ELECTROCARDIOGRAPH STUDIES IN NORMAL DAIRY CATTLE

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FOREWORD

The results reported in this thesis are based upon data from bovine electrocardiograms obtained on cattle in the dairy herd during the period from January 1937 to June 1938.

Since an attempt is being made to determine the normal bovine electrocardiogram, the tabulation and discussion of the data is intentionally detailed. All variations which could be construed to be even remotely significant have been noted and an attempt has been made to place upon them a fair evaluation.

Since this study has been carried out on a relatively small group of animals, it is possible that these data do not give a complete picture of the normal limits of the bovine electrocardiogram. However, the animals used would seem to be representative of normal dairy cattle and confirmation of these results must await further work using larger samples.

TABLE OF CONTENTS

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INTRODUCTION AND REVIEW OF LITERATURE

It has now been some three decades since Einthoven made electrocardiography experimentally and clinically feasible by adapting to this use the string galvanometer. This tremendous foreward stride was the motivating stimulus to research of such intensity that the science today occupies an important niche in the field of human medicine. Unfortunately for those interested in animal investigation of purely veterinary interest, much of our knowledge of electrocardiography is based on clinical work on the human subject. The bulk of the extant animal data are principally on such laboratory species as the dog and exist as the result of experimental procedures performed by workers seeking basic information primarily of interest to investigators in the human field. Since the larger domestic animals are not employed for this purpose, there is little that can be borrowed. It is interesting to note, however, that one of the earlier reports comes from such a source. Waller, (1), in 1889 while employing the capillary electrometer in a study of various lead combinations on dogs and cats, mentions having used one horse as a subject. This same worker in a subsequent report, (2), (1913) indicates that the species is of sufficient interest to warrant study of a few more individuals.

A perusal of the available literature reveals that to date comparatively little has been done by way of a systematic attempt to study the normal electrocardiogram of domesticated animals. Of the several species included in this category, the horse has perhaps received more attention than any other. Nörr, (3), in 1913 and Kahn, (4), later in the same year, employing a single lead from the xiphoid cartilage of the sternum to the shoulder region, report their normal findings on a few horses. More recently (1937) Yacoel and Spitz, (5), studied 17 different combinations of experimental leads in this species. In the case of cattle, the most comprehensive report is that by Nörr, (6), (1921) who studied the EKG of 11 animals employing, with but one exception, the single "regio apicis-regio praescapularis" lead which is favored by continental workers. A rather extensive bibliography of the German reports concerning both normal and abnormal electrocardiograms of domestic animals is cited by Neumann-Kleinpaul and Steffan, (7). Barnes and associates, (8), (1938), while studying the effect of cod liver oil in the diet of young calves on EKG intervals, report normal intervals in four controls. A limited amount of normal bovine EKG work is in progress in this country at the present time, (9).

From the foregoing, it can be seen that this field of investigation as applied to the common domestic animals has scarcely been touched. The paucity of work as evidenced by scarcity of reports is the challenging stimulus prompting the present study. Since the bovine species, especially the dairy breeds, figures so prominently in animal research concerning nutrition, metabolism, and other problems of animal husbandry; and since the economics of milk production requires more and more scientific knowledge to meet the needs for increased efficiency, the value of the electrocardiograph as an additional instrument to aid in certain phases of this work must be determined.

Since progress cannot be made until the normal has been studied, the present report will concern itself solely with this phase of animal electrocardiography.

EXPERIMENTAL PROCEDURE

Selection of Subjects. Ninety-seven animals composing the major portion of the institution's dairy herd, and representing the following breed distribution, were selected for study:

Jersey	23
Guernsey	22
Ayrshire	13
Brown Swiss	19
Holstein	20

It was felt that this group would be quite satisfactory for several reasons. The subjects were, with but very few exceptions, thoroughly accustomed to the presence of strangers and might be expected to react least unfavorably when brought into the strange surroundings of the EKG room. They were representative animals kept under modern conditions of herd management on a fairly high plane of nutrition necessary for optimum milk production. The age distribution ranged from five months to 12 years inclusive. Varying stages of gestation and lactation were represented. Sick or extremely nervous animals were not included. Males, being notoriously poor subjects in experimental work involving observations on such physiological phenomena as heart rate, respiration, etc., were excluded.

Apparatus. The apparatus employed was a Hindle #2 model of the Einthoven electrocardiograph purchased from the Cambridge Instrument

Company. Current for the field coils of the galvanometer magnet was supplied by three Edison storage batteries with a total maximum discharge rate of six amperes. No tracings were taken when this rate fell below three. Current for the projection lamp and camera motor was supplied by an AC-DC motor generator unit placed in another room at a distance of some fifteen feet from the galvanometer. All necessary parts of the apparatus were carefully grounded.

The time-marker was the standard type controlled by a tuning fork and arranged to form vertical time lines 0.04 seconds apart on the record.

The galvanometer string tension was uniformly adjusted so that the introduction of a potential of one millivolt into the string circuit would deflect the string shadow on the record one cm. Once this was obtained for lead I, further readjustment was rarely required for the other two leads. The apparatus was placed in a special room in another building separated from the dairy barn by some 300 yards. It was thus necessary to lead the animals this distance prior to taking the tracing. They were then tied in an improvised stall and sufficient time was allowed for the animal to return to as nearly a normal state as was possible under the circumstances before a record was attempted.

No effect of temperature variations or other environmental factors upon the efficiency of the apparatus could be discerned. These were occasionally quite extreme. During the winter months the room was often uncomfortably cold. At times the humidity was so high that beads of moisture were discernable on the walls of the room and on two or three occasions the lenses of the optical system of the galvanometer had to be wiped frequently with lens paper to remove the moisture which condensed so heavily as to almost completely obscure the string shadow.

Selection of Leads. The three standard leads only were employed, namely: lead I, right front leg to left front leg; lead II, right front leg to left rear leg; lead III, left front leg to left rear leg.

Since there exists some difference of opinion concerning the choice of leads in electrocardiogram studies in the large domestic animals, a brief review of the salient features involved may not be amiss at this point.

Perusal of the available reports indicates that the various investigators are almost wholly unanimous in the opinion that tracings taken by the three standard Einthoven leads employed in the human subject are entirely unsuitable for use in these animals. The principal reason given is the variations in the records obtained by this method. These variations are attributed to the difference in anatomical position of the heart in the horse and cow in relation to the leads as compared to the human.

Of the three species, bovine, equine, and human, the former possesses a heart whose long axis, through apex and middle of base, is more nearly perpendicular to the ventral thoracic floor. In the case of the equine heart it is known that, while it occupies a position in the thorax roughly comparable to that of the bovine, its basal attachment is such that the anatomical axis is more horizontal. To elaborate further using the descriptive methods of Nörr, (6), an imaginary line drawn through the apex and middle of the base would in the bovine pierce the skin anteriorly at about the level of the cervical angle of the scapula, while a comparable point in the horse would be at a more ventral level. Kahn, (4), indicates this point to be at about the distal end of the middle third of the scapula. It follows that the posterior emergence of this line would be slightly more anterior in the ox than in the horse. This is of little importance, however, the apical region in each species being usually selected by investigators for placement of one electrode in obtaining tracings by this type of lead.

The long axis (base-apex axis) of the human heart makes a smaller angle with the frontal plane than the corresponding axis of the bovine or equine heart.

Classifying these three species as to the relatively greater proportion of the heart lying to the left of the median plane, the human has 2/3 (11), the bovine 5/7 (6), and the horse 3/5 (12), of its mass thus located. It can be seen that there is relatively little dissimilarity.

From the foregoing discussion it is obvious that the standard Einthoven leads applied to horses and cattle do not approach the plane of the long axis of the heart to the degree reached in humans. This is the reasoning back of the decision by many workers (Nörr - 3 - 6; Kahn - 4; Yacoel and Spitz - 5) to attempt other leads and explains the usual dismissal of the matter with the remark that the results with standard lead combinations are worthy of little more than passing comment.

It is believed that, due to the relatively greater ease of electrode application, and the more extensive information obtainable from three derivations, as compared to the single lead of Kahn and others, the possible significance of results obtained by the three standard Einthoven leads should be investigated first. The necessity of these data, if for no other purpose than as a basis for comparison with results obtained from other lead combinations, can be readily appreciated. This is in general agreement with the opinion of Dukes (9).

Selection and Technique of Placement of Electrodes. The Cambridge German silver plate electrodes similar to those employed in human clinical work were used exclusively in this study. This decision resulted after a small amount of preliminary experimentation on three cows using first warm saline pad electrodes*, and comparing these results with those obtained with German silver plate electrodes,

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* This method consisted essentially of wrapping the limbs with a soft cloth soaked in very warm saturated saline solution around which was wound five turns of #19 bare copper wire.

contacting the skin through the medium of a special saline paste*. No appreciable differences were noted in the potentials recorded for the same individual with the two types of electrode. It was further observed that use of the former method was attended by greater uneasiness on the part of the animal regardless of the temperature of the saline solution employed. The latter method was therefore adopted, the technique of which is discussed below.

The plate electrodes were applied to the front limbs on their lateral surfaces immediately above the knee joint on a slightly convex area formed by the distal portions of the ulnaris lateralis and digital extensor groups of muscles. The site of application of the left rear limb electrode was on the antero-lateral surface 2 to 3 inches above the humero-radial (hock) joint where the peroneus tertius and digital extensor muscles form an exterior convexity most nearly adapted to the slight concavity of the electrode plate.

In applying the electrodes the hair was first closely clipped on the sites previously described over an area about two or three times that required for its apposition. The decision to merely close clip the area of application resulted after tracings obtained by this method were compared with results obtained in the same individual

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* Formula supplied through courtesy of Dr. F. N. Wilson, Dep't. of Internal Medicine, University Hospital, Ann Arbor, Mich. The paste consists essentially of sodium chloride, potassium bitartrate, glycerin, and pumice incorporated in a gum tragacanth gel with phenol added as a preservative.

after the area was carefully shaved with no appreciable difference in the recorded potentials being noted, providing sufficient electrode paste was used. The former method, because of greater convenience and safety, was accordingly adopted.

The skin was then vigorously rubbed with a liberal quantity of electrode paste. The plates were immediately applied after first covering their surfaces with the paste. A moderately firm pressure accompanied by a very slight rotary motion was used to insure a good contact before tightening the rubber straps binding the electrode firmly but not too tightly to the limb. While a liberal quantity of paste should be used, care should be taken not to contaminate the lead cable at the point of juncture with the electrode since when this happens polarization often occurs.

After the tracing was recorded, the paste was carefully removed from the skin with a wet cloth. If this was not done, a peculiar local vesicular type of dermatitis resulted in many cases.

The patient leads approached the electrodes from above the subject to avoid lessening the contact surface by reason of separation of the plate from the skin as the result of side pull from the weight of the lead cable, which often happened when the approach was from below.

At no time during the recording of an electrocardiogram were the subject's feet allowed to make a wet contact with the floor. In the event that this happened, the wet area was liberally covered with dry wood shavings before a record was attempted.

Record Treatment. Three serial electrocardiograms approximately one month apart were recorded for each member of the entire series. It was originally planned to allow an interval of four weeks between tracings, but in practice this period was occasionally exceeded or decreased by three to five days, and in a very few cases seven to ten days. Without exception, curves were obtained in the afternoon.

Bromide paper was the photographic medium used. The exposed strips were developed, trimmed, and mounted one lead above the other upon a special bristol board mounting card as shown in Fig. III. All unused portions of records were carefully labelled and saved to be used in making up composite groupings as exemplified by Fig. II, etc.

Methods of Analysis. In this study the nomenclature introduced by Einthoven was employed, and the letters P, Q, R, S, and T were assigned to the various electrocardiographic deflections according to the rules in common use in human electrocardiography. A second upright QRS deflection encountered in certain cases was designated R'. All electrocardiograms used in this study were carefully analyzed according to the sample analysis chart shown in Fig. X in the Appendix. The determinations made and methods employed will be considered in order.

The heart rate was determined in each lead by taking an average of five or six R-R intervals.

The intervals selected, namely P-R, QRS, and Q-T were measured as carefully as possible by employing a reading glass and counting the number of 0.04 second time spaces occupied by the interval. It is probable that the accuracy of this method is somewhat less than 0.01 second for all intervals. The grouping of values in Table XXIX suggests, however, that the measurements were often to an accuracy of 0.02 seconds. Readable complexes were always selected for measurement of intervals. Especial care was taken in choosing those displaying a level base line. In a few tracings, due to wandering of the string, this was rather difficult. Contrary to the usual custom in human investigations, the cardiac electrical axis range was too extreme to permit arbitrary selection of any given lead for determination of interval length.

The systolic index or systole: cycle ratio was calculated for each electrocardiogram according to the formula devised by Bazett, (13), which is stated as follows:

$$K = \frac{Q\text{-}T}{\sqrt{R\text{-}R}}$$

in which Q-T is the time interval from the beginning of QRS to the end of T and R-R is the interval from QRS in one cardiac cycle to QRS in the next. Since K varies directly with duration of ventricular systole when calculated by the above formula, an increase in its value represents an increase in the duration of Q-T in proportion to the length of the entire cycle (R-R). The value K is commonly considered as being practically constant in normal human electrocardiograms, (24).

The potential of the several waves, with the exception of P, was measured according to the method, (14), commonly employed in the analysis of human electrocardiograms. Due largely to the tendency of the galvanometer string to wander in many subjects, it was decided to use the relatively shorter P-R level as a base line in the measurement of the potential of P as well as for QRS and R'. The T-P segment was employed as the base line in the measurement of T. Upward deflections were measured from the top of the string shadow to the absolute upper limit of the wave while with downwardly directed waves, the procedure was reversed (i.e., from the bottom of the string shadow at the proper segment to the bottom of the wave).

The variations in the potential of the QRS deflections between the leads upon which is based the determination of the cardiac electrical axis, is only superficially treated in the present study. Using a series of triangular diagrams based upon the recommendations of Wilson, (10), and representing axis gradations in steps of 30°, the approximate electrical axis of each electrocardiogram in the series was determined. No attempt was made to accurately measure the potential in the three leads at the same relative time instant using graphic methods of the type employed, for example, by Fahr, (15). The only criterion of evaluation of QRS was the approximate net area of its deflection, as nearly as this could be estimated by viewing the complex, (10). No attempt was made to determine the manifest potential according to the method of Einthoven, (16). Whether it is justifiable to apply the principles of Einthoven's equilateral triangle to the analysis of the bovine electrocardiogram is, of course, uncertain.

THE HEART RATE

Since the heart rate has been shown to directly influence especially the Q-T and to a lesser extent the P-R intervals in the human subject, (14), it is necessary to include a discussion of this factor as encountered in the present study and to compare these data with the established normals for the various dairy breeds.

The subject has been reviewed by Fuller, (17). It is noteworthy that in the various per-minute frequencies given by the ten authorities listed in this review there is considerable disagreement; the variations being from 40-50, (18), to 40-80, (19). Fuller reports, in the four major dairy breeds (Jersey, Guernsey, Ayrshire and Holstein) embracing a total of 39 adult female animals, a range of from 46 to 96 per minute. The mean for the breeds ranged from 59.8 for Guernseys to 69.6 for Ayrshires. The average for all breeds was 65.7 per minute.

The results in the present study obtained by the analysis of electrocardiograms show somewhat higher values. Examination of Table I reveals that in the 97 animals composing the 5 breeds reported the range is from a minimum of 48 to a maximum of 98 per minute with an average per minute frequency for the entire series of 71.6. The mean for the breed groups ranged from 65.9 for the Jerseys to 76.6 for the Ayrshires. The most striking difference between this and the data by Fuller is in the Guernsey group where the former exceeds the latter average by 13 beats per minute. Next in order is the Ayrshire group where the rate exceeds Fuller's average by 7 beats. In the remaining breeds compared, the difference is not great.

Table I. Summary of Heart Rate (Average of Three Leads and Three Monthly Tracings of All Age Groups)						Summary of Fuller's Data (17) (Placed Here for Comparison)				
		Heart Rate (Per Minute)						Heart Rate (Per Minute)		
Breed	No. of Animals	Minimum	Maximum	Mean	Standard Deviation of Means	No. of Animals	No. of Observations	Minimum	Maximum	Mean
Jersey	23	48	83	65.91	1.7445	9	356	46	84	62.7
Guernsey	22	49	98	72.72	2.6543	7	317	48	72	59.8
Ayrshire	13	61	96	76.38	3.4417	8	332	52	90	69.6
Brown Swiss	19	50	90	74.21	2.2941		No Data			
Holstein	20	52	95	71.50	2.9154	15	687	51	96	68.6
Total	97	48	98	71.60	1.2226	39	1692	46	96	65.7

There are several factors incident to the recording of electrocardiograms as performed in this study that could be responsible for cardiac frequencies even higher than those actually encountered. In the first place it was necessary to lead each animal for a distance of some 300 yards before tracings could be taken. This in itself ordinarily would not be expected to cause a very marked increase, but a few fractious individuals (especially Ayrshires and young animals of other breeds) were led with considerable difficulty; invariably arriving at the EKG room showing a marked increase in both heart and respiratory rate. However, since it has been demonstrated by Lewis and Cotton, (20), that the decrease in duration of the P-R interval coincident with the increase in cardiac frequency during exercise returns to normal in three to five minutes in human subjects, and, since it usually requires about ten to fifteen minutes to prepare an animal for the actual taking of tracings, it seems a reasonable assumption that this should not be a factor of great importance.

The matter of nervousness, psychic, or emotional stimulation (sympathetic effects generally always present in animals, to a greater or lesser degree depending upon temperament, when transported to a strange environment) cannot be thus casually dismissed. Rothberger and Winterberg, (21), have demonstrated that the increase in heart rate in dogs from sympathetic stimulation is accompanied by changes in the electrocardiogram similar to those observed by Lewis and Cotton during exercise. It is possible that emotional excitement which increases the heart rate may also shorten the P-R interval of the bovine electrocardiogram.

Due to the troublesome nature of this factor further elaboration seems necessary concerning environmental conditions responsible for and methods employed to minimize it as much as possible. The first precaution taken, as previously mentioned, was the selection of a herd accustomed to the presence of strangers. Even some of these relatively socialized animals in the presence of the electrocardiograph, the buzzing of the tuning fork in the timer circuit, a semi-darkened room, and a strange stall, showed evidence of excitement.* In nervous breeds

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* It is interesting to note in passing that a marked increase in cardiac frequency was observed during the act of urination. No tracing was recorded in which this is shown.

such as the Ayrshire a few individuals maintained a relatively slow cardiac frequency quite out of keeping with all the outward signs of extreme uneasiness, while in a few individuals of other breeds (especially Holsteins) the reverse was occasionally observed.

The foregoing observations were obtained by watching the movement of the galvanometer string shadow with everything in readiness for the actual recording of an electrocardiogram. If any evidence of excitement occurred prior to or during the taking of tracings resulting in an increased heart rate, operations were halted until it was evident solely in the opinion of the operator, that the rate had returned to normal. In spite of this, however, a significant amount of variation is seen between leads in a few tracings. Monthly variations in the same subject were very common.* These may have been influenced to a certain extent by any one or a combination of the following factors: ingestion of food, period of the day, temperature, and changes in status of pregnancy. As to the first two, since all records were taken in the afternoon and since all the animals were on a fairly strict feeding regimen which did not appreciably change throughout the entire experiment, these may be considered to be of minor importance. In the case of changes in environmental temperature it should be remarked that since this study extended over a period of eight months, from October to the following June, this may have been a factor

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* For further information Table XXIX (Appendix), showing the rate during each lead of the three monthly tracings for every individual, may be consulted.

contributing to some of the monthly rate changes observed. The principal change in the status of pregnancy would be the occurrence of parturition between the recording of any of the three monthly tracings. This occurred (exclusive of 2 abortions) in 9 individuals* with results too inconclusive to warrant the drawing of any conclusions.

Finally it must be pointed out that, while the majority of animals investigated can be classified as adults, the inclusion of a few young individuals** would naturally cause a wider standard deviation from the mean than if the age group had been more restricted. Furthermore, the majority of mature animals were on a relatively high level of milk production, and the increase in heart rate coincident with the heightened plane of nutrition necessary for maximum production has been thoroughly established, (22; 17).

From the foregoing discussion it may be safely concluded that, when all conditioning factors are considered, the heart rates found in this series do not depart materially from the values found by others and may be considered to be within normal limits for the bovine.

* Jersey Nos. 73, 79, 101, 100 and 63; Guernsey Nos. 7 and 47; and Brown Swiss Nos. 239 and 300.

** Nineteen of the 97 animals were under 1 year of age.

INTERVALS OF THE BOVINE ELECTROCARDIOGRAM

The three intervals, P-R, QRS, and Q-T, were measured according to the method described under procedure. These measurements in each lead of the three monthly tracings as well as the computation of the systolic index according to Bazett's formula are recorded in Table XXIX (Appendix). The time values may all be read directly in decimal fractions of seconds. It will be observed that the sign "NM" occurs occasionally; indicating that the interval was not measurable. This was usually due to the obscuring of at least one of the waves bounding the interval by muscle tremor, interference by A-C induction, extremely low potential or, more rarely, complete absence of a wave. It is thus apparent that an interval in a lead may be measurable one month and not measurable the next.

Note that the data in this table are grouped according to breeds, the individuals within each group being arranged according to age, beginning with the youngest and proceeding to the oldest member.

The distribution of the various intervals by breeds, arbitrarily selected from the first monthly tracings, is shown in tabular form integrated with the discussion of each. For the sake of uniformity and since the longest interval in any lead of the first monthly electrocardiogram was rarely exceeded in the two subsequent tracings, the greatest interval in any lead of the former was arbitrarily selected for these tables. In the case of the Q-T interval a table is included showing the average of three leads and three tracings making a total of nine items.

A partial statistical summary of the minima, maxima, and mean measurements for the three intervals as well as the value for K is included in Table X. In connection with this table the standard deviation of the means has been computed according to the formula:

$$SD = \frac{\text{sum of squares of items}}{\text{no. of items}} - (\text{mean})^2$$

and

$$SD\ Mean = \frac{SD}{N}$$

where

SD = Standard Deviation

N = Number of items

I = Items (intervals, etc.)

Due to the human tendency to read to the nearest 0.02 second in the measurement of borderline intervals as discussed under procedure, Table XI showing the distribution of all intervals in steps of this value is included.

The P-R Interval

The duration of P-R as shown in Table X ranged from the minimum of 0.1 to the maximum of 0.3 second with an average duration of 0.192 second. The S. D. Mean indicates very close grouping of the values about the mean. This is borne out by Table II in which is set forth the distribution of the longest P-R interval in any lead of the first monthly tracings. The grouping is even more apparent if the values are distributed in steps of 0.02 second as is shown in Table XI.

Analysis of Table II reveals that 85 per cent of the 97 animals are found in the range from 0.16 to 0.24 second inclusive.

Table II. Distribution of Values in 0.01 Second Found for the Longest P-R Interval in Any Lead of the First Monthly Tracings.

Intervals (0.01 sec.)→	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Totals
Jersey	1				1		3	3	4		4	3	4									23
Guernsey					1	2	1	2	2	3	3		4	1	2				1			22
Ayrshire								1	2		4		4	1	1							13
Brown Swiss					1	1	5	1	4		4		1		1	1						19
Holstein			1				1	1	2		3	1	1	1	5	1	1	1			1	20
TOTALS	1		1		3	3	10	8	14	3	18	4	14	3	9	2	1	1	1		1	97

Concerning variations in duration of P-R between the leads of individual electrocardiograms, recourse must be had to Table XXIX in the appendix where all individual measurements are given. Here it may be seen that agreement between the leads is very close. Taking lead II as a standard for comparison, the values in leads I and III are more often within 0.01 second of this measurement. Occasionally the difference may be 0.02 second; only very rarely is this exceeded. These variations agree rather closely with those found by Lewis and Gilder, (23), in the human subject.

No particular lead seems more favorable for showing greater length of P-R than any other. Study of Table XXIX may create the impression that lead I is slightly more favorable than leads II and III in spite of the fact that this is most often the unfavorable lead from the standpoint of recorded potential. It is a fair assumption that the low potential QRS in this lead with perhaps absence of the initial effects of P and QRS present in the favorable leads, are factors contributing to errors in measurement.

Table X shows some slight differences between the breeds. Due to the small size of each group the significance of these variations is questionable. The mean shows some breed differences, ranging from 0.176 second for Jerseys to 0.217 for Holsteins. Data on a larger number of animals are needed before conclusions can be drawn as to the occurrence of significant differences between breeds in this respect.

Variations of P-R between the three serial electrocardiograms of each individual are relatively minor. A monthly variation of 0.01 second occurs in one or more leads of every individual. This is within the limit of human error in measurement previously mentioned. Less frequently there is a variation of 0.02 to 0.03 second, and in a very few cases (eight animals) 0.04 second, in one case 0.05 second, and in two cases 0.06 second. The 0.04 second variation was usually associated with a marked decrease in heart rate. However, a few of these, as well as the more extreme variations, were due to monthly variations in diphasic P waves. It is conceivable that should the initial phase be absent one month, the interval would be as much shorter as the duration of the absent phase. This would also be true if monthly inconstancy occurred in the initial effects of QRS and may, as previously mentioned, account for the longer P-R interval seen in unfavorable low potential leads. This factor is only of interest when leads are compared and has no influence on tabulated data containing only the longest interval in any lead.

Analysis of Table XXIX shows little correlation of length of P-R and heart rate between individuals. The lower values are more often associated with the faster rate. Extreme changes of rate from month to month in the same individual seem to affect the interval more markedly than any other factor. Minor rate changes seldom exert any influence.

Of the nine individuals freshening in the interim between the recording of electrocardiograms, six showed no appreciable change in P-R, while three exhibited a slight increase (0.02 to 0.04 second).

The Duration of QRS

The duration of QRS ranged from 0.06 to 0.12 second with an average value of 0.094 second. Table III below gives the distribution by breeds of the longest QRS interval in any lead of the first monthly tracings.

Table III. Distribution of Values, in 0.01 Second Found for the Longest Duration of QRS, in Any Lead of the First Monthly Tracings.

Intervals (0.01 sec.) →	6	7	8	9	10	11	12	Total
Jersey			3	7	10	1	2	23
Guernsey			3	7	7		5	22
Ayrshire			3	6	3	1		13
Br. Swiss		1	6	3	5	3	1	19
Holstein	2	1	4	5	2	5	1	20
TOTALS	2	2	19	28	27	10	9	97

Two subjects (both Holstein calves 9 and 5 months old respective-16) showed the minimum of 0.06 second, while the maximum of 0.12 second was seen in nine individuals. There is considerable variability of measurement between leads in any given electrocardiogram. In general, the smallest value is seen in lead I and the greatest in lead III. However, the difference between leads II and III rarely exceeds 0.01 second and quite often the measurements are equal. Very exceptionally a variation of 0.02 second is observed. The only extremes noted were the tracings of Brown Swiss No. 240 where lead III exceeded II by about 0.04 second and Jersey No. 63 where lead II exceeded III by 0.06 second. As to lead I, the duration of QRS varied from equality to a decrease of fifty percent below the value for lead II. If an average were to be obtained for lead I of the entire series it would show a definitely smaller interval than in the other two leads.

No apparent breed differences are observed in the statistical summary in Table X. The average duration of QRS of 0.094 second in the entire series compares very favorably with the mean for each breed group.

Variations between serial electrocardiograms are relatively infrequent in leads II and III. When present they are usually within the range of 0.01 second. The greatest variation is found in lead I where differences of 0.02 to 0.03 second are occasionally seen. Since this is usually the unfavorable lead in cattle, these results are not surprising and are associated with monthly variations of the low potential deflections.

Changes in heart rate or status of pregnancy were without influence on this interval in the entire series. The lower values (about 0.08 second or less) were most consistently present in animals below two years of age.

The Q-T Interval

The Q-T interval ranged from a minimum of 0.29 to a maximum of 0.47 second with an average duration of 0.389 second.

Table IV gives the distribution by breeds of the longest Q-T interval in any lead of the first monthly tracing. However, due to the inherent tendency of this measurement to vary inversely with the heart rate and since the rate varies in many cases from lead to lead within a given tracing as well as from month to month, it is believed that an average of the longest Q-T interval in each lead of the three monthly tracings for every individual would give a more uniform value for this phase of the cardiac cycle. This distribution is incorporated in Table V. As is to be expected, a more uniform distribution is obtained with less scattering of the groupings under the various values.

In this table the minimum of 0.29 second was observed in two cases. These were two calves five and nine months old respectively showing a mean heart rate in the three monthly tracings of 95 per minute in the former and 96 in the latter. The maximum, 0.47 second, was present also in two cases, a five year old Jersey with a mean heart rate of 56 and an eleven year old Brown Swiss showing an average rate of 49 per minute.

Table IV. Distribution of Values, in 0.01 Second Found for the Q-T Interval, in the First Monthly Tracings.

Intervals (0.01 sec.) →	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	Tot-als
Jersey									1			2	1		5		3	3	4	2	1				1	23
Guernsey				1	1		1			1	1	1	3		6		1		4		2					22
Ayrshire			1				2			1			2		5		1		1							13
Br. Swiss							2		1		3		3		4		2		2		2					19
Holstein	1								1		4		3	2	6		1		2							20
TOTALS	1		1	1	1		5		3	2	8	3	12	2	26		8	3	13	2	5				1	97

Table V. Distribution of Values, in 0.01 Second, Found for the Average Q-T Time of Three Leads and Three Monthly Tracings.

Intervals → (0.01 sec.)	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
Jersey							1	1		3	2	3	5	4	1		1	1	1
Guernsey			2		1	1	2	1	1	2	4	1	1	1	1	4			
Ayrshire	1			3			1		1		1	3	1	2					
Br. Swiss					1	2	2	3		1	1	1		3	2	2			1
Holstein	1					1	3	1		3	3	3	2	1		1	1		
Totals	2		2	3	2	4	9	6	2	9	11	11	9	11	4	7	2	1	2

Examination of Table XXIX (Appendix) indicates that variability between leads is more common with this interval than either P-R or QRS. Equality is the exception rather than the rule. Taking lead II merely as a standard for comparison, a plus or minus difference in leads I and III of 0.01 to 0.02 second is very common. A difference of 0.03 to 0.04 second between leads is present in a few cases, with the maximum of 0.05 to 0.06 second of very infrequent occurrence. On the whole there is a tendency for leads II and III to be more nearly equal, with lead I showing a slightly lesser value. But considerable variation is seen and this statement should be accepted with some reservation.

The statistical summary of Q-T presented in Table X indicates no significant breed differences as to minima and maxima. With respect to the mean values the table shows that the Guernsey, Brown Swiss, and Holstein groups show a close correlation with the average for the entire series.

In the Jersey group the mean exceeds the total average by 0.018 second. This breed also records the lowest average heart rate. The average of Q-T in the Ayrshires is 0.019 second less than the mean for the entire series. The average heart rate in this group is two beats less per minute than the Brown Swiss. It is interesting to note that the average duration of Q-T in the latter breed exceeds that of the former by 0.021 second. This difference in Q-T between two breeds showing approximately equal heart rates, while interesting, is perhaps too minor to warrant the drawing of any conslusions.

Monthly variations are even more prominent than the differences observed between the leads and are in general closely associated with variations in heart rate, there being an increase in the duration of Q-T with a decrease in heart rate and vice versa.* The range is too inconsistent to be dealt with in a general discussion. For further details reference can only be made to Table XXIX in the appendix.

* Since monthly variations in diphasic T waves are common, it is entirely possible that, should the final phase be absent (isoelectric) one month, the interval would have a tendency to be as much shorter as the duration of the absent phase. This would also be true of the monthly inconstancy seen in the initial effects of QRS. Variations extreme enough to cause a marked difference in Q-T time are relatively infrequent providing the longest interval in any lead be chosen, and any influence this factor may have tends to be lost in the variations due to rate. This phase of electrocardiography in the human subject is statistically treated by Adams, (25).

To further clarify the relationship existing between duration of Q-T and heart rate in the various breed groups constituting this series, Table VI, showing the duration of Q-T at various levels of cardiac frequency, was devised. In formulating this table the duration of Q-T and the heart rate in each lead of the three monthly tracings was used. Thus there are nine values for both the interval and rate on each animal represented. It will be observed, however, that of the total of 873 leads, only 839 appear in the table. The difference represents unfavorable leads in which the interval or the rate (one case) were not accurately measurable.

The results with this type of tabular treatment show a remarkably consistent decrease in duration of Q-T with an increase in heart rate. The mean values are especially uniform in this respect. Although the average bovine Q-T time is apparently somewhat longer at comparable rate levels, the general trend in the table is similar to the findings of Fridericia, (26), in the normal human subject.

Since considerable variation in heart rate is present in the series, the facts elucidated in Table VI may largely explain the relatively extreme variability of Q-T previously discussed.

Table VI. The Duration of Q-T at Various Levels of Cardiac Frequency.

			Q-T (in 0.01 sec.)		
Rate	Breed	No. of Leads	Minimum	Maximum	Mean
	Jersey	9	0.44	0.50	0.453
	Guernsey	3	0.44	0.44	0.440
43 to 50	Ayrshire	0			
	Br. Swiss	5	0.46	0.50	0.482
	Holstein	5	0.40	0.46	0.428
	Total	22	0.40	0.50	0.452
	Jersey	40	0.38	0.50	0.436
	Guernsey	32	0.40	0.48	0.435
50 to 60	Ayrshire	13	0.40	0.46	0.424
	Br. Swiss	8	0.43	0.52	0.450
	Holstein	36	0.40	0.48	0.425
	Total	129	0.38	0.52	0.432
	Jersey	76	0.38	0.48	0.414
	Guernsey	49	0.36	0.46	0.410
60 to 70	Ayrshire	41	0.32	0.44	0.400
	Br. Swiss	54	0.36	0.47	0.420
	Holstein	43	0.34	0.48	0.401
	Total	263	0.32	0.48	0.410
	Jersey	53	0.34	0.44	0.386
	Guernsey	59	0.33	0.44	0.378
70 to 80	Ayrshire	17	0.32	0.42	0.381
	Br. Swiss	52	0.32	0.44	0.387
	Holstein	51	0.34	0.44	0.376
	Total	232	0.32	0.44	0.382
	Jersey	6	0.32	0.36	0.346
	Guernsey	26	0.30	0.44	0.350
80 to 90	Ayrshire	17	0.30	0.40	0.353
	Br. Swiss	23	0.30	0.40	0.349
	Holstein	29	0.31	9.40	0.354
	Total	101	0.30	0.44	0.351
	Jersey	8	0.30	0.36	0.322
	Guernsey	24	0.28	0.36	0.312
90 to 125*	Ayrshire	24	0.26	0.34	0.302
	Br. Swiss	21	0.28	0.38	0.328
	Holstein	15	0.28	0.36	0.308
	Total	92	0.26	0.38	0.313

* Only 10 leads in this group showed a rate greater than 104 beats per minute.

The Systolic Index

Due to the wide range of Q-T as the result of the variability in heart rate in this study, it was thought highly desirable to apply Bazett's formula, as discussed under procedure, to each of the three electrocardiograms of every individual constituting the series. The selection of a complex for this purpose was solely on the basis of distinctness of the necessary waves. While not invariably used, lead II was usually most favorable. The constant in each monthly tracing is included in Table XXIX to which previous reference has been made. Monthly changes only will be considered directly from this table.

The value for K in this series, as shown in Table X, ranges from 0.34 to 0.48, with an average of 0.418.

Table VII below gives the breed distribution of the various values for K encountered in this study. To obtain more average figures, the mean of the constant in the three monthly tracings of each individual was taken and expressed to the nearest second place decimal fraction.

Table VII. Distribution of Value for K (Bazett's Formula) to the Nearest Whole Decimal No. Average of the Three Monthly Tracings.

K →	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.41	0.42	0.43	0.44	0.45	0.46	0.47	0.48	Totals
Jersey							3	4	7	4	1	1	1	2		23
Guernsey				1	1	1	1	6	5	3		2	1		1	22
Ayrshire		1	1	1	1			2	2	4			1			13
Brown Swiss				1	1	1	2	1	2	1	6	3	1			19
Holstein	1				1	4		4	5	2	1	1	1			20
TOTALS	1	1	1	3	4	6	6	17	21	14	8	7	5	2	1	97

In this table the lower values of 0.34, 0.35, and 0.36 were seen in three young animals, 5, 13, and 8 months old respectively. The two individuals showing the value of 0.47 were five and two years old. The maximum of 0.48 was observed in only one case, an eight-year-old Guernsey. The statistical summary of the value for K in this series presented in Table X shows a range in the minimum values of from 0.34 in the Holstein to 0.40 in the Jersey group with the maxima remaining remarkably constant. It must be pointed out that the Holstein group contained the youngest member (5 months of age) of the entire series. The average values for the several breeds is very close to the mean for the entire group. Examination of Table XXIX shows considerable minor variation from month to month with little correlation between changes in K and rate in the same individual. Using the values in the second monthly tracing merely as a basis for comparison we find the first and third monthly values showing the following plus or minus differences:

Table VIII. Distribution of Agreement of Value for K (Bazett's Formula) in the Second Month With the First and Third Monthly Records.

Agreement		Range of plus or minus disagreement						
In all three monthly tracings*	1st or 3rd month with 2nd month	0.001 to 0.010	0.010 to 0.020	0.020 to 0.030	0.030 to 0.040	0.040 to 0.050	0.050 to 0.060	0.060 to 0.070
6	18	51	59	27	20	3	3	1

* This agreement is within 0.001.

This table shows that the value for K was identical in all three serial tracings in only six of the ninety-seven animals constituting this series. Of the 182 possibilities in the remaining ninety-one subjects, perfect agreement of the first or third month with the second occurred eighteen times. Disagreement within the range 0.001 to 0.020 occurred almost two and one-half times more frequently than the wider range of 0.020 to 0.040. In but seven instances was the difference greater than 0.040 and only one of these showed the widest variation recorded in the series. This was in the range 0.060 to 0.070. While not indicated in Table VIII, there are many cases in which the first and third months are in closer agreement with each other than with the value for K in the second monthly tracing. It is believed that of the three possible combinations for comparison, the one selected would serve the purpose here as adequately as either of the other two.

In an effort to further explain the variation of K between individuals, the following table showing the relationship between age and the systolic index is presented:

Table IX. Minimum, Maximum, and Mean Values for K (Bazett) at Various Age Levels.

Age Groups	No. of Cases	Minimum	Maximum	Mean
		K (Bazett's Formula)*		
5 to 8 mo.	3	0.34	0.40	0.377
8 to 10 mo.	6	0.36	0.41	0.390
10 mo. to 1 yr.	8	0.37	0.42	0.398
1 to 1 1/2 yrs.	7	0.35	0.44	0.408
1 1/2 to 2 yrs.	13	0.38	0.47	0.415
2 to 3 yrs.	12	0.38	0.46	0.429
3 to 4 yrs.	17	0.39	0.46	0.428
4 to 5 yrs.	10	0.39	0.47	0.426
5 to 6 yrs.	9	0.40	0.45	0.433
6 to 8 yrs.	5	0.41	0.44	0.424
8 to 10 yrs.	3	0.43	0.48	0.450
10 to 12 yrs.	4	0.39	0.42	0.410

The table shows a relatively uniform increase in the value for K in the age groups from five months to about two years. It is possible that this may be a failure on the part of Bazett's formula to correct for rate in the higher frequencies obtaining in young subjects.

* Average of the three monthly tracings on each individual.

Table X. Partial Statistical Summary of the Value for K and Duration of Bovine EKG Intervals.

	P-R (Sec.)				QRS (Sec.)			
Breed	Mini.	Maxi.	Mean	St. Dev. of Mean	Mini.	Maxi.	Mean	St. Dev. of Mean
Jersey	0.10	0.22	0.176	0.0131	0.08	0.12	0.096	0.0128
Guernsey	0.14	0.28	0.197	0.0073	0.08	0.12	0.098	0.0035
Ayrshire	0.17	0.24	0.206	0.0005	0.08	0.11	0.091	0.0024
Br. Swiss	0.14	0.25	0.183	0.0067	0.07	0.12	0.093	0.0031
Holstein	0.12	0.30	0.217	0.0091	0.06	0.12	0.091	0.0037
Total All Breeds	0.10	0.30	0.192	0.0002	0.06	0.12	0.094	0.0018

	Q-T* (Sec.)				K (Bazett's Formula)**			
Breed	Mini.	Maxi.	Mean	St. Dev. of Mean	Mini.	Maxi.	Mean	St. Dev. of Mean
Jersey	0.35	0.47	0.407	0.0061	0.40	0.47	0.425	0.0043
Guernsey	0.31	0.44	0.384	0.0095	0.37	0.48	0.419	0.0054
Ayrshire	0.29	0.42	0.370	0.0117	0.35	0.46	0.407	0.0097
Br. Swiss	0.33	0.47	0.391	0.0094	0.37	0.46	0.424	0.0059
Holstein	0.29	0.45	0.384	0.0077	0.34	0.46	0.411	0.0058
Total All Breeds	0.29	0.47	0.389	0.0039	0.34	0.48	0.418	0.0027

* The values used here are averages of all three leads in three tracings.

** The figures for K are purely numerical.

Table XI. Distribution of EKG Intervals in Steps of 0.02 Second by Breeds.

Breed	Interval	Interval (0.01 Sec.) 6 to 8	8 to 10	10 to 12	12 to 14	14 to 16	16 to 18	18 to 20	20 to 22	22 to 24	24 to 26	26 to 28	28 to 30	30 to 32	32 to 34	34 to 36	36 to 38	38 to 40	40 to 42	42 to 44	44 to 46	46 to 48	48 to 50	50 to 52	Totals
Jersey	P-R			1		1	6	4	7	4															23
Guernsey						3	3	5	3	5	2		1												22
Ayrshire							1	2	4	5	1														13
Br. Swiss						2	6	4	4	1	2														19
Holstein					1		2	2	4	2	6	2		1											20
Totals				1	1	6	18	17	22	17	11	2	1	1											97
Jersey	QRS		10	11	2																				23
Guernsey			10	7	5																				22
Ayrshire			9	4																					13
Br. Swiss		1	9	8	1																				19
Holstein		3	9	7	1																				20
Totals		4	47	37	9																				97
Jersey	Q-T															1	2	1	5	6	6	1		1	23
Guernsey													1	1	1	1	2	3	6	1	4	2			22
Ayrshire													1		2	1		2	5	1	1				13
Br. Swiss															2	1	3	3	4	2	2	2			19
Holstein												1				1	4	5	6	1	2				20
Totals												1	2	1	5	5	11	14	26	11	15	5		1	97
Jersey	Ave. Q-T*															1	1	5	8	5	1	2			23
Guernsey														2	1	3	2	6	2	2	4				22
Ayrshire													1		3	1	1	1	4	2					13
Br. Swiss															1	4	3	2	1	5	2	1			19
Holstein													1			4	1	6	5	1	2				20
Totals													2	2	5	13	8	20	20	15	9	3			97

* Average of three leads in the three monthly tracings.

BOVINE EKG DEFLECTIONS - THEIR OCCURRENCE, POTENTIAL AND FORM

While this phase of electrocardiography is usually more logically considered before the intervals, it was decided to reverse the order in this report. The principal reason for this decision lies in the fact that here is encountered the greatest confusion and difficulty of classification and discussion.

As previously mentioned, the nomenclature of the waves is the same as that employed for electrocardiograms taken by the three standard leads in the human subject. Due to the rather frequent occurrence of a second positive QRS deflection, it was necessary for purposes of convenience to designate this as R'.

Deflections were considered to be present even when of so low a potential as to be not accurately measurable. As will be noted, the inconstancy of low potential waves unfortunately increases the occurrence of monthly variations in the summary tables. These variations are probably due to a combination of several factors. It must be borne in mind that the taking of electrocardiograms of animals while in the standing position, with the possible exception of the horse*, introduces the factor of potential from contraction of voluntary muscle. This may be one or both of two forms. The most common is a steady tremor from persistent muscular contraction (Fig. VII) incident to maintenance of a quiet standing position. Less frequently there is a wandering of the string (Fig. VII, and lead III of Fig. IX)

* Due to the peculiar anatomy of this species relatively complete muscular relaxation may be present while in the standing position.

in certain animals, possibly from normal body sway in maintaining balance, but also associated with nervousness. The effect is somewhat similar to that seen in human subjects during emotional excitement. While marked changes in the bovine electrocardiogram from month to month are most probably due to a shift in the axis of the rather mobile heart, the interference due to muscular effects accounts for the failure to recognize many low potential deflections (below 0.3 m v). For this reason any changes between the three monthly tracings must not be considered too seriously. The summarized occurrences should rather be viewed as a total unit indicating a species tendency.

It must be emphasized that voluntary muscle effects with the apparatus employed were seldom serious enough to obscure deflections of definite measurable potential. This is contrary to the observations of Nörr, (6). Alternating current induction was a troublesome factor in low potential waves in a very few cases.

Occurrence of the Various Deflections

The P Wave. The auricular deflection or P wave, in common with all the deflections composing a bovine cardiac cycle, shows characteristics differing materially from those encountered in human tracings. These differences are largely an increase in the incidence of diphasic and extremely low potential or, more rarely, complete absence of waves.

Monophasic P occurred 23 times in lead I, 35 times in lead II, and 80 times in lead III. The direction of this wave was almost without exception upward. In two or three instances an unfavorable low potential deflection showed a negative tendency (Table XXX). Diphasic P occurred 64 times in lead I, 62 times in lead II, and 8 times in lead III. The two phases composing this type of wave were always of either approximately equal potential or with positive (upward) summation, never of negative summation. In other words, there was never a diphasic P the potential of whose positive phase was not equal to or greater than its negative phase. The sequence of events in all but four individuals showing this form was an initial quick, downward deflection followed by a much slower upward phase. Regardless of how inconsequential the character of the minor phase, a wave showing this characteristic was always classified as diphasic. Approximately 80 per cent of the diphasic P waves in all leads of the first monthly tracings in this series showed a positive phase of greater potential than the negative phase. Four individuals displayed diphasic P with a plus to minus sequence. This always occurred in lead III and showed a marked tendency to vary from month to month. The potential of the two phases did not depart from the tendency displayed by the other type of diphasic P discussed previously.

In a few cases P was totally absent or when present was of such extremely low potential that its form could not be accurately determined. This occurred 10 times in lead I and 9 times in lead III. The deflection was always present in lead II.

The general form of this wave presents no other outstanding features worthy of critical discussion which may not be obtained by careful examination of Figures II - A, B, C, D, and E. It may not be amiss to note that true notching of P, such as was found by Kahn, (4), in the horse and to a lesser extent by Nörr, (6), in the bovine, when employing the single regio-apicis: regio praescapularis lead, did not occur in a single instance in this series.

In Table XII is summarized the occurrence of the various combinations of P wave types with respect to leads in the first monthly tracings. Of the 64 possible combinations of positive and negative monophasic, diphasic, and non-determinable waves in the three leads only 15 occurred. Of these the DD+* combination occurred most frequently (34 times). The sum of the instances in which DD+, D++, DDD, and +++ occurred accounts for 68 per cent of the 97 animals constituting this series with the balance distributed as shown in the table.

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* The symbols DD+ means that the deflection was diphasic in leads I and II, and positive monophasic in lead III. Similarly, +++ indicates a positive monophasic wave in leads I, II, and III, etc.

When monophasic P occurs in only one lead of an electrocardiogram, it almost invariably appears in lead III. Its presence in any other lead than III is always coincident with its appearance in more than one of the leads. For example, monophasic P never occurs in lead II without also being present in leads I and/or III. Diphasic P appeared with about equal frequency in the single leads I and II. Its most frequent occurrence, however, was in the lead I and II combination.

Table XII. Summary of the Occurrence of Various Combinations of P Waves With Respect to Leads in the First Monthly Tracings.

Lead I	Lead II	Lead III	Jersey	Guernsey	Ayrshire	Br. Swiss	Holstein	Totals
D	D	D	-	-	2	1	4	7
D	D	+	8	10	3	5	8	34
D	+	+	7	2	3	1	3	16
+	D	D	1	-	-	-	-	1
+	D	+	1	1	1	2	-	5
-	D	+	-	-	-	-	2	2
+	+	+	3	2	-	2	2	9
+	+	-	-	-	-	1	-	1
+	D	NM	-	1	-	-	-	1
NM	+	+	1	-	-	-	-	1
NM	D	+	2	5	-	-	-	7
D	D	NM	-	1	2	3	-	6
NM	+	+	-	-	1	1	1	3
+	+	NM	-	-	1	2	-	3
M	+	+	-	-	-	1	-	1
TOTAL			23	22	13	19	20	97

Key: + = upward deflection
- = downward deflection
D = diphasic wave
NM = absent, non-measurable, or non-determinable wave
M = M shaped complex with positive summation

<u>The QRS Group</u>. Before considering the several deflections composing the QRS group it might be well to again emphasize the fact that waves were considered to be present even when of so small a potential as to constitute merely a trace (below 0.03 millivolt). It should be borne in mind that the ease with which these may be obscured by A-C induction and muscle tremor doubtless gives rise to apparent variations that do not exist.

The deflection Q occurred 59 times in lead I, 78 times in lead II, and 68 times in lead III. R was present 76 times in lead I, 96 times in lead II, and 96 times in lead III. S was found 28 times in lead I, 8 times in lead II, and 20 times in lead III. The second positive QRS deflection (called R' in this study) occurred twice in lead I, 5 times in lead II, and 14 times in lead III. To gain a better conception of the significance of these figures, Table XIII, showing the approximate percentage incidence of occurrence of these deflections in the various leads, is presented.

Table XIII. Percentage Occurrence of the Various Deflections Composing QRS in the Three Leads.

	Per Cent			
Lead	Q	R	S	R'
I	60	78	28	2
II	80	99	8	4
III	70	99	20	14

The above table indicates the almost invariable occurrence of R in leads II and III, the great frequency of Q in all leads, and the relative infrequency of S and R' waves.

Table XIV summarizes the occurrence of Q, R, S, and R' waves alone and in combination in the various leads and lead combinations of the first monthly tracings. QRS was represented by a single downwardly directed (Q) wave in 20 instances and this only in lead I. QRS occurred as a lone upward deflection (R wave) mainly in the single leads I and III, and simultaneously in the two leads I and II, appearing 11, 10, and 6 times in the order mentioned. Diphasicity of QRS (Q and R waves) occurred most frequently simultaneously in leads II and III (36 times), and I, II, and III (22 times). Next in order comes the single lead II which showed this combination in 11 instances. The second possible type of diphasicity (R and S waves) never occurred in more than one lead of any electrocardiogram, being present 16 times in lead I, once in lead II, and 4 times in lead III. The "typical" complex composed of Q, R, and S waves occurred 10 times in lead I. Its presence in any other lead or lead combination was relatively negligible. As to QRS groups showing R' waves, little can be said at this point beyond the fact that the RSR' sequence occurred most frequently, being present in the greatest number of instances in lead III (9 times).

Concerning breed differences, conclusions based on such a small number of animals as compose each group must be drawn with extreme reserve. It is noteworthy that Q waves were most frequent in Jerseys and least in Holsteins, while this latter breed showed the greatest incidence of R' waves. For the rest, the mean trend in the several breeds presents no differences worthy of mention.

Table XIV. Summary of the Occurrence of the Deflections of QRS in the Various Leads and Lead Combinations of the First Monthly Tracings.

Deflections	Q only	R only						Q and R						R and S			Q, R, and S			QRSR'	R, S, and R'			
Lead Combinations →	I	I	II	III	I II	II III	I II III	II	III	I II	I III	II III	I II III	I	II	III	I	II	II III	III	I	II	III	II III
Jersey	10	1	0	2	0	1	1	2	1	2	0	10	5	4	0	1	0	0	1	0	0	1	1	0
Guernsey	4	2	0	1	0	0	0	2	0	0	0	11	6	5	0	0	5	1	1	2	0	0	0	0
Ayrshire	0	1	3	2	1	0	0	3	0	0	1	4	2	5	0	2	2	0	0	0	1	0	2	0
Brown Swiss	6	1	0	4	1	1	0	4	1	2	0	6	5	1	0	0	3	0	0	0	0	0	2	0
Holstein	0	6	0	1	4	0	1	0	1	2	0	5	4	1	1	1	0	0	0	2	1	2	4	1
TOTALS	20	11	3	10	6	2	2	11	3	6	1	36	22	16	1	4	10	1	2	4	2	3	9	1

The T Wave. The final electrical effects of ventricular systole evidenced in the electrocardiogram by the deflection T, like the P wave presents characteristic peculiarities rarely encountered in human tracings. Diphasicity is the outstanding feature of this wave. It is not to be inferred that monophasic deflections do not occur, but tracings in which T was not diphasic in one, and more frequently, two leads are extremely rare. Monophasic waves resemble somewhat those seen in the human subject except that the summit tends to be more sharply defined and less rounded. One limb is often, but not always, more quickly executed and therefore finer in outline than the other. In this respect it is reminiscent of that portion of diphasic T where the change in direction of potential is recorded. Diphasic complexes are largely characterized by relatively slow broad initial and terminal deflections, the movement of the string during change in direction of potential being usually rather quickly executed. (See Figure II, etc.)

The sequence of events (as with the P wave) was, with but two exceptions, an initial negative followed by a positive phase. In the two individuals showing a positive to negative sequence, considerable monthly variation occurred. (See Table XXX).

Monophasic T occurred 79 times in lead I, 27 times in lead II, and 29 times in lead III. Of these, 75 in lead I, 22 in lead II, and 4 in lead III were negative. This indicates that, in this series, monophasic T1 and 2 were largely negative while T3 was mainly positive. Diphasic T occurred 14 times in lead I, 70 times in lead II, and 64 times in lead III. The two phases composing this type of wave showed negative summation in 107 instances, phases of equal potential in 25 instances, and positive summation in 14 instances in the 146 leads in which diphasic T occurred. From this it can be seen that diphasic T is largely negative.

Triphasic T was seen only once*, and then only in the first monthly tracing. This wave varied from diphasic to positive monophasic in the two succeeding monthly tracings.

Extremely low potential undeterminable T waves occurred four times in lead I and four times in lead III. Unlike P, complete absence of T was never encountered.

The occurrence of the various combinations of T waves with respect to leads in the first monthly tracings is summarized in Table XV. Of the 64 possible combinations of positive and negative monophasic, diphasic, and non-determinable waves in the three leads, only 19 occurred. The three most frequent combinations were the following: -DD, 37 times; --D, 17 times; -D+, 13 times. The foregoing embraces 69 per cent of the 97 animals constituting this series. The remainder are distributed as shown in the table.

The table further shows that when monophasic T occurred in only one lead of an electrocardiogram, it invariably presented itself in lead I or III, never in lead II. Its occurrence in lead II was always coincident with monophasic T1 and/or T3, the most common combination being leads I and II. Diphasic T occurred in all leads and lead combinations,

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* Guernsey No. 46, see Table XXX.

the most favorable single leads being II and III, and the most favorable lead combinations, lead II and III. Since the trend in all breeds was roughly the same and since each group represented such a small number of individuals, no conclusions as to breed differences can be safely drawn.

Table XV. Summary of the Occurrence of Various Combinations of T Waves with Respect to Leads in the First Monthly Tracings.

Lead I	Lead II	Lead III	Jersey	Guernsey	Ayrshire	Br. Swiss	Holstein	Totals
D	D	D	2	1	1	1	-	5
D	D	+	1	-	2	-	-	3
D	D	-	1	1	-	-	-	2
D	+	+	-	3	-	-	-	3
+	D	D	1	-	-	-	-	1
-	D	D	12	7	3	6	9	37
-	-	D	2	2	-	5	8	17
+	D	-	1	-	-	-	-	1
-	D	+	-	4	4	3	2	13
-	D	-	-	-	1	-	-	1
+	-	-	-	1	-	-	-	1
-	+	+	1	-	-	-	-	1
-	-	+	-	1	-	2	-	3
+	D	ND	1	-	-	-	-	1
ND	D	D	-	1	-	1	1	3
ND	D	-	1	-	-	-	-	1
D	D	ND	-	-	1	-	-	1
-	-	ND	-	-	1	1	-	2
-	D	W*	-	1	-	-	-	1
Total			23	22	13	19	20	97

Key:

+ = upward deflection
- = downward deflection
D = diphasic wave
ND = non-measurable or non-determinable wave
W = W shaped complex

* Triphasic wave with slightly positive summation.

Potentials of EKG Deflections

In order to obtain a more accurate understanding of the significance of the tabulated values to be presented in this section, a brief explanatory discussion must be entered into at this point. The prevalence of slight voluntary muscle tremor and, to a lesser extent A-C induction in certain tracings, precluded extreme accuracy in the measurement of very low potential waves. Clearly recognized deflections of a potential of 0.03 millivolts or less were recorded as having this value. Deflections of such extremely low potential as to be almost lost in a vibrating string shadow were recorded as non-determinable (N.D.). Totally absent waves were, of course, recorded as such. Where, as frequently occurred, slight variations were seen in the potential of a wave within a lead, the largest value was used. In the case of diphasic waves, the potential of the largest phase was recorded; or, where the phases were of equal value, one phase was taken. In so far as possible, measurements were made at points within the lead where the string shadow was not wandering since it was observed that this factor may produce apparent changes in potential leading to considerable error. Since there is, with but few exceptions, relatively little variation in size of potential from month to month, the tabulated measurements in this section were arbitrarily taken from the first monthly tracings.

The Distribution of Potentials by Leads

<u>The Potential of P</u>. With a wave of such absolute low potential, breed differences, if any, are difficult to evaluate. For this reason the series will be considered mainly as a group. Study of Table XVI shows that the range for measurable waves is from the minimum of 0.03 millivolt in all three leads to the maximum of 0.12 in lead I, 0.18 in lead II, and 0.22 in lead III. It must be stated, however, that non-determinable waves occurred in 28 instances in lead I and in 17 instances in lead III. Therefore, the absolute minimum is less in these leads than is actually recorded in the table. It is interesting to note that the Ayrshire breed displayed this type of wave in 6 out of 13 individuals composing this group. The remainder of the breed groups exhibited non-determinable waves to a lesser and more uniform degree. The mean values for the entire group was 0.06, 0.10, and 0.07 millivolt in leads I, II, and III respectively.

Table XVI. Minimum, Maximum, and Mean values for Potential of P in the First Monthly Tracings.

Breed	No. of Animals	Occurrence			Potential (Millivolts)								
					Minimum			Maximum			Mean		
Lead →		I*	II	III*	I	II	III	I	II	III	I	II	III
Jersey	23	16	23	23	.03	.10	.04	.10	.15	.10	.06	.12	.08
Guernsey	22	14	22	20	.03	.03	.03	.12	.15	.22	.05	.11	.09
Ayrshire	13	7	13	7	.03	.03	.03	.08	.10	.08	.05	.08	.06
Brown Swiss	19	15	19	12	.03	.03	.03	.10	.18	.12	.07	.10	.06
Holstein	20	17	20	18	.03	.03	.03	.10	.12	.10	.05	.09	.06
All Breeds	97	69	97	80	.03	.03	.03	.12	.18	.22	.06	.10	.07

* The discrepancy in numbers here is due to non-determinable waves.

<u>The Potential of Q.</u> The occurrence of Q, alone and in combination with other waves, was more frequent in lead II, being present in 60, 80, and 70 per cent of leads I, II, and III respectively.

The range of potential for the group as set forth in Table XVII is from the minimum of 0.03 millivolt in all three leads to the maximum of 0.60, 1.00, and 0.90 millivolt in leads I, II, and III respectively. The mean for the group was 0.23 millivolt in lead I, 0.16 in lead II, and 0.11 in lead III.

Breed differences are not significant beyond the fact that of the Holsteins in which Q occurred only two individuals displayed a potential greater than 0.12 millivolt.

Table XVII. Minimum, Maximum, and Mean Values for Potential of Q in the First Monthly Tracings.

Breed	No. of Animals	Occurrence			Potential (Millivolts)								
					Minimum			Maximum			Mean		
Lead →		I	II	III	I	II	III	I	II	III	I	II	III
Jersey	23	16	20	17	.08	.03	.03	.60	.60	.25	.26	.13	.07
Guernsey	22	15	22	20	.03	.03	.03	.60	1.00	.90	.26	.23	.17
Ayrshire	13	5	10	7	.10	.03	.03	.40	.23	.30	.23	.09	.10
Brown Swiss	19	16	17	12	.03	.03	.03	.50	.50	.40	.21	.19	.11
Holstein	20	6	11	12	.03	.03	.03	.40	.32	.30	.15	.08	.09
All Breeds	97	58	80	68	.03	.03	.03	.60	1.00	.90	.23	.16	.11

<u>The Potential of R.</u> This wave was present in all cases in lead III, in all but one case in lead II, and in 72 per cent of the individuals in lead I.

The potential ranged from the minimum of 0.03 millivolt in all leads to the maximum of 0.70, 2.60, and 1.50 millivolt in leads I, II, and III respectively. The average for the entire series was 0.16 millivolt in lead I, 0.37 millivolt in lead II, and 0.35 millivolt in lead III. Table XVIII displays the necessary tabulated data.

No marked discrepancies of average potentials between the five breed groups are evident.

Table XVIII. Minimum, Maximum, and Mean Values for Potential of R in the First Monthly Tracings.

Breed	No. of Animals	Occurrence			Potential (Millivolts)								
					Minimum			Maximum			Mean		
Lead →		I	II	III	I	II	III	I	II	III	I	II	III
Jersey	23	11	23	23	.05	.10	.03	.70	2.60	1.50	.21	.54	.53
Guernsey	22	15	22	22	.03	.03	.05	.30	.60	.65	.12	.27	.29
Ayrshire	13	12	13	13	.05	.10	.10	.50	.80	1.00	.21	.33	.29
Brown Swiss	19	13	19	19	.05	.04	.10	.30	.75	.95	.13	.30	.33
Holstein	20	19	19	20	.03	.13	.05	.43	1.10	.93	.18	.40	.29
All Breeds	97	70	96	97	.03	.03	.03	.70	2.60	1.50	.16	.37	.35

<u>The Potential of S</u>. Next to R' this wave was of the least frequent occurrence and showed the lowest potential of any deflection composing the QRS group. It occurred 29 times in lead I, 6 times in lead II, and 18 times in lead III. Table XIX indicates that, aside from a tendency to occur most frequently in lead I of the Guernseys, no outstanding breed differences are present.

Potentials were uniformly low and ranged from a minimum of 0.03 millivolt in all leads to a maximum of 0.20, 0.10, and 0.25 millivolt in leads I, II, and III respectively. Mean values were very low, 0.06 millivolt in lead I, 0.07 in lead II, and 0.12 in lead III. The lower potential specimens of this wave showed a marked tendency to vary from month to month, often being present one month and completely absent the next or vice versa.

Table XIX. Minimum, Maximum, and Mean Values for Potential of S in the First Monthly Tracings.

Breed	No. of Animals	Occurrence			Potential (Millivolts) Minimum			Maximum			Mean		
Lead →		I	II	III	I	II	III	I	II	III	I	II	III
Jersey	23	4	2	2	.03	.05	.05	.10	.10	.06	.07	.07	.05
Guernsey	22	10	2	3	.03	.10	.10	.20	.10	.20	.06	.10	.13
Ayrshire	13	8	0	4	.03	-	.06	.15	-	.20	.06	-	.12
Brown Swiss	19	4	0	1	.03	-	-	.05	-	-	.03	-	.10
Holstein	20	3	2	8	.03	.03	.03	.15	.05	.25	.07	.04	.13
All Breeds	97	29	6	18	.03	.03	.03	.20	.10	.25	.06	.07	.12

<u>The Potential of R'</u>. The significance of the second positive QRS deflection is not clear. Since the R' wave seldom occurs, is consistently associated with bizarre, splintered R waves, displays considerable monthly change, and is uniformly of such low potential as to vary from zero to trace within a lead, the question arizes as to whether or not it should be considered as an actual deflection. Furthermore, since its presence is apparently the result of an exaggerated splintering or notching of R*, perhaps it should with more justice be accorded the scant notice usually evidenced when present in lead III of human tracings, (27). Table XX shows that R' occurred 2 times in lead I, 5 times in lead II, 14 times in lead III, and was more prevalent in Holsteins than in any of the other breeds. Due to the infrequency of its occurrence no definite conclusions can be drawn as to the effect of breed or lead on differences in potential. Potentials ranged from a minimum of 0.03 to a maximum of 0.20 millivolt, with a mean of 0.15 millivolt in lead I, 0.11 in lead II, and 0.10 in lead III.

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* See discussion, page 65.

Table XX. Minimum, Maximum, and Mean Values for Potential of R' in the First Monthly Tracings.

Breed	No. of Animals	Occurrence			Potential (Millivolts)								
					Minimum			Maximum			Mean		
Lead →		I	II	III	I	II	III	I	II	III	I	II	III
Jersey	23	-	1	1	-	-	-	-	-	-	-	.20	.10
Guernsey	22	-	1	3	-	-	.03	-	-	.20	-	.15	.11
Ayrshire	13	1	-	2	-	-	-	-	-	-	.10	-	.15
Brown Swiss	19	-	-	2	-	-	.06	-	-	.10	-	-	.08
Holstein	20	1	3	6	-	.03	.05	-	.10	.15	.20	.07	.09
All Breeds	97	2	5	14	-	.03	.03	-	.10	.20	.15	.11	.10

The Potential of T. T was present in all individuals and in all leads. The fact that potentials were not recorded for 4 cases in leads I and III does not mean that this wave was absent in these instances. The potential was merely so low as to fail to bring it under the 0.03 millivolt classification. Here, as with all the other deflections, breed differences are not significant enough to merit consideration.

Table XXI shows the range of potential to be from a minimum of 0.03 millivolt in all three leads to a maximum of 0.60, 1.10, and 0.90 millivolt in leads I, II, and III respectively. The mean values are 0.20 millivolt in lead I, 0.31 millivolt in lead II, and 0.18 millivolt in lead III.

Table XXI. Minimum, Maximum, and Mean Values for Potential of T in the First Monthly Tracings.

Breed	No. of Animals	Occurrence			Potential (Millivolts) Minimum			Maximum			Mean		
Lead →		I	II	III	I	II	III	I	II	III	I	II	III
Jersey	23	22	23	22	.03	.12	.06	.35	.70	.40	.17	.30	.18
Guernsey	22	21	22	22	.03	.10	.05	.33	1.10	.90	.14	.23	.17
Ayrshire	13	13	13	11	.10	.03	.10	.40	.70	.32	.25	.30	.16
Brown Swiss	19	18	19	18	.06	.06	.10	.60	.60	.40	.23	.31	.19
Holstein	20	19	20	20	.08	.10	.03	.43	.70	.40	.24	.41	.21
All Breeds	97	93	97	93	.03	.03	.03	.60	1.10	.90	.20	.31	.18

Occurrence, Distribution, and Range of the Highest Potential EKG Deflections in Any Lead of the First Monthly Tracings*

To gain a better conception of the distribution, size, and mean values for the maximum potential waves of the bovine electrocardiogram, this section has been included. The material presented will be limited to a brief resume of the findings for each wave. For reasons mentioned several times previously, conclusions concerning breed differences must be accepted with reserve. Table XXII showing distribution and table XXIII showing minima, maxima and mean values for the various breeds will be found on pages 61 and 62.

The P Wave. The maximum potential of the auricular deflection ranged from 0.03 to 0.22 millivolt with a tendency toward rather uniform distribution about the mean. Ten animals showed a potential of 0.08, 38 a potential of 0.10, and 19 a potential of 0.12 millivolt. Of the remaining 30 animals, 15 were grouped in the range from 0.13 to 0.15 millivolt inclusive. The balance were distributed above and below these limits as shown in Table XXII. The mean potential in the various breed groups ranged from 0.083 in the Ayrshires to 0.129 in the Jerseys. The average for the entire series was 0.106 millivolt.

The Q Wave. Tables XXII and XXIII show extremely wide and uneven scattering of the values about the mean. The absence of Q in all leads of 10 individuals lowers the average potential in the latter table. The range for actually occurring waves was from 0.03 millivolt in eight cases to 1.00 millivolt in one individual. The mean in the various

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* Due to the variability of R', the maximum potential of this wave is taken from any lead of the three monthly tracings.

breed groups ranged from 0.093 millivolt in the Holsteins to 0.302 millivolt in the Guernseys; the average for the entire series (including the ten zero, or absent cases) was 0.208 millivolt. The Holstein group displayed rather definite characteristics deserving further mention. Of the ten cases showing total absence of Q in all leads, seven were in this breed. Nine individuals displayed potentials of 0.12 millivolt or less, six of which were 0.05 millivolt or less. These latter were usually associated with R wave preponderance and showed considerable tendency toward monthly variation from low potential to complete absence and vice versa. This tendency, however, was seen in all breeds showing not only low potential Q but also small R' and S waves.

The R Wave. The most consistently present deflection of QRS, R displayed even greater irregularity in distribution about the mean than the previous wave. The range in maximum potential in any lead was from 0.10 millivolt in five instances to 2.60 millivolts in one instance. It is interesting to note that the average in the various breed groups ranged from the maximum of 0.618 millivolt in the Jerseys to from 0.337 to 0.394 millivolt in the other breed groups. The mean for the entire series was 0.425 millivolt.

The S and R' Waves. With such infrequently occurring irregular waves as these, the statistical methods employed in this section may not be applicable; and, since the treatment accorded these two deflections in the preceding section may be less apt to mislead, the picture will not be further complicated by a summary discussion of the data in Tables XXII and XXIII.

Table XXII. Distribution of the Highest Potential EKG Waves in Any Lead of the First Monthly Tracings*.

Wave	Potential (Millivolts)	0	0.03	0.04	0.05	0.06	0.07	0.08	0.10	0.11	0.12	0.13	0.14	0.15	0.17	0.18	0.20	0.22	0.23	0.25	0.30	0.32	0.33	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.72	0.80	0.90	0.95	1.00	1.10	1.20	2.60
P Wave	Jersey								6		7	2	3	4			1																						
	Guernsey				1			1	8	1	6	3		1				1																					
	Ayrshire		1	1	1			3	6			1																											
	Brown Swiss				1		2	2	9		2			1	1	1																							
	Holstein		1		1		1	4	9		4																												
	Total		2	1	4		3	10	38	1	19	6	3	6	1	1	1	1																					
Q Wave	Jersey	2			1	2			4	1				2			2	1	1	1				1	1	1	1		2										
	Guernsey		1						6					1			2				3	1		2	2	1			1		1					1			
	Ayrshire	1	2		1				3			1				1		1			1	1			1														
	Brown Swiss		2	1					2		2		2		1		1			1	1				2	1	2						1						
	Holstein	7	3	1	2				2		1										2	1			1														
	Total	10	8	2	4	2			17	1	3	1	2	3	1	1	5	2	1	2	7	3		3	7	3	3		3		1		1			1			
R Wave	Jersey								1		1									1	3			3	2	1	2	1			1		1	3		1		1	1
	Guernsey								2	1	1			2			5				2				1	1		1	4	2									
	Ayrshire																3			2	1		1	1	1		1	1	1							1			
	Brown Swiss								1					1		1	3		1	2	2	1			3		1			1			1		1				
	Holstein								1					3		1	1			2	1			1	3	3			1		2						1		
	Total								5	1	2			6		2	12		1	7	9	1	1	5	10	5	4	3	6	3	3		2	3	1	2	1	1	1
S Wave	Jersey	16	1			2			3																		1												
	Guernsey	11	3		3			1	2								2																						
	Ayrshire	4	3			1		1	2					1							1																		
	Brown Swiss	14	3		1				1																														
	Holstein	9	3	1	2									1			2			1	1																		
	Total	54	13	1	6	3		2	8					2			4			1	2						1												
R' Wave*	Jersey	19							2					1			1																						
	Guernsey	18	1						2								1																						
	Ayrshire	7			1				2					2			1																						
	Brown Swiss	16				1	1							1																									
	Holstein	9	1		1	1		1	4			1		1			1																						
	Total	69	2		2	2	1	1	10			1		5			4																						
T Wave	Jersey													1			5		1	2	6			2	3		2				1								
	Guernsey								2		2	1		2			8	1			2		1	1	1									1					
	Ayrshire													2			2				5			1			2				1								
	Brown Swiss															1	3		1		2	2		1	4	2	2		1										
	Holstein													2			1					2		1	4	2	3	3			2								
	Total								2		2	1		7		1	19	1	2	2	15	4	1	6	12	4	9	3	1		4			1					

* Due to the variability of R' the maximum potential of this wave is taken from any lead of the three monthly tracings.

Table XXIII. Partial Statistical Summary of the Size of the Greatest Deflections in Any Lead of the Bovine Electrocardiogram (Expressed in Millivolts).

	P				Q				R			
Breed	Mini.	Maxi.	Mean	St. Dev. of Mean	Mini.	Maxi.	Mean	St. Dev. of Mean	Mini.	Maxi.	Mean	St. Dev. of Mean
Jersey	0.10	0.20	0.129	0.0049	0	0.60	0.216	0.0370	0.10	2.60	0.618	0.1021
Guernsey	0.05	0.22	0.114	0.0065	0.03	1.00	0.302	0.0486	0.10	0.65	0.337	0.0433
Ayrshire	0.03	0.13	0.083	0.0076	0	0.40	0.150	0.0333	0.20	1.00	0.394	0.0602
Br. Swiss	0.05	0.18	0.104	0.0072	0.03	0.80	0.252	0.0461	0.10	0.95	0.356	0.0504
Holstein	0.03	0.12	0.092	0.0050	0	0.40	0.093	0.0278	0.10	1.10	0.386	0.0532
All Breeds	0.03	0.22	0.106	0.0031	0	1.00	0.208	0.0197	0.10	2.60	0.425	0.0336

	S				R'				T			
Breed	Mini.	Maxi.	Mean	St. Dev. of Mean	Mini.	Maxi.	Mean	St. Dev. of Mean	Mini.	Maxi.	Mean	St. Dev. of Mean
Jersey	0	0.50	0.041	0.0216	0	0.20	0.023	0.0114	0.15	0.70	0.316	0.0257
Guernsey	0	0.20	0.041	0.0126	0	0.20	0.019	0.0102	0.10	0.90	0.239	0.0351
Ayrshire	0	0.30	0.067	0.0223	0	0.20	0.057	0.0194	0.15	0.70	0.326	0.0419
Br. Swiss	0	0.10	0.012	0.0058	0	0.15	0.014	0.0085	0.18	0.60	0.352	0.0265
Holstein	0	0.30	0.066	0.0208	0	0.20	0.055	0.0134	0.15	0.70	0.427	0.0334
All Breeds	0	0.50	0.044	0.0081	0	0.20	0.032	0.0057	0.10	0.90	0.328	0.0161

Variations in the Form of QRS and Distribution of the Various Types

In figure I is presented a complete general grouping of the various representative types of QRS encountered in this study. On turning to this figure, it will be apparent at a glance that for those familiar with normal human electrocardiograms, considerable mental readjustment may be necessary in order to eliminate the impression that one is dealing with abnormal tracings. The arrangement is purely arbitrary. Beginning with typical R wave predominance, the progression is through varying types of multiphase complexes to negative (Q-wave) predominance and finally representative unfavorable low potential QRS types. Beginning with type 1, their form and occurrence will be considered in order. The discussion will be based upon the figure referred to above, and Tables XXIV and XXV showing various features concerning occurrence of the several forms. Table XXIV indicates the per cent incidence of occurrence in the entire series. Table XXV shows the actual number of times each form was present in the three leads tabulated according to breed groups. In compiling the data for this table, the sum of the three leads in the three serial electrocardiograms for each of the 97 animals was used, making a total of 291 each of leads I, II, and III. Due to the occurrence of monthly variations, it is believed that this procedure will yield data upon which more accurate conclusions can be based. For greater clarity of comparison, Table XXIV will be drawn upon for occurrence of the QRS forms while Table XXV will be referred to concerning possible breed differences.

Under types 1 and 2 are grouped those complexes showing definite R wave predominance varying from a quick fine up and downstroke to more or less progressive degrees of coarsening of both limbs of this deflection. Type 1, the only QRS most typical of normal human tracings, occurred in but one individual and is reproduced in full in Figure III. Type 2 appeared in 19 per cent of the instances in lead I, 4 per cent in lead II, and 2 per cent in lead III. Table XXV indicates that this form occurred about four times more frequently in lead I of the Holsteins than in any other breed.

Types 3 and 4 are characterized by a quick fine upstroke of R with slurring or coarsening of the descending limb which may be complete (type 3) or merely confined to its terminal portion (type 4). Type 3 occurred in 2 per cent of the instances in lead I, 10 per cent in lead II, and 4 per cent in lead III. No significant breed differences are shown in Table XXV. Type 4 was seen in lead I of only one individual. However, it occurred in 36 per cent of the instances in lead II and 26 per cent in lead III. There is an apparent tendency for the occurrence of this type of QRS to be more frequent in the Jersey than in any of the other breed groups. The two types together appeared in about 24 per cent of the 873 leads in the three serial electrocardiograms of the 97 animals constituting this series.

In type 5 is seen the beginning of the very troublesome and changeable group of vibratory complexes. Type 5a shows notching of the downstroke at the point where the terminal portion becomes coarsened. With a lowering in potential of the initial spike, forked or somewhat M-shaped, complexes such as 5b occur. Since these two closely related forms occurred with about equal frequency, they will be considered together. The two types were totally absent in lead I, present in 8 per cent of the instances in lead II, and 17 per cent in lead III.

In type 6, the descending limb of the initial spike crosses the isoelectric level giving rise (according to the accepted classification in such cases) to a second positive QRS deflection or R' wave of which the coarsened terminal portion of R in type 4a seems to be the remote analogue. This occurred in 7 per cent of the instances in lead III, and was entirely absent in the other two leads.

From this point the forms pass through various stages of M-shaped complexes in which the notching may (type 8) or may not (type 7) cross the isoelectric level. Type 7 occurred in 1 per cent of the instances in lead I, 3 per cent in lead II, and 7 per cent in lead III. Table XXV indicates this form to be much more prevalent in the Brown Swiss and Holstein groups. Type 8 was of negligible occurrence in lead I, appeared in 2 per cent of the instances in lead II, and 7 per cent in lead III. These two forms complete the class showing initial upward (R wave) deflections of QRS.

Types 9 to 12 inclusive, exhibit downwardly directed initial effects of QRS. The complexes as a whole are W-shaped vibratory (types 9 and 10b) or truly W-shaped (type 10a). In many of these the excursion of the string shadow in executing the vibrations may be broad enough to cross the base line at two points, giving rise again to a second positive QRS deflection or R' Wave (type 10b and possibly 9b). Due to their relative similarity of form, types 9 and 10 are considered together. Comparative occurrence in the three leads are not especially significant. The two forms together were present in 8 per cent of all the leads.

Type 11 shows two typical variations of diphasic (QR) complexes displaying opposite potential excursions which are broad enough to indicate considerable rotation of the electrical axis during systole. Occurring with considerable uniformity in the several breed groups, this form of QRS was present in 9 per cent of the instances in lead I, 22 per cent in lead II, and 8 per cent in lead III.

Type 12 is characterized by Q predominance reminiscent of human electrocardiograms showing abnormal axis deviation. It is interesting to note that the two limbs of Q in this class were prone to be less broad or coarse than the oppositely directed complex displayed in type 2. The occurrence of this form was very largely in lead I, being present in 22 per cent of the instances in this lead and only 7 and 4 per cent in leads II and III respectively. Table XXV indicates this type to be of most frequent occurrence in all three leads of the Guernsey group, while the Jerseys and Brown Swiss follow in order with occurrence principally in lead I. The appearance of this form in the two remaining groups (Ayrshire and Holstein) is relatively infrequent.

Under type 13 of the figure is arbitrarily lumped all extremely unfavorable low potential QRS. Examination of the four specimens will reveal resemblances to previously classified complexes. Due to the extremely low potential displayed by the members and the difficulty attending the accurate classification of many of these, a separate group presented the only logical solution. Study of Table XXIV reveals that unfavorable QRS is largely confined to lead I where it was present in 40 per cent of the instances. The distribution was remarkably uniform in the five breed groups.

<u>Summary</u>. To summarize the foregoing data more comprehensibly, the resume below is presented.

In lead I, type 2 occurred in 19 per cent, type 12 in 22 per cent, and type 13 in 40 per cent of all individuals. Type 5, 6, and 8 were totally absent, and the balance were thinly scattered among the remaining forms.

In lead II the distribution is somewhat more uniform, the more frequently occurring forms being types 3, 4, and 11, which were present in 10, 36, and 22 per cent of the individuals respectively.

Lead III shows the most uniform distribution of all, with type 4 occurring in 26 per cent of the individuals and the balance rather evenly distributed among the remaining types.

Type 1, being present in only one individual, was not considered of sufficient importance to warrant mention in the foregoing summary.

Finally, attention must be directed to one constantly present characteristic of QRS in this series. Beginning with type 2 and ending with type 11, the final effects are almost invariably broader and slower than any other phase of the complex. A faint suggestion of this is also definite enough in the remaining forms to warrant the conclusion that this pheomenon is a characteristic feature of the bovine electrocardiogram.

Table XXIV. Per Cent* Incidence of Occurrence of the 13 QRS Types Shown in Figure I.

QRS					5									
Types →	1	2	3	4	a	b	6	7	8	9	10	11	12	13
L I	1	19	2	1	0	0	0	1	0	4	1	9	22	40
L II	1	4	10	36	5	3	0	3	2	5	2	22	7	4
L III	1	2	4	26	8	9	7	7	7	6	5	8	4	7
All Leads	1	8	5	19	5	4	2	3	3	5	3	13	11	17

* To the nearest whole number.

Table XXV. Distribution of the QRS Types, Represented in Figure I, in the Three Serial Electrocardiograms*.

QRS Type →		1	2	3	4	5 a	5 b	6	7	8	9	10	11	12	13	Total Leads
Jersey	L I	3	6		3								2	18	37	69
	L II	3		2	30	7	4		1	1	4		11	6		69
	L III	3	1	5	31	8	6	5		2	2		3		3	69
	Total	9	7	7	64	15	10	5	1	3	6		16	24	40	207
Guernsey	L I		11								3		5	24	23	66
	L II			6	16		1		1		4	3	19	14	2	66
	L III		2	1	15	6	1	2	2	1	8	6	4	10	8	66
	Total		13	7	31	6	2	2	3	1	15	9	28	48	33	198
Ayrshire	L I		7	3					2	1	3	1	5	4	13	39
	L II			6	10	5					7		8		3	39
	L III				9	1		5	3	6	7	1	3		4	39
	Total		7	9	19	6		5	5	7	17	2	16	4	20	117
Brown Swiss	L I		6	3							3	2	10	15	18	57
	L II		3	10	11	1	3		3			3	19	1	3	57
	L III		2	4	11	4	13	3	9			3	4	1	3	57
	Total		11	17	22	5	16	3	12		3	8	33	17	24	171
Holstein	L I		27								3		3	2	25	60
	L II		8	6	22	3	2		3	5			8		3	60
	L III			1	9	5	6	5	5	10		6	10		3	60
	Total		35	7	31	8	8	5	8	15	3	6	21	2	31	180
All Breeds	L I	3	57	6	3				2	1	12	3	25	63	116	291
	L II	3	11	30	89	16	10		8	6	15	6	65	21	11	291
	L III	3	5	11	75	24	26	20	19	19	17	16	24	11	21	291
	Total	9	73	47	167	40	36	20	29	26	44	25	114	95	148	873

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* Since there are three serial electrocardiograms for each of the 97 animals represented, the data for this table is obtained from a total of 291 records (873 leads). Any discrepancies occurring are due to monthly variations in form of QRS.

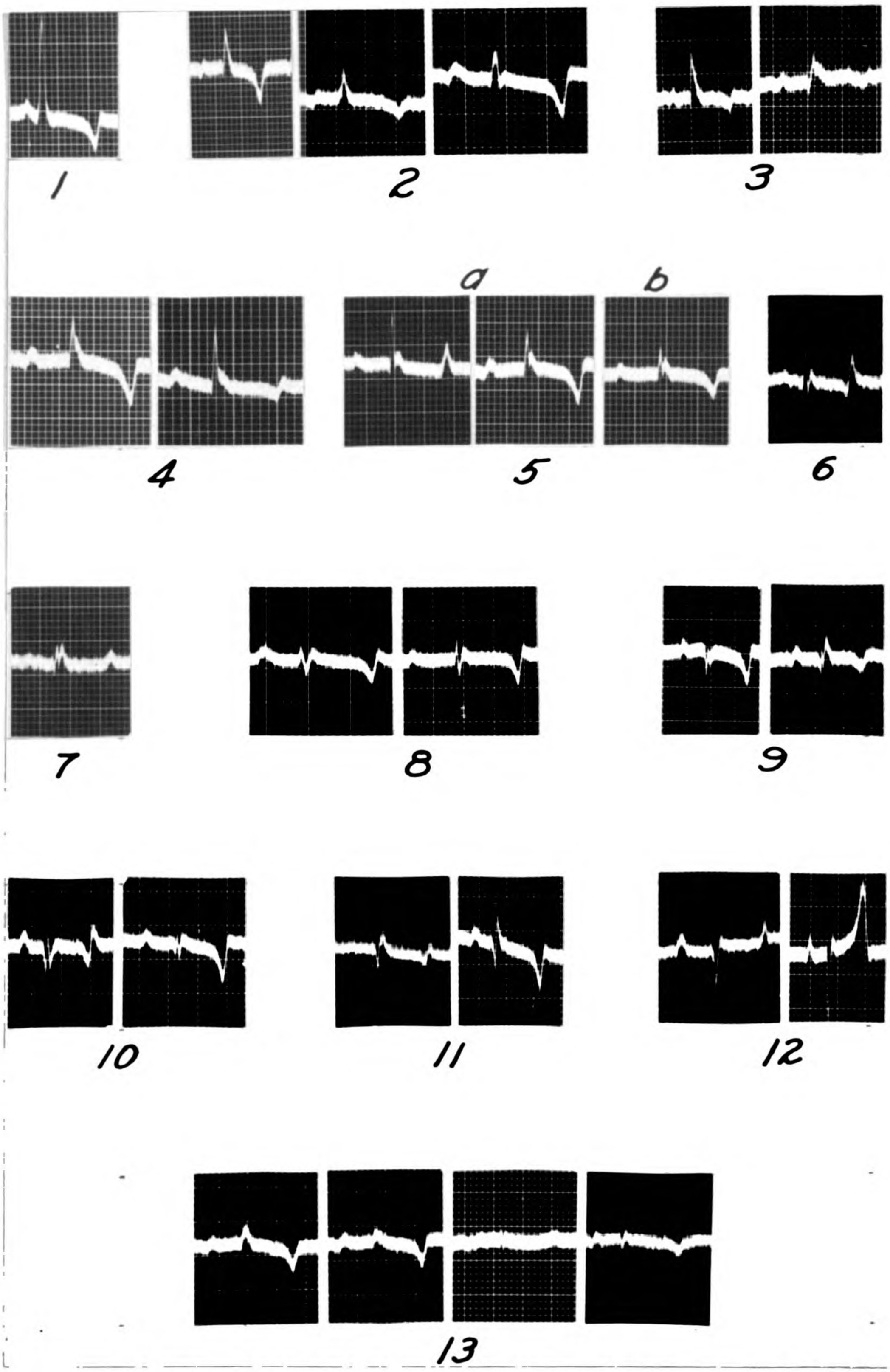

Figure I. Various types of Bovine EKG Complexes Arranged According to Form of the QRS Group.

Classification of the Bovine Electrocardiogram

Since no two individuals in this series displayed identical electrocardiograms, any method of classification will perforce not be entirely satisfactory and above criticism. The form and character of QRS based upon the type complexes exhibited in Figure I were arbitrarily taken as the basis for the arrangement of major groups. The occurrence of the several types in the different lead combinations and the form of QRS in the aberrant lead were the criteria employed in the arrangement of sub-groups. The final result of this arrangement is the basis for the detailed outline on the following pages. The three tracings from each individual were not separated. Where monthly changes were extreme enough to permit placement of the individual in more than one position, the predominant characteristics of the three tracings were employed as the basis for final classification. Furthermore, it is conceivable that certain electrocardiograms may show unlike QRS types in the different leads causing them to be unclassifiable. These are grouped in a separate class.

Figure II-A shows specimens of the various types encountered and is so labeled as to be readily integrated with the outline presented on pages 72 to 78. Since the photographic reduction necessary for inclusion of the entire figure within the dimensions of a page is so great as to obscure the form of the complexes, the components of the figure have been broken up into smaller units and are reproduced as figures II-B, II-C, II-D, and II-E on pages 79 to 85. Figure III on page 85 shows an unusual type of bovine electrocardiogram.

Detailed Classification of Bovine Electrocardiograms According to Form of QRS

I. Tracings showing R wave predominance characterized by:

A. Coarsened ascending and descending limbs (Figure II-1, 2, and 3), entire (Figure II-7), or terminal portion (Figure II-4, 5, and 6) of descending limb of R wave.

1. In leads I and II -

a. Showing mainly low potential positive, coarse, and somewhat vibratory type of QRS in lead III:

Ayrshire #141 Figure II-1 (EKG B312);

b. Showing split or M-shaped QRS in lead III:

Ayrshire #159 Figure II-2 (EKG B336);

c. Showing diphasic (RS) type of QRS in lead III:

Holstein #186 Figure II-3 (EKG B568).

2. Coarsened terminal portion of downstroke of R in leads II and III with a quick fine ascending limb -

a. Showing mainly positive QRS in lead I:

Jersey #101 Figure II-4 (EKG B151);
Jersey #115;
Ayrshire #162;
Holsteins #252 and 254;

b. Showing low potential mainly diphasic (QR) deflections in lead I:

Jersey #95 and 97;
Jersey #114 Figure II-5 (EKG B267);
Guernsey #9;
Holstein #258 Figure II-6 (EKG B650);

c. Showing mainly negative W-shaped QRS in lead I:

Guernsey #6 Figure II-7 (EKG B438);

d. Showing mainly negative (Q) deflection in lead III:

Jersey #88;
Guernsey #1 Figure II-8 (EKG B348);
Guernsey #30;
Ayrshire #146 Figure II-9 (EKG B130);
Brown Swiss #234 and 248.

B. Coarsened notched terminal portion of descending limb of R wave.

1. Notching of down-stroke in lead III with coarsened down-stroke of R in lead II -

a. With mainly positive summation in lead I:

Jersey #80;
Guernsey #59 Figure II-10 (EKG B325);
Holstein #269 Figure II-11 (EKG B345);
Holstein #275;
Holstein #282 Figure II-12 (EKG B116);
Brown Swiss #301 and 307;

b. With mainly diphasic (QR) deflection in lead I:

Ayrshire #161;
Holstein #220 Figure II-13 (EKG B404).

2. In leads I and II -

With vibratory R3:

Guernsey #7 Figure II-14 (EKG B122).

3. In leads II and III -

a. With mainly positive summation in lead I:

Jersey #62 Figure II-15 (EKG B580);
Brown Swiss #300;

b. With mainly diphasic (QR) deflection in lead I:

Jersey #85 Figure II-16 (EKG B320);
Jersey #87 and 108;
Guernsey #48 Figure II-17 (EKG B89);

c. With very low potential QRS in lead I:

Jersey #116 Figure II-18 (EKG B328);

d. With mainly negative summation in lead III:

Jersey #111;
Jersey #118 Figure II-19 (EKG B639).

II. Tracings showing vibratory type QRS characterized by:

A. M type QRS with R wave predominance.

1. In leads II and III -

a. With mainly positive deflection in lead I:

Holstein #180 Figure II-20 (EKG B570);
Holstein #278;

b. With mainly diphasic (QR) deflection in lead I:

Brown Swiss #237 and 239*;

c. With mainly low potential negative deflection in lead I:

Jersey #73 Figure II-21 (EKG B85).

2. In lead II only with negative (Q wave) QRS in lead I and upward deflection (R wave) with coarsened downstroke in lead III -

Brown Swiss #303.

B. W type wave showing split Q wave predominance.

1. In lead III with negative summation in leads I and II -

Guernsey #25 Figure II-22 (EKG B94).

2. In leads I and III with QR deflection in lead II -

Ayrshire #163 Figure II-23 (EKG B442).

C. Splintered or split type QRS of sufficient breadth to often cause the formation of a second positive QRS deflection (R' wave) by reason of the passing of the downstroke of the first spike of the complex below the isoelectric level.

1. Coarsened notched downstroke type in lead III (or exaggeration of the notching or splitting classified in part IB of the outline) -

---

* QRS in leads II and III were so nearly like that of Figure II-21 that no specimen complexes were taken from this group.

a. Showing smallest R in lead I with coarsened notched or merely coarsened downstroke of R in lead II:

Ayrshire #152 Figure II-24 (EKG B127);
Holstein #195, 226, and 286;
Brown Swiss #240;

b. Showing negative predominance in lead I with diphasic or vibratory QRS in lead III:

Jersey #86;
Ayrshire #160 Figure II-25 (EKG B390).

2. M type or split complexes of sufficient breadth to produce generally distinct S waves -

a. In lead III with mainly positive deflections in leads I and II:

Ayrshire #153;
Holstein #281 Figure II-26 (EKG B115);

b. In lead III with mainly negative lead I and slightly negative or diphasic lead II:

Guernsey #3;
Ayrshire #156;
Holstein #260 Figure II-27 (EKG B366);

c. In leads II and III:

(1) With positive deflection in lead I:

Holstein #280 Figure II-28 (EKG B114);

(2) With negative lead I:

Jersey #90;

d. In leads I, II, and III:

Ayrshire #144 Figure II-29 (EKG B304).

3. Tracings showing varying degrees of W type split complexes -

a. In leads I and II with very low potential diphasic QRS in lead III:

Brown Swiss #245;

b. In leads I and III with diphasic (QR) deflections in lead II:

Guernsey #41;
Brown Swiss #231 Figure II-30 (EKG B305);

c. In leads II and III:

(1) With R wave in lead I:

Guernsey #44 Figure II-31 (EKG B93);
Guernsey #57;
Holstein #253 Figure II-32 (EKG B362);

(2) With extremely low potential of all waves in lead I:

Guernsey #50 Figure II-33 (EKG B92);
Ayrshire #151.

III. Tracings whose QRS indicates rather extreme rotation of the electrical axis during systole:

1. In lead II -

With mainly sharp Q wave in lead I and coarsened downstroke or splintered or notched summit of the predominant R wave in lead III:

Jersey #79 Figure II-34 (EKG B145);
Jersey #100 Figure II-35 (EKG B97);
Jersey #117;
Guernsey #14;
Guernsey #28 Figure II-36 (EKG B96);
Guernsey #46 and 55;
Brown Swiss #230 and 305;
Brown Swiss #306 Figure II-37 (EKG B199).

2. In leads I and II -

With vibratory R predominance in lead III:

Brown Swiss #232 Figure II-38 (EKG B135);
Brown Swiss #302.

3. In lead III -

With mainly negative summation in lead II and low potential slightly negative lead I:

Jersey #89 Figure II-39 (EKG B319).

4. In leads II and III -

a. With small R wave in lead I:

Ayrshire #150;
Holstein #259 Figure II-40 (EKG B552);

b. With very low non-determinable QRS in lead I:

Guernsey #37 Figure II-41 (EKG B144);

c. With largely negative (Q wave) predominance in lead I:

Brown Swiss #233 Figure II-42 (EKG B402);
Holstein #261 Figure II-43 (EKG B367).

IV. Tracings showing negative predominance of QRS characterized by:

a. Unfavorable negative or diphasic QRS in lead I:

Guernsey #8 Figure II-45 (EKG B34);
Guernsey #42;
Guernsey #47 Figure II-46 (EKG B123);

b. Unfavorable diphasic QRS in lead III:

Jersey #63 Figure II-44 (EKG B271).

V. Miscellaneous tracings presenting peculiarities precluding rational classification.*

a. Tracings showing low voltage QRS in all three leads - generally negative summation in lead I, diphasic lead II, and positive lead III characterized by considerable monthly change:

Guernsey #60 Figure II-47 (EKG B380);
Brown Swiss #238;
Brown Swiss #304;
Holstein #256 Figure II-48 (EKG B560);

b. Tracings showing quick fine R waves of extreme amplitude in all three leads:

Jersey #84 Figure III.

---

* While justification could perhaps be obtained for the disposition of this group by placing them in the nearest correct position in the preceeding outline, it was thought best to create for the time being a separate class for these tracings.

<u>Summary of the Distribution of the Various Groups in the Classification.</u> The breed distribution of the various types through the second subdivision in the outline is summarized in the table below. This compilation shows that type I and II embraced 72 per cent of the entire group of 97 animals, with type III next in order (18 per cent) and type IV and V of relatively infrequent occurrence. The series is too small to warrant conclusions as to breed differences if any. It may be significant that of the 21 Jerseys 14 were in type I.

Table XXVI. Summary of the Distribution of EKG types according to the Outline on pages 72 to 78 and as illustrated in Figure II.

Types →	I						II								III					IV	V
Subgroups →	A		B			Totals	A		B		C			Totals					Totals		
	1	2	1	2	3		1	2	1	2	1	2	3		1	2	3	4			
Jersey		6	1		7	14	1				1	1		3	3		1		4	1	1
Guernsey		4	1	1	1	7			1			1	4	6	4			1	5	3	1
Ayrshire	2	2	1			5				1	2	3	1	7				1	1		
Brown Swiss		2	2		1	5	2	1			1		2	6	3	2		1	6		2
Holstein	1	3	4			8	2				3	3	1	9				2	2		1
All Breeds	3	17	9	1	9	39	5	1	1	1	7	8	8	31	10	2	1	5	18	4	5

F I G U R E S

The figures on the following pages are arranged to illustrate the various types of bovine electrocardiograms encountered:

Figure II A shows various types of electrocardiograms arranged according to the classification on pages 72 to 78. The Roman numerals on the extreme right have reference to leads; the Roman numerals to the left, as well as the capital letters, have reference to the major subdivisions of the classification referred to above, and the Arabic numbers under each EKG refer to individuals. The figure is reduced to about one-fourth actual size of the original.

Figures II B, C, D, and E are the components of Figure II A, as indicated by the number under each EKG, enlarged to the actual size of the original records.

Figure III is an unusual type of bovine electrocardiogram, about one-half original size to show type of mounting card employed. The arrangement of leads is I, II, and III in descending order from top to bottom of the figure.

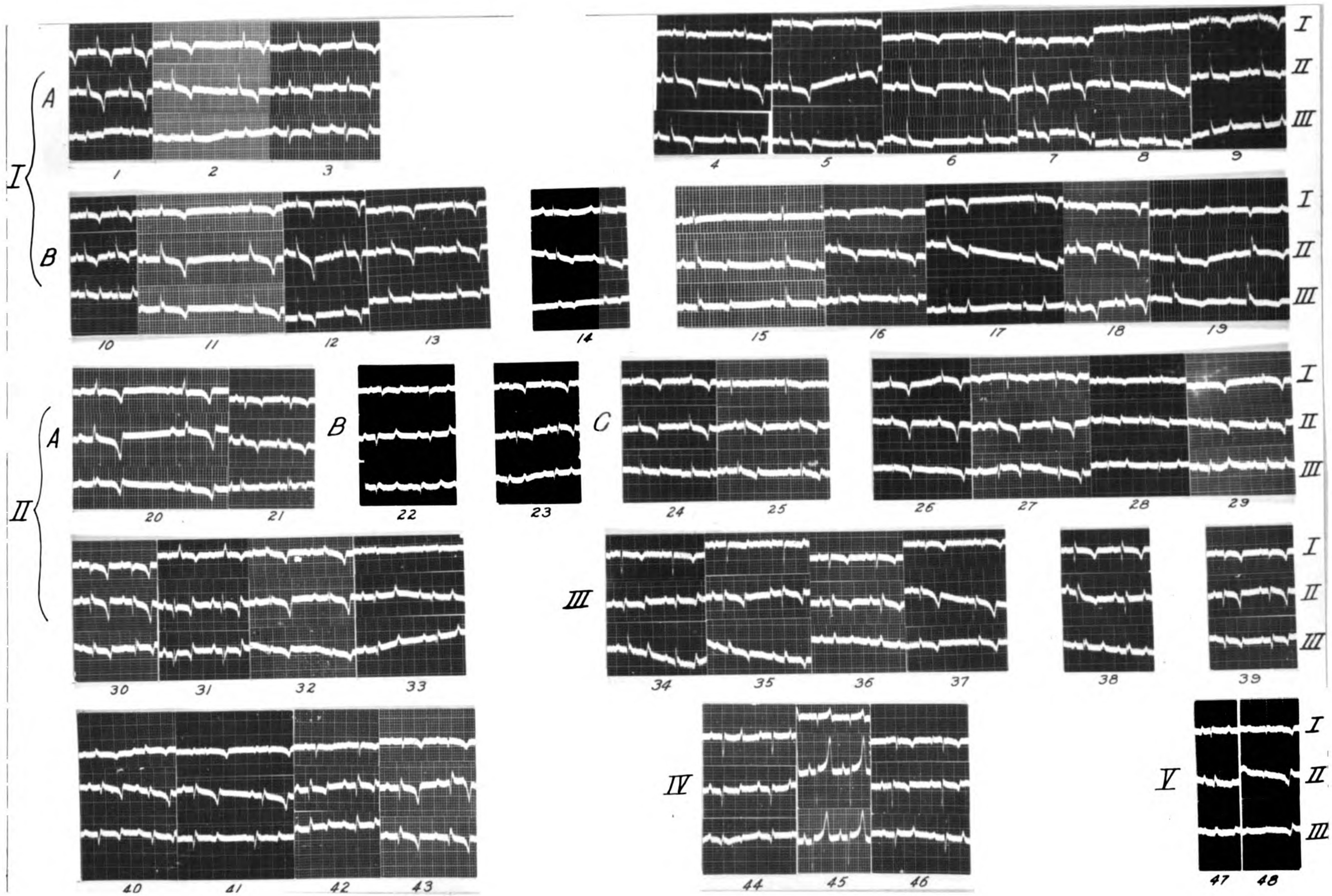

Figure IIA - Bovine EKG Types.

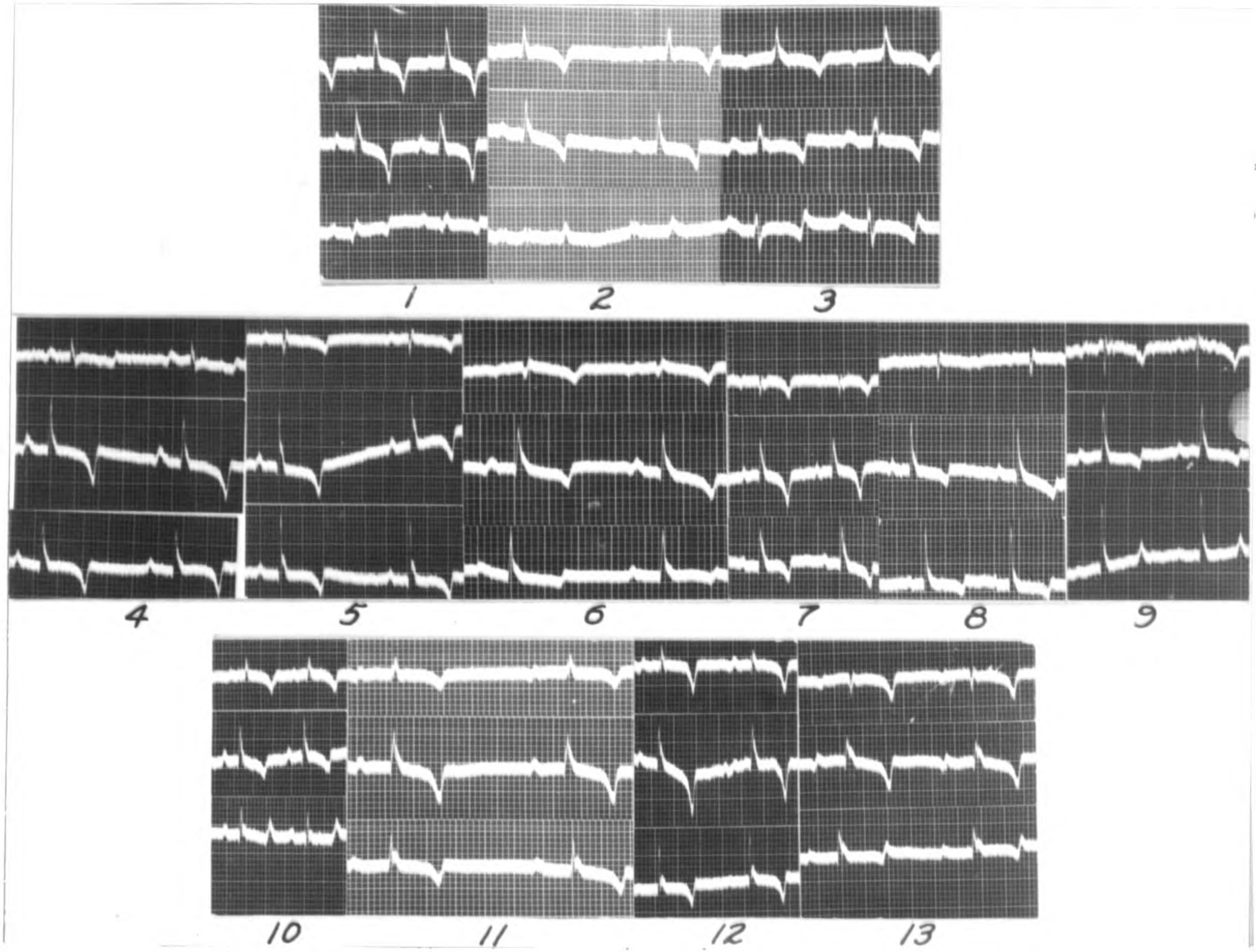

Figure IIB - Components 1 to 14 of Fig. IIA, Enlarged to Actual Size of the Records.

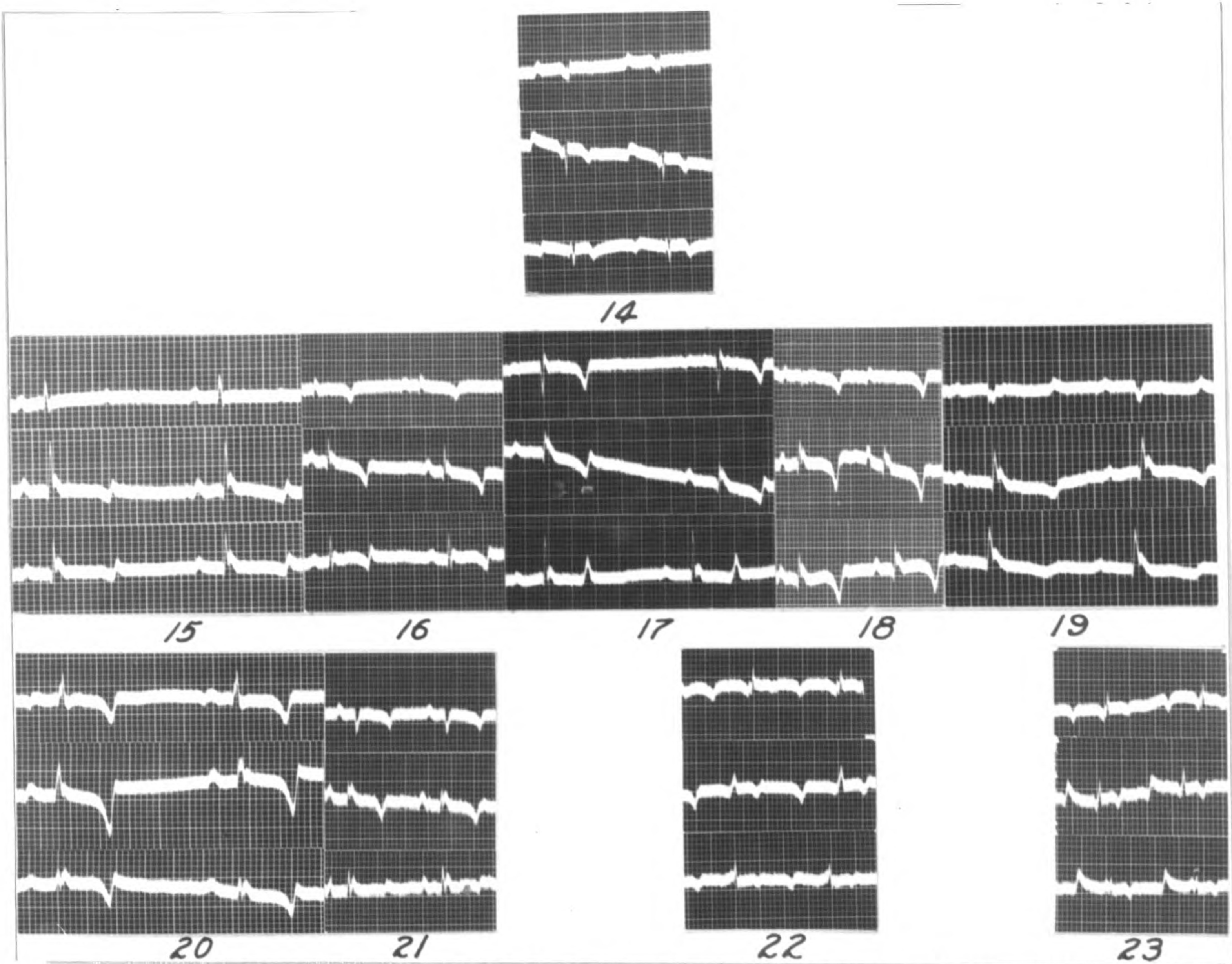

Figure IIC - Components 14 to 24 of Fig. IIA, Enlarged to Actual Size of the Records.

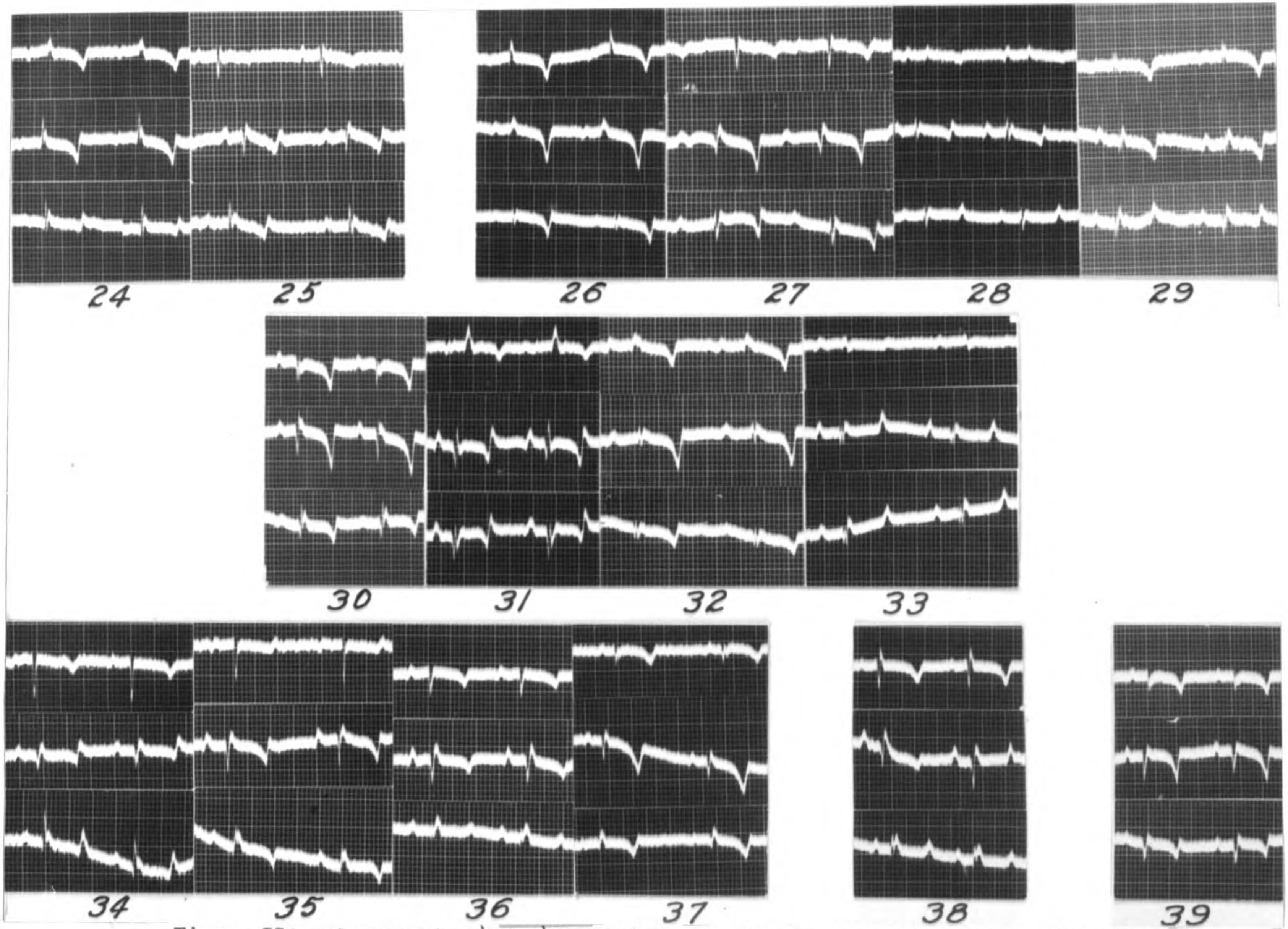

Figure IID - Components 24 to 40 of Fig. IIA, Enlarged to Actual Size of the Records.

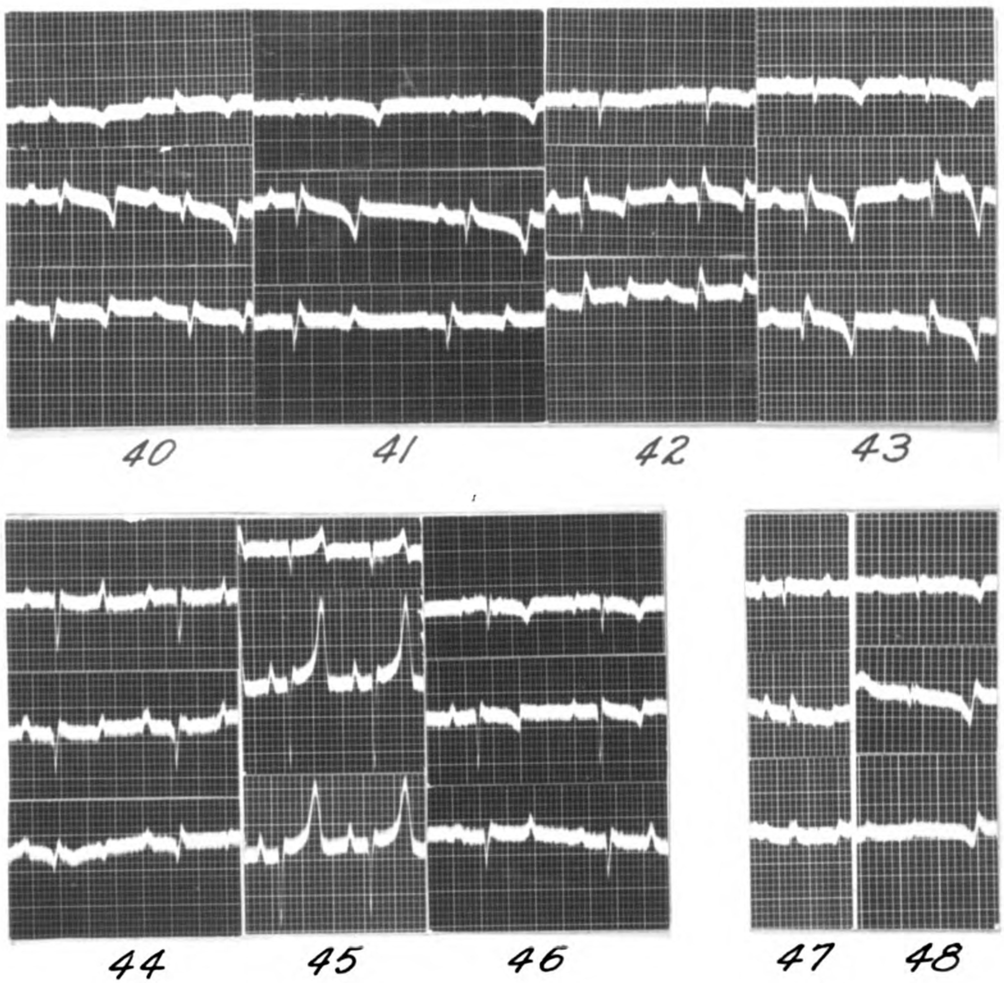

Figure IIE - Components 40 through 48 of Fig. IIA, Enlarged to Actual Size of the Records.

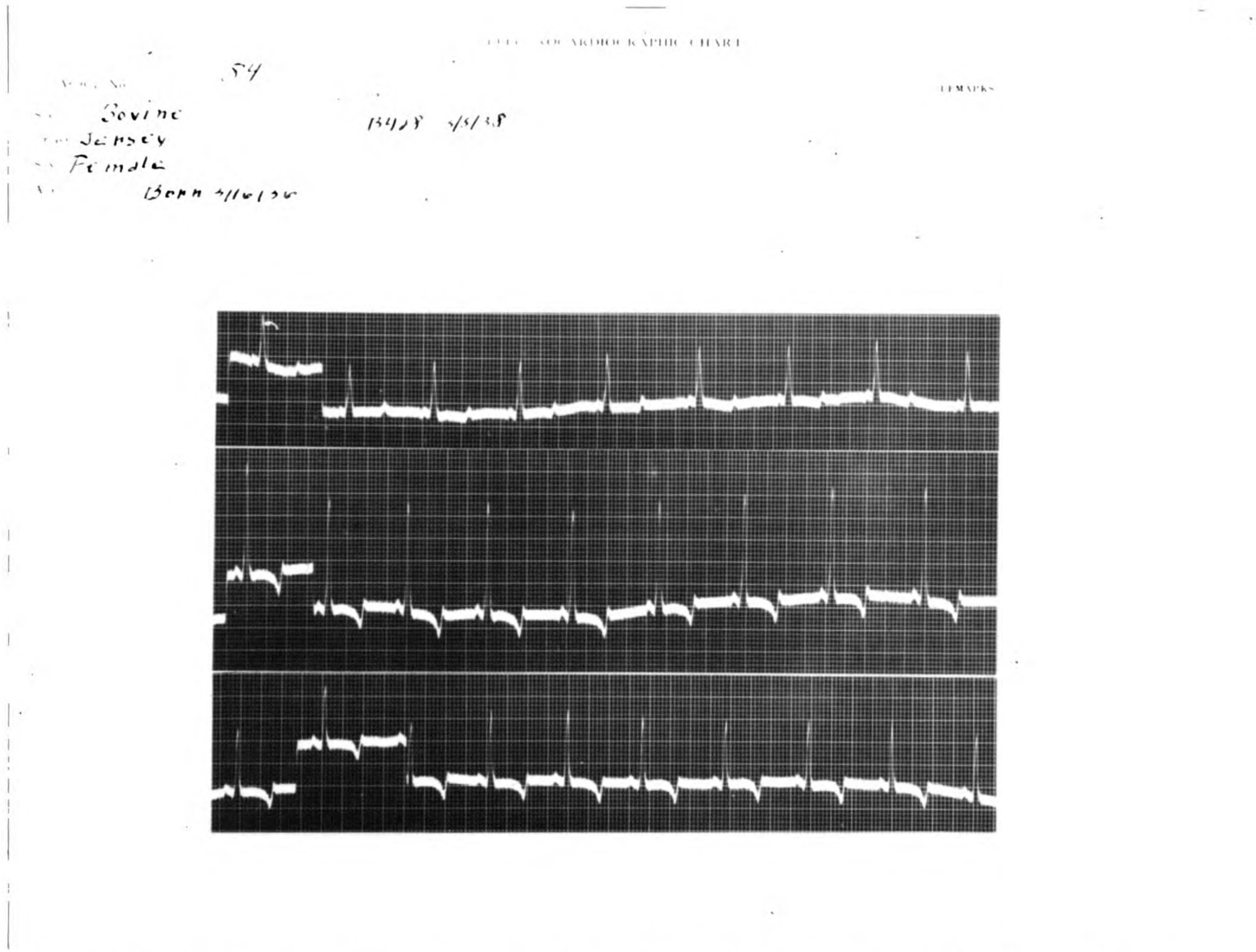

Figure III - An Unusual Type of Bovine Electrocardiogram. This figure is reduced in size to show type of mounting card employed. The dimensions of the original card are 8 1/2 by 11 inches.

THE ELECTRICAL AXIS OF THE BOVINE HEART

The approximate electrical axis of each electrocardiogram in the series was determined by the method described under procedure. These values are recorded in Table XXX. Due to the superficial methods employed and the general unfavorableness of many tracings, the data presented in this section are only of the most general nature and do not warrant definite conclusions. If the electrocardiograph should prove to be of value in certain bovine experimental procedures, more detailed study of the normal is essential.

Table XXVII shows the electrical axis distribution in the first monthly tracings of the five breeds composing the present series. Study of this table shows that practically 50 per cent of the animals are in the axis range from +30° to +90° inclusive, and 65 per cent from +30° to +170°. Only 17 per cent are grouped in the -30° to -160° range,

Table XXVII. Distribution of Electrical Axes by Breeds in the First Monthly Tracings.

Range →	+30° to +91°	+91° to +170°	-30° to -91°	-91° to -160°	180°	Non-Determinable
Jersey	13	5	0	3	2	0
Guernsey	7	5	4	3	2	1
Ayrshire	6	2	1	0	1	3
Brown Swiss	8	5	0	3	1	2
Holstein	14	0	2	1	0	3
TOTAL	48	17	7	10	6	9

with but 6 per cent showing the extreme deviation of 180°. It is interesting but perhaps not significant to note that no individuals were present in a radius of 30° on either side of zero. Considering the relatively small size of the group and the methods employed in axis determination, conclusions concerning breed differences should perhaps not be drawn.

Ten animals (about 10 per cent) displayed, in the course of the three monthly tracings, electrocardiograms of a type precluding even an approximate axis determination. This group is best described in the following outline:

I. Electrocardiograms showing a non-determinable axis in all three monthly tracings.

   A. Due to marked rotation of the electrical axis during systole*:

      1. Ayrshire #163 Fig. II-A 23;
      2. Ayrshire #151;
      3. Brown Swiss #302;
      4. Holstein #280 Fig. V-J;
      5. Holstein #261 Fig. II-A 43;

   B. Due to unfavorable, low potential, and often vibratory type of QRS in two or more leads:

      1. Guernsey #57;
      2. Brown Swiss #245;
      3. Holstein #256 Fig. II-A 48.

II. Electrocardiograms showing a non-determinable electrical axis in only one of the three monthly tracings.

   A. Ayrshire #144 (EKG #B 131). This tracing (Fig. IV, page 90) is unique in that QRS in leads II and III are approximately mirror images of each other. This coupled with an unfavorable vibratory type QRS in lead I renders axis determination impossible. The succeeding two monthly records

* Discussed on page 66.

in this animal show a definite electrical axis of approximately +90°.

B. Brown Swiss #306. Since this individual is especially prone to show changes* during the actual recording of its EKG, Figure VIII (EKG #B316) is selected for discussion here. Paying no attention to the last half of lead III which will be taken up later (page 97), it can be seen that the low potential upward summation of QRS in all three leads makes axis determination impossible.

To sum up the foregoing outline, it is apparent that records of which the electrical axis is not determinable are largely confined to those individuals whose QRS is either of two types:

(a) Tracings showing usually vibratory QRS of low potential;

(b) Tracings showing usually di- and sometimes triphasic QRS the algebraic sum of whose potential is very close to zero**.

In concluding this section the periodic variations in electrical axis shown in Table XXX will be briefly considered. Taking the first monthly record merely as a basis for comparison, the distribution of the maximum deviation in either direction from this standard in the two succeeding electrocardiograms is as follows:

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* This is evidenced by comparing the third monthly tracing in K of Figure V with the figure referred to above. Both of these illustrations were obtained from the same recording.

** These are referred to in the discussion as showing considerable rotation of the electrical axis during systole.

Table XXVIII. Distribution of the Maximum Monthly Axis Variation From Those Present in the Initial Tracings.

Degree of Variation →	10°	20°	30°	40°	45°	60°	80°	Total
Jersey	0	0	2	1	0	0	0	3
Guernsey	3	1	3	0	1	0	1	9
Ayrshire*	2	0	1	0	0	1	0	4
Brown Swiss	3	2	2	0	0	0	0	7
Holstein	0	1	2	0	0	0	0	3
All Breeds	8	4	10	1	1	1	1	26

From these figures it is evident that the most frequently occurring deviation is in the 10 to 30 degree range, where we find grouped 22 of the 26 animals showing appreciable monthly variations. It must be remarked further that many individuals displayed monthly axis changes which were minor enough to be undetected because of the rough methods employed. This warrants the opinion that more accurate and painstaking analyses would bring to light a greater incidence of periodic variation than that indicated in Table XXX. Finally, when one considers the unfavorable plane from which current is lead off by the standard Einthoven leads in cattle and superimposes upon this the relative mobility of the bovine heart, it is extremely doubtful that axial changes in experimental procedures requiring repeated records can ever be safely considered as significant in this species. That part of this conclusion which concerns cardiac mobility is in general agreement with the findings of Katz, et al., in dogs (28).

* These figures are exclusive of Ayrshire #144 whose electrical axis could not be determined in the first monthly tracing.

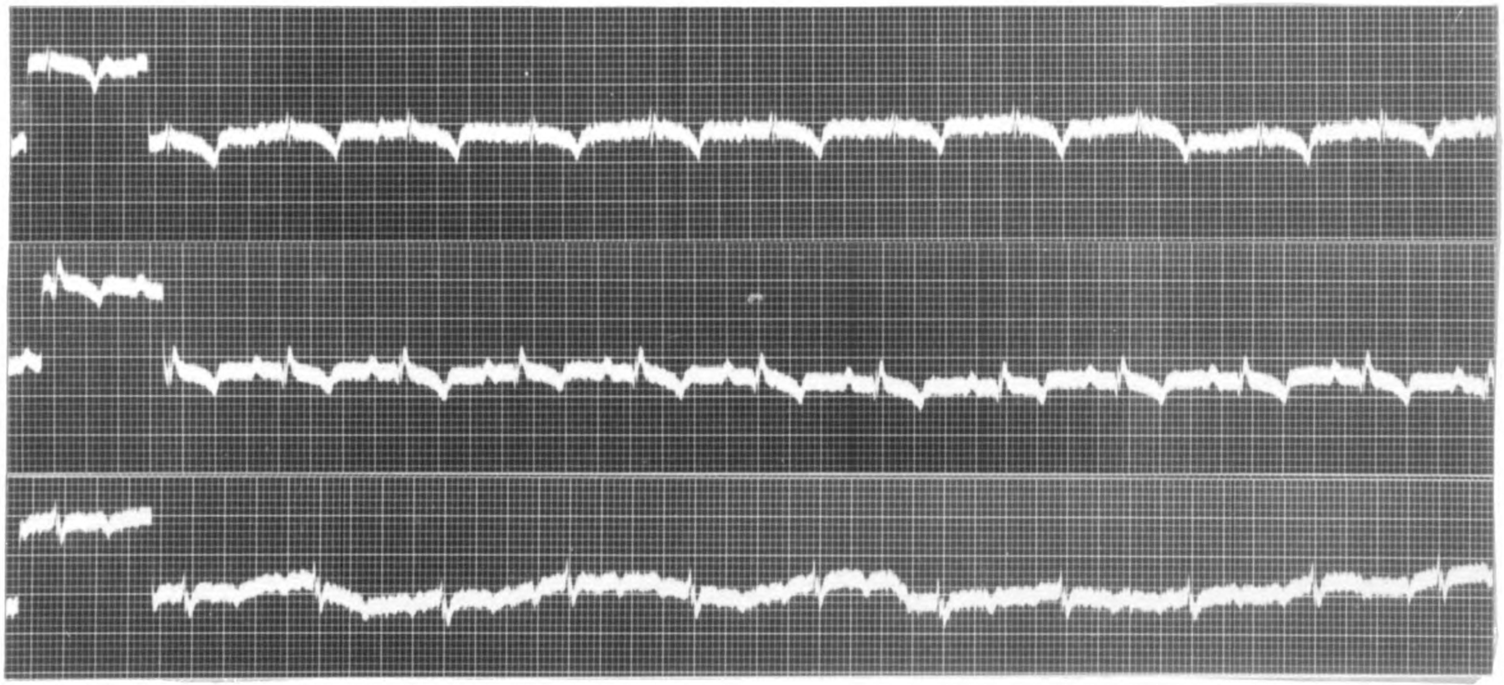

Figure IV - A Bovine EKG of a Type Precluding Cardiac Electrical Axis Determination.

VARIATIONS IN THE BOVINE ELECTROCARDIOGRAM

The three monthly tracings on each animal included in this series affords a reasonable opportunity for studying any changes in the bovine electrocardiogram occurring during these intervals. For convenience in comparison Table XXX (appendix), showing the occurrence of all the waves composing a complete cardiac cycle in each of the three monthly electrocardiograms arranged according to breeds, etc., was devised. In order that the table embody as much information as possible, symbols indicating the more general nature of the various deflections were necessary, and detailed study cannot be made without strict reference to the appended key. Since even the most minor changes were recorded, any attempt at statistical treatment of this phase of the subject could only end in confusion. Therefore, the discussion at this point will be of a far more general nature than has hitherto been employed. Concerning the table, only a few more or less sweeping generalizations will be drawn. Monthly changes in the P and T deflections are largely but not always, associated with the variable diphasicity so characteristic of these waves in the bovine electrocardiogram. The nature of this change is discussed more completely on pages 23 and 29. In the case of P, we have superimposed upon this type of variability the inconstancy of low potential waves in certain subjects. Variability in the occurrence of deflections composing the QRS groups is due in many cases to inconstant low potential Q and S waves.

Since Table XXX fails to show certain significant changes in form of the QRS group in serial electrocardiograms, further elaboration of the general character of these variations is necessary. For this purpose Figure V is presented. This illustration contains EKG complexes from each lead of the three monthly tracings of the eleven animals showing the most outstanding periodic variations. For purposes of convenience only those subjects showing changes not only in QRS but also P and T waves were selected. It is not to be assumed that these represent an average cross section of the series. Many individuals displayed varying degrees of change in P, QRS, or T alone. In many cases these were quite minor. A few showed practically no monthly change.

To return to a discussion of the figure, it will be seen that subjects A, B, C, and D illustrate changes in R wave types characterized by varying degrees of coarsening with or without notching of the descending limb. While the complexes of each individual in general tend to resemble each other, the changes show no definite trend, there being no correlation between notching one month, and coarsening of the entire, or the terminal portion of the downstroke in succeeding or preceeding tracings. Subjects E, F, G, H, and I show, in addition to R and Q wave types of QRS, mainly changes in the vibratory QRS complexes so frequently encountered in this study. The change here is almost invariably an increase in excursion of the descending limb of the first spike which is often great enough to cross the isoelectric level, or vice versa in the case of QRS showing negative summation. Subject K is representative of changes observed in unfavorable electrocardiograms.

Since monthly changes in potential of QRS are in the main not striking, it would seem difficult to reconcile these variations with simple axial rotation of the bovine heart. Very little is known about this subject. Prior to 1935, variations in serial electrocardiograms of animals were given little thought. At about this time Katz, et al, (28), working with serial electrocardiograms of dogs found significant variations referable to changes in electrical axes due to the greater mobility of the heart in the chest of this species as compared to the human subject.

Monthly changes in P occur more frequently in the low potential waves, (especially lead I and to a lesser extent lead III). The principal variation is in potential, great enough to result in complete absence in certain subjects (A, B, E, and I of the figure). This may happen occasionally within a lead (subject K, lead III of the first monthly tracing). In one subject (C, lead I) there is direct reversal of potential. The changes in diphasic P waves showing positive or negative summation one month to monophasic in the direction of their predominance in a subsequent or previous monthly tracing, so strikingly illustrated in Table XXX, is unfortunately not well shown in the figure. Lead II in subject C and G, and lead III in subject H illustrate this somewhat.

Monthly changes in T, unlike P, are not associated largely with low potential. Here, as with the other deflections, no definite trend is shown and classification is impossible. The principal variation seen is diphasic to positive or negative monophasic, and this is not always in the direction of predominance of the diphasic wave in a previous or subsequent tracing. These changes occur quite regularly in the electrocardiograms shown in the figure and appear in all leads. More or less direct reversal is seen in leads I and III of subject A and K, and lead II of subjects E, H, and I. Subject A is interesting in that complete reversal occurred the third month with diphasic waves in the second monthly tracing.

<u>Changes Within Leads</u>. Reserved for final discussion in this phase of the study are the changes occurring within a lead during the actual recording of a bovine electrocardiogram. Since intra-lead changes in QRS phasic with respiration is not infrequent in the human subject (29), and has also been observed in cattle (6), it is not inconceivable that this factor may be of importance here. This was not carefully checked in the present study and must await further investigation.

Very slight changes in potential of QRS (0.05 to 0.1 millivolt) occurred in a great majority of the records. Potential changes slightly greater than this, especially in the type 5 and 7 complexes of Figure I, results in an apparent change in the character of QRS. This is due to the fact that the lowering of potential is proportionally greater in the initial spike so that an R wave with a coarsened notched downstroke, for example, or an M-shaped QRS with a higher usually fine initial deflection during one cardiac cycle may in a succeeding cycle be more truly in the shape of the letter M. Varying degrees of this form of change are most outstandingly shown in the following subjects:

Brown Swiss #303	L III of Fig. VI (EKG B142)
Holstein #220	L III of Fig. II A-13 (EKG B405)
Jersey #116	L II of Fig. II A-18 (EKG B328)
Holstein #180	L II of Fig. II A-20 (EKG B570)

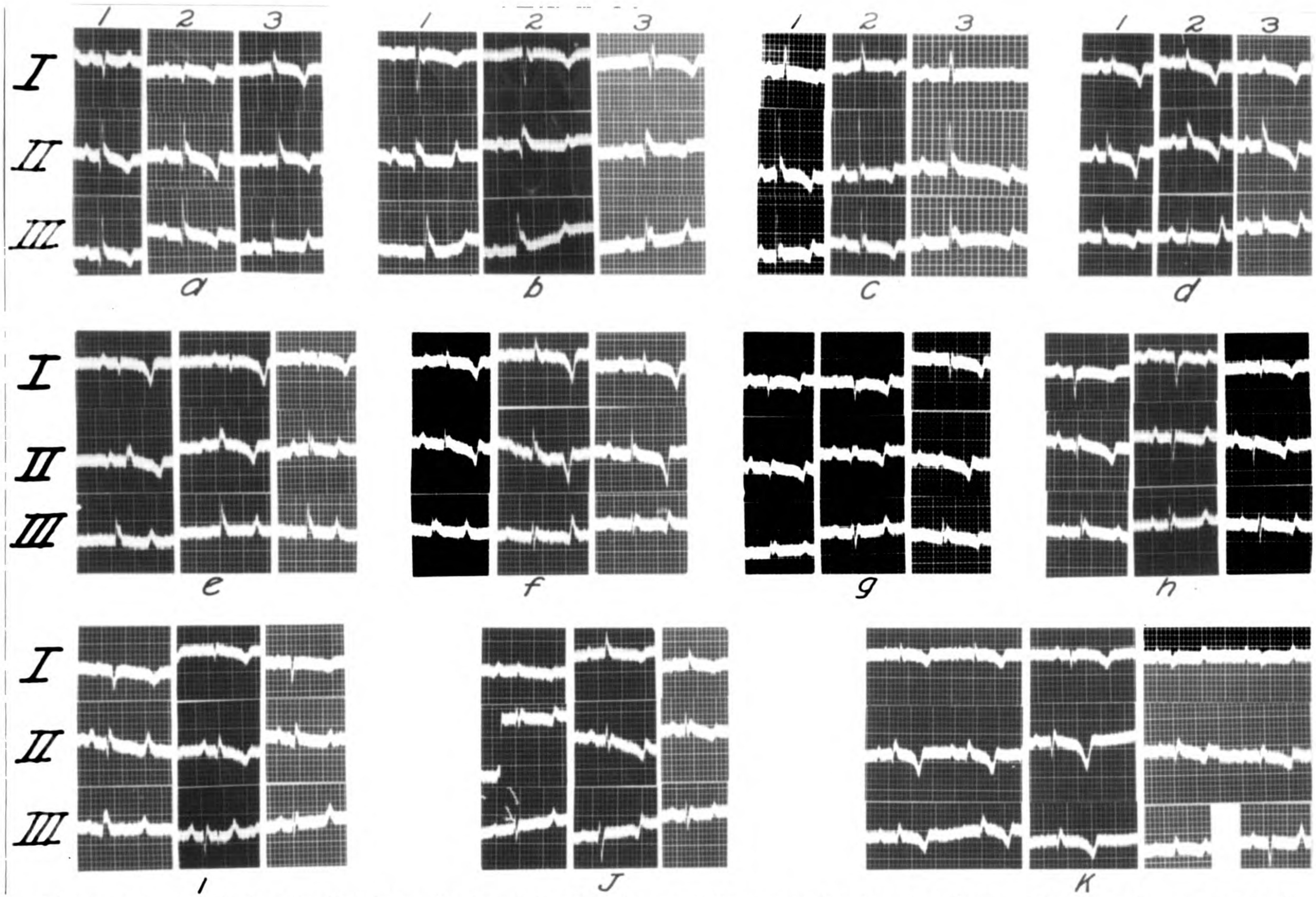

Figure V - Monthly Variations in Serial Electrocardiograms in the Bovine. The Arabic numbers 1, 2, and 3 indicate first, second, and third monthly tracings respectively; the Roman numerals to the left of the figure indicate the derivation or lead; and the letters "a" to "k" designate individual animals. The variation within lead III of the third monthly tracing in subject K occurred during the recording of the lead.

Sometimes the change is from R with a coarsened notched downstroke to a coarsened blur suggestive of letter M as in Ayrshire #162 (L II of Figure VII, EKG B440).

Marked changes were sometimes encountered after movement due to restlessness or nervousness during the EKG recording. This is most strikingly seen in lead III of Brown Swiss #306 (Figure VIII, EKG B316). During the recording of the third lead in this tracing, sufficient restlessness occurred to necessitate cessation of operations for a moment or two. When the record was resumed it can be seen that grave changes in the character of the entire complex had taken place. These are mainly an increase in potential of all waves with direct reversal of QRS. It must be further observed that the factor of heart rate is probably of little significance here since sufficient time was allowed for this to return to the normal which obtained in the first half of the lead recording. Another subject (Guernsey #1, Figure IX) during the recording of lead I shows a change from mainly Q predominance with only a faint suggestion of R to a definite QR type of complex after restlessness so slight as to be accompanied by muscular effects only great enough to cause a shift of the string of approximately one cm., and no appreciable increase in heart rate.

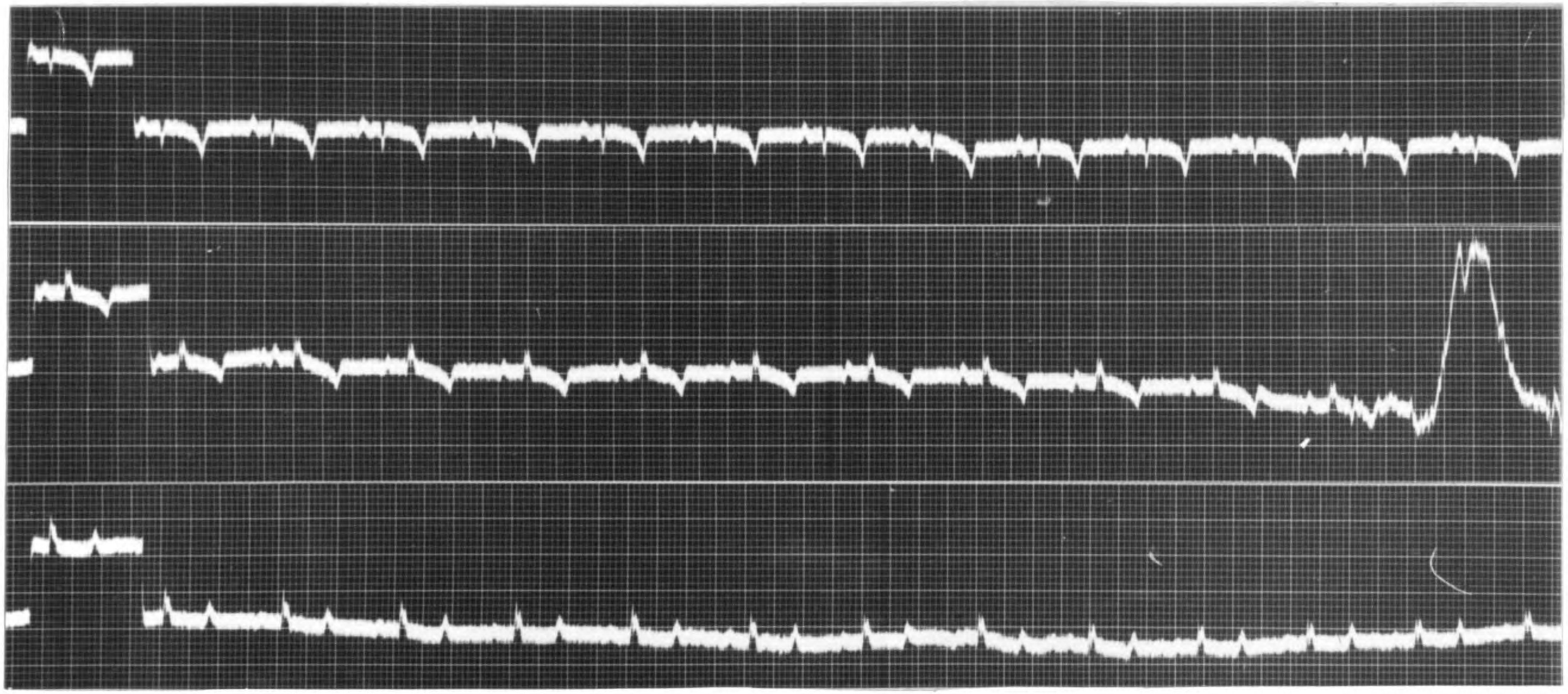

Figure VI - Bovine EKG Showing Variations in the QRS Group During the Recording of Lead III.

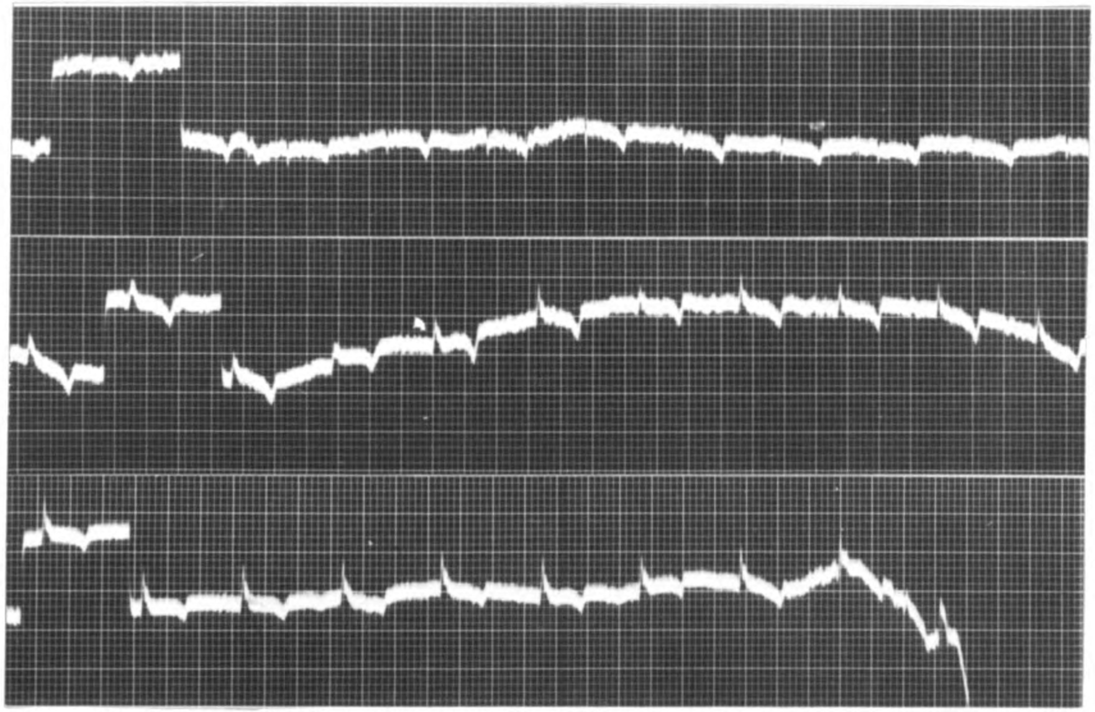

Figure VII - Bovine EKG Showing Changes in Character of QRS During the Recording of Lead II in a Nervous Animal. The disappearance of the string shadow in lead III is due to muscular movement.

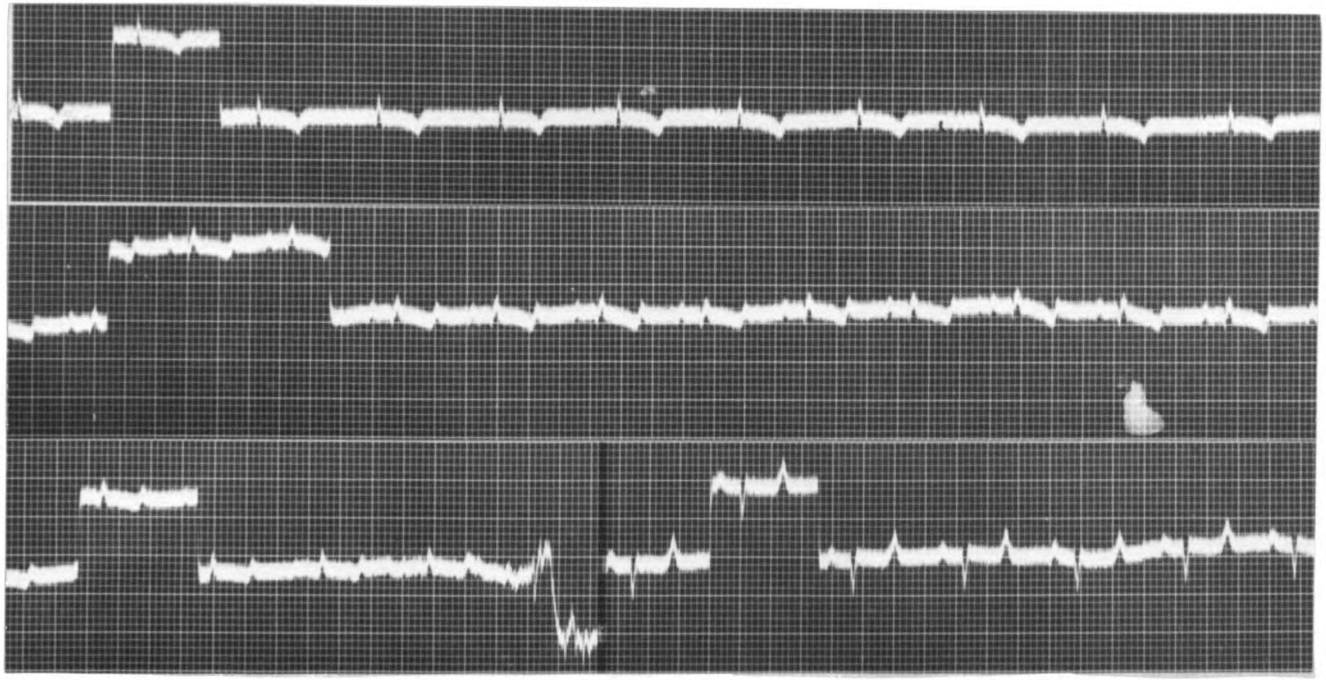

Figure VIII - Bovine EKG Showing Changes in Character of Waves Following Restlessness During the Recording of Lead III.

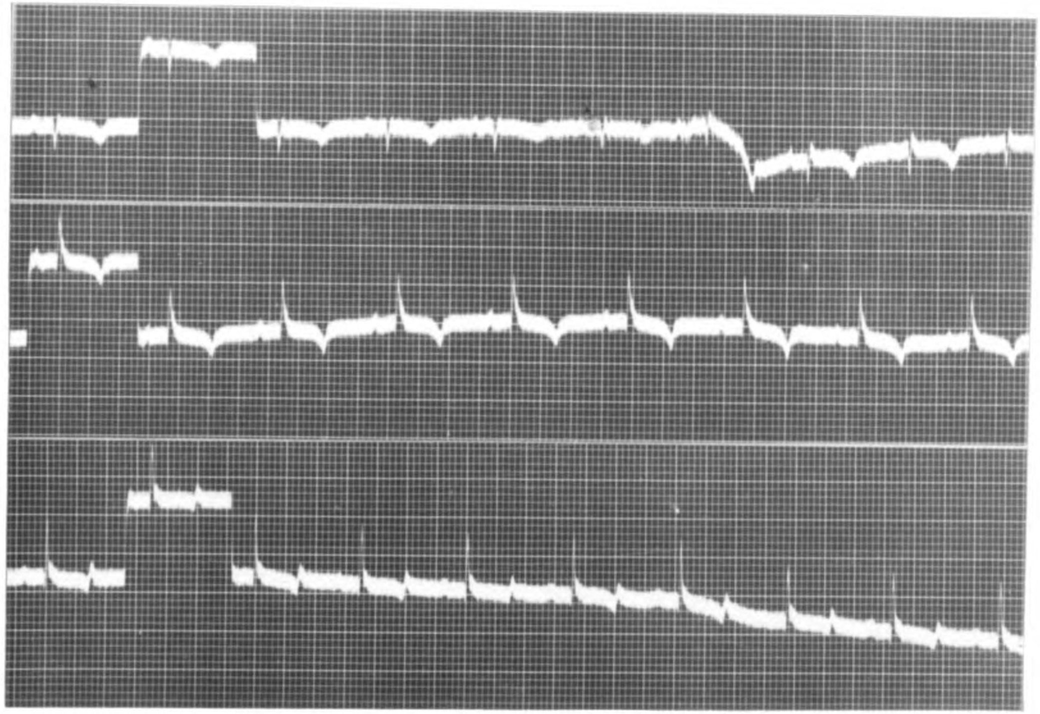

Figure IX - Bovine EKG Showing Changes in Complexes Following Very Slight Muscular Movement During the Recording of Lead I.

SUMMARY

1. Three serial electrocardiograms approximately one month apart were taken on each of 97 normal cattle composing an entire dairy herd and representing the Jersey, Guernsey, Ayrshire, Brown Swiss, and Holstein breeds. The group was kept under modern conditions of herd management and maintained for optimum milk production. All ages from five months to twelve years were included. In this manner the effect of variations in age, period of gestation and lactation, breed differences, and individual monthly variations on the electrocardiogram could be studied.

2. The cardiac frequencies encountered ranged from a minimum of 48 to a maximum of 98 per minute, with a mean of 71.6 for the entire group. These values very closely approximate the normals determined by other investigators, when all conditioning factors are considered.

3. The deflection P was invariably present in lead II. In a few cases it was totally absent in leads I and III or when present was of such extremely low potential that its form could not be satisfactorily determined. The potential of determinable waves ranged from below 0.03 millivolt in all three leads to the maximum of 0.12 in lead I, 0.18 in lead II, and 0.22 in lead III. The mean values for the entire group were 0.06, 0.10, and 0.07 millivolt in leads I, II, and III respectively. Broadly speaking the deflection was more prone to be diphasic in leads I and II and monophasic in lead III, although several combinations of

the two types in the three leads were present. In about 90 per cent of the cases the net area of the deflection was positive. The balance was composed of diphasic waves with opposite excursions of about equal size. Negative P waves occurred in only two instances in lead I and in a single instance in lead III.

4. The deflection Q was found to occur in 60 per cent of the instances in lead I, 80 per cent in lead II, and 70 per cent in lead III. Its potential ranged from below 0.03 millivolt in all three leads to maxima of 0.60, 1.00, and 0.90 millivolt in leads I, II, and III respectively. The means for the group were 0.23 millivolt in lead I, 0.16 in lead II, and 0.11 in lead III. Of the Holstein group in which Q occurred, only two individuals displayed a potential greater than 0.12 millivolt.

5. The deflection R occurred in 78 per cent of the instances in lead I, and 99 per cent in leads II and III. Its potential ranged from below 0.03 millivolt in all three leads to maxima of 0.70, 2.60, and 1.50 millivolts in leads I, II, and III respectively. The mean for the entire series was found to be 0.16 millivolt in lead I, 0.37 in lead II, and 0.35 in lead III.

6. The deflection S was present in 28 per cent of the cases in lead I, only 8 per cent in lead II, and 20 per cent in lead III. Potentials were uniformly low, never above 0.25 millivolt in any lead. The mean for the series was 0.06 millivolt in lead I, 0.07 in lead II, and 0.12 in lead III.

7. The second upright QRS deflection was of the least frequent occurrence, being present in 2 per cent of the instances in lead I, 4 per cent in lead II, and 14 per cent in lead III. Potentials were very low, ranging from the minimum of below 0.03 to the maximum of 0.20 millivolt.

8. The deflection T was present in all individuals and in all leads. This wave was more frequently monophasic in lead I and diphasic in leads II and III. However, several combinations of the two types in the three leads were present. Monophasic waves were largely negative in leads I and II, and positive in lead III. Diphasic waves showed negative summation in most instances. Potentials were found to range from a minimum of below 0.03 millivolt in all three leads to the maxima of 0.60, 1.10, and 0.90 millivolts in leads I, II, and III respectively. The mean values were 0.20 millivolt in lead I, 0.31 in lead II, and 0.18 in lead III.

9. The duration of the P-R interval ranged from a minimum of 0.1 to a maximum of 0.3 second, with an average duration of 0.19 second. Some slight individual monthly variations as well as variations between the breeds were found.

10. The duration of QRS ranged from 0.06 to 0.12 second with an average value of 0.094 second. In general the lowest values were more common in lead I and the highest in lead III. However, the differences between leads II and III were not very great. Monthly variations were more common in lead I.

11. The Q-T interval ranged from a minimum of 0.29 to a maximum of 0.47 second, with an average duration of 0.389 second. This interval increases in duration with a decrease in heart rate and vice versa. For this reason great variations occurred.

12. The systolic index as determined by Bazett's formula ranged from 0.34 to 0.48, with an average of 0.418. Individual monthly variations of from 0.001 to 0.030 were not uncommon.

13. The electrical axis of the bovine heart ranged in 65 per cent of the individuals from +30 to +170 degrees. The balance were largely grouped in the -30 to -160 degree range. Ten animals displayed, in one or more of the three serial electrocardiograms, records of a type precluding even an approximate axis determination.

14. An attempt was made to classify the bovine electrocardiogram according to the following general scheme:

Group I. Tracings in which R was the largest QRS deflection in at least two leads.

Group II. Tracings characterized mainly by extremely uneven rotation of the electrical axis during the execution of QRS, thus giving rise to various types of bizarre multiphase complexes.

Group III. Tracings showing mainly diphasic QRS complexes of rather extreme breadth.

Group IV. Tracings showing QRS complexes with a negative net area in at least two leads.

Group V. Miscellaneous unfavorable, low potential, or otherwise unclassifiable electrocardiograms.

The major groups were further subdivided upon the basis of QRS type and its occurrence in the several lead combinations as well as the form of QRS in the indifferent lead.

15. Variations in serial electrocardiograms as well as variations occurring during the recording of leads were studied. The former occurred with great frequency, but were on the whole relatively minor. The various deflections usually retained a rather close resemblance to each other in the three serial tracings of most individuals. In general, the auricular deflection was the most constant in form from month to month.

Variations within a lead occurred infrequently and are discussed.

Breed differences were not sufficiently great to warrant the drawing of conclusions in view of the relatively small number composing each group.

16. No marked influence of stage of gestation upon the bovine electrocardiogram could be discerned in this study. Whether some of the variations observed were due to this factor could not be determined.

The above observations also hold true for any possible influence of stage of lactation.

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A P P E N D I X

Animal No. .... Species .... Breed ....

EKG No.	Date	Rate	Intervals			POTENTIALS AND DEFLECTIONS															Electrical Axis	K (Bazett's Formula)
			PR	QRS	QT	P			Q			R			S			T				
						L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3		

KEY

Abs.... absent wave
C...... coursened wave
CD..... coursened downstroke
CID.... coursened irregular downstroke
CND.... coursened notched downstroke
CU..... coursened upstroke
D...... diphasic (both + and - potentials measured)
F...... forked
I...... inconstant low potential wave

N..... notched
NM.... non-measurable (i.e., below 0.03 millivolt)
R..... rounded
S..... slow
T..... trace
Va.... variable
Vi.... vibratory
VD.... vibratory downstroke
VU.... vibratory upstroke
W..... "W" shape complex

Figure X - Sample of chart employed in tracing analysis. The interval measurements were taken for each lead and entered in descending order in the proper space. The appended key is merely a code system arbitrarily devised to afford a limited and very general description of the various deflections.

Table XXIX. EKG Intervals for All Leads in Each of the Three Monthly Tracings, Including Bazett's Constant.

JERSEY

Animal No.	Age (1st Month) Yrs.	Mo.	Lead No.	Rate (Per Min) 1st Month	2nd Month	3rd Month	EKG Intervals (Sec.) PR 1st Month	PR 2nd Month	PR 3rd Month	QRS 1st Month	QRS 2nd Month	QRS 3rd Month	QT 1st Month	QT 2nd Month	QT 3rd Month	K(Bazett) 1st Mo.	2nd Mo.	3rd Mo.
62	-	8	I	91	100	59	0.14	0.16	0.16	0.04	0.04	0.09	0.32	0.32	0.40	0.425	0.400	0.400
			II	84	94	60	0.14	0.14	0.16	0.10	0.08	0.08	0.34	0.32	0.40			
			III	84	94	65	0.14	0.14	0.16	0.08	0.08	0.08	0.32	0.32	0.40			
90	-	11	I	65	103	72	0.16	NM	0.16	0.04	0.05	0.05	0.40	0.32	0.40	0.447	0.412	0.407
			II	68	100	77	0.15	0.14	0.14	0.06	0.06	0.07	0.42	0.30	0.36			
			III	72	100	94	0.14	0.13	0.12	0.08	0.07	0.07	0.40	0.32	0.36			
80	1	3	I	75	58	63	0.16	NM	0.18	0.06	NM	0.07	0.37	NM	NM	0.436	0.430	0.428
			II	70	60	63	0.17	0.17	0.18	0.07	0.07	0.07	0.40	0.43	0.42			
			III	68	58	60	0.18	0.18	0.18	0.08	0.08	0.08	0.43	0.44	0.44			
89	1	4	I	72	63	65	0.18	NM	0.18	0.08	NM	0.06	0.36	0.38	0.38	0.414	0.408	0.408
			II	72	63	63	0.17	0.18	0.17	0.08	0.08	0.08	0.38	0.40	0.40			
			III	72	63	63	0.17	0.18	0.18	0.09	0.09	0.08	0.38	0.40	0.38			
88	1	6	I	60	56	73	0.20	0.18	0.18	0.07	0.05	0.07	0.40	0.44	0.38	0.421	0.421	0.426
			II	65	54	68	0.18	0.18	0.18	0.08	0.08	0.09	0.40	0.44	0.40			
			III	58	58	68	0.18	0.17	0.17	0.09	0.09	0.09	0.43	0.43	0.40			
85	1	7	I	60	50	60	0.16	0.16	0.16	0.07	0.07	NM	0.40	0.44	0.40	0.400	0.401	0.400
			II	57	48	58	0.15	0.16	0.16	0.10	0.09	0.08	0.38	0.44	0.40			
			III	56	48	60	0.16	0.16	0.16	0.08	0.08	0.08	0.40	0.44	0.42			
86	1	7	I	73	54	59	NM	0.18	0.19	0.07	0.06	0.06	0.36	0.40	0.42	0.436	0.401	0.440
			II	72	48	60	0.17	0.18	0.18	0.08	0.07	0.08	0.40	0.44	0.44			
			III	72	50	58	0.16	0.17	0.17	0.08	0.08	0.08	0.40	0.44	0.44			
87	1	7	I	75	68	79	0.16	NM	0.16	0.05	NM	0.06	0.40	NM	0.36	0.405	0.436	0.412
			II	68	72	79	0.16	0.16	0.15	0.08	0.08	0.08	0.38	0.40	0.34			
			III	68	75	79	0.15	0.14	0.14	0.09	0.09	0.09	0.40	0.40	0.36			
73	1	9	I	74	88	88	0.16	0.16	0.16	0.06	0.06	0.06	0.36	0.34	0.36	0.407	0.413	0.424
			II	74	79	84	0.17	0.16	0.16	0.09	0.09	0.09	0.37	0.36	0.36			
			III	72	79	88	0.17	0.17	0.16	0.09	0.09	0.09	0.36	NM	0.36			
84	1	10	I	75	65	65	0.10	0.10	0.10	0.08	0.08	0.10	NM	NM	0.44	0.469	0.458	0.474
			II	77	65	70	0.08	0.08	0.08	0.10	0.11	0.11	0.42	0.44	0.44			
			III	77	65	75	0.08	0.08	0.08	0.10	0.10	0.10	0.40	0.40	0.42			
79	2	1	I	63	75	68	NM	NM	0.17	0.04	0.04	0.05	0.40	0.38	0.40	0.459	0.458	0.469
			II	63	75	68	0.18	0.17	0.18	0.10	0.10	0.10	0.45	0.42	0.44			
			III	63	75	68	0.16	0.16	0.16	0.10	0.10	0.10	0.44	0.42	0.40			
116	3	5	I	59	79	72	0.18	0.18	0.18	0.06	NM	NM	0.44	0.36	0.42	0.460	0.425	0.469
			II	60	75	68	0.17	0.16	0.17	0.10	0.10	0.10	0.46	0.38	0.44			
			III	63	75	67	0.17	0.16	0.17	0.10	0.10	0.10	0.44	NM	0.46			
117	3	6	I	60	68	75	0.21	0.20	0.20	0.08	0.08	0.08	0.42	0.40	0.36	0.401	0.436	0.436
			II	58	72	72	0.20	0.18	0.18	0.09	0.08	0.08	0.41	0.40	0.40			
			III	58	68	79	0.20	0.18	0.17	0.09	0.09	0.09	0.40	0.38	0.36			
114	3	7	I	46	48	48	0.22	0.21	0.22	0.06	0.06	0.06	NM	NM	0.45	0.389	0.423	0.420
			II	47	51	50	0.22	0.20	0.20	0.10	0.10	0.10	0.44	0.46	0.46			
			III	47	50	48	0.20	0.20	0.20	0.10	0.10	0.09	0.45	0.48	0.48			
115	3	7	I	54	72	68	0.22	0.20	0.22	0.06	0.07	0.07	0.43	0.38	0.40	0.406	0.436	0.426
			II	54	72	68	0.22	0.20	0.20	0.10	0.10	0.10	0.43	0.40	0.40			
			III	56	72	65	0.22	0.20	0.22	0.10	0.09	0.10	0.40	0.38	0.40			
118	3	11	I	56	70	72	0.22	0.21	0.20	0.08	0.06	0.06	0.43	0.40	0.40	0.415	0.447	0.432
			II	54	77	63	0.22	0.20	0.21	0.10	0.10	0.09	0.44	0.40	0.42			
			III	52	77	65	0.22	0.20	0.20	0.10	0.10	0.10	0.44	0.40	0.40			
111	4	1	I	60	70	72	0.16	0.17	0.16	0.06	0.06	0.08	0.38	0.36	0.37	0.400	0.405	0.405
			II	60	68	68	0.17	0.17	0.17	0.11	0.10	0.10	0.40	0.38	0.38			
			III	60	68	72	0.17	0.18	0.17	0.10	0.10	0.09	0.40	0.40	0.38			
108	4	10	I	60	62	47	NM	NM	NM	0.08	0.08	0.08	0.44	0.48	0.44	0.468	0.450	0.480
			II	52	67	54	0.21	0.19	0.21	0.08	0.08	0.09	0.47	0.48	0.50			
			III	52	60	48	0.20	0.20	0.21	0.09	0.08	0.08	0.50	0.46	0.50			
101	5	7	I	56	58	55	0.22	0.22	NM	0.10	0.08	0.10	0.44	0.42	NM	0.415	0.415	0.473
			II	54	56	56	0.22	0.21	0.22	0.08	0.08	0.08	0.44	0.44	0.48			
			III	50	57	54	0.22	0.20	0.20	0.09	0.09	0.09	0.44	0.44	0.48			
100	5	8	I	62	73	70	0.20	0.20	0.20	0.06	0.04	0.08	0.41	NM	0.40	0.447	0.437	0.431
			II	63	72	70	0.20	0.18	0.20	0.08	0.09	0.09	0.44	0.40	0.40			
			III	63	73	72	0.19	0.16	0.20	0.10	0.10	0.10	0.41	0.38	0.40			
95	5	10	I	63	58	65	NM	NM	0.20	0.08	0.08	0.08	0.40	0.43	0.38	0.404	0.396	0.412
			II	62	58	64	0.20	0.21	0.20	0.09	0.10	0.09	0.40	0.40	0.40			
			III	62	60	61	0.19	0.20	0.20	0.09	0.09	0.08	0.40	0.42	0.40			
97	8	4	I	63	61	60	NM	NM	0.20	NM	NM	0.08	NM	NM	0.44	0.428	0.435	0.428
			II	63	59	63	0.20	0.20	0.20	0.10	0.10	0.10	0.42	0.44	0.42			
			III	60	63	61	0.17	0.17	0.17	0.12	0.10	0.10	0.44	NM	0.42			
63	12	2	I	72	65	68	0.21	0.24	0.24	0.05	0.08	0.08	0.36	0.42	0.40	0.403	0.438	0.426
			II	72	65	68	0.21	0.24	0.23	0.12	0.12	0.12	0.37	0.42	0.40			
			III	72	65	68	0.20	0.25	0.23	0.06	0.06	0.06	NM	0.44	0.44			

Table XXIX. Continued.

GUERNSEY

Animal No.	Age (1st Month) Yrs.	Mo.	Lead No.	Rate (Per Min) 1st Month	2nd Month	3rd Month	EKG Intervals (Sec.) PR 1st Month	PR 2nd Month	PR 3rd Month	QRS 1st Month	QRS 2nd Month	QRS 3rd Month	QT 1st Month	QT 2nd Month	QT 3rd Month	K(Bazett) 1st Mo.	2nd Mo.	3rd Mo.
6	-	10	I	100	82	82	NM	0.16	NM	0.08	0.08	0.08	0.28	0.33	0.32	0.362	0.385	0.358
			II	100	79	86	0.14	0.16	0.16	0.08	0.08	0.08	0.28	0.33	0.32			
			III	94	77	86	0.15	NM	0.16	0.09	0.09	0.09	0.29	0.34	0.30			
8	-	10	I	104	84	100	0.16	0.16	NM	0.04	0.05	0.06	0.28	0.32	0.28	0.413	0.402	0.375
			II	104	82	103	0.14	0.15	0.14	0.08	0.08	0.08	0.31	0.33	0.30			
			III	100	79	94	0.14	0.15	0.16	0.08	0.08	0.08	0.32	0.35	0.30			
3	-	11	I	72	100	100	0.16	0.14	NM	0.10	0.08	0.08	0.40	0.34	0.34	0.388	0.406	0.424
			II	70	86	84	0.16	0.14	0.16	0.08	0.04	0.06	0.36	0.34	0.36			
			III	72	84	84	0.18	0.16	0.16	0.08	0.08	0.08	0.38	0.36	0.37			
1	1	1	I	84	94	94	0.15	0.16	0.14	0.06	0.06	0.06	0.34	0.34	NM	0.390	0.400	0.388
			II	79	94	70	0.15	0.16	0.14	0.08	0.08	0.08	0.34	0.32	0.36			
			III	84	100	75	0.15	0.16	0.14	0.09	0.09	0.08	0.35	0.34	0.36			
9	1	1	I	115	100	94	0.14	0.15	0.16	0.06	0.07	0.07	0.28	0.32	0.34	0.432	0.436	0.436
			II	100	86	88	0.14	0.15	0.17	0.09	0.10	0.09	0.29	0.36	0.33			
			III	125	88	88	0.13	0.16	0.16	0.09	0.09	0.08	0.30	0.36	0.36			
57	1	8	I	88	68	NM	NM	NM	NM	0.05	NM	NM	0.34	NM	NM	0.426	0.416	0.387
			II	68	68	68	NM	0.18	0.16	0.08	0.08	0.08	0.36	0.40	0.38			
			III	68	65	60	0.17	0.17	0.16	0.10	0.10	0.10	0.40	0.40	0.38			
60	1	6	I	88	79	75	0.18	0.16	0.20	0.06	0.06	0.04	0.34	0.34	NM	0.387	0.389	0.379
			II	100	79	75	0.16	0.16	0.20	0.08	0.08	0.08	0.30	0.34	0.34			
			III	91	75	72	0.16	NM	0.20	0.08	0.09	0.08	0.36	0.40	0.38			
59	1	7	I	97	75	88	0.16	0.20	0.18	0.06	0.07	0.06	0.34	0.37	0.32	0.425	0.413	0.394
			II	88	75	91	0.16	0.19	0.16	0.09	0.09	0.08	0.36	0.36	0.32			
			III	82	75	91	0.17	0.19	NM	0.08	0.08	0.08	0.37	0.38	0.32			
55	1	11	I	75	65	60	0.19	NM	NM	0.06	0.06	0.06	0.36	0.38	0.38	0.380	0.437	0.431
			II	60	72	58	0.19	0.17	0.19	0.08	0.06	0.08	0.40	0.40	0.44			
			III	60	72	58	0.17	0.16	0.20	0.08	0.08	0.07	0.40	0.36	0.40			
46	2	8	I	61	63	54	0.20	NM	NM	0.09	0.10	0.09	0.44	0.44	0.46	0.444	0.448	0.459
			II	61	63	63	0.20	0.20	0.19	0.10	0.11	0.10	0.44	0.44	0.45			
			III	61	58	54	0.18	0.18	0.19	0.10	0.10	0.10	0.44	0.44	0.44			
50	2	9	I	58	60	54	0.24	0.24	0.24	0.08	0.08	0.09	0.40	0.40	0.41	0.420	0.420	0.415
			II	60	60	54	0.22	0.21	0.23	0.09	0.09	0.09	0.42	0.42	0.44			
			III	60	54	55	0.22	0.22	0.22	0.09	0.09	0.10	0.42	0.42	0.42			
48	3	-	I	54	55	50	0.26	NM	0.28	0.08	0.08	0.08	0.42	0.44	0.42	0.372	0.401	0.401
			II	43	50	50	0.28	0.28	0.27	0.10	0.10	0.10	0.44	0.44	0.44			
			III	43	50	48	0.25	0.24	0.24	0.10	0.10	0.11	0.44	0.44	0.44			
47	3	1	I	65	75	79	0.22	0.21	NM	0.10	0.07	0.08	0.38	0.37	0.38	0.426	0.424	0.424
			II	68	75	75	0.20	0.21	0.20	0.09	0.08	0.09	0.40	0.38	0.38			
			III	68	75	75	0.19	NM	0.20	0.10	0.10	0.10	0.40	0.38	0.40			
44	3	10	I	75	79	72	0.19	0.17	0.18	0.08	0.08	0.08	0.35	0.36	0.35	0.447	0.418	0.436
			II	75	82	72	0.18	0.18	0.18	0.12	0.08	0.07	0.40	0.36	0.40			
			III	75	84	75	0.16	0.16	0.16	0.12	0.12	0.12	0.40	0.38	0.40			
41	4	-	I	68	68	68	NM	0.20	0.20	0.11	0.08	0.09	0.42	0.42	0.38	0.447	0.447	0.446
			II	68	68	79	0.20	0.19	0.18	0.10	0.09	0.09	0.42	0.42	0.39			
			III	65	68	72	0.20	NM	0.18	0.12	0.09	0.10	0.44	0.44	0.40			
42	4	-	I	56	63	60	NM	0.16	0.18	0.10	0.10	0.10	0.44	0.42	0.42	0.434	0.447	0.458
			II	54	68	65	0.19	0.16	0.16	0.08	0.08	0.08	0.46	0.42	0.44			
			III	58	72	52	0.16	NM	0.18	0.10	0.10	0.10	0.46	0.42	0.44			
37	4	7	I	58	50	57	0.22	0.22	0.22	0.08	0.08	0.08	0.42	0.42	0.40	0.424	0.401	0.404
			II	54	50	56	0.20	0.22	0.20	0.08	0.08	0.08	0.45	0.44	0.42			
			III	54	52	56	NM	NM	NM	0.09	0.10	0.10	0.46	0.44	0.44			
30	5	11	I	79	65	75	0.22	0.22	0.24	0.05	0.04	0.05	0.36	NM	0.37	0.424	0.431	0.416
			II	79	63	70	0.22	0.22	0.24	0.12	0.10	0.10	0.38	0.42	0.38			
			III	75	58	65	0.21	0.21	0.22	0.10	0.10	0.10	0.38	0.44	0.40			
28	6	10	I	84	75	68	0.20	NM	0.20	0.06	0.06	0.06	0.36	0.40	0.44	0.418	0.402	0.416
			II	75	84	68	0.20	0.19	0.20	0.09	0.09	0.09	0.37	0.40	0.42			
			III	73	75	65	0.20	0.20	0.20	0.08	0.08	0.08	0.38	0.36	0.40			
25	6	11	I	72	75	65	0.23	0.24	0.24	0.10	0.06	0.04	0.38	0.38	0.40	0.426	0.436	0.428
			II	68	72	64	0.22	0.22	0.22	0.10	0.12	0.08	0.40	0.40	0.42			
			III	72	72	63	0.20	0.22	0.20	0.12	0.12	0.12	0.40	0.40	0.42			
14	8	2	I	79	79	66	0.21	0.22	0.22	0.10	0.12	0.12	0.40	0.44	0.46	0.480	0.504	0.461
			II	72	84	55	0.22	0.21	0.24	0.12	0.12	0.12	0.42	0.44	0.45			
			III	72	79	56	0.20	0.20	0.24	0.12	0.08	0.08	0.44	0.44	0.48			
7	11	6	I	65	77	68	0.24	0.22	0.24	0.08	0.08	0.08	0.37	0.36	0.38	0.396	0.407	0.421
			II	65	77	66	0.22	0.22	0.24	0.10	0.10	0.10	0.38	0.36	0.40			
			III	70	77	68	NM	0.20	0.24	0.09	0.09	0.09	0.36	0.36	0.40			

Table XXIX. Continued.

AYRSHIRE

Animal No.	Age (1st Month) Yrs.	Mo.	Lead No.	Rate (Per Min) 1st Month	2nd Month	3rd Month	EKG Intervals (Sec.) PR 1st Month	PR 2nd Month	PR 3rd Month	QRS 1st Month	QRS 2nd Month	QRS 3rd Month	QT 1st Month	QT 2nd Month	QT 3rd Month	K(Bazett) 1st Mo.	2nd Mo.	3rd Mo.
163	-	8	I	97	72	84	0.18	0.16	0.17	0.08	0.08	0.08	0.29	0.32	0.32	0.387	0.354	0.366
			II	94	68	97	0.16	0.16	0.16	0.07	0.07	0.06	0.32	0.32	0.32			
			III	88	69	82	0.16	0.16	0.18	0.09	0.09	0.08	0.32	0.34	0.33			
162	-	9	I	94	94	94	0.20	NM	NM	0.04	NM	NM	0.29	NM	0.28	0.367	0.350	0.375
			II	107	94	97	0.18	NM	NM	0.06	0.06	0.06	0.32	0.28	0.28			
			III	100	91	97	0.16	NM	NM	0.08	0.08	0.08	0.30	0.30	0.30			
161	1	1	I	94	91	107	0.16	0.16	NM	0.06	0.06	0.06	0.34	0.32	0.32	0.353	0.350	0.347
			II	84	94	107	0.17	NM	NM	0.08	0.08	0.08	0.30	0.28	0.26			
			III	84	91	107	NM	NM	NM	0.08	0.08	0.08	0.35	0.30	0.32			
160	1	8	I	84	63	84	NM	0.20	0.19	0.09	0.08	0.09	0.34	0.36	NM	0.392	0.391	0.371
			II	72	63	75	0.22	0.23	0.21	0.08	0.08	0.08	0.38	0.36	0.32			
			III	75	64	94	0.19	0.20	0.17	0.10	0.08	0.08	0.38	0.40	0.28			
159	1	8	I	72	65	60	NM	0.20	NM	0.07	0.08	0.06	0.40	0.38	0.40	0.427	0.421	0.438
			II	52	65	58	0.20	0.20	0.22	0.09	0.07	0.08	0.40	0.40	0.40			
			III	60	58	58	0.20	NM	0.23	0.07	0.08	0.08	0.40	0.40	0.42			
156	2	2	I	84	84	86	0.20	0.17	0.18	0.08	0.08	0.08	0.37	0.37	0.36	0.471	0.448	0.454
			II	84	88	86	0.23	0.16	0.18	0.08	0.08	0.08	0.40	0.37	0.38			
			III	84	86	84	0.20	0.18	0.18	0.09	0.09	0.10	0.38	0.34	0.36			
153	2	5	I	84	72	68	0.22	NM	0.24	0.06	0.09	0.09	0.36	0.40	0.38	0.435	0.426	0.426
			II	79	68	68	0.22	0.22	0.22	0.08	0.08	0.08	0.38	0.40	0.40			
			III	75	65	68	NM	0.24	0.24	0.10	0.10	0.10	0.38	0.42	0.40			
152	2	7	I	65	58	65	0.22	NM	0.20	0.08	0.10	0.09	0.40	0.44	0.42	0.408	0.417	0.416
			II	63	58	65	0.22	0.24	0.20	0.08	0.08	0.08	0.40	0.42	0.40			
			III	65	58	63	0.24	0.20	0.20	0.09	0.10	0.10	0.44	0.44	0.44			
151	2	8	I	68	69	68	0.22	0.22	0.22	0.07	0.07	0.08	0.38	0.40	0.40	0.426	0.426	0.426
			II	68	68	68	0.21	0.18	0.19	0.08	0.07	0.08	0.40	0.40	0.40			
			III	68	68	65	0.20	0.20	0.20	0.09	0.09	0.09	0.40	0.40	0.42			
150	2	11	I	91	72	58	0.18	NM	0.20	0.07	0.05	0.08	0.34	0.40	0.41	0.436	0.421	0.423
			II	75	68	58	0.16	0.20	0.18	0.10	0.10	0.10	0.38	0.40	0.44			
			III	72	68	60	0.18	0.22	0.20	0.10	0.11	0.10	0.40	0.42	0.44			
146	3	4	I	72	65	60	NM	0.24	0.24	0.07	0.05	0.05	0.42	0.42	0.42	0.426	0.412	0.432
			II	68	63	63	0.22	0.24	0.22	0.08	0.08	0.08	0.40	0.40	0.42			
			III	68	68	58	0.24	0.20	0.22	0.08	0.08	0.08	0.40	0.40	0.41			
144	3	6	I	79	72	56	0.20	0.20	0.24	0.08	0.08	0.08	0.40	0.41	0.44	0.436	0.427	0.431
			II	79	65	58	0.20	0.21	0.23	0.11	0.12	0.11	0.38	0.40	0.44			
			III	77	63	54	0.20	0.20	0.24	0.10	0.11	0.10	NM	0.42	0.46			
141	4	9	I	115	90	84	0.20	0.20	0.20	0.08	0.08	0.08	0.28	0.32	0.36	0.404	0.406	0.413
			II	125	90	79	0.18	0.17	0.20	0.08	0.09	0.08	0.28	0.33	0.36			
			III	115	88	72	0.16	NM	0.20	0.09	NM	0.09	NM	NM	0.38			

ROOM USE ONLY

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