures in test station results, because they measure growth during the period when the bulls are together under test conditions. Selection for 140-day gains should improve weaning weights and feedlot performance because some of the genes which affect feedlot growth rate also affect pre-weaning growth rate. The gain ratio is obtained by dividing the individual animal's gain by the test group average and multiplying by 100. A ratio of 100 means the bull is exactly average in his group, 115 means he is 15 percent above the average, 90 means he is 10 percent below the average, etc. This ratio makes animal comparisons easier and is much more meaningful than the actual measurement.

Weaning weights and within-herd weaning weight ratios provide good comparisons of bulls which come from the same herd but are less useful for comparing bulls from different herds. This is the best available measure of the dam's milk production, so it is desirable to have a weaning weight above the average of the herd in which the calf was produced (i.e., within-herd weaning weight ratio above 100). Actual weaning weights and the date weighed are reported to provide information on gain during the interim period between weaning and initial test weights. Loss of weight or very low gains during this period may result in higher than normal gains during the subsequent test period. The size of this "compensatory" error in test gains would depend on the length of the interim period and the rate of gain.

The 365-day adjusted weight and 365-day weight ratio combine adjusted weaning weight and post-weaning gain into one composite measurement. The 365-day weight ratio is the best measure for comparing growth of calves from the same herd. It is very highly heritable (approximately 60 percent). However, among bulls from different herds in a central test, care must be exercised in using this measurement, because the weaning weight portion was not made under comparable conditions. (Note the method of computation in Figure I.)

The most reliable estimates of gainability to one year of age are obtained when gain ratios and 365-day weight ratios are nearly the same. Weight-per-day-of-age is an alternate measurement of growth during this same period, but it does not include an adjustment for age of dam and can be biased by differences in age at weaning and post-weaning period length.

Efficiency of feed conversion is expressed as pounds of feed per 100 pounds of gain. It is difficult to measure. Most tests do not attempt to get individual feed conversion because it would

FIGURE 1. FORMAT FOR TEST STATION REPORTS

MEASUREMENTS RECOMMENDED FOR ALL TEST STATIONS — OPTIONAL MEASUREMENTS FOR ALL TEST STATIONS

		WEANING				GAIN TEST					YEARLING		YEARLING						
Lot No.	Birth Date	Actual Wt.	Weaning Date	Adj. 205-day Wt.	W.W. Ratio W/in Herd and No.	(Date) Initial Test Wt.	(Date) Final Test Wt.	Age in Days	ADG	Test Gain Ratio	Adj. 365-Day Wt.	365-Day Wt. Ratio	Wt. Per Day of Age	Conf. Score	Index	Fat Thick.	Est. Yield Grade	Adj. Feed Conv.	Initial Cond. Score
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)

Owner, address, breed, and sire. (Inserted between sire groups, or in a column at the left.)
Each test group (i.e., breed and age group) should be listed together on the report and averaged. (Age range in each group should not exceed 90 days and breed should be averaged separately within age group.)
Sire group averages are shown for 3 or more progeny of same sire.
If sire groups include calves from different age groups, data may be listed together by sires, but with only the average of ratios shown.

(1) Ear tag test number. Tattoo should be recorded elsewhere and may be put on this report if space permits.
(2) Month/day/year of birth. Ex. 2/15/71 for Feb. 15, 1971. If all in the same year, may omit year.
(3) Actual weight used to compute 205-day adj. weight.
(4) Month/day/year when weights were taken to compute 205-day adj. weight.
(5) Weaning weight adjusted to 205 days and for age of dam according to BIF. If creep fed, add C after weight.
(6) Adj. 205-day wt. divided by average of all bull calves in same herd in same weaning season group and same management code. Minimum entrance requirement is optional with test management. The number of calves making the average is listed in parentheses. Ex. 105 (17)
(7) &
(8) Average of at least 2 full weights taken on different days. May be more than 1 day apart if desired.
(9) Age at end of test.
(10) Final weight - initial weight ÷ days on test. Minimum length, 140 days, no maximum.
(11) Average Daily Gain ÷ test group average of average daily gain. (Breed within age group average.)
(12) $\frac{\text{Final test weight - Actual weaning weight}}{\text{Days between weights}}$ x 160 + adj. 205-day wt. (adj. for dam's age).
(13) Adj. 365-day wt. ÷ test group average of adj. 365-day weights. (Breed within age group average.)

OPTIONAL
(14) Test wt. ÷ days of age when weighed.
(15) Any locally adopted scoring system.
(16) Indexes will vary with individual test objectives. They should all be based on ratios to the group average of a trait multiplied by some percentage figure, thus resulting in values ranging below and above a mean of 100.
(17) Fat thickness may be measured by sonoscope and should be expressed per cwt. <u>and</u> the absolute value.
(18) Cutability estimates based on sonoscope readings of ribeye area and fat thickness may be classified into the market yield grades of 1, 2, 3, 4, or 5.
(19) Feed conversion of any group fed together in one pen should be expressed as pounds of feed per 100 pounds of gain. The actual amount of feed should be adjusted to a common body weight to eliminate differences in maintenance requirements. (See Appendix 3.)
(20) Initial degree of fatness may be visually estimated and scored on a scale of 1 to 5, with 1 being very thin; 5, excessively fat; and 3, average in condition.

require individual feeding. Where sire progeny groups are fed in separate pens, a good measure of the sire's ability may be obtained. This also provides some information on the individual half-brothers in the pen. Since size differences affect feed requirements, feed conversion should be adjusted to a common body weight. Appendix 2 provides a method for adjusting feed conversion values for differences in maintenance requirements associated with size differences. Fortunately, growth rate and gain per unit of feed are highly correlated. Selection for gain alone should result in 80 percent as much improvement in feed per unit of gain as direct selection for feed conversion.

Conformation score or grade is optional among test stations. This measurement should be based strictly on skeletal soundness and indications of carcass desirability (including carcass weight and cutability). Since it is an "opinion value", it is less useful to the bull buyer than the other measurements. Each buyer should make his own visual evaluation after evaluating the production records.

Ration composition should be stated in station reports. Rations vary considerably among test stations, particularly in level of energy. This variation causes some differences in the average daily gains among different tests that are not heritable. Bulls can usually be compared as accurately if the test average is near 2.5 pounds per day as they can if the test average is higher than 3.0 pounds per day. Breed differences and local preferences should be considered in deciding the desired average rate of gain. High roughage rations which produce moderate gains are likely to result in less excessive fattening and fewer health problems than higher energy rations. Bull calves grown on higher roughage rations should adapt to a variety of feed and pasture conditions after the test. They should be ready for service within less time than fatter bulls.

GENERAL CONSIDERATIONS

Even under the best possible conditions at a central test station, not all pre-test environmental effects can be eliminated. Therefore, small differences in measurements are not very meaningful. Some bulls may be sick or off feed for varying lengths of time, but there is no way to adjust the data for such circumstances. The only reasonable course is to assume that all had equal opportunity.

The breeder must decide which traits will receive the most emphasis in his selection program. Only a few traits and a limited number of bulls can be measured at test stations. Testing does not improve the bulls, it only helps to identify the superior ones. Complete performance programs in seedstock herds of the Nation are essential to maximize genetic progress in the beef cattle industry.

BEEF CARCASS EVALUATION

Beef is the end-point of all beef cattle improvement programs and activities. Quality of product and quantity of edible portion are the basic factors of carcass merit. However, the relative values of the quality and quantity are subject to change as market demands change.

Carcass evaluation is the technique by which the components of quality and quantity are measured. The methods recommended in this publication have been chosen because of their wide use and ease of application. Evaluation techniques are subject to change. For example, changes in USDA grades necessitate changes in recommended procedures.

Beef carcass evaluation should be compatible with efficient beef production.

BASIC FACTORS OF CARCASS EVALUATION

Quality refers to the overall palatability of the edible portion of the carcass. The 1976 USDA Quality Grades are recommended as the base for quality evaluation.

The USDA Quality Grades are Prime, Choice, Good, Standard, Commercial, Utility, Cutter, and Canner. The grades are determined by visually evaluating certain carcass characteristics. These characteristics are maturity, marbling, texture of lean, color of lean, and firmness of lean. The final grade should be reported by one-third of a grade. It is often desirable to independently record the score for one or more of the characteristics which make up the grade.

Many people are particularly interested in one or more grade characteristics. If so, they should make sure that those characteristics are recorded. In sire evaluation programs, it is recommended that the score for all components of the quality grade be recorded. Low choice quality grade is recommended as a minimum goal in sire evaluation programs and carcass contests.

The Warner-Bratzler shear test and taste panel test have been recommended as methods of measuring tenderness; however, cost and availability will restrict usage.

Quantity is the amount of salable meat the carcass will yield.

It is recommended that USDA Yield Grade be used as a basis for evaluating carcass cutability.

There are five USDA Yield Grades numbered 1 through 5. Yield Grade 1 carcasses have the highest yields of retail cuts; Yield Grade 5 has the lowest. The USDA Yield Grades are based on four factors:

1. Amount of external fat (adjusted measurement at the 12th rib).
2. Amount of kidney, pelvic, and heart fat.
3. Area of ribeye (measured at the 12th rib).
4. Hot carcass weight.

The Yield Grade can be expressed in whole numbers from 1 to 5 or in tenths of the grade. For example, a carcass will have a Yield Grade of 2.0 whether it is 2.0 or 2.9. A 3.9 Yield Grade indicates that a carcass is one-tenth better than a 4.0; however, it is still a Yield Grade 3. Yield Grades should be expressed to a tenth of a grade. Yield Grade can also be converted to cutability, which estimates the percent of trimmed boneless retail cuts from the round, loin, rib, and chuck. Various cutability figures correspond to Yield Grades; for example:

Yield Grade	Cutability (Percent)
1.0	54.6
1.5	53.5
2.0	52.3
2.5	51.2
3.0	50.0
3.5	48.9
4.0	47.7
4.5	46.6
5.0	45.4
5.5	44.3

The formula for calculating percent of cutability is:

Percent cutability = 51.34 - 5.784 (single thickness of fat over *longissimus dorsi* in inches) - .462 (estimated percent of kidney, pelvic, and heart fat) + 0.740 (area *longissimus dorsi* in square inches) - 0.0093 (hot carcass weight in pounds).

Pre-slaughter growth rate is an important part of all performance programs. However, measures of growth rate prior to slaughter do not measure the composition of the gain. In order to measure the composition of the carcass in terms of growth rate, it should be expressed as pounds of trimmed retail cuts (cutability) per day of age. Example: Pounds of trimmed retail cuts per day of age = carcass weight x cutability (in percent) ÷ age in days.

For example:

600-pound carcass
52.3 percent cutability (Yield Grade 2.0)
365 days of age

600 x .523 ÷ 365 = .86 lbs. of trimmed cuts per day of age.

600-pound carcass
50.0 percent cutability (Yield Grade 3.0)
365 days of age

600 x .500 ÷ 365 = .82 lbs. of trimmed cuts per day of age.

OBTAINING CARCASS DATA

Persons desiring carcass data should plan in advance. Identification of the cattle to be slaughtered is a must if individual data are desired. Although many research and Extension personnel are qualified and can collect carcass data, their services are not always available. In most cases, if requested, data can be collected by the USDA Grading Services.

BEEF CARCASS DATA SERVICE

The Beef Carcass Data Service (BCDS) is a joint USDA-beef cattle industry effort to help cattle producers and feeders obtain data on important value-determining characteristics of the carcasses their cattle produce.

This service, conducted in cooperation with participating cattle producer and feeder associations, agricultural organizations, and State Departments of Agriculture, is primarily designed to provide carcass data to breeders who may not own the animals at the time of slaughter.

It works simply and conveniently. Specially designed eartags used for official identification in this program can be purchased from one of the cooperating sources. Producers and feeders can apply these bright orange, shield-shaped, serially numbered eartags to those cattle on which they want to obtain carcass information.

When eartagged cattle are slaughtered, a meat inspector will remove the tag from the ear, attach it to the carcass, and notify the USDA meat grader assigned to the plant.

After the tagged carcasses have been sufficiently chilled, the meat grader evaluates quality and yield grade factors and records this carcass data together with the eartag serial number and slaughter date on a special carcass data form (Figure 2 shows a completed carcass data form). The completed data forms are forwarded to the Agricultural Marketing Service's Carcass Data Center in Washington, D.C. The Carcass Data Center will process the data and mail it to the "cooperator" who, in turn, will send it to the eartag owner. These eartag owners will be billed for each completed data form received.

Persons planning to use the BCDS should realize that purchase of an eartag does not guarantee that carcass data will be received on every animal identified. Eartags may be lost--either prior to or during the slaughtering process--or removed at any time during the production, feeding, and marketing processes. When this happens, positive identity from live animal to carcass--the key to the successful operation of the BCDS--is lost, and data cannot be collected. However, the minimal cost of eartags, plus the fact that the charge for this service is not made until the completed data form is received, makes the financial risk of losing eartags negligible.

Feeder calf producers should keep in mind that most cattle today are slaughtered at 16 to 24 months of age. Thus, the calf producer may not receive the eartag carcass report for several months after he sells the animal. Feedlot operators who tag animals will receive the report in a short period of time after sale of the animal.

FIGURE 2. BEEF CARCASS DATA SERVICE FORM

FORM LS-106-1
(9-4-73)

CARCASS DATA SERVICE *(BEEF)*

USDA - AMS
Livestock Division

CONFORMATION *(Thirds of a grade)*	MATURITY *(Thirds of a group)*	MARBLING *(Thirds of a degree)*	QUALITY GRADE *(Thirds of a grade)*	PACKER'S WARM CARCASS WEIGHT *(Lbs.)*	ADJUSTED FAT THICKNESS *(Inches)*	RIBEYE AREA *(Sq. Inches)*	KIDNEY, PELVIC, & HEART FAT *(Percent)*	YIELD GRADE *(Tenths)*	EVALUATION DATE
C+	A	SM	C-	700	.45	12.4	2.5	2.8	9-11-74

NAME OF ASSOCIATION OR PRODUCER

Grader Code: LY

EARTAG NUMBER†: 078807

REMARKS:

Conformation not considered in determination of final quality grade.

† Duplicate eartags for different carcasses denoted by an asterisk (*)

PRODUCER'S COPY

(See reverse side for code abbreviations)

GRADE	ABBREVIATION
Prime	P
Choice	C
Good	G
Standard	S
Commercial	CM
Utility	U
Cutter	CU
Canner	CA

DEGREES OF MARBLING	ABBREVIATION
Abundant	AB
Moderately Abundant	MDA
Slightly Abundant	SLA
Moderate	MD
Modest	MT
Small	SM
Slight	SL
Traces	T
Practically Devoid	PD

\+ indicates upper 1/3 of grade, degree, or maturity group.

\- indicates lower 1/3 of grade, degree, or maturity group.

P, C, G, MT, SM, etc. - indicates the middle 1/3 of a grade, degree, or maturity group.

The BCDS provides producers with the following official USDA carcass data:

1. Conformation grade
2. Maturity
3. Degree of marbling
4. Quality grade
5. Fat thickness (tenths of inches)
6. Ribeye area (square inches)
7. Kidney, pelvic, and heart fat (percent)
8. Hot carcass weight
9. Yield grade

The BCDS costs:

$0.50 -- for each eartag
$0.75 -- for a tool for attaching the tag (you need only one)
$1.50 -- for each completed carcass data report

Official eartags can be obtained from organizations, associations, and some State Departments of Agriculture which have entered into a cooperative agreement with the Agricultural Marketing Service (AMS) as participating cooperators. Eartags cannot be obtained directly from the Livestock Division's Carcasss Data Center. For information on sources of eartags, contact:

Livestock Division
Agricultural Marketing Service
U.S. Department of Agriculture
Washington, D.C. 20250

or the Extension Livestock Specialist at your State University.

USDA'S BEEF CARCASS EVALUATION SERVICE

This service is provided on a fee basis and must be requested directly from a USDA Meat Grading Office. The fee will vary, depending upon the amount of information requested and expenses incurred by the grader, such as travel.

The grader records the information requested for each animal on a USDA form (shown in Figure 3), which is forwarded to the producer or feeder. This method differs from the BCDS program in that the person desiring the information must contact the Grading Service directly, tag his cattle with suitable tags, and make purchase and slaughter arrangements with a cooperative packer.

Conformation has been eliminated as a grade factor in the revised beef grade standards which became effective February 23, 1976. Conformation will be evaluated and recorded in both BCDS and BCES. However, it will not be considered in determining quality grade.

USDA Area Meat Grading Offices are listed on Pages 34-35.

CARCASS CONTESTS

Carcass contests are the show-window of carcass evaluation. Presently, there are many different procedures used. It is recommended that carcass contests be based on specific procedures as recommended by the American Meat Science Association.

Beef Carcass Contest Judging. The following information should be collected for quality beef carcass contests:

1. Age (desirable if can be obtained)
2. USDA quality grade
    a. Maturity
    b. Marbling
3. USDA estimated cutability percent
    a. Hot carcass weight 1/
    b. Fat thickness over ribeye
    c. Ribeye area
    d. Estimated percent kidney, pelvic, and heart fat

1/ A minimum carcass weight of 550 pounds is recommended for carcass contests. No maximum weight restrictions are suggested and are left to the discretion of the carcass contest management. It is recommended that all cattle entered in carcass contests be mouthed on foot. Only cattle with all temporary incisors should be allowed in the contest.

FIGURE 3. BEEF CARCASS EVALUATION REPORT FORM

FORM LS-106
(3-1-66)

BEEF CARCASS EVALUATION REPORT

U. S. DEPARTMENT OF AGRICULTURE
CONSUMER AND MARKETING SERVICE
LIVESTOCK DIVISION

USDA NO.	OTHER IDENTIFICATION	BREED *(As supplied by owner)*	MEAT GRADING CERTIFICATE NO.
49	———	———	LG0391001

NAME OF PRODUCER	NAME OF PACKER
MARK SHELDON	ELMAN PACKING Co.

1

QUALITY GRADE

CHOICE
BY THIRDS

A. CONFORMATION, MARBLING, AND MATURITY FACTORS

CONFORMATION	DEGREE OF MARBLING	MATURITY (APPROXIMATE AGE SHOWN) *(Circle one)*
PRIME	MODEST	**(A)** *(Under 30 mos.)* **B** *(30 to 48 mos.)* **C D E** *(Over 48 mos.)*

B. OTHER FACTORS

TEXTURE OF MARBLING *(Check one)*

- ☐ FINE ☑ MEDIUM ☐ COARSE

COLOR OF LEAN *(Check one)*

- ☐ VERY LIGHT CHERRY RED ☑ CHERRY RED ☐ SLIGHTLY DARK RED ☐ MODERATELY DARK RED ☐ DARK RED ☐ VERY DARK RED ☐ BLACK

FIRMNESS OF LEAN *(Check one)*

- ☐ VERY FIRM ☑ FIRM ☐ MODERATELY FIRM ☐ SLIGHTLY SOFT ☐ SOFT ☐ VERY SOFT ☐ EXTREMELY SOFT

TEXTURE OF LEAN *(Check one)*

- ☐ VERY FINE ☑ FINE ☐ MODERATELY FINE ☐ SLIGHTLY FINE ☐ SLIGHTLY COARSE ☐ COARSE ☐ VERY COARSE

2

YIELD GRADE

2.6
BY TENTHS

YIELD FACTORS

CARCASS WEIGHT *(From packer's hot wt. tag)*	FAT THICKNESS *(Inches, nearest 1/10 in.)*		RIB EYE AREA *(from Grid)*	KIDNEY, PELVIC AND HEART FAT *(As per-cent of carcass weight)*
706 LB.	.2 IN. ACTUAL	.2 IN. ADJUSTED	11.7 SQ. IN. BY TENTHS	3.5 PCT. ESTIMATED

3-12-75
(DATE)

Robert Hall
(SIGNATURE OF GRADER)

To aid in placing, each one-third of a grade change in USDA quality grade above Choice may be considered to be comparable to an increase of 0.8 percent in yield of boneless retail cuts. However, the advisability of giving credit for a quality grade above USDA low Prime is questionable. Also, if certain placings are very close and difficult to make with objective measurements, subjective evaluation should be used. Therefore, it is imperative that a qualified person or persons be responsible for interpreting the data obtained, as well as for determining the final ranking of the carcasses in a quality beef contest.

Helpful Publications and Materials. For those interested in beef carcass evaluation, there are other sources of information. Several of these are listed here.

USDA Publications

Beef Carcass Yield Grade Finder

This handy slide rule is useful in determining the yield grade by tenths. Printed on the back of it is a conversion table showing the percent cutability for each tenth of a yield grade.

Official Standards for Grade of Carcass Beef

This is the official standard by which carcass beef is graded. It covers both the quality and yield grades.

USDA Yield Grades for Beef, Marketing Bulletin No. 45

This bulletin explains in everyday language how the yield grades work for live cattle and beef and shows some economic differences between yield grades.

The above publications may be obtained by writing to:

U.S. Department of Agriculture
Agricultural Marketing Service
Livestock Division - Standardization Branch
Washington, D.C. 20250.

American Meat Science Association Publication

Recommended Procedures for Beef Carcass Evaluation and Carcass Contests

This publication has been prepared by the American Meat Science Association in cooperation with the Beef Improvement Federation as a guide to carcass evaluation in beef. The publication goes into considerable detail and should be useful to those interested in beef carcass evaluation.

The above publication may be obtained by writing to:

American Meat Science Association
36 South Wabash Avenue
Chicago, Illinois 60603.

DISTRICT OFFICES OF THE USDA MEAT GRADING SERVICE

AREA	ADDRESS	TELEPHONE
Eastern		
Georgia	1718 Peachtree St., N.W. Room 204 Atlanta, Georgia 30309	404/526-5159
New Jersey, Ohio, and Pennsylvania	1101 State Road Building E Princeton, New Jersey 08540	609/921-3305
Tennessee	465 West Trigg Avenue Memphis, Tennessee 38106	901/948-2815
Central		
Illinois	4101 South Halsted St. Room 203 Chicago, Illinois 60609	312/353-5751
Iowa	225 Livestock Exchange 800 South Chambers Street Sioux City, Iowa 51107	712/252-3287
Minnesota	236 North Concord St. Post Office Bldg. - Box 27 South St. Paul, Minn. 55075	612/451-6877
Missouri	760 Livestock Exchange Bldg. Kansas City, Missouri 64102	816/842-3810
Nebraska	609 Livestock Exchange Bldg. Omaha, Nebraska 68107	402/731-2015

AREA	ADDRESS	TELEPHONE
Western		
California	4747 Eastern Avenue Bldg. 7, Section A Bell, California 90201	213/265-0536
	630 Sansome Street Room 745 San Francisco, Calif. 94111	415/556-5815
Colorado	206 Livestock Exchange Bldg. Denver, Colorado 80216	303/837-4089
Oklahoma	232 Livestock Exchange Bldg. Oklahoma City, Oklahoma 73108	405/232-5425
Oregon	2416 N. Marine Drive Room 217 Portland, Oregon 97217	503/289-8848
Texas	104 Livestock Exchange Bldg. Fort Worth, Texas 76106	817/624-2209
	P.O. Box 9175 Amarillo Livestock Auction, Amarillo, Texas 79105	806/372-7361
Utah	North Salt Lake Stockyards North Salt Lake, Utah 84054	801/524-5001

ESTIMATED BREEDING VALUES

The issue in record utilization is selection. The central concept in selection is the notion of breeding value. Records can be utilized to estimate the breeding value of prospective parents. Selecting an estimated breeding value can enhance the effectiveness of selection. The purpose of this section is to consider the estimation of breeding values from performance records available in performance programs and to examine their value in beef breeding programs.

UTILIZATION OF EXISTING RECORDS

Beef performance records are relatively expensive both in terms of money and in time required to obtain them. Cattle have a long generation interval, a low reproductive rate, and are expensive. These latter two problems result in a low intensity of selection, especially in cows. If the existing records can be utilized to increase the accuracy of selection even a bit, without increasing the generation interval or reducing the intensity, this advantage should be used in performance programs serving the beef industry. This can be done by estimating breeding values, based on the available relative and individual performance records.

SELECTION AND BREEDING VALUES

Selection and breeding values are related, since the response to selection per year is:

$$\text{Response/Year} = \frac{\tfrac{1}{2}(\text{Breeding Value of Sires}) + \tfrac{1}{2}(\text{Breeding Value of Dams})}{\text{Average of Sire's and Dam's Generation Interval}}$$

where the Breeding Value = Heritability x Selection Differential.

This applies to selection based on the individual performance of the parents. Using the same logic, the estimated breeding value of a bull for yearling weight based on his own record is the difference between his record and the contemporary average multiplied by heritability. His superiority or inferiority is regressed toward the average by the fraction of the difference expected to be heritable. If heritability is 40 percent and a bull is 100 pounds superior to his contemporaries in yearling weight, his estimated breeding value is .4 x 100 = 40 pounds. On the average, this bull would be expected to transmit 20 pounds to his progeny.

RELATIVE SOURCES OF INFORMATION

Progeny, half-sibs, and parents, as well as the performance of an individual, can be used in breeding value estimation, since they all have genes that are identical by descent from some common ancestor. Table 1 presents the various sources of relative information available in most performance programs.

Table 1. Accuracy of Records on Relatives for Estimating Breeding Value of an Individual Animal

Relatives	Number	Genetic relationship	Heritability 20%	40%	60%
Parent	1	1/2	.22	.31	.39
Midparent	2	.71	.317	.449	.55
Paternal half-sibs	10	1/4	.30	.36	.40
	40	1/4	.41	.45	.47
Maternal half-sibs	2	1/4	.15	.22	.26
	4	1/4	.21	.28	.33
Individual	1	1	.45	.63	.77
Progeny	10	1/2	.59	.72	.80
	40	1/2	.82	.90	.94

To evaluate the sources, the table gives the accuracy or correlation between the true breeding value and the estimated breeding value, using the particular relative information. Three heritability values are used. The accuracy is higher, the more heritable the trait. As the genetic relationship to the individual animal increases, so does the accuracy. When the numbers in the relative groups increase, the accuracy goes up. The rate of of increase is faster for high heritability than for low, but diminishing returns for increasing numbers set in more quickly for high than for low heritability. The accuracy of selection is influenced by heritability, relationship, and number of relatives in the average.

The primary relatives in beef records are the individual animal, his paternal and maternal half-sibs, and his progeny. If sibs are available, the parent records add little. The first three sources are available at or before reproductive maturity, while the progeny require an increased generation interval to obtain. The use of sib or progeny averages helps in breeding value estimation, since the groups are usually unselected and the averaging of several records tends to cancel out the plus and minus environmental differences, leaving more nearly a genetic value for the average.

These sources of information can be combined into a single estimate of breeding value for each animal that is the subject of selection. This is done by using the numbers in the averages, the heritability, and the relationships to develop a set of linear equations that, when solved, give proper weighting factors to the particular information available on the individual animal for the trait. Then, these weights times the records expressed as deviations will give an estimated breeding value. The value is for the particular trait, using the available information. This procedure has some desirable properties for the breeder using the values for selection. First, the correlation between true and estimated breeding value is maximum. Second, the estimate is regressed toward the average, depending on the amount of information. This latter feature makes it possible for the breeder to use these values to fairly rank individual animals that differ in the amount of information available. The computation of estimated breeding values is done easily by computer, but otherwise is extremely difficult.

Table 2. Relative Amount of Attention that Should Be Paid to Various Relative Groups in Estimating Breeding Value of an Individual Animal

Numbers				Percentage attention			
IND	PHS	MHS	PROG	IND	PHS	MHS	PROG
1	10	2	0	44	42	14	0
1	20	4	0	33	46	21	0
1	10	2	10	18	17	6	59
1	20	4	20	10	14	6	69

SELECTION INDEX

Theory is available to combine information on several traits into a selection index, so that selection could be based on the index. The additional information necessary to compute such an index is the economic value of each trait, the genetic and phenotypic correlations between the traits, and a specification by the breeder of net merit. Which traits are used and how they relate economically are individual breeder problems in the determination of goal and cannot be set for him by his performance record program.

Two logical alternatives exist for the breeder that gets estimated breeding values on his herd for several traits. First, he can weight the estimated breeding values by appropriate economic values and use this as his selection criterion. Second, he can use an independent culling level for each trait. When the values for the first trait are available, he can select a fraction P of the animals, and when the second trait values are available, he can select a fraction Q of the remaining animals. The product P x Q must equal the number of replacements necessary.

PRESENTATION OF ESTIMATED BREEDING VALUES

There are two ways estimated breeding values can be presented for use by the breeder. The first is in the form of a selection worksheet, and the second is in the form of a performance pedigree. The first is useful in making selections in a breeding program; the second has as its purpose promotion of breeding stock.

Selection Worksheet

The selection worksheet gives the animal identification, available data for that animal, and estimated breeding value, based on the records on a contemporary group of animals in a herd. The purpose is to use the selection worksheet in conjunction with common sense to select breeding stock. For example, each time a group of calves is weaned, the breeder receives selection worksheets that give the estimated breeding values of the male and female calves separately, along with the values for the dams and sires. These are current worksheets which give all relevant weaning data for each individual animal that is on record. From this, the breeder can make his first selection on the calves and cull his cows in conjunction with a pregnancy test. When yearling selection worksheets are sent, the breeder can select his sire prospects, develop his sale bull offering, and make decisions about his herd bulls before he lots his sires for breeding. Use of the selection worksheet is a way to make effective use of records in a breeding program.

Performance Pedigrees

Performance pedigrees are primarily promotion, especially if the selection worksheets are being used. Using the information on a performance pedigree to estimate a breeding value for each trait of importance is a much safer procedure than trying to come up with a sound analysis of the pedigree mentally. Human nature is such that the good records get over-evaluated, and the poorer ones are sometimes forgotten. The individual performance of the ancestors when expressed relative to their contemporaries provides an excellent means of determining the selection practiced in the herd. As a promotional tool, the breeding value is an estimate of what that individual animal is expected to transmit to his or her offspring. The breeding value concept is precisely what a breeding stock breeder is selling. It is what the stock of a breeder does in the herd of the buyer that makes the performance reputation.

BREEDING VALUE ESTIMATION

Following are the statistical and computational details of estimating breeding values. This information may be used by BIF organizations to develop programs to estimate these values routinely. The information needed for each individual animal, if available, is as follows:

1. His own performance as a deviation or a ratio deviation from his contemporary group.

2. The average performance of his paternal half-sibs as the average of the individual deviations or ratio deviations and the number of sibs. The individual animal's own record should be excluded from the average.

3. The same as number 2, except for maternal half-sibs.

4. The average performance of his progeny as the average of the individual deviations or ratio deviations and the number of progeny.

After this information has been collected, the following set of linear equations must be solved for the B values for each individual:

$$
\begin{aligned}
1/H \cdot B_1 &+ 1/4 \cdot B_2 &+ 1/4 \cdot B_3 &+ 1/2 \cdot B_4 &= 1 \\
1/4 \cdot B_1 &+ \frac{4+(N_1-1)H}{4N_1H} \cdot B_2 &+ 0 \cdot B_3 &+ 1/8 \cdot B_4 &= 1/4 \\
1/4 \cdot B_1 &+ 0 \cdot B_2 &+ \frac{4+(N_2-1)H}{4N_2H} \cdot B_3 &+ 1/8 \cdot B_4 &= 1/4 \\
1/2 \cdot B_1 &+ 1/8 \cdot B_2 &+ 1/8 \cdot B_3 &+ \frac{4+(N_3-1)H}{4H_3H} \cdot B_4 &= 1/2
\end{aligned}
$$

The values that change from one animal to the next are as follows:

N_1 = number of paternal half-sibs excluding the individual
N_2 = number of maternal half-sibs excluding the individual
N_3 = number of progeny

The symbol H is the heritability for the particular trait. Only the lead diagonal coefficients change; all other coefficients are genetic relationships. If an individual has only part of the information, the row and column where no data is available are eliminated. The solution to these equations can be obtained by matrix inversion as:

$$C \cdot B = R$$
$$B = C^{-1} \cdot R$$

where C^{-1} is the inverse of the matrix of coefficients C. After solution, a set of weights or regression coefficients is available. These are multiplied by their respective relative average and summed as:

B_1 . Individual deviation
$+ B_2$. Paternal half-sib average deviation
$+ B_3$. Maternal half-sib average deviation
$+ B_4$. Progeny average deviation.

This sum of products equals the estimated breeding value. The accuracy of the estimated breeding value is:

$$\text{Accuracy} = \sqrt{B_1 \cdot 1 + B_2 \cdot 1/4 + B_3 \cdot 1/4 + B_4 \cdot 1/2}$$

The accuracy is an indication of the confidence to be placed in the estimated breeding value, but the estimate has already been regressed; therefore, this value should not be considered again. An approximate standard error of the estimated breeding value is:

$$\text{Standard Error} = \sqrt{H \cdot \text{Variance} \cdot (1 - \text{Accuracy}^2)}$$

where Variance is the phenotypic variance of the particular trait. This information on each animal should be listed for use by the breeder and returned to him as soon as possible after the trait has been evaluated.

PERFORMANCE PEDIGREE

A performance pedigree can be a useful tool for the producer in his breeding program. Its value and usefulness will be fully realized when a large segment of the industry utilizes performance programs. A major role of progressive recording organizations may be to provide the performance pedigree to seedstock producers.

In the future, the recording organization should combine the genealogy and performance pedigrees. Such a pedigree would contain a complete listing of an animal's performance record and its ancestors' performance and progeny records.

The concise form of such a certificate will make it useful in reporting performance information in sale and promotion efforts. A performance pedigree discourages reporting incomplete or selected performance data.

A performance pedigree should include at least individual performance on the animal, sire, and dam, along with progeny information on the sire and dam, and could include information through three generations. Each recording organization may develop a pedigree format consistent with its needs. Information in addition to that which is recommended may be added to this pedigree as deemed desirable by individual organizations.

The recommended basic performance information is as follows:

Animal's individual record --

- Birth weight
- 205-day adjusted weaning weight
- Weaning weight ratio
- Number of contemporaries, weaning
- 365, 452, or 550-day adjusted yearling weight
- Yearling weight ratio
- Number of contemporaries, yearling

Progeny of each individual in pedigree --

- Number of progeny and average weight ratios

Additional considerations --

- Breeding values may be added to any traits that are considered important.

NATIONAL SIRE EVALUATION PROGRAM

GENERAL CONSIDERATIONS

Goals. Sire selection and, consequently, sire evaluation are basic to all beef breeding programs. The performance of the individuals, of their ancestors and collateral relatives, and of their progeny can all be used to estimate differences in breeding values among sires. The usefulness of these sources of information depends on the heritability of the trait, on whether the trait can be measured in the individual, on the number of sires in the group which can be fairly compared, and on the prospective use of the selected sires.

National sire evaluation has as its goal the increase in the number of sires that can be fairly compared on breeding value differences obtained from all sources of information. Today, fair comparisons among sires on their own performance are impossible unless they were tested together in the same group. This is due to large differences among groups caused in part by genetic, but primarily by environmental differences. As more is learned about the beef population through the progeny tests, all sources of information on breeding value will become more useful.

Sire selection for most traits is paramount in within-breed improvement. This increase can be transmitted directly to the commercial producer, even though he may be crossing breeds for heterosis and combining breed strengths in a systematic program. This economic potential for crossbreeding suggests the encouragement of breed-wide sire evaluation programs to strengthen breeds in their effort to be relevant commercially.

Definition. A National Sire Evaluation Program for a breed is a program designed and conducted by one organization having no direct interest in the test bulls. The purpose of such a program is to enhance the effectiveness of sire selection in the breeding programs of breeders. Currently, this is being accomplished by conducting a program that provides fair comparisons among as many sires of the breed as possible on expected progeny differences, computed using progeny averages compared through the progeny averages of reference sires for the traits of major economic concern to the breed.

Foundation. The foundation stones of such a sire evaluation program are the many creative breeding programs being conducted in the breed. When heritability is at least moderate and the trait is measurable on the individual, a sequential selection scheme results in near maximum gain. A sequential scheme involves selection first on own performance followed by selection based on the performance of progeny. Top yearling bulls based on their own performance and that of their close relatives are candidates for use and, as a result, are candidates for a progeny test. The development and conduct of a progeny test by the breeder are critical. Such a test can be conducted in the breeding herd and/or in a commercial herd as well, when carcass evaluation is important. Proper allocation of cows to test bulls and equal treatment of progeny will result in fair comparisons among test bulls. All that is needed to tie such a program to a breed-wide sire evaluation program is to use reference sires in the test to provide comparison with all bulls of the breed so tested. This gives the participating breeder many more bulls from which to accurately select and thus enhance the effectiveness of his sire selection.

History. The basic problem in sire evaluation reduces to one of comparison. Since the world is comparative, the issue becomes to what should sires be compared? Throughout livestock history, cattlemen have developed procedures to make comparisons among sires. The oldest is the fair where cattle were assembled and subjectively compared by recognized judges.

Relatively recently, objective performance tests were developed, and the performance of animals was compared to a designated standard. Then, the contemporary average of a group became the standard for comparing individuals in one group with others in similar groups using the ratio. Already, a national sire evaluation procedure was operational for dairy cattle, made practical by the widespread use of artificial insemination and a national record system.

The BIF Guidelines for National Sire Evaluation Program have incorporated the experience of dairy sire evaluation and the realities of the beef industry into a system using as the base of comparison reference sires. Comparisons among individually fitted show animals, with set performance standards, with within-group ratios all for one reason or another fail to make adequate comparisons for the current beef industry.

PROGRAM TYPES

To date, several National Sire Evaluation Program types are being conducted. This diversity is healthy and is encouraged. The types range from the use of existing field records, through designed tests that use beef progeny tests, to programs completely conducted by the organization. The common element of each program type is the base of comparison among sires -- which is reference sires. Organizations that conduct sire evaluation programs either designate bulls as reference sires, or they establish rules by which sires used extensively become reference sires. The gradient between program types is the amount of control both in design and conduct exercised by the organization.

Field Records. These programs use the performance records available from routine performance programs to estimate the expected progeny differences of sires. Extensive artificial insemination in a breed is necessary to have enough sires used over groups to tie the sire comparisons together. The newly-introduced breeds have capitalized on the widespread use of artificial insemination and the performance requirement for registration to develop this type of program for sire evaluation. Fair comparisons among sires have been the rule. As vested interests become involved in exclusively testing bulls, problems can arise because of no control over cow assignment or progeny treatment. Clearly, more progeny from more groups will be required to eliminate the chance of such problems influencing the comparisons. As the established breeds relax their artificial insemination restrictions, the opportunity exists for them to use such programs in conjunction with existing programs designed to monitor the value of sires being used extensively in the breed.

Designed Test. These sire evaluation programs are designed in that the organization specifies the conduct of the breeder-operated progeny tests and specifies the particular use of designated reference sires. Such programs vary in the amount of control over the progeny tests and in the use of reference sires. The reference sires can be compared together in a series of progeny tests conducted by the organization; then, only one such sire need have progeny in a particular breeder test. The accuracy of this system is dependent on how well the reference sires are compared initially. In another system, each breeder progeny test pays its proportionate share of reference sire comaprisons by using two or more reference sires. Large numbers of progeny spread over numerous tests give good reference sire comparisons, reducing the possible chance of expected progeny differences more nearly to a function of progeny numbers from the test bulls. Various degrees of control over the tests can be exercised by the organization. Minimum inspection prerogatives to complete conduct of the program are possible.

THE PROGENY TEST

Basics. Today, the progeny test using reference sire progeny as the common base of comparison is the method to fairly compare bulls on their breeding value differences. The basics of a sound progeny test are as follows:

> COMPARABLE COWS: All bulls to be compared must be mated to a comparable set of cows. This is necessary to eliminate cow differences from the differences between sire progeny averages.
>
> EQUAL PROGENY TREATMENT: The resulting progeny from all bulls must be given equal treatment. This is necessary to eliminate environmental differences from the differences between sire progeny averages.

Any deviation from these basics leads to comparisons among bulls that are not true reflections of their breeding value differences. Organizations conducting a National Sire Evaluation Program must develop a set of progeny test procedures that comply with BIF recommendations for testing, measuring, and reporting specific traits and a set of checks on the conduct of the participating progeny tests. The criteria for developing procedures and checks are as follows:

> CREDIBILITY: The degree of control over the progeny tests must be such that the results of the program will have industry credibility.
>
> PARTICIPATION: The procedures and checks imposed must be simple enough to folow so that there will be maximum participation in the program by breeders.

Procedures and Checks. To design and conduct a program that has nationwide participation of the significant germ plasm of a breed while maintaining high credibility is not easy. Suggested test procedures and checks for designed programs are as follows:

> Planning. All breeder progeny tests need to be planned carefully in advance, and plans need to be approved by the organization. The number of cows available is usually the limiting factor. Management factors that may affect the conception rate must be optimized to insure that an optimum number of calves will result from the matings made by artificial insemination for the progeny test. To optimize

the use of the test herd, a compromise must be made between the number of bulls to test and the number of progeny to test per bull. In a sequential scheme, at least 20 progeny per test bull are necessary. The number of progeny from reference sires is 10 when only 1 bull is being compared. The number of progeny from reference sires increases by 5 for the addition of 1 more bull, up to 7 when it requires 40 progeny. Additional test bulls over 7 require no more progeny from reference sires. Multi-herd tests are encouraged.

Cow Assignment. Progeny tests may be conducted using any kind of cows, since the comparisons among test bulls and the reference sires are all within equal opportunity groups. The available test cows need to be grouped according to all known causes of differences, such as age, breed or cross, and management group. Each test bull and the reference sires need to be bred to a proportion of each cow group.

Cow Randomization. Within each cow group, the bulls must be mated at random to cows. Randomization is an admission of ignorance. When no way can be found to predict which cow is mated to which bull, the assignment is random. The reason for randomization is to assure that unknown differences among cows do not influence the comparisons among sire progeny groups. Two randomization procedures are recommended, depending on the circumstances.

(1) The organization can assign cows to bulls within cow groups at random before the breeding season. This procedure is recommended for breeders testing bulls in their own herd to increase the credibility.

(2) The organization can randomly assign bulls to a breeding chute rotation listing the order of bulls to be used as cows come into estrus. Some bulls may need to be listed more than once within the rotation order to provide the number of matings needed. This procedure is recommended for breeders testing bulls in contract herds where those doing the breeding have no direct interest in the test bulls. This chute randomization procedure helps to spread the calves by each sire over the season and is the method of choice.

Progeny Treatment. The progeny tests must manage the resulting progeny as uniformly as possible within cow groups or in a stratified fashion such that all sire progeny groups are represented in each management-sex group. Bull, steer, or heifer progeny may be used in the test.

Data Control. The organization needs assurance that the cows were bred as planned. Birth dates need to be reported promptly and accurately. The tests and resulting measurements required by the organization for the particular breed need to be taken and recorded as prescribed by BIF. The organization needs at least the prerogative to inspect the performance records for accuracy.

REFERENCE SIRE SYSTEMS

The organization conducting the breed sire evaluation is responsible for the reference sire system. For the designed test where the reference sires are stipulated by the organization, cooperative handling and distribution of frozen semen to the progeny tests are a part of the program. Also, the organization must have a procedure for assigning usage of sires such that all reference sires are compared with each other adequately.

The criteria for a reference sire in those programs using field records is that he have a large number of progeny (100 to 500) evaluated in a large number of herd-groups (10 to 50) in comparison with many (5 to 10) other reference sires. In those programs that designate reference sires, these should be chosen from among the top sires tested previously, such that a sire is used as a reference sire for at least 2 years and that approximately half are replaced in any one year, which allows for ties to be created between sets of reference sires. The number of designated reference sires should be the minimum needed to facilitate accurate comparisons among them, and yet enough to service an expanding program.

A well-conducted reference sire system offers the breeds a unique opportunity to measure genetic change in the breed by comparing the progeny performance of new sires with that of the base set of reference sires.

EXPECTED PROGENY DIFFERENCE

The expected progeny difference is an estimate from the existing progeny data of half of the breeding value of a sire or what he is expected to transmit to his offspring. It is an estimate of how future progeny of the sire are expected to perform relative to the progeny performance of the reference sires, when both are mated to comparable cows and the resulting progeny are treated alike. The important aspect is to predict future progeny performance from the sample of progeny performance currently available. Therefore, the sire progeny differences are regressed toward the average expected progeny difference, which is zero, depending on the number and distribution of progeny involved in the difference and on the heritability of the particular trait. The expected progeny difference should be reported in the units of measure of the trait. It can be either a plus difference or a minus difference. For most traits evaluated, a plus value indicates a superior sire.

With each expected progeny difference will be a possible change value. This change value is a measure of the accuracy (based on the number and distribution of available progeny) of the expected progeny difference in predicting future progeny performance. It indicates the amount of change, either plus or minus, that is possible in the expected progeny difference when additional progeny are included. Changes of twice the possible change should occur only 1 time in 20.

Because the expected progeny differences are regressed back toward the average, depending on the number and distribution of progeny, the expected progeny differences of sires are directly comparable, even though the progeny numbers and resulting possible change values are different. The choice of sires to use should be on their expected progeny differences for the traits of importance to the breeder making the choices. When two sires have the same expected progeny difference, then the possible change can be used to indicate the extent to which the sires should be used.

Bulls evaluated with 10 to 50 progeny along with reference sire progeny will allow breeders to select breed-improving sires from among the top 10 to 20 percent of bulls tested. Which of the several are best will not be known.

ANALYSIS PROCEDURES

The calculated expected progeny differences and their possible change values from all sire evaluation programs need to have the same interpretation for the beef industry. A common analysis procedure will help, but is not essential. For those organizations not yet having an analysis procedure, Appendix 1 provides a recommended procedure.

PUBLICATION OF A SIRE SUMMARY

Periodically, the organization conducting the program should publish a sire summary that includes information on all of the sires evaluated regardless of their merit. The purpose of such a sire summary is to describe the germ plasm available for the traits considered of major economic importance to the breed. Selection of sires from among those described is the prerogative of the breeder.

A sire summary should strive to give as much descriptive data as is necessary and available, so that the breeders can have available to them the necessary data on which to make rational decisions. Suggested inclusions are as follows:

> IDENTIFICATION: Complete sire information, including the parentage, is necessary.
>
> EARLY PERFORMANCE: A report on the individual performance of the sire in his herd of origin, along with performance on ancestors and close collateral relatives, especially for maternal evaluation, would be valuable.
>
> SIRE EVALUATION: For the traits considered of prime importance to the breed, at least the following three items should be included on each sire:
>
> > The expected progeny difference reported in the units of measure of the trait. For weaning and yearling weight, ratios can also be included.
> >
> > The possible change reported in the units of measure of the trait.
> >
> > The actual total number of progeny tested for the sire. This may differ for different traits.

The exact format for such a sire summary is left to the organization conducting the breed program. The summary should include a description of how to use the sire summary in selection.

TRAITS

Performance. Selection of the particular traits that should be evaluated in a National Sire Evaluation Program is the prerogative of the organization conducting the program for the breed. Individual progeny tests are encouraged, in order to evaluate extra traits, especially when these could be important to breed improvement. Traits suggested for consideration by breed programs are as follows:

> Reproduction. Some adequate measure of calving ease would be beneficial to some breeds. The inclusion of provisions to evaluate the maternal performance of daughters as to their overall reproductive potential, including calving and breeding data, would enhance those breeds, considering their maternal potential in the commercial industry.
>
> Production. BIF recommends several measures of growth during the relevant commercial period, such as weaning weight and several measures of yearling weight (365-day, 452-day, or 550-day). Again, provisions to include the weaning weights of daughters are desirable.
>
> Product. The amount (yield grade) and quality (quality grade) of the product produced is not directly meaurable on the sires. Information on carcass evaluation adds new information in a sequential selection scheme. Such carcass progeny tests can be used effectively as sib tests on the sons from the tested sires.

Undesirable Genes. The problem of undesirable genes is always present in the beef industry. At this writing, work is being done on the development of guidelines for the classification of all detrimental physiological conditions in cattle known to be inherited, the identification procedures necessary to identify the sire once a genetically-defective calf exists, and the action to be taken once a sire has been incriminated, including consideration of his sons.

Bulls may be progeny-tested for undesirable recessive genes by two methods. Both test for all recessives. The first method is breeding to a large cross-section of cows. The probability of detection is a function of the existing gene frequency. The probability of detection equals:

$$1 - (1 - \tfrac{1}{2}q)^n$$

where (q) is the gene frequency in the cow, and (n) is the number of progeny. This procedure allows a short generation interval, yet is effective in keeping undesirable, recessive genes at a low frequency.

The second method is to breed a sire to his daughters under strict supervision by the organizations sponsoring the test.

The probability of detection uses the same formula, with (q) equal to ¼. The production of normal offspring from 22 daughters gives a probability of 19 in 20 that the sire does not contain a specific recessive gene. From 35 daughters, the probability is 99 in 100.

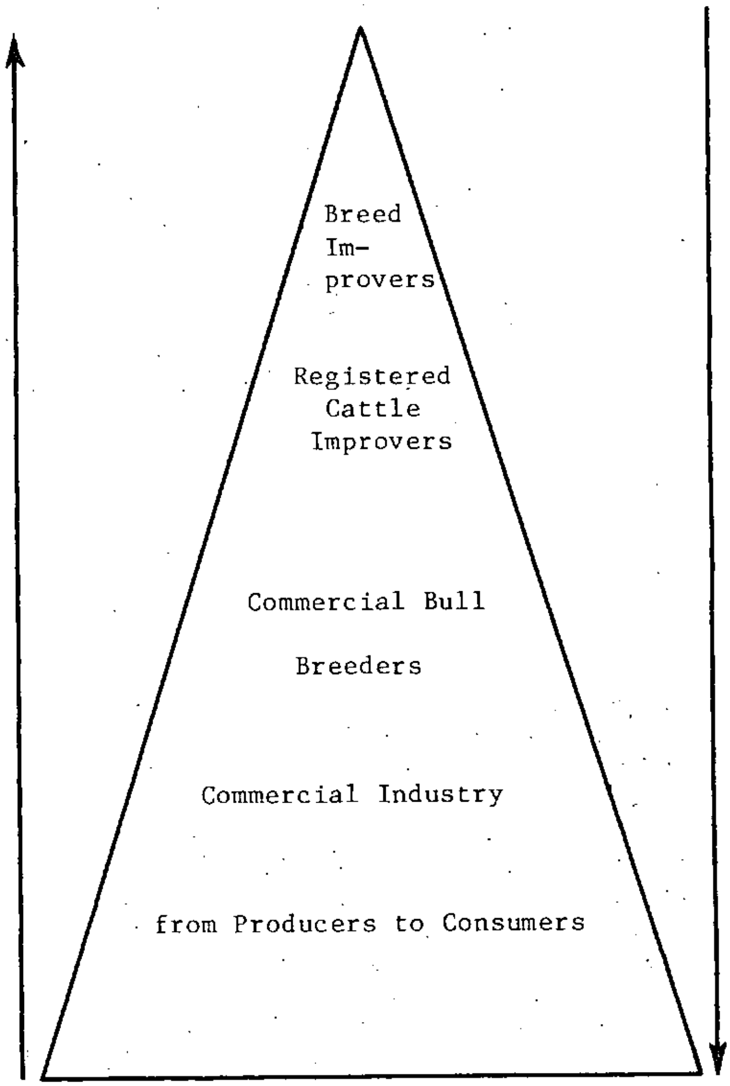
CONCLUSION

The philosophy employed in the development of guidelines for National Sire Evaluation Programs by BIF is one of dealing with the overall spirit and rationale of sound programs, rather than detailing the specifics. This is intentional. Several sound programs of different types are now in operation in the beef industry. Much can be learned from this variety of approaches to the problem of sire evaluation. With the spirit of cooperation now prevailing in the Beef Improvement Federation among the organizations conducting sire evaluation programs, shared experiences should lead to marked improvements in design and conduct of these program, to the improvement of the entire beef industry.

RECORD UTILIZATION

The following diagram illustrates that the performance record system needed by a particular producer depends on his production goals. However, independently of the type of records producers keep, they must be utilized if they are to return any value.

1. <u>Responsibility</u> for performance records.
2. <u>Essentiality</u> of performance records for survival.
3. <u>Complexity</u> & sophistication of records needed.
4. <u>Value added</u> to sale of cattle by superior records.



The following areas are being worked in by BIF to bring about improved utilization of beef performance records:

1. Three sets of guidelines for performance programs offered to the beef industry by BIF member organizations are developed, so that the programs can provide records that can best be utilized by the participants. These guidelines are as follows:

   a. GUIDELINES FOR BREEDING STOCK PERFORMANCE PROGRAMS
   b. GUIDELINES FOR LARGE COMMERCIAL PERFORMANCE PROGRAMS
   c. GUIDELINES FOR FEEDER CALF PERFORMANCE PROGRAMS

2. Develop means to promote enrollment and continued participation of cattlemen in performance programs. This is being worked on by the following means:

   a. Publishing educational material on performance record use for all segments of the beef industry. Examples of this activity are the pamphlet on THE BULL SELECTION PROBLEM and the section in this publication on ESTIMATED BREEDING VALUES.

   b. Working with BIF member organizations in developing educational material, revising existing programs to include reproduction data and breeding values, and developing new programs to service new segments of the beef industry.

   c. Working with the news media to promote record utilization throughout the beef industry. This is being done through articles and news stories that appear in the farm news media.

Organizations within BIF with strong, active performance programs need to consider developing other performance programs that generate profitable record systems for other segments of the beef industry. With many State BCI associations phasing out of the recordkeeping business, the opportunity is great for active organizations with computer hardware and software capabilities to increase volume and reduce cost per unit of output. Many good commercial producers need or will need good performance programs. Opportunity exists to develop cheap, simple, and complete commercial programs for the large producer, and feeder calf programs for both the large and small commercial producer.

PROGRAM GUIDELINES

Three sets of guidelines have been developed and are discussed here, so that revisions and updates of old performance programs can be made and new performance programs made more useful to the beef industry.

GUIDELINES FOR BREEDING STOCK PERFORMANCE PROGRAMS

Reproduction. Calf crops start with the mating decisions a year prior to birth. Breeding stock programs should have breeding forms to record matings and dates. Following a pregnancy exam, the breeding forms can be sent in, where they constitute the prelist for birth and weaning data the following year. Such forms record the reproductive performance of the cow herd. Further, they can be used for registration of the calf crop.

Simplicity. Programs should be simple for the breeder or the customer. Worksheets must be prelisted in some useful sequence and previous weights given, if applicable, convenient in size for easy writing, of high quality paper, and with enough space to record easily. Performance programs must be developed with the breeder or customer in mind, and not with the data flow being the primary consideration. Carbon copy use on the farm should be avoided. Hand-copying of records by the breeder is obsolete and errors are often generated by this method. Copy machines are available. The less desk work required of the customer, the greater will be the participation.

Timing. The adjusted and analyzed records need to be available to the breeder at the time they can be used in selection and for other decisions. Adjusted weaning weights are of little value after selection. Contemporary groups should be processed immediately. Dam summaries are of value when culling is done. Sire summaries should be available, especially for yearling and carcass data before sires are selected to go into the breeding season. The general rule for record processing is "raw data in, processed data out as soon as possible".

Utilization. The available information on a trait for a particular set of individuals to be compared should be utilized. The records on close relatives exist in the data sets for herds and can be used to provide the customer with estimated breeding values. Ranking of individuals on their estimated breeding value using all available information for a trait will increase the accuracy of selection. Refer to the section on estimated breeding values.

Honesty. The honesty and accuracy of the breeder in keeping records are the backbone of the system. The beef industry is built on this. The breeding stock producer sells breeding values, and that is how the calves of his breeding stock perform for the buyer. When his stock does not perform for others, free enterprise solves the problem.

Innovation. Performance programs need to adapt quickly to unified sire evaluation programs. Since sire selection is the key to genetic change in the beef industry, this is imperative. Adoption of uniform testing programs for performance of individual bulls and for uniform progeny evaluation should be accomplished.

Involvement. All cattle in the herd should be involved in the programs.

Participation.

1. Development by each performance organization of a clear, concise write-up of procedures to follow in enrolling and continuing to participate is essential. A calendar for recordkeeping can help the breeder in planning his program. The order involves calving, yearling, breeding, and weaning. Three calf crops are involved in any one calendar year. First, last year's crop must be evaluated as yearlings; second, this year's crop must be born and weaned; and third, cows must be bred for next year's crop. Calving twice a year compounds the problem and calving the year around presents real difficulty.

2. Becoming acquainted with a set of records and how they can be used is a significant aid in interesting new participants in a performance program. Breeders sometimes become disenchanted before sufficient records are accumulated to be of real value. If they could practice on a simulated set of records, they could select and see results as well as become acquainted with the forms and procedures. Such a tool is available in the computer cow game. It has been adapted to use actual forms of a member organization. The opportunities to educate customers using the computer cow game are limitless.

3. Educational material must be developed in depth by the member organizations on just how to use records in selection and in the entire process of beef production. For an organization to serve its customers requires it to challenge all. No breeder today is utilizing his records for selection at near maximum potential.

4. There should be cooperation between all performance programs operating in a State.

GUIDELINES FOR LARGE COMMERCIAL PERFORMANCE PROGRAMS

Large commercial beef producers need performance programs that can be conducted within costs they can afford. By combining records on performance, quality of product, and cost into a management control system, a more modern and scientific approach can be developed for these ranches. The controlled program--production, quality, and cost--should measure in some degree the biological processes that are typical in today's beef production. To direct those biological processes, management must have measurements taken periodically which indicate whether the processes are operating in a normal manner or are deviating sufficiently to justify corrective action. Then, a study should be made to determine the cost of correcting the situation.

What follows are specific guidelines for large commercial performance programs:

The Ranch -- Present and Future. Before any rancher embarks on a continuing record of production and quality characteristics, his first step should be to document his present production and quality level, and set goals for periods of 5 to 10 years in the future. These goals should include records of production characteristics such as number of (and percentage, when applicable) cows bred, calves born, calves weaned, average weaning weight, and average cow weight. To document the quality level of young cattle produced on the ranch, there is a need to record such traits as age and weight in the feedlot, and weight, quality, and yield grade of the finished cattle.

Goals should reflect what appears to the rancher to be the necessary changes in production and quality to establish the most profitable ranch operation within his own personal preferences.

Herd Bulls. Information on young bulls, such as an average 205-day weaning weight and an average weaning weight ratio of all bulls purchased within a given year, is necessary. A registered breeder would also be able to furnish yearling weights and ratios if young bulls are purchased after 12 months of age. A few breeders will furnish feedlot and carcass data on half sibs. Performance information on the individual bulls, plus feedlot and carcass data on half-brothers, is ideal. A 205-day weaning weight and a yearling weight are the minimum. When feedlot and carcass data is available on half-brothers, bulls may be purchased at a younger age, based on 205-day weights and ratios. This would reduce the extra cost of feeding the young bulls, a well as the possible loss of breeding ability because of feeding.

Cow Herd. A calf cannot be weighed that has not been born, and a 600-pound calf weaned from a cow that failed to calve the year before is not very profitable. The most important records the cow-calf producer has are those on the reproductive performance of the breeding herd. Percent calf crop should be calculated every year. It is determined by dividing the number of cows exposed to bulls into the number of calves born. Percent calf crop calculated in this manner furnishes information that relates directly to the reproductive performance of the herd and leaves out calf losses following birth. Records should establish calving intervals. If large numbers of cows exceed an average of 12 months as a calving interval, corrective action should be taken in management and/or breeding.

Weaning Calves. Calf and cow weights can indicate many things related to production efficiency. These are not individual weights, but group weights taken at the time calves are weaned. If calves are weaned and sold at one time, calf weights are available. The weight of the cows annually culled from the breeding herd or a random sample of cows is excellent information. This information will have some meaning as annual weight records. The trend of the calf weight and cow weight over a period of years will reflect some changes in nutrition level, and possibly some genetic change. These two weights can be expressed as an efficiency ratio, using weaning weight as a percentage of mature cow weight. Both calf and cow weights become the basis for many comparisons in subsequent records that help to answer questions about overall efficiency and profitability of the ranch operation.

Feeder Calves. A record program for a cow and calf operation should record the kind of product that is being marketed. This product can be measured by its performance through a feedlot and the carcass characteristics after the feeding period. Goals of a rancher, as they relate to the quality of the product, may vary considerably. In all ranching operations, production efficiency should be of primary consideration. Rate of gain and feed required per 100 pounds of gain is a better figure than the cost of gain on long-term records because of changing feed prices. This information is easy to obtain on large ranches, since weaning calves are sold in large groups to one buyer, and some large ranchers maintain ownership of their cattle. Rate and efficiency of gain can be measured every 3 or 4 years on most ranches, since breeding programs require at least this much time to change one-third of the genetic make-up of the breeding herd. Some ranches may wish to use a random sample of the steer calves instead of feeding the entire calf crop.

Slaughter Cattle. Even though cattle are efficient at weaning time and grow efficiently through the feedlot, carcass characteristics have an effect on profit. Yield and quality grades are used to indicate the product's quality. Grading carcasses on yield and quality is done by USDA graders. When the cattle are sold, it is necessary to make arrangements to have a Federal grader available. A rancher must set his own goal for his market that may require different carcass characteristics. Product quality does not have to be measured on the entire calf crop, but can be measured on a reasonable sample of feeder calves every 3 or 4 years.

Unit Cost and Income. To make decisions on ranch management, records should be more detailed than generally shown in total ranch costs and total ranch income. Costs and income per cow along with costs and selling price per 100 pounds of calf weaned give the rancher an opportunity for a different kind of study of total ranch operation. A section should deal with only cost and income per cow showing these figures on the same form. The comparison of these figures provides an excellent indicator of production efficiency. A section on cost and selling price per 100 pounds of weaned calf would be used to make direct comparisons with costs of production and selling price of each 100 pounds of weaned calf. Differences in these figures are probably the best measures of overall efficiency, other than the percentage of return to total capital investment.

Individual Cow Records. Records can be maintained on large ranches without considerable effort, provided that details of breeding stock programs are omitted. Any individual cow record on large ranches requires a number identification on each cow. This is not unusual, since other industries individually identify production machinery. This number can be put on in the form of a fire brand, an ear tag, a neck chain, or a neck band. Keeping an individual cow record for large ranches does not require that calves be identified with their mothers. A record showing only the identification number of each cow that did not calve or that produced a "reject" calf is all that is necessary for a useful individual cow record. Cows that calve regularly and produce acceptable calves would be considered normal, and records would be so marked. Pregnancy checks can be used to cull cows before the dry perido, which is usually the high-cost time.

GUIDELINES FOR FEEDER CALF PERFORMANCE PROGRAMS

A feeder calf performance program will help breeders to evaluate their breeding and selection programs. Such a program will encourage the production of beef cattle with superior genetic potential for feedlot performance and carcass merit. The program provides a way to develop and document a performance reputation by specification of the product offered for sale.

Feedlot performance would be evaluated by the gain produced during the feeding period. Carcass information evaluated would be on those traits mentioned in this publication in the section on beef carcass evaluation. Consistency with BIF programs would be brought about through the use of the USDA Beef Carcass Data Service program.

PROGRAM ALTERNATIVES

1. Random sampling of the weaning calf crop. The random sample should consist of a minimum of 10 percent of the total calf crop or 10 head, whichever is larger. Fifty head will measure average herd performance, but more may be fed.

2. Random sampling of weaning calf crop with herd certification. It is recommended that the same number of animals be sampled as outlined for the preceding method. In this program, herds that meet minimum feedlot performance and carcass merit standards would be certified by the sponsoring organization.

3. Progeny tests of sire groups. In herds with known sires, 10 head per sire should be enrolled in the feeder calf performance program.

4. Herd certification by using sires meeting standards of performance. This system specifies only half of the genetic input. Over time, producers on such a program can improve their herds, but such a system does not specify the product offered for sale. Therefore, the sampling system where the performance of calves is measured is the method of choice.

HERD SAMPLING

One of the key factors involved in an unbiased evaluation of feeder calf performance is the herd sampling procedure. Each animal should have an equal opportunity of being chosen, if the performance is to reflect an accurate estimate of the herd average.

It is recommended that only steers be used in evaluating feeder calf performance. Before taking the test sample, the producer has the option of sorting of cutbacks that would be made on a normal scale, which should not exceed 5 percent of the calf crop. If the calves are sampled from different pastures within a herd, a proportional part of the sample should come from each location.

PROGRAM MANAGEMENT RECOMMENDATIONS

1. Weight limitations need not be imposed on calves entering the program; however, the sample should be representative of the herd.

2. Calves should be started in the feedlot not later than 30 days after weaning. All calves should be weaned at least 7 days before entry. A growing program between weaning and the feedlot may be incorporated in a program, if desired.

3. Calves should be dehorned and castrated, so that complete recovery occurs before delivery.

4. Calves should be individually identified upon entry. The calves should be the individual production of the ranch and carry individual consignor identification.

5. An adjustment period should be allowed after delivery to the feedlot. At the end of this period, calves should be individually weighed, when possible, and fed a growing and/or finishing ration commensurate with the growth potential of the breed type of cattle involved. The feeding period should be a length of time consistent with producing a desirable carcass at an acceptable market weight.

6. The calves involved may be fed out by the producer in his own lot or by contract in a commercial lot.

7. Detailed carcass data may be obtained through the USDA Beef Carcass Data Service; however, if this program is not utilized, local arrangements should be made with cooperating plants and the USDA meat graders.

In States where feeder calves are produced, but a limited feeding industry exists, cooperation with another BIF member State in a feeding area may be necessary.

UTILIZATION OF DATA

For the rancher who keeps records of production, the data from a feeder calf performance program provides complete performance records. If herd records are not kept, the program provides valuable information, which is difficult to obtain otherwise.

A cow-calf producer may wish to evaluate the contribution of his present bull battery, the contribution of individual sires, or the effectiveness of his crossbreeding program.

RECORD STANDARDIZATION

It is recommended that the descriptive aspect of performance records be emphasized rather than the competitive one. The following NAAB Uniform Breed Codes are recommended. (See Appendix 2 for further details on breed codes.)

Breed	Code	Breed	Code
Africander	AF	Jersey	JE
Angus	AN	Limousin	LM
Ayrshire	AY	Lincoln Red	LR
Barzona	BA	Luing	LU
Beefalo	BE	Maine-Anjou	MA
Beef Friesian	BF	Marchigiana	MR
Beefmaster	BM	Maremmana	ME
Belgian Blue	BB	Meuse-Rhine-Ijssel (MRI)	MI
Belted Galloway	BG	Murray Grey	MG
Blonde d'Aquitaine	BD	Normande	NM
Braford	BO	Norwegian Red	NR
Brahman	BR	Parthenaise	PA
Brangus	BN	Piedmont	PI
Brown Swiss (beef)	SB	Pinzgauer	PZ
Brown Swiss (dairy)	BS	Ranger	RA
Canadienne	CN	Red Angus	AR
Charbray	CB	Red Brangus	RB
Charolais	CH	Red Dane	RD
Chianina	CA	Red Holstein	WW
Danish Red & White	RW	Red Poll	RP
Devon	DE	Romagnola	RN
Dexter	DR	Rotbunte	RO
Eringer	ER	Salers	SA
Flamand	FA	Santa Gertrudis	SG
Fribourg	FR	Shorthorn (milking)	MS
Galloway	GA	Shorthorn (Beef-Scotch)	SS
Gelbvieh	GV	Shorthorn (polled)	SP
Groninger	GR	Shorthorn (Illwara)	IS
Guernsey	GU	Simmental	SM
Hays Converter	HC	South Devon	DS
Hereford (horned)	HH	Sussex	SX
Hereford (polled)	HP	Tarentaise	TA
Highland (Scotch)	SH	Welsh Black	WB
Holstein	HO	West Flemish Red	WF
Hybrid (Alberta)	HY	Crossbreds	XX

Sex. Single birth (or twins where only 1 is raised on dam)

1. Bull
2. Heifer
3. Steer
4. Heifer born twin to bull

Calving Ease Scores.

0 = No difficulty
1 = Difficulty

Management Code.

a. Weaning.

   1. Dam only.
   2. Dam and creep feed (6 weeks or longer)
   3. Irregulars -- for all records not desired in averages. Calves raised under abnormal management, such as twin calf raised as twin, nurse cow, foster mother, sick, injured, or deformed calf.

b. Post-weaning (use as 2-digit combinations).

   1. Age at end of test (1st digit)

      1 -- 12 months (365-day weight)
      2 -- 15 months (452-day weight)
      3 -- 18 months (550-day weight)

   2. Feed levels (2nd digit)

      4 -- Fitted
      5 -- Full Fed
      6 -- Intermediate Feeding
      7 -- Roughage and/or Pastures

      Example of Use:

      14 = Fitted 12-month animal (365-day weight)
      25 = Full Fed 15-month animal (452-day weight)
      37 = Pasture Fed 18-month animal (550-day weight)

Proposed State Code Numbers for Beef Performance Testing Programs (same as DHIA uses).

State Code Numbers (USDA - DHIA)

11. Maine
12. New Hampshire
13. Vermont
14. Massachusetts
15. Rhode Island
16. Connecticut
21. New York
22. New Jersey
23. Pennsylvania
31. Ohio
32. Indiana
33. Illinois
34. Michigan
35. Wisconsin
41. Minnesota
42. Iowa
43. Missouri
45. North Dakota
46. South Dakota
47. Nebraska
48. Kansas
50. Delaware
51. Maryland
52. Virginia
54. West Virginia
55. North Carolina
56. South Carolina
57. Georgia
58. Florida
61. Kentucky
63. Tennessee
64. Alabama
65. Mississippi
71. Arkansas
72. Louisiana
73. Oklahoma
74. Texas
81. Montana
82. Idaho
83. Wyoming
84. Colorado
85. New Mexico
86. Arizona
87. Utah
88. Nevada
91. Washington
92. Oregon
93. California
94. Puerto Rico
95. Hawaii

County Codes. Each State designate - recommend use of USDA-DHIA codes already set up.

Herd Codes. Each State designate.

COMMENTS CODES

Calf Codes

C0	Twin calf--raised on foster dam
C1	Twin calf--raised on own dam as twin
C2	Calf sick
C3	Calf sold prior to weaning
C4	Not weighed
C5	Calf weighed under 160 days of age
C6	Calf weighed over 250 days of age
C7	Calf died at calving
C8	Calf died due to disease
C9	Calf died for other reason

Dam Codes

D0	Cow died--at calving	D5	Cow sold--for breeding use
D1	Cow died--disease	D6	Cow sold--because of age
D2	Cow died--other reason	D7	Cow sold--physical defect
D3	Cow failed to calve	D8	Cow sold--poor fertility
D4	Cow aborted	D9	Cow sold--inferior calves

Sire Codes

S1 Sire owned by another breeder
S2 Sire unknown
S3 Unfertile bull

Temperament Codes

T1 Satisfactory temperament
T2 Fair temperament
T3 Poor temperament

SUMMARY

The essence of record use is selection in the broad sense; that is, records must be used in the decisionmaking of the enterprise, or they are simply an expense. In breeding stock programs, records must be used in selecting parents to make genetic change. In commercial breeding programs, records must be used in selection of parent stock both within the program and in evaluation of breeding herd programs from which to obtain breeding stock. Also, in both programs, these records, properly evaluated, can aid in many management decisions. This is not genetic selection, but selection among alternaties. In commercial feeding enterprises, records are necessary in evaluating sources of stock and determining optimum management. Specification in terms of economically important records, not just groundless advertisement, is becoming the rule in all segments of the beef industry. The development of a performance reputation is the key to tomorrow's success.

MERCHANDISING

Effective merchandising depends on integrity of the breeder, coupled with the use of well-defined terms relating to the product to be sold. Standardized terminology relative to beef cattle improvement has been developed through the Beef Improvement Federation. Use of these standard terms is very important and is strongly encouraged by BIF in advertising and merchandising performance-tested cattle. For example:

205-day adj. wt.	365-, 452-, 550-day adj. wt.
No. of contemporaries	No. of contemporaries
ratio	ratio

BIF is strongly opposed to the use of misleading statements which tend to be deceptive, make impossible claims, or use only selected portions of the total record in the merchandising of performance-tested cattle. Examples of such phrases are:

1. During a 60-day test, this bull gained 5 lbs./day.
2. Son-o-ray ribeye at 2,165 lbs. was ________.
3. Weight of this bull at 23 mos. and 5 days was ________.
4. Calf weighed 363 lbs. at 4 mos. and 19 days.
5. The last 3 calves by this sire weighed 628 lbs.
6. This bull weighed 1,300 lbs. at 14 mos.
7. One calf sired by this bull weighed 1,220 lbs. at 14 mos.

The use of misleading information such as the examples listed above is detrimental to the whole concept of performance testing. Therefore, BIF strongly recommends that member organizations exert every possible effort to inform and educate cattlemen to use BIF recommended standards in advertising and merchandising their performance-tested cattle.

APPENDIX 1: Analysis of Sire Evaluation Data by Mixed Model Procedures 1/

The intent of this Appendix is to demonstrate the procedures to follow for a mixed model analysis of sire evaluation data. Information contained herein should provide the necessary background for getting the programming ready for data inputs and carrying out solutions to yield expected progeny difference (EPD) values and possible change values.

The model for the analysis is $y_{ijk} = \mu + h_i + s_j + e_{ijk}$ where y_{ijk} is the record on the k-th progeny by the j-th sire in the i-th herd or group, μ is the population mean, h_i is the effect of the i-th herd or contemporary group, s_j is the effect of the j-th sire, and e_{ijk} is the unexplainable random portion of y_{ijk}. Equations are set up to solve for the sire effects (EPD's) with μ and h_i effects absorbed. Absorption is merely a mathematical manipulative technique which allows the herd effects to be considered in the analysis without actually estimating them, thus minimizing the number of equations to be solved.

The equations are most easily presented in matrix notation. These equations are As = B where A is a pxp matrix (p = number of sires to be evaluated) and is called the coefficient matrix, s is a px1 vector of the sire effects, and B is a px1 vector and

---

1/ The procedures described and the theory on which they are based were developed by C. R. Henderson. For detailed account, readers are referred to:

Henderson, C.R., 1973, "Sire Evaluation and Genetic Trends," proc. of the Animal Breeding and Genetics Symposium in Honor of Dr. Jay L. Lush, American Society of Animal Science and American Dairy Science Assoc., Champaign, Ill., p. 10.

Henderson, C.R., 1974, "General Flexibility of Linear Model Techniques for Sire Evaluation," Journal of Dairy Science, 57:963.

is called the right-hand-side vector. The following shows the equations in more detail:

$$\begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1p} \\ A_{21} & A_{22} & & \\ \vdots & & \ddots & \\ A_{p1} & & & A_{pp} \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \\ \vdots \\ s_p \end{bmatrix} = \begin{bmatrix} B_1 \\ B_2 \\ \vdots \\ B_p \end{bmatrix} \qquad (1)$$

or in linear form

$$\begin{aligned} A_{11}s_1 + A_{12}s_2 + \ldots + A_{1p}s_p &= B_1 \\ A_{21}s_1 + A_{22}s_2 + \ldots + A_{2p}s_p &= B_2 \qquad (2) \\ \vdots \qquad\qquad & \quad \vdots \\ A_{p1}s_1 + A_{p2}s_2 + \ldots + A_{pp}s_p &= B_p. \end{aligned}$$

Thus, there are p equations with p unknowns (s values).

The values in A and B are as follows:

$$A_{11} = \sum_i n_{i1.} \left(1 - \frac{n_{i1.}}{n_{i..}}\right) + \alpha$$

$$A_{22} = \sum_i n_{i2.} \left(1 - \frac{n_{i2.}}{n_{i..}}\right) + \alpha$$

Thus, the r-th diagonal element of A is $\sum_i n_{ir.} \left(1 - \frac{n_{ir.}}{n_{i..}}\right) + \alpha$

where $\alpha = 4/h^2 = 1$, h^2 = heritability of the trait.

$$A_{12} = -\sum_i \frac{n_{i1.}\, n_{i2.}}{n_{i..}}$$

$$A_{13} = -\sum_i \frac{n_{i1.}\, n_{i3.}}{n_{i..}}$$

$$A_{1p} = -\sum_i \frac{n_{i1.}\, n_{ip.}}{n_{i..}}$$

$$A_{21} = -\sum_i \frac{n_{i2.}\, n_{i1.}}{n_{i..}}$$

Note that $A_{12} = A_{21}$, the two halves of the A matrix, are mirror images; i.e., any $A_{ij} = A_{ji}$. The uv-th off-diagonal element of A is $-\sum_i \frac{n_{iu.}\, n_{iv.}}{n_{i..}}$.

$$B_1 = \sum_i n_{i1.}\, (\bar{y}_{i1.} - \bar{y}_{i..})$$
$$B_2 = \sum_i n_{i2.}\, (y_{i2.} - y_{i..})$$

Thus, the r-th element of B is $\sum_i n_{ir.}\, (y_{ir.} - y_{i..})$. An explanation of the notation may be necessary here.

$n_{i1.}$ = number of progeny by sire No. 1 in the i-th herd

$n_{i..}$ = number of total progeny in the i-th herd

$n_{i2.}$ = number of progeny by sire No. 2 in the i-th herd

i = summation over subscript i (over all herds)

$\bar{y}_{i1.}$ = mean of progeny records by sire No. 1 in the i-th herd

$\bar{y}_{i..}$ = mean of all progeny records in the i-th herd

Consider the following example where the only progeny are those by sires 1, 2, and 3 in herds 1, 2, and 3.

	sire 1	sire 2	sire 3	herd summary
herd 1	10 progeny 1000 lb. avg.	10 progeny 1050 lb. avg.	no progeny	20 progeny 1025 lb. avg.
herd 2	20 progeny 1050 lb. avg.	no progeny	10 progeny 900 lb. avg.	30 progeny 1000 lb. avg.
herd 3	no progeny	30 progeny 925 lb. avg.	10 progeny 825 lbs. avg.	40 progeny 900 lb. avg.

$n_{11.}=10, n_{12.}=10, n_{13.}= 0, n_{1..}=20, \bar{y}_{11.}=1000, \bar{y}_{12.}=1050, \bar{y}_{13.}= 0,\ \bar{y}_{1..}=1025$

$n_{21.}=20, n_{22.}= 0, n_{23.}=10, n_{2..}=30, \bar{y}_{21.}=1050, \bar{y}_{22.}= 0,\ \bar{y}_{23.}=900, y_{2..}=1000$

$n_{31.}= 0, n_{32.}=30, n_{33.}=10, n_{3..}=40, \bar{y}_{31.}= 0,\ \bar{y}_{32.}=925,\ \bar{y}_{33.}=825, \bar{y}_{3..}= 900$

The elements of A and B can be found in the following ($h^2 = .40$, $\alpha = 9$):

$$A_{11} = 10(1 - 10/20) + 20(1 - 20/30) + 0(1 - 0/40) + 9 = 20.667$$
$$A_{22} = 10(1 - 10/20) + 0(1 - 0/30) + 30(1 - 30/40) + 9 = 21.500$$
$$A_{33} = 0(1 - 0/20) + 10(1 - 10/30) + 10(1 - 10/40) + 9 = 23.167$$

$$A_{12} = A_{21} = -[(10.10)/20 + (20.0)/30 + (0.30)/40] = -5.000$$
$$A_{13} = A_{31} = -[(10.0)/20 + (20.10)/30 + (0.10)/40] = -6.667 \qquad (3)$$
$$A_{23} = A_{32} = -[(10.0)/20 + (0.10)/30 + (30.10)/40] = -7.500$$

$$B_1 = 10(1000 - 1025) + 20(1050 - 1000) + 0(0 - 900) = 750$$
$$B_2 = 10(1050 - 1025) + 0(0 - 1000) + 30(925 - 900) = 1000$$
$$B_3 = 0(0 - 1025) + 10(900 - 1000) + 10(825 - 900) = -1750$$

Note here that the sum of the elements in B is zero. The equations to be solved are:

$$\begin{aligned} 20.667\ s_1 - 5.000\ s_2 - 6.667\ s_3 &= 750 \\ -5.000\ s_1 + 21.500\ s_2 - 7.500\ s_3 &= 1000 \\ -6.667\ s_1 - 7.500\ s_2 + 23.167\ s_3 &= -1750 \end{aligned} \qquad (4)$$

Solutions to the equations As = B can be obtained by iteration. Iteration is a repetitive process of re-estimating the values of s using previous estimates of s. Iteration is completed when successive estimates of all s_j value meet a prescribed degree of agreement. The equations in (2) can be written as follows:

$$s_1 = \frac{1}{A_{11}} (B_1 - A_{12}s_2 - A_{13}s_3 - \dots - A_{1p}s_p)$$

$$s_2 = \frac{1}{A_{22}} (B_2 - A_{21}s_1 - A_{23}s_3 - \dots - A_{2p}s_p)$$

$$\vdots$$

$$s_p = \frac{1}{A_{pp}} (B_p - A_{p1}s_1 - A_{p2}s_2 - \dots - A_{p(p-1)}s_{p-1})$$

Initially, no estimates for the s vector are available, and so, they are assumed to be zero. Thus, the first estimates, ${}^1s$, are the following:

$${}^1s_1 = B_1/A_{11}$$

$$\vdots$$

$${}^1s_p = B_p/A_{pp}$$

From here on, the most recent estimates of the s values are used. Observe the following (the notation ${}^2s_1$ refers to the second estimate for sire #1):

$$
\begin{aligned}
{}^{2}s_1 &= \frac{1}{A_{11}}\left(B_1 - A_{12}\,{}^{1}s_2 - A_{13}\,{}^{1}s_3 - \dots - A_{1p}\,{}^{1}s_p\right)\\
{}^{2}s_2 &= \frac{1}{A_{22}}\left(B_2 - A_{21}\,{}^{2}s_1 - A_{23}\,{}^{1}s_3 - \dots - A_{2p}\,{}^{1}s_p\right)\\
{}^{2}s_3 &= \frac{1}{A_{33}}\left(B_3 - A_{31}\,{}^{2}s_1 - A_{32}\,{}^{2}s_2 - A_{34}\,{}^{1}s_4 - \dots - A_{3p}\,{}^{1}s_p\right)
\end{aligned}
$$

For ${}^{2}s_1$ above, only the first estimates on the other sires were available. For ${}^{2}s_2$, the second estimate of s_1 plus the first estimates on the other sires were available. In general notation, these are represented by the following:

$$
{}^{K+1}s_j = \frac{1}{A_{jj}}\left(B_j - \sum_{m=1}^{j-1} A_{jm}\,{}^{K+1}s_m - \sum_{m=j+1}^{p} A_{jm}\,{}^{K}s_m\right)
$$

The process continues or repeat through the sires until $\left|{}^{K+1}s_j - {}^{K}s_j\right|$ is less than some prescribed value for <u>all</u> sires.

From the example in equations (4), solutions via iteration would proceed as follows:

$$
\begin{aligned}
{}^{1}s_1 &= 750/20.667 = 36.2897\\
{}^{1}s_2 &= 1000/21.500 = 46.5116\\
{}^{1}s_3 &= 1750/23.167 = -75.5385
\end{aligned}
$$

$$
\begin{aligned}
{}^{2}s_1 &= \frac{1}{20.667}\left[750 - (-5.000)(46.5116) - (-6.667)(-75.5385)\right] = 23.1743\\
{}^{2}s_2 &= \frac{1}{21.500}\left[1000 - (-5.000)(23.1743) - (-7.500)(-75.5385)\right] = 25.5503\\
{}^{2}s_3 &= \frac{1}{23.167}\left[-1750 - (-6.667)(23.1743) - (-7.500)(25.5503)\right] = -60.5978
\end{aligned}
$$

etc.

When finished, the final s values are the EPD values.

The possible change (PC) values accompanying the EPD for the j-th sire can be calculated as $(\sigma^2/A_{jj})^{\frac{1}{2}}$. Possibly a better calculation of PC for the j-th sire EPD is $(\sigma^2/G_{jj})^{\frac{1}{2}}$; $G_{jj} = A_{jj} + \sum_{\substack{i=1 \\ i=j}}^{p} \frac{A_{ij}}{M_j}$ where M_j = number of A_{ij} values not equal to zero (literally G_{jj} is the diagonal element A_{jj} plus the average of the off-diagonal elements). The value of σ^2 requires some etra calculations on the data, but these are relatively simple. The following describes what is necessary for these calculations:

$$\sigma^2 = (T - H - S)/(n_T - n_h - n_s + 1)$$

where $T = \sum_{ijk} y_{ijk}^2$ = sum of the squared progeny records

$H = \sum_i y_{i..}^2/n_{i..}$ = sum of the herd totals squared and divided by the number in them

$S = \sum_j s_j B_j$, s_j is the final EPD value

n_T = total number of progeny in the data = n

n_h = number of herds in the data

and n_s = number of sires in the data.

AMENDING THE ANALYSIS TO INCLUDE AN INTERACTION BETWEEN SIRE AND HERD (GROUP)

This provides a method of considering the extra correlation between progeny from the same sire in the same contemporary group. The modifications necessary in the equation As=B are:

1) replace each $n_{ij.}$ with $\frac{n_{ij.}\beta}{n_{ij.} + \beta}$

and 2) replace each $\bar{y}_{ij.}$ with $\frac{\bar{y}_{ij.}\beta}{n_{ij.} + \beta}$

The β represents the ratio of the within sire-group component of variance to the sire by group component of variance. With these modifications, the interaction is absorbed into the sire equations and, thus, is accounted for in the analysis.

SOLUTIONS USING MATRIX INVERSION - AN ALTERNATIVE TO ITERATION

If it is computationally feasible, the equations can be solved by $s = A^{-1}B$. Then, the PC associated with the EPD for the j-th sire is $(\sigma^2 \cdot A^{jj})^{\frac{1}{2}}$ where A^{jj} denotes the j-th diagonal element of A^{-1}. The EPD values produced by either this method or iteration will be the same. The PC values may differ. Calculating PC as $(\sigma^2/A_{jj})^{\frac{1}{2}}$ or $(\sigma^2/G_{jj})^{\frac{1}{2}}$ is used as an approximation to $(\sigma^2 \cdot A^{jj})^{\frac{1}{2}}$.

IDEAS ON HANDLING THE DATA

It may be best to have a data file in storage that can be added to each time another herd's data are submitted to the computing facility. The data should be screened so that only records on sires to be evaluated are included. This data could be stored in some form of equations (1) or (2). Only A and B need to be stored until EPD's are calculated. The dimensions of A and B are the number of sires to be evaluated. Each sire must be assigned a number to indicate which row and column of A and element of B receives the data for the sire. If an additional sire(s) needs to be included, one row(s) and column(s) need to be added to A and one element(s) to B. When a herd's data come in, merely add the appropriate values to the appropriate elements of A and B. This can be seen in equations (3) for the three herds. Note in going from left to right across the page how each herd's data are added on. The values of α may be added to the diagonal elements at the first or after the last herd's data are tabulated.

Also needed are the values to calculate the PC values. As the data come in, $\sum_{ijk} y^2_{ijk}$ should be updated, i.e., each (progeny record)^2 and added; plus $\sum_i y^2_{i..}/n_{i..}$ should be updated, i.e., each (herd total)^2/(number in herd) and added.

APPENDIX 2: Uniform Coding System for Identifying Semen--National Association of Animal Breeders (NAAB)

The purpose of the NAAB Uniform Coding System for Identifying Semen is to provide a unique code number for each bull that includes 1) identification of the source of the semen (the organization that processed the semen), 2) identification of the breed of the bull, and 3) a code number identifying each respective bull within breed within each stud.

It is recognized that the registration number for each bull is a unique number. However, it does not identify the source of the semen and, in some cases, is not readily recognizable by breed. Experience has proven that individual herd owners, managers, and technicians prefer to use a more familiar code number instead of the registration number when identifying a sire used. The NAAB uniform code number will, in many cases, be seven or eight characters, which is equally as long as a registration number. However, since different segments of the code number have specific meanings, the entire code is much easier to remember and more acceptable by people in the field than is the registration number. In addition, by eliminating all blanks and leading zeroes, the code number when written will often be shorter than most registration numbers.

The NAAB uniform code number is basically intended for use by commercial artificial insemination (A.I.) organizations in identification of semen as it is exchanged and sold throughout the industry. In addition, the A.I. Requirements of the Purebred Dairy Cattle Association require a code identifying the source of dairy sire semen on each individual unit. Logically, there will be other needs for a code number identifying the source of semen in the future. An example would be pending Federal regulations governing the import, export, and interstate movement of semen. It would not be feasible to print a different code number for each of these and other purposes on each unit of semen in view of space availability and unnecessary duplication.

Incomplete sire identification by registration number in DHI records has for years been a concern because of the tremendous loss of records that otherwise would be available for sire evaluation. Since many herd owners, managers, and DHI supervisors use bull code numbers instead of registration numbers when completing DHI records, most of the DHI record-computing centers are, in many cases, attempting to convert the code numbers into registration numbers by use of a cross-reference listing of each bull by code number and registration number. For this purpose, the entire code number, including stud and breed identification and individual bull number, is necessary for the number to be unique for each bull. Thus, the NAAB Uniform Coding System has been adopted for use in the DHI program by USDA and the DHI computer centers.

The NAAB Uniform Code for Identifying Semen is made up of a total maximum combination of eight characters as follows:

Stud Code - Indicates the semen-producing organization that collected and processed the semen. Stud code numbers are assigned by the NAAB to its member organizations and other semen-producing organizations, where warranted. It is comprised of two characters and may be either numeric, alpha, or a combination of alpha and numeric. Leading zeroes and blanks are omitted.

Breed Code - Dairy breed codes are single alpha characters, consistent with codes designated by USDA for the DHI program. Changes in dairy breed codes should be made only on mutual agreement of the NAAB, USDA, and DHI computer centers. Beef breed codes are two alpha characters and are assigned by NAAB.

Bull Code - Bull codes should be numeric codes with a maximum of four characters, from 1 to 9,999. Individual bull codes are assigned by the respective stud collecting semen from each individual bull. All leading zeroes and blanks should be omitted. When a bull is transferred to a second stud for collection, a different code number should be assigned to the same bull. The stud code appearing as a part of the code combination is different for each stud. Therefore, it is not necessary to attempt to retain the same individual bull code when a bull is moved to a different stud.

Example: 1H166 -- 1 = Stud code for Noba, Inc.
H = Breed code for Holstein
166 = Bull code for Elevation Mission, Registration No. 1600155

APPENDIX 3: Table for Converting Average Weights During Test to Metabolic Weight for Adjusting Feed Efficiency Values for Differences in Maintenance Requirement

(Wt.)	Metabolic Wt.	(Wt.)	Metabolic Wt.	(Wt.)	Metabolic Wt.	(Wt.)	Metabolic Wt.
700	166	850	192	1,000	217	1,150	240
710	168	860	193	1,010	218	1,160	242
720	169	870	195	1,020	220	1,170	244
730	171	880	197	1,030	222	1,180	245
740	173	890	198	1,040	223	1,190	247
750	175	900	200	1,050	225	1,200	248
760	176	910	202	1,060	227	1,210	250
770	178	920	203	1,070	228	1,220	252
780	180	930	205	1,080	229	1,230	253
790	182	940	207	1,090	231	1,240	255
800	183	950	208	1,100	233	1,250	257
810	185	960	210	1,110	234	1,260	258
820	186	970	212	1,120	236	1,270	259
830	188	980	213	1,130	237	1,280	261
840	190	990	215	1,140	239	1,290	263
						1,300	264

HOW TO USE THE TABLE

Compute the mid-weight of each pen of bulls fed together.

$$\frac{\text{(Avg. final wt. - avg. initial wt.)}}{2}$$

Compute the test group average of pen mid-weights.

$$\frac{\text{(Sum of pen mid-wts.)}}{\text{(Number of pens)}}$$

Convert these mid-weights to metabolic weights by using the above table.

Compute actual pounds of fed per 100 pounds of gain for each pen.

$$100 \times \frac{\text{(Total feed consumed)}}{\text{(Total gain)}}$$

Compute the adjusted feed efficiency as follows:

$$\frac{\text{Test group avg. metabolic wt.}}{\text{- Pen avg. metabolic wt.}} \times \text{Actual feed/100 lb. gain}$$

Note: This method adjust for differences in maintenance requirements of bulls of different sizes. The feed/gain of heavier-than-average bulls will adjust downward, and feed/gain of lighter-than-average bulls will adjust upward. Maintenance requirement is proportional to weight (in kilograms) raised to the 3/4 power.

GLOSSARY

ACCURACY (OF SELECTION). Correlation between "true" breeding value and estimated breeding value.

AD LIB FEEDING. No limit placed on amount of intake (self-feeding).

AVERAGE DAILY GAIN. Measurement used to indicate daily change in body weight when animals are fed for tests.

BEEF CARCASS DATE SERVICE. A program whereby any producer can receive carcass evaluation data on his cattle by using a special "carcass data" eartag in his slaughter animals. See your county Extension Director, your breed representative, your BCIA representative, or your area office of USDA meat grading service for information.

BEEF IMPROVEMENT FEDERATION (BIF). A federation or organization interested or involved in performance evaluation of beef cattle. The purposes of BIF are to bring about uniformity of procedures, development of programs, cooperation among interested entities, education of its members and its ultimate consumers, and confidence of the beef industry in the principles and potentials of performance testing.

BIRTH WEIGHT. The weight of a calf taken within 24 hours after birth. Heavy birth weights are correlated with calving problems, but the conformations of the calf and the cow are contributing factors.

BREED. Animals having a common origin and characteristics which distinguish them from other groups within the same species.

BREED AVERAGE (HERD-MATES). A herd-mate (offspring of another sire in the same herd at the same time) producing at the current average production for that particular breed.

BREEDING VALUE. Value of an animal as a breeder. The working definition is twice the difference between an infinitely large number of progeny and the population average when the individual is mated to random numbers of the population and all progeny are managed alike. The difference is doubled because only a sample half (one gene of each pair) is transmitted to the progeny. Breeding value exists for each trait and is dependent on the population in which the animal is evaluated.

BULL. An uncastrated male bovine.

CALF. The sexually immature young of certain large mammal including cattle.

CALF CROP. Calves produced by a herd of cattle in one season.

CARCASS EVALUATION. Technique of measuring components of quality and quantity of carcasses.

CARCASS MERIT. Desirability of a carcass relative to quantity of edible portion and quality of product.

CARCASS QUALITY. Overall palatability of edible portion of carcass.

CARCASS QUANTITY. Amount of salable meat the carcass will yield. (Basically synonymous with cutability.)

CARRIER. A heterozygote for any trait.

CATALO (CATTALO). A hardy crossbreed of the American Bison and domestic cattle. They are usually of lesser fertility than the parental types.

CLOSED HERD. A herd in which no outside blood is introduced.

CONCEPTION. The fecundation of the ovum. The action of conceiving or becoming pregnant.

CONGENITAL. Acquired during prenatal life. It exists at or dates from birth.

CORRELATION. A measure of how two traits vary together. A correlation of +1.00 means that as one trait increases the other also increases--a perfect positive relationship. A correlation of -1.00 means that as one trait increases the other decreases--a perfect negative, or inverse, relationship. A correlation of 0.00 means that as one trait increases, the other may increase or decrease--no relationship. Thus, a correlation coefficient may lie between +1.00 and -1.00.

COW. A mature female bovine.

CROSSBREEDING. The mating of animals of different breeds (or species).

CULLING. The process of eliminating nonproductive or undesirable animals.

CUTABILITY. An expression of the amount of salable meat in a carcass. In practice, it is determined through proper combination of records, including carcass weight, ribeye area, fat thickness, and estimated percent of kidney, pelvic, and heart fat.

DAM. The female parent.

DEVIATION. A difference between one value and the average value. These differences sum to zero when the average is used. A ratio deviation is the ratio less the average ratio or 1.00.

DOMINANT. Dominant genes affect the phenotype when present in either homozygous or heterozygous condition.

DYSTOCIA. Abnormal or difficult labor, causing difficulty in delivering the fetus and placenta.

ECONOMIC VALUE. The net return to an enterprise for making a unit change in a particular trait.

ENVIRONMENT. All external conditions which affect the life of an animal.

ESTIMATE (verb). The process of calculating a particular value from data. (noun) -- The value itself obtained from data. The idea is that the true value is being obtained from the calculated value within limits of sampling variation.

ESTRUS (OESTRUS). The recurrent, restricted period of sexual receptivity (heat) in female mammals, marked by intense sexual urge.

EXPECTED PROGENY DIFFERENCE. Is the difference in performance to be expected from future progeny of a sire, compared to that expected from future progeny of the average bull in the same test.

FEED CONVERSION (FEED EFFICIENCY). Units of feed consumed per unit of weight increase. Also, the production (meat, milk, eggs) per unit of feed consumed.

FETUS. The unborn young of animals (usually vertebrates) which give birth to living offspring.

FREEMARTIN. Female born twin to a bull calf (approximately 9 out of 10 will not conceive).

GENERATION INTERVAL. Average age of the parents when the offspring destined to replace them are born. A generation represents a complete turnover of a herd.

GENES. The particulate units of heredity that occur in pairs and have their effect in pairs in the individual, but which are transmitted singly (one or the other gene at random of each pair) from parent to offspring and, thus, segregate and recombine each generation.

GENETIC CORRELATIONS. Correlations between two traits caused by the same genes having effects on both traits.

GENOTYPE. Actual genetic constitution (makeup) of an individual as determined by its germ plasm. For example, there are two genotypes for brown eyes, BB and Bb.

GONAD. The gland of a male or female which produces the reproductive cells; the testicle or ovary.

HALF-SIB. In genetics, a half-brother or half-sister.

HEIFER. A female of the cattle species less than 3 years of age which has not borne a calf.

HERD. A group of animals (especially cattle, horses, and swine), collectively considered as a unit.

HEREDITY. The hereditary transmission of genetic or physical traits of parents to their offspring.

HERITABILITY. A technical term used by animal breeders to describe what fraction of the differences in a trait, such as milk production or growth, is due to differences in genetic value rather than environmental factors; variation due to genetic effects divided by the total variation (genetic plus environmental variation).

HERITABILITY ESTIMATE. An estimate of the proportion of the total phenotypic variation between individuals for a certain trait that is due to heredity. More specifically, hereditary variation due to additive gene action.

HETEROSIS (hybrid vigor). Amount by which the crossbreds exceed the average of the two purebreds that are crossed to produced the crossbreds.

HETEROZYGOUS. Genes of a specific pair are unlike in an individual.

HOMOZYGOUS. Genes of a specific pair are alike in an individual.

INBREEDING. Production of offspring from parents more closely related than the average of a population. Genetically, inbreeding increases the proportion of homozygous genes in a population.

INCOMPLETE DOMINANCE. A situation in which neither allele is dominant to the other, with the result that both are expressed in the phenotype which is intermediate between the two traits.

INTENSITY (OF SELECTION). The difference between the selected animals and the average of the animals from which they came, expressed relative to the amount of variation in the trait. Intensity is a function of the fraction of a population saved, such as 1 percent.

INVOLUTION. The return of an organ to its normal size or condition after enlargement, as of the uterus after parturition. A decline in size or activity of other tissues; e.g., the mammary gland tissues normally involute with advancing lactation.

LINEBREEDING. A form of inbreeding in which an attempt is made to concentrate the inheritance of some ancestor in the pedigree.

LINECROSS. A cross of two inbred lines.

MARBLING. The distribution of fat in muscular tissue which gives meat a spotted appearance.

METABOLIC BODY SIZE. The weight of the animal raised to the 3/4 power ($W^{0.75}$); a figure to indicate level of metabolism to maintain a certain body weight.

METABOLISM. The transformation by which energy is made available for body uses.

MOST PROBABLE PRODUCING ABILITY. A measure of cow productivity weighed for number of progeny and repeatability of the trait measured.

NATIONAL SIRE EVALUATION. Programs of sire evaluation conducted by breed associations to compare sires on a progeny test basis.

NUMBER OF CONTEMPORARIES. The number of animals of similar breed, sex, age, etc., against which an animal was compared in performance tests. The greater the number of contemporaries, the greater the accuracy of comparisons.

OPEN. A term commonly used for farm animals to indicate a nonpregnant status.

OUTCROSS. Mating of an individual to another in the same breed which is not closely related to it.

OVULATION. Release of the female germ cell (egg) by the ovary.

PEDIGREE. A list of an animal's ancestors, usually only those of the three to five closest generations.

PERFORMANCE DATA. The record of the animal itself--its birth weight, weaning weight, gain and grade, etc.

PERFORMANCE PEDIGREE. Contrasted to a conventional pedigree which lists names of ancestors, a performance pedigree is a listing of an animal's performance record and of its ancestors' performance and progeny records. It suffers from the same ills in that evaluation of said records necessitates proper weighting of relationship of an ancestor to the animal of interest and also of the trait heritability. Breeding value is a much more useful tool.

PERFORMANCE TESTING. The measurement of certain traits of performance in livestock with the intent of using the records in selection and/or sales.

PHENOTYPE. The visible or measurable expression of a character; for example, coat color or weaning weight.

PHENOTYPIC CORRELATIONS. Correlations between two traits caused by both genetic and environmental factors influencing both traits.

POLLED. A naturally hornless animal. Having no horns.

POUNDS OF RETAIL CUTS PER DAY OF AGE. A measure of cutability and growth combined, it is calculated as follows: (cutability x carcass weight)   age in days.

PROGENY. The offspring of animals.

PROGENY DATA. The record of a bull's calves -- weaning weights, feedlot gains, and possibly their carcass evaluation. The progeny test is the best measure of the breeding value of a bull, though it is slow to accomplish.

PROGENY TESTING. Evaluating the genotype of an individual by a study of its progeny.

PUBERTY. The age at which the reproductive organs become functionally operative and secondary sex characteristics develop.

PUREBRED. An animal of a recognized breed that is eligible for registry in the official herdbook of that breed.

QUALITATIVE TRAITS. Those traits in which there is a sharp distinction between phenotypes, such as black and white or polled and horned. Usually, only one or two pairs of genes are involved.

QUALITY. A term indicating fineness of texture as opposed to coarseness. Commonly used to indicate relative merit.

QUANTITATIVE TRAITS. Those traits in which there is no sharp distinction between phenotypes, with a gradual variation from one phenotype to another, such as weaning weight. Usually, several genes are involved, as well as environmental factors.

RANDOM MATING. A system of mating where every male has an equal chance of mating with every female (or, more practically, has had cows allocated without selection or bias).

RATE OF GENETIC IMPROVEMENT. Dependent on: (1) heritability of traits considered; (2) selection differential; (3) genetic correlation among traits considered; and (4) generation interval of the species.

RECESSIVE GENE. Recessive genes affect the phenotype only when present in a homozygous condition.

REFERENCE SIRE. A bull designated to be used as a "bench mark" in progeny-testing other bulls (young sires). Progeny by reference sires in several herds enable comparisons to be made between bulls not producing progeny in the same herd.

REGRESSION (REGRESSED). A measure of the relationship between two variables. The response in one can be predicted by knowing the value of the other variable.

SELECTION. Causing or allowing certain individuals in a population to produce the next generation.

SELECTION DIFFERENTIAL. The difference between the selected animals and the average of the group from which they came.

STEER. A male bovine castrated before the development of secondary sex characteristics.

USDA YIELD GRADE. Measures of carcass cutability categorized into numerical categories with 1 being the best and 5 the poorest. Lean carcasses receive the better yield grades, and fat carcasses receive the poorer grades.

VARIANCE. Variance is a statistic which describes the variation we see in a trait. Without variation, no genetic progress is possible, since genetically superior animals would not be distinguishable from genetically inferior ones.

WEIGHT RATIO. In beef cattle evaluations, weight ratios refer to the weight of an individual animal relative to the average of all animals in the same group. It is calculated as:

$$\frac{\text{Individual record}}{\text{Average of animals in group}} \times 100$$

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