EVALUATION OF ADJUSTED NET K^{40} COUNT AS A PREDICTOR OF MUSCLE MASS IN YEARLING BEEF BULLS

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CHAPTER I

INTRODUCTION

The development of an accurate, non-destructive measure of animal composition, with emphasis on estimating the muscle component, would be of great economic value to producers of breeding animals, since many carcass traits have been shown to be moderately to highly heritable. The increased emphasis placed on leanness in meat animals in the market place during recent years has focused attention of the K^{40} whole-body counter as a useful aid in selection when lean composition becomes important. The importance of leanness is reflected in today's "Fast-Food" Industry and its need for cattle with rapid muscle growth, and also by the demand of the consumer for a lean product. The development of whole-body counters has made it possible to quantitate naturally occurring gamma rays arising from a radioactive isotope of potassium, K^{40}. The basic principal of this evaluation technique is that a large part of total body potassium is found in the muscle and in quite constant amounts within a species. It follows that differences in K^{40} count among animals should estimate differences in the quantity of total lean in meat animals in a non-destructive manner.

Earlier research at the Oklahoma State University Live Animal Evaluation Center, using animals quite uniform in weight, has shown the estimation of fat-free lean in yearling beef bulls by the K^{40} counter to be useful when used with other performance data in selecting yearling bulls that have superior genotypes for rapid muscle growth. Later research emphasized the need to identify and adjust for sources of variation in K^{40} counting, especially where differences in the live weight of test animals occur. The counter was found to be less efficient on heavier animals and thus, there is a tendency to underestimate the amount of potassium and hence the amount of muscle in the animal's body. Researchers using "phantoms" (non-living masses) of different materials have found that counter efficiency is reduced when larger masses are counted by the phenomena called background depression and self-absorption.

Another source of variation is the circular rear detector in the counter (referred to as the end detector). When turned "on", the end detector may detect any slight forward or backward movement of the animal and thus produce variable results that reflect animal movement in the counting chamber. Repeated net counts may indicate decreased instrument stability provided by the end detector than provided by the "horseshoe" configuration of detectors only, which surround the animal. The accuracy obtainable for prediction of lean muscle mass in heavier weight animals will determine the ultimate usefulness of the K^{40} counting technique to the livestock producer.

The objectives of this study were 1) to create phantoms approximating the dimensions and density of bulls weighing 900, 1,000, 1,100, 1200 and 1,300 pounds for the purpose of developing an adjustment for background depression, 2) to involve yearling beef bulls representing the live weight range of 900 to 1,300 pounds for the purpose of developing prediction equations for these more modern, heavier weight cattle than those used in the development of the equation currently in use,

3) to include in the prediction equations adjustments for background depression and self-absorption which take into account the lower counting efficiency naturally occurring when heavier bulls are counted, and 4) to evaluate the usefulness of the circular rear detector in the counter.

CHAPTER II

REVIEW OF LITERATURE

This review of literature will concern itself with previous research generally concerning the bovine in the areas of K^{40} whole-body counting and the sources of variation associated with its use in predicting lean muscle mass.

Principles of the K^{40} Counting Technique

In meat animal composition research, there has been considerable research in the past decade concerning the element potassium and its relation to other body constituents. There are two properties of potassium that make its quantitative measurement in the living animal both useful and practical as an estimator of lean. First, a high proportion and relatively constant amount of the total body potassium is contained in the intracellular, non-fat (muscle) phase of body tissue (Kulwich et al., 1958; Forbes, 1963; Kirton et al., 1963; Pfau et al., 1963). Second, all naturally occurring potassium has associated with it a radioactive isotope K^{40} which makes up a constant fraction (.0119% ± .000056%) of the total potassium (Anderson, 1959; Forbes, 1963; Ward et al., 1967). The natural isotope K^{40} emits approximately 11 percent of its radiation as high energy (1.46 MEV) gamma radiation which will penetrate the body tissues and can be measured providing a suitable detection system has been established. Other properties of

K^{40} that make it unique for estimating total potassium are that potassium is the only major element found in body tissue in significant amounts that has predictive value for estimating body composition (Ward, 1968); and the naturally occurring radiation of K^{40} is virtually constant because of the long half-life of 3 x 10^9 years.

Biological variability of potassium content in animal tissues can be implicated as an important source of error in the usefulness of K^{40} whole-body counting. The question of concentration, constancy and distribution of potassium in the whole-body, carcass and component parts has been debated more than the other principles upon which whole-body counting has been founded. Pfau et al. (1961) studied the potassium content in the ham using K^{40} counting and found 84 percent of potassium was located in the muscle, 8 percent in fat, 6 percent in bone, and 2 percent in the skin. A linear relation was reported between percent muscle and potassium content with a standard error of estimate of about 2.3 percent.

Lohman and Norton (1968) used 90 steers belonging to four breeds and four slaughter-weight groups to study the potassium distribution in the body, as estimated from K^{40} measurements of six body components. Standard trimmed lean was found to contain 53.4 percent of total potassium and had a coefficient of variation of 5.9 percent. Carcass bone contained 12.4 percent of total potassium, gastrointestinal tract 16.4 percent, head and organs 7.7 percent, blood, mesenteric fat and feet 2.7 percent and adipose tissue 3.8 percent (coefficients of variation of 14.3, 33.6, 9.6, 21.2 and 24.7 percent, respectively). These workers reported a decrease in potassium concentration as body mass increased in all of the body components studies, except the bone and gastrointestinal tract. There was also a tendency for potassium concentration to increase in muscle, bone and organs, and to decrease in other components, as the percentage of beef breeding in the cattle increased.

The mean potassium content of the internal organs of cattle, as found by Bennink et al. (1968), was approximately the same as the mean potassium content of meat samples, although considerably more variation was noted among the organs than among the meat samples.

Using a four-pi liquid scintillation counter to study potassium distribution in 10 lambs, Kirton et al. (1961) observed 2.98 g K/kg live weight in separable lean compared to 0.7 g K/kg for separable fat and 1.41 g K/kg for bone. Counting errors for these estimates were 5.35, 66.41 and 34.85 percent for lean, fat and bone, respectively. The relatively low counting error associated with lean indicates that the proportion of potassium in this tissue is relatively constant. Non-carcass components contained 1.78 g K/kg live weight on the average with a counting error of 6.56 percent. No significant relationships were found between carcass composition and the gamma activity of the carcasses, partly because of the limited variability among the animals in comparison with the counting precision. Stant et al. (1969) found that chemical estimates of total potassium in the lean, fat and bone represented approximately 79.1, 6.2 and 14.6 percent of the total carcass potassium, respectively, when averaged across four weight groups (23, 46, 68 and 91 kg) of 24 Yorkshire-Duroc crossbred barrows and 24 Yorkshire-Chester White crossbred barrows. When potassium was expressed on a fat-free basis, Clark et al. (1972) reported a range of 0.290 to 0.297 percent for muscle potassium levels in 99 beef carcasses from three different feeding trials.

The constancy relationship between potassium and muscle was questioned in the work of Lawrie and Pomeroy (1963). These workers discovered differences in potassium concentration as great as 30 percent among five muscles from six pigs representing three weight groups (150, 200, and 250 pounds). Gillett et al. (1967) reported significant differences in the potassium concentration per unit muscle weight in eight muscles excised from 14 steers slaughtered at weights ranging from 232.2 to 344.3 kg. Potassium concentration of each muscle was determined by the flame photometric method and these differences in concentration were apparent when expressed on a wet, fat-free, moisture-free or protein-free basis. Variations as high as 12.91 percent occurred in the potassium concentration of muscles when means were compared. It was suggested that variation in the potassium concentration among muscles of the same animal indicated that constancy does not exist in the potassium-muscle relationship, and therefore may be an important source of error in the K^{40} method of estimating composition. Variation between breeds was of little consequence to the relationship. The differences among muscles amounted to only approximately 5 grams of total body potassium; therefore, McLellan (1970) noted that it is doubtful whether the K^{40} counter would be sensitive enough to detect so small a difference consistently.

Using gamma spectrophotometry of the radioactive K^{40}, Ward et al. (1967) tested 42 samples of ground beef to determine if there was a difference in the potassium concentration of eight wholesale cuts from five cow carcasses. A significant difference was found between cows in potassium concentration on a fat-free basis but not between wholesale cuts within animals. Coefficients of variation for the potassium content were of 9.0 and 14.7 percent, respectively, expressed on a fat-free basis or a fat-free dry matter basis. The results are somewhat questionable because of the limited number of animals involved in this study.

Bennink and co-workers (1968) determined the concentration of potassium on 36 ground meat samples representing composites from sides of 12 beef steers, and on eight wholesale cuts from each of three mature dairy cows. The potassium contents were not significantly different among the wholesale cuts from the three cows or among cows, or among ground beef samples from different steers. This data provided support to the constancy of potassium.

Studying the technical variation in the measurement of potassium by atomic absorption spectrophotometry, Lohman et al. (1970a) examined seven cuts constituting the entire boneless, trimmed right side from each of 98 steer carcasses utilized by Lohman and Norton (1968). They found that 13 percent of the error variance was associated with duplicate samples and the coefficient of variation was 9.6 percent based on the mean of duplicates. Such data suggest serious limitations in estimating potassium by atomic absorption spectrometry. Similar findings by Johnson et al. (1972) were reported in the measurement variation in the analysis of muscle potassium when samples from the longissimus muscle of 36 crossbred Hereford-Angus steers were evaluated by atomic absorption techniques. The standard error of duplicate analysis was 0.332 g K/kg and the coefficient of variation was 11.1 percent based on the mean of duplicates. These workers indicated that much of the inconsistency concerning muscle potassium variation might be attributed to variation associated with the method of potassium determination.

Additional work by Lohman and co-workers (1970b) evaluated the biological sources of variability of lean potassium concentration in beef cuts. All muscles except those of the head, feet and tail were represented. The 98 steers were of four breed types and slaughtered at four weights with carcasses being handled similar to that reported by Lohman (1970a). Individual cuts deviated significantly in potassium from the composition of the weighted mean (maximum deviation between cuts were 11 percent). The total coefficient of variation (biological plus technical) within breed type and treatment was 6.4 percent on a fat-free dry matter basis. After accounting for technical error, the biological coefficient of variation was 3.0 percent. Large technical errors in measuring potassium caused much of the total variability. Breed type and treatments were of limited importance, so the workers suggested potassium is found in a relatively constant proportion to the fat-free dry matter provided it is precisely and accurately measured.

Data obtained from the chemical analyses of 99 beef carcasses, from three different feeding trials, were evaluated to determine the level and distribution of potassium (Clark et al., 1972). There were significant differences among the three weight groups (227, 341 and 454 kg live weight) in the potassium levels for different retail cuts when expressed on the wet basis. However, results were more consistent when potassium in the retail cuts was expressed on the fat-free basis. When analyzed on a within group basis, there were significant differences in potassium when expressed on a wet, fat-free, or fat-free, moisture-free basis. Total carcass potassium differences were dependent upon the method of expressing the data; however, when potassium was expressed on a fat-free basis, no difference due to weight group was observed.

Recently, Sim and Wellington (1976) studied potassium concentration in six muscle categories comprising the entire musculative of 36 cattle consisting of equal numbers of Angus and Holstein bulls, steers and heifers. Animal to animal variation in potassium concentration, as well as variations among muscle categories, were found regardless of the method of expressing concentration. However, the coefficient of variation of the weighted mean potassium level in total muscle for all 36 animals was only 2.43 percent when expressed as potassium in fat-free, wet tissue. These workers suggested that muscle to muscle variation within animals is greater than animal to animal variability within muscle. This supports the hypothesis of Lohman et al. (1970b). No breed by muscle interactions were observed, nor did sex account for a significant proportion of the total variation in potassium concentration. Because the major proportion of total potassium associated with the musculature and animal to animal variation is less than within animal variation, the previous research indicates whole-body counting has potential as an estimator of composition, if error inherent to instrumentation can be controlled (Stiffler, 1976).

Relationship Between K^{40} and Leanness

The use of body potassium as a predictor of lean body mass was reported as early as 1955 when Cheek and West found a linear relationship between total body potassium and lean body mass in rats. Considerable work has been done to measure natural K^{40} radiation particularly in human subjects (Woodward et al., 1956; Forbes and Hursh, 1963). Kulwich et al. (1958) first evaluated the usefulness of the K^{40} count as an index of the amount of lean in meat products. He reported a correlation coefficient of 0.983 between the K^{40} gamma counts per second, per pound and the percentage of fat-free lean in hams.

Encouraged by early findings, further research has been published concerning K^{40} whole-body count and the physical and chemical composition of lamb, pork and beef. Kirton et al. (1961) found significant correlations between the gamma activity of live lambs and their carcass composition; however, these relationships did not appear high enough to be of practical importance. In 1963, Kirton and Pearson reported correlations of 0.81, -0.92 and 0.81 between potassium content, as determined by flame photometry, and separable lean, fat and bone, respectively in lamb carcasses.

Using a pooled prediction equation for fat-free lean in 115 market weight pigs, Addison (1973) reported that 78.3 percent of the variation was accounted for by the live K^{40} cound and 78.7 percent was accounted for when weight was added to the model. Both prediction equations had standard errors of 2.94 pounds, but animals were similar in type and within a narrow weight range. Schmidt et al. (1974) also found K^{40} count and live weight to be highly correlated with all of the parameters measured in crossbred swine. Carr et al. (1978) evaluated 30 Yorkshire and 70 Hampshire barrows which were K^{40} counted and then slaughtered at live weights of 45.4, 68.2, 90.9, 113.6 and 136.4 kg. Net K^{40} count, when added to slaughter weight in a prediction equation, accounted for 98.1 percent and 96.2 percent of the variation in fat-free lean in Yorkshire and Hampshire pigs, respectively. The standard error of estimate was 1.79 kg for Yorkshire and 2.05 kg for the Hampshires. The coefficient of determinations were 2.0 to 2.6 percent higher than when weight was used alone; however, the increased accuracy was rather small. Live weight had the most value in predicting fat-free lean, thus the ability of the whole-body counter to differentiate among a sample of very muscular pigs at approximately the same weight could not be evaluated in this study.

Sixteen beef rounds were counted for a period of 42 to 51 minutes and the gamma ray emission data were related to their physical and chemical composition (Kulwich et al., 1961). The correlation coefficient between pounds of separable lean and K^{40} count was 0.982 when adjustments were made for differences in efficiency due to differences in round weights (non-adjusted $r = 0.975$). Fat-free lean and K^{40} count had an $r = 0.983$, with a sample standard deviation from regression of 1.15 pounds. Also of importance were the correlations between the K^{40} count and percent lean of 0.798 and K^{40} count and percent fat of -0.865. Although the number of samples was small, the study pointed out that differentiations can be made between samples that differ by more than a few percent in composition.

Lohman et al. (1966), in a study involving 21 steers in each of two years, reported that whole-body potassium as estimated by K^{40} counting accounted for 51 percent of the total variation in carcass lean muscle mass with a standard error of estimate of 10.2 kg or 9.0 percent of the mean carcass lean. In the second year a low radioactive diet was fed to reduce the radioactivity of the gastrointestinal contents. Whole-body potassium accounted for 88 percent of the variation in carcass lean with a standard error of estimate of 5.3 kg (4.9%).

With sources of variation minimized or accounted for, whole-body count was repeatable from day to day to within 2 or 3 percent and predicted carcass lean with standard errors of estimate less than 3 percent for slaughter weight groups of 284 to 306 kg and 352 to 385 kg. Carcass K^{40} measurements predicted carcass lean with standard errors of estimate of 3.5 percent, which was somewhat greater than the whole-body count standard errors of estimate.

McLellan (1970) evaluated 16 Angus heifers and fifteen Angus steers of uniform weight and found that live and carcass weight accounted for 21 to 31 percent of the variation in fat-free lean. The average of two K^{40} counts (after 24 hours shrink) was associated with 64 percent of the variation in fat-free lean. When live or carcass weight alone was used in a prediction equation, the standard error of estimate was 15.0 pounds fat-free lean. When count alone was used, the standard error of estimate ranged between 10.1 and 12.0 pounds. Combining weight and count in a prediction equation produced a standard error of estimate from 8.8 to 10.5 pounds.

Frahm and co-workers (1971) evaluated 40 yearling Angus bulls of similar weight which were K^{40} counted and subsequently slaughtered in four different weight groups. The bulls had been in a 160-day feedlot performance test before counting. The repeatability estimate computed intragroup and pooled over groups was 0.95 for two 10-minute counts taken on each animal after a 24-hour shrink. Following a 24-hour shrink, the intragroup correlations between individual K^{40} counts and fat-free lean ranged from 0.70 to 0.92. They reported a pooled-within group correlation of 0.87 between the average of two K^{40} counts taken on the same day, after 24 hours shrink, and pounds of fat-free lean.

Prediction equations based on average K^{40} count yielded a standard error of estimate of 3.8 kg (2.8 percent of the mean) which was approximately one-half as large as the 7.4 kg standard deviation in fat-free lean for this group of bulls that averaged 135 kg fat-free lean. By design, these bulls were of similar breeding, body type and weight; thus, these workers concluded that prediction equations utilizing count and weight were no more accurate in predicting fat-free lean than those based on K^{40} counts alone. Research by Johnson et al. (1973) indicated the most precise K^{40} comparisons of fat-free lean between animals can be made when animals are of similar weight and have been subjected to similar conditions prior to counting.

K^{40} counts were obtained on 69 purebred Shorthorn bulls, 14 crossbred bulls, 33 crossbred heifers and 20 crossbred steers (Martin et al., al., 1974). The repeatability of duplicate measurements was 0.97 and regression analysis indicated that a second count did not increase precision as a predictor of carcass lean content. Live weight explained 3.5 percent of the variance in percent lean content of the carcass primal cuts; addition of a single K^{40} count increased the variance explained to 64.9 percent, with a standard deviation of 1.38 percent. Application of the Oklahoma State University prediction equation indicated comparable predictive precision.

Using the whole-body K^{40} counting technique, Clark et al. (1976) estimated the body composition of 56 Hereford steers ranging in weight from 183 to 574 kg. Live weight and K^{40} live accounted for 95 and 94 percent of the variation in fat-free body weight, respectively. The use of K^{40} and live weight together to predict fat-free body weight and fat-free carcass weight accounted for 97 percent and 96 percent, respectively of the total variation. The combination of live weight and K^{40} live resulted in a 14 percent reduction in the standard error of estimate compared to either variable alone. Live weight and K^{40} accounted for 87 percent of the variation in lean weight of the carcass and the standard error of estimate was found to be 8.16 kg. Similar results were found when K^{40} live was used alone. To some observers, the effectiveness of K^{40} count as a predictor of lean in this study is somewhat questionable with the extreme range in weight and the influence of weight on count and body composition.

The relationship between adjusted K^{40} count and carcass composition using 48 Herefords and 48 Charolais crossbred steers, counted and slaughtered at weights of 500, 700, 900 and 1100 pounds, was studied by Stiffler (1976). There was a tendency for the increase in adjusted count to decrease as slaughter weight increased. The relationship between mean adjusted count and mean weight of fat-free lean generally showed a reasonably linear response across the four slaughter weight groups for the respective breed types. Pooled within slaughter weight group correlations between adjusted count and pounds of fat-free lean were .473 and .581, respectively for the Herefords and crossbreds. In prediction equations ignoring slaughter weight group, adjusted count (adjusted for differences in counting efficiency by the use of phantoms) accounted for 90.9 percent of the variation associated with pounds of fat-free lean for Herefords and 85.7 percent for crossbreds. The standard errors of estimate associated with the prediction equation based on a combination of adjusted count and empty body weight were 12.5 pounds for the Herefords and 13.5 pounds for the crossbreds. This was a significant reduction in the standard errors of estimate from when each variable was used alone.

In summary, past research supports a strong relationship between K^{40} whole-body counting techniques and leanness in beef cattle and swine. Belyea et al. (1978) also reported that potassium-40 detection appears to be nontraumatic and highly repeatable for estimating body composition in dairy cows. This counting technique could be of further usefulness if sources of variation were reduced.

Sources of Variation and Factors Related to Counting Efficiency in K^{40} Whole-Body Counting

Accuracy of the whole-body counter in predicting lean mass hinges upon the ability to identify and, where possible, reduce the sources of variation that are inherent both to the animal and to the instrumentation. In 1964, Smith et al. recognized sources of variation due to external and internal contamination of the animal, variation inherent to instrument instability and balancing, and variation inherent to the animal. Those listed inherent to the animal were: size or mass of the animal, conformation or shape, muscle distribution, variation in size and K content of non-carcass components, variation in the K content of muscle, changes in sample geometry, self-absorption by the sample and background depression.

Variation in the potassium content of muscle and the relationship of non-carcass components to total body potassium were referred to earlier in this literature review. Due to an increase in the radioactive materials in the atmosphere, there could be surface contaminants contributing to variation in K^{40} counting. Kirton et al., 1961; and Twardock et al., 1966 demonstrated that thoroughly washing the animal before counting reduced external contamination. Internal contamination was also found to be an important source of variation. Gamma rays were found to be contributed by radioactive substances in the gastrointestinal contents (Kirton et al., 1963; Johnson and Ward, 1966; Johnson et al., 1972). This radioactivity in the gastrointestinal tract was found to be reduced and partly standardized by either feeding a diet low in potassium prior to counting or having a constant shrink period of holding animals off feed (Twardock et al., 1966; Lohman et al., 1966; Lohman and Norton, 1968; McLellan, 1970). Belyea, Martz and co-workers (1978) reported that evacuation of the rumen contents decreased estimates of body potassium and body composition. Gut radioactivity appeared to be a major source of variation that must be controlled, although dietary potassium seemed to be of little importance.

Instrumentation Sources of Variation

Sources of instrumentation variation are background fluctuations, instrument instability and errors in routine balancing of electronics. Accurate measurements of K^{40} count rates depend upon a stable background count rate during the time animal measurements are made. Detector stability is usually described in terms of a comparison to nuclear decay variability (Twardock et al., 1966). These workers stated that the instrument's electronic stability upon repeated measurements of background or of a single radioactive sample during a 60 to 120 minute interval should have a statistical variation almost the same as the nuclear decay standard deviation. Instrument electronic drift causes the observed count standard deviation to deviate increasingly from the nuclear decay standard deviation as the time interval during which measurements are made increases. Over a 12 hour interval the observed background variation (0.83 percent S.D.) was much greater than the nuclear decay variation (0.38 percent S.D.). Twardock et al. (1966) reported that long-term fluctuations (drift) in detection efficiency are attributed primarily to: (a) changes in photomultiplier tube performance; (b) oxygen absorption in the scintillator causing quenching of scintillation light; and (c) changes in performance of electronic components other than the photomultiplier tubes. Photomultiplier gain variation or "fatigue" can cause serious errors in counting measurements at relatively low counting rates such as 10,000 cpm (Karzmark, 1965). Karzmark also indicated that gain variations could be limited to 1 percent with suitable precautions, while neglect could result in errors of 10 to 20 percent.

Lohman et al. (1966) observed that day to day variation in counting efficiency of the instrument had a coefficient of variation of 1.6 percent as measured by counting the activity of a 5 kg KCl standard contained in a cylindrical box 30 cm in height by 20 cm in diameter. This procedure could not adequately account for changes in the efficiency with which large samples were counted. Anderson (1968) found that the best method for quantitative evaluation of instrument stability is the frequent measurement of stable, inanimate reference samples that resemble the experimental objects to a reasonable approximation. Twardock et al. (1966) reported that corrections for long-term drift can be made by counting standards composed of K^{40} in the form of KCl diluted in sugar or water to a weight approximating that of the sample being measured.

Counting Efficiency

Twardock et al. (1966) proposed that sample-to-detector geometry and sample mass influenced the detection efficiency of a whole-body counting system. The sample-to-detector geometry (distance relationship between the animal and the counter detector) has been found to have a significant influence on the detection efficiency of a K^{40} counter. Twardock and co-workers (1966) found that a small sample was more effectively surrounded by the detector position in counting cattle than a larger sample, and therefore the detector should pick up more of the gamma rays leaving the sample. Using two different detector positions, these workers discovered that the "close-fitting" detector was 20 percent more efficient than the "loose-fitting" detector. Because of the high count rates of cattle, precise measurements were also readily attained at the lower detection efficiency. Lohman et al. (1966) reported that positioning of steers, with respect to the liquid scintillation detector, was a source of counting error affecting the precision of estimated whole-body potassium. Forbes (1968) found counting rate changes as a radioactive sample is moved down the long axis of the counter chamber, however, movement in a direction perpendicular to the long axis had no effect on counting efficiency. Conversely, there was little difference in efficiency whether bottles of radioactive material were bunched at the mid-point or spread out along the long axis.

In a study involving the K^{40} counting of hogs weighing 100, 150, 200, 250 and 300 pounds, Moser (1970) observed lower correlations between K^{40} counts and measures of leanness in hogs of lighter weights when compared to those of heavier weights. Positioning of the animals in the counter and the ratio of sample to detector volume were concluded to have detrimental effects on correlations involving lighter weight pigs. The smaller pigs occupied a smaller portion of the volume of the counting chamber allowing a lesser chance for the gamma radiation emitted from the animals to reach the detectors. Another alternative was that the variation in animal composition is considerably less at lighter weights and therefore, more sensitivity would be required to detect small differences.

According to Remenchik and Miller (1961), whole-body K^{40} appears to underestimate potassium content in obese human subjects by approximately 7 percent. Sample mass affects counter efficiency and has been attributed to the phenomena of "background depression" and "self-absorption". Sample mass has two important effects on the count from a given sample according to Anderson (1959). First, increasing the sample mass lowers the total count by absorption of a fraction of the background radiation, which in the absence of a sample would pass into a detector and be registered as a greater portion of gross count. This physical phenomenon results in lowering the background radiation reaching the detectors below that actually present in the atmosphere, and is known as "background depression". Reporting this same phenomenon, Twardock et al. (1966) determined background depression of large volume samples by filling four box phantoms with distilled water, ranging in weight from less than 200 kg to approximately 450 kg, and measuring background count rates. A linear relationship was found between counts depressed and phantom weight. For every 100 kg increase in weight the background count was depressed by 228 counts.

Using a four-pi plastic scintillation counter, Forbes (1968) plotted percent of background against successive additions of one-liter plastic bottles filled with double distilled water. For every liter of water introduced into the counting chamber the percent background was decreased by 0.292 percent, which is approximately a 1.3 percent decrease for every 10 pounds increase in weight. Forbes concluded a small correction for background depression must be made for samples of large size. Lohman (1968) placed non-radioactive samples of various sizes into a counter to measure the decrease in background count due to gamma ray absorption by the sample. Balloon filled boxes containing 3.6 kg of distilled water per balloon were constructed and background counts were taken with and without the samples in the counter. A linear relation was found between sample mass and background depression between 182 and 454 kg, with sample mass accounting for 97 percent of the variation in background count rate. Kessler et al. (1968) reported that a depression in background, rather than an increase, had always been observed with their human counter. Eight phantoms weighing 50 lb. each were prepared using pure sugar packed in cloth bags. Multiples of these weighing 50 to 400 lb. were counted and the fractional background depression by adding to the net sample count rate the product of the background and the fractional background depression. Anderson (1968) indicated that when a massive sample is introduced into a K^{40} counter, it will absorb some of the background radiation, thus introducing a potential error proportional to sample mass and independent of sample activity. Therefore, a correction for background depression cannot be combined with the efficiency calibration.

The second effect of sample mass on the count of a given sample that Anderson (1959) referred to was the phenomenon of "self-absorption" of radiation emitted by the sample. Anderson indicated there is a higher probability that as the sample size increases a gamma ray will lose part or all of its energy before leaving the sample and may never reach the detector. The result is that net count may be an underestimation of the true amount of gamma events from the potassium source. As sample mass increases, the lower is the counting efficiency. In a later discussion, Anderson (1968) stated that gamma radiation is significantly scattered and absorbed by any sample whose mass exceeds a few kilograms, causing a need to establish counting rates as a function of sample mass. He noted that calibration for the phenomenon could be accomplished by construction of phantoms of known amounts of K^{40} and by introduction of known amounts of K^{42} into the living animal. There was excellent agreement between the two methods. Kessler et al. (1968) stated the K^{42} method was more reliable in determining counting efficiencies over a wide range of sample size. Anderson also pointed out the need to consider variations in sample shape as well as the distribution of the radioactivity within the sample.

The influence of sample size (as to the effect of self-absorption) on detection efficiency was researched by Twardock et al. (1966). Five box phantoms (weights of 200, 296, 392, 488 and 585 kg) were constructed to contain known quantities of KCl in water. The box dimensions were selected to approximate the length, girth and width of a steer of the same weight. The count rate was measured and the K^{40} detection efficiency for each phantom weight was determined from its known K^{40}

gamma-emission rate. There was a loss in counting efficiency of .0056 percent for each kilogram increase in phantom weight upon regression of weight on percent gamma detection. The efficiency calibration would deviate from the true K^{40} detection of the animal to the extent that the box phantoms do not reproduce the geometry, self-absorption and K^{40} distribution of the animal being measured. Therefore, a more meaningful efficiency calibration was obtained by means of K^{42} injections and measurements of cattle of selected body weights. Upon conducting such experiments, the regression of weight on percent gamma detection indicated there was a loss in counting efficiency of .0074 percent for each kilogram increase in weight of the animal. Live weight accounted for 88 percent of the variation in K^{42} detection efficiency, with a standard error of estimate of 0.25 percent. Additional calibration studies were suggested for the remainder of the variation, possibly due to errors in positioning the animal in the counter, K^{42} injection or variation caused by differences in body conformation.

Martin et al. (1968) investigated the effects of weight, length and K^{40} activity level of the sample on counting efficiency. Twenty-seven cylinders containing a sugar-KCl mixture were constructed so that a 3x3x3 factorial arrangement of treatments was formed with three lengths (60, 113 and 166 cm), three weights (13.6, 40.9 and 68.2 kg) and three activity levels (100, 150 and 200 g of potassium). Length, weight and activity level, whether singly or in combinations, all were significant sources of variance in affecting efficiency of detection of potassium content. The effects of weight were curvilinear, with an increase in weight being associated with a decrease in efficiency of gamma detection. The effects of activity level were of minor importance, and the interaction between length and weight indicated that the efficiency curves should correct for effects of both weight and length on efficiency of counting.

Lohman (1968) determined the influence of sample mass on counting efficiency using phantoms containing known quantities of potassium chloride in distilled water and by injecting K^{42} into cattle of selected body weights (Twardock et al., 1966). The four phantoms were constructed of wood to contain 181, 272, 363 or 454 kg of water and to approximate the dimensions of steers of the same masses. The boxes were filled with balloons each containing 38.2 gm of KCl dissolved in 3.6 kg of distilled water. In general, a linear relation was found between steer or phantom mass and detection efficiency for data from both the K^{42} and K^{40} counts. An increase in mass was associated with a decrease in counting efficiency. The variation in detection efficiency unaccounted for by body mass ranged from 11 to 4 percent for the K^{42} phase of the experiment. Greater than 99 percent of the variation in counting efficiency of the K^{40} phantoms was accounted for by weight and the standard error of estimate was .09 percent. It was also noted that electronic instrument drift affected the counting efficiency of large phantoms more than that of a smaller sample.

The relationship between the counting efficiency of a small standard source (619.03 g KCl) and four phantoms (constant density and .33 percent KCl by weight) weighing 500, 700, 900 and 1100 pounds was studied by Stiffler (1976). As weight increased the counting efficiencies of the phantoms decreased, while counting efficiency of the small standard source remained reasonably constant. The counting efficiencies of the 500, 700, 900 and 1100 pound phantoms were 7.61, 8.04, 8.31 and 8.57 percent less, respectively, than the small standard source efficiencies. Standard source counting efficiency accounted for 98.4 to 99.9 percent of the variation in phantom counting efficiency, suggesting a strong, essentially linear relationship between these variables. Stiffler concluded that phantoms provide an effective means of correcting count data for differences in counting efficiency attributed to mass, and data using a small standard source can be used to predict phantom counting efficiency with a high degree of accuracy.

Johnson (1978) developed five phantoms weighing approximately 200, 260, 320, 380 and 440 pounds at each of two potassium concentrations to determine the influence of weight and potassium concentration on the detection of potassium by the K^{40} counter. The high potassium concentration was to approximate the amount of potassium in the body of a lean, heavily muscled gilt, and the low concentration that of the amount of potassium in the body of a fat, light muscles gilt. Phantoms were K^{30} counted in two replications of four individual counts at each of three instrument counting efficiencies. Net K^{40} count was observed to increase as phantom weight increased from 200 to 440 pounds, but at a somewhat variable rate. Phantom counting efficiency decreased as mass increased. Reductions in counting efficiency ranged from 3.5 to 9.14 percent for each 60 pound increase in phantom weight for the low potassium concentration. The high potassium concentration ranged from 3.2 to 9.38 percent reduction in efficiency for each 60 pound increase in phantom weight. Mean net K^{40} phantom counts at both concentrations had significant linear and quadratic effects for phantom weight and significant interaction between concentration linear and phantom weight linear effects. Standard error of estimates ranged from 1.5 to 2.0

percent of their means from the regression equations at the three instrument counting efficiencies. Johnson then used reverse regression analysis to produce prediction equations for the estimation of potassium in phantoms or animals of varying weights.

In view of the findings of previous research in whole-body counting, it was the primary objective of this study to develop equations for the prediction of carcass lean in Angus and Hereford bulls ranging in live weight from 900 to 1300 pounds. Special emphasis was placed on background depression and self-absorption lowering the counting efficiency (decreasing detection of K^{40} emissions) when animal mass increased.

CHAPTER III

MATERIALS AND METHODS

Whole-Body Counter

The K^{40} whole-body counter housed at the Live Animal Evaluation Center at Oklahoma State University was used in this study. The principles of this counter were described by Moser, 1970; McLellan, 1970 and in detail by Frahm et al., 1971. There has been some modification of the counter and counting time since these earlier studies. In addition, cattle are no longer placed in an electrically powered restraining crate for movement into the counting chamber. Cattle are now placed in a mobile metal shell for movement into the counting chamber. Gates on both ends of the shell allow the animal to be loaded at the rear, rolled into the chamber on a track and released out the front following counting. The shell provides protection to the detector logs from possible damage by the animal.

The K^{40} detection system consists of 14 plastic scintillation detector logs arranged in a horseshoe configuration which approximates a 3-pi arrangement of the logs. A circular scintillator (end detector), 88.9 cm in diameter, is located at the rear of the counting chamber. The system is designed for the counting of animals weighing up to approximately 1200 to 1300 pounds, however somewhat lighter animals were primarily counted before this study.

Phantoms

Increasing sample mass lowers the total K^{40} count by absorption of a fraction of the background radiation, which in absence of a sample would pass into a detector and be registered as a greater portion of the gross count (Anderson, 1959). This physical phenomenon known as "background depression" results in lowering the background radiation reaching the detectors below that actually present in the atmosphere, and in turn lowers counting efficiency.

To develop an adjustment for "background depression", phantoms (non-living masses) weighing 900, 1000, 1100, 1200 and 1300 pounds were constructed in such a fashion as to simulate the length, width, height and general form of similar weight beef bulls. One gallon plastic cube containers $(6 \text{ in})^3$ were filled with 10 pounds of a water solution containing 13 percent sodium chloride. The sodium salt was added to deionized water in order that the desired density of the solution (1.13 g/ml) would more closely approximate that of the typical live beef bull (Stiffler, 1976). The plastic containers were arranged in multiple layers placed on a mobile dolly in a fashion resembling the general form of animals weighing 900, 1000, 1100, 1200 and 1300 pounds (Figure 1). These phantoms were used to determine the degree of background depression in K^{40} counts for each particular mass (void of potassium). This provided a method of adjustment for a portion of the K^{40} disintegrations not detected in earlier work with bulls over a rather wide range of live weights.

Plywood Standard

A three-dimensional plywood standard in the form of a bull was

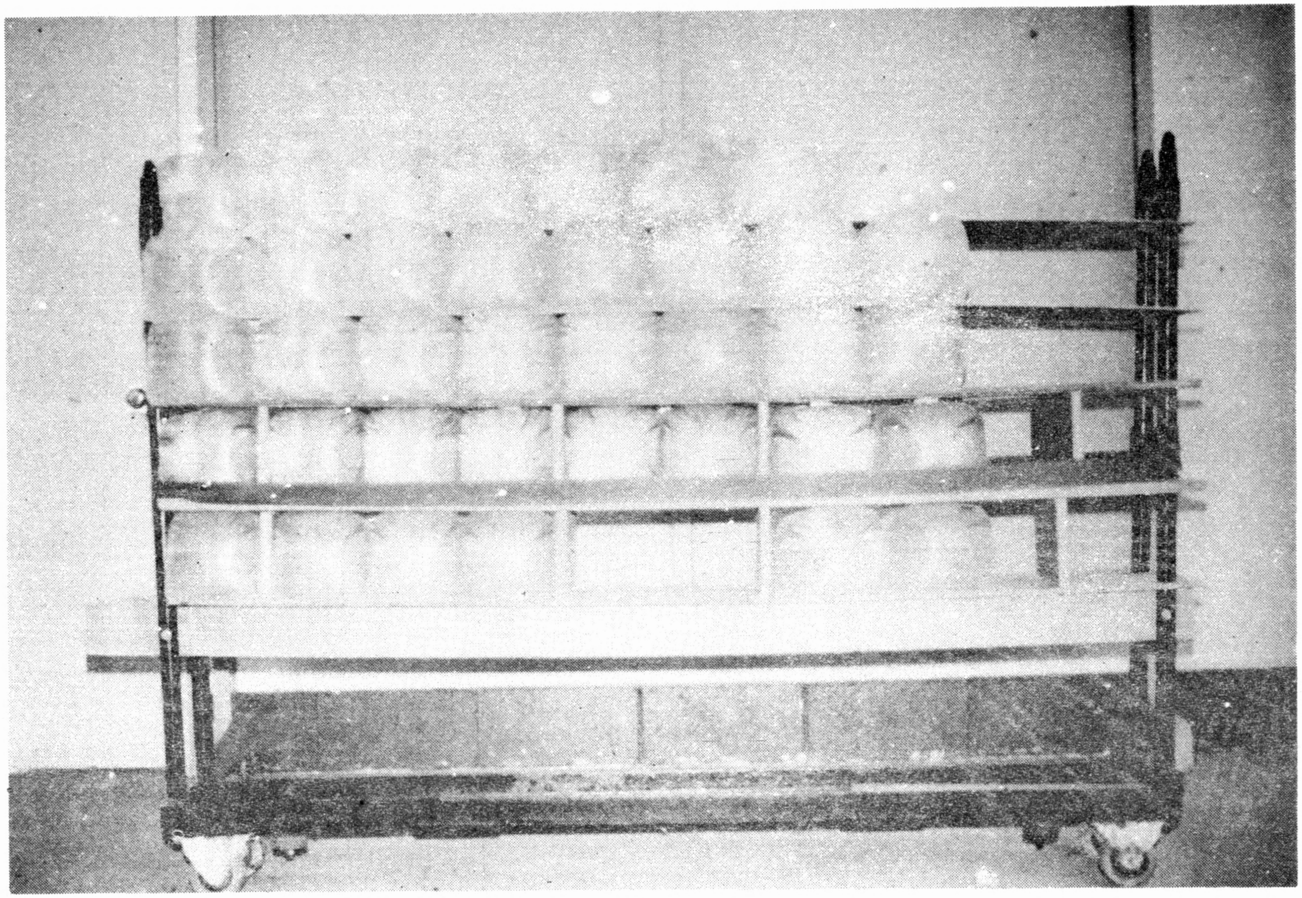

Figure 1. Typical 1000 Pound Phantom

constructed for the purpose of measuring instrument counting efficiency (Figure 2). The objective in this phase of the study was to K^{40} count a standard of relatively little mass with the same approximate distribution of potassium as proportionate to the distribution of lean meat in a bull. Three concentration levels of potassium chloride were used to allow for the shielding effects of the standard. Anderson (1959) reported that increasing sample mass lowers the total K^{40} count by absorption of a fraction of the background radiation and a gamma ray will lose part or all of its energy before leaving the sample. Arrangement of the three levels of potassium was structured in such a manner that K^{40} emissions would be similar to emissions from all parts of a beef bull. The lowest concentration level of potassium was located in the innermost layer of the plywood standard to simulate reduced gamma ray energy from emissions deep within the animal. Based on previous research, it was assumed that the potassium in a near weightless configuration would practically eliminate a decrease in detection of K^{40} counts of the plywood standard due to background depression and self-absorption described by Anderson (1959).

Plywood layers were bolted together in a vertical configuration and spaced apart to simulate the general body dimensions and contours of a beef bull. The approximate location of each wholesale cut was marked on the plywood standard and calculations were made to distribute capsules containing a known amount of potassium chloride in an arrangement similar to the distribution of the lean mass in the animal. The capsules were inserted into holes in the plywood layers in spacings proportionate to the estimated potassium distribution and concentration of a 1000 pound slaughter animal. Location of the capsules was

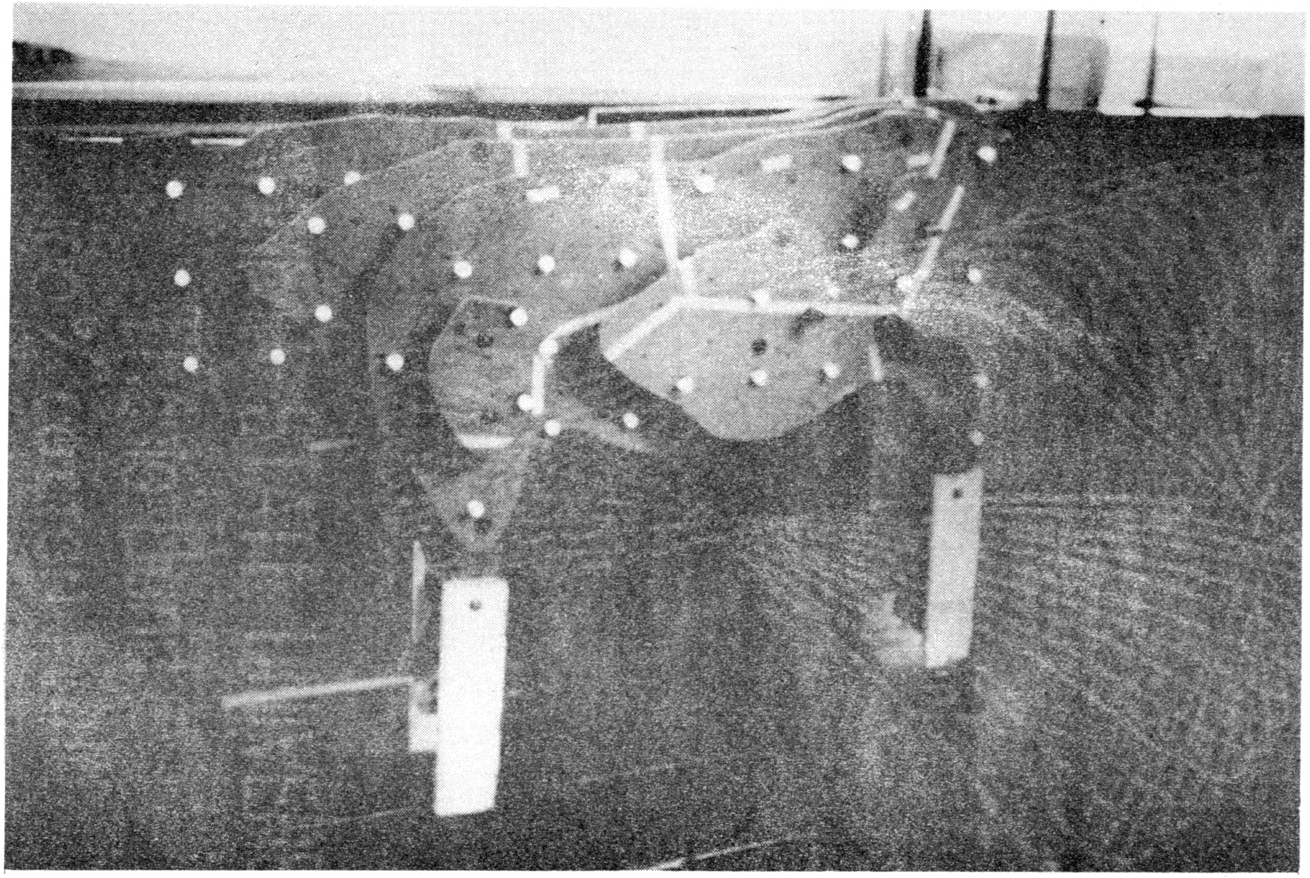

Figure 2. Three-dimensional Plywood Standard

determined from actual carcass lean distribution data previously developed at the O.S.U. Meat Laboratory. Anderson (1968) noted that if the concentration of potassium is non-uniform throughout the sample but the pattern of distribution is similar in all samples, then the deduced potassium concentrations may be in the correct ratios to one another even though they all suffer a consistent error. The carcass lean cutting data used in building the plywood standard had uniform distribution of lean in the wholesale cuts from animal to animal. Knowing the amount of potassium chloride in the standard allowed calculation of the possible gamma emissions per minute emitted by the standard (Radiological Health Handbook, 1970):

$$771.82 \text{ g KCl} \times 110 \text{ gamma disintegrations/min/g} = 8.49\text{x}10^4 \text{ events per min.}$$

The gamma emissions per minute were used later to arrive at instrument counting efficiency.

Phantom and Plywood Standard Counting Procedure

The circular rear detector in the whole-body counter has been observed to produce variable count rates with slight forward or backward movement of the animal during counting. The count rates may not be as constant as provided by the "horse-shoe" configuration of detectors only. The end detector switch was turned both "on" and "off" during the counting procedure to evaluate the usefulness of the end detector.

Sixteen net counts were obtained for each of the five phantom weights (Table I). The plywood standard was counted at the beginning,

TABLE I

COUNTING DESIGN FOR STANDARD SOURCE AND FIVE PHANTOMS

			Phantom Weight (Pounds)				
Date	End Detector	Std[a]	900	1000	1100	1200	1300
9/5	On	3	2[b]	2	2	2	2
	Off	3	2	2	2	2	2
9/7	On	3	2	2	2	2	2
	Off	3	2	2	2	2	2
9/13	On	3	2	2	2	2	2
	Off	3	2	2	2	2	2
9/15	On	3	2	2	2	2	2
	Off	3	2	2	2	2	2
Total Net Counts		24	16	16	16	16	16

[a] Plywood Standard Source.

[b] Each net count was the average counts per minute obtained from a 5-minute count.

mid-way and at the end of the counting day to establish the instrument counting efficiency for work done during that day in an effort to monitor instrument stability. Each phantom weight was counted four times (five minutes each) on a given day in a random order. These four net counts consisted of a phantom weight counted with the circular rear detector "on" and with it "off" and then repeated a second time in the counting day (Table II). This phantom counting procedure was repeated four times over a period of approximately 21 days. Each day the randomized counting was determined by drawing phantom weights out of a hat and the flip of a coin was used to determine the position of the end detector switch.

Each time a phantom or the plywood standard was counted, two consecutive one-minute background counts were taken of the empty chamber, followed by five consecutive one-minute counts with either the plywood standard or a phantom in the counting chamber. Immediately following the standard or phantom count, two consecutive one-minute background counts (empty chamber counts) were obtained. In this way, between each standard or phantom count, four one-minute background counts were taken. The first two counts were used with the preceding standard or phantom. The second two counts were used for the upcoming standard or phantom, in such a fashion that each of the background, sample, and background counts could be a set of independent observations. This procedure was repeated twice during a counting day for each phantom weight at each end detector switch position. Net K^{40} count per minute (NCPM) for both the plywood standard and the phantoms was calculated by removing that portion of the detectable radiation attributed to the environment (background) using the following formula:

TABLE II

EXAMPLE OF A "TYPICAL" DAY OF RANDOMIZED PLYWOOD STANDARD AND PHANTOM COUNTING (TO DERIVE BACKGROUND DEPRESSION)

Counting Order	Plywood Standard or Phantom Weight	End Detector Switch Position
1	Plywood Standard	On/Off
2	1300	On/Off
3	1000	On/Off
4	900	On/Off
5	900	Off/On
6	1100	Off/On
7	Plywood Standard	On/Off
8	1200	Off/On
9	1000	On/Off
10	1200	Off/On
11	1300	Off/On
12	1100	On/Off
13	Plywood Standard	Off/On

$$\text{NCPM} = \text{Mean Sample Count} - \text{Mean Background Count}$$

Mean sample count was calculated by averaging the five one-minute counts obtained for the plywood standard or phantoms. The mean background count was determined from the average of the two one-minute background counts obtained prior to and the two obtained after the standard or phantom counting. The negative net counts calculated mathematically for the phantoms were background counts depressed at the respective phantom weights.

The net K^{40} count data for the plywood standard was expressed as a percent of the total gamma disintegrations emitted per minute (γ DPM) and was referred to as instrument counting efficiency. This was determined mathematically from the known potassium concentration of the plywood standard. The 8.49×10^4 events per minute referred to earlier represented the γ DPM emitted by the plywood standard. The percent instrument counting efficiency for these data was determined as follows:

$$\text{Instrument Counting Efficiency} = \frac{\text{NCPM of Plywood Standard} \times 100}{\gamma \text{ DPM of Plywood Standard}}$$

Experimental Animals

Twenty-five Hereford and 22 Angus yearling bulls were fed a ration similar to that used by the Bull Test Station operated by Oklahoma Beef Inc. (Table III). They were fed under dry-lot conditions to randomly pre-assigned K^{40} count weights ranging from 950 to 1300 pounds. The hereford bulls were obtained from the Animal Science experimental beef herd and the Angus bulls were produced on a purebred ranch in Oklahoma. The younger Hereford calves averaged 460 pounds going on feed while the older Angus calves averaged 686 pounds. Some bulls were slaughtered

TABLE III

COMPOSITION OF FINISHING RATION

Ingredients	%	%
Steam rolled corn	27.8	
Steam rolled oats	29.5	
Dehydrated alfalfa pellets	4.3	
Cottonseed hulls	18.2	
Molasses	5.4	
Supplement pellets	14.8	
	100.0	
Soybean meal (44% protein)		50.91
Wheat middlings		43.00
Calcium carbonate		3.75
Salt		2.00
Vitamin A		0.085
Aureofac 50		0.0575
Trace mineral mix		0.20
		100.00

earlier than planned because of their inability to continue acceptable gains at heavier weights.

As the bulls reached the pre-determined count weight, they were trucked less than one mile to the Live Animal Evaluation Center and held off-feed and water for 24 hours prior to counting. Each bull was thoroughly washed using a low potassium soap in an effort to remove foreign materials that might alter the net K^{40} count. The height of the bulls was measured enabling counting chamber floor adjustments to be made with wooden planks in order to maintain a comparable space relationship between the sacral vertebrae of the bull and the center detector at the top of the chamber.

A maximum of five bulls was counted on any count day. The daily counting procedure for the bulls was the same as that for the phantoms. The plywood standard was counted three times during the count day both with the end detector "on" and "off". The 1000 pound phantom was counted following the plywood standard in order to determine background depression for that counting day. This 1000 pound phantom was counted if and when background count changed as much as 300 counts per minute. Each bull was counted in a random order, like the phantoms, twice with the end detector "on" and twice with the end detector "off". The mean NCPM (average of the first and second NCPM) for each bull was calculated for each rear detector switch position. The plywood standard provided a means of adjustment of bull count data for day to day variation in instrument counting efficiency. The adjusted count data (ADCT) for each bull was developed from the following formula using mean NCPM and percent instrument counting efficiency on the day the bull was counted:

$$\text{ADCT} = \frac{\text{Mean NCPM} \times 100}{\text{\% Instrument Counting Efficiency}}$$

Shrunk live weights (count weights) were recorded on each bull immediately after each net count. Table IV presents a distribution of the bulls by breed across count weights.

TABLE IV

DISTRIBUTION OF BULLS BY BREED AND COUNT WEIGHT GROUPS

Weight Groups	I	II	III	IV	V	VI	
Count Weight (lbs)	1000	1050	1100	1150	1200	1250	
Angus	4	3	2	6	3	4	
Hereford	4	8	2	3	6	2	
Number of Bulls	8	11	4	9	9	6	47

Slaughter and Physical Separation of the Carcass

Following the counting, the animals were trucked to the O.S.U. Meat Laboratory and slaughtered the following morning. The hot carcasses were weighed, shrouded and placed in a 34° F chill cooler for 48 hours. Routine carcass data and/or estimates were obtained and a U.S.D.A. yield and quality grade determined for each carcass. The right side of each carcass was physically separated into very closely trimmed lean, fat and bone and individual carcass component weights were recorded. Weights were first recorded for the untrimmed round, short-loin, sirloin, rib, chuck, and "thin cuts", which included foreshank, brisket, plate and flank. The separation was made on a wholesale cut weight basis using a muscle systems technique in an effort to effectively remove as much intermuscular fat as possible. The "thick" muscle systems were removed from the short loin, sirloin, rib, round and chuck, trimmed of all visible fat and seam fat in excess of .1 inch removed. The following "thick" muscle systems were removed from the wholesale cuts: (1) chuck--the supraspinatus, arm portion, inside and outside chuck, (2) rib--the rib-eye muscle, (3) short loin--the loin eye and tenderloin, (4) sirloin--the tenderloin and top sirloin butt and (5) round--the eye of the round, sirloin tip, heel, inside and outside round. Thinner muscle systems were also removed from these five cuts and trimmed of all visible fat.

The foreshank, brisket, plate and flank were deboned and all fat in excess of .1 inch removed. The boneless, closely trimmed "thin" lean from these cuts was blended with similar "thin" lean from the five major wholesale cuts, ground and sampled for chemical fat analysis.

Chemical Fat Analysis

The procedure used to sample the closely trimmed "thin" lean involved two coarse grinds (3/8 in plate) and one fine grind (1/8 in plate) with intermediate mixing. Nine "grab samples" were taken during the final grinding period to obtain representative samples of the carcass. Each of three subsamples was composed of three random "grab samples" and the subsamples designated as an A, B, or C sample. The principles of this sampling procedure are explained in more detail by Munson et al. (1965). Three plastic "whirl-pac bags" were filled with portions of the three subsamples and frozen for later analysis. After thawing, chemical fat was determined by the modified Babcock Fat Test for ground lean meat (Horwitz, 1975).

To represent the whole carcass, right side "thick" lean was divided by right side cold weight, then multiplied by left side cold weight to arrive at the left side "thick" lean. Right and left side "thick" lean were added together to obtain total "thick" closely trimmed, boneless lean. The same procedure was used to obtain the total "thin" trimmed lean. This adjusted for uneven cold side weights. Chemical fat was determined by multiplying percent Babcock fat by total "thin" trimmed lean. Total carcass lean was calculated to be total "thick" closely trimmed boneless lean + (total "thin" trimmed lean--chemical fat). This carcass lean was practically fat-free, but not in the same sense as provided by the Soxhlet method of ether-extract fat analysis (A.O.A.C., 1965).

Statistical Analyses

Data presented in this study were analyzed using the Statistical Analysis System (Barr et al., 1976). Means, standard deviations, analyses of variance, R-Squares, and regression analyses were computed using SAS procedures. Predicting carcass lean in beef bulls using regression analyses was the endpoint of this study. The analyses of variance are included in Appendix A.

CHAPTER IV

RESULTS AND DISCUSSION

Phantom Results and Background Depression Adjustment

The mean net K^{40} counts depressed for the five phantom weights at the two circular rear detector positions are presented in Table V. The mean net K^{40} counts in the table represent eight observations per mean. Phantoms (and animals) were counted with the end detector switch in both the "on" and "off" position in order that the count data taken from both switch positions could be compared. For comparison purposes, background depression adjustment systems were needed for both end detector switch positions.

A depression in net counts was observed as phantom weight increased. Analyses of variance (Tables XIV and XV in Appendix A) indicated significant differences ($P < .01$) between phantom weights for net counts depressed. These reduced net counts are referred to as background depression. They represent the lowering of background radiation reaching the detectors as sample mass was increased. These counts were shielded from detection by the mass of the animal and in reality should be registered as a greater portion of the gross count. These depressed counts should be added to the net count of the live animals to arrive as near the actual count as possible. Table V also presents the depression in net counts for each successive 100 pound

TABLE V

MEAN NET K^{40} COUNTS PER MINUTE DEPRESSED[a] (BACKGROUND DEPRESSION) AND STANDARD ERRORS[b] FOR FIVE PHANTOM WEIGHTS AT TWO END DETECTOR SWITCH POSITIONS

End Detector Switch Position	Phantom Weights (Pounds)								
	900		1000		1100		1200		1300
On	935 (29.2)		1032 (29.2)		1124 (29.2)		1203 (29.2)		1289 (29.2)
Depression in NCPM		97 (41.2)		92 (41.2)		79 (41.2)		86 (41.2)	
Off	706 (26.5)		876 (26.5)		1046 (26.5)		1069 (26.5)		1169 (26.5)
Depression in NCPM		170 (37.5)		170 (37.5)		23 (37.5)		100 (37.5)	
Average Depression in NCPM[c]		134		131		51		93	

[a] Eight observations per mean.

[b] Standard errors in parentheses.

[c] Averaged across the two end detector positions.

increase in phantom weight for each end detector position. The two largest reductions in net count occurred between 900 and 1000 pound phantoms, and the 1000 and 1100 pound phantoms for both end detector positions. These reductions in net counts per minute were 97 and 92, respectively (end detector on), and 170 and 170, respectively (end detector off). The largest reductions occurred between the same phantom weights when the average depression (averaged across the two end detector positions) was observed.

A larger depression in mean net count appeared at each weight when the end detector was in the "on" position compared to the "off" position. A graphic representation of the mean net K^{40} counts depressed for the five phantom weights at each of two detector positions is presented in Figure 3.

Table VI presents the mean squares within day by weight for the phantom net counts. The mean squares represent the variation among replications in net count for a certain weight phantom within the count day, pooled across all phantom counting days. Mean squares were generally lower when the end detector switch was "off", than when "on" except at the 1100 pound phantom weight where the net count mean square was markedly greater for the end detector "off". This appeared to be due to one atypical phantom count made on the first day of counting.

Two methods of adjustment for background depression were compared. The first involved regressing phantom net count on weight and was called the "net count method". The second was a "ratio method" utilizing ratios of phantom net counts to the net count of the 1000 pound phantom. The ratios were based on the 1000 lb phantom which was to be used in the bull counting procedure. The 1000 lb phantom was counted

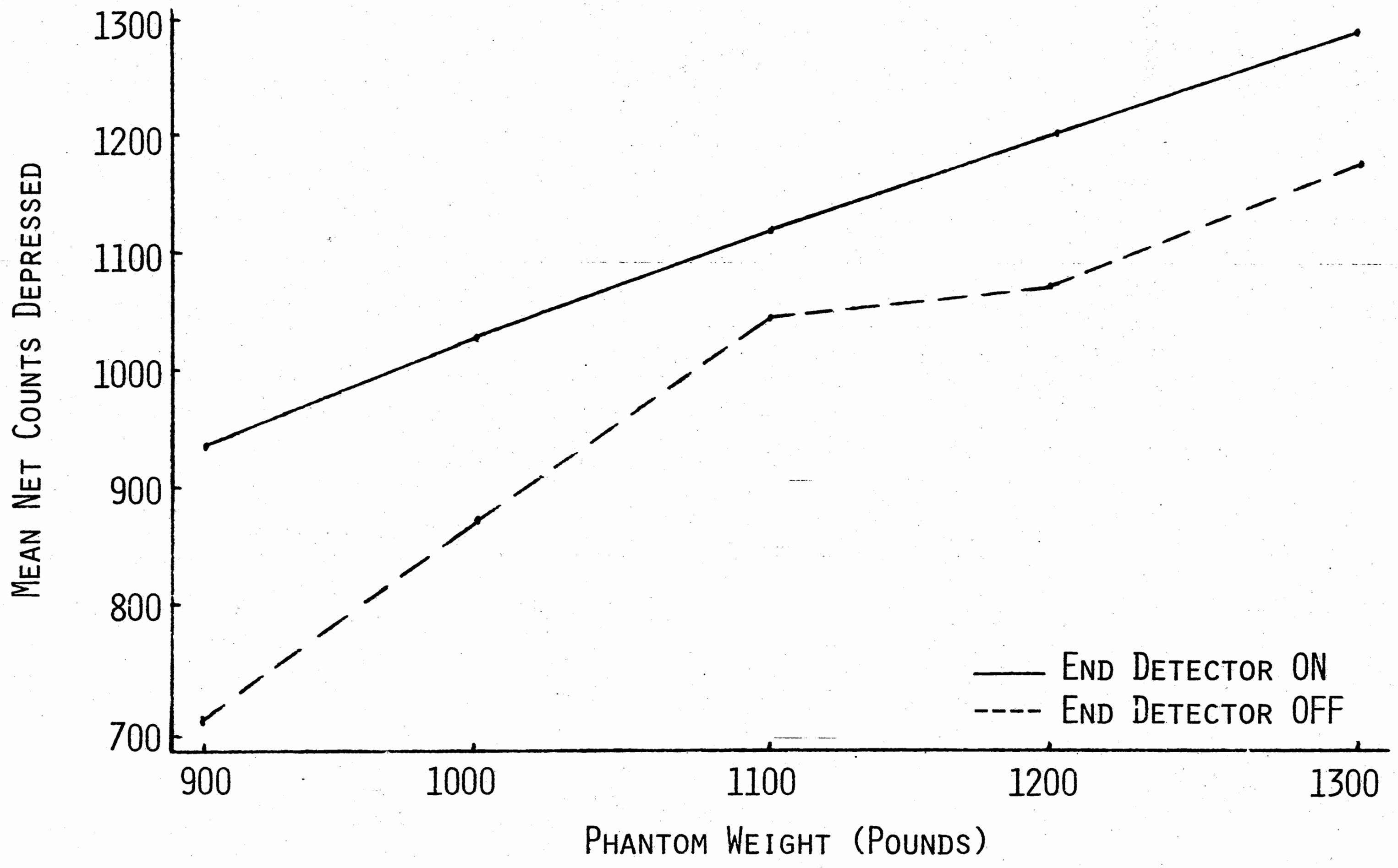

Figure 3. Comparison of Mean Net K^{40} Counts Depressed for Five Phantom Weights (Background Depression) at Each of Two End Detector Positions

TABLE VI

MEAN SQUARES WITHIN DAY BY WEIGHT FOR NET COUNTS OF PHANTOMS AT TWO END DETECTOR POSITIONS

Weight (Pounds)[a]	d.f.	Mean Square	
		ON[b]	OFF[b]
900	4	3642	438
1000	4	6828	5227
1100	4	3877	19538
1200	4	11888	1838
1300	4	7772	1155
Average	20	6801	5639

[a] Two readings per weight per day for each detector position.

[b] End detector switch positions (detector "on" and "off").

on the same day as the bulls to determine the background depression for the 1000 lb phantom on that day, since instrument counting efficiency differs somewhat from day to day. A ratio of the background depression for a particular phantom weight to the background depression of the 1000 pound phantom was established for each weight:

$$\text{Ratio for Phantom Weight} = \frac{\text{NCPM of a Particular Phantom Weight}}{\text{NCPM of 1000 lb Phantom}}$$

The ratio for each phantom weight was then regressed on phantom count weight to produce a prediction equation. Entering a particular weight in the equation would yield a predicted ratio. The predicted ratio for a particular bull was multiplied by the mean net count of the 1000 lb phantom (counted the same day as the bull) to determine the background depression adjustment to be added to the bull net count. This method was referred to as the "ratio method."

Tables XIV and XV in Appendix A present the analyses of variance for both the phantom net counts and the ratios of phantom net counts to the net count of the 1000 lb phantom. Table XIV presents analyses for the end detector "on" and Table XV presents analyses for the end detector "off". Net counts regressed on weight and the ratios regressed on weight were both found to be linear when the end detector was "on". The $\text{Wt}_{\text{Linear}}$ and residual component in the analyses of variance indicate the linear relationship. Twardock et al. (1966) and Lohman (1968) also observed a linear relationship between sample mass and background depression. The lines also were observed to be parallel from day to day; however, the means were not equal. The different means for each phantom counting day indicate that the 1000 lb phantom should be counted each bull counting day because of difference in instrument counting from day to day. Furthermore, the ratios did not remove the differences among dates. When the end detector was "off", there appeared to be a slight curvature effect to the data (believed to be due to the one atypical count at 1100 pounds).

Regression coefficients for the regression of phantom net count on weight are presented in Table VII. The pooled regression coefficients were .88 and 1.12 for the end detector "on" and "off" respectively. Table VIII presents the regression coefficients for the regression of the ratio of phantom net counts, with no intercept, on weight. The intercept was forced to be one at the 1000 pound phantom. The pooled regression coefficients were 0.00095 and 0.0012 for end detector switch "on" and "off", respectively. For both the "net count method" and "ratio method", there was more variation in the regression coefficients across days when the end detector was "on" than when "off".

The regression formula for the prediction of the ratio of phantom net counts for a particular weight, where b is the regression coefficient was:

$$\text{Ratio of Net Count} = a + b*WT$$

The intercept, a, was forced at one and a background depression adjustment (BADJ) for the "ratio method" was developed from the previous formula:

$$BADJ = [1 + b*(WT-1000)]CT$$

End Detector "ON" b = .00095; End Detector "OFF" b = .00120

CT = Depressed Net Count of 1000 lb phantom on bull counting day.

TABLE VII

REGRESSION COEFFICIENTS FOR THE REGRESSION OF NET PHANTOM COUNT ON WEIGHT BY DATE AND POOLED (BOTH END DETECTOR POSITIONS)

	End Detector Switch Position	
Date	ON	OFF
1	.60 ± .18	.99 ± .24
2	.87 ± .14	.97 ± .16
3	.90 ± .18	1.40 ± .12
4	1.15 ± .17	1.12 ± .19
Pooled	.88 ± .09	1.12 ± .09

TABLE VIII

REGRESSION COEFFICIENTS FOR THE REGRESSION OF RATIO OF PHANTOM NET COUNTS WITH NO INTERCEPT[a] ON WEIGHT BY DATE AND POOLED (BOTH END DETECTOR POSITIONS) (MULTIPLY BY 10^{-3})

	End Detector Switch Position	
Date	ON	OFF
1	.61 ± .15	1.15 ± .24
2	.97 ± .11	1.23 ± .30
3	.96 ± .14	1.36 ± .18
4	1.27 ± .15	1.39 ± .11
Pooled	.95 ± .08	1.20 ± .09

[a] Forced intercept to be one at a 1000 pound phantom.

The equation adjusts for differences in weight from 1000 pounds using the regression coefficients.

The formula to predict net phantom counts depressed for a particular weight was:

$$\text{Net Phantom Counts Depressed} = a + b{*}WT$$

A background depression adjustment (BADJ) for the "net count method" was developed from the previous formula:

$$BADJ = CT + b{*}(WT-1000)$$

End Detector "On" b = .88; End Detector "Off" b = 1.12

Example: $BADJ = 888 + (1.12)(1190 - 1000)$

$= 1100.8$ cpm adjustment for an 1190 lb bull

Adjustment for differences in weight from 1000 pounds was accomplished by the regression coefficient.

Adjusted net count (ADJNC) for each animal was calculated using the following equation, where NCPM of the bull was adjusted for background depression and instrument counting efficiency (EFF) (as discussed in Materials and Methods).

$$ADJNC = (NCPM + BADJ)/EFF$$

Table IX presents the estimated variances of net phantom counts adjusted by the "net count" and "ratio" method. Variances were larger in animals over 1000 lb with the "ratio method". In light of this, it was decided that the "net count method" of adjustment would be used. Both methods provided an adjustment for the phenomena of background depression; however, careful evaluation indicated the "net count method" would produce an adjustment with greater precision time after time. The equation for the adjustment was: $BADJ = CT + b*(WT-1000)$ where $b = .88$ (End detector "on") and $b = 1.12$ (End detector "off").

TABLE IX

ESTIMATED VARIANCES OF ADJUSTED NET PHANTOM COUNTS ADJUSTED BY REGRESSION OF NET COUNT ON WEIGHT[a] AND BY REGRESSION OF RATIO WITH NO INTERCEPT ON WEIGHT[b]

	"Net Count Method"		"Ratio Method"	
Weight (Pounds)	ON	OFF	ON	OFF
900	6901	5759	5639	4429
1000	6801	5639	6801	5639
1100	6901	5759	8223	7136
1200	7001	5879	9905	8921
1300	7101	5999	11847	10993

[a] Phantom net counts were adjusted by the net count method.

[b] Phantom net counts were adjusted by the ratio of net counts method.

It was also noted in Table IX that estimated variances were smaller when the end detector was "off" than when "on". The detector comparison continued through the animal work, but observations made early in the study indicated that greater instrument stability, as measured by repeated NCPM for the phantoms, was found when the end detector was "off".

Bull Carcass Composition and K^{40} Count Data

Ranges, means and standard deviations for count weight, carcass lean, age and various other carcass parameters for the 47 bulls are presented in Table X. Count weight ranged from 970 to 1264 pounds with a mean count weight of 1114 pounds and a standard deviation of 88 pounds. The mean pounds of carcass lean was 377.3 with a standard deviation of 29.4 pounds. Age at slaughter ranged from 415 to 552 days with a mean of 486 days and the standard deviation was 28 days.

The repeatability of independent K^{40} count estimates made on the same animal on the same day is important in determining the precision of an evaluation technique such as whole-body counting. Repeatability of the O.S.U. whole-body counter was estimated by counting each animal twice on a given day. The correlation coefficient (used here as an estimate of repeatability) between the first and second NCPM (unadjusted) on the same animal on the same day was .93. This positive correlation indicates a strong association between readings and that the counter was repeating itself reasonably well. This correlation is similar to those reported by McLellan (1970) or Frahm et al. (1971) in studies with beef cattle.

Means for net count per minute, adjusted net count, carcass lean and ratio of adjusted net count to carcass lean are presented in Table XI by breed and pooled into one population (ignoring breed). The pooled means are weighted averages of the means for each breed.

TABLE X

RANGES, MEANS AND STANDARD DEVIATIONS FOR COUNT WEIGHT, CARCASS LEAN, AGE AND OTHER CARCASS DATA FOR THE BULLS

Item	Range	Mean	Standard Deviation
Count weight[a] (lbs)	970-1264	1114	88
CL[b] (lbs)	318.4-445.5	377.3	29.4
Slaughter age (days)	415-552	486	28
% Carcass lean[c]	30.2-37.9	33.9	1.8
Carcass lean/day age	.64-.92	.78	.07
USDA yield grade	1.9-5.0	3.2	.7
Dressing percent[d]	59.5-66.1	63.6	1.6

[a] 24-hr shrunk weight.

[b] Carcass lean (CL).

[c] % Carcass lean = CL/count weight x 100.

[d] Hot carcass weight/count weight x 100.

TABLE XI

MEANS FOR COUNT PARAMETERS AND CARCASS LEAN FOR ANGUS AND HEREFORD BULLS BY END DETECTOR SWITCH POSITION

End Detector	Breed[a]	NCPM[b]	ADJNC[c]	CL[d]	Ratio ADJNC/CL
ON	Angus	12517	85599	383.3	224.0
	Hereford	12081	83895	372.0	226.3
	Pooled	12285	84693	377.3	225.2
OFF	Angus	10714	85019	383.3	222.4
	Hereford	10407	84149	372.0	226.9
	Pooled	10551	84556	377.3	224.8

[a] 22 Angus and 25 Herefords.

[b] Net count per minute (NCPM).

[c] Adjusted net count (ADJNC).

[d] Carcass lean, pounds (CL).

Comparison of the means in Table XI indicated that the Angus bulls had higher mean ADJNC and mean pounds of carcass lean than the Hereford bulls. Counting date was not incorporated in the model in the analyses of variance (Tables XVI, XVII and XVIII in Appendix A) because of the random distribution of weights of animals and breeds on count days. No set weight of animal nor breed was counted on certain days. Analyses of variance indicated there were no significant differences between breeds for carcass lean or the count parameters. Differences in carcass lean within the breed appeared to be greater than differences among breeds. The range in body composition of animals within each breed was rather wide. Pooled means in Table XI were quite similar for each end detector position, except for NCPM. Less count was detected when the end detector was "off" than when "on". After adjustment of NCPM for background depression and instrument counting efficiency, the mean ADJNC for each detector position becomes quite comparable.

The methods of predicting carcass lean that were evaluated are presented in Table XII. The "ADJNC/CL method" utilizes the ratios of adjusted net count to carcass lean for each animal and is described in Appendix B. Weight alone, ADJNC alone and combined weight and adjusted net count were evaluated for predicting carcass lean, as well as combined weight and ADCT (where adjusted count was <u>not</u> adjusted for background depression, but was adjusted for instrument counting efficiency).

Table XII presents the mean squares (error term) between observed and predicted carcass lean of the bulls for the different methods. There was little difference in error of predicting within each method when breed was considered in the model or omitted. Based on this observation and the non-significance of breed in the analyses of

TABLE XII

MEAN SQUARES IN PREDICTING CARCASS LEAN BY VARIOUS METHODS WITH AND WITHOUT BREED IN THE MODEL AND BY END DETECTOR POSITION

	With Breed in Model		Without Breed in Model[a]	
Method	ON	OFF	ON	OFF
ADJNC/CL[b]	213	146	223	151
Weight and ADJNC	158	118	160	124
Weight and ADCT[c]	--	--	172	151
Weight	--	--	363	363
ADJNC	--	--	603	510

[a] All 47 bulls were considered to be one population.

[b] Method involving adjusted net count per pound of carcass lean for each bull.

[c] Adjusted count was not adjusted for background depression due to animal mass, but was adjusted for instrument counting efficiency.

variances, all 47 bulls can be statistically considered as one population for prediction purposes. In all of the methods using count parameters, the end detector "off" mean squares were lower (lower error) than when the detector was "on". The smaller the mean squares, the lower is the error associated with that prediction method. It is apprent that when turned "on", the end detector may respond to slight forward or backward movement of the animal causing more variation in count than was found with the "horseshoe" configuration of detectors surrounding the animal. Prediction equations involving adjusted net count had the highest mean squares, followed by using weight alone for prediction. The "ADJNC/CL method" improved accuracy rather significantly as indicated by the substantially reduced mean squares compared to the ADJNC method and weight method. Equations involving weight and ADCT (unadjusted for background depression) had even lower mean squares which were 172 and 151 for each end detector "on" and "off", respectively. The lowest values observed were 160 and 124 for end detector "on" and "off", respectively, for equations involving weight and ADJNC. It appears, from the lower mean squares, that the adjustment for background depression improved the accuracy of predicting carcass lean. Results indicated that combined weight and ADJNC in an equation was more accurate for prediction purposes than the "ADJNC/CL method". Some self-absorption adjustment may have occurred within the multivariate regression of weight and ADJNC.

The count weight and measured quantity of carcass lean for each of the 47 bulls is plotted in Figure 4. The regression equation is: $\hat{Y}$ = predicted CL 91bs) = 93.17 + 0.2550 (WT). The adjusted net count and measured quantity of carcass lean for each of the 47 bulls for each

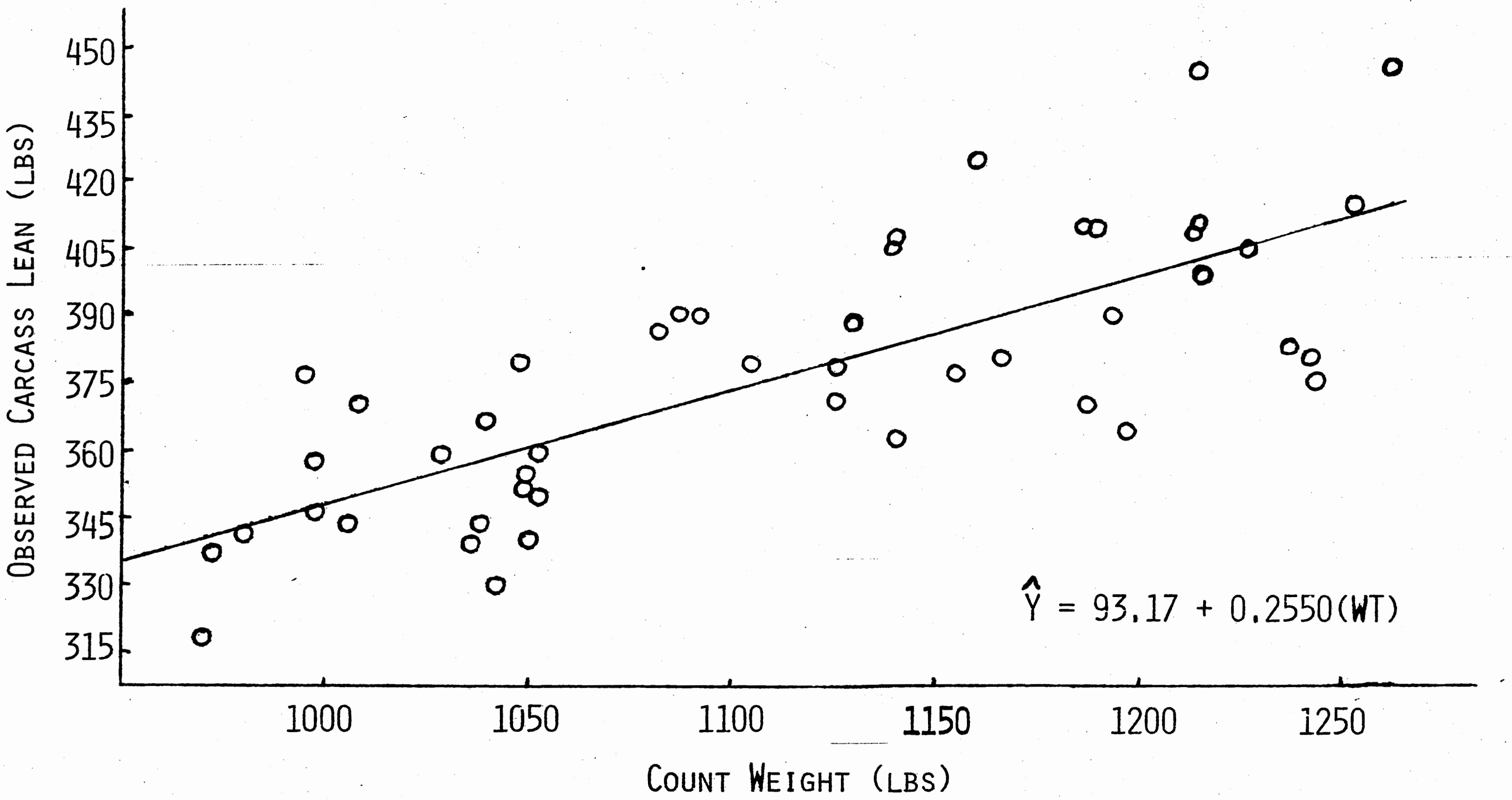

Figure 4. Plot of Count Weight and Observed Carcass Lean for all Bulls

end detector position is plotted in Figures 5 and 6. The regression equation for end detector "on" is: $\hat{Y}$ = predicted CL (lbs) = 91.88 + 0.0033804 (ADJNC). The regression equation for end detector "off" is $\hat{Y}$ = predicted CL (lbs) = 25.86 + 0.0041714 (ADJNC). A linear relationship appeared to exist in the plots between CL and count weight and between CL and ADJNC of the live animal.

The prediction equations, standard error of estimate, coefficient of determination and coefficient of variation for each of the various methods of predicting carcass lean at each end detector position are presented in Table XIII. For each method the end detector "off" gives a reduced standard error of estimate, an increased r-square, and a reduced C.V. compared to end detector "on". The average quantity of CL in this group of 47 bulls was 377.3 lb with a standard deviation of 29.4 lb. The prediction equation for CL based on count weight yielded a standard error of estimate of 19.1 lbs with weight accounting for 58.8 percent of the variation in CL. The prediction equation for CL based on ADJNC with the end detector "off" yielded a standard error of estimate of 22.6 lbs with ADJNC accounting for 42.2 percent of the variation in CL. Prediction equations utilizing count parameters and weight were more accurate in predicting CL than those based on ADJNC alone or weight alone. Equations utilizing weight and ADCT (unadjusted for background depression) were not as accurate as when the adjustment was made for background depression (equations with weight and ADJNC). Standard errors of estimate, r-squares and C.V.s were similar whether breeds were considered in the model or not. The prediction equation for CL based on weight and ADJNC with end detector "off" yielded a standard error of estimate of 11.1 lbs which was 18.3 lbs less than

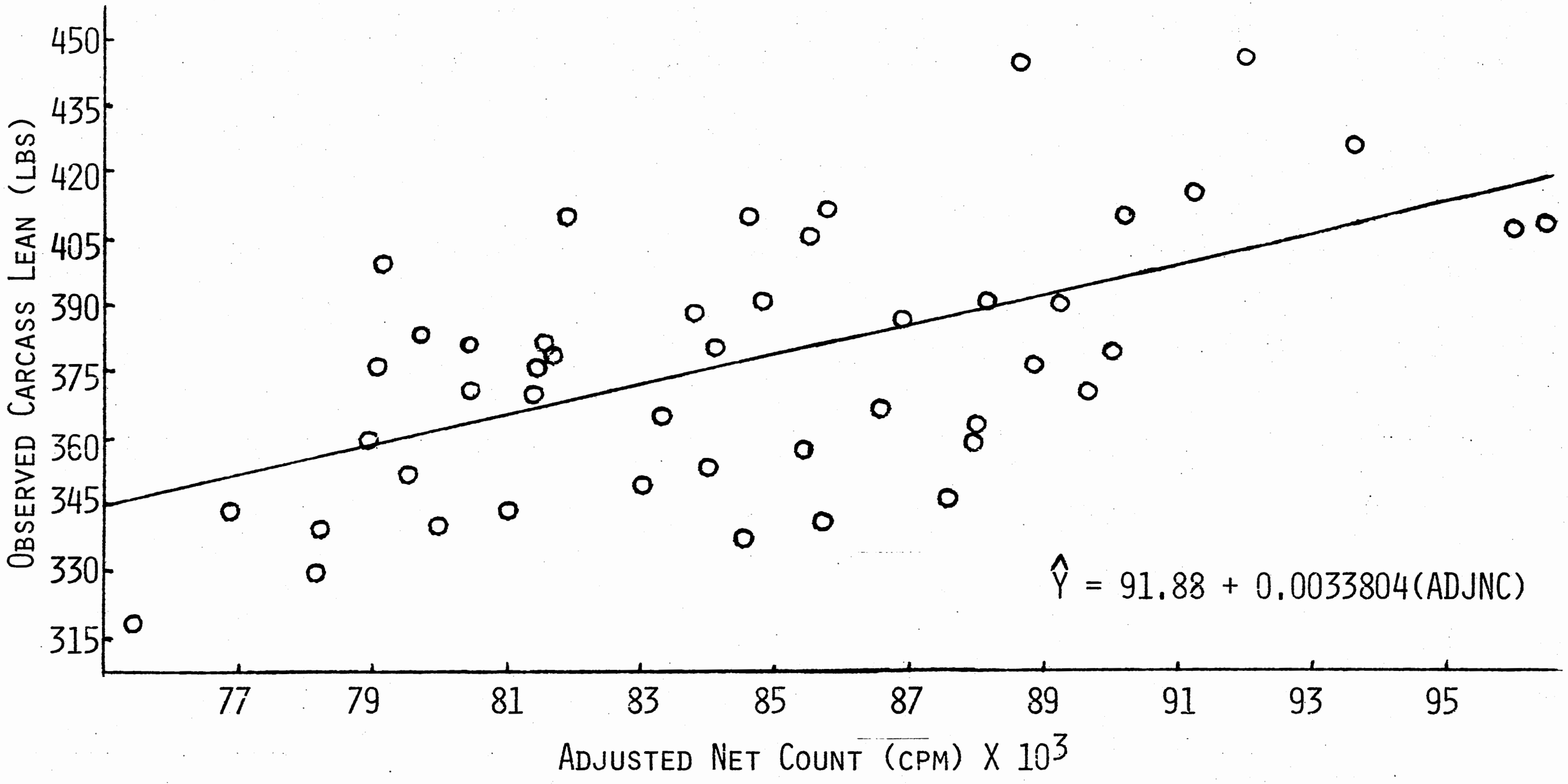

Figure 5. Plot of Adjusted Net Count and Observed Carcass Lean for all Bulls (End Detector Switch "ON")

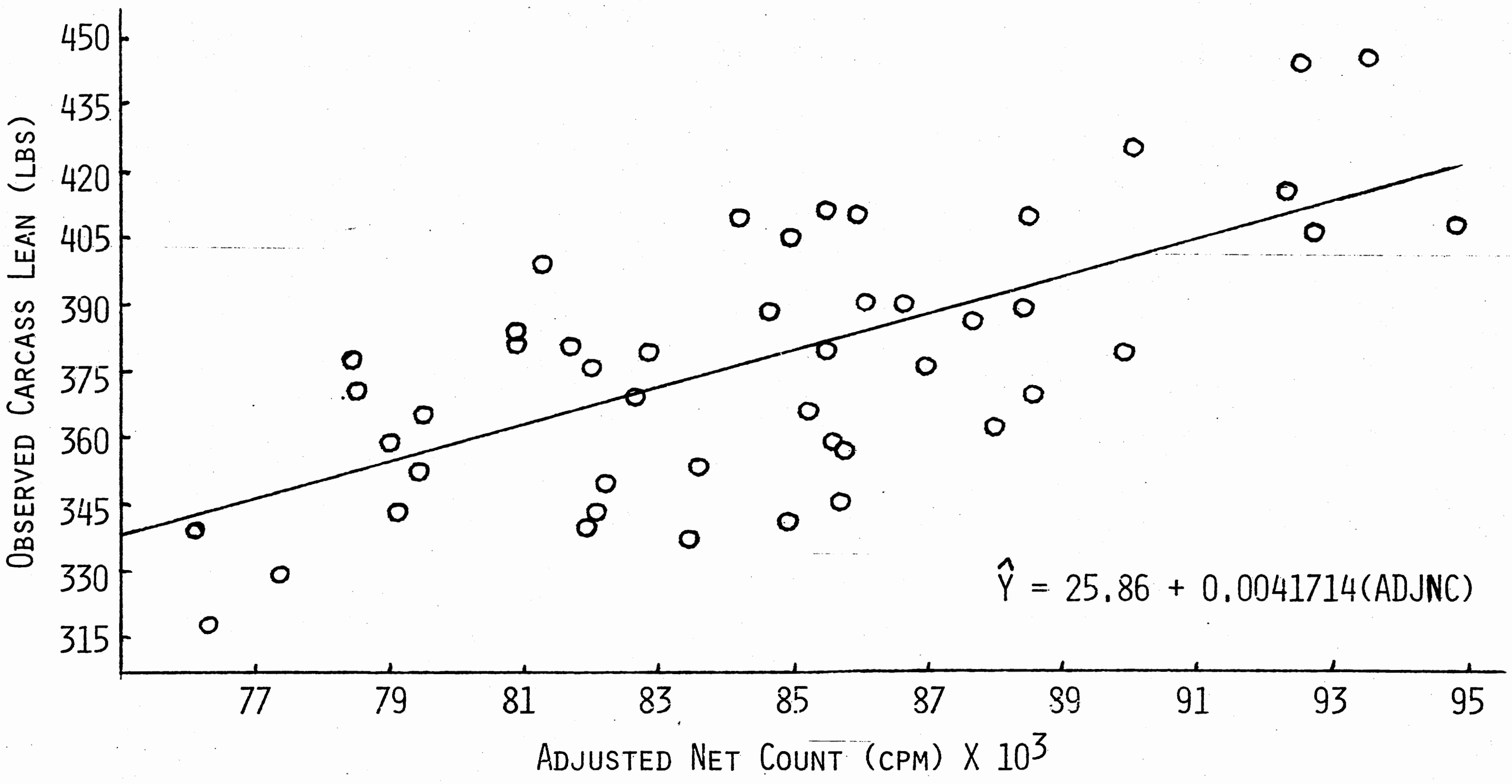

Figure 6. Plot of Adjusted Net Count and Observed Carcass Lean for all Bulls (End Detector Switch "OFF")

TABLE XIII

PREDICTION EQUATIONS[a], STANDARD ERROR OF ESTIMATE, COEFFICIENT OF DETERMINATION AND COEFFICIENT OF VARIATION FOR THE METHODS OF PREDICTING CARCASS LEAN AT EACH END DETECTOR SWITCH POSITION

Methods	Standard Error of Estimate (lbs)	r^2	C.V.[b] (%)
ON			
$\hat{Y} = 93.17 + .2550\ (WT)^c$	19.1	.588	5.0
$\hat{Y} = 91.88 + .0033804\ (ADJNC)$	24.5	.317	6.5
$\hat{Y} = -118.9 + .2449\ (WT) + .0028911\ (ADCT)^d$	13.1	.809	3.5
$\hat{Y} = Bo^* + .2308\ (WT) + .0028546\ (ADJNC)^e$	12.6	.825	3.3
$\hat{Y} = -126.2 + .2318\ (WT) + .0028955\ (ADJNC)$	12.6	.823	3.3
OFF			
$\hat{Y} = 93.17 + .2550\ (WT)$	19.1	.588	5.0
$\hat{Y} = 25.86 + .0041714\ (ADJNC)$	22.6	.422	6.0
$\hat{Y} = -144.8 + .2418\ (WT) + .0032771\ (ADCT)^d$	12.3	.832	3.3
$\hat{Y} = Bo^{**} + .2112\ (WT) + .0033900\ (ADJNC)^e$	10.9	.870	2.9
$\hat{Y} = -150.4 + .2134\ (WT) + .0034294\ (ADJNC)$	11.1	.863	2.9

[a] Form of the prediction equation: $\hat{Y} = Bo + b_1\ (WT) + b_2\ (ADJNC)$.

[b] The coefficient of variation is based on the mean carcass lean (377.3 lbs).

[c] Shrunk weight, pounds.

[d] Adjusted count (ADCT) was not adjusted for background depression due to animal mass.

[e] Breed was considered in the regression model.

[*] Bo = -120.22 for Angus; Bo = -122.71 for Herefords.

[**] Bo = -142.08 for Angus; Bo = -146.82 for Herefords.

the 29.4 lb standard deviation in CL for the bulls. This equation utilizes all 47 bulls as one population with the variation in weight and ADJNC associated with 86.3 percent of the variation in CL. The coefficient of variation was 2.9 percent based on the mean pounds of carcass lean for the bulls. The 11.1 lb standard error of estimate obtained from these data is higher poundage-wise than the 8.6 lb standard error of estimate reported by Frahm et al. (1971) from 40 yearling Angus bulls of uniform and lighter weight evaluated by the K^{40} counter at O.S.U. Percentage-wise the coefficients of variation are very similar.

Count weight and residual carcass lean (observed minus predicted CL using weight and ADJNC in the prediction equations) were plotted for all bulls in the computer analysis and there was no pattern of distribution. This indicated that the predicted CL and weight relationship was not curvilinear. Adjusted net count and residual carcass lean for all bulls were plotted in the computer analysis. There was no pattern of distribution, indicating that the predicted CL and ADJNC relationship was not curvilinear.

Net count per minute should be adjusted for background depression due to increasing animal mass and instrument counting efficiency to an ADJNC. Variation was reduced and accuracy increased by turning the end detector switch "off". The prediction equation utilizing weight and ADJNC with the end detector "off" should be used to predict carcass lean in these heavier bulls more accurately. This equation is as follows:

$$\hat{Y} = \text{Predicted CL (lbs)} = -150.4 + 0.2134\ (\text{WT}) + 0.0034294\ (\text{ADJNC})$$

The coefficient of determination for this equation was .863, the standard error of estimate was 11.1 lbs, and the coefficient of variation was 2.9 percent of the mean carcass lean. This equation should be used for predicting CL in Angus and Hereford yearling bulls with shrunk weights in the range of 970 to 1264 lbs with two readings of NCPM taken per animal on the counting day. These data suggest the whole-body counter can be an effective technique for detecting differences in total carcass lean among yearling beef bulls. K^{40} count of the live animal in conjunction with other performance data could provide an effective method of selecting bulls that have superior genotypes for rapid growth of muscle.

The following example steps indicate how to calculate predicted CL for a bull when the end detector is "off".

1. Bull count weight = 1150 pounds and NCPM = 10551.

2. The net counts depressed by the 1000 lb phantom on the day the bull was counted = 850 cpm.

3. The instrument counting efficiency (EFF) was 13.6 percent on the counting day.

4. The background depression adjustment was calculated:

$$\begin{aligned} \text{BADJ} &= \text{CT} + b*(\text{WT}-1000) \\ &= 850 + 1.12\ (1150-1000) \\ &= 1018 \text{ cpm adjustment for 1150 lb bull} \end{aligned}$$

5. The background depression and instrument counting efficiency adjustment was made:

$$\begin{aligned} \text{ADJNC} &= (\text{NCPM} + \text{BADJ})/\text{EFF} \\ &= (10551 + 1018)/.136 \\ &= 85066 \text{ cpm} \end{aligned}$$

6. Predicted CL was calculated:

$$\hat{Y} = -150.4 + .2134\ (WT) + .0034294\ (ADJNC)$$

$$= -150.4 + .2134\ (1150) + .0034294\ (85066)$$

$$= 386.7 \text{ lbs predicted CL.}$$

CHAPTER V

SUMMARY

Five phantoms weighing approximately 900, 1000, 1100, 1200 and 1300 pounds each were developed in an effort to determine the influence of weight (mass) on background depression in K^{40} net count evaluation techniques. The phantoms contained a water solution of sodium chloride in order that the density of the solution would closely approximate that of the typical live beef bull. The phantoms were constructed in a fashion resembling the general form and weight of animals to be evaluated in this study. Phantoms were K^{40} counted in four replications of two individual counts with the end detector switch "on" and two individual counts with the end detector switch "off". The circular rear detector in the whole-body counter was evaluated to determine which position of the switch during counting provided greater instrument stability. Regression analysis was used to develop an adjustment for "background depression" (portion of the K^{40} disintegrations not detected) where animals differing in live weight were K^{40} counted.

A depression in net counts of the phantoms was observed as phantom weight increased from 900 to 1300 pounds, but the depression was at a somewhat variable rate. These reduced net counts are referred to as background depression. The depressed counts should be added to the net count of the live animal to correct for what has been shown to be undetected. A larger depression in net count appeared at each weight when the end detector was in the "on" position. The mean squares for repeated phantom net counts within day by weight, pooled across all phantom counting days were generally lower when the end detector was "off" than when "on". Repeatability of net count was increased with the end detector "off".

Two methods of adjustment for background depression were compared. The first involved regressing phantom net count on weight ("net count method"). The second was a "ratio method" utilizing ratios of phantom net counts to the net count of the 1000 lb phantom. There was a linear relationship between phantom net counts and weight and between the ratios and weight of phantom net counts to the net count of the 1000 lb phantom and weight when the end detector was "on". A slight curvilinear relationship was observed when the end detector was "off". This is believed to be due to one atypical count. Both methods provided an adjustment for background depression, but analysis indicated the "net count method" produced an adjustment with greater precision time after time than the "ratio method".

Twenty-five Hereford and 22 Angus yearling bulls were fed to randomly pre-assigned K^{40} count weights ranging from 950 to 1300 pounds. Each bull was K^{40} counted twice with the end detector switch "on" and twice with it off, following a 24-hour shrink. The bulls were subsequently slaughtered and, following chilling, the right side of each carcass was physically separated into very closely trimmed lean, fat and bone. The separation was made on a wholesale cut weight basis using a muscle systems technique in an effort to effectively remove as much intermuscular fat as possible. After obtaining modified Babcock Fat analysis on the lean from the foreshank, brisket, plate, flank and minor muscles of the major wholesale cuts, carcass lean was determined for each bull. Regression analyses were used to evaluate methods utilizing K^{40} count parameters and weight to predict carcass lean in beef bulls.

Count weight of the bulls ranged from 970 to 1264 lbs with a mean count weight of 1114 lbs and a standard deviation of 88 lbs. The mean pounds of carcass lean was 377.3 with a standard deviation of 29.4 lbs. The repeatability estimate between the net counts on the same animal on the same day was .93. Because of the random distribution of weights of animals and breeds on count days, date was not incorporated in the analyses of variance model and there were no significant differences between breeds for carcass lean or the count parameters. The mean net counts per minute of the bulls were lower for the end detector "off" than when "on". After adjustment of the net counts for background depression and instrument counting efficiency, the mean adjusted net counts for each detector position become quite comparable.

All the bulls were statistically considered as one population and equations developed for different methods of predicting carcass lean. Lower mean squares (error term) indicated that combined weight and adjusted net count in an equation was more accurate for prediction purposes than ratios of adjusted net count to carcass lean for the bulls, than weight alone, or than adjusted net count alone. Where counts of the animals are unadjusted for background depression mean squares are higher than after adjustment. Adjustment of counts for background depression improved the accuracy of predicting carcass lean. In addition, when the end detector switch was "off", the mean squares were lower for each method of predicting than when the end detector was "on".

A linear relationship appeared in the plots between carcass lean and count weight and between carcass lean and adjusted net count of the live animal. Weight accounted for 58.8 percent of the variation in carcass lean and a prediction equation based on count weight yielded a standard error of estimate of 19.1 lbs. When the end detector was "off" compared to "on", prediction involving adjusted net count had reduced standard errors of estimate, increased r-squares and reduced coefficients of variation. Adjusted net count (end detector "off") accounted for 42.2 percent of the variation in carcass lean. The standard error of estimate was 22.6 lbs. A prediction equation for carcass lean based on adjusted net count (end detector "off") and weight had a standard error of estimate of 11.1 lbs with a coefficient of variation of 2.9 percent. The variation in carcass lean accounted for by weight and adjusted net count was 86.3 percent. The average miss was 18.3 lbs less than the standard deviation in carcass lean for the bulls.

These data suggest that the whole-body counter can be an effective technique for detecting comparable differences in total carcass lean among yearling beef bulls of a wide range in weight. K^{40} count of the live animal in conjunction with other performance data could provide an effective method of selecting bulls that have superior genotypes for rapid growth of muscle.

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APPENDIXES

APPENDIX A

ANALYSES OF VARIANCE

TABLE XIV

ANALYSES OF VARIANCE FOR PHANTOM NET COUNT AND RATIO OF NET COUNTS (END DETECTOR ON)[a]

		Net Count		Ratio	
Source	d.f.	Mean Square	F	Mean Square	F
Total	39	--	--	--	--
Date	3	65,698	9.66[b]	.0178	2.62
Weight	4	155,199	22.82[b]	.1522	22.38[b]
$\text{Wt}_{\text{Linear}}$	1	619,911	91.15[b]	.6077	89.37[b]
Residual	3	340	.05[c]	.0003	.04[c]
Date*Wt	12	6,189	.91	.0055	.81
$\text{Date*Wt}_{\text{Linear}}$	3	10,269	1.51[d]	.0080	1.17[d]
Residual	9	4,829	.71[d]	.0047	.69[d]
Replication (Date*Wt)	20	6801		.0068	

[a] Ratio of net count of a particular weight phantom to net count of 1000 pound phantom.

[b] Significant ($P < .01$).

[c] No curvature of line (linear trends of variables regressed on weight).

[d] Lines are parallel from day to day.

TABLE XV

ANALYSES OF VARIANCE FOR PHANTOM NET COUNT AND RATIO OF NET COUNTS (END DETECTOR OFF)

Source	d.f.	Net Count		Ratio	
		Mean Square	F	Mean Square	F
Total	39	--	--	--	--
Date	3	46,183	8.19[a]	.0295	3.55[b]
Weight	4	267,627	47.46[a]	.3440	41.44[a]
$\text{Wt}_{\text{Linear}}$	1	1,003,573	177.97[a]	1.2887	155.27[a]
Residual	3	22,330	3.96[b,c]	.0290	3.50[b,c]
Date*Wt	12	5,695	1.01	.0057	.69
$\text{Date*Wt}_{\text{Linear}}$	3	7,782	1.38[d]	.0048	.58[d]
Residual	9	5,019	.89[d]	.0060	.72[d]
Replication (Date*Wt)	20	5639		.0083	

[a] Significant (P < .01).

[b] Significant (P < .05).

[c] Slight quadratic effect believed due to one atypical 1100 pound count.

[d] Lines parallel from day to day.

TABLE XVI

ANALYSES OF VARIANCE FOR ADJUSTED NET COUNT AND OTHER COUNT DATA (END DETECTOR ON)

Source	d.f.	Mean Square		
		ADJNC	NCPM	Ratio ADJNC/CL
Total	93	--	--	--
Breed	1	67,914,344	4,455,108	131.5
Animal (Breed)[a]	45	48,998,812	1,138,871	415.8
Reading[b]	47	1,662,173	78,817	11.5

[a] Variation among animals of the same breed (both within the same day and among different days) is used as the error term.

[b] Variation among readings on the same animals.

TABLE XVII

ANALYSES OF VARIANCE FOR ADJUSTED NET COUNT AND OTHER COUNT DATA (END DETECTOR OFF)

Source	d.f.	Mean Square		
		ADJNC	NCPM	Ratio ADJNC/CL
Total	93	--	--	--
Breed	1	17,706,392	2,206,276	472.8
Animal (Breed)[a]	45	43,201,065	746,555	321.9
Reading	47	1,613,193	57,686	11.3

[a] Variation among animals of the same breed (both within the same day and among different days) is used as the error term.

TABLE XVIII

ANALYSIS OF VARIANCE FOR OBSERVED CARCASS LEAN

Source	d.f.	Sum of Squares	Mean Square	F
Total	93	79,434	--	
Breed	1	3,009	3,009	1.77
Animal (Breed)[a]	45	76,425	1,698	
Reading	47	0.0	0.0	

[a] Variation among animals of the same breed (both within the same day and among different days) is used as the error term.

APPENDIX B

THE ADJNC/CL METHOD OF PREDICTING CARCASS LEAN

A ratio of adjusted net count to carcass lean was calculated for each animal to determine the ADJNC per pound of carcass lean. If ADJNC/CL for each bull was plotted against the weight of each bull, it would be observed that as the weight increased the ADJNC/lb CL decreased. This decrease was attributed to self-absorption of irradiation emitted by animals of increased mass. Regression of ADJNC/CL on weight provided some adjustment for the self-absorption phenomena. Entering a weight of a bull in the equation would yield a predicted ADJNC/CL. Dividing ADJNC for the bull by the predicted ADJNC/CL would yield the predicted pounds of carcass lean. The equations for both end detector switch positions for predicting carcass lean by this method are as follows:

$$\text{End Detector "ON"} \quad \hat{Y} = \text{predicted CL (lbs)} = \frac{\text{ADJNC}}{370.97 - .1308\ (\text{WT})}$$

$$\text{End Detector "OFF"} \quad \hat{Y} = \text{predicted CL (lbs)} = \frac{\text{ADJNC}}{359.02 - .1205\ (\text{WT})}$$

The standard error of estimate for end detector "on" was 14.9 lbs and for end detector "off" was 12.3 lbs.

VITA 2

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Master of Science

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